DETROIT DIESEL

Inline Series 71 Service Manual

DETROIT DIESEL®
CORPORATION
13400 Outer Drive, West / Detroit, Michigan 48239-4001
Telephone: 313-592-5000
Telex: 4320091 / TWX: 810-221-1649
FAX: 313-592-7288

Foreword

This manual contains instructions regarding the overhaul, maintenance and operation of Inline Series 71 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, the technician should read the manual carefully to become familiar with the parts or subassemblies of the engine.

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.

Notice

Inline Series 71 Engines contain many parts dimensioned in the metric system as well as the U.S. customary system. Many fasteners are metric and are very close in dimension to familiar fasteners in the U.S. customary system. It is important to note that, during any maintenance procedure, replacement fasteners must have the same measurement and strength as those removed, whether metric or standard. (Numbers marked on the heads of metric bolts and on surfaces of metric nuts do not have strength markings.) Mismatch or incorrect fasteners removed from the engine should be saved for reuse in the same locations whenever possible. Where the fasteners are not satisfactory for reuse, care should be taken to select a replacement that matches the original. For additional information, contact your Detroit Diesel Service Outlet.

1993 New Model Release

Effective with the 1993 model year, a number of improvements were made to Inline Series 71 Engines. As a result of these improvements, many parts have changed within the engines. The components changed in the 1993 model year are as follows: addition of Detroit Diesel Electronic Controls (DDEC), revised electrical system and many other improvements. Any differences in the servicing of these components are detailed in this manual. These changes are compatible with pre–1993 engines. Detroit Diesel Corporation will continue to service the pre–1993 engine parts that have changed.

6SE164 MAY 1994

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

Printed in U.S.A.

Inline Series 71 Service Manual Revision May, 1994

Since the Inline Series 71 Engine was first released, there have been numerous improvements and design changes made to the engine. This service manual has been rewritten and revised to include any changes that have been made through the 1993 Model Year.

The changes made to this manual include new format, revision of all sections to current information, addition of Detroit Diesel Electronic Control (DDEC) information into Section 2 (Fuel System) and additional revisions to Section 7 (Electrical). Shop Notes, Specifications and Service Tools have also been revised as necessary.

CAUTION:

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully understood.

Proper service and repair are important to the safety of the service technician and the safe, reliable operation of the engine. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part. Do not use a replacement part of lesser quality.

The service procedures recommended by Detroit Diesel Corporation and described in this service manual are effective methods of performing service and repair. Some of these procedures require the use of tools specially designed for this purpose.

Accordingly, anyone who intends to use a replacement part, service procedure or tool, which is not recommended by Detroit Diesel Corporation, must first determine that neither his safety nor the safe operation of the engine will be jeopardized by the replacement part, service procedure or tool selected.It is important to note that this manual contains various "Cautions" and "Notices" that must be carefully observed in order to reduce the risk of personal injury during service or repair or the possibility that improper service or repair may damage the engine or render it unsafe.

It is also important to understand that these "Cautions" and "Notices" cannot cover all circumstances, because it is impossible for Detroit Diesel Corporation to warn of all the possible hazardous conditions that might result from failure to follow these instructions.

SCOPE AND USE OF THIS MANUAL

This manual discusses the Inline Series 71 diesel engines built by the Detroit Diesel Corporation. Multiple engine units are available in various combinations. Complete instructions on operation, adjustment (tune–up), preventive maintenance and lubrication, and repair (including complete overhaul) are covered. This manual was written primarily for persons servicing and overhauling the engine. In addition, it contains all of the instructions essential to operators and users. Basic maintenance and overhaul procedures are common to all Inline Series 71 Engines, and therefore, apply to all engine models.

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

Information regarding a general subject, such as the lubrication system, can best be located by using the Table of Contents. Opposite each subject in the Table of Contents is a section number which coincides 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 Corporation service parts are available from authorized Detroit Diesel Corporation 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 assures satisfactory performance. It should be emphasized that 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 Inspection under General Procedures in this section.

Bolt, nut and stud torque specifications are also listed at the end of each section.

PRINCIPLES OF OPERATION

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

THE TWO–CYCLE PRINCIPLE

In the two–cycle engine, intake and exhaust take place during part of the compression and power strokes respectively (Figure 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.

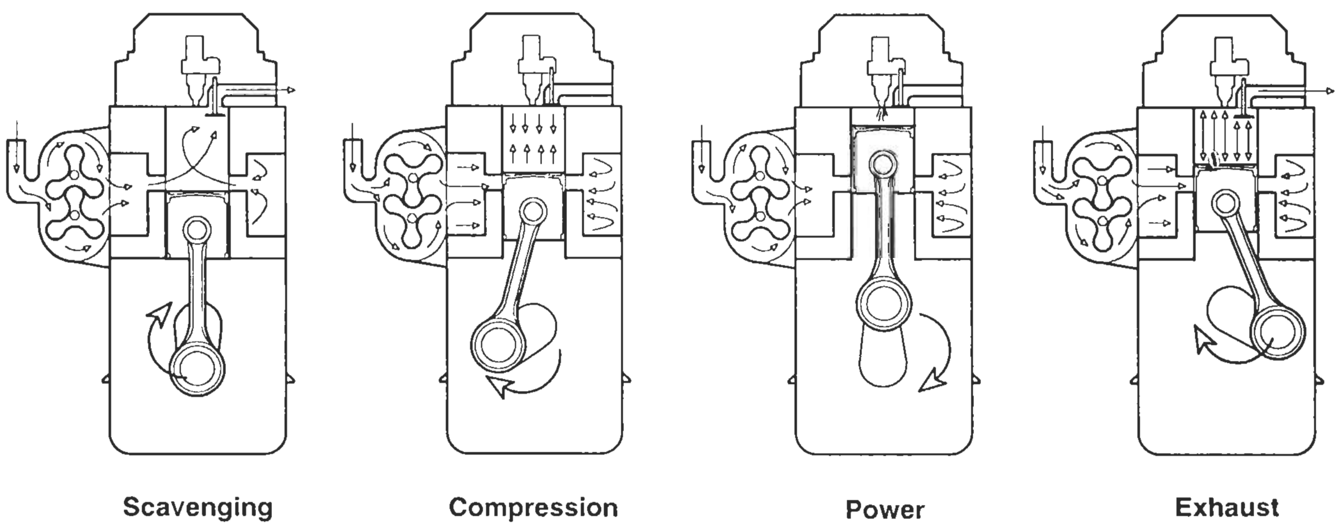


Figure 1. The Two–Stroke Cycle

SCAVENGING

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 (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.

COMPRESSION

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression (compression.)

POWER

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the fuel injector (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.

EXHAUST

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 (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 3, 4 and 6 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 blower, water pump, governor and fuel pump form a group of standard accessories which can be located on either side of the engine, regardless of the direction of rotation. Further flexibility in meeting installation requirements can be accomplished by placing the exhaust manifold and the water outlet manifold on either side of the engine (Figure 2.) This flexibility in the arrangement of parts is obtained by having both the cylinder block and the cylinder head symmetrical at both ends and with respect to each other.

The letter L or R indicates left–hand or right–hand engine rotation as viewed from the front of the engine. The letter A, B, C or D designates the blower and exhaust manifold location as viewed from the rear of the engine.

Each engine is equipped with an oil cooler, lubricating oil filter, fuel oil strainer, fuel oil filter, air cleaner or silencer, governor, fan, 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 enters a longitudinal oil gallery in the cylinder block where the supply divides; a portion entering the bypass filter, if used, and then draining back into the oil pan, part going to the cam and balance shaft end bearings and cylinder head, with the remainder going to the main bearings and connecting rod bearings via the drilled crankshaft.

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

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

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

Engine speed is regulated by a mechanical or hydraulic type engine governor on mechanically configured engines. An Electronic Control Module (ECM) regulates engine speed on electronically configured engines. General specifications and cylinder designations and various firing orders of the engine are shown in (Figure 3.)

MODEL DESIGNATION

1 0 6 5 – 7 0 0 1

SERIES 71 IN-LINE ENGINE	NUMBER OF CYLINDERS	APPLICATION DESIGNATION (see below)	BASIC ENGINE ARRANGEMENT AND DRIVE SHAFT ROTATION (see below)	DESIGN VARIATION (see below)	SPECIFIC MODEL NUMBER

APPLICATION DESIGNATIONS:

1062–7001	MARINE
1063–7001	INDUSTRIAL F–F
1064–7001	POWER–BASE
1065–7001	GENERATOR
1067–7001	VEHICLE F–F
1068–7001	VEHICLE F–F

BASIC ENGINE ARRANGEMENTS:

Rotation: L (left) and R (right) designates rotation viewed from the front of the engine. Type A–B–C–D designates the accessory arrangements.

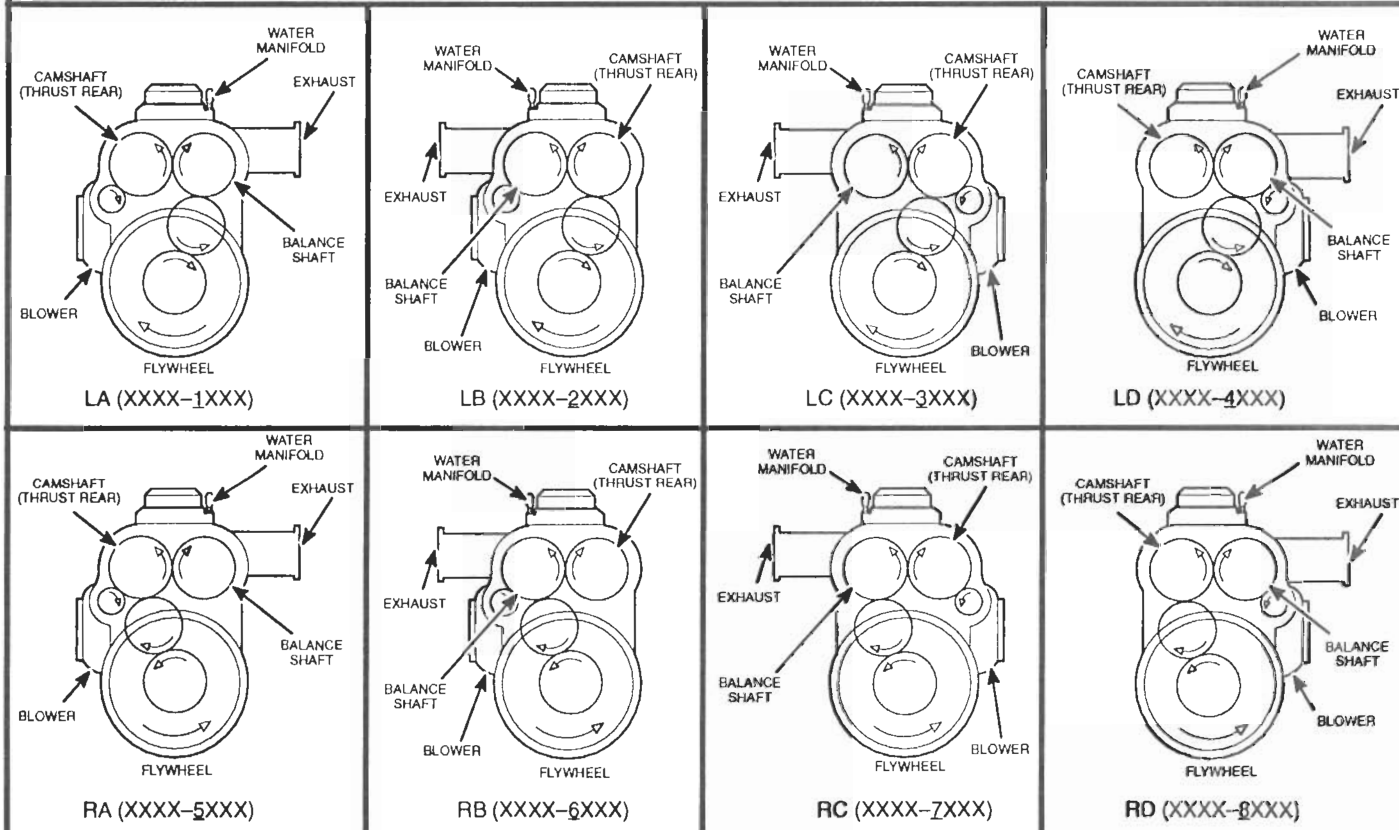
DESIGN VARIATIONS:

1062–7001	4 VALVE HEAD ("N" ENGINE)
1062–7101	2 VALVE HEAD ENGINE
1062–7201	4 VALVE HEAD ("E") ENGINE
1062–7301	TURBOCHARGED ENGINE
1062–7501	CUSTOMER SPEC. ENGINE
1067–7701	CONSTANT HORSEPOWER

DRIVE SHAFT ROTATIONS:

11220001 LEFT–HAND
11229001 RIGHT–HAND

Shaft rotation on multiple units is determined from the rear of the unit.



ALL VIEWS FROM FLYWHEEL REAR END OF BLOCK
ENGINE ROTATION DETERMINED BY VIEWING ENGINE FROM BALANCE WEIGHT COVER (FRONT) END

Figure 2. Model Numbering, Rotation And Accessory Arrangements

GENERAL SPECIFICATIONS

ITEM	3–71	4–71	6–71
Type	2 Cycle	2 Cycle	2 Cycle
No. Of Cylinders	3	4	6
Bore (Inches)	4.25	4.25	4.25
Bore (mm)	108	108	108
Stroke (Inches)	5	5	5
Stroke (mm)	127	127	127
Comp. Ratio (Std. & Turbo)	17:1	17:1	17:1
Comp. Ratio (N/A & Certain Turbos)	18.7:1	18.7:1	18.7:1
Displacement – $in.^3$	213	284	426
Displacement – Liters	3.49	4.66	6.99
Number Of Main Bearings	4	5	7

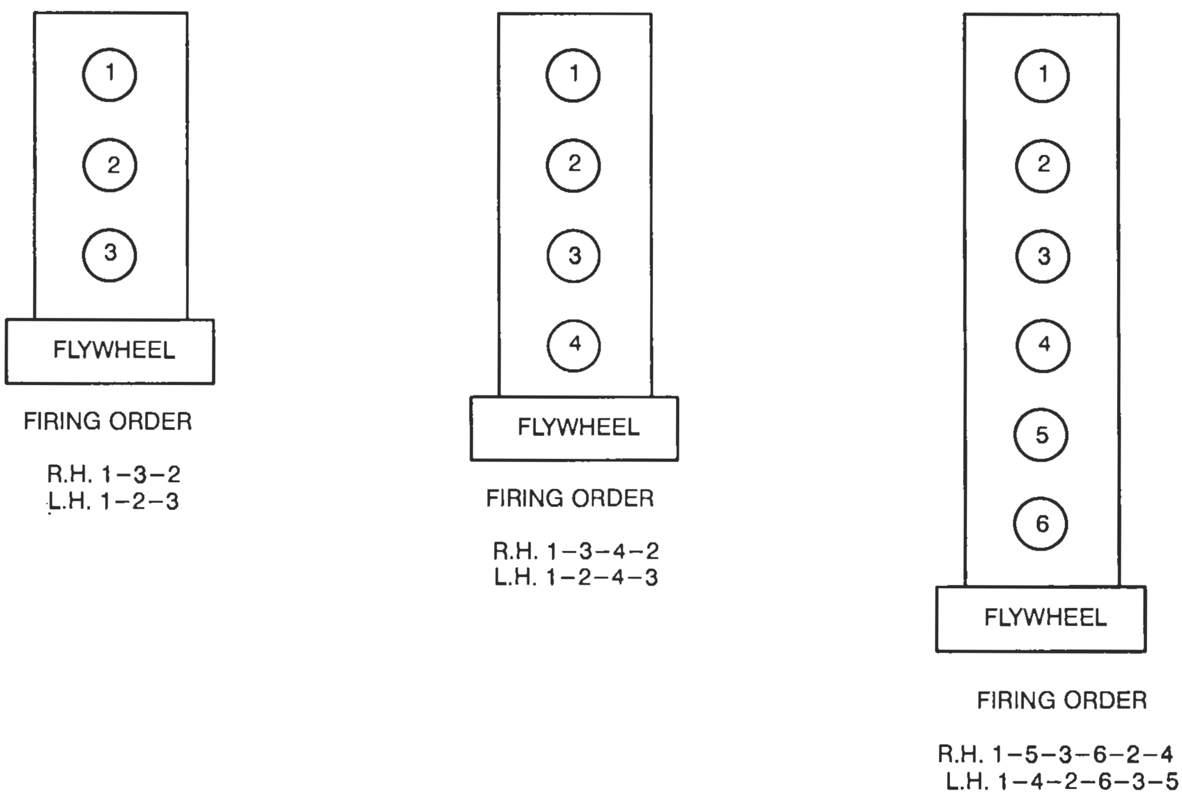


Figure 3. Inline Series 71 Engine Cylinder Designation And Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION LABEL

On all Inline Series 71 Engines, the engine serial number and the engine model number are stamped on the cylinder block (Figure 4.) The engine serial number and model number also are printed on the option label attached to the valve rocker cover.

Inline Series 71 Engines are identified by an eight digit model number. The engine model number 1065–7001 is interpreted as follows: Inline Series 71 Engine (1), six–cylinder (06), generator set (5), right–hand rotation with "C" accessory arrangement (7), four–valve head "N" engine (0) and specific model variation No. 01 (01).

Option Label (Metal Labels)

An option plate, attached to the valve rocker cover (one valve rocker cover of a multiple engine unit), carries the engine serial number, model number and, in addition, lists optional equipment used on the engine (Figure 5.)

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 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 Label (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 DDC manufactured engines. Distributor–typed label(s) will indicate the distributor name, address and the group/type revisions that reflect the changes to engines originally manufactured by DDC.

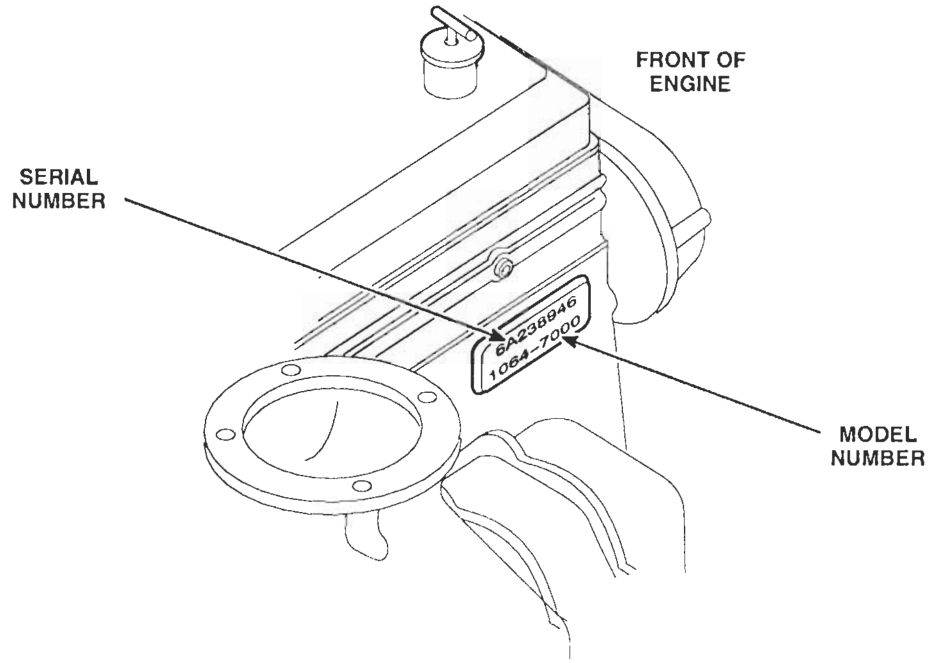


Figure 4. Serial Number and Model Number Location

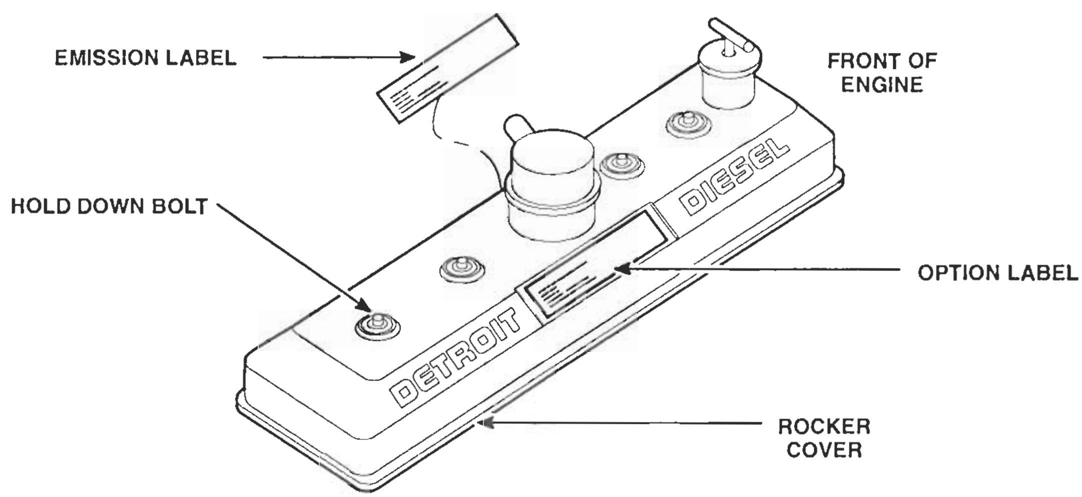


Figure 5. Option Label Location

ENGINE MODEL NUMBER, SERIAL NUMBER AND OPTION LABEL (CONT.)

Attaching Labels

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. Be 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 affixed 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.

NOTE: 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 serviceman 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 contained in Clean Cylinder Block 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 accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180°–200°F (82°–90°C).

Fill the tank with a commercial heavy–duty 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 and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other defects.

ASSEMBLY

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of the proper equipment and tools makes the job progress faster and produces better results. Likewise, a suitable working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment and space will be repaid many times.

Keep the working space, the equipment, tools and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

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

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 an 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 where specifically stated in the manual.

WORK SAFETY

A technician can be severely injured if caught in the pulleys, belts or fan of an engine that is accidentally started. To avoid injury, 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 An 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 working with 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 the 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 spirit 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 GASKETS

Many gasket materials contain bonded asbestos, which 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 Corporation 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 hammer or ball bearing.
5. When stripping gaskets from a part, do not grind or file off the material or use 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 a "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 (Figure 6.) and dispose of it in a solid waste disposal facility (land fill) which will accept asbestos material. Heavy plastic garbage bags (6 mills thick), each sealed separately or other closed and impermeable container may be used.

CAUTION

CONTAINS ASBESTOS

AVOID OPENING OR BREAKING CONTAINER

BREATHING ASBESTOS IS HAZARDOUS TO YOUR HEALTH

DATE FILLED____________________

Caution Label

FABRICATING, ALTERING, REMOVING AND DISPOSING GASKETS (CONT.)

Fluoroelastomer (Viton) Caution

Under normal design conditions, fluoroelastomer (Viton) parts, such as O–rings and seals, are perfectly safe to handle. However, a potential hazard may occur if these components are raised to a temperature above 600°F (316°C) such as during a cylinder failure or engine fire. At temperatures above 600°F (316°C) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

CAUTION:

To avoid personal injury, wear goggles or a faceplate and neoprene or PVC gloves when handling fluoroelastomer O–rings or seals which have been degraded by excess heat. Make sure engine parts have cooled before handling them. If hydrogen fluoride condensate is expected, wash equipment and parts well with lime water (calcium hydroxide solution) before reusing. Discard gloves after handling degraded fluoroelastomer.

Diesel Fuel Caution

CAUTION:

Diesel fuel is relatively harmless at normal ambient temperatures. However when diesel fuel is heated, it may pose certain hazards which must be guarded against by service technicians, engine operators, and/or bystanders

1. **To avoid possible personal injury, always keep those notdirectly involved in servicing away from the engine when it is being serviced.**
2. **The vapors from hot diesel fuel may be flammable under certain conditions. To avoid possible personal injury and/or property damage from fire, stop the engine immediately if a fuel leak is detected. This is especially important if the fuel is contacting hot turbocharger or exhaust system surfaces.**
3. **To avoid a potential fire hazard, do not allow open flames nearby or smoke when replacing fuel filters on a hot engine or when working on an operating engine. To guard against burns from direct contact with hot fuel, wear adequate protective clothing (face shield, insulated gloves and apron, etc) when performing either of these operations.**
4. **To prevent a buildup of potentially volatile vapors from hot fuel, keep the engine area well ventilated during operation.**

ENGINE (LESS MAJOR ASSEMBLIES)

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CYLINDER BLOCK

The cylinder block is the basic engine structure establishing and maintaining the alignment of all engine working parts.

Inline Series 71 cylinder blocks are available in naturally aspirated, turbocharged and turbocharged–aftercooled configurations. Transverse members and cast integrally provide rigidity and strength which helps ensure alignment of the block bores and bearings under load.

Cylinder blocks for naturally aspirated three, four and six cylinder engines are identical in design and dimensions (Figure 1.) The two ends of the block are similar so the flywheel housing and gear train can be assembled to either end.

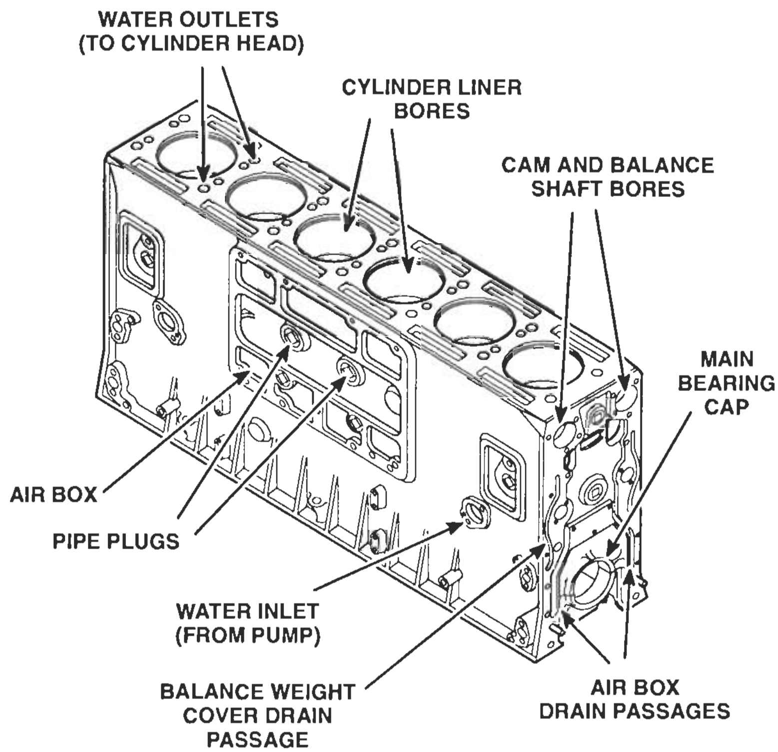


Figure 1. Typical Naturally Aspirated Engine Block

The only difference between the three cylinder blocks is machining in the blower cavity and a turbo drain hole (Figure 2. and Figure 3.)

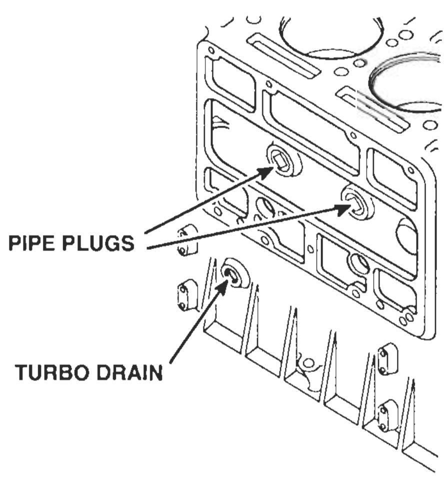


Figure 2. Turbocharged Block (6 cyl. only)

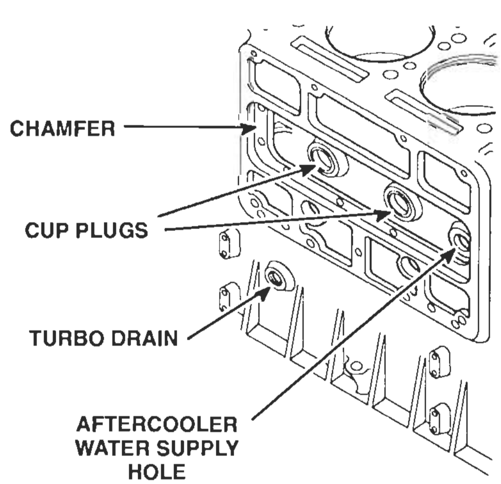


Figure 3. Turbocharged–Aftercooled Block (6 cyl. only)

SECTION 1.1–CYLINDER BLOCK

The block is bored to receive replaceable dry cylinder liners. Water jackets, that extend the full length of the block bores, are divided into upper and lower sections which are connected by hollow struts. Coolant from the pump enters at the bottom of each water jacket and leaves at the top of the block through holes that register with corresponding openings in the cylinder head (Figure 4.)

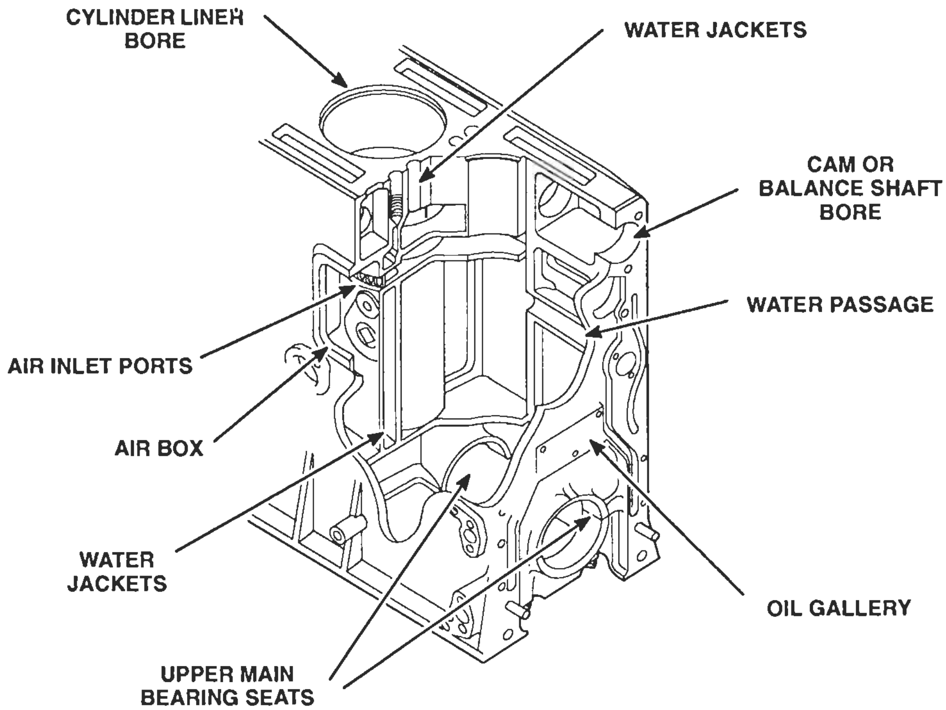


Figure 4. Cutaway View of Cylinder Block Showing Air and Water Passages

An air box surrounding the water jackets conducts the air from the blower to the air inlet ports in the cylinder liners. Air box openings on the side of the block opposite to the blower provide access to the air box and permit inspection of the pistons and compression rings through the air inlet ports in the cylinder liners (Figure 5.)

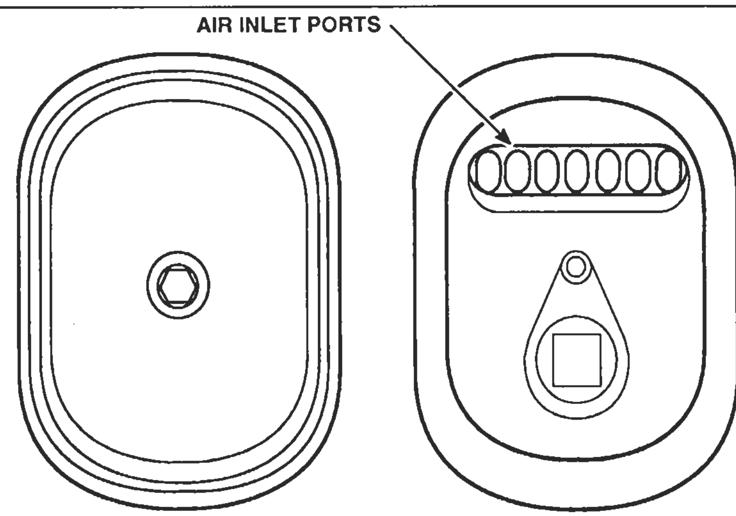
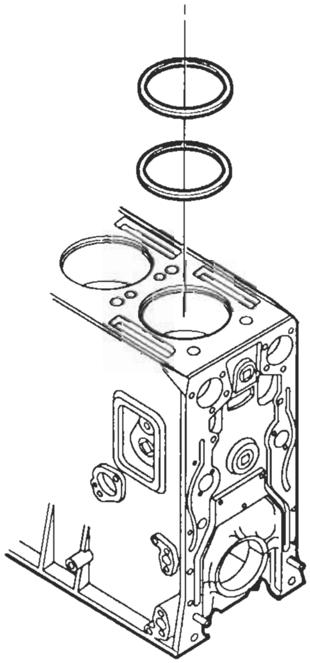


Figure 5. Air Box Covers and Inlet Ports

The upper halves of the main bearing supports are cast integral with the block. The main bearing bores are line–bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping. The perimeter of the top surface of the cylinder block is grooved outside of the cam pockets, to accommodate a block–to–head oil seal ring. The top surface of the block is also counterbored to accommodate individual seal rings (Figure 6.)

Each cylinder liner is retained in the block by a flange at its upper end. The liner flange rests on a cast iron insert located in the counterbore in the block bore. Any .010 inch oversize and larger liners require larger inside diameter cast iron inserts for adequate liner–to–insert clearances. An individual compression gasket is used at each cylinder.



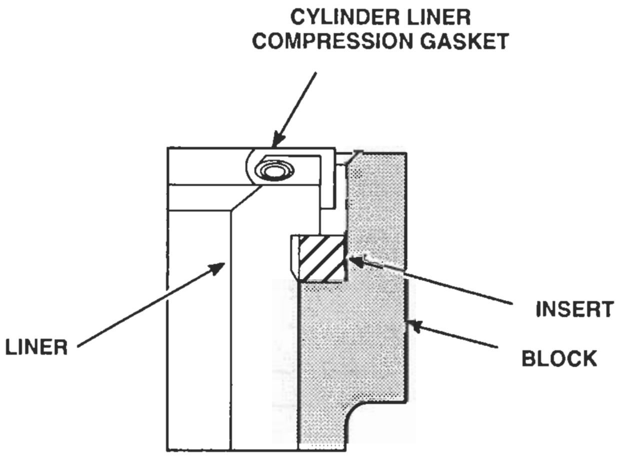


Figure 6. Sealing Arrangement of Cylinder Liner

New service replacement cylinder block assemblies include the main bearing caps and bolts as well as dowels and necessary plugs. The hydraulically operated overhaul stand (J 29109) provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It then may be rotated 360° in either direction and locked into place for maintenance.

ENGINE REMOVAL AND DISASSEMBLY

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

1. Drain the cooling system.
2. Drain the lubricating oil.
3. Disconnect the fuel lines.
4. Remove the air silencer or air cleaner and mounting bracket.
5. Remove the turbocharger (if used).
6. Disconnect the exhaust piping and remove the exhaust manifold.
7. Disconnect the throttle controls.
8. Disconnect and remove the starting motor, battery–charging generator, and other electrical equipment.
9. Remove the air compressor (if used).
10. Remove the radiator and fan guard or the heat exchanger and other related cooling system parts.
11. Remove the air box covers.
12. Disconnect any other lubricating oil lines, fuel lines, or electrical connections.

CAUTION:

A spreader bar should be used with a sling and adequate chain hoist when lifting any engine. The lifting device should be adjusted so the lifting hooks are vertical to prevent bending of the engine lift brackets. To ensure proper weight distribution, all engine lift brackets provided must be used to lift the engine. Be sure the spreader bar is adequate to prevent lifter brackets from contacting the rocker cover, which may damage the rocker cover. Never lift any engine by any other means.

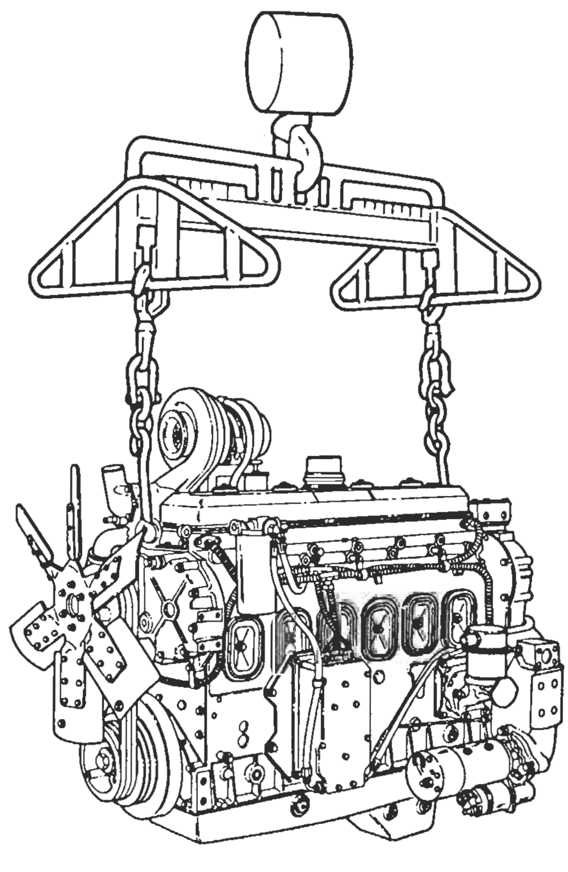


Figure 7. Lifting Engine

ENGINE REMOVAL AND DISASSEMBLY (CONT.)

NOTICE:

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

13. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base. 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.
14. Separate the engine from the transmission or other driven mechanism.
15. Remove the engine mounting bolts.

CAUTION:

Be sure the engine is securely mounted in 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.

16. Locate the center lug of the overhaul stand adaptor plate (J 33850) in the proper air box opening on the side of the block opposite the blower. The center lug is located in the center air box opening of three cylinder engines, in the number two opening of four cylinder engines and in the number four opening of six cylinder engines.

The adaptor plate, used with the hydraulic engine overhaul stand, must be attached to the mounting plate on the overhaul stand with six spacers and bolts. Long spacers and bolts are used with the three and four cylinder engines and short spacers and bolts are used with the six cylinder engines. The spacers provide the necessary clearance for the front balance weight cover and the flywheel housing when the engine is rotated (Figure 8.)

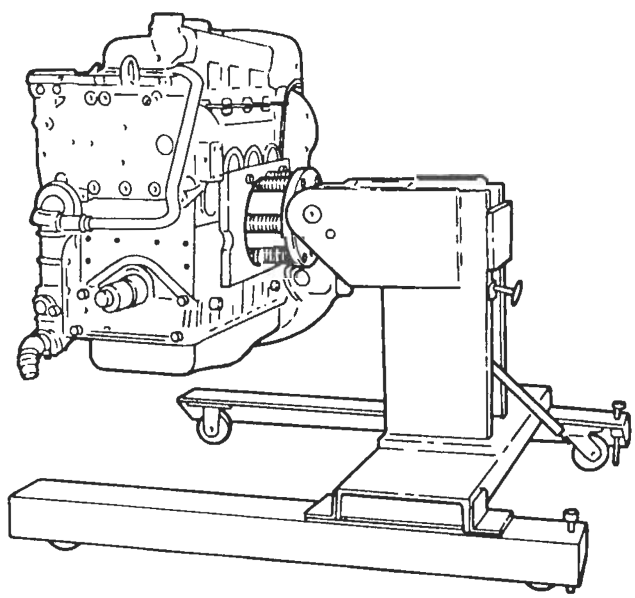


Figure 8. Engine Mounted on Overhaul Stand

ENGINE REMOVAL AND DISASSEMBLY (CONT.)

17. Loosen the locknuts on the two holding lugs on the adaptor plate and lower the engine while guiding the lugs into the air box openings.
18. Turn the holding lugs crosswise in the air box openings and tighten the locknuts, drawing the engine tight against the adaptor plate.

CAUTION:

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

19. To be sure the engine does not shift on or break away from the overhaul stand, insert a minimum Grade 5, 7/16–14 x 2 inch bolt with a plain washer under the head of the bolt through the hole in the adaptor plate and into the pad on the cylinder block.
20. With the engine mounted on the overhaul stand, remove all of the remaining subassemblies and parts from the cylinder block.

The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair and assembly of each, will be found in the various sections of this manual. After stripping the cylinder block must be thoroughly cleaned and inspected.

CYLINDER BLOCK CLEANING

Scrape all gasket material from the cylinder block. Then remove all oil gallery plugs and core hole plugs to allow the cleaning solution to contact the inside of the oil and water passages. If a core hole plug is difficult to remove, hold a 3/4 inch drift against the plug and give it a few sharp taps with a one–pound hammer. With a 1/2 inch 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. This procedure is for cast iron and steel parts only.

Cleaning Cast Iron Cylinder Block

1. Remove the grease by agitating the cylinder block in a hot bath of commercial heavy–duty alkaline cleaner solution.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

2. Rinse the block in hot water or steam clean it to remove the alkaline solution.

CYLINDER BLOCK CLEANING (CONT.)

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 action stops (approximately 30 minutes).
   c. Lift the block, drain it and immerse it in the same acid solution for ten 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.
5. Make certain that all water passages, oil galleries and air box drain holes have been thoroughly cleaned.

CYLINDER BLOCK PRESSURE TESTING

Extremely tight fitting cylinder liners, severe scoring of the liners and overheating of the engine may result in cracks in the cylinder bores. Overheating of the engine may also result in cracks between the water jackets and the oil passages.

The cylinder block may be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make plates to seal the water openings in the top of the block (Figure 9.)

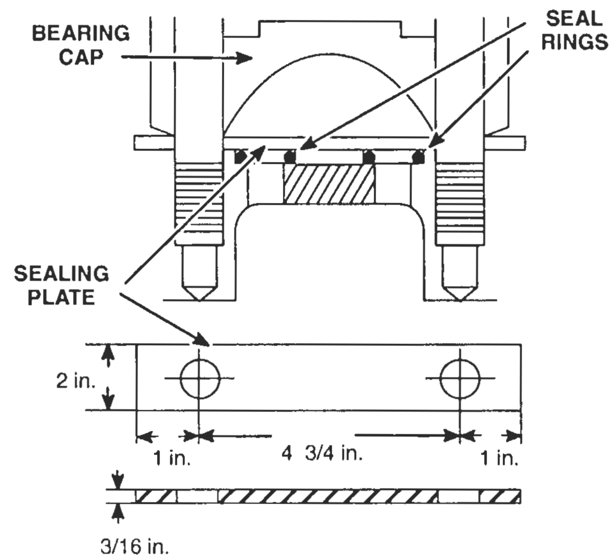


Figure 9. Sealing Plate Details for Pressure Testing Cylinder Block

Main bearing caps may be used to secure the plates to the block with the cylinder head bolts or studs and nuts (Figure 10.) Cylinder head seal rings may be used as gaskets between the plates and the block. It will also be necessary to use water hole cover plates and gaskets to cover the water pump inlet openings in the block. Drill and tap one cover plate to provide a connection for an air line.

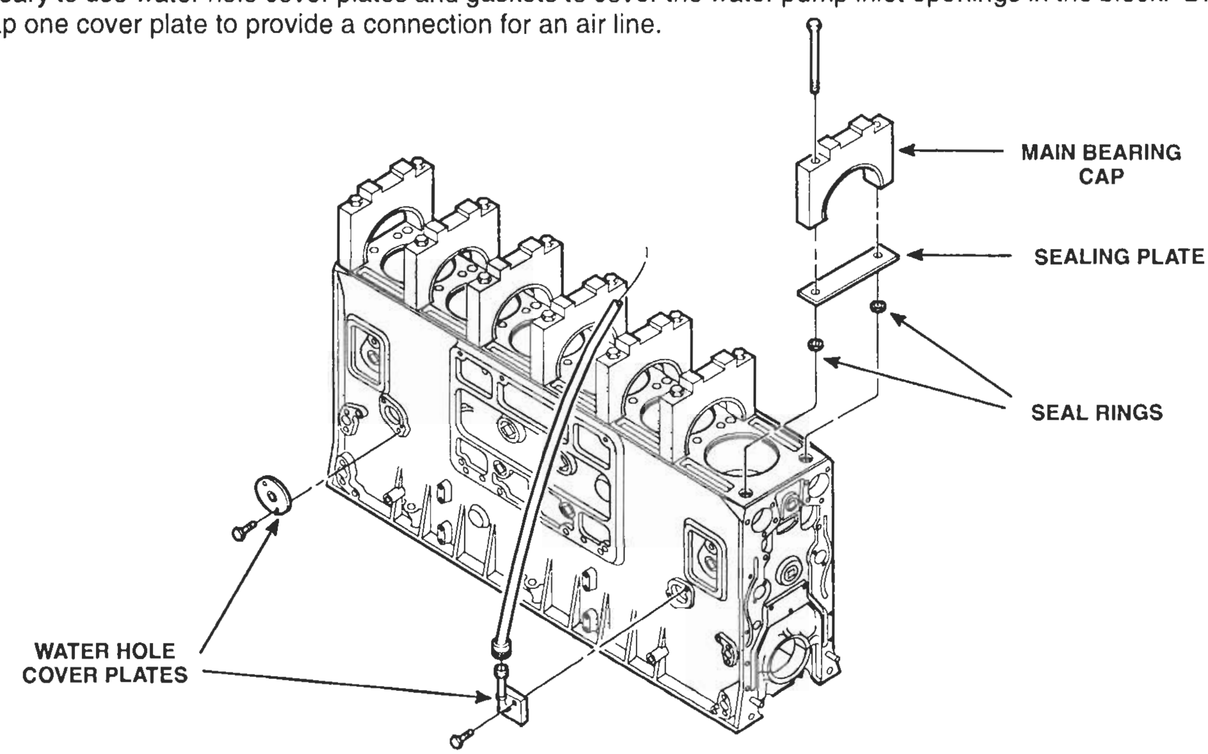


Figure 10. Preparing Cylinder Block for Pressure Test

CYLINDER BLOCK PRESSURE TESTING (CONT.)

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. Immerse the block for twenty minutes in a tank of water heated to 180–200°F (82–93°C).

CAUTION:

To prevent possible personal injury, wear adequate eye protection an do not exceed 40 lb/in^2 (276 kPa) air pressure.

2. Apply 40 lb/in.^{2} (276 kPa) air pressure to the water jacket and observe the water in the tank for bubbles which indicate the presence of cracks or leaks in the block. A cracked cylinder block must be replaced by a new block.
3. After the pressure test is completed, remove the block from the water tank. Then, remove the plates and gaskets and dry the block with compressed air.

Method "B"

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

1. Attach sealing plates and gaskets. 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 because it is detrimental to the water seals.

CAUTION:

To prevent possible personal injury, wear adequate eye protection an do not exceed 40 lb/in^2 (276 kPa) air pressure.

2. Install the remaining sealing plate and tighten it securely.
3. Apply 40 lb/in.^{2} (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 with a new block.
5. After the test is completed, remove the plates, drain the water jacket and blow out all of the passages in the block with compressed air.

CYLINDER BLOCK INSPECTION

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. Before attempting to check the block bores, hone them throughout their entire length until about 75% of the area above the ports has been "cleaned–up."

1. Hone the block bores as follows:

   a. Use a hone (J 5902–01) in which the cutting radius of the stones can be set in a fixed position to remove irregularities in the bore, rather than following the irregularities as with a spring–loaded hone. Clean the stones frequently with a wire brush to prevent stone loading. Follow the hone manufacturer's instructions regarding the use of oil or kerosene on the stones. Do not use such cutting agents with a dry hone. In a cast iron cylinder block, use 120 grit stones J 5902–14.

   b. Insert the hone in the bore and adjust the stones snugly to the narrowest section. When correctly adjusted, the hone will not shake in the bore, but will drag freely up and down when the hone is not running.

   c. Start the hone and "feel out" the bore for high spots which will cause an increased drag on the stones. Move the hone up and down the bore with short overlapping strokes about one inch long. Concentrate on the high spots in the first cut. As these are removed, the drag on the hone will become lighter and smoother. Do not hone as long at the air inlet port area as in the rest of the bore because this area, as a rule, cuts away more rapidly. Feed lightly to avoid an excessive increase in the bore diameter. Some stones cut rapidly even under low tension.

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

   e. Wash the cylinder block thoroughly after the honing operation is completed.

CYLINDER BLOCK INSPECTION (CONT.)

2. The cylinder liner is alternately expanding and contracting during engine operation, due to temperature variations. This may result in irregularities in the block bores (out–of–round and taper), the effects of which will be seen as high pressure areas on the outside diameter of the cylinder line (Figure 11.) A slight increase in block bore size is normal with high mileage or long periods of engine operation.

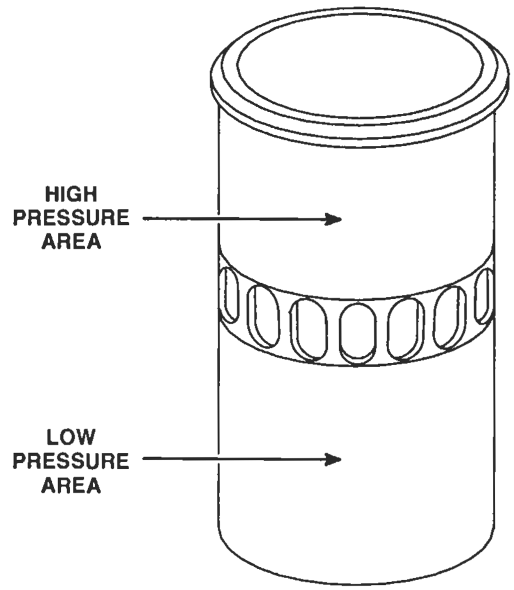


Figure 11. High Pressure Areas on Cylinder Liner

a. Visually check the contact area as revealed by the honed surface. There must not be any low spots which are larger in area than a U.S. half dollar.

b. Measure the entire bore of each cylinder with cylinder bore gage J 5347–B which has a dial indicator calibrated in .0001 inch increments (Figure 12.) The standard block bore is 4.6256 to 4.6275 inch.

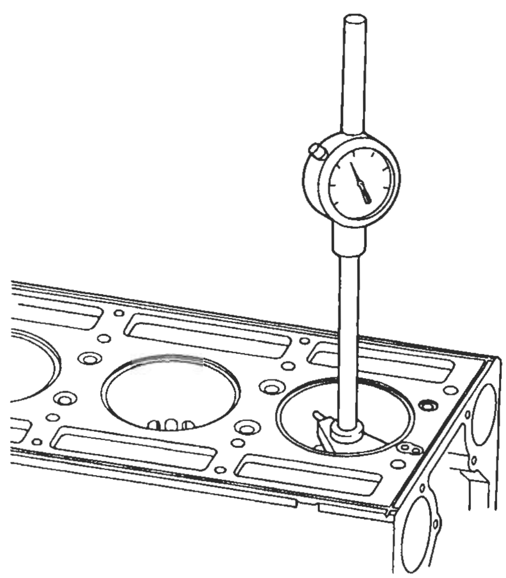


Figure 12. Checking Bore of Cylinder Block with Tool J 5347–B

CYLINDER BLOCK INSPECTION (CONT.)

Place the bore gage in the master ring gage J 8386–01 which has an I.D. of 4.6270 inch and set the dial to zero. Take measurements on the cleaned–up surface only at positions A, B, C, D, E and F in the bore on axes 45° apart (Figure 13.) Read the measurements from the zero mark on the gage. The readings may be recorded on a form similar to the one shown in Table 1. Dial bore gage setting master tool J 23059–01 may be used in place of the master ring gage.

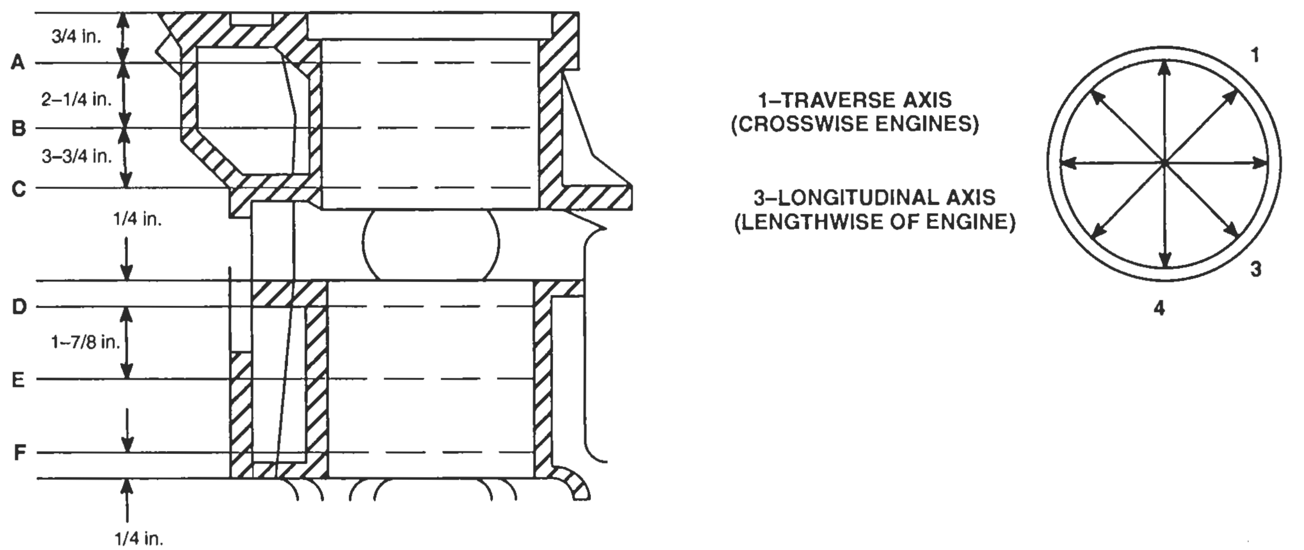


Figure 13. Cylinder Bore Measurement Diagram

The I.D. of the cylinder block bores will be classified #0, #1, #2, #3 or #4 (see Section 1.6.3).

	Trans.	45°	Long.	45°
A				
B				
C				
Port Belt	X	X	X	X
D				
E				
F				

TABLE 1

The upper cylinder bore must be relatively straight, within .0005 inch of the classification diameter ("B"). This will insure proper liner to block fit and combustion heat transfer to the block water jacket.

CYLINDER BLOCK INSPECTION (CONT.)

"A" Diameter – Must be the same size as "B" diameter within +.0006 inch and never smaller – (no bottleneck allowed).

"B" Diameter – Is the classification area for determining whether a cylinder bore is a #0, #1, #2, #3 or 4 size (see Section 1.6.3). "B" has a .001 inch tolerance band.

"C" Diameter – Must be the same size as "B" diameter. However, due to a bell mouth flare caused by the honing stones traveling through the airbox area a maximum +.0022 inch diameter flare over "B" diameter will be allowed.

"D" Diameter – Must be the same size as "B" diameter. However, due to a bell mouth flare caused by the honing stones vertical travel, a maximum +.0022 inch diameter flare over "B" diameter will be allowed.

"E" Diameter – Must be within the .0005 inch classification range as determined by "B" diameter (see Section 1.6.3).

"F" Diameter – Must be the same size as "B" diameter. However, due to a bell mouth flare caused by the honing stones vertical travel, a maximum flare tolerance of +.0012 inch over "B" diameter will be allowed.

3. The liner–to–block clearance with new parts is zero to .0015 inch. With used parts, the maximum clearance is .0025 inch. After measuring the block bores, measure the outside diameter of the cylinder liners (Section 1.6.3). Then, determine the block–to–liner clearances (Section 1.0) and whether it will be necessary to bore the block for oversize cylinder liners.

4. If necessary, bore the cylinder block as follows:

   a. Each bore in a used block must not be out–of–round or tapered more than .002 inch. If the average block bore is over 4.6285 inch, the block should be bored oversize (refer to Tables 2 and 3).

For Average Block Bore I.D. Size	Use Linear O.D. Size	For Linear–to–Block Clearance
	CAST IRON BLOCK	
4.6256 4.6275	Standard	.000 to .0025 inches
4.6266 4.6285	#4	.000 to .0025 inches

TABLE 2

Block Boring Dimensions	Liner O.D. Size	Max. Block Bore I.D. on Used Block
	CAST IRON BLOCK	
4.6316 4.6325	.005 inch Oversize	4.6325 inches
4.6356 4.6375	.010 inch Oversize	4.6375 inches
4.6456 4.6475	.020 inch Oversize	4.6475 inches
4.6556 4.6575	.030 inch Oversize	4.6575 inches

TABLE 3

CYLINDER BLOCK INSPECTION (CONT.)

b. A portable boring tool can be used for boring the engine block. Instructions on correct use of the boring bar are provided by the manufacturer.

c. After boring the block for an oversize cylinder liner, check the bore finish to be sure it is smooth (120 RMS). Heat transfer from the cylinder liner to the block will be adversely affected if the block bore is not smooth.

d. Wash the block thoroughly after the boring operation.

e. When an oversize liner is used, stamp the size of the liner on the top deck of the block adjacent to the liner counterbore. An oversize liner insert must be installed whenever an oversize liner is used (Section 1.6.3).

5. Check the top of the block for flatness with an accurate straight edge and a feeler gage (Figure 14.)

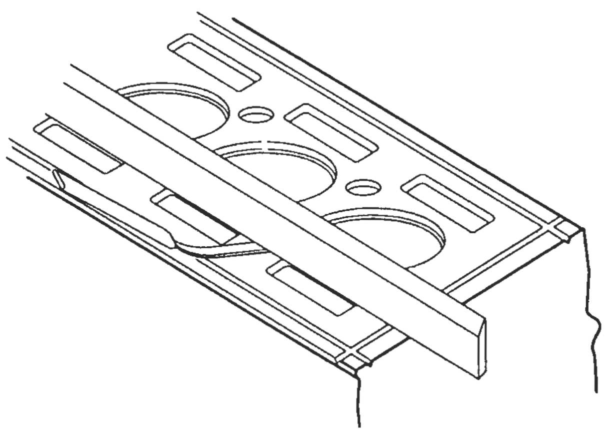


Figure 14. Checking Top Face of Cylinder Block

a. The top surface of the block must not vary more than .003 inch transversely and not over .006, .007 or .009 inches longitudinally on the 3, 4 and 6 cylinder blocks respectively. It will be difficult to prevent water, oil and compression leaks if the top surface of the block exceeds these tolerances.

b. If it is necessary to machine the top surface of the block to correct for the above conditions, do not remove more than .008 inch of metal. Stamp the amount of stock removed on the face of the block. The distance from the centerline of the crankshaft to the top of the block must not be less than 16.176 inch (Figure 15.).

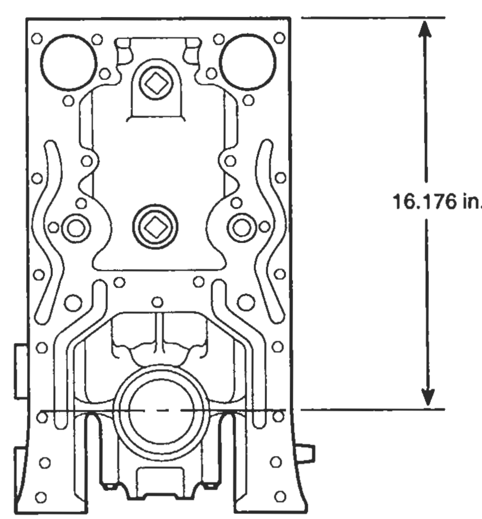


Figure 15. Minimum Distance from Center Line of Crankshaft to Top of Cylinder Block

CYLINDER BLOCK INSPECTION (CONT.)

c. If stock is removed from the top surface of the block, check the depth of the seal ring grooves and counterbores. The cylinder head seal strip grooves must be .092–.107 inch deep. The large water hole counterbores (between the cylinders) must be .109–.120 inch deep and the combination water and oil hole counterbores and small water hole counterbores must be .087–.098 inch deep. If necessary, deepen the grooves or counterbores to the specified limits to retain the proper "crush" on the seal rings. It is not necessary to deepen the counterbores for the cylinder liners since .004 and .008 inches undersize thickness inserts are available for adjusting the liner position (Section 1.6.3).

6. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then, check the depth (Figure 16.) The depth must be .4770 to .4795 inches (cast iron block) and must not vary more than .0015 inch throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within .001 inch total indicator reading. There must not be over .001 inch difference between any two adjacent cylinder counterbores when measured along the cylinder longitudinal centerline of the cylinder block.

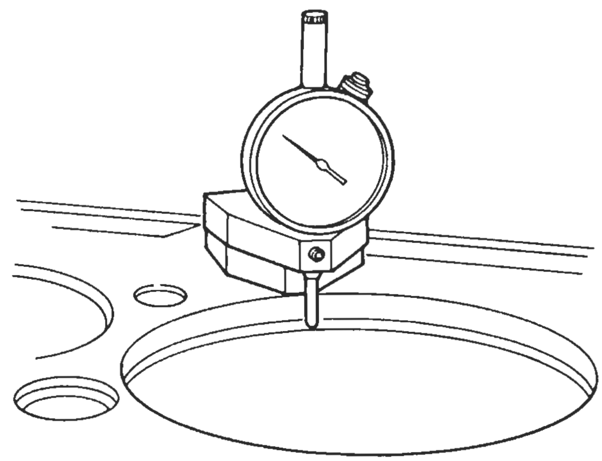


Figure 16. Checking Depth of Counterbore for Cylinder Liner with Tool J 22273–01

7. Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions. Apply a small quantity of International Compound No. 2, or equivalent, to the threads on the bolts and to the bolt head contact area. Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Then, install and tighten the bolts to 165–175 lb·ft (224–238 N·m) torque or stud nuts to 140–155 lb·ft (190–211 N·m) torque. The specified bore diameter is 3.812 to 3.813 inches. If the bores do not fall within these limits, the cylinder block must be rejected.

CYLINDER BLOCK INSPECTION (CONT.)

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 stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Figure 17.), regardless of engine rotation or accessory arrangement. As originally manufactured, the main bearing caps are installed with the numbered side facing the blower side of the engine. Machining of the cylinder block and main bearing caps is such that the mating parts are "offset" to prevent installation of the bearing caps 180° from their correct position. However, if an engine has been converted for a new application and the cylinder and bearing numbering sequence has been reversed, the bearing caps must be reinstalled in the original positions regardless if the block and bearing caps have or have not been renumbered.

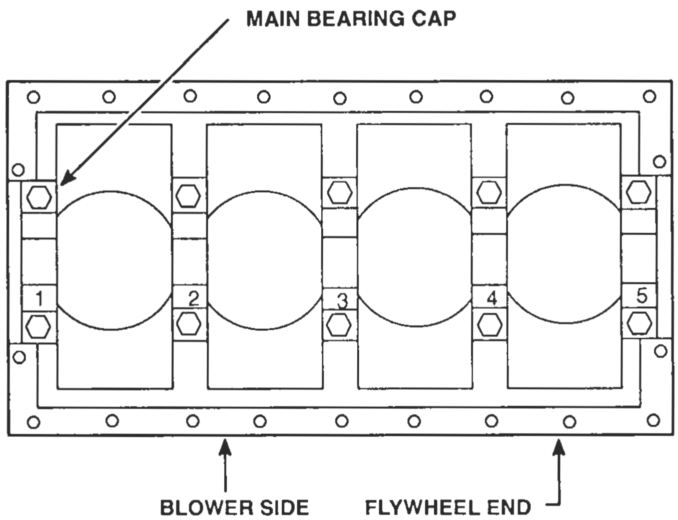


Figure 17. Cylinder Block Markings

b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a finished replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap. Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

c. Main bearing bores are line–bored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated and the bearing caps have been secured in place and the bolts tightened (Section 1.3.4). If a main bearing bore is more than .001 inch out of alignment, the block must be line–bored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat or other damage.

d. If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line–bored. Install the bearing caps in their original positions and tighten the bolts to 165–175 lb·ft (224–238 N·m) torque. Line–bore the block, but do not remove more than .001 inch stock. After boring, all bores must be within the specified limits of 3.812 to 3.813 inches.

CYLINDER BLOCK INSPECTION (CONT.)

8. Install the necessary cylinder block plugs (Section 1.0) and dowels. Use tool J 34650 to install the new sealant–coated 1/8–27 pipe plugs.
9. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend .625 inch from the face of the block.

The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend .110 to .120 inch 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 inch) or No. 12 (.1890 inch) 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.

10. Replace main bearing cap studs, if used, which are damaged or broken. Install new studs to a height of 4 ±1/32 inches above the upper bearing seat at a torque of 35–75 lb·ft (47–102 N·m).
11. If used, replace damaged or broken cylinder head studs. Install and drive a new stud to a height of 4 3/8 ±1/32 inches at a minimum torque of 75 lb·ft (102 N·m).
12. Examine the tapped bolt holes for the cylinder head or main bearing cap bolts and, if the threads are damaged, “clean–up” the threads or install a helical thread insert. The tapped holes may be tapped with a 5/8–11 UNC3B tap. All cylinder head bolt or stud holes must have the threads extending 1.84 inches below the block surface. The current service replacement cast iron cylinder blocks use a special cylinder head bolt in all positions.
13. Check the drive pins (that plug the vertical oil galleries) in the corners of the block to be sure they are flush with or below the top surface of the block.
14. Check the remaining cylinder block surfaces and threaded holes. Check all of the mating surfaces, or mounting pads, for flatness, nicks and burrs. The flatness of the blower mounting pad must not vary more than .004 inch. Clean–up damaged threads in tapped holes with a tap or install helical thread inserts, if necessary.
15. After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil.
16. 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.

ENGINE ASSEMBLY AND INSTALLATION

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

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

1. Mount the 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 pad located in the upper right–hand corner on the blower side of the block. Also, stamp the position numbers on the main bearing caps (Figure 17.) 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 good grade of non–hardening sealant on the threads of the plugs and drain cocks. Install the plugs flush with or below the surface of the block.
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 by following the run–in procedure (Section 13.2.1).
8. Reinstall the engine in the equipment that it powers.

CYLINDER BLOCK END PLATES

A flat steel plate, one bolted to each end of the cylinder block, provides a support for the flywheel housing at the rear and the balance weight cover and crankshaft cover at the front of the engine. Since the blower drive gear assembly is supported on the rear end plate, this plate has a different contour than the one used at the front. Gaskets are used between the block and each 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 plate and the cylinder block. Clean the end plate (Section 1.1).

Inspect both surfaces of each end plate for nicks, dents, scratches, or score marks and check the end plates for warpage. Also, check the tapped holes in the end plate. If nicks or scratches on the sealing surfaces of the end plates are too deep to be cleaned up, replace the end plates.

Effective with engines 4A–52814 and 6A–48855, the cylinder block was revised by drilling passages at each end of the camshaft gallery to provide a means of draining the oil (Figure 1.)

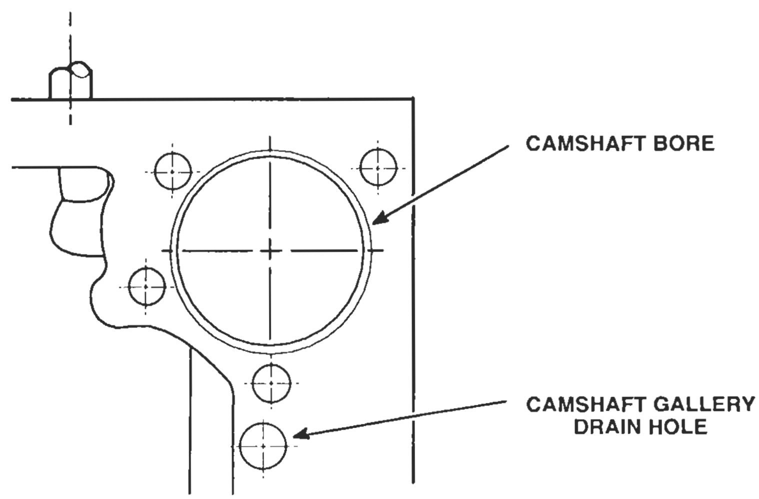


Figure 1. Current Method of Draining Camshaft Gallery

Although only one drain hole is used, the block is drilled at each end to permit its use in either a "B" or "D" type engine. The drain hole in the block registers with holes in the current rear end plate (Figure 2.) and gasket. During engine operation, excess lubricating oil in the camshaft gallery flows through the drain holes in the block and end plate and returns to the oil pan. The drain hole at the front is blocked–off by the front end plate.

NOTE: The former rear end plate and gasket must NOT be used with a current cylinder blocks. Otherwise, the drain hole will be blocked–off. However, the current rear end plate and gasket may be used with the former cylinder block.

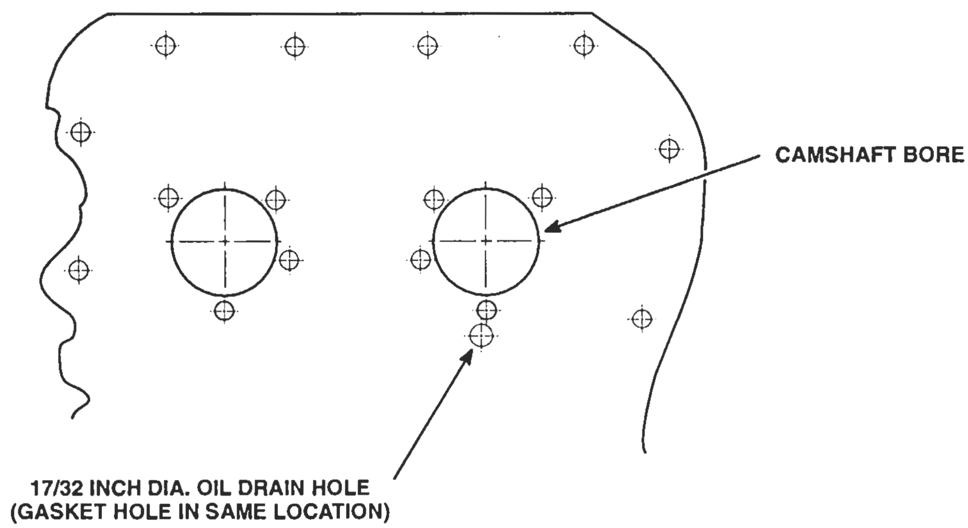


Figure 2. Current Rear End Plate

INSTALL END PLATES

With all of the necessary plugs properly installed, the end plate–to–cylinder block dowels in place, attach the cylinder block front and rear end plates as outlined below.

1. Affix a new gasket to each end of the cylinder block, using a non–hardening gasket cement. Also, apply an even coating of gasket cement to the outer surface of each gasket.
2. Use guide studs J 1927–01 to set the front end plate (Figure 3.) next to the cylinder block and install the bolts and lock washers. Do not tighten the bolts at this time. Wipe the excess gasket cement from the bores in the end plate and the cylinder block.

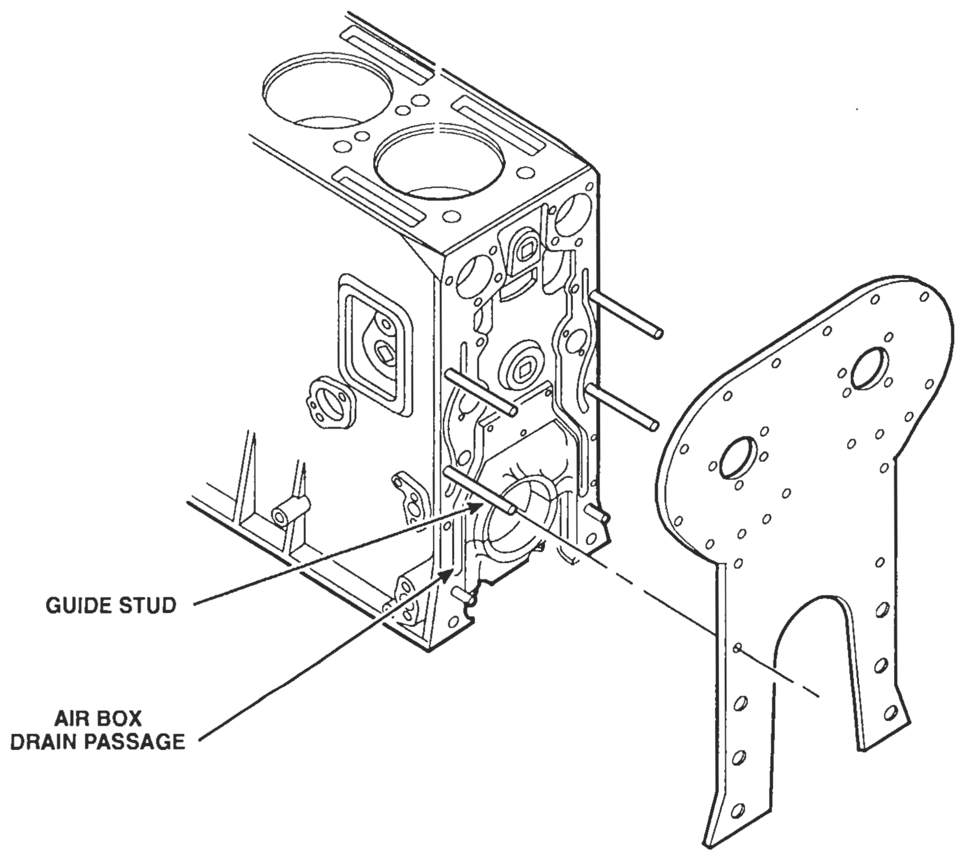


Figure 3. Front End Plate Installation

SECTION 1.1.1 – CYLINDER BLOCK END PLATES

INSTALL END PLATES (CONT.)

3. Insert a 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 (Figure 4.)
4. With the bearing in place, tighten the 3/8–16 end plate retaining bolts to 30–35 lb·ft (41–47 N·m) torque. Tighten the 1/2–13 bolts to 71–75 lb·ft (96–102 N·m) torque. Remove the camshaft bearing which served as a pilot while attaching the end plate.
5. Use the guide studs J 1927–01 and the camshaft end bearing to install the rear end plate in the same manner as outlined above.

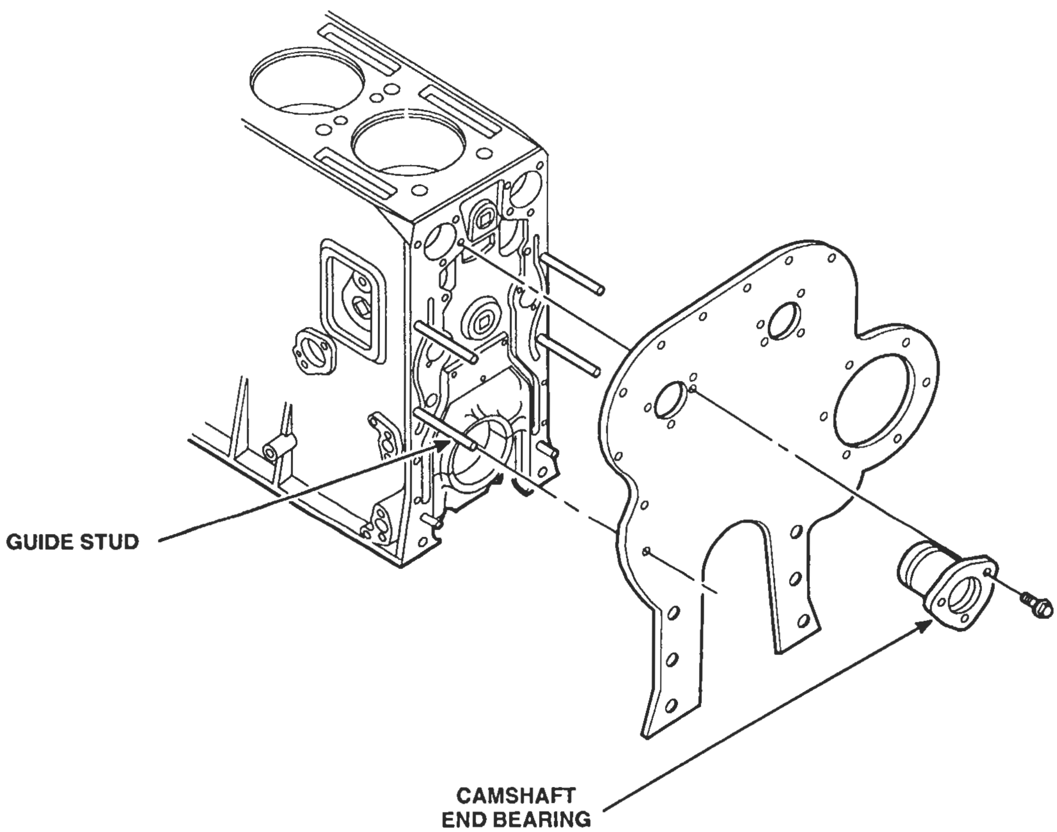


Figure 4. Rear End Plate Installation

AIR BOX DRAINS

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through cored passages located at the front and rear of the cylinder block with drain outlets in the side of the block (Figure 1.)

Some engines are equipped with a drain tank to collect and retain the sediment from the air box. Air box drains must be kept open at all times; otherwise, water and oil that may accumulate will be drawn into the cylinders.

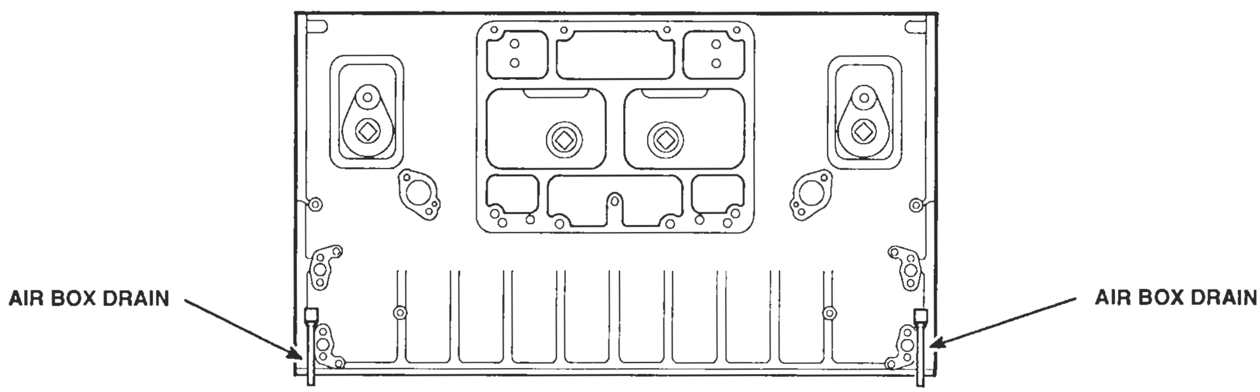


Figure 1. Former Air Box Drain Tubes

An air box drain tube and check valve were added to Inline 6–71 T and TT vehicle engines, effective with unit number 6A–382107. This closed design was replaced by the open design check valve and drain tube effective with unit number 6A–405930. The former closed design is now obsolete for production and service. DDC recommends replacing the closed design with the open design at engine overhaul or whenever practical.

To accommodate the closed design air box drain tube and check valve, the cylinder block was revised to include two additional tapped and drilled holes. The closed design air box drain tube was routed to the crankcase, at the rear face of the cylinder block on the side opposite the blower. This hole should now be plugged. The open design air box drain is mounted at either of the rear corners of the block. With this design the drainage is routed to the atmosphere.

The air box check valve allows drainage only at low air box pressure.

SECTION 1.1.2–AIR BOX DRAINS

The air box check valve cutaway (Figure 2.), shows the valve operating at engine idle speed. As the engine r/min (approximately 900 r/min) and air box pressure increase, the valve moves forward and seats, blocking airflow. The engine utilizes this additional air.

A limited number of 6–71T and TT engines were built with the check valves installed in the air box floor. This design is now obsolete. See Section 1.0 for conversion to the new external, open air box drain system.

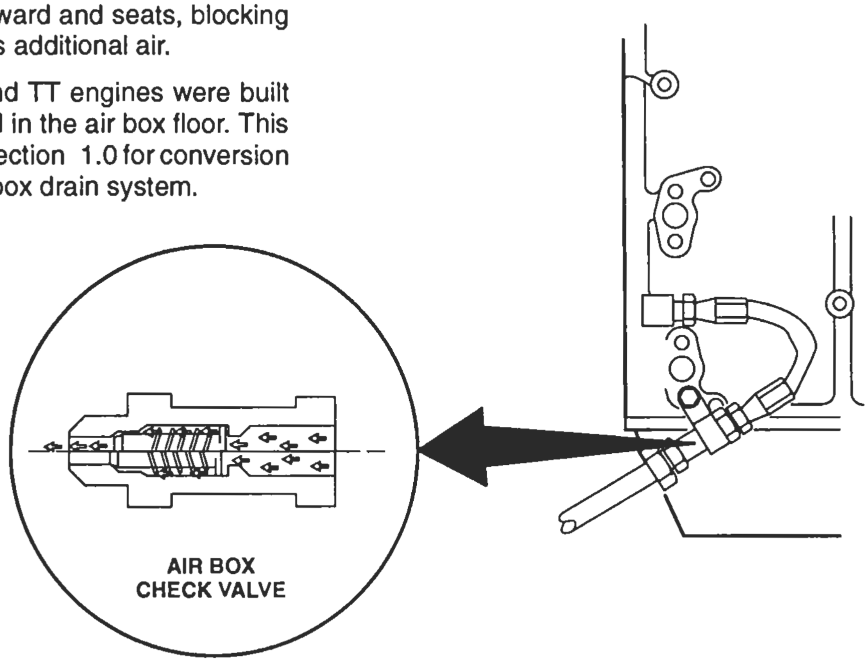


Figure 2. Current Open Design Air Box Drain Tube (6–71T and 6–71TT)

INSPECTION

Check for air flow from the air box drain tubes as required (Section 15.1).

If a drain tank is used, service it periodically (Section 15.1).

Inspect the check valve for proper operation as follows:

1. Run the engine and note the air flow through the check valve at idle speed.
2. Increase the engine speed.
3. If the check valve is operating properly, there will be no airflow at engine speeds above 900 r/min. To check the air box pressures on an engine with the new drain tubes, use air box covers with a tapped hole for a fitting, or one of the corner plugs.
4. Remove the plug in the cover or the plug at one of the four corners of the cylinder block.
5. Install a fitting and short drain tube.
6. Attach a manometer to the end of the drain tube and check the air box pressure (Section 13.2).

CYLINDER HEAD

The cylinder head is a one–piece casting securely held to the top of the cylinder block by special bolts.

The exhaust valves, fuel injectors and the valve and injector operating mechanism are located in the cylinder head. Depending upon the engine application, either two or four exhaust valves are provided for each cylinder (Figure 1. and Figure 2.) 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.

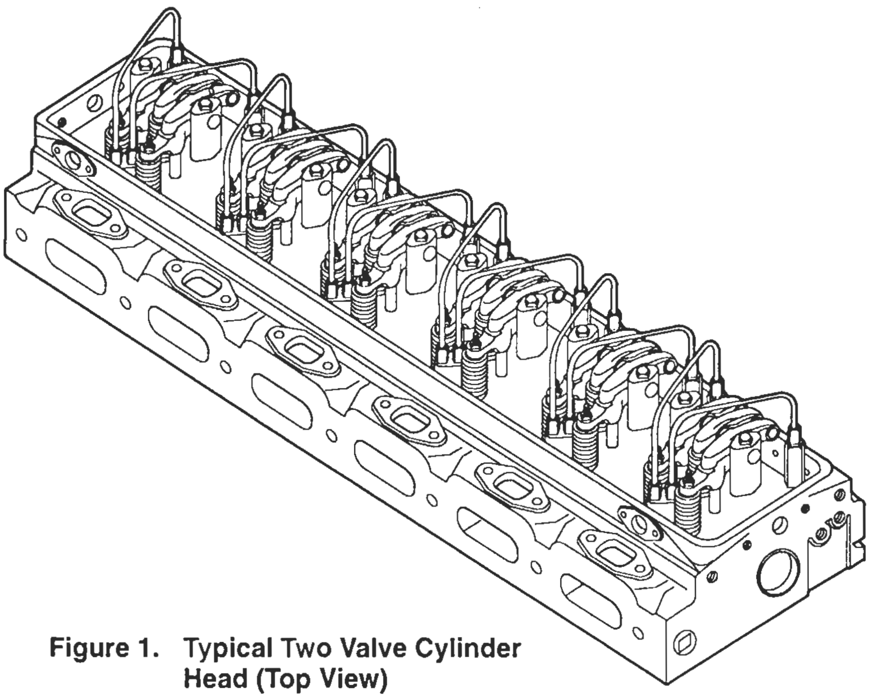


Figure 1. Typical Two Valve Cylinder Head (Top View)

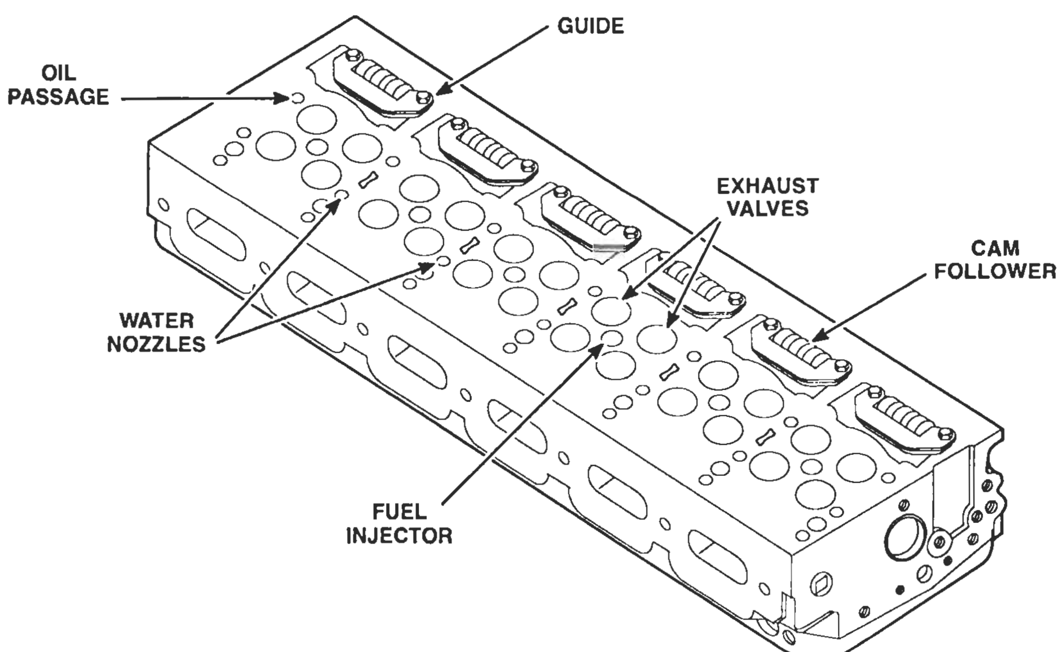


Figure 2. Typical Four–Valve Cylinder Head (Bottom View)

SECTION 1.2 – 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 (Figure 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 neoprene seal. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

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

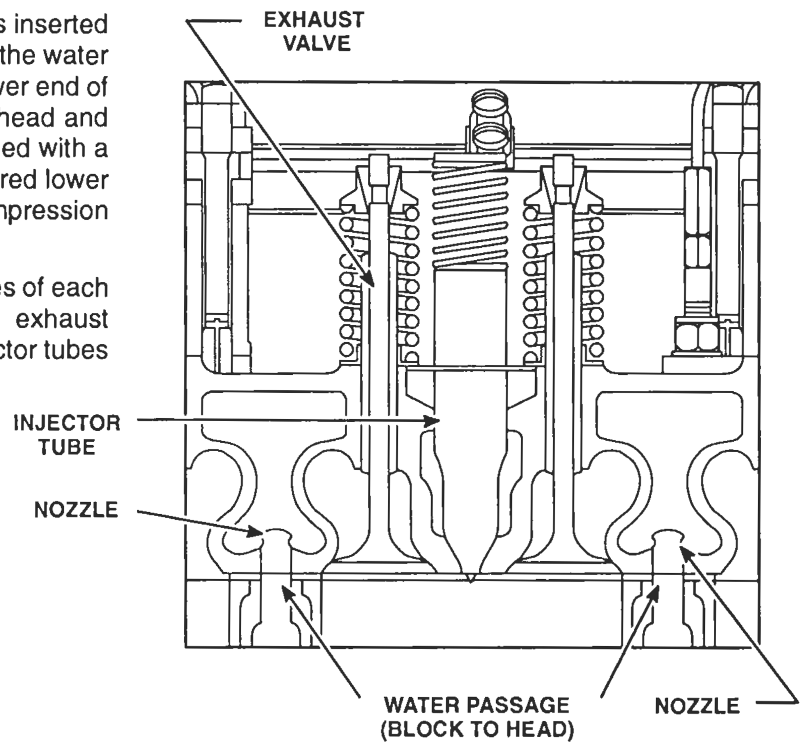


Figure 3. Coolant Passage Around Exhaust Valves and Fuel Injectors

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 (Figure 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.

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

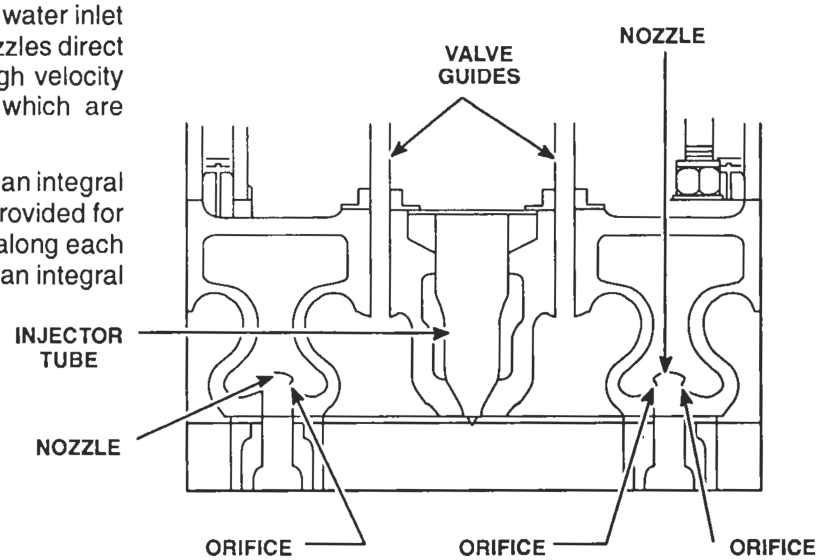


Figure 4. Water Nozzles in Two–Valve Cylinder Head

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 synthetic rubber 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. When the cylinder head is drawn down, a positive leakproof metal–to–metal contact is assured between the head and the block.

To make the cylinder heads more tolerant of abnormal coolant temperature, relief areas have been cast in the current four valve cylinder heads. These stress relief areas, which are shaped like a "dog bone" are cast in the fire deck of the cylinder head between the cylinders (Figure 5.)

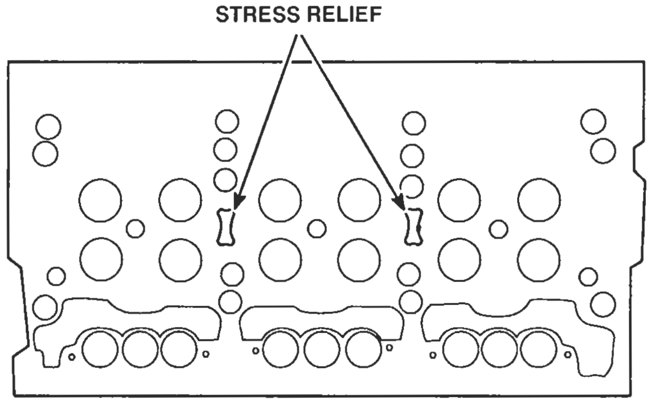


Figure 5. Current Four Valve Cylinder Head

For visual identification of the current cylinder head on an engine, two bosses or a raised boss the shape of a "dog bone" are cast on the fuel manifold side of the three cylinder heads and a raised boss the shape of a "dog bone" is cast on the exhaust manifold side of the four and six cylinder heads (Figure 6.) The current service cylinder heads which include the stress relief areas in the fire deck also include the non–magnetic turbo exhaust valve inserts identified by the letter "T" stamped on the face of the cylinder head.

Production non–turbocharged cylinder heads include cast steel exhaust valve seat inserts which have magnetic qualities. An easy method for determining the type of exhaust valve seat insert in a cylinder head is with a magnet. The magnet will be attracted to the non–turbo insert (will stick). The magnet will not be attracted to the turbo insert, it will jump to the cylinder head.

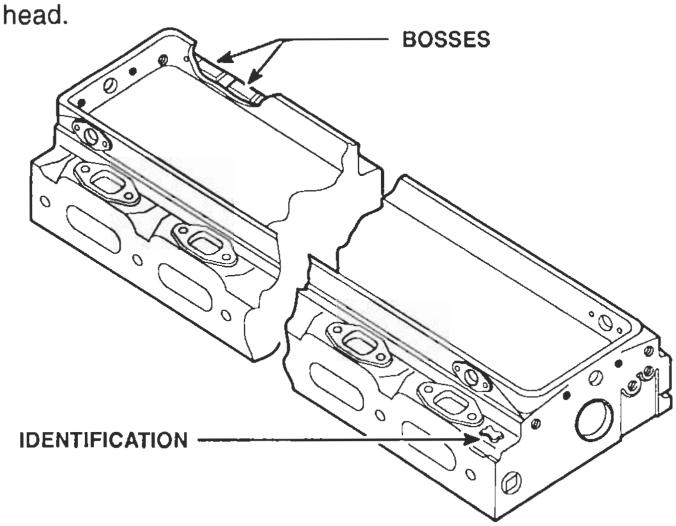


Figure 6. Current Four–Valve Cylinder Head Identification

CYLINDER HEAD MAINTENANCE

The engine operating temperature should be maintained (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 coolant 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 (Section 13.3).

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

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

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

- Excess fuel in the cylinders caused by leaking injectors
- Slipping fan belts can cause overheating by reducing air flow through the radiator
- 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
- Inoperative radiator cap which will result in loss of coolant

Fuse Plugs

Heat–sensitive fuse plugs are installed in the exhaust manifold side of all Series 71 Engine cylinder heads. The insert in these plugs will melt if the critical temperature of the head 257°F or 125°C is exceeded. Former Series 71 Engine cylinder heads used an 1/8 in. fuse plug with a slotted head. Current cylinder heads have a larger fuse plug hole and use a 1/4 in. recessed square socket head fuse plug. Special sealant is applied to the new plug to improve sealing.

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. Cylinder heads which have experienced higher than normal operating temperatures will display expansion of the solder and can only be evaluated under a microscope. If a melted fuse plug insert is found in a cylinder head, the cylinder head must be checked for serviceability. Make sure the proper fuse plug is installed before returning a reusable cylinder head to service.

The following are some conditions which will require cylinder head removal:

- Remove and install pistons and cylinder liners
- Remove and install exhaust valves and guides
- Recondition exhaust valves and valve seat inserts
- Replace fuel injector tubes
- Install new cylinder head gaskets and seals
- Remove and install camshaft

CYLINDER HEAD REMOVAL

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

1. Drain the cooling system.
2. Disconnect the exhaust piping at the exhaust manifold. On turbocharged engines, remove the connections from the exhaust manifold to the turbocharger. Remove the turbocharger, if necessary.
3. Remove the air cleaners, or air silencer, and the air inlet housing.
4. Remove the exhaust manifold.
5. Disconnect the fuel lines at the cylinder head and remove the fuel filter.
6. Remove the thermostat housing assembly.
7. Remove the water manifold.
8. Clean and remove the valve rocker cover and the governor cover.
9. Disconnect the fuel rod from the injector control tube lever and the governor. Remove the fuel rod.
10. Remove the injector control tube and brackets as an assembly.
11. 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. (Section 2.1, 2.1.1).
12. Loosen (three or four turns) the two bolts directly below each lifter bracket which attach the balance weight cover and flywheel housing to the front and rear end plates. Otherwise, the threaded ends of the bolts may interfere with removal of the cylinder head.
13. Remove the two bolts that secure the front lifter bracket to the balance weight cover and the two bolts attaching the rear lifter bracket to the flywheel housing. On heat exchanger units, remove the bolts securing the vent casting to the balance weight cover and the heat exchanger tank. Remove the vent casting and gasket.
14. Check the torque on the cylinder head bolts before removing the head. Then, remove the bolts and nuts and, using lifting hooks and a chain hoist, lift the cylinder head from the cylinder block. 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 from possible damage (if the injectors were not removed) by resting the valve side of the head on 2 in. thick wood blocks.

CYLINDER HEAD REMOVAL (CONT.)

If complete disassembly of the cylinder head is necessary, remove the exhaust valves and injector operating mechanism (Section 1.2.1, 1.2.2).

15. Place the cylinder head on its side and remove the engine lifter brackets and gaskets. Then, attach the cylinder head holding plates J 3087–01 to raise the head above the work bench (Figure 7.)
16. Remove and discard the cylinder head compression gaskets, oil seals and water seals.
17. 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.

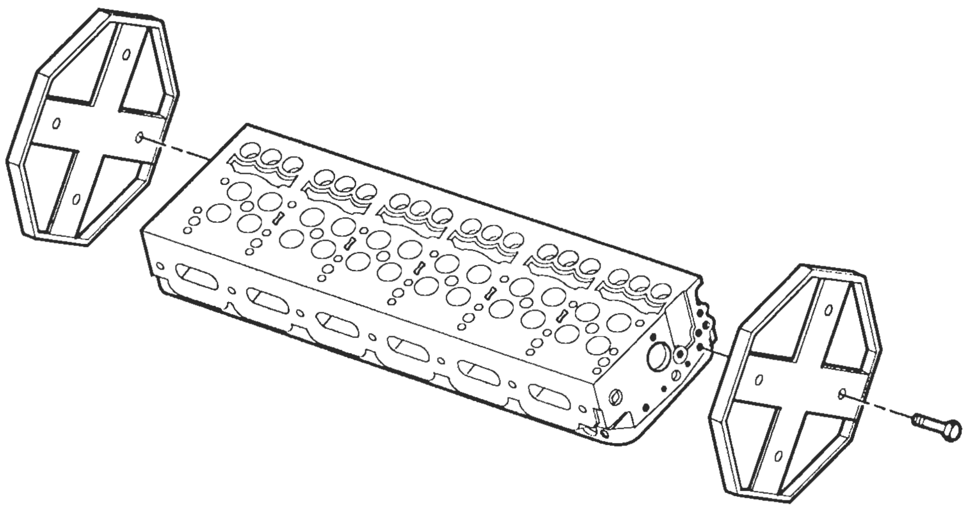


Figure 7. Cylinder Head Mounted on Holding Plates (J 3087–01)

CYLINDER HEAD CLEANING

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.

CYLINDER HEAD INSPECTION

Before a cylinder head can be reused, it must be inspected for cracks. If any method reveals cracks, the cylinder head should be considered unacceptable for reuse. Any one, or a combination of the following methods can be used for checking a cylinder head for cracks:

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."

CYLINDER HEAD INSPECTION (CONT.)

Fluorescent Penetrant Method: A highly fluorescent liquid penetrant is applied to the area in question. 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 1 to 30 minutes for the dye to dry. Remove the excess surface penetrant with clean cloths moistened with cleaner/remover. DO NOT flush surface with cleaner/remover. This will impair sensitivity. Repeat the procedure with additional wiping until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

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

If cracks are visible in the head, DO NOT use the Pressure Test Method.

Pressure Test Method – Cylinder Head Disassembled

NOTE: 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 this manual.

To seal off the water holes in the cylinder head, assemble tool set J 28454 as follows (Figure 8.)

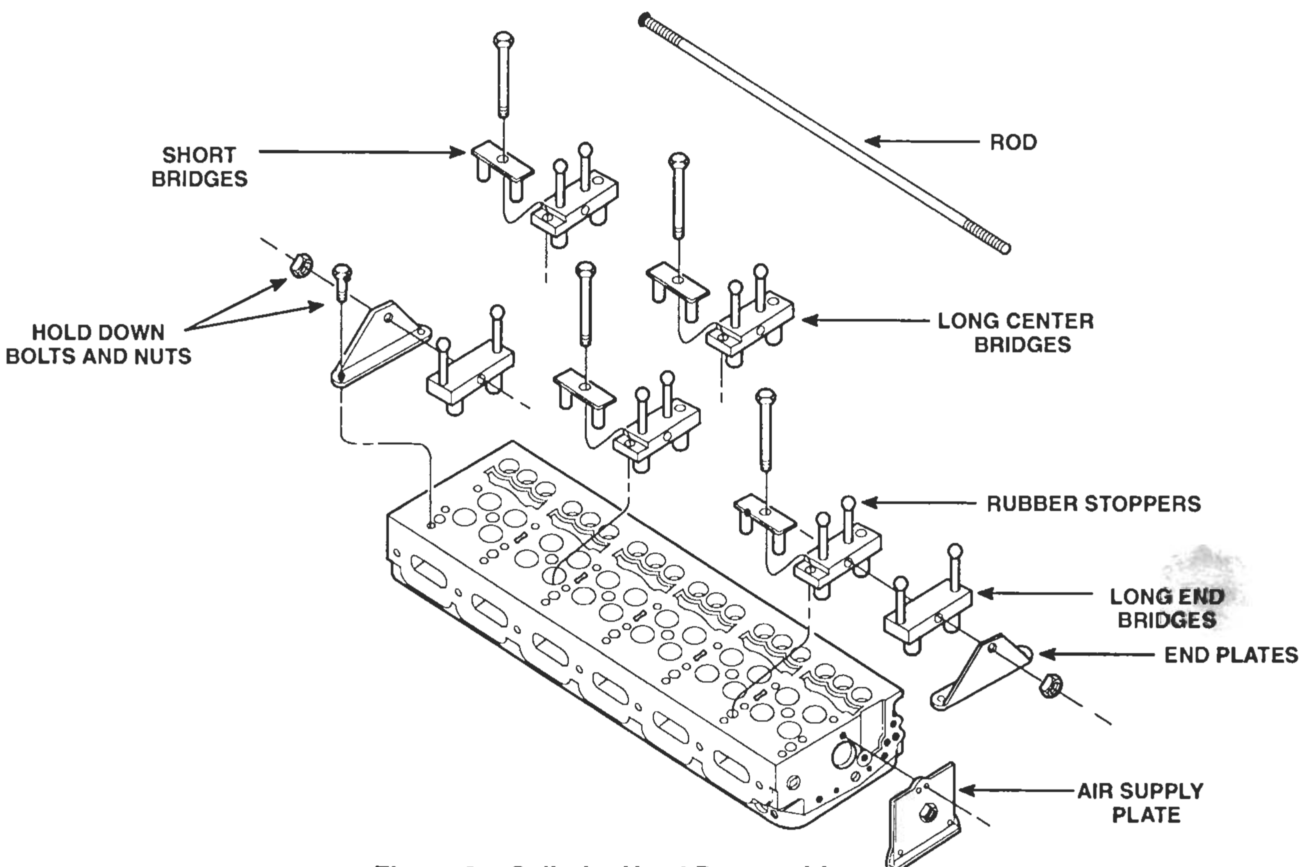


Figure 8. Cylinder Head Prepared for Pressure Test using Tool J 28454

CYLINDER HEAD INSPECTION (CONT.)

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 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.

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.

5. 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.
6. Apply 40 lb/in.^{2} (276 kPa) air pressure to the water jacket. Then, immerse the cylinder head in a tank of water, previously heated to 180°–200°F (82°–93°C), for about 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 the top and bottom of the cylinder head.
7. 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 lb/in^2 (276 kPa) air pressure.

Pressure Test Method – Cylinder Head Assembled and Removed from Engine

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.

CYLINDER HEAD INSPECTION (CONT.)

4. Install the air supply plate to water jacket opening.
   a. Apply 40 lb/in.^{2} (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.
   b. Relieve the air pressure slowly. Then, remove all plates and gaskets.
5. 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 (Figure 9.) Refer to Table 1 for maximum allowable warpage.

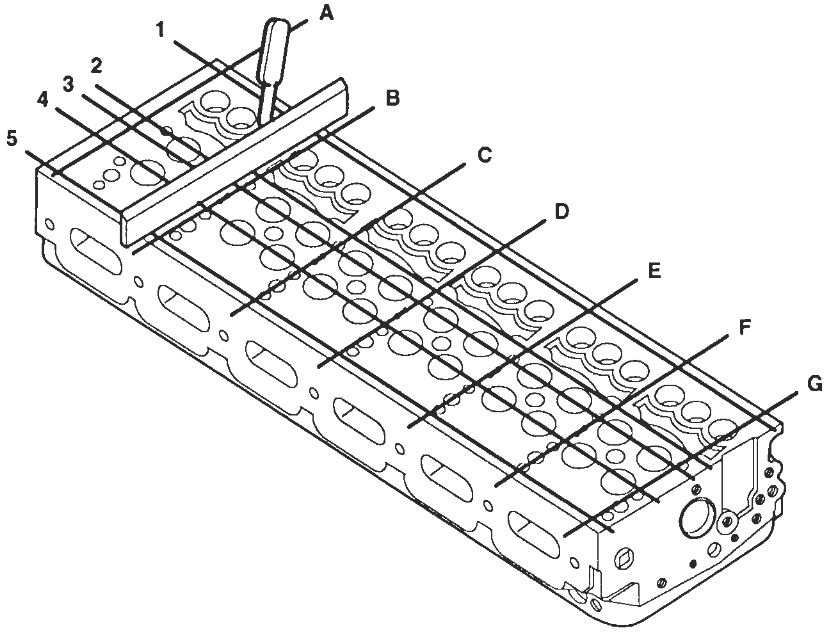


Figure 9. Checking Bottom Face of Cylinder Head

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
3–71	.0055 inches	.004 inches
4–71	.008 inches	.004 inches
6–71	.010 inches	.004 inches

TABLE 1 – MAXIMUM ALLOWABLE CYLINDER HEAD WARPAGE

CYLINDER HEAD INSPECTION (CONT.)

b. Use the measurements obtained and the limits given in the previous table as a guide to determine wether or not to reinstall the head on the engine or of reface it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

c. If the head is to be refaced, remove the injector tubes prior to machining. Do not remove more metal from the fire deck of any cylinder head below the minimum distance of 3.536 inches (Figure 10.)

NOTICE:

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.

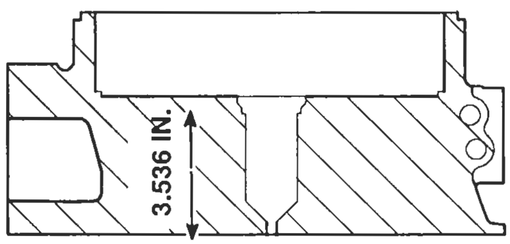


Figure 10. Minimum Distance Between Top and Bottom Faces of Cylinder Head

6. Install new injector tubes (Section 2.1.4) if the old tubes leaked or the cylinder head was refaced.
7. Inspect the exhaust valve seat inserts and valve guides (Section 1.2.2).
8. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the followers and bores to determine the cam followers–to–bore clearances. The clearance must not exceed .006 inches with used parts (Section 1.0). If the bores are excessively scored or worn, replace the cylinder head.

CYLINDER HEAD INSPECTION (CONT.)

9. Check the water hole nozzles to be sure they are not loose. Early engines did not incorporate water nozzles in the cylinder head. It is recommended that nozzles be installed when an early engine is in for a regular overhaul or for reconditioning of the cylinder head. If necessary, replace the nozzles as follows:

   a. Remove the old nozzles.

   b. Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes at each end of the head may be cleaned up with a 1/2 inch drill and the intermediate holes may be cleaned up with a 13/16 inch drill. Break the edges of the holes slightly.

   c. Press the nozzles in place with the nozzle openings parallel to the longitudinal center line of the two–valve cylinder head (Figure 11.) Install the 1/2 inch diameter nozzles at the ends of the cylinder head with their openings toward the center of the engine.

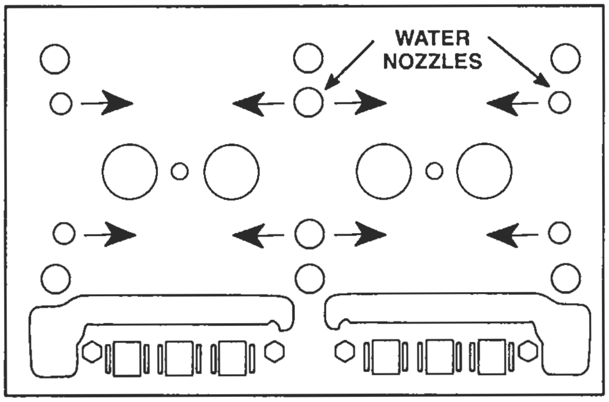


Figure 11. Correct Installation of Water Nozzles in Two–Valve Cylinder Head

   d. For the positioning of the nozzles in a four–valve cylinder head (Figure 12.), press the nozzles .003 inch above to .010 inch below the surface of the cylinder head. Check to make sure the nozzles fit tight. If necessary, use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder.

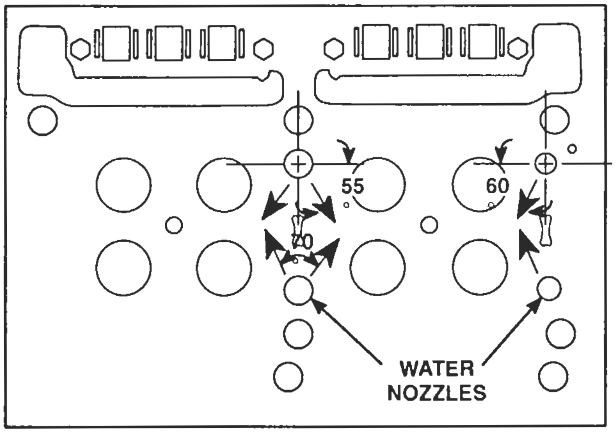


Figure 12. Correct Installation of Water Nozzles in Four–Valve Cylinder Head

SECTION 1.2 – CYLINDER HEAD

CYLINDER HEAD INSPECTION (CONT.)

10. 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).
11. Pilot sleeves have been added to the head mounting bolt holes at each end of the four–valve cylinder heads (on the camshaft side on current heads or exhaust side of former heads). Make sure the sleeves are flush or recessed below the fire deck of the cylinder head. Replace damaged sleeves. Pilot sleeves can be installed on early cylinder heads by reaming the end bolt holes (camshaft side of head) to .687/.688 inch diameter by .750 inch deep and pressing the sleeves flush or slightly recessed below the fire deck. 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.
12. 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 a 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 inch 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, 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.

Injector clamp bolts are not included and it is necessary to use new parts or transfer the old parts to the new head.

CYLINDER HEAD ASSEMBLY

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

1. Coat the threads of the plugs with Loctite Pipe Sealant with Teflon, then install the necessary plugs and tighten them to the specified torque (Section 1.0 – Specifications). Drive headless plugs flush to .0625 inch below the surface of the cylinder head. The 3/8 inch socket head oil gallery plug at each end of the head must not protrude more than .0625, and a .2187 inch diameter rod placed in the vertical oil feed hole must pass the inner face of the plug (Section 1.0).
2. After the following parts are cleaned, 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).

CYLINDER HEAD ASSEMBLY (CONT.)

c. Place new washers on the fuel connectors. Then, install the connectors and tighten them to 40–45 lb·ft (54–61 N·m) torque. If a new cylinder head is used, discard the manifolds and old fuel connectors.

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.

e. Attach the engine lifter brackets temporarily to the cylinder head, without gaskets, to permit lifting the head into position. The lifter brackets must not be permanently attached until the cylinder head attaching bolts have been installed and tightened to the specified torque.

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.
6. Check the four corner plugs or drive pins, used to plug the vertical oil galleries, to ensure that they are flush with, or below the top surface of the cylinder block.

CYLINDER HEAD INSTALLATION

1. Install the water and oil seal rings and compression gaskets as follows:

NOTE: Never install used compression gaskets or seals.

   a. Place a new compression gasket on top of each cylinder liner. A new cylinder liner compression gasket with improved sealing capabilities is now being used. The new gasket can be identified by GM–MC–H, GM–VG–H, or GM–FP–H. The compression gasket is also color coded black, orange or white. The service gasket kits will only include a single color (black or orange). Only one color compression gaskets (seal) can be used under a single cylinder head to provide proper clamping.

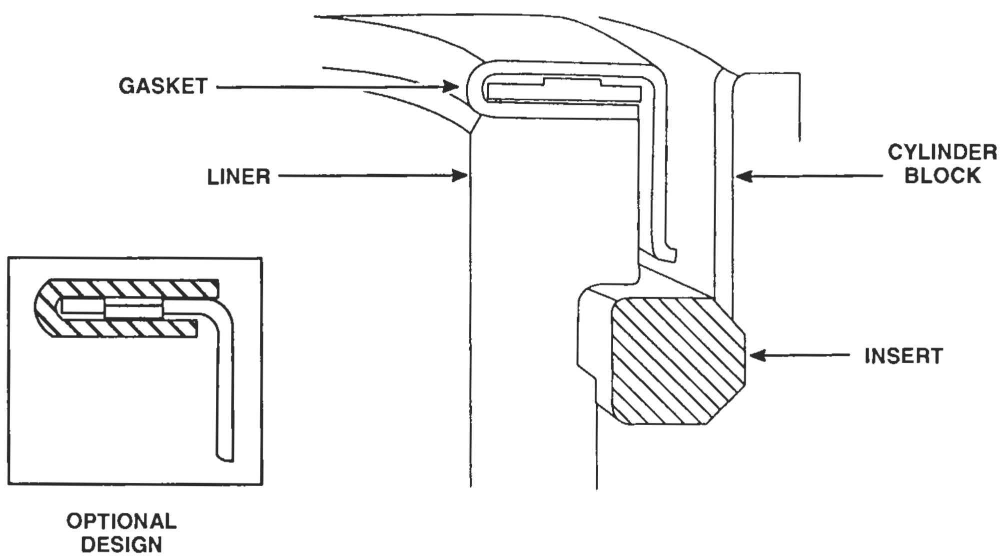


Figure 13. Compression Gasket Mounting in Cylinder Block

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

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

CYLINDER HEAD INSTALLATION (CONT.)

4. 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 inner diameter of the seal and the spray propellant may cause the seal to swell temporarily.

   a. 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.

NOTE: The square–cut perimeter seal rings used on Series 71 Engines have been dimensionally revised to provide improved head–to–block sealing. These lathe–cut seals were formally .135 – .150 inch thickness. They are now .122 – .137 inches thick. Part numbers have not changed. Instead, the revised seals are identified by a green paint stripe. The former seals were identified by a blue stripe.

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

5. To install the cylinder head on the engine without disturbing the gaskets and seals, install guide studs J 9665 in two corner bolt holes in the cylinder block.

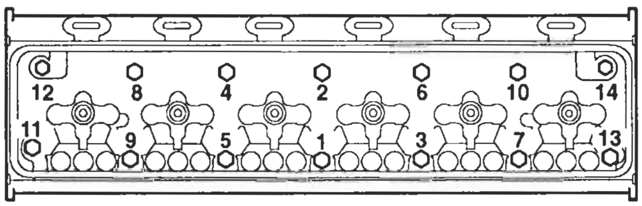
NOTE: Current four–valve cylinder heads have piloting sleeves installed in the corner bolt holes on the camshaft side of the head (former heads had the piloting sleeves on the exhaust side). A new pilot sleeve is available for the three and four cylinder heads. It has a larger outside diameter. The inside diameter remains the same standard size. The sleeves provide more accurate alignment of the cylinder head with the block bores. DO NOT install the guide studs in the bolt holes which line–up with piloting sleeves in the head.

6. Insert the hooks of a chain; attached to a hoist, in the vent holes of the cylinder head, or the lifter brackets, and lift the head into position above the cylinder block.
7. Make a final visual check of the compression gaskets and seals to ensure that they are in place before the cylinder head is lowered. This is a very important check. Gaskets and seals which are not seated properly will cause leaks and "blow–by" and result in poor engine performance and damage to the engine.
8. Wipe the bottom of the cylinder head clean. Then, lower the head until it is about 1/2 inch from the surface of the cylinder block.
9. Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of all cylinder head attaching bolt (threads and head contact surface). Then, install a bolt through each piloting sleeve (four–valve head) at the corners of the head and thread them, finger tight, into the cylinder block. Continue to tighten these bolts finger tight as the head is lowered into position on the cylinder block. The shoulder of the bolt side must contact the cylinder head. Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.
10. After the head is in place, remove the guide studs and chain hoist and install the remaining bolts, running all bolts down snug tight with a speed handle (15–20 lb·ft or 20–27 N·m torque). However, before tightening the bolts, loosen the lifter bracket–to–cylinder head attaching bolts, otherwise the head may be prevented from seating properly on the cylinder block. A similar condition could exist if the exhaust manifold is attached to the cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block. On some engine models, these bosses serve as a rest for the exhaust manifold after the cylinder head has been installed on the cylinder block.

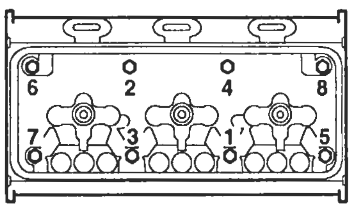
CYLINDER HEAD INSTALLATION (CONT.)

11. Tighten the bolts to 170–180 lb·ft (231–244 N·m) torque in 50 lb·ft (68 N·m) increments with a torque wrench, in the sequence (Figure 14.) Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tightening of the remaining bolts. Apply a steady pressure for two or three seconds at the prescribed torque to allow the bolts to turn while the gaskets yield to their final designed thickness. Begin on the cam follower side of the head to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification, but do not exceed the limit or the bolts may stretch beyond their elastic limits. Attempting to tighten the bolts in one step may result in trouble and consequent loss of time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

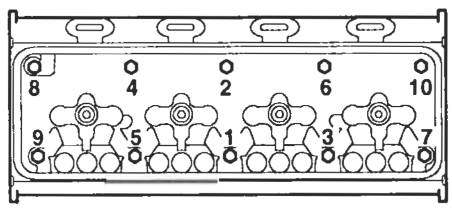
NOTE: Tightening the cylinder head bolts will not correct a leaking compression gasket or seal. The head must be removed and the damaged gasket or seal replaced.



6–CYLINDER ENGINE CYLINDER HEAD



3–CYLINDER ENGINE CYLINDER HEAD



4–CYLINDER ENGINE CYLINDER HEAD

Figure 14. Cylinder Head Bolt Tightening Sequence

12. Tighten the two flywheel housing attaching bolts directly below the rear lifter bracket. Install a new gasket and secure the rear engine lifter bracket to the cylinder head and the flywheel housing. Tighten the bolts to 55–60 lb·ft (75–81 N·m) torque.
13. Affix a new gasket to the front lifter bracket (or vent casting) and attach the bracket to the cylinder head and the balance weight cover. Tighten the bolts in the same sequence and to the same torque as on the rear lifter bracket bolts.
14. If the fuel injectors were not previously installed, install them at this time (Section 2.1 or 2.1.1).
15. On a four–valve cylinder head, adjust the exhaust valve bridges (Section 1.2.2).
16. Tighten the rocker arm bracket bolts to the specified torque (Section 1.0).
17. Align the fuel pipes and connect them to the injectors and the fuel connectors. Fuel pipes with O–ring seals may be reused if they are not bent, twisted, restricted and if ends are not distorted or otherwise damaged.

CYLINDER HEAD INSTALLATION (CONT.)

NOTICE:

To avoid possible fuel leakage, never reuse flared end fuel pipes, regardless of their apparent condition.

18. To help insure more consistent fastening, tighten fuel pipe nuts on new or flared end jumper lines and new or reusable O–ring sealed 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).

Jumper Line Usage	Torque
Endurion®–coated	130–160 lb·in. (14..7–18.1 N·m)
Uncoated	160 lb·in. (18.3 N·m)
Jacobs Brakes (see Note)	120 lb·in. (13.6 N·m)
Load limiting devices	160 lb·in. (18.3 N·m)
O–ring sealed jumper lines	145 lb·in. (15.6 N·m)

TABLE 2

NOTE: Because of their low friction surface, Endurion–coated nuts on fuel jumper lines must be tightened to within a range of 130–160 lb·in (14.7–18.1 N·m) torque. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion–coated nuts on the same cylinder head.

NOTE: 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 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 Pressurize Fuel System – Check for Leaks – Shop Notes in Section 2.0).

19. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the control tube, be sure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10–12 lb·ft (14–16 N·m) torque.

20. 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.

CYLINDER HEAD INSTALLATION (CONT.)

21. When equipped with a hydraulic governor, start the fuel rod through the opening in the throttle rod bracket and the cylinder head. Press in the fuel rod knob and at the same time lower the subcap down on the governor housing so that the fuel rod enters the slot in the terminal lever and the fuel rod collar rests against the front finished surface of the terminal lever. Secure the subcap to the governor with bolts. Install bolts through the subcap the the throttle control bracket to secure the subcap to the cylinder head. Tighten the bolts.
22. When equipped with a mechanical governor, attach the fuel rod to the differential lever in the governor housing. Secure the governor to the cylinder head with bolts and lock washers.
23. Connect the governor fuel rod to the injector control tube lever.
24. Install the fuel filter and connect the fuel lines.
25. Install the exhaust manifold.
26. If used, install the water manifold.
27. Install the temperature gage thermocouple in the adaptor at the rear end of the water manifold.
28. Install the thermostat and secure the thermostat housing to the water manifold or heat exchanger with four bolts and lock washers.
29. Position the seal and clamp between the water manifold and the thermostat housing on a heat exchanger unit and tighten the seal clamp. Slide the hose into position on a radiator unit and secure it with two clamps.
30. Install any other equipment or parts that were previously removed.
31. Fill the cooling system and lubrication system (Section 13.1).
32. Before starting the engine, perform an engine tune–up (Section 14).

VALVE & INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder (Figure 1.). 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 the camshaft through cam followers and short push rods extending through the cylinder head.

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes.

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

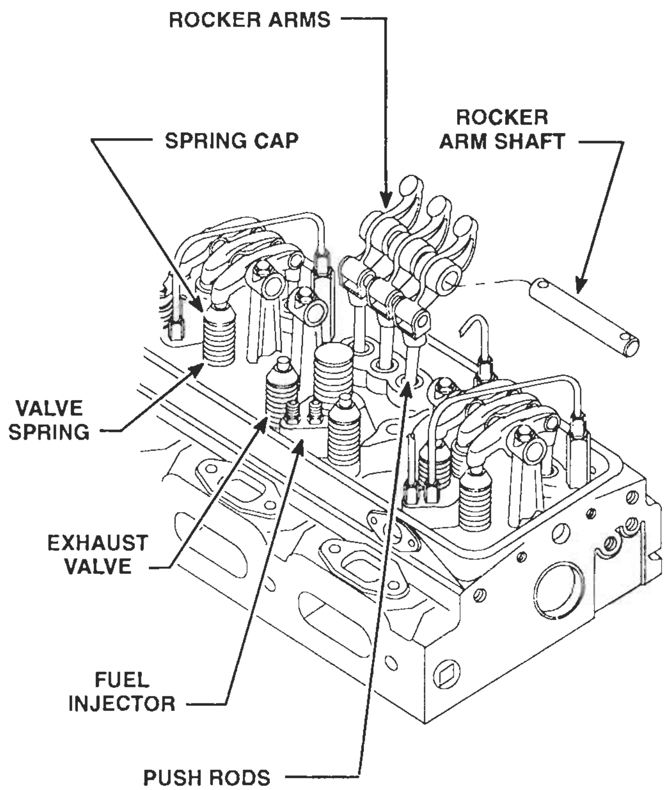


Figure 1. Valve and Injector Operating Mechanism

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms.

Overflow oil from the rocker arms lubricates the exhaust valves, 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.

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.

VALVE & INJECTOR OPERATING MECHANISM (CONT.)

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 (four–valve head).
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 (Section 1.2.2).

ROCKER ARM ASSEMBLY REMOVAL

1. Clean and remove the valve rocker cover.
2. Remove the fuel pipes from the injector and the fuel connectors.

NOTE: 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.

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

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

NOTE: 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 injury, wear proper eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Inspect the rocker arm shaft and rocker arm bushings for wear. A maximum shaft to bushing clearance of .004 inches is allowable with used parts (Section 1.0). Service replacement bushings must be reamed to size after installation.

The injector rocker arm used on coach engines does not use a bushing at the push rod clevis. The bore area is "lubrited" to provide improved lubrication in this area.

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 inches. However, proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also, inspect the valve bridges (four–valve head) for wear.

Remove Cam Follower And Push Rod (Cylinder Head On Engine)

When removing the cam followers and associated parts, tag them so they can 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.
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 (Figure 2.)
6. Unscrew the locknut to release the spring. Remove the nut, flat washer and tool from the push rod.
7. Pull the push rod, spring, spring seats and cam follower out of the cylinder head.

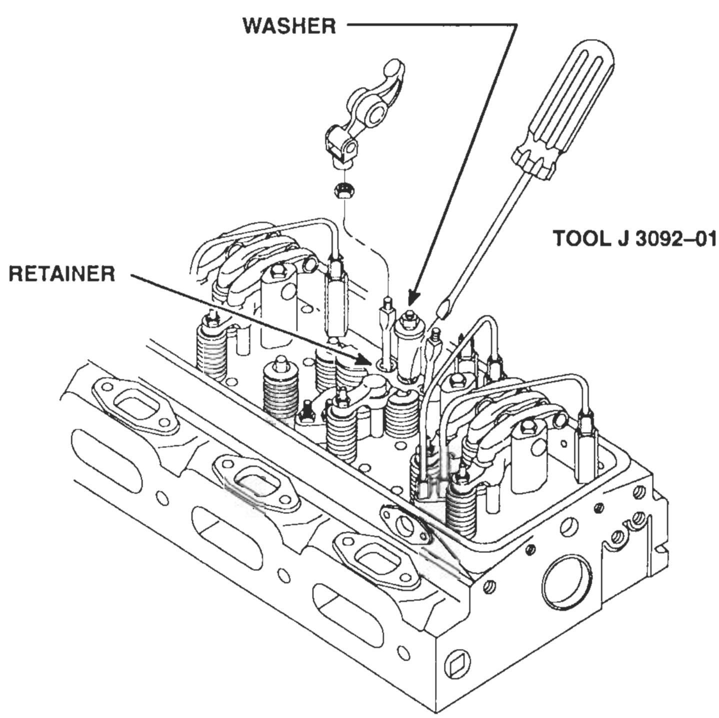


Figure 2. Removing Push Rod from Upper Side of Cylinder Head

INSPECTION (CONT.)

Remove Cam Follower And Push Rod (Cylinder Head Removed)

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

1. Rest the cylinder head on its side and remove the cam follower guide (Figure 3.)
2. Pull the cam follower out of the cylinder head.
3. Loosen the push rod locknut and unscrew the push rod from the rocker arm clevis.
4. Remove the fuel pipes from the injector and the fuel connectors.

NOTE: 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.

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.

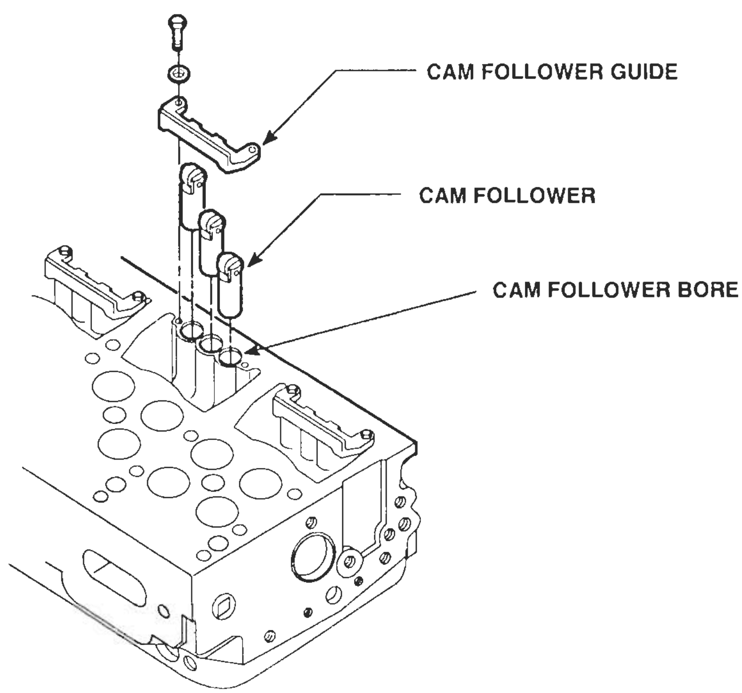


Figure 3. Cam Followers and Guides

INSPECTION (CONT.)

Proper inspection and service of the cam follower is 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.

NOTE: If an injector push rod bends or breaks during engine operation, the push rod AND cam follower for that rod must be replaced regardless of their apparent condition.

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 injury, wear proper eye protection and do not exceed 40 lb/in^2 (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 (Figure 4.) Cam followers stamped with the letter "S" on the pin, roller and follower body are equipped with an oversize pin and roller. The same clearances apply to either a standard or oversize cam follower assembly.

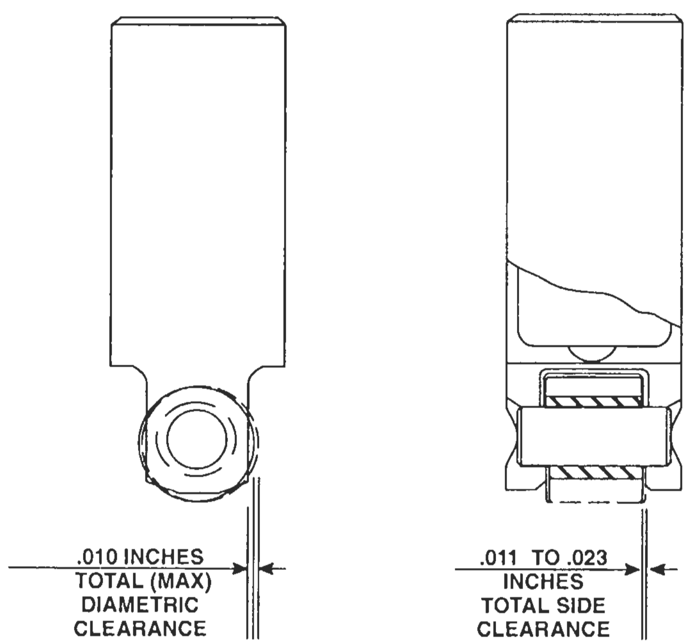


Figure 4. Cam Roller Clearances

INSPECTION (CONT.)

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 (see Section 1.0 for Specifications).

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.

Examine the cam follower springs for wear or damage and check the spring load. Replace a spring if a load of less than 172 lb. will compress it to a length of 2.125 inches. Use spring tester J 22738–02 to check the spring load (Figure 5.)

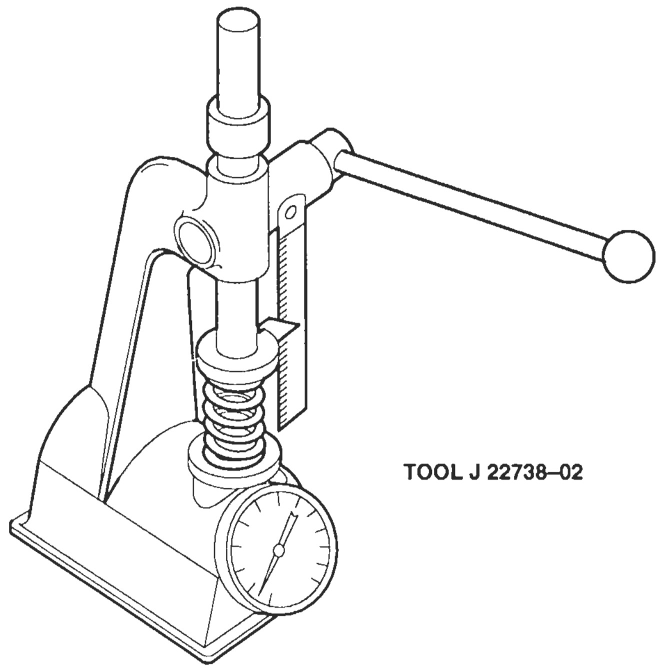


Figure 5. Testing Cam Follower Spring

Inspect the push rods and spring seats for wear. The current push rods have milled wrench flats and a bright "turned" finish and the lower spring seats are serrated along the push rod contact surfaces (Figure 6.)

NOTE: When replacing a push rod or lower spring seat, do not use a plain spring seat with a current type push rod. Any other combination of spring seat and push rod may be used.

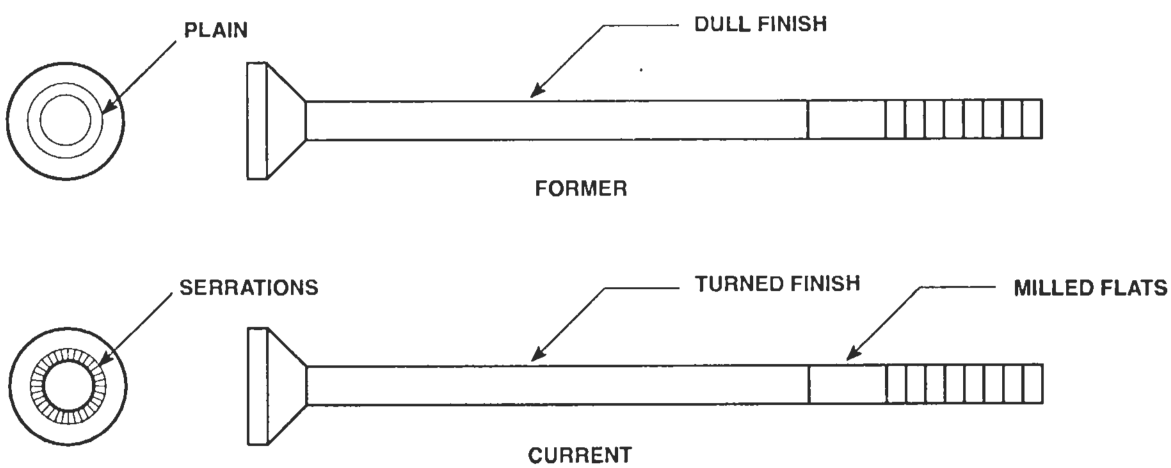


Figure 6. Comparison of Push Rods and Lower Spring Seats

REPLACE CAM ROLLER AND PIN

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

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

Cam Follower Disassembly

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

Cam Follower Assembly

NOTE: 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.

NOTE: 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, use adapter J32421–22. Both adaptors have 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. The clearance must be .011 to .023 inches.

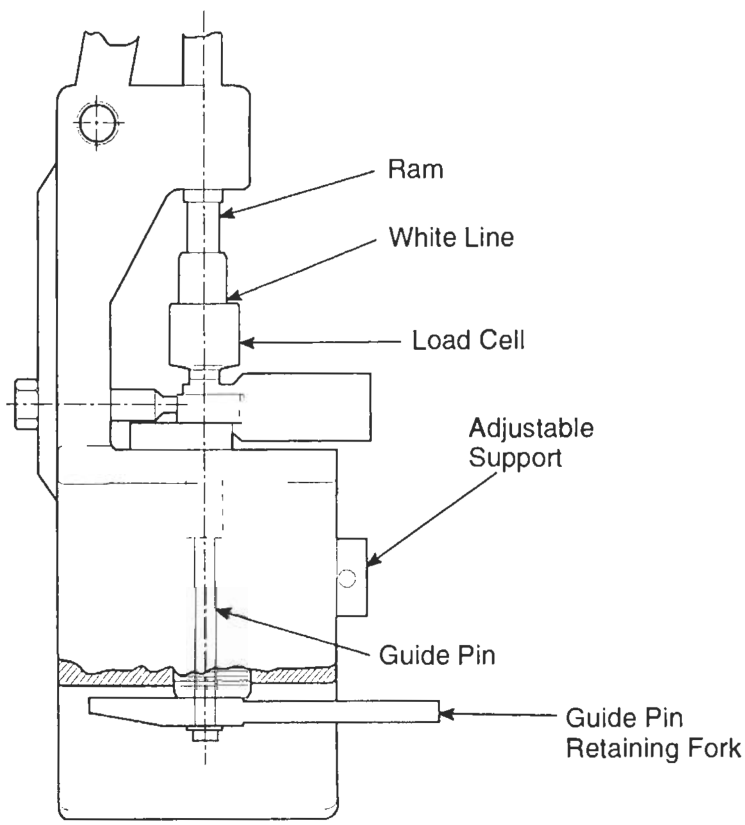
REPLACE CAM ROLLER AND PIN

Roller Pin Test

After rebuilding the cam follower, test the roller pin using Load Test Cell J 33421–26. The pin must sustain an axial force of 300 pounds without pushing out. Install the load cell on the pressing ram of the service fixture and proceed as follows:

1. Push sprint–loaded guide pin (J 33421–12) down and insert fork (J 33421–31) as shown (Fig.9)
2. Pull support slide (j 33421–2) out, install cam follower, and lower handle, putting slight pressure on roller pin.
3. Push support (j 33421–2) in until resistance is felt.
4. Apply pressure on handle until white line on load cell just disappears from view. (300 pounds has now been applied to the roller pin.)

NOTICE:
Do not continue downward force after the white line disappears, as load cell will bottom out and eventually push out pin. Do not use the load cell for installation or removal of the roller pin.



CAM FOLLOWER ASSEMBLY (CONT.)

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

NOTICE:

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

NOTE: If completely new followers are being installed, pre–lube with Cindol 1705 is not necessary.

Install used cam followers and push rods in their original locations. Refer to Figure 7. and proceed as follows:

Cylinder Head On Engine

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

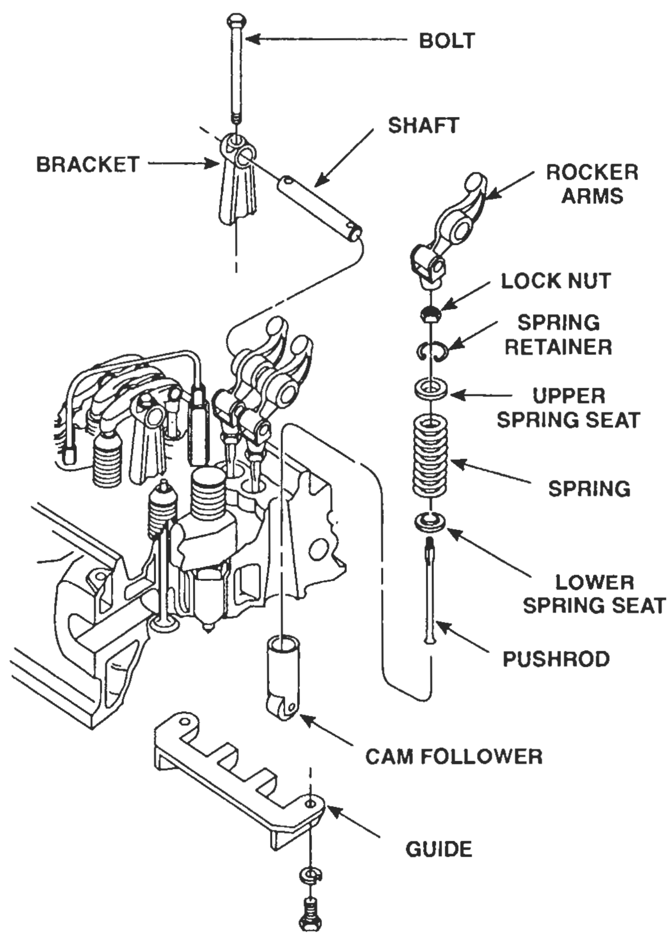


Figure 7. Valve and Injector Operating Mechanism and Relative Location of Parts

CAM FOLLOWER ASSEMBLY (CONT.)

Cylinder Head Removed From Engine

To install the cam follower and push rod, proceed 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, 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 (cast iron head).
5. Check to be sure there is at least .005 inch clearance between the cam follower legs and the cam follower guide (Figure 8.)

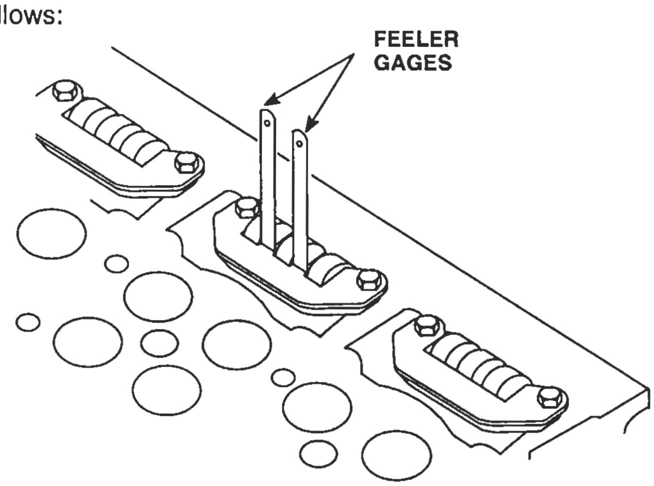


Figure 8. Checking Cam Follower to Guide Clearance and Adjusting Cam Follower Guide

6. If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Figure 9.) Retighten the bolts to the specified torque.

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

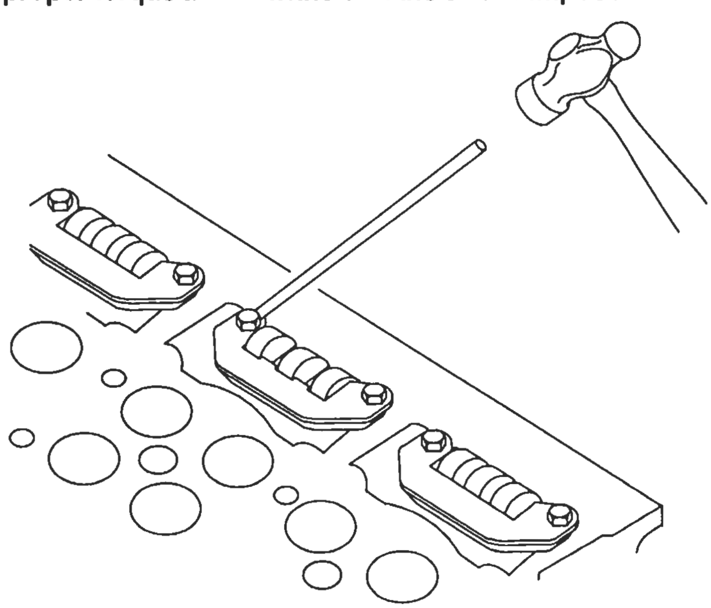


Figure 9. Adjusting Cam Follower Guide

ROCKER ARM ASSEMBLY INSTALLATION

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

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

NOTICE:

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

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.
2. If removed, install the cylinder head on the engine (Section 1.2).
3. Lubricate the valve bridge guides (four–valve cylinder head) 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 (Section 1.0).
7. Align the fuel pipes and connect them to the injectors and fuel connectors. Tighten the fuel pipe nuts with socket J 8932–01. Because of their low friction surface, the Endurion®–coated nuts on flared end fuel jumper lines must be tightened to 130–160 lb·in (14.7–18.1 N·m) torque, instead of the previous 12–15 lb·ft or 144–180 lb·in (16–20 N·m) torque required with the former uncoated nuts. Tighten O–ring sealed fuel pipes to 160–200 lb·in(18.1–22.6 N·m) torque.

NOTE: To avoid possible confusion when tightening jumper line nuts, do not mix jumper 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. These should continue to be tightened to 120 lb·in (13.6 N·m) torque. O–rings sealed fuel pipes on Jacobs Brakes should be tightened to 143 lb·in (16.16 N·m) 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

Two or four exhaust valves are provided for each cylinder, depending upon the engine model (Figure 1.) The valve heads are heat treated and ground to the proper seat angle and diameter.

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head. Certain engines are equipped with exhaust valve guide oil seals.

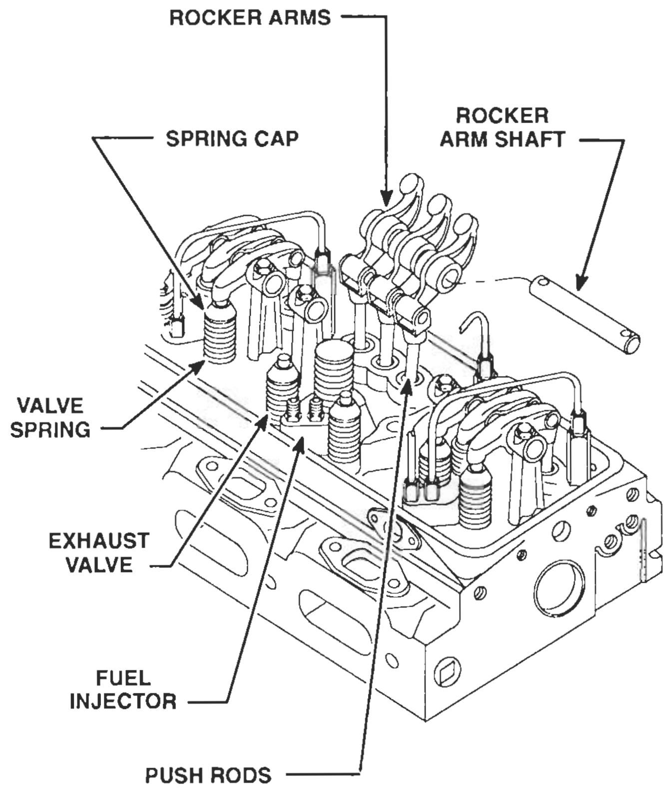


Figure 1. Location of Exhaust Valves and Guides Two–Valve Cylinder Head

The valve stems are ground to size and hardened at the end which contacts the rocker arm (two–valve head) or the exhaust valve bridge (four–valve head) (Figure 2.)

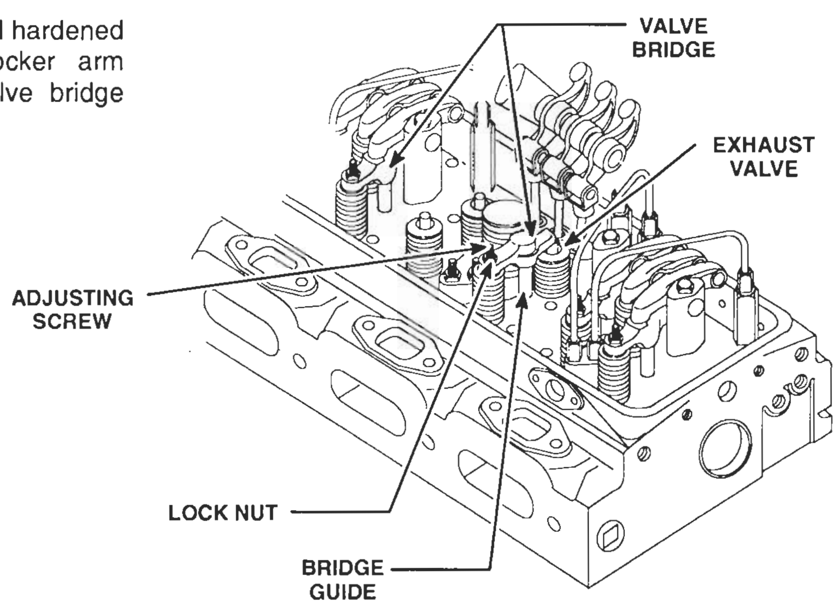


Figure 2. Location of Exhaust Valves and Guides Four–Valve Cylinder Head

EXHAUST VALVES (CONT.)

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves are ground to a 30° seating angle while the exhaust valve seat inserts are ground to a 31° seating angle. The exhaust valve springs are held in place by the valve spring caps and tapered two–piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

EXHAUST VALVE MAINTENANCE

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and non–pitted to assure leakproof seating, valve stems must work freely and smoothly within the valve guides and the correct valve clearance (Section 14.1) must be maintained.

Proper maintenance and operation of the engine is important to long valve life. Normal engine operating temperatures should be maintained (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 according to specifications 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 very important that injector timing and valve clearance be accurately adjusted according to specifications. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

EXHAUST VALVE SPRING REMOVAL (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, personnel should keep their hands and clothing away from the engine as there is a remote possibility the engine could start.

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

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

4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then, remove the brackets and shaft. Remove the exhaust valve bridge (four–valve cylinder head only).
5. Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.

EXHAUST VALVE SPRING REMOVAL (CYLINDER HEAD INSTALLED) (CONT.)

6. Thread the valve spring compressor adaptor J 7455–7 into one of the rocker arm bracket bolt holes in the cylinder head (Figure 3.) Then, compress the valve spring and remove the two–piece tapered valve lock.
7. Release the tool and remove the valve spring cap, valve spring and spring seat.

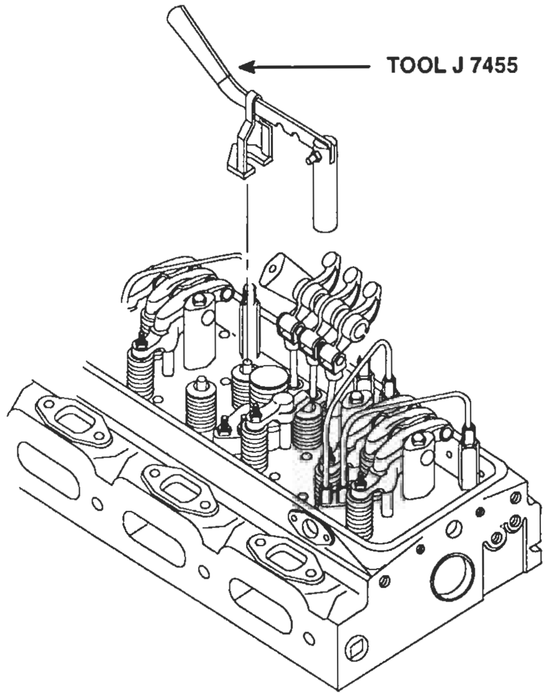


Figure 3. Removing Exhaust Valve Spring (Four–Valve Head Shown)

EXHAUST VALVE SPRING REMOVAL (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 inch thick wood blocks to keep the cam followers clear of the bench.
2. Remove the fuel pipes from the injectors and the fuel connectors.

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

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then, remove the brackets and the shaft.
4. Remove the fuel injectors.
5. Remove the exhaust valve bridges (four–valve cylinder head).
6. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in steps 6 and 7 of previous procedure 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 (Section 1.2.1).

SECTION 1.2.2 – EXHAUST VALVES

INSPECTION

Clean the springs with fuel oil, dry them with compressed air and inspect them.

CAUTION:

To prevent possible injury, wear proper eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Replace a pitted or fractured spring. Use spring tester J 22738–02 to check the spring load (Figure 4.) Replace a two–valve cylinder head exhaust valve spring when a load of less than 25 lbs will compress it to 2.20 inch (installed length). The exhaust valve spring used on the four–valve cylinder head has an outside diameter of approximately .953 inch. Replace this spring when a load of less than 25 lbs will compress it to 1.80 inch (installed length).

NOTICE:

When an exhaust valve spring is replaced on a four–valve head, both springs under a valve bridge should be replaced at the same time to ensure balanced valve operation.

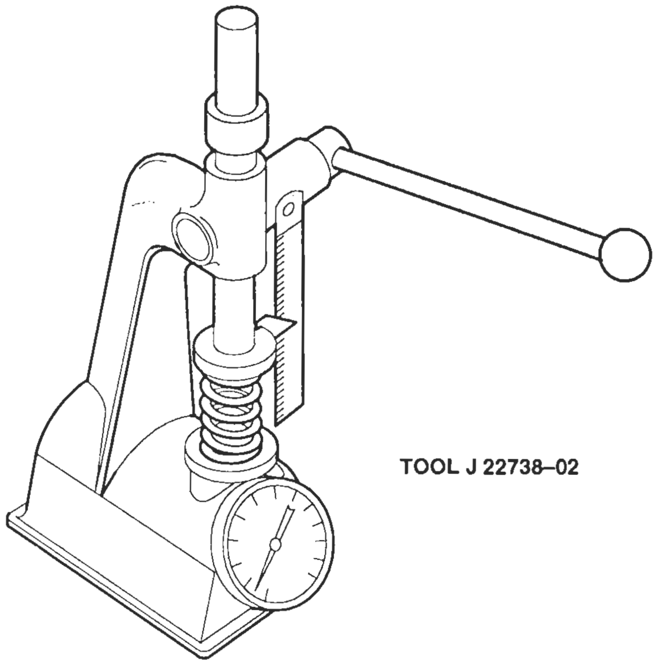


Figure 4. Testing Exhaust Valve Spring

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 or 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. High operating temperatures are normally due to overloads, inadequate cooling or improper timing, which results in carbonization of the lubricating oil.

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

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

INSPECTION (CONT.)

Clean the inside diameter of the valve guides with brush J 5437. This brush will remove all gum or carbon deposits from the valve guides, including the spiral grooves.

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

EXHAUST VALVE AND GUIDE REPLACEMENT

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 3 inch thick wood blocks.
3. Drive the valve guide out of the cylinder head with valve guide remover J 267 (two–valve head) or J 6569 (four–valve head) – (Figure 5.)

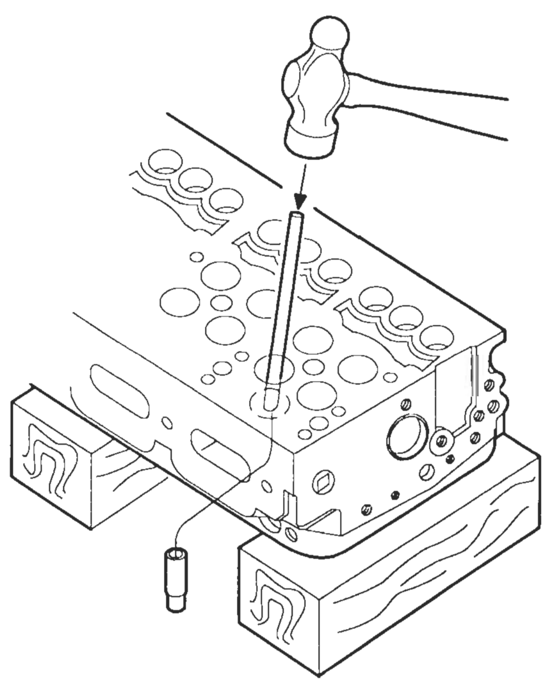


Figure 5. Removing Exhaust Valve Guide

SECTION 1.2.2 – EXHAUST VALVES

EXHAUST VALVE GUIDE REPLACEMENT (CONT.)

Place the cylinder head right side up on the bed of an arbor press and install the valve guide (Figure 6.) as follows:

1. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to Table 1). Be sure to use the correct tool to avoid damage to the valve guide, and to locate the valve guide to the proper dimension.

When replacing the valve guides in a four–valve cylinder head, the current guide which is machined for use with a valve guide seal should be used in place of the 45° chamfered valve guide. The current guide will facilitate field installation of valve guide seals when it is felt their use will be beneficial.

When replacing the valve guides in a two–valve cylinder head, use J 9530 with the current thin exhaust valve insert (.2505–.2465 inch) or when a valve guide oil seal is used.

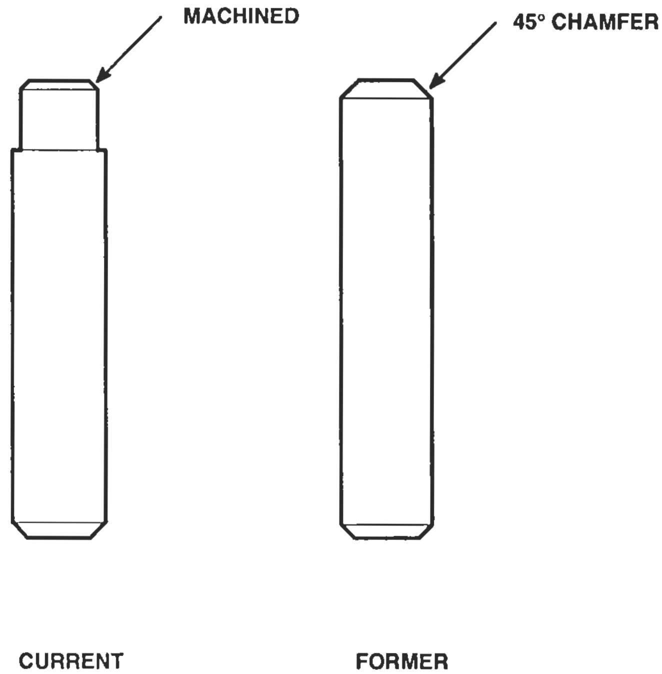


Figure 6. Former and Current Valve Guides

Tool No.	Cylinder Head	Valve Guide	Distance of Guide Above Top of Head
J 9530	2–Valve		1.530 inch
J 21520	4–Valve	Machined	.690 inch

TABLE 1

EXHAUST VALVE GUIDE REPLACEMENT (CONT.)

2. Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (Figure 7.) Then, press the guide in until the tool contacts 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.

A service replacement valve guide which is .016 inch oversize on the outside diameter is also provided for service (two–valve cylinder head only).

3. Install a new valve guide oil seal, if used (see Item 5 under Exhaust Valve and Spring Installation).

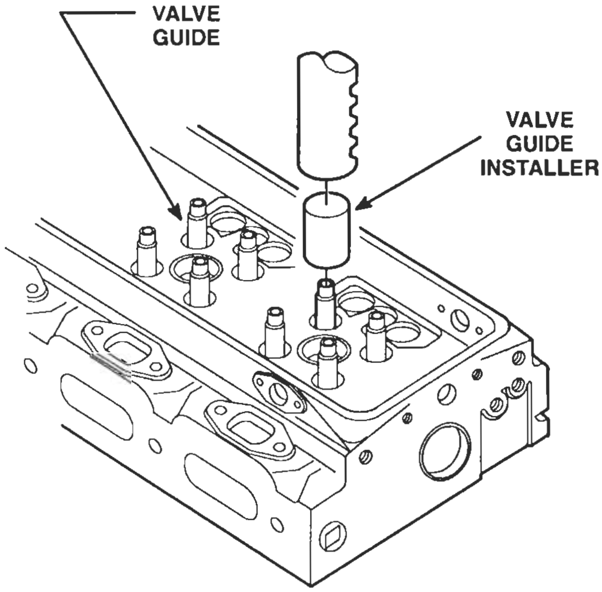


Figure 7. Installing Valve Guides

VALVE BRIDGE AND GUIDE INSPECTION (FOUR–VALVE CYLINDER HEAD)

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

Two designs of the valve bridge are used. One has a drilled oil hole and the other has a forged oil hole in the side. The two bridges are interchangeable and can be mixed in an engine.

In addition, a new valve bridge adjusting screw with a redesigned valve contact surface replaces the former adjusting screw. The new screw may be identified by the machined (undercut) surface at the lower end of the screw. Only the new adjusting screw is available for service. Replace the former adjusting screws at the time of an engine overhaul.

EXHAUST VALVE BRIDGE GUIDE REMOVAL

Remove the valve bridge guide from a four–valve cylinder head as follows:

1. Remove the former threaded guide, identified by the hexagon section at the lower end, with socket J 6846.
2. Remove the press–fit guide (Figure 8.) with tool set J 7091–01 as follows:
   a. File or grind two diametrically opposite notches 1/16 inch deep in the side of the guide, approximately 1 1/4 to 1 1/2 inches from the upper end.

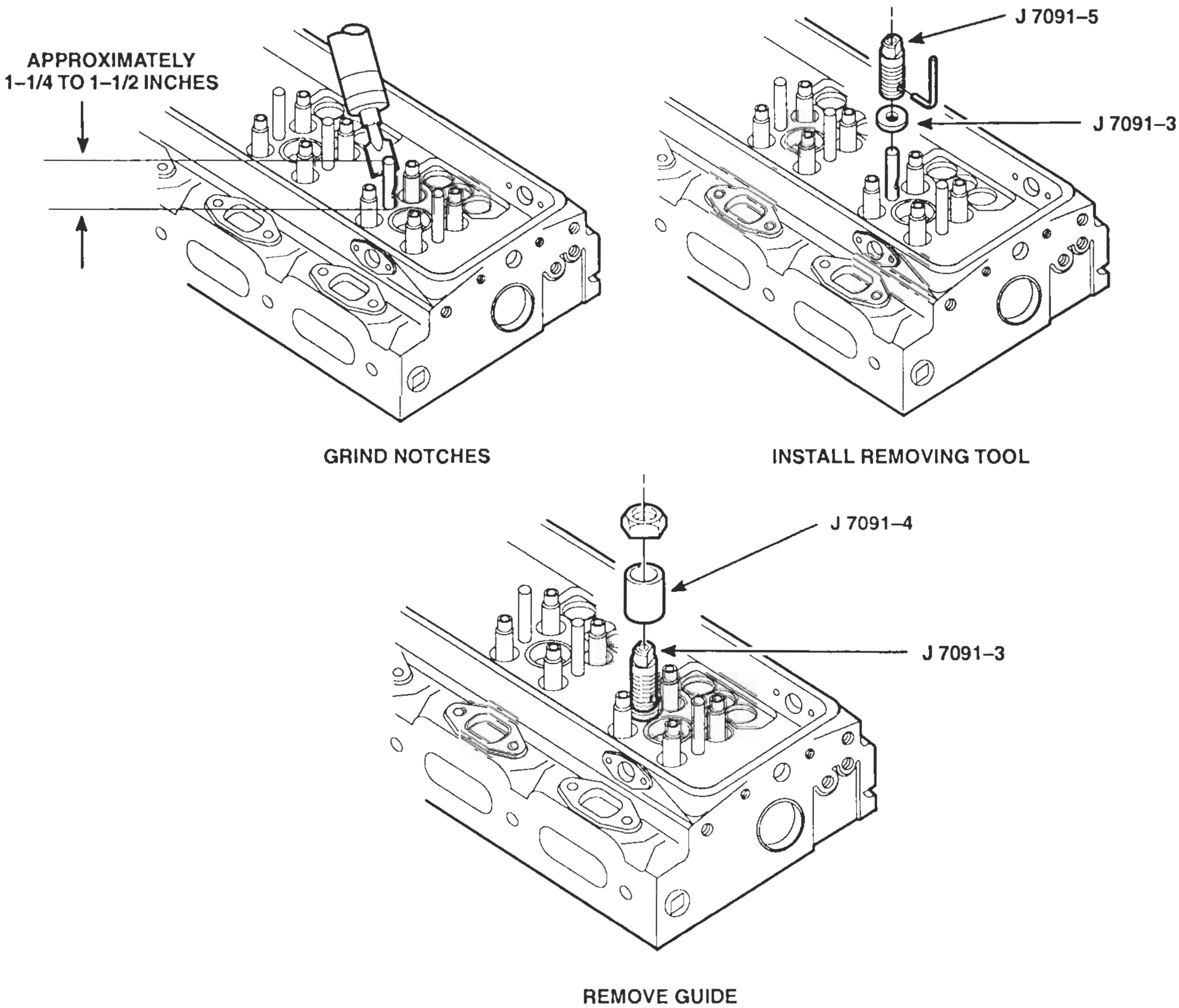


Figure 8. Removing Press–Fit Exhaust Valve Bridge Guide

EXHAUST VALVE BRIDGE GUIDE REMOVAL (CONT.)

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 inch deep in the end of the guide with a No. 3 (.2130 inch) 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 (Figure 9.)

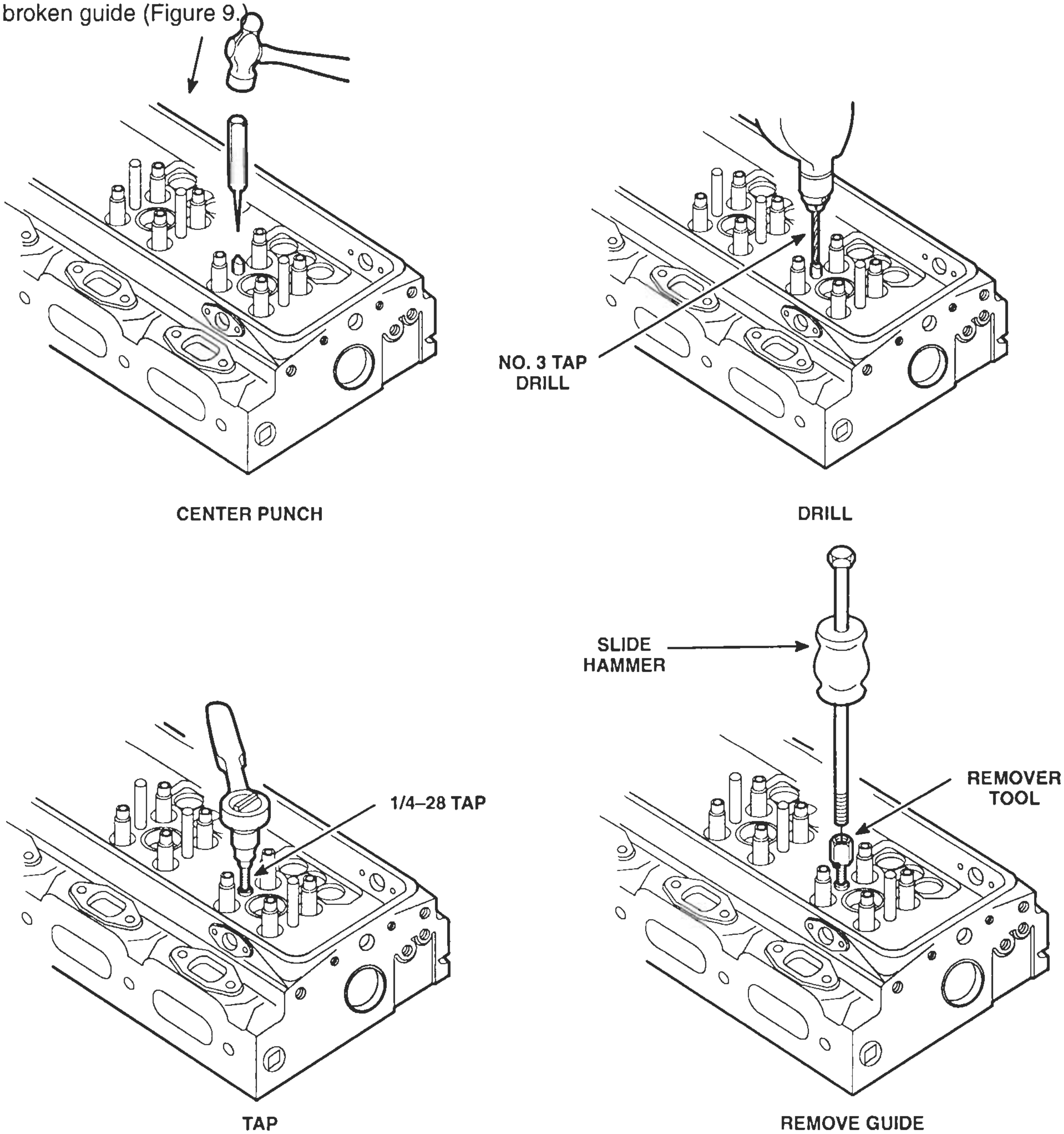


Figure 9. Removing Broken Exhaust Valve Bridge Guide

SECTION 1.2.2 – EXHAUST VALVES

EXHAUST VALVE BRIDGE GUIDE INSTALLATION

Apply a sealant such as Permatex #1, 3M–EC971, or equivalent to the valve bridge guide.

1. Start the guide (undercut end first) into the cylinder head.
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 (2.040 inch).

EXHAUST VALVE SEAT INSERT INSPECTION

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

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°.

EXHAUST VALVE SEAT INSERT REMOVAL

The valve seat inserts are pressed into the cylinder head and must be removed using one of the following methods to avoid damaging the cylinder head:

Method 1

1. Place the cylinder head on its side (Figure 10.)
2. Place the collet of tool J 23479–271 (two–valve head) or J 23479–471 (four–valve head) inside of the valve seat insert so that that bottom of the collet is flush with the bottom of the insert.
3. Hold the collet handle and turn the T handle to expand the collet cone until the insert is held securely by the tool.
4. Insert the drive bar of the tool through the valve guide.
5. Tap the drive bar once or twice to move the insert about 1/16 inch away from its seat in the cylinder head.
6. Turn the T handle to loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.
7. Tighten the collet cone and continue to drive the insert out of the cylinder head.

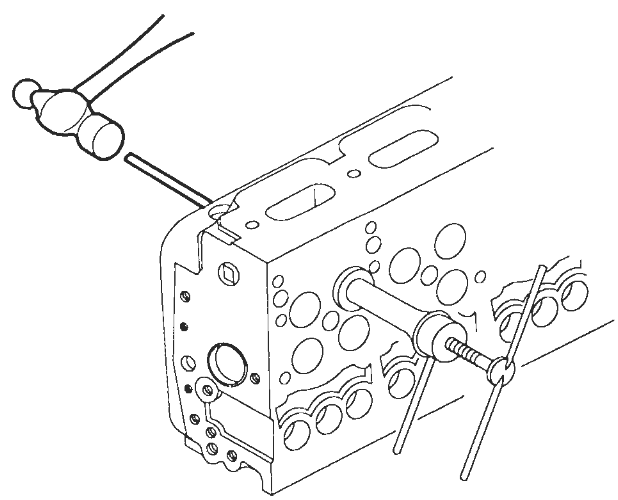


Figure 10. Removing Valve Seat Insert

EXHAUST VALVE SEAT INSERT REMOVAL (CONT.)

Method 2

1. Screw collet handle into collet J 23479–29 (2–valve) or J 23479–30 (4–valve) and assemble in puller as shown (Figure 11.)
2. With the cam handle in lax position (low point of cam contacting receiver body), expand collet by tightening tapered nut until pulling lip of collet just slips through valve seat insert.
3. Hold handle in lax position and install collet portion into valve seat insert.
4. While holding receiver body down and square with cylinder head, pull cam handle down until resistance is felt and hold. *Rotate Cam Only in Direction of Arrow.*
5. While holding cam handle down with one hand, grasp the collet handle with the other hand and rotate back and forth several times. This will scrape carbon from beneath the insert and permit the operator to determine proper engagement of the collet.
6. Transfer grasp from collet handle to receiver body and continue pulling cam handle down until insert is removed.

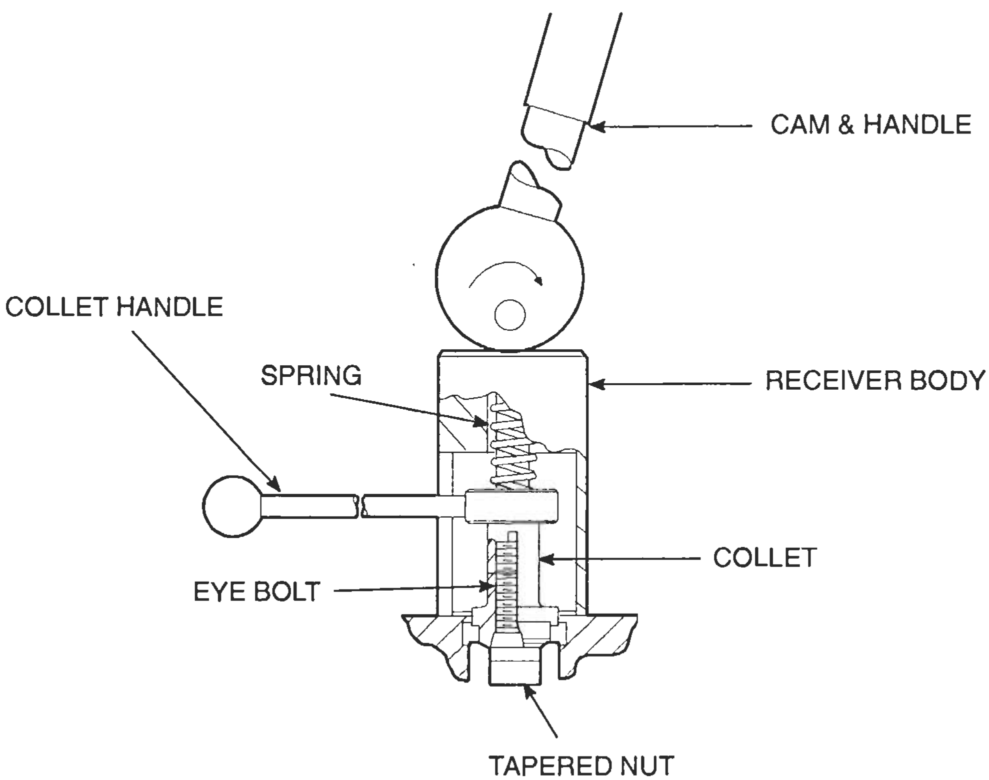


Figure 11. Removing Valve Seat Insert (Method 2)

EXHAUST VALVE SEAT INSERT INSTALLATION

1. Clean the valve insert counterbore in the cylinder head with 1,1,1,–Trichloroethane. Also, wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.
2. Inspect the counterbores in the cylinder head for cleanliness, concentricity, flatness and cracks. The counterbores in a two–valve cylinder head have a diameter of 1.626 to 1.627 inches and a depth of .3705 to .3845 inches. The counterbores in a four–valve cylinder head have a diameter of 1.260 to 1.261 inches and a depth of .338 to .352 inches. The counterbores must be concentric with the valve guides within .003 inch total indicator reading. Valve seat inserts which are .010 inch oversize on the outside diameter are available, if required.
3. Immerse the cylinder head for at least thirty minutes in water heated to 180°–200°F (82°–93°C).
4. Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore valve seat side up. Install the insert in the cylinder head while the head is still hot and the insert is at room temperature, otherwise installation will be difficult and the parts may be damaged.
5. Drive the insert in place with installer J 1736 (two–valve head) or J 6568 (four–valve head) until it seats solidly in the cylinder head (Figure 12.)
6. Check the valve seat inserts for concentricity in relation to the valve guides.

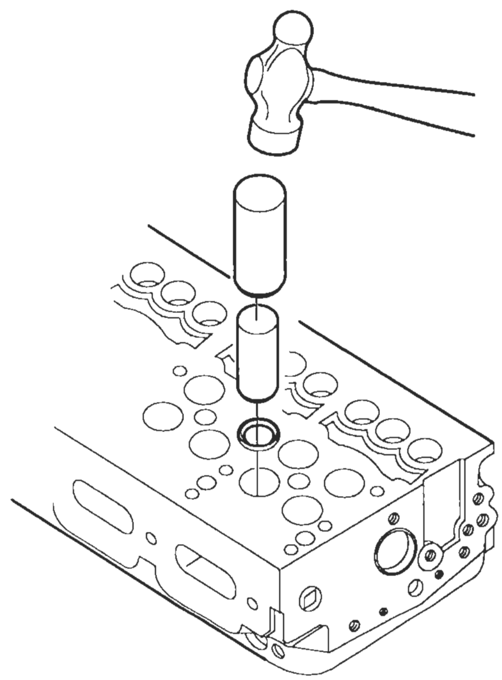


Figure 12. Installing Valve Seat Insert

EXHAUST VALVE AND VALVE SEAT RECONDITIONING

An exhaust valve which is to be reused may be refaced, if necessary. To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than .031 inch thickness and must still be within the specifications after refacing.

Before either a new or used valve is installed, examine the valve seat insert (Figure 13.) in the cylinder head for proper valve seating. The proper angle for the seating face of the valve is 30° and for the valve seat insert it is 31°.

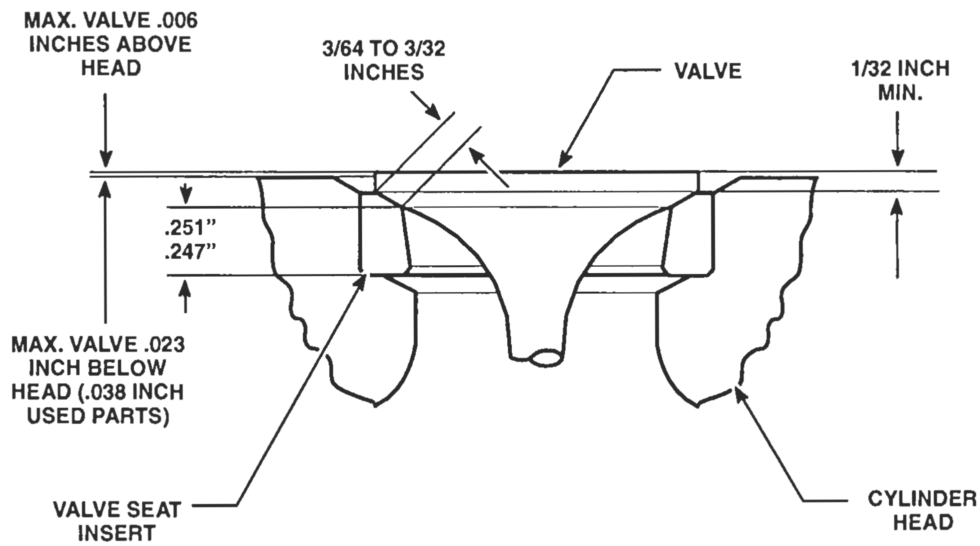


Figure 13. Valve Resurfacing

EXHAUST VALVE AND VALVE SEAT RECONDITIONING (CONT.)

When a new valve seat insert is installed or an old insert is reconditioned, the work must be done with a grinding wheel (Figure 14.)

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

Eccentric valve seat grinder set J 7040–A, which includes the grinder, dress stand and pilot, and dial gage, is used to grind the inserts. An adaptor set which includes the grinding wheels and pilot is used with the grinder.

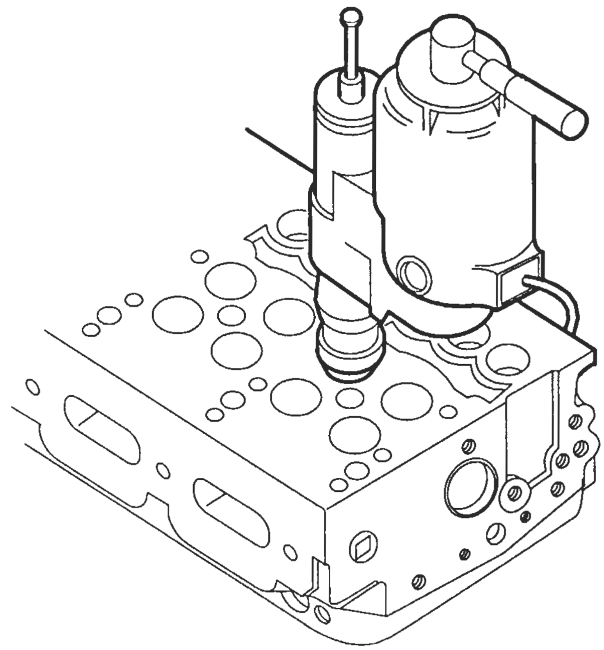


Figure 14. Reconditioning Valve Seat Insert

Adaptor set J 6390–02, used for the four–valve head, consists of the following:

- Pilot, tool J 7659–1
- Grinding wheel (15°), tool J 6390–2
- Grinding wheel (31°), tool J 6390–3
- Grinding wheel (60°), tool J 6390–4

Adaptor set J 8165–8, used for the two–valve cylinder head, consists of the following:

- Pilot, tool J 8165–3
- Grinding wheel (15°), tool J 8165–4
- Grinding wheel (31°), tool J 8165–5
- Grinding wheel (60°), tool J 8165–7

Grind the inserts as follows:

1. First apply the 31° grinding wheel on the valve seat insert.
2. Use the 60° grinding wheel to open the throat of the insert.
3. Grind the top surface of the insert with the 15° wheel to narrow the width of the seat to the dimensions shown in Figure 13. 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 insert. When an insert has been ground to the extent that the grinding wheel will contact the cylinder head, install a new insert.

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 (Figure 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.

EXHAUST VALVE AND VALVE SEAT RECONDITIONING (CONT.)

NOTE: Engines with 18.7:1 compression ratios must incorporate valve seat inserts that are no more than .251 inch thick to ensure adequate clearance between the pistons and the exhaust valves.

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Figure 15.)

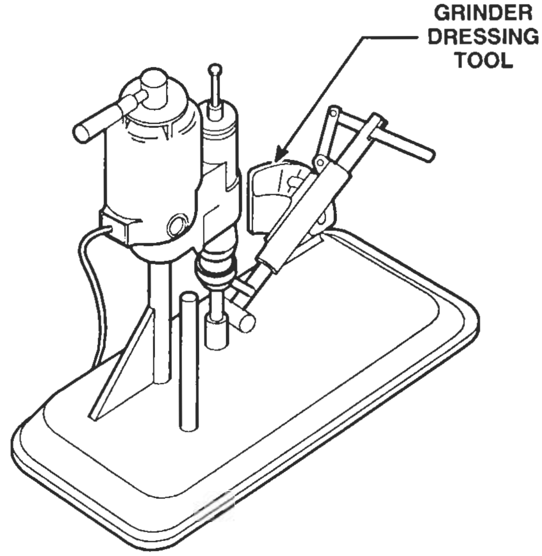


Figure 15. Grinding Wheel Dressing Tool

4. After grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165–2 in position and rotate it to determine the concentricity of each valve seat insert relative to the valve guide (Figure 16.). If the runout exceeds .002 inch, check for a bent valve guide before grinding the insert.
5. After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:
   a. Apply a light coat of Prussian blue, or a similar paste, to the valve seat insert.
   b. Lower the stem of the valve in the valve guide and "bounce" the valve on the seat. Do not rotate the valve. This procedure will show the area of contact on the valve face. The most desirable area of contact is at the center of the valve face. The use of valve lapping compounds is not recommended.

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

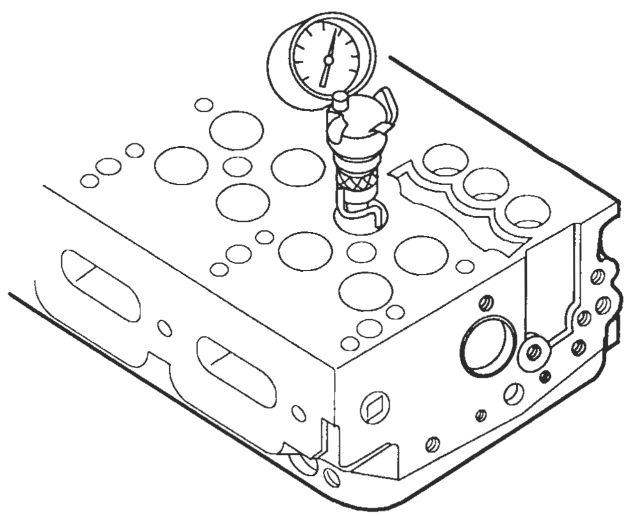


Figure 16. Determining Concentricity of Valve Seat Insert with Dial Indicator

EXHAUST VALVE AND SPRING INSTALLATION

Valve spring caps and seats of a corresponding diameter must be used with the valve springs. Since the current service cylinder heads are counterbored for use of the larger diameter spring, a service valve spring seat with a larger diameter and a raised center section is provided when the smaller spring is used.

Install the exhaust valves as follows:

1. Clean the valve guides.
2. Lubricate the valve stems with clean oil 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.
3. Hold the valves in place temporarily with a strip of masking tape. Then turn the cylinder head right side up on the work bench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.
4. Install the valve spring seats.
5. Install the valve guide oil seals, if used, on the valve guides as follows:

NOTICE:
Before installing an exhaust valve guide oil seal onto a cylinder head already mounted on the engine, make sure the piston is at top dead center for the cylinder involved. Failure to take this precaution can result in the valve dropping into the cylinder, requiring cylinder head removal for valve extraction.

   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 inch 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.
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.

EXHAUST VALVE AND SPRING INSTALLATION (CONT.)

NOTICE:

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

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 valves. Support the cylinder head at each end with wood blocks and remove the masking tape so that the exhaust valves are free. Then, give the 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.
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 (Figure 17.) The minimum allowable pressure required to start to open the exhaust valve must not be less than 15 lbs for a two–valve cylinder head or 20 lbs for a four–valve cylinder head (two–spring design).
12. Install the injectors, rocker arms, shafts, brackets and any other parts previously removed from the cylinder head.
13. Install the cylinder head. Refer to Pre–Installation Inspection and Install Cylinder Head in Section 1.2. If the engine is equipped with a four–valve cylinder head, adjust the exhaust valve bridges as outlined below.

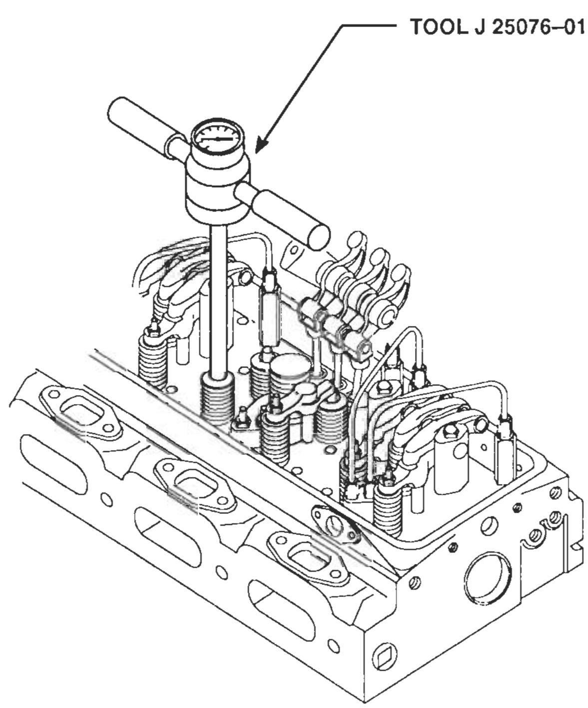


Figure 17. Checking Exhaust Valve Opening Pressure

EXHAUST VALVE BRIDGE ADJUSTMENT

On an engine equipped with a four–valve cylinder head, the exhaust valve bridge assembly is adjusted and the adjustment screw is locked securely after the cylinder head is installed on the engine. Until wear occurs, or the cylinder head is reconditioned, no further adjustment is required on the valve bridge. 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 lock nut 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 (Figure 18.)

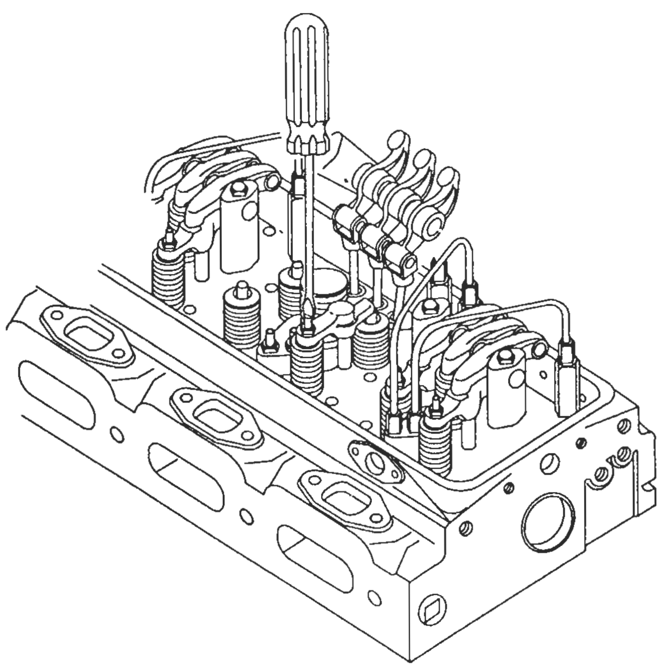


Figure 18. Valve Bridge Adjustment (Four–Valve Cylinder Head)

EXHAUST VALVE BRIDGE ADJUSTMENT (CONT.)

4. Remove the valve bridge and place it in a vise. Hold the adjustment screw from turning with a screwdriver and tighten the locknut on the adjustment screw 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 inch feeler gage (J 23185) under each end of the valve bridge or use a narrow strip cut from .0015 inch 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 2 and 3.
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 improperly located valve bridges. Tighten the rocker arm shaft bracket bolts to the torque specified in Section 1.0.

After the cylinder head is installed and the valve bridges adjusted (four–valve head), proceed as follows:

1. Refer to Section 2.1 or 2.1.1 under Install Injector and install the fuel pipes.
2. Fill the cooling system. Remove the vent plug from the thermostat housing or open the vent valve when filling 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.

ENGINE LIFTER BRACKETS

The engine lifter brackets not only provide a means of lifting the engine assembly, the cylinder head or the flywheel housing, but also serve as a vent for the crankcase vapors.

On certain engines, such as marine units, eyebolts, installed in the front balance weight cover pads, serve as engine lifters; a vent casting is used in place of the rear engine lifter bracket (Figure 1.) The vent casting is provided with drilled bosses to which the heat exchanger tank is attached.

The rear engine lifter bracket may also be provided with drilled bosses to permit the use of a throttle control crosshaft. Lifter brackets require no servicing other than removal during other service operations.

CAUTION:

To lift the engine, use a suitable lifting device (Figure 1). A spreader bar should be used with a sling and adequate chain hoist when lifting any engine. The lifting device should be adjusted so the lifting hooks are vertical to prevent bending of the engine lift brackets. To ensure proper weight distribution, all engine lift brackets provided must be used to lift the engine. Be sure the spreader bar is adequate to prevent lifter brackets from contacting the rocker cover, which may damage the rocker cover. Never lift any engine by any other means.

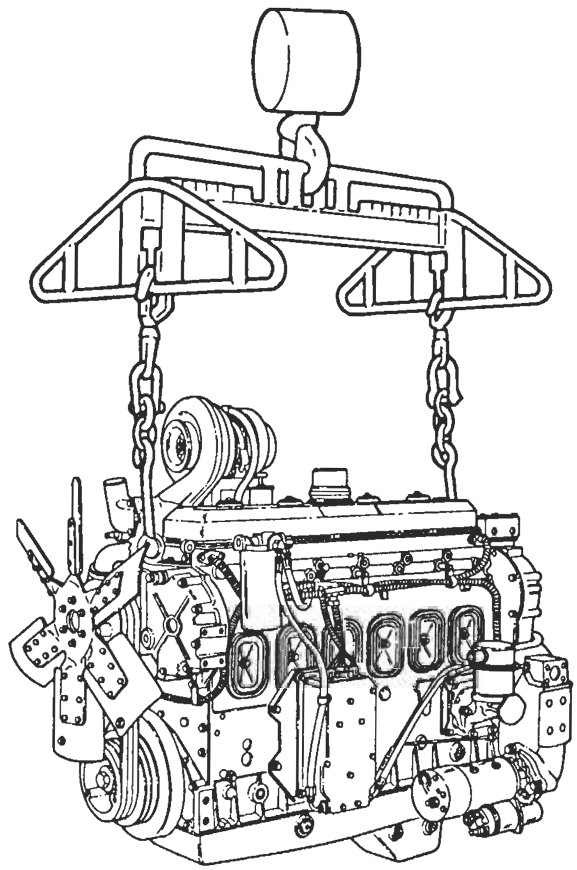


Figure 1. Lifting Engine

SECTION 1.2.3 – ENGINE LIFTER BRACKETS

ENGINE LIFTER BRACKET INSTALLATION

1. Remove all traces of the old gasket material.
2. Affix a new gasket to the front lifter bracket (or vent casting).
3. Attach the lifter bracket and gasket to the cylinder head with two bolts and to the front balance weight cover with two bolts.

NOTE: The lifter brackets must not be permanently attached until all of the cylinder head retaining bolts have been tightened to their specified torque.

4. Install the bolts finger tight, draw them down snug and then tighten to the specified torque. Draw the bolts down in the proper sequence (Figure 2.) for each of these steps to draw the mating parts together evenly, thus providing a good seal. Tighten the bolts to 55–60 lb·ft (75–81 N·m) torque.
5. Install the rear lifter bracket to the cylinder head and flywheel housing in a similar manner.

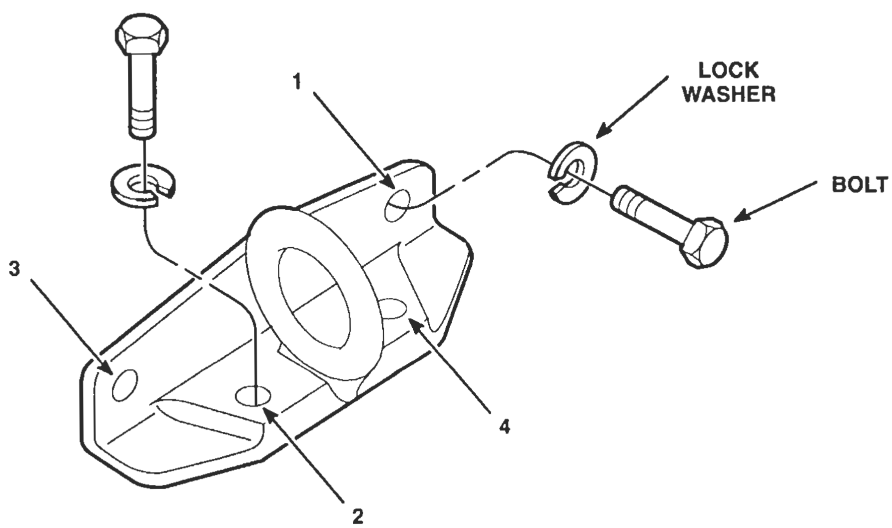


Figure 2. Engine Lifter Bracket and Bolt Tightening Sequence

VALVE ROCKER COVER

The valve rocker cover assembly (Figure 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 flange edge of the former stamped metal rocker cover.

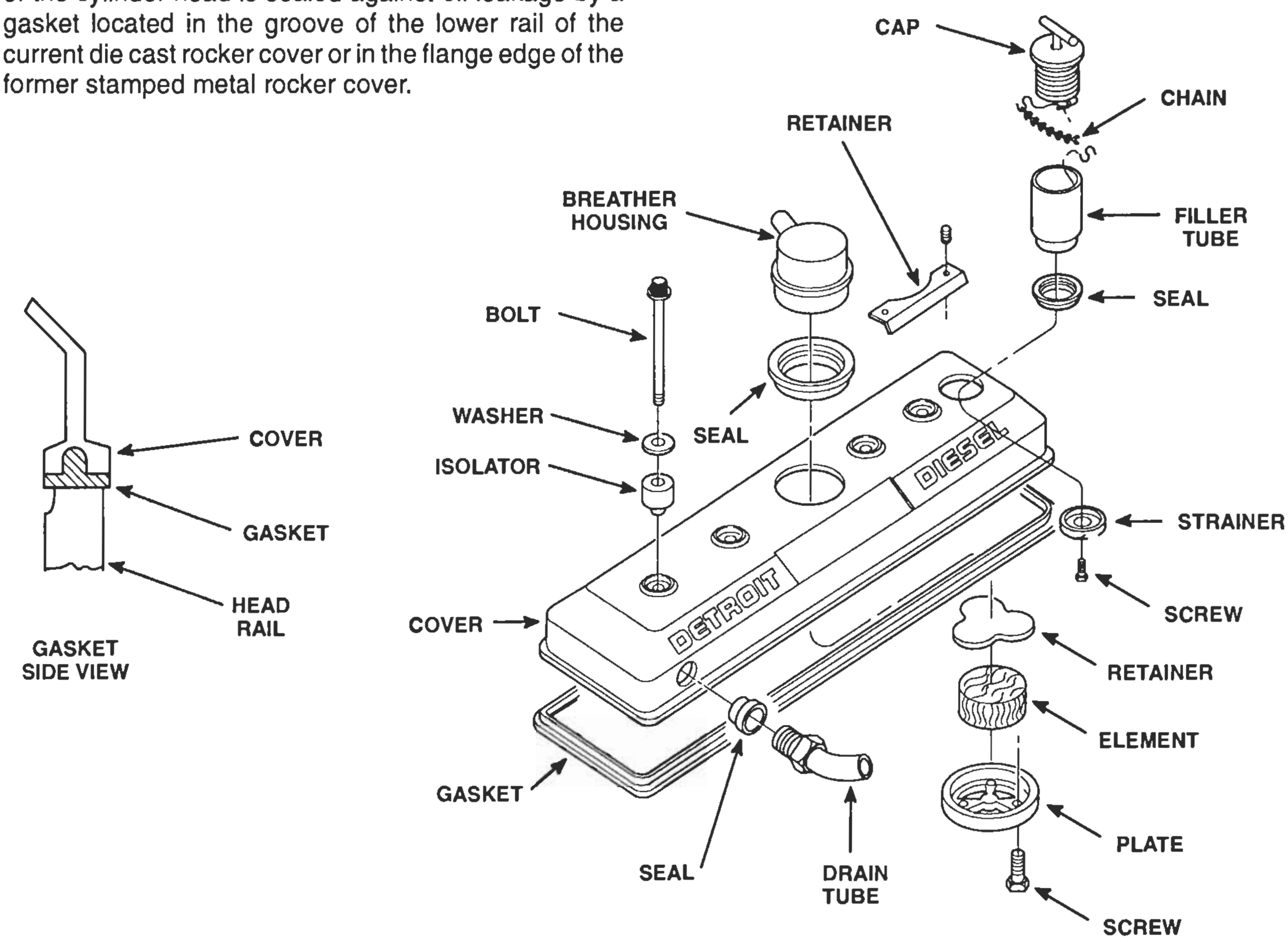


Figure 1. Valve Rocker Cover Assembly

The die cast rocker cover 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.

NOTE: The shorter rocker cover bolt, which threads into the throttle delay bracket, can crack the bracket if over tightened.

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

SECTION 1.2.4 – VALVE ROCKER COVER

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

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 inch 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.

REMOVE AND INSTALL VALVE ROCKER COVER

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

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 injury, wear proper eye protection and do not exceed 40 lb/in^2 (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. Be sure the stem of the entire gasket bottoms in the groove.

NOTE: 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

The crankshaft is a one–piece steel forging, heat–treated to ensure strength and durability (Figure 1.) All main and connecting rod bearing journal surfaces are induction hardened.

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

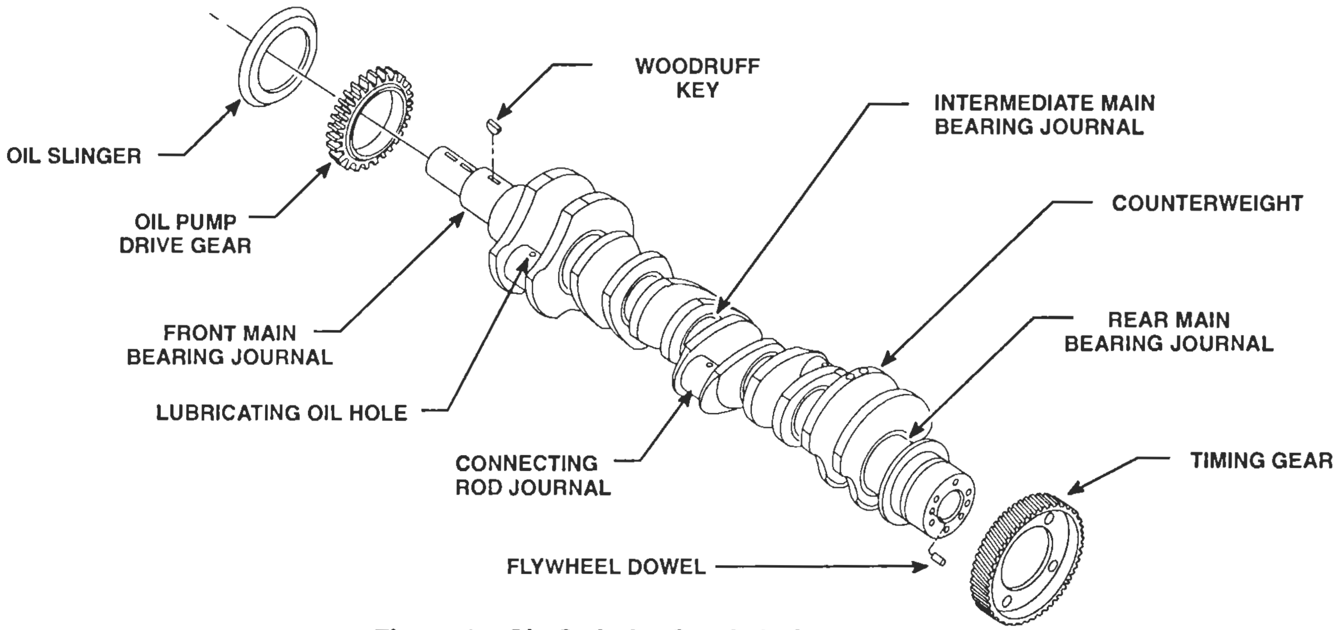


Figure 1. Six Cylinder Crankshaft

CRANKSHAFT REMOVAL

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 eyebolts 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 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 and then lubricating pump.

CRANKSHAFT REMOVAL (CONT.)

8. Remove the flywheel and flywheel housing.

CAUTION:

Extreme caution should be used when removing a flywheel by either leaving one or two bolts in the flywheel, or installing two suitable guide pins to support the flywheel until a lifting tool or some other suitable safe lifting device is attached to the flywheel.

9. Remove the crankshaft cap or pulley.
10. Remove the vibration damper, if used.
11. Remove the front engine support.
12. Remove the crankshaft front cover.
13. Remove the vibration damper inner cone or oil seal spacer.
14. Remove the cylinder head.
15. Remove the connecting rod bearing caps.
16. Remove the main bearing caps.
17. Remove the thrust washers from each side of the rear main bearing.
18. Remove the pistons, connecting rods and liners.
19. Remove the crankshaft, including the timing gear and oil pump drive gear.
20. Refer to Section 1.7.5 for removal of the crankshaft timing gear and Section 4.1 for the procedure covering removal of the oil pump drive gear.

INSPECTION

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

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then, reinstall the plugs and torque to 10–12 lb·ft (14–16 N·m). Use tool J 34650 to install the new sealant–coated 1/8–27 pipe plugs.

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

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

 May, 1994

INSPECTION (CONT.)

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Figure 2.) Ridges exceeding .0002 inches must be removed. If the ridges are not removed, localized high unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than .0005 inches, first use 120 grit emery cloth to clean up the ridge, 240 grit emery cloth for finishing and wet crocus cloth for polishing.

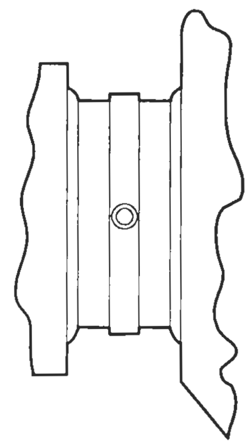


Figure 2. Ridging of Crankshaft

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.

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seal may be repositioned in the flywheel housing as outlined in Section 1.3.2.

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

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

Check the crankshaft dowel extension. Former dowels extend 1/2 inch from the crankshaft. When converting to or rebuilding engines for Torqmatic Converter applications, check to make sure the dowels Do not extend more than 1/2 inch, otherwise interference with the Torqmatic Converter flywheel will result.

Inspect the crankshaft for cracks as outlined in 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. Check the alignment at the adjacent intermediate main journals with a dial indicator.

When the high spots of runout on the adjacent journals are in opposite directions, the sum must not exceed .003 inch total indicator reading. When the high spots of runout on the adjacent journals of the four and six cylinder crankshaft are in the same direction, the difference must not exceed .003 inch total indicator reading. When the high spots of runout on the adjacent journals of the three cylinder crankshaft are at right angles to each other, the sum must not exceed .004 inch total indicator reading, or .002 inch on each journal. If the runout limit is greater than given in Table 1, crankshaft must be replaced.

	CRANKSHAFT RUNOUT	
Engine	Journals	Max. Runout (Total indicator reading)
3–71	At No. 2 and No. 3	.002 inch
4–71	At No. 2 and No. 4 At No. 3	.002 inch .004 inch
6–71	At No. 2 and No. 6 At No. 3 and No. 5 At No. 4	.002 inch .004 inch .006 inch

TABLE 1 – CRANKSHAFT RUNOUT

Measure all of the main and connecting rod bearing journals (Figure 3.) 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 journal–to–bearing shell clearance (with new shells) exceeds .0044 inches, the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest .0002 inch. Also, if the journal taper of a used crankshaft exceeds .0015 inch or the out–of–round is greater than .001 inch, the crankshaft must be reground.

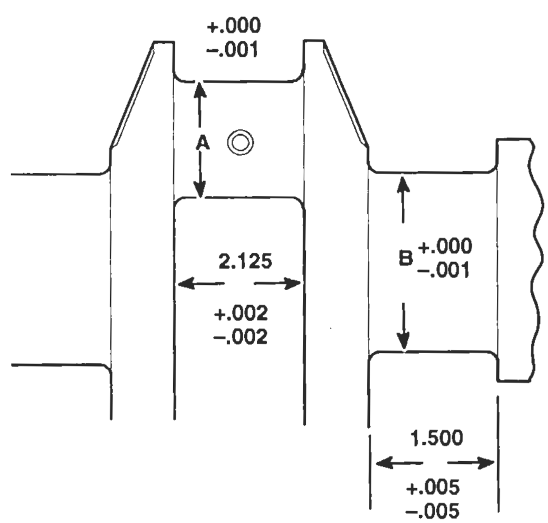


Figure 3. Dimensions of Crankshaft Journals

CRANKSHAFT MEASUREMENT (CONT.)

Also measure the crankshaft thrust surfaces (Figure 4.)

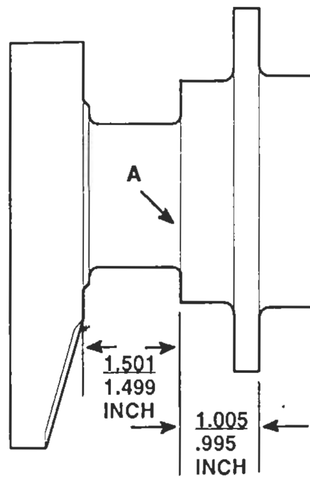


Figure 4. Standard Dimensions at Crankshaft Thrust Surfaces

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 de–magnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employes 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."

Florescent Penetrant Method: This is a method which may be used on both non–magnetic and magnetic materials. A highly fluorescent liquid penetrant is applied to the part. Then, the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under "Black Light."

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.

INSPECTION FOR CRACKS (CONT.)

Crankshaft failures are rare and when a crankshaft cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service: a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Figure 5.)

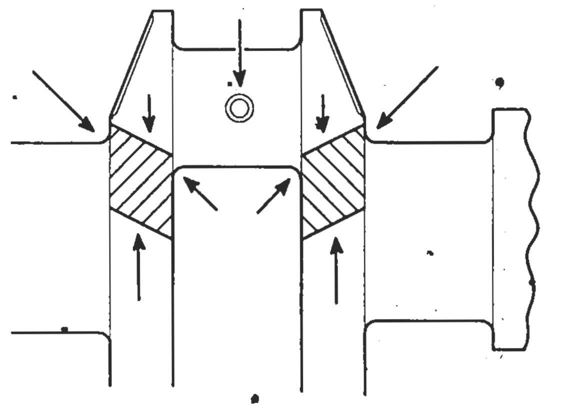


Figure 5. Critical Crankshaft Loading Zones

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes (Figure 6.) Replace the crankshaft when cracks of this nature are found.

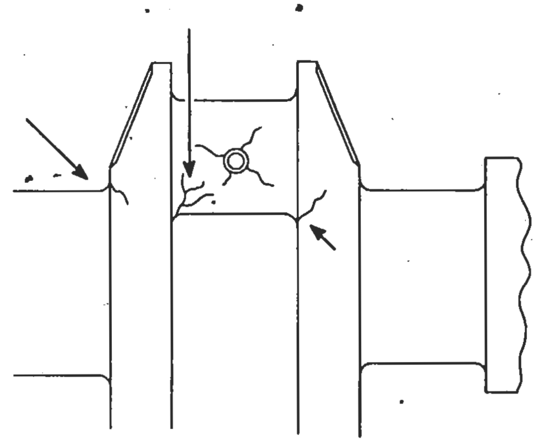


Figure 6. Crankshaft Fatigue Cracks

CRANKSHAFT GRINDING

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

The .002 inch undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

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

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

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 2 (and in Figure 3.) to determine the size to which the journals are to be reground.

Bearing Sizes	Conn. Rod Journal Dia. "A"	Main Bearing Journal Dia. "B"
Standard	2.750 inch	3.500 inch
.002 Undersize	2.750 inch	3.500 inch
.010 Undersize	2.740 inch	3.490 inch
.020 Undersize	2.730 inch	3.480 inch
.030 Undersize	2.720 inch	3.470 inch

TABLE 2 – BEARING SIZES

2. If one or more main connecting rod journals require grinding, grind all of the main journals or all of the connecting rod journals to the same required size.
3. All journal fillets must have a .130 to .160 inch radius between the crank cheek and the journal and must not have any sharp grind marks (Figure 7.) The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.
4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.
5. Polish the ground surfaces to an 8–12 R.M.S. finish. The reground journals will be subject to excessive wear unless polished smooth.

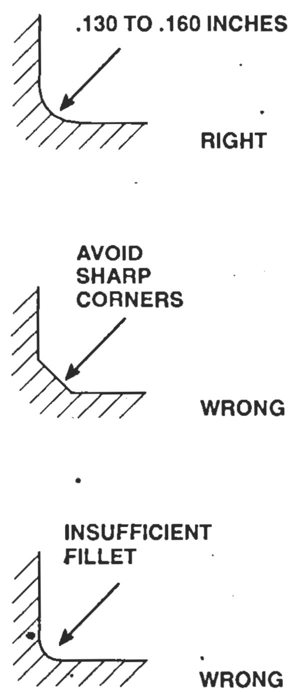


Figure 7. Crankshaft Journal Fillets

CRANKSHAFT GRINDING (CONT.)

6. If the thrust surfaces of the crankshaft are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a .130 to .160 inch radius between each thrust surface and the bearing journal.
7. Stone the edge of all oil holes in the journal surfaces smooth to provide a radius of approximately 3/32 inch.
8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.
9. Demagnetize the crankshaft.
10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

For additional information refer to DDC Manual 6SE453.

CRANKSHAFT INSTALLATION

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.

A new or remanufactured crankshaft receives a rolling process in the fillet area for added strength. This often leaves a slightly raised area at each end of the fillet (Figure 8.) This is an acceptable shaft and must not be confused with outside reground shafts that are left with a notch rather than a required blend as outlined under Crankshaft Grinding.

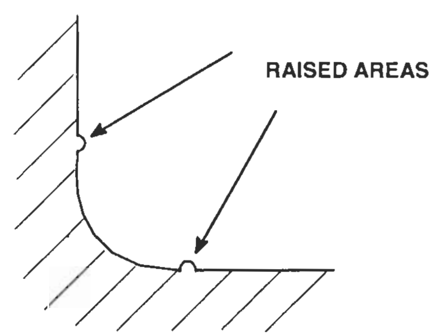


Figure 8. New or Remanufactured Crankshaft

CRANKSHAFT INSTALLATION (CONT.)

1. Assemble the crankshaft timing gear (Section 1.7.5) and the oil pump drive gear (Section 4.1) on the crankshaft.
2. Refer to Section 1.3.4 for main bearing details and install the upper grooved main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed. When a new or reground crankshaft is installed, all new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

Then, install the crankshaft as follows:

3. Apply clean engine oil 360° around all crankshaft journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to Section 1.7.1 for the correct method of timing the gear train.
4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. The grooved side of the thrust washers must face toward the crankshaft thrust surfaces. 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 Table 3.

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

TABLE 3 – THRUST WASHER THICKNESS

5. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.
6. Install the bearing caps and lower bearing shells (Section 1.3.4). If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.
7. Check the crankshaft end play by moving the crankshaft toward the gage with a small (less than 12 inches) pry bar (Figure 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 inches with new parts or a maximum of .018 inch 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.

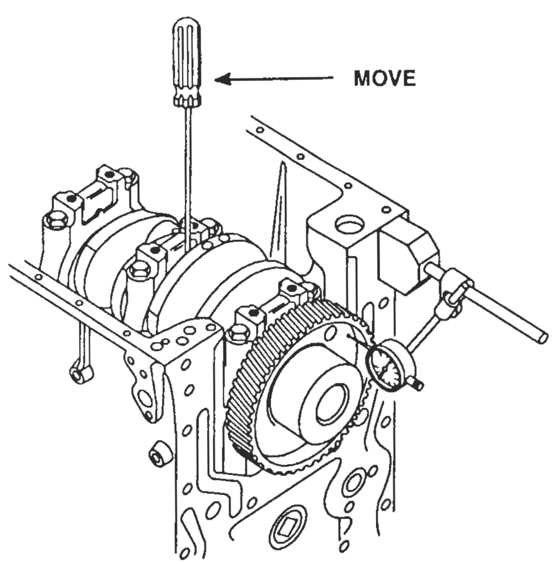


Figure 9. Checking Crankshaft End Play

CRANKSHAFT INSTALLATION (CONT.)

8. Install the cylinder liner, piston and connecting rod assemblies (Section 1.6.3).
9. Install the cylinder head (Section 1.2).
10. Install the flywheel housing (Section 1.5), then install the flywheel (Section 1.4).
11. Install the crankshaft front cover and gasket.

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.

12. Install the engine front support.
13. Install the vibration damper inner cone or oil seal spacer.
14. Install the vibration damper assembly, if used.
15. Install the crankshaft cap or pulley (Section 1.3.7).
16. Install the lubricating oil pump assembly (Section 4.1).
17. Check the crankshaft for distortion at the rear connecting rod journal counterweights before and after installing the power takeoff reduction gear assembly, transmission or power generator. An improperly installed power takeoff reduction gear assembly, transmission or power generator can distort the crankshaft and cause a crankshaft failure.

Check the crankshaft distortion as follows:

a. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the six o'clock position.

b. Center punch a hole in the inside face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gage.

c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight (Figure 10.)

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 inches total indicator reading. Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings.

e. If the reading on the gage exceeds .0045 inch, check the reduction gear, transmission or power generator for improper installation and realign as necessary.

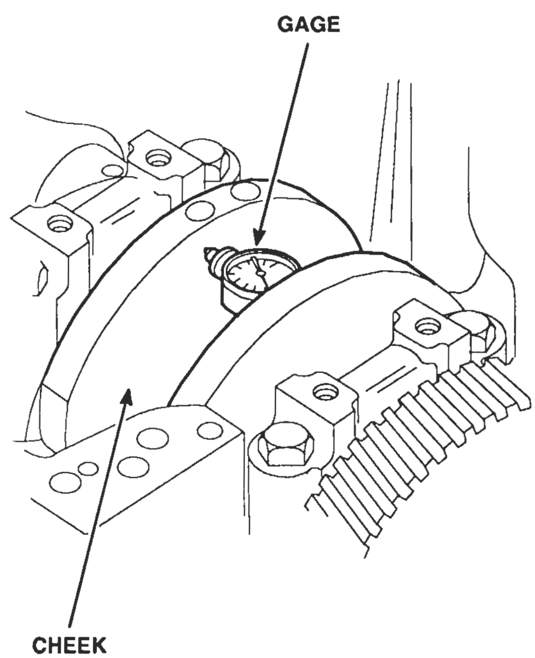


Figure 10. Crankshaft Distortion Measuring Gage Mounted on Crankshaft

CRANKSHAFT INSTALLATION (CONT.)

18. Affix a new gasket to the oil pan flange and install the oil pan.
19. Use a chain hoist and sling attached to the lifting bracket or eyebolts at each end of the engine and remove the engine from the overhaul stand.
20. Install all of the accessories that were removed.
21. After the engine has been completely reassembled, (Section 13.3) refill the crankcase to the proper level on the dipstick.
22. Close all of the drains and fill the cooling system.
23. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine (Section 13.2.1).

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a coil spring.

The front oil seal is pressed into the crankshaft front cover, and the lip of the seal bears against a removable spacer or vibration damper inner cone on the end of the crankshaft, next to the lubricating oil pump drive gear (Figure 1.)

The front oil seal is pressed into the crankshaft front cover.

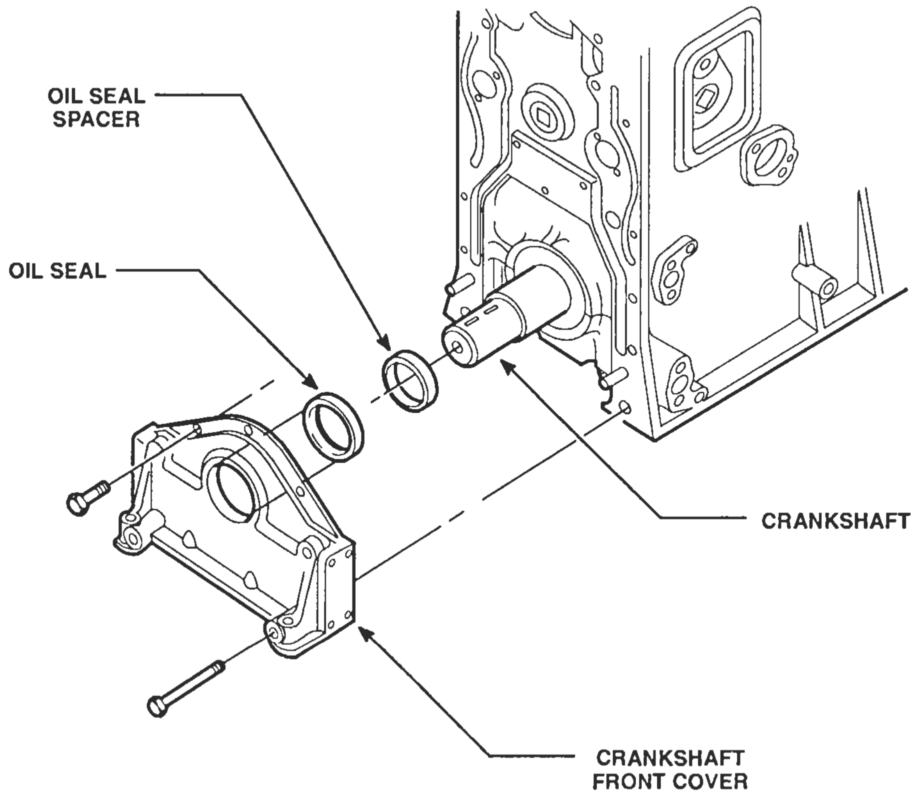


Figure 1. Crankshaft Front Oil Seal and Mounting

SECTION 1.3.2 – CRANKSHAFT OIL SEALS

A single–lip oil seal is used at the rear end of the crankshaft of most industrial engines.

A double–lip oil seal is used in engines where there is oil on both sides of the oil seal, (as in the hydraulic marine gear; the lips of the seal face in opposite directions).

The rear oil seal is pressed into the flywheel housing (Figure 2.)

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

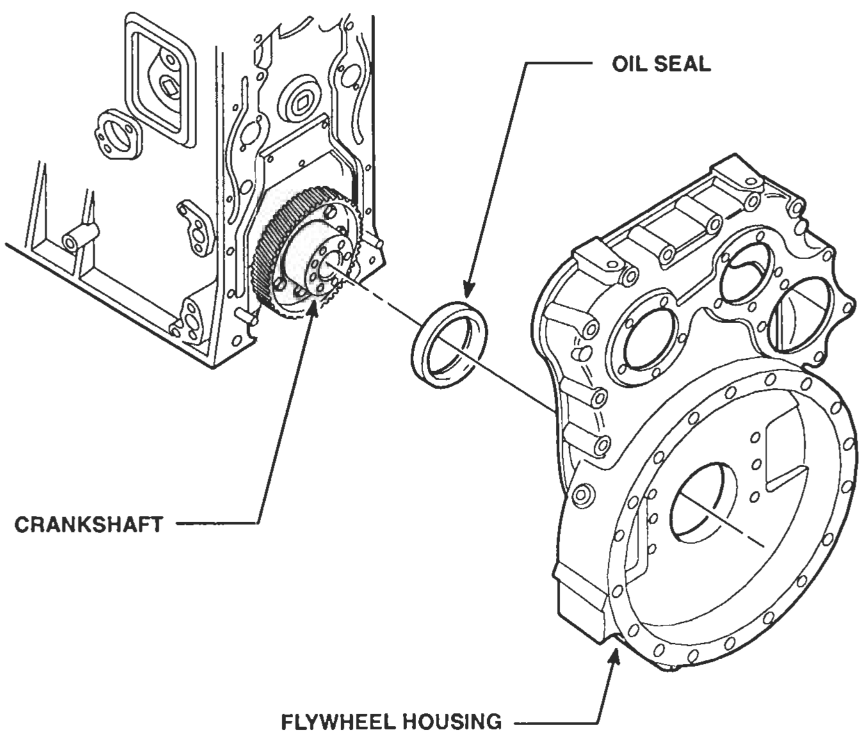


Figure 2. Crankshaft Rear Oil Seal & Mounting

CRANKSHAFT OIL SEAL REMOVAL

Remove the crankshaft front cover (Section 1.3.5) and the flywheel housing (Section 1.5) and remove the oil seals as follows:

1. Support the forward face of the front cover or the rear face of the flywheel housing on wood blocks.
2. Drive the oil seal out and clean the seal bore in the front cover or flywheel housing. Discard the oil seal.

When necessary, an oil seal may be removed without removing the front cover or flywheel housing (except a front cover that is used with trunnion mounts – this cover must be removed). This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars.

INSPECTION

Inspect the rear end of the crankshaft for wear caused by the rubbing action of the oil seal, dirt build–up 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. Slight ridges may be removed from the crankshaft as outlined under Inspection in Section 1.3. The maximum runout of the oil seal bore in the flywheel housing is .008 inch. 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 in place on the engine and the oil seal removed.

If the crankshaft rear oil seal surface is grooved excessively, an oil seal spacer (Figure 3.) may be installed between the counterbore in the flywheel housing and the oil seal. The spacer changes the relative position of the seal and establishes a new contact surface.

NOTE: The spacer cannot be used with a double–lip type seal since the grooves worn in the crankshaft are too close together to permit repositioning of the seal.

When the oil seal spacer can no longer be used, an oil seal sleeve may be installed on the crankshaft to provide a replaceable wear surface at the point of contact with the rear oil seal. The oil seal sleeve may also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

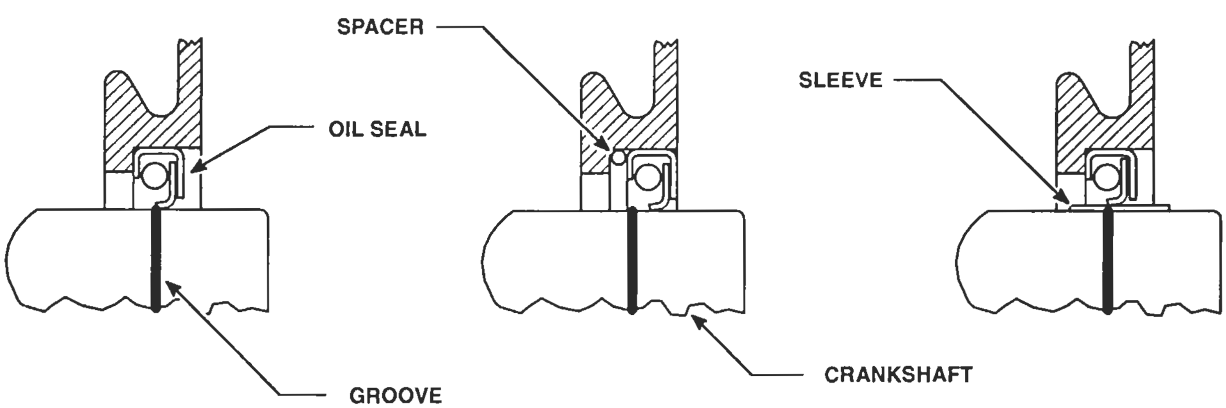


Figure 3. Rear Oil Seal Spacer or Sleeve on Grooved Crankshaft

SECTION 1.3.2 – CRANKSHAFT OIL SEALS

CRANKSHAFT OIL SEAL SLEEVE INSTALLATION

1. Stone the high spots from the oil seal contact surface of the crankshaft.
2. Apply a thin, even coat of Permatex Form–a–Gasket No. 3, or equivalent, to the inside diameter of the oversize wear sleeve.
3. Using crankshaft oil seal sleeve installer J 4194–01 and handle J 8092, drive the sleeve onto the crankshaft. Wipe off the excess sealant.
4. These seals must be installed **Dry.** Current front and rear oil seals have Teflon sealing lips. Do not lubricate the seals or crankshaft wear sleeves before installing.

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

OIL SEALS

Current crankshaft front oil seals are made of a Teflon lay down type lip seals. The seal is a unidirectional design (Figure 4.)

Current crankshaft rear oil seals are double–lip (Teflon inner lip and silicone outer lip) and incorporate a molded rubber seal case O.D. Seals are also nondirectional relative to engine rotation. That is, they are designed for use on either left–hand or right–hand rotating engines.

Service seals are the same design as production seals, except that the I.D. is oversize and the seal must be used with a wear sleeve. When replacing a crankshaft rear oil seal on a used crankshaft and/or seal–worn crankshaft butt, DDC recommends using an oversize I.D. seal with a crankshaft wear sleeve.

NOTICE:

Standard size crankshaft oil seals should only be used with a new crankshaft. Installing new seals on a worn crankshaft surface can result in seal damage and subsequent oil leakage.

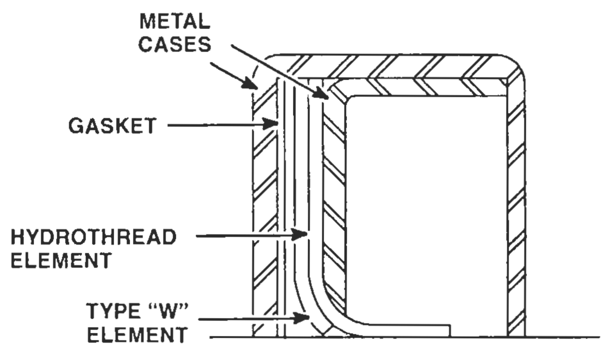


Figure 4. Oil Seal

CRANKSHAFT FRONT OIL SEAL INSTALLATION

NOTE: Do not lubricate the new seal before or during installation. Teflon seals must be installed dry. This allows transfer of the Teflon to the wear surface for proper sealing. Use care to make sure the seal is not cut or nicked during installation.

1. Drive the seal into the front cover with installer J 9783, which seats the oil seal in the bore. The installer prevents damage to the seal by exerting force only on the outer edge of the seal casing.
2. Remove any excess sealant from the cover and seal.
3. Install the crankshaft front cover as outlined in Section 1.3.5.
4. Install the vibration damper inner cone or oil seal spacer after the front cover and seal assembly is in place.

CRANKSHAFT REAR OIL SEAL INSTALLATION

The crankshaft rear oil seal should be installed with the crankshaft in place, flywheel housing mounted on the engine. Use the following procedure to install the crankshaft wear sleeve and rear oil seal:

1. Install guide stud assembly J 9727–2 (6–bolt crank) or guide stud set J 9227–5 (8–bolt crank) into the butt end of the crankshaft.
2. Apply a thin, even coat of Permatex Form–a–Gasket No. 3, or equivalent, to the inside diameter of the oversize wear sleeve. The new sleeve has been hardened and is darker in color.
3. Using crankshaft oil seal sleeve installer J 4194–01 and handle J 8092, drive the sleeve onto the butt of the crankshaft. Wipe off the excess sealant.

NOTE: Do not lubricate a Teflon seal lip or the crankshaft wear sleeve prior to seal installation. Teflon lip seals must be installed dry. This is to allow transfer of the Teflon to the wear sleeve surface for proper sealing.

4. Using oil seal installer J 9727–1 and handle J 3154–1, drive the seal into place (Figure 5.) Remove the guide studs from the end of the crankshaft.

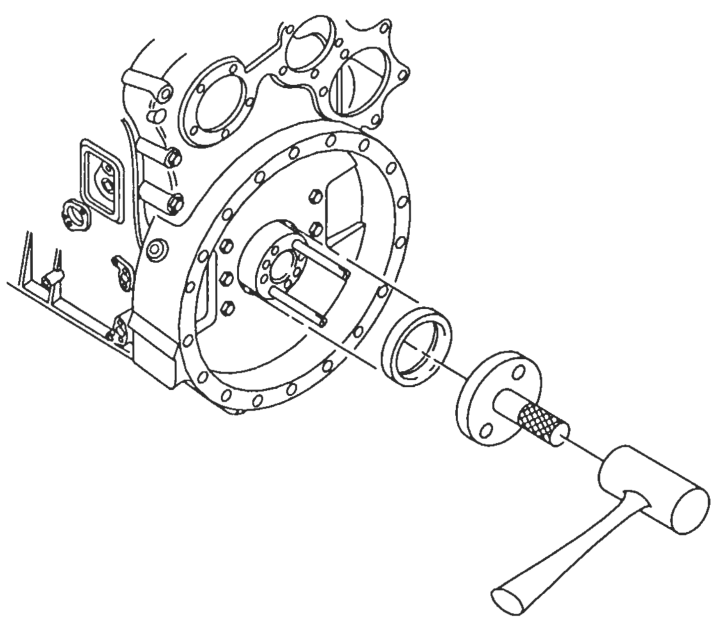


Figure 5. Installing Crankshaft Rear Seal

CHECK 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 must be checked after seal installation. Use the following procedure:

1. Attach magnetic base dial indicator J 7872 to the rear butt of the crankshaft (Figure 6.) 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 inches.

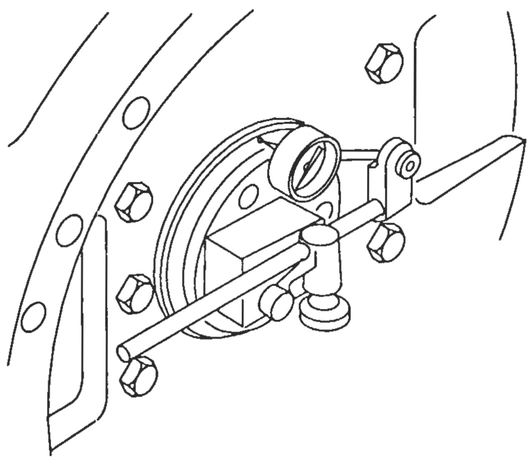


Figure 6. Checking Crankshaft Rear Seal Squareness

2. If any reading is over 0.015 inches, 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.

 May, 1994

CRANKSHAFT CAP

A one–piece crankshaft cap (Figure 1.) is installed on the front end of the crankshaft on engines which are not equipped with a crankshaft pulley. 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.

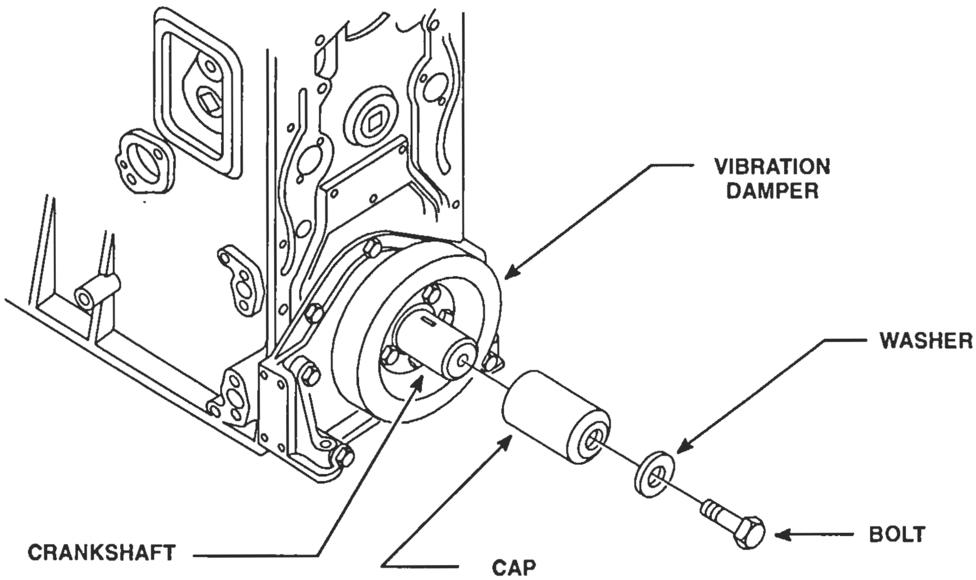


Figure 1. Crankshaft Cap Mounting

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

The crankshaft bolts are 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). The washer (retainer) is case hardened.

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. On 3–71 and 4–71 engines, tighten the bolt to 300 lb·ft (407 N·m) torque and strike the bolt again. Then tighten the bolt to 290–310 lb·ft (393–421 N·m) final torque. Do not strike the bolt after final torque has been applied.
4. On 6–71 engines, tighten to 450 lb·ft (670 N·m) torque and strike the bolt again. Then tighten the bolt again to 450 lb·ft (670 N·m) final torque.

NOTE: 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.

CRANKSHAFT MAIN BEARINGS

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

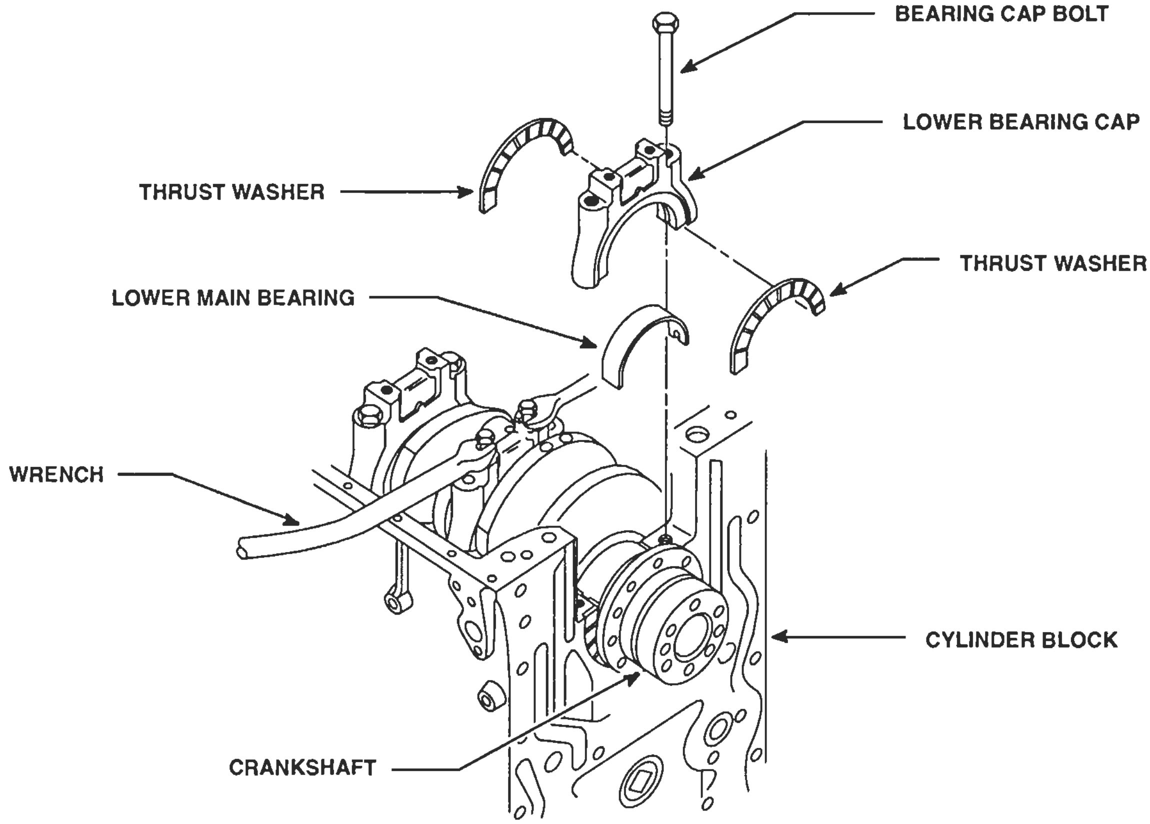


Figure 1. Main Bearing Caps, Bearing Shells and Crankshaft Thrust Washers

Bearings are made of multiple layer copper–lead coplated. These bearings have an inner surface, called the matrix, of copper–lead or aluminum. A thin deposit of babbitt is then plated onto the matrix. This babbitt overlay has excellent resistance to friction, corrosion and scoring tendencies which, combined with the material of the matrix, provides improved load carrying characteristics. These bearings are identified by the satin silver sheen of the babbitt when new and a dull gray after being in service.

An oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings. 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. The lower halves of the two–piece washers are doweled to the bearing cap; the upper halves are not doweled. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time, as outlined below and examine the bearing shells.

SECTION 1.3.4 – CRANKSHAFT MAIN BEARINGS

MAIN BEARING SHELL REMOVAL (CRANKSHAFT IN PLACE)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position. All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bearing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.
2. Remove the oil pump and the oil inlet and outlet pipe assemblies.

NOTE: 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 at a time and inspect the bearing shells (see Inspection). Reinstall each bearing shell and bearing cap before removing another bearing cap:

   a. To remove all except the rear main bearing shell, insert a 1/4 x 1 inch bolt with a 1/2 inch diameter and 1/16 inch 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 (Figure 2.)

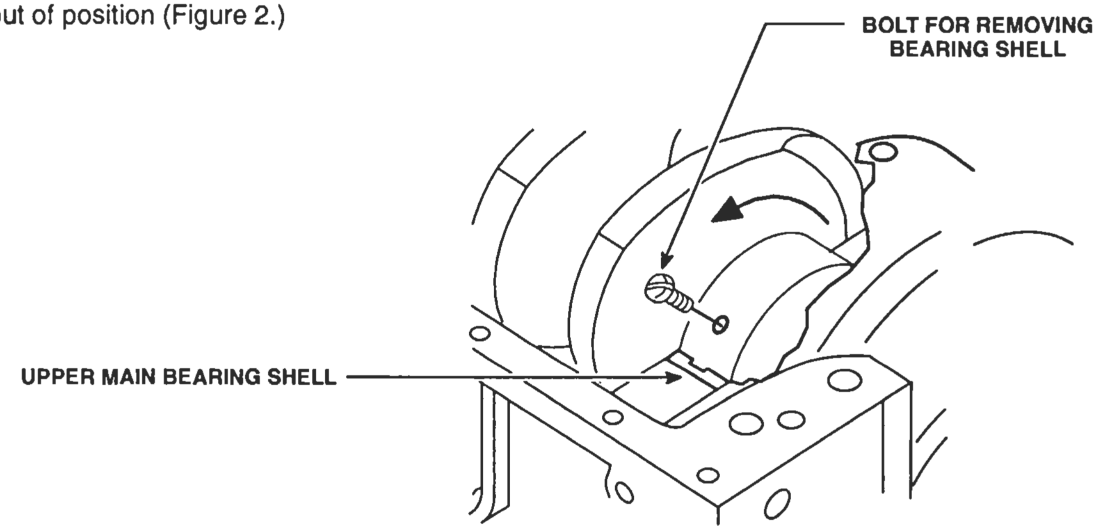


Figure 2. Removing Upper Main Bearing Shell (Except Rear Main)

MAIN BEARING SHELL REMOVAL (CRANKSHAFT IN PLACE) (CONT.)

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 (Figure 3.)

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 brass rod, forcing them around and out of the main bearing support.

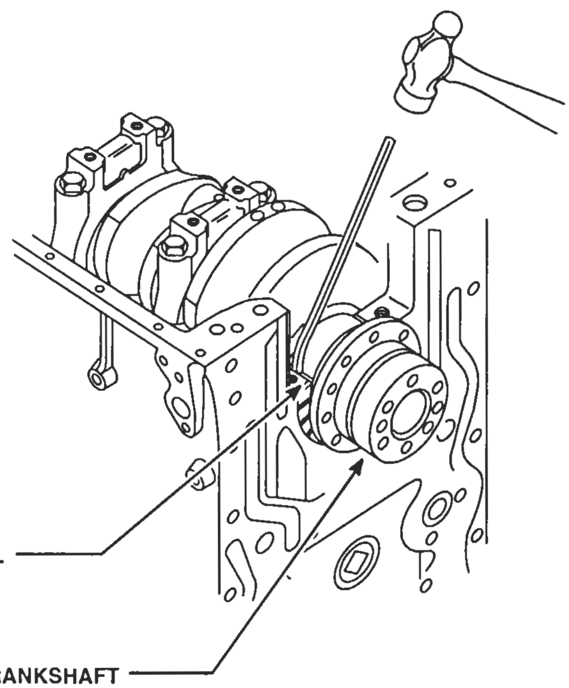


Figure 3. Upper Rear Main Bearing Shell Removal

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.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt or signs of overheating. 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.

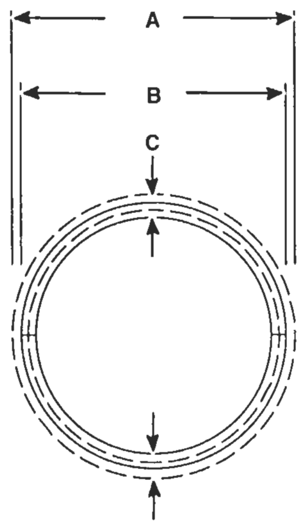
Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

SECTION 1.3.4 – CRANKSHAFT MAIN BEARINGS

INSPECTION (CONT.)

Measure the thickness of the bearing shells at point "C", 90° from the parting line. 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 .1530 inch 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 .1548 to .1553 inches. Refer to Table 1 and Figure 4.



A – FREE DIAMETER
B – INSTALLED DIAMETER
C – BEARING THICKNESS

Figure 4. Main Bearing Measurements

Bearing Size	Bearing Thickness	Minimum Worn Thickness
Standard	.1548/.1533 inches	.1530 inches
.002 Undersize	.1558/.1563 inches	.1540 inches
.010 Undersize	.1598/.1603 inches	.1580 inches
.020 Undersize	.1648/.1653 inches	.1630 inches
.030 Undersize	.1698/.1703 inches	.1680 inches

TABLE 1 – BEARING MEASUREMENTS

INSPECTION (CONT.)

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 (see 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 (Figure 5.) when installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are .001 inches larger in diameter at the parting line than 90° from the parting line.

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 inches, all of the bearing shells must be discarded and replaced. This clearance is .0014 to .0044 inches with new parts.

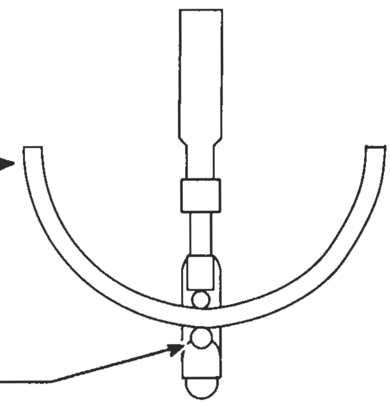


Figure 5. Measuring Thickness of Bearing Shell

Before installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oil holes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Section 1.3 under Crankshaft Inspection for removal of ridges and inspection of the crankshaft.

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

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

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

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 (see Section 1.3). If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is .1190 to .1220 inches thick. Thrust washers are available in .005 and .010 inch size.

MAIN BEARING SHELL INSTALLATION (CRANKSHAFT IN PLACE)

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

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

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.
2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap (Figure 6.)

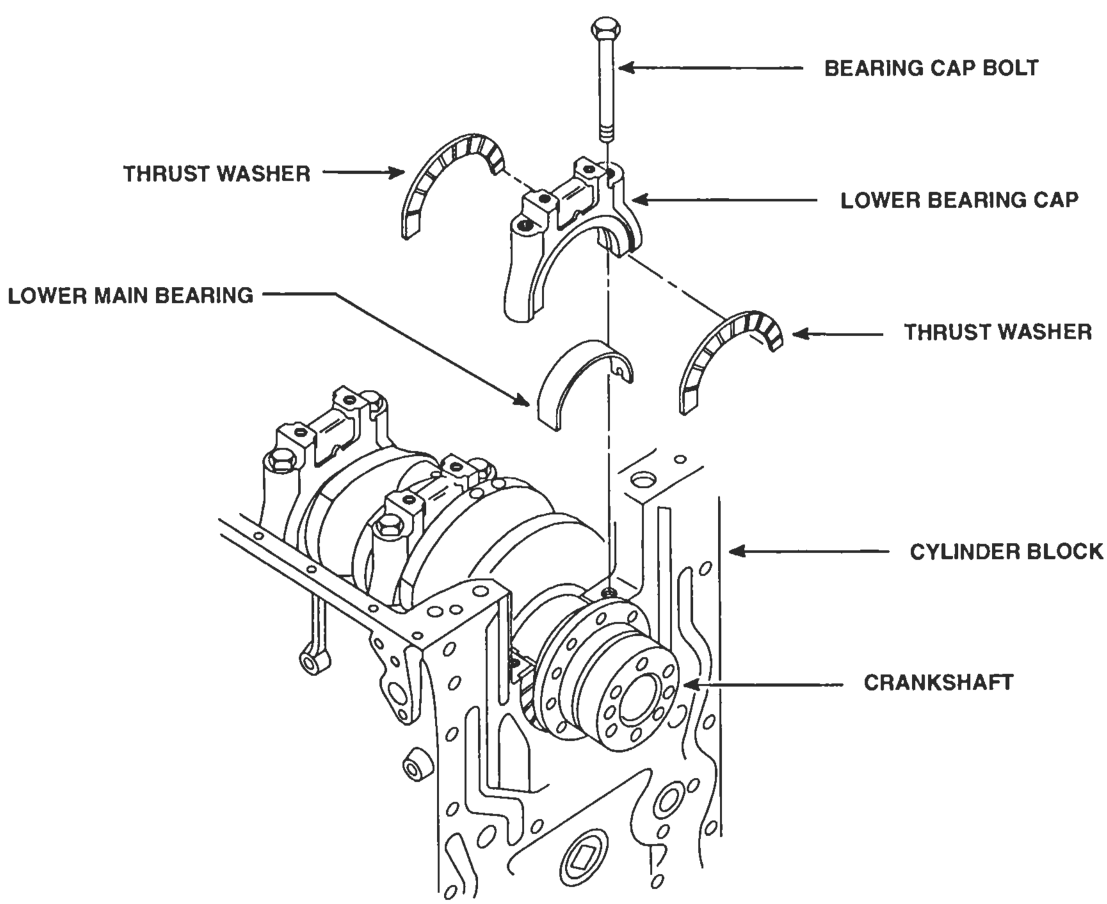


Figure 6. Crankshaft Thrust Washers in Place

MAIN BEARING SHELL INSTALLATION (CRANKSHAFT IN PLACE) (CONT.)

3. Assemble the crankshaft thrust washers before installing the rear main bearing cap. Clean both halves of each thrust washer carefully and remove any burrs from the washer seats — the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then, assemble the lower halves over the dowel pins in the bearing cap.

NOTE: The main bearing caps are bored in position and stamped 1, 2, 3, etc. (Figure 7.) They must be installed in their original positions with the marked side of each cap toward the blower side of the cylinder block.

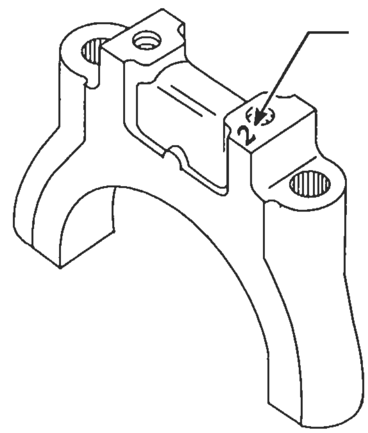


Figure 7. Main Bearing Cap Marking

4. With the lower main bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2 (or equivalent) to the bolt threads and the bolt head contact area. Install the bearing caps and draw the bolts up snug. Then, rap the caps sharply with a soft hammer to seat them properly and tighten the bolts uniformly to 190–200 lb·ft (258–272 N·m) torque.

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

5. Check the crankshaft end play (Section 1.3).
6. Install the lubricating oil pump and the oil inlet and outlet pipe assemblies.

NOTE: 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 (Section 13.3).
9. After installing new bearing shells, operate the engine on a run–in schedule (Section 13.2.1).

CRANKSHAFT FRONT COVER

The crankshaft front cover is mounted against the cylinder block end plate at the lower front end of the engine. The engine is supported at the front end by engine supports attached to the front cover. It will be necessary to remove the crankshaft front cover to remove and install the crankshaft or when the engine is overhauled.

CRANKSHAFT FRONT COVER REMOVAL

1. Drain the oil and remove the oil pan.
2. Remove the vibration damper (see Section 1.3.6), crankshaft pulley (see Section 1.3.7) and any other accessories that may be mounted on the front of the crankshaft.
3. Remove the vibration damper inner cone or oil seal spacer.
4. Remove the cover attaching bolts and washers (Figure 1.)
5. Strike the rear face of the ears on the cover with a soft hammer to free the cover from the dowels. Pull the cover straight off the end of the crankshaft.
6. Remove the cover gasket.
7. Remove and inspect the oil slinger.
8. Replace the oil seal (see Section 1.3.2).

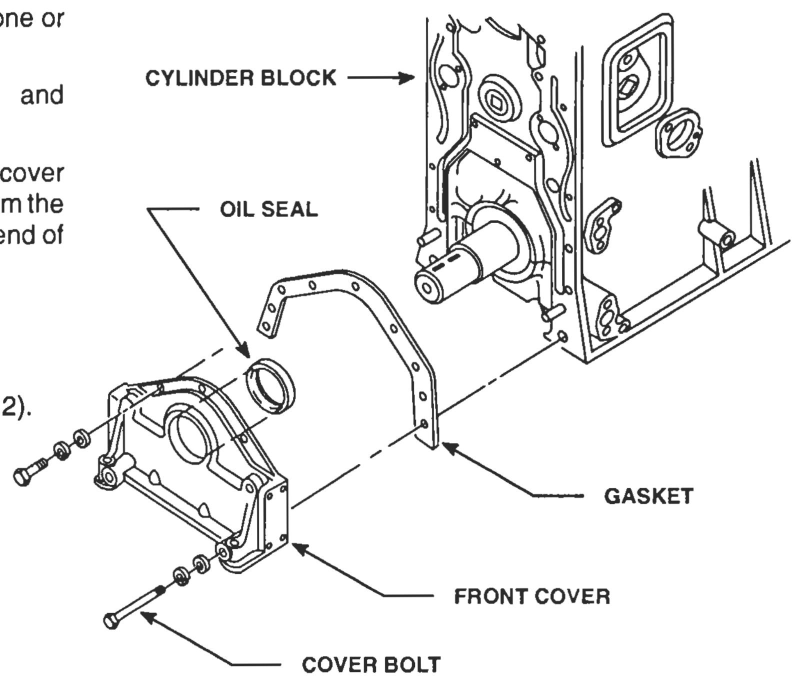


Figure 1. Crankshaft Front Cover

SECTION 1.3.5 – CRANKSHAFT MAIN BEARING

CRANKSHAFT FRONT COVER INSTALLATION

1. Install the oil slinger in place next to the oil pump drive gear, with the dished outer diameter of the slinger facing away from the gear.
2. Using 3M–77 adhesive (or equivalent), attach a new gasket to the bolting flange of the crankshaft front cover.
3. Attach the cover to the cylinder block front end plate with bolts and lock washers. Use plain washers in addition to lock washers on aluminum covers.
4. Tighten the cover attaching bolts by following the tightening sequence (Figure 2.) Follow this sequence as the bolts are drawn up and then tightened to their proper torque to effect a good seal between the mating parts. Tighten the 3/8–24 inch bolts to 25–30 lb·ft (34–41 N·m) and the 1/2–13 inch bolts to 80–90 lb·ft (108–122 N·m) torque.
5. Apply a light coating of engine oil to the vibration damper inner cone or the oil seal spacer and slide it into place on the crankshaft.
6. Install the oil pan, using a new gasket.
7. Refill the crankcase with oil to the proper level on the dipstick (Section 13.3).

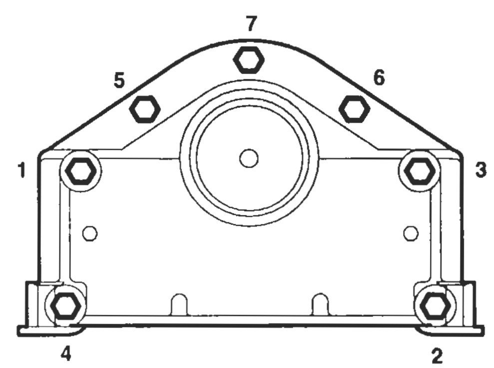


Figure 2. Crankshaft Front Cover Bolt Tightening Sequence

CRANKSHAFT VIBRATION DAMPER

Some four and six cylinder engines require a vibration damper to reduce the crankshaft stresses to a safe value. The three cylinder engines do not require a vibration damper. Three different types of vibration dampers are available and their particular use depends on the number of cylinders, the governed speed and other characteristics of each engine. The three types of vibration dampers are described below.

The double (rubber) damper is made up of a light damper, a heavy damper, a hub, an inner cone and an outer cone. The light and heavy dampers in the assembly are in turn made up of rubber blocks bonded to an inertia mass in the form of a metal ring on one side and a stamped metal disc on the opposite side.

The two metal parts are, therefore, entirely separated and free to move freely within certain prescribed limits by virtue of the rubber blocks. The light and heavy dampers are bolted and doweled together and to the driving hub.

The hub in turn is secured in place at the front end of the crankshaft between an inner and outer cone (Figure 1.) The two cones provide an adequate rigid mounting when the crankshaft cap, or a pulley, is drawn up tight against the outer cone by the bolt in the end of the crankshaft.

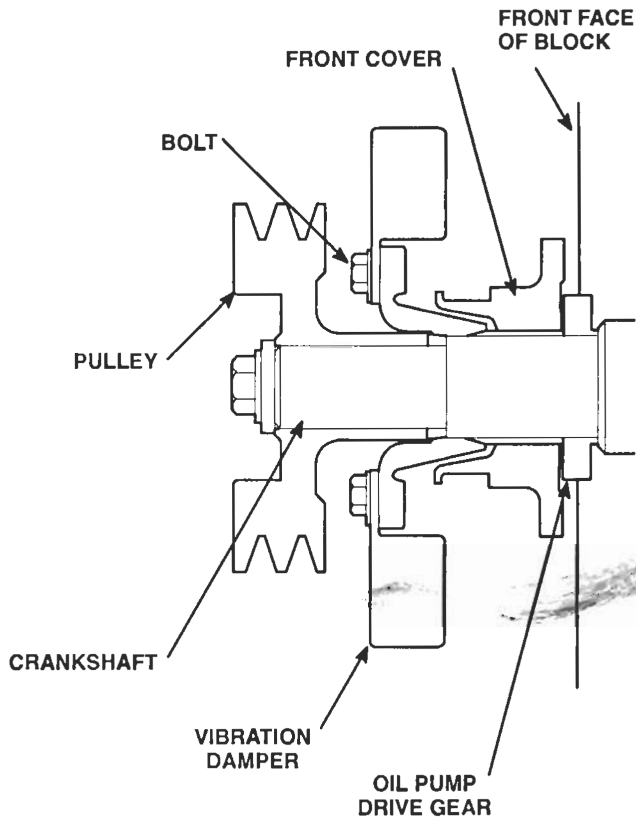


Figure 1. Crankshaft Cap and Double Vibration Damper Mounting

The 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 washer (retainer) is now case hardened. The bolts and washer can be identified by their black color.

The single (rubber) damper is similar to the double damper described above except that only the light damper is used with the hub and cones.

These vibration dampers are rigidly constructed and should give no trouble if given proper care; nevertheless, since rubber is used in the assembly, certain precautions are necessary. Fuel oil and lubricating oil, as well as excessive heat, are destructive to rubber. The assembly, therefore, should be protected against these destructive agents. Furthermore, for the damper to function properly and safeguard the crankshaft, it should be securely fastened to the shaft by the cones and the crankshaft cap or pulley which also act as a cone retainer.

The viscous (fluid) type damper is employed where the equipment which the engine powers requires frequent speed and load changes. The viscous damper provides faster response to load and speed changes and high temperatures have a less adverse effect than on the rubber type damper.

SECTION 1.3.6 – CRANKSHAFT VIBRATION DAMPER

The viscous damper assembly consists of a sealed outer shell, an internal flywheel and a quantity of highly viscous fluid (Figure 2.) The small clearance between the flywheel and the outer shell is filled with the fluid which causes the flywheel to be driven upon acceleration and permits it to "freewheel" upon deceleration. The new 12 inch nylon coated flywheel style vibration dampers are now being used on the 6–71 engines. Only the current nylon coated dampers will be serviced.

During operation, the outer shell, which is firmly attached to the crankshaft, turns at the same speed as the crankshaft, its motion being transferred to the flywheel through the fluid within the shell. Inasmuch as "fluid–drive" is more or less inefficient with frequent speed changes, considerable slippage of the flywheel will take place as the power impulses are transmitted through the crankshaft. In this type of operation, the slippage is desirable since the acceleration and deceleration of the flywheel in the damper lessens the amplitude of the vibrations, thereby reducing their effects to a point where they are not harmful to the engine.

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

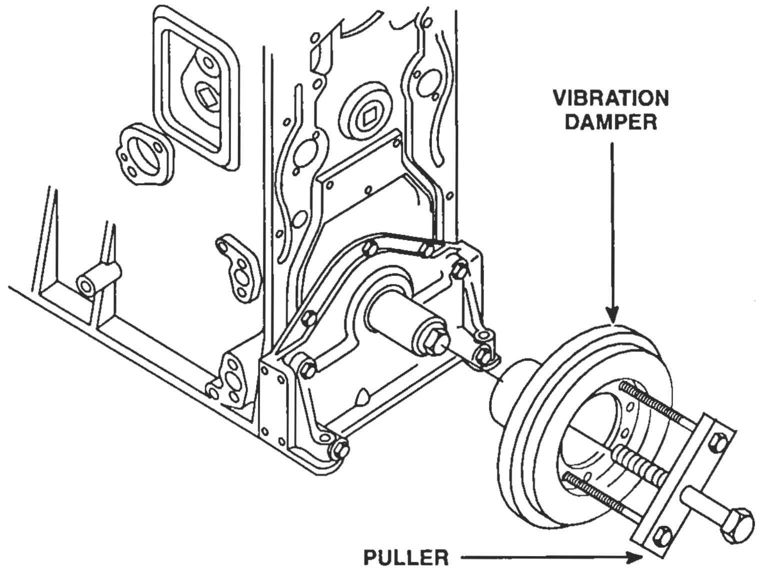


Figure 2. Removing Vibration Damper Assembly

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 original OEM 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:

- Shields should be made from 1/8 to 3/16 inches perforated steel or heavy steel screen.
- 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.
- Shields should be no closer than 1/2 inches from the damper when installed.
- 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 OEMs 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.

VIBRATION DAMPER REMOVAL FROM CRANKSHAFT

1. Remove the crankshaft pulley or cap retaining bolt and washer.
2. Remove the crankshaft pulley or cap.
3. On rubber–type vibration dampers, remove two damper–to–hub bolts and lock washers diametrically opposite to each other. Two puller holes are provided in the bolt circle of the viscous damper.
4. Reinstall the pulley crankshaft bolt and install a puller to loosen the outer cone wedge between the crankshaft and the damper hub (Figure 3.) After loosening the cone, it may be "fished" from the inner diameter of the damper hub with two thin shank screwdrivers.

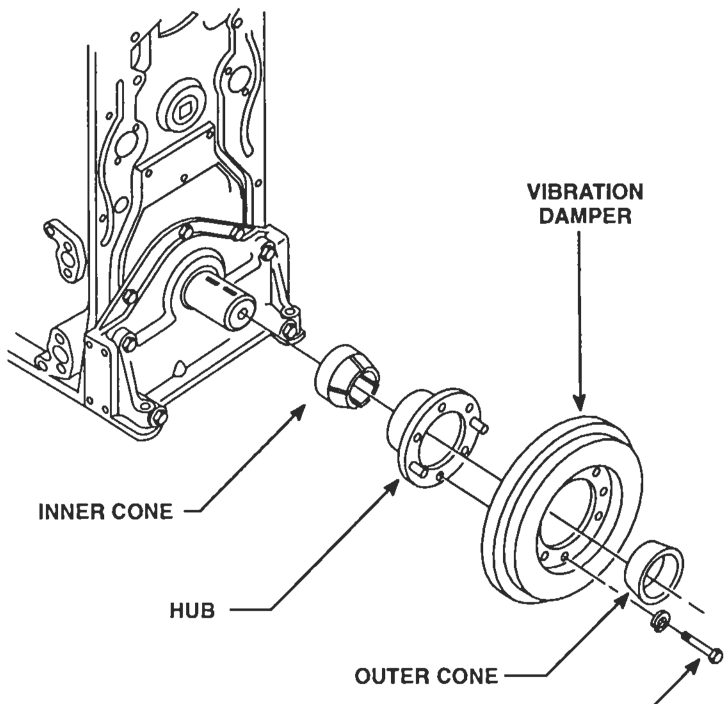


Figure 3. **Double Vibration Damper (Rubber Type)**

NOTICE:

Pounding with a hammer or prying with other tools must not be resorted to in removing the viscous type damper from the crankshaft, since the outer shell may be dented and cause the flywheel to turn at the same speed as the outer shell, thus rendering the damper ineffective. The damper cannot be repaired.

5. Slide the vibration damper or dampers and damper hub as an assembly off the end of the crankshaft by hand.
6. Slide the inner cone from the crankshaft.

VIBRATION DAMPER INSPECTION

After removal, clean the vibration damper in fuel oil and dry it with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

NOTICE:

Do not allow fuel oil to remain on a rubber type vibration damper too long, but dry it immediately after cleaning, otherwise, damage due to the action of the fuel oil on the rubber may result.

Inspect the rubber type damper to see that the rubber is firmly bonded to the metal parts at each side. If the damper has been exposed to fuel oil, lubricating oil or excessive heat, the rubber may have become loosened from the metal. In this event, the damper must be discarded and replaced with a new one. Also, check to see that the metal discs are not bent.

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

Since the viscous type damper is a precision built closely fitted and sealed device, it is not possible to repair it. Regardless of condition, the viscous type damper should be replaced at time of normal periodic major engine overhaul.

The former damper used on 6–71, 6–71T, 6–71TA, 6–71TT and 6–71TTA engines **must be replaced** with the new damper and scuff plate assembly at the time of normal engine overhaul or when physical damage or fluid leakage are evident.

NOTICE:

Do not install the new damper on any other Detroit Diesel engine models. Engines not designed to use this damper may experience serious crankshaft damage.

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

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

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.

VIBRATION DAMPER INSTALLATION

Refer to the illustrations for relative location of the parts and assemble as follows:

1. Slide the sleeve, if used, over the large diameter of the crankshaft and against the oil slinger, being sure the slinger is tight against the oil pump drive gear; then slide the spacer against the sleeve.
2. With the Woodruff keys (if used) in place, slide the inner cone, with the tapered end pointing to the front of the crankshaft, next to the oil slinger or against the spacer, if used.

NOTE: When the vibration damper and crankshaft pulley are bolted together and mounted on the front end of the crankshaft (Figure 4.), extra precaution should be taken to be certain that the inner cone does not prematurely clamp to the crankshaft.

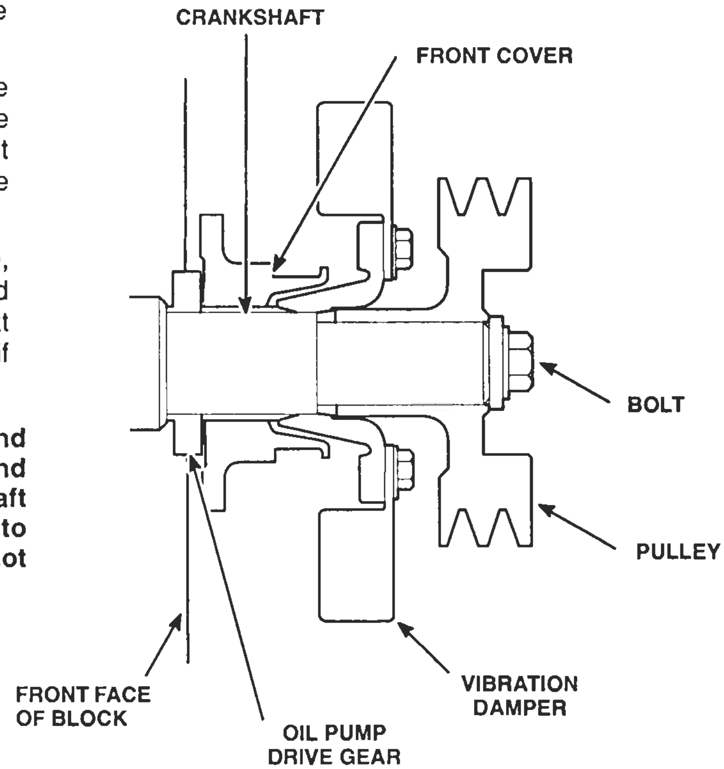


Figure 4. Vibration Damper and Crankshaft Pulley Mounting

3. If the light and heavy dampers were removed from the hub, assemble the two dampers over the dowels and against the hub with the flat faces of the dampers facing each other. Secure the dampers to the hub with bolts and lock washers.
4. Slide the damper and hub as an assembly (long end of the hub facing the crankshaft cover) into position.

VIBRATION DAMPER INSTALLATION (CONT.)

NOTICE:

Do not hit a viscous type damper with a hammer to position it on the crankshaft. Engine damage may result.

5. Install the crankshaft pulley and vibration damper assembly with the damper assembly side of the pulley facing the crankshaft front cover.
6. Slide the outer cone over the crankshaft and into the hub of the vibration damper (or the crankshaft pulley).
7. Install the crankshaft cap (or crankshaft pulley).
8. Thread the crankshaft cap (or pulley) retaining bolt with washer, into the crankshaft and tighten it 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 lb. lead hammer.
   c. On 4–71 engines, tighten the bolt to 300 lb·ft (407 N·m) torque and strike the bolt again. Then tighten the bolt to 290–310 lb·ft (393–421 N·m) final torque. Do not strike the bolt after final torque has been applied.
   d. On 6–71 engines, tighten to 450 lb·ft (670 N·m) torque and strike the bolt again. Then tighten the bolt again to 450 lb·ft (670 N·m) final torque.

NOTE: 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.

CRANKSHAFT PULLEY

The engine application determines the type of crankshaft pulley to be used. One type of pulley used incorporates a rubber insulator between the pulley and the pulley hub for vibration dampening.

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

The crankshaft pulley bolts are 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 washer (retainer) is case hardened.

New crankshaft pulley bolts are used on all inline 6–71 Engines, effective with unit number 6A0452843. The new bolts are dimensionally similar to the former bolts, but have larger heads (1 1/2 vs. 1 5/16 inch hex width across flats) and are made of harder steel. Only the new bolts should be used to retain the front crankshaft pulley on inline 6–71 Engines.

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

INSPECTION

The condition of a rubber mounted 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. An unsatisfactory rubber bushing should be replaced.

CRANKSHAFT PULLEY REMOVAL

The difference in the design of pulleys dictates the use of various puller tools as outlined below:

1. Remove the bolt and washer.
2. If a rubber mounted pulley with an internal thread is being removed, use puller J 5356 (Figure 1.) Clean the threads of the tool and pulley. Screw the 2 1/2–16 inch thread into the pulley hub as far as possible with the center screw backed off. Then force the pulley off the crankshaft by turning the center screw in.
3. If a rigid type pulley without any tapped holes is being removed, use a two–jaw puller (J 4643).

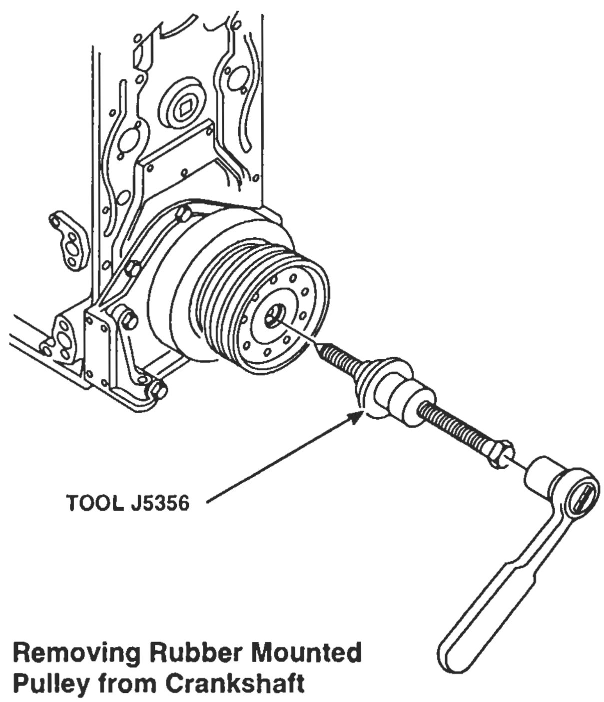


Figure 1. Removing Rubber Mounted Pulley from Crankshaft

CRANKSHAFT PULLEY REMOVAL (CONT.)

4. If tapped holes are provided in the pulley hub, install the pulley bolt in the end of the crankshaft and use puller J 24420–A (Figure 2.)

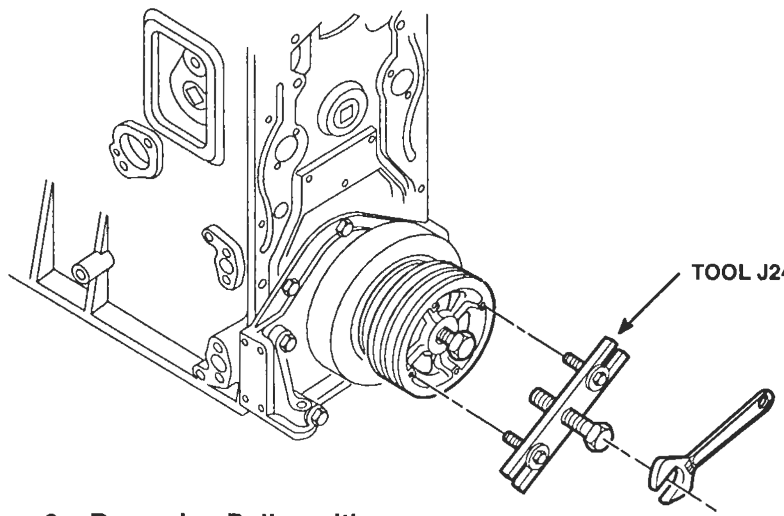


Figure 2. Removing Pulley with Tapped Holes from Crankshaft

CRANKSHAFT PULLEY INSTALLATION

1. Install the keys and/or cones in the front end of the crankshaft as they were removed (Figure 3.) Slide the pulley over the end of the crankshaft.
2. Place the washer on the bolt and thread the bolt into the end of the crankshaft, drawing the pulley tight against the oil seal spacer. If the engine is equipped with a vibration damper, the pulley must be drawn tight against the outer cone.
3. Tighten the crankshaft pulley retaining bolt to 180 lb·ft (244 N·m) torque.
4. Strike the end of the bolt with a sharp blow with a 2 or 3 lb lead hammer.
5. On 4–71 engines, tighten the bolt to 300 lb·ft (407 N·m) torque and strike the bolt again. Then tighten the bolt to 290–310 lb·ft (393–421 N·m) final torque. Do not strike the bolt after final torque has been applied.
6. On 6–71 engines, tighten bolt to 450 lb·ft (670 N·m) torque and strike the bolt again. Then tighten the bolt again to 450 lb·ft (670 N·m) final torque.

NOTE: Do not strike the bolt after final torque has been applied.

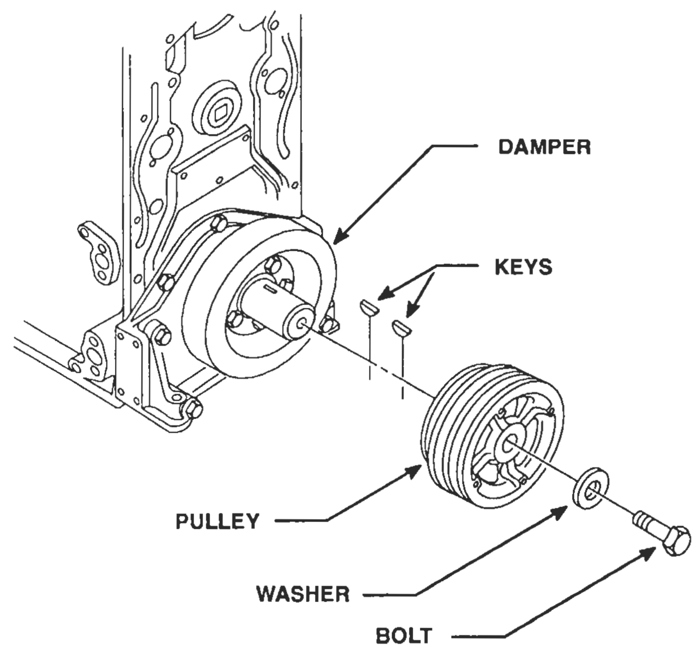


Figure 3. Crankshaft Pulley

CRANKSHAFT PULLEY REMOVAL (CONT.)

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 (Figure 4.) 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.

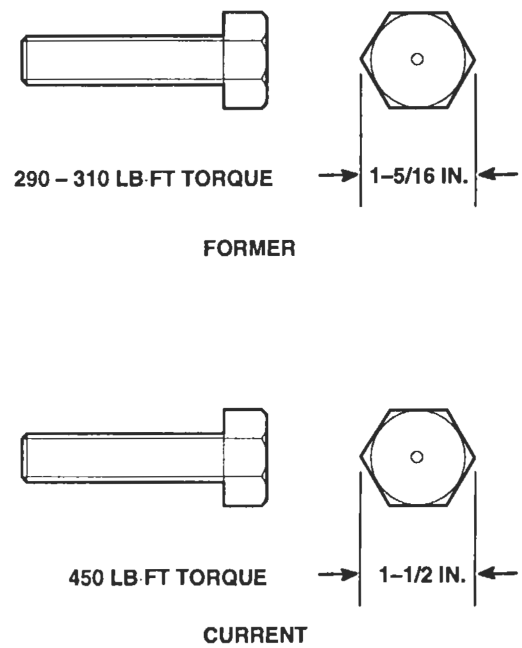


Figure 4. Former and New 6–71 Crankshaft Pulley Bolts

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with six self–locking bolts (Figure 1.) Two dowels in the end of the crankshaft aid flywheel alignment and provide support when the flywheel bolts are removed. 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.

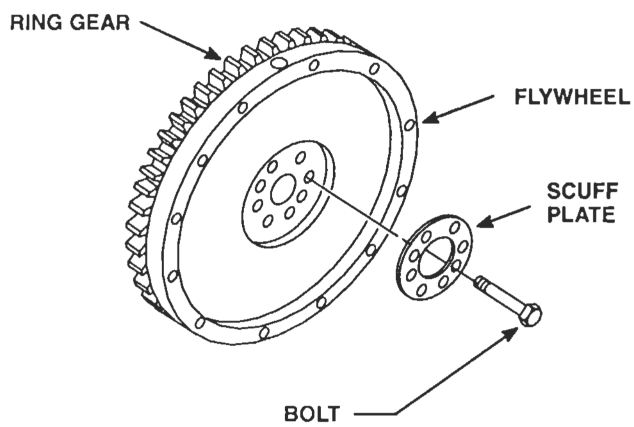


Figure 1. Typical Flywheel Assembly

On current engines, a split tube type retainer (Figure 2.) is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity. Former engines used a washer type retainer.

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

On some flywheel installations, a drive flange is attached to the rear face of the flywheel. The drive flange incorporates internal splines to receive a splined drive shaft.

On other applications, a clutch wear plate is bolted to the flywheel or four drive pins are installed in the inner diameter of the flywheel rim.

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

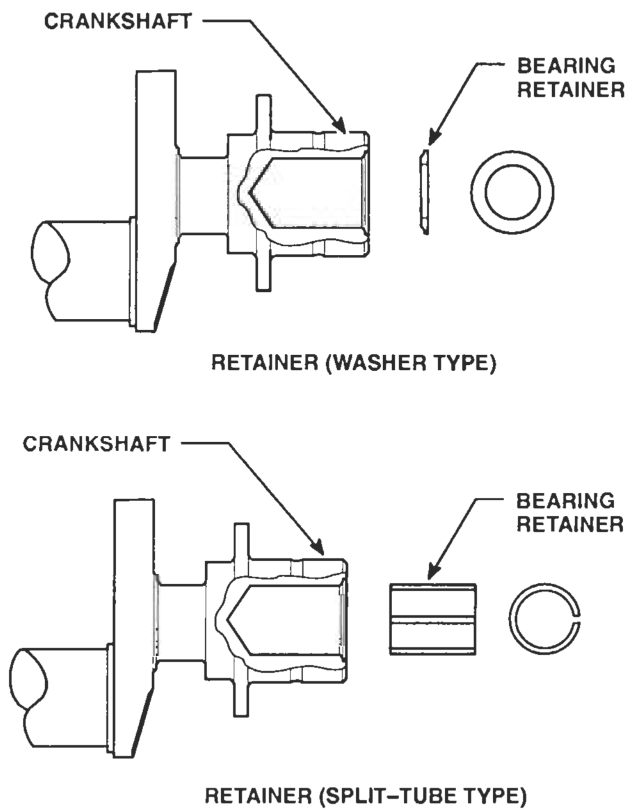


Figure 2. Pilot Bearing Retainers

FLYWHEEL REMOVAL

Remove the flywheel as follows:

1. Remove the six flywheel attaching bolts and scuff plate. If the crankshaft is not provided with dowels, install one flywheel bolt after removing the scuff plate to hold the flywheel in place until the lifting tool is attached.

NOTE: If the flywheel is equipped with a splined drive flange, it must be removed first.

2. Attach flywheel lifting tool J 6361–01 to the flywheel with two 7/16–14 bolts of suitable length or use tool J 25026. Remove the remaining flywheel attaching bolt.
3. Attach a chain hoist to the lifting tool to support the flywheel (Figure 3.)
4. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.
5. Remove the clutch pilot bearing, if used, as outlined in Section 1.4.1.
6. Remove the washer type pilot bearing retainer, if used. It is not necessary to remove the split tube type retainer.

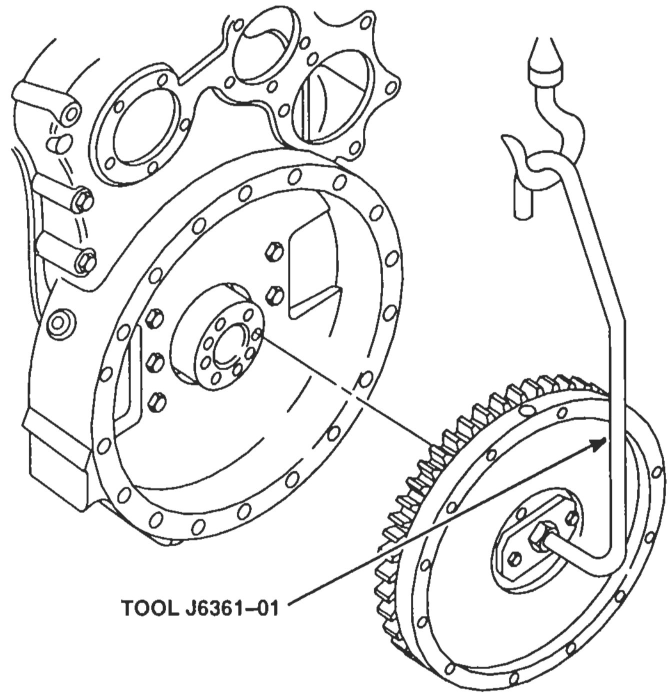


Figure 3. Removing Flywheel Using

INSPECTION

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

Replace the ring gear if the gear teeth are excessively worn or damaged. Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

On crankshafts with dowels, be sure and check the dowel extension. Dowels must not extend more than 1/2 inch 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 insure proper metal–to–metal contact and maximum friction, before attaching the flywheel.

New bolts must be used to mount or remount the flywheel.

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 predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer 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, observing the notice above.

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 the washer type pilot bearing retainer, if used. To install a split tube type retainer, drive the retainer in flush with the end of the crankshaft with a soft hammer.

NOTE: Do not mar the bearing contact surface of the retainer.

4. Install two bolts through the scuff plate (or drive flange) 180° from each other. Snug the bolts to hold the flywheel and scuff plate (or drive flange) to the crankshaft. Remove the guide studs.
5. Remove the flywheel lifting tool.
6. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

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

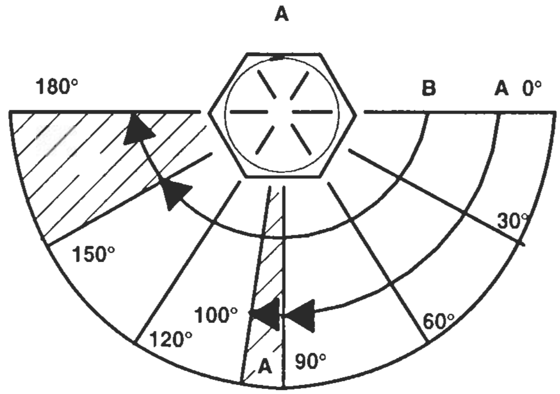
7. Install the remaining bolts and run them in snug.

INSTALL FLYWHEEL (CONT.)

8. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.
9. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb·ft (68 N·m) torque.
10. Turn the bolts an additional 90°–120° to obtain the required clamping (Figure 4.)
11. Mark the heads of the bolts and rotate each as follows to obtain required clamping:

    Bolts 2 3/4 inch long and under –
    Turn 90 – 100°
    Bolts over 2 3/4 inch long –
    Turn 150 – 180°
12. Check flywheel runout and complete the installation (See Section 1.4 of the service manual).

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



A–BOLTS 2–3/4 IN. LONG AND UNDER
B–BOLTS OVER 2–3/4 IN. LONG

Figure 4. Torque–Turn Limits

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 under–clamping.

13. 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 inch total indicator reading per inch of radius (or .001mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

NOTICE:
Flywheel mounting bolts are considered "one–use" items and cannot be reused. New mounting bolts must be installed when attaching the flywheel. Reusing bolts may lead to loss of torque or bolt breakage during engine operation, resulting in serious engine damage.

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

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.

On engines equipped with a power take–off assembly using a straight–roller type pilot bearing or unshielded ball bearing, the cavity in the end of the crankshaft is packed with Shell Alvania No. 2 grease or equivalent.

CLUTCH PILOT BEARING REMOVAL (TRANSMISSION REMOVED)

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

1. Remove the six bolts (and lock wires, if used) attaching the flywheel to the crankshaft. Remove the bearing retainer and reinstall two of the bolts to hold the flywheel in place.

NOTICE:
Install two 9/16–18 inch studs in place of two of the flywheel bolts, on engines without dowels in the end of the crankshaft 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.

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

4. Place the flywheel on wood supports to provide clearance for the bearing.
5. 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.

SECTION 1.4.1 – CLUTCH PILOT BEARING

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 may not be entirely removed from the bearing. Clean the other types of bearing thoroughly 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 lb/in^2 (276 kPa) air pressure.

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.

CLUTCH PILOT BEARING INSTALLATION

Install a ball type bearing as follows:

1. Lubricate the outside diameter of the bearing with clean engine oil.
2. 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.
3. If a straight–roller type bearing or an unshielded ball bearing is used, pack the crankshaft cavity with Shell Alvania No. 2 grease or equivalent flush with the rear face of the crankshaft. Make sure there are no air pockets in the grease.
4. Install the flywheel on the crankshaft (Section 1.4).

ENGINE DRIVE SHAFT FLEXIBLE COUPLING

The engine drive shaft flexible coupling (Figure 1.) is of the spring–loaded type having a splined hub to match with the splines on the transmission drive line shaft used on certain applications. The coupling, bolted to the engine flywheel, serves as a drive and also dampens out torque fluctuations between the engine and the transmission.

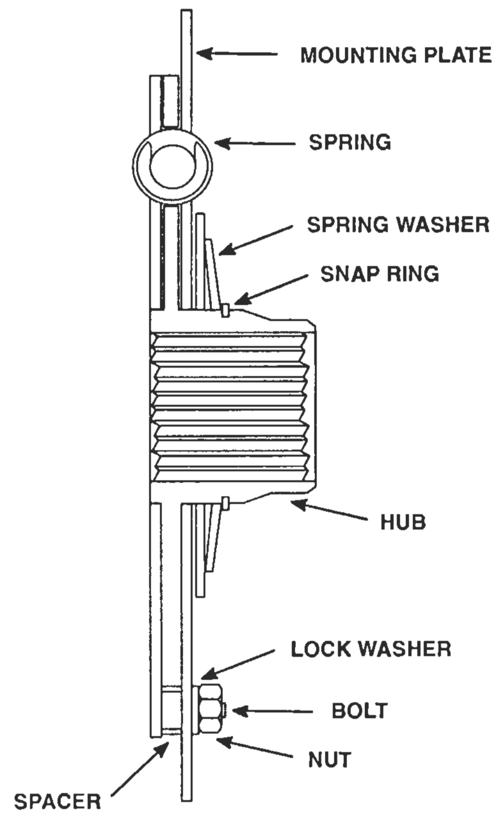


Figure 1. Engine Drive Shaft Flexible Coupling

COUPLING REMOVAL

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

SECTION 1.4.2 – ENGINE DRIVE SHAFT FLEX COUPLING

COUPLING INSPECTION

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 lb/in^2 (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 removing the 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 the plates, spacers and hubs are manufactured in matched sets, worn hubs or plates cannot be replaced individually, but must be replaced by a complete flexible coupling assembly.

COUPLING INSTALLATION

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 inch bolts and tighten them securely.

FLYWHEEL HOUSING

The flywheel housing (Figure 1.) is a one–piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the transmission.

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

The size of the tapped holes in the SAE No. 1 flywheel housings, used for transmission attaching bolts, has been increased from 3/8–16 to 7/16–14 inch to conform with a revision in SAE flywheel housing standards. The retaining bolt holes in power transfer element housings have likewise been revised from 13/32 to 15/32 inch diameter to accommodate the larger retaining bolts. Current transmission housings incorporating the 15/32 inch diameter holes can be used with flywheel housings having 3/8–16 inch tapped holes. However, former transmission housings must have the bolt holes enlarged to 15/32 inch for use with revised flywheel housings with the 7/16–14 inch tapped holes.

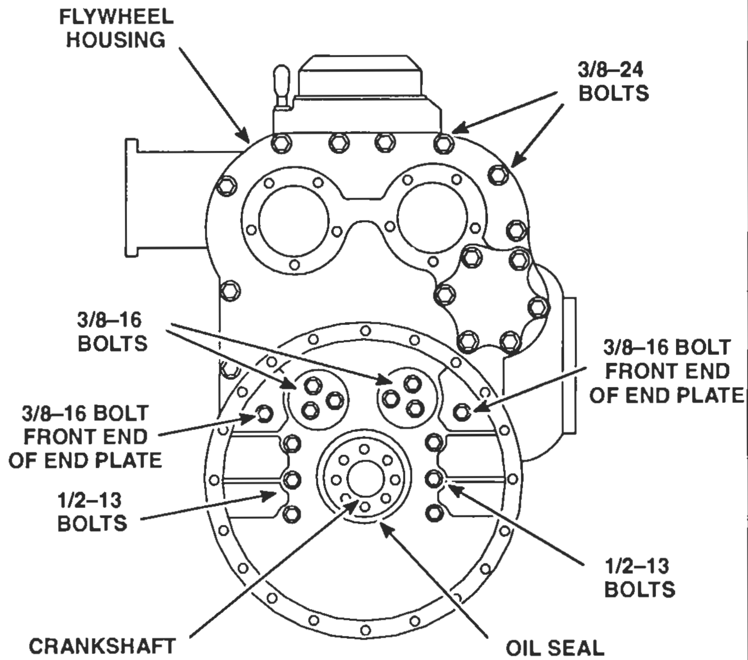


Figure 1. Flywheel Housing and Related Parts

REMOVE FLYWHEEL HOUSING REMOVAL

1. Mount the engine on an overhaul stand as outlined in Section 1.1.
2. Remove the starting motor, oil pan, flywheel and any accessories attached to the flywheel housing.
3. Remove the two bolts securing the engine lifter bracket to the cylinder head. This will leave the lifter bracket attached to the flywheel housing for convenience in handling.
4. Remove the twelve attaching bolts inside of the flywheel housing bell which attach the housing to the idler gear hub, spacer and cylinder block. Remove the twelve 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.

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

FLYWHEEL HOUSING REMOVAL (CONT.)

5. To guide the flywheel housing until it clears the end of the crankshaft, thread four pilot studs J 1927–01 into the cylinder block (Figure 2.)
6. With the flywheel housing supported by a chain hoist attached to the lifter bracket, strike the front face of the housing alternately on each side with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.

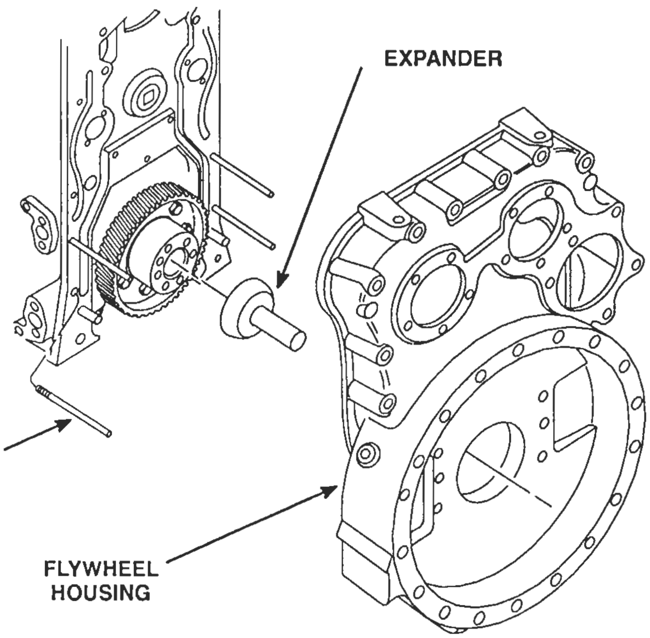


Figure 2. Flywheel Housing Removal and Installation

INSPECTION

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

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

Remove and discard the crankshaft rear oil seal. Install a new oil seal (Section 1.3.2).

FLYWHEEL HOUSING INSTALLATION

1. Lubricate the gear train teeth with clean engine oil.
2. Affix a new housing–to–end plate gasket to the flywheel housing. Also, if a former design idler gear hub (used with the early design flanged idler gear bearing) or an idler gear hole spacer is used, attach the gaskets to the hub or the spacer or both, as required. No gasket is used with the current design hub or spacer (Section 1.7.4).

FLYWHEEL HOUSING INSTALLATION (CONT.)

NOTE: On certain flywheel housings, the idler gear hole spacer is cast integrally in the housing, opposite the idler gear (Figure 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 four pilot studs J 1927–01 into the cylinder block to guide the housing in place. Use oil seal expander J 22425 (standard size seal) or expander J 4195–01 and handle J 8092 (oversize seal) on the end of the crankshaft to pilot the oil seal on the crankshaft.

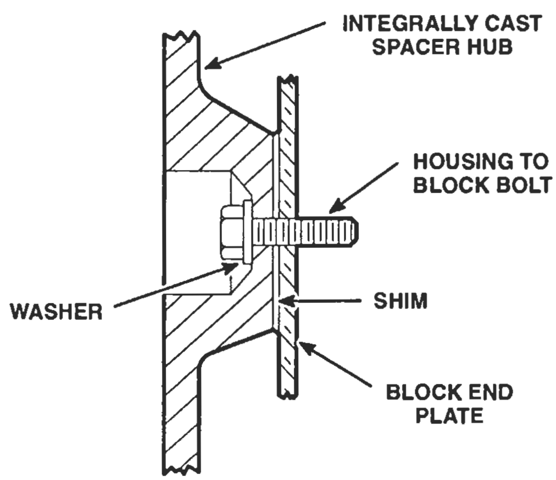


Figure 3. Idler Gear Hole Spacer Shim

4. With the housing suitably supported, position it over the crankshaft and up against the cylinder block rear end plate and gasket. Remove the oil seal expander.
5. If the idler gear hole spacer is integrally cast into the housing, be sure the shim is in place.
6. Install the six 3/8–16 x 1.255 inch sealant–coated, flange hex head bolts in the tapped holes of the dummy hub and idler hub areas of the flywheel housing (locations 1 thru 6 on Figure 4.) Do not use washers with these self–locking bolts. Tighten bolts finger tight and remove the pilot studs.
7. Install the six 1/2–13 inch housing–to–block bolts with lock washers, finger tight.
8. Install the remaining flywheel housing attaching bolts and washers, finger tight.

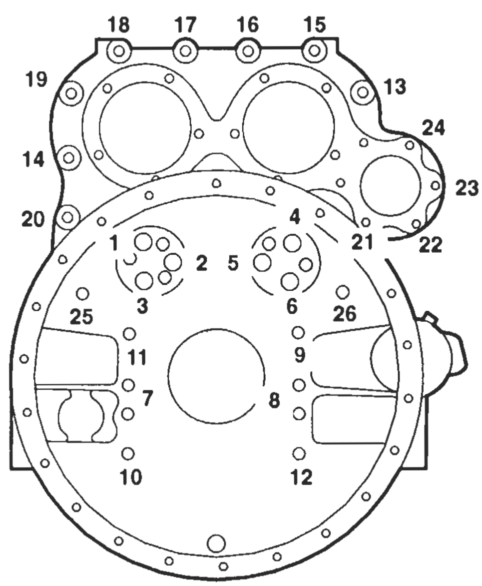


Figure 4. Flywheel Housing Bolt Tightening Sequence (Operation 1)

SECTION 1.5 – FLYWHEEL HOUSING

FLYWHEEL HOUSING INSTALLATION (CONT.)

9. Start at number 1 on a right–hand rotation engine or at number 4 on a left–hand rotation engine and, using the proper sequence, bring all bolts to within 10–15 lb·ft (14–20 N·m) of their specified torque, drawing the mating parts together evenly.

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

10. Refer to Figure 5. for the final bolt tightening sequence and, starting at number 1, tighten all of the bolts to the specified torque. Tighten the 3/8–16 inch idler gear hub and hole spacer flange hex head bolts to 30–35 lb·ft (41–47 N·m) torque. Tighten all other 3/8–16 and 3/8–24 inch bolts to 25–30 lb·ft (34–41 N·m) torque, and the 1/2–13 bolts to 90–100 lb·ft (122–136 N·m) torque (cast iron housing) or 71–75 lb·ft (96–102 N·m) torque (aluminum housing). Be sure to rotate the crankshaft when tightening the idler gear hub bolts and flywheel housing bell bolts.

11. If drilled head idler gear hub and spacer bolts are used, tighten them to 25–40 lb·ft (34–54 N·m) torque. Line–up the lock wire holes in the bolt heads and install the lock wire, locking each group of three bolts together. The wide range in the torque specification permits alignment of the bolt heads.

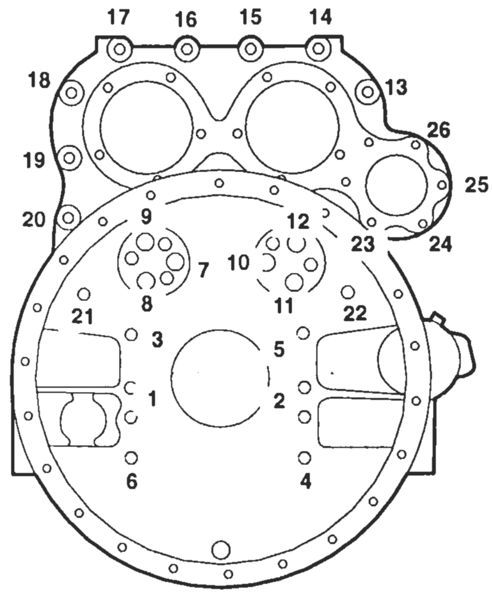


Figure 5. Flywheel Housing Bolt Tightening Sequence (Operation 2)

12. Install the flywheel (Section 1.4).

13. Check the flywheel housing concentricity (Figure 6.) and bolting flange face runout with tool set J 9737–C as follows:

    a. Thread the base post J 9737–3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

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

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

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

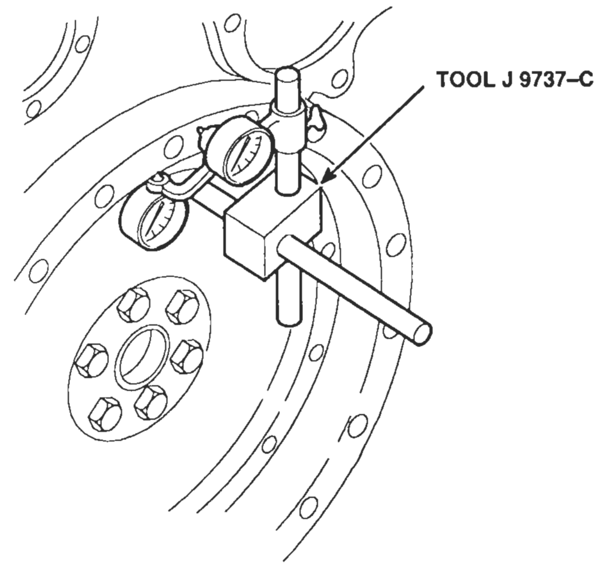


Figure 6. Checking Flywheel Housing Concentricity

FLYWHEEL HOUSING INSTALLATION (CONT.)

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.

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.

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

BORE AND FACE RUNOUT

The following requirements apply to the dial indicator readings taken for both the bore and the face of the flywheel housing.

Check value at six o'clock position. This value cannot exceed ± .013 inches.

Check values at three o'clock and nine o'clock positions.

1. Both readings "P" or "N". The difference must not exceed .013 inches.
2. Both readings different, "P/N" or "N/P". The total of dimensions must not exceed .013 inches.

SECTION 1.5 – FLYWHEEL HOUSING

BORE DIAMETER

Verification of bore diameter roundness is required when three and nine o'clock readings are both "P" or both "N". The total of dimensions must not exceed .030 inches.

a. 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. Also, make certain the idler gear hub and the idler gear hole spacer gaskets, if required, are used correctly. No gaskets are required with the hub and spacer on current units with the roller type idler gear bearing. Conversely, gaskets are required with the former design hub and spacer on units equipped with the flange type idler gear bearing. However, if a roller bearing has replaced a flange type idler gear bearing, but the early design spacer (dummy hub) remains the same, one gasket is required with the spacer.

b. 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.

3. Remove the bolts holding the lifter bracket to the flywheel housing. Affix a new gasket to the bracket, then alternately tighten the bracket–to–flywheel housing and bracket–to–cylinder head bolts, thus drawing the bracket into the corner formed by the cylinder head and housing (Section 1.2.3).
4. Install the oil pan (Section 4.7).
5. 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 .125 inch 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 minutes before the cover is to be secured to the flywheel housing.

NOTE: 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

TRUNK TYPE PISTON

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

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

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

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

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin. After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a steel retainer. Thus, lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

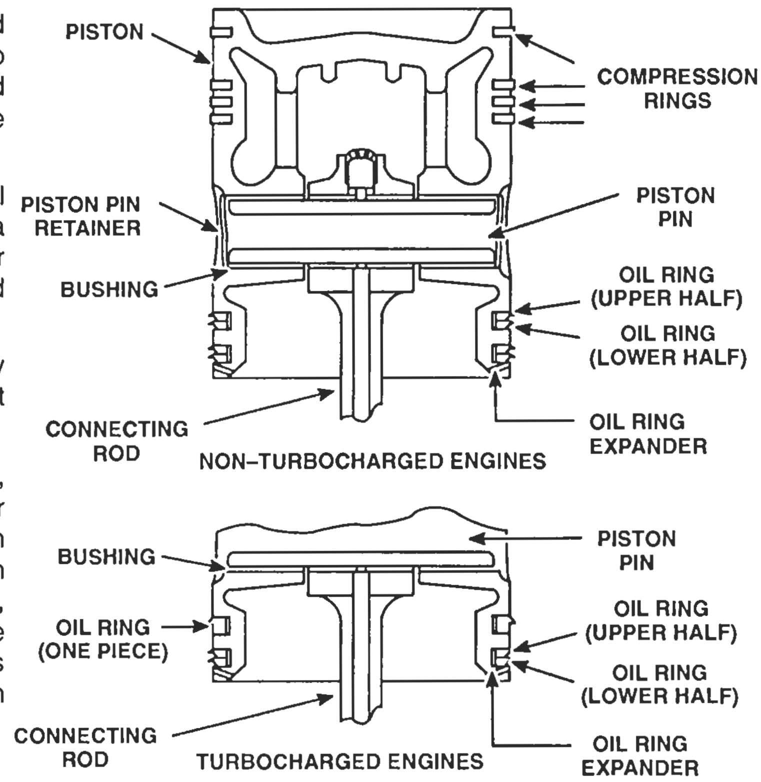


Figure 1. Piston Assembly

The current turbocharged engines use a piston pin with a highly polished external surface finish and an oil hole to provide oil under pressure to the piston pin bushings. A groove on each side of the oil hole is for stress distribution (Section 1.6.1).

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

PISTON RING INSPECTION

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

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

SECTION 1.6 – PISTON AND PISTON RINGS

PISTON AND CONNECTING ROD REMOVAL

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

PISTON AND CONNECTING ROD DISASSEMBLY

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

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 (Figure 2.)
2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushings.
3. Withdraw the piston pin from the piston, then remove the connecting rod.
4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Figure 2. Removing or Installing Piston Rings

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 lb/in^2 (276 kPa) air pressure.

CLEANING (CONT.)

If fuel oil does not remove the carbon deposits, use a chemical solvent (Figure 3.) that will not harm the piston pin bushings or the tin–plate on the piston. If a chemical solvent is used, refer to the container for "Safe Use Instructions".

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

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

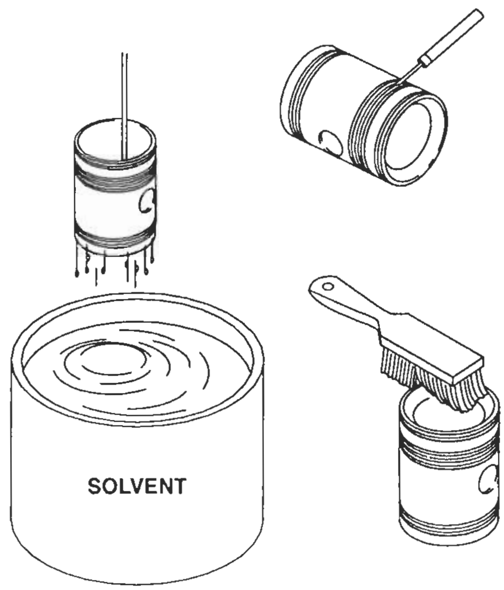


Figure 3. Cleaning Piston

INSPECTION

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

Excessively worn or scored pistons, rings or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce to a minimum the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

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

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

Examine the piston for score marks, cracks, damaged ring groove lands or indications of overheating. A piston with light score marks which can be cleaned up may be reused. Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage. Replace the piston if cracks are found across the internal struts.

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

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

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

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

When replacing worn parts (pistons, rings, etc.), refer to the parts catalog or microfiche to select the current parts for the particular engine being serviced.

PISTON BUSHING REMOVAL

Remove the piston pin bushings (naturally aspirated engines) with tool set J 1513–02 as follows:

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

1. Place the piston in the holding fixture J 1513–1 so that the bushing bores are in alignment with the hole in the fixture base.
2. Drive each bushing from the piston with bushing remover J 1513–3 and handle J 1513–2 (Figure 4.)

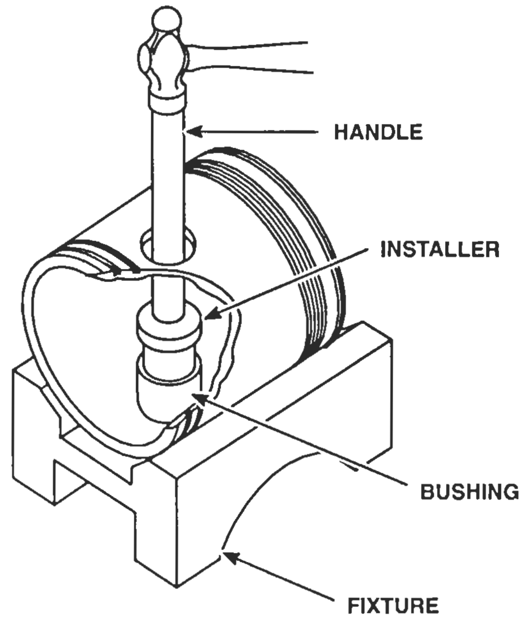


Figure 4. Removing or Installing Piston Pin Bushings in Piston

PISTON BUSHING INSTALLATION

1. Place the spacer J 1513–4 in the hole in the fixture J 1513–1.
2. Place the piston on the fixture so that the spacer protrudes into the bushing bore.
3. Insert the installer J 1513–6 in a bushing, then position the bushing and installer over the lower bushing bore. Locate the joint in the bushing toward the bottom of the piston (Figure 5.)
4. Insert the handle J 1513–2 in the bushing installer and drive the bushing in until it bottoms on the spacer.
5. Install the second bushing in the same manner.
6. The bushings must withstand an end load of 1800 pounds without moving after installation.

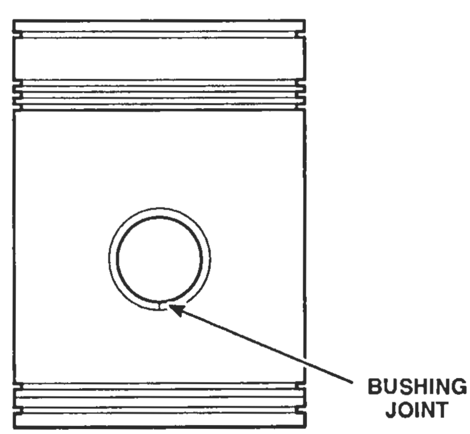


Figure 5. Piston Pin Bushing Joint

PISTON BUSHING INSTALLATION (CONT.)

7. Ream the bushings to size, using tool set J 3071–B as follows:
   a. Clamp the reaming fixture J 5273 in a vise (Figure 6.) Then, insert the guide bushing J 3071–7A in the fixture and secure it with the set screw.
   b. Place the piston in the fixture and insert the pilot end of the reamer J 3071–6A through the clamping bar, bushings and into the guide bushing.
   c. With the piston, fixture and reamer in alignment, tighten the wing nuts securely.
   d. Ream the bushings. Turn the reamer in a clockwise direction only, when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.
   e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.5025 to 1.5030 inch.

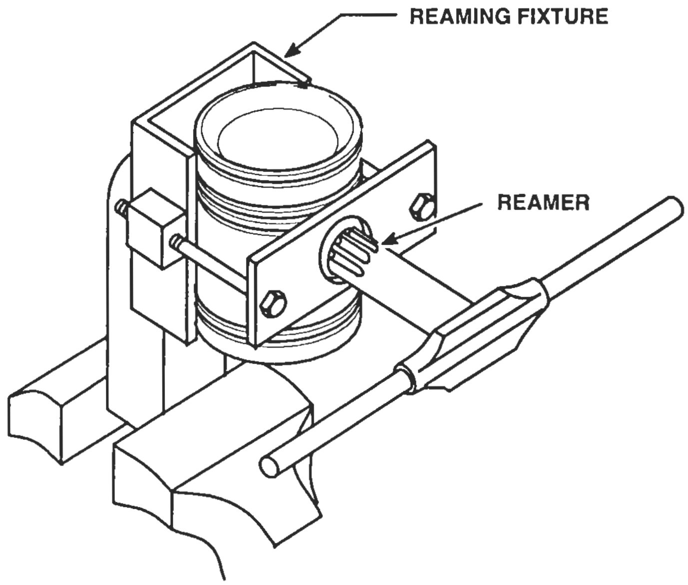


Figure 6. Reaming Piston Bushing

PISTON FITTING

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

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

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places 90° apart (Figure 7.)

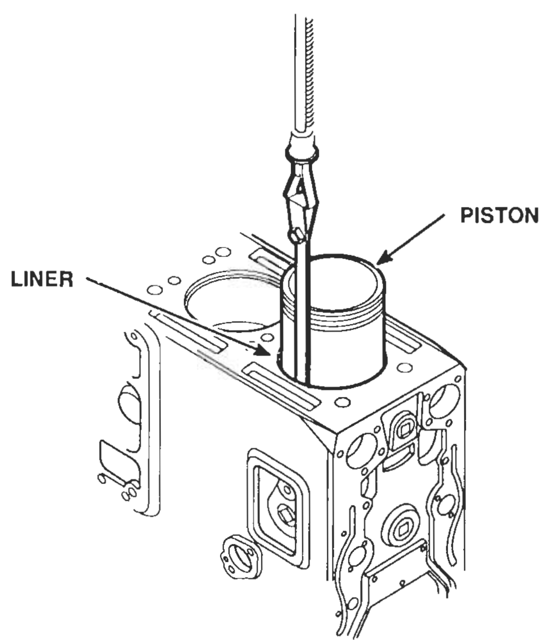


Figure 7. Measuring Piston–to–Liner Clearance

PISTON FITTING (CONT.)

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 inch greater than the thickness of the feeler gage used, i.e., a .004 inch feeler gage will indicate a clearance of .005 inch 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.

PISTON RING FITTING

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

Insert one ring at a time inside of the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston 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 (Figure 8.) Refer to Specifications – Section 1.0 for ring gap specifications.

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

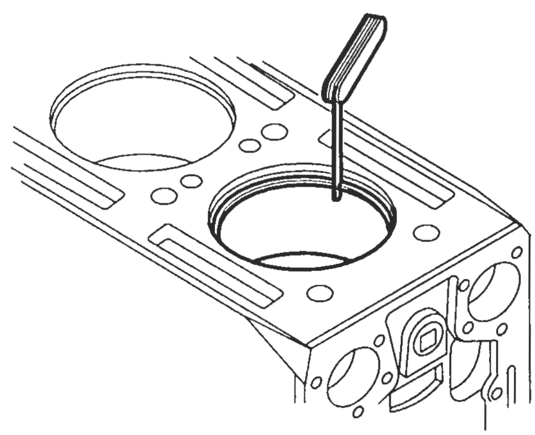


Figure 8. Measuring Piston Ring Gap

Check the ring side clearance (Figure 9.) Ring side clearances are specified in Specifications – Section 1.0.

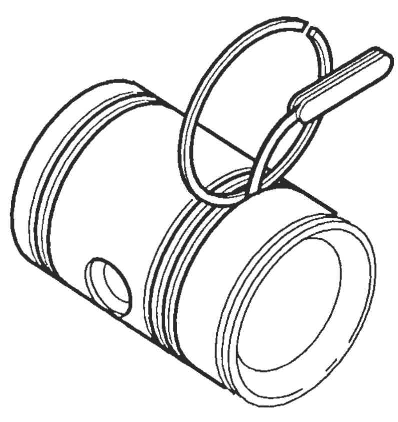


Figure 9. Measuring Piston Ring Side Clearance

LUBRICATION

Use a mixture of clean engine oil/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).

PISTON RING INSTALLATION

Before installing the piston rings, assemble the piston and rod (Section 1.6.1). Then, (Figure 10.) install the piston rings. Lubricate the piston rings and piston with the engine oil/STP mix before installing the rings.

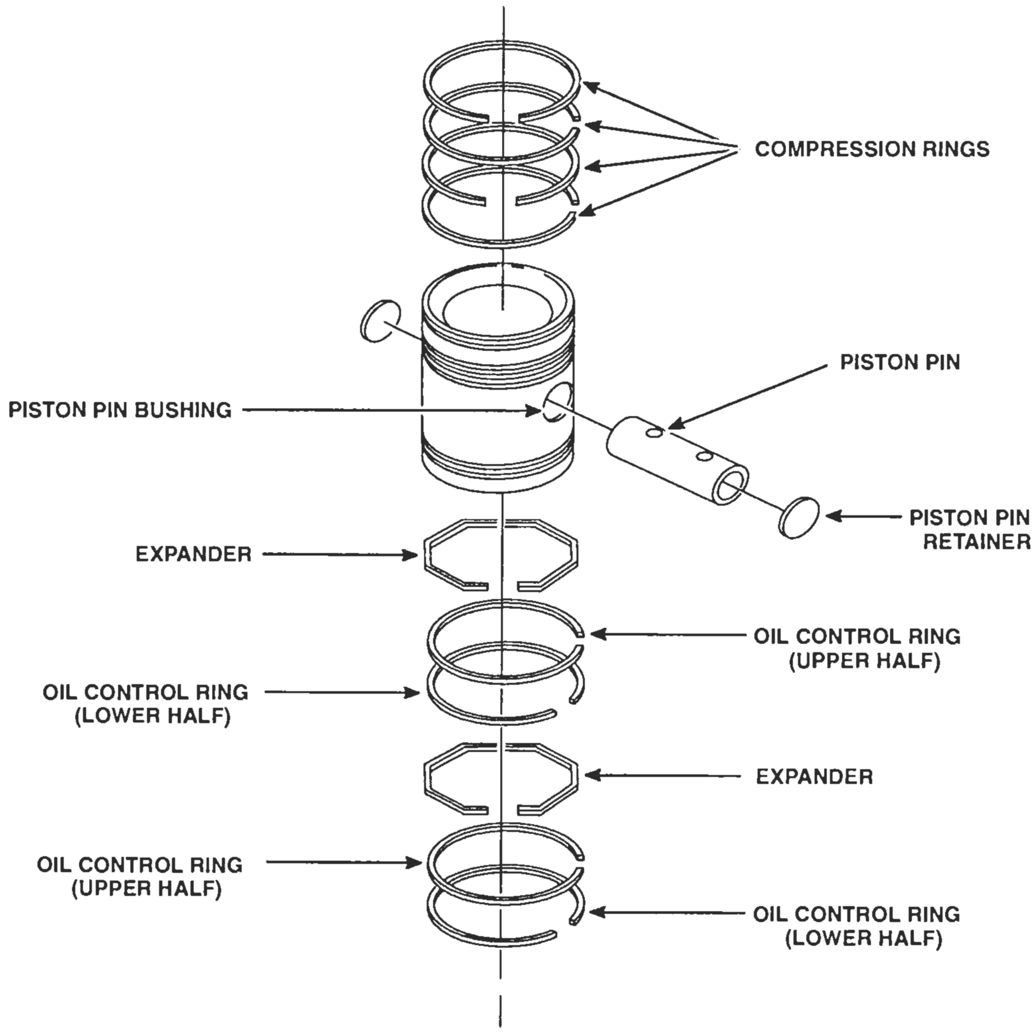


Figure 10. Piston, Piston Rings, Pin and Part Locations

PISTON RING INSTALLATION (CONT.)

Compression Rings

1. Starting with the bottom ring, install the compression rings with tool J 8128. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston. When installing the fire ring (top groove) and the top compression ring (second groove), be sure the oval marks are toward the top of the piston.

NOTE: Do not use fire rings with chrome in the new non–hardened fire ring groove. The new no chrome fire ring should not be used with the former hardened fire ring groove.

2. Stagger the ring gaps around the piston.

Oil Control Rings

The upper and lower oil control rings used on pistons for non–turbocharged engines consist of two halves (upper and lower). The upper oil control ring used on pistons for turbocharged engines is a one–piece ring while the lower ring is a two–piece ring (upper and lower halves). Peripheral abutment type oil ring expanders (Figure 11.) are used on 71N and 71T engines. Install the oil control rings as follows:

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

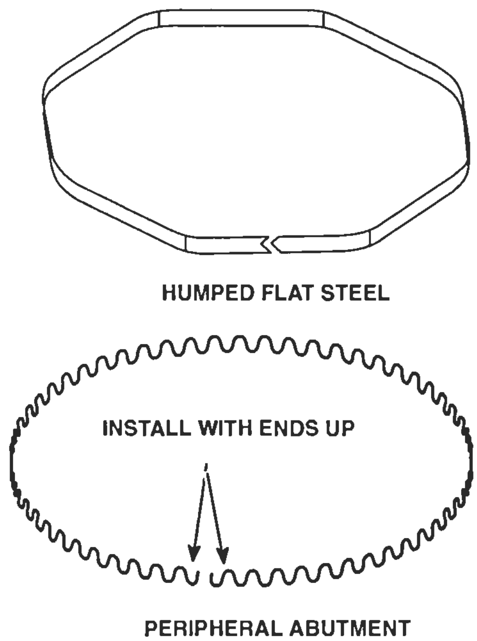


Figure 11. Oil Control Ring Expanders

2. When peripheral abutment type ring expanders are used, install them with the legs of the free ends toward the top of the piston. With the free ends pointing up, a 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.

3. To install the one–piece ring (turbocharged engines), position it over the upper ring groove, using tool J 8128, with the gap 180° from the gap in the expander and the scraper edge facing down. Press the ring against the gap side of the expander to prevent the ends of the expander from overlapping, then align the ring with the groove and release the tension on the tool, permitting the ring to slip in position. Install the upper and lower halves of the lower oil control ring by hand. Install the upper half with the gap 180° from the gap in the expander. Then, install the lower half with the gap 45° from the gap in the upper half of the ring. Make sure the scraper edges are facing down (toward the bottom of the piston). The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

CROSSHEAD TYPE PISTON

The crosshead piston (Figure 12.) is a two–piece piston consisting of a crown and skirt. A fluoroelastomer oil seal ring is used between the crown and skirt which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 150° slipper type bushing (bearing).

The piston skirt incorporates two oil control ring grooves, piston pin holes and piston pin retainer counterbores. Equally spaced drain holes are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase. A lubricating oil tube and floating nut are contained inside of the piston pin. Two bolts and spacers are used to attach the connecting rod to the floating nut in the piston pin.

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.

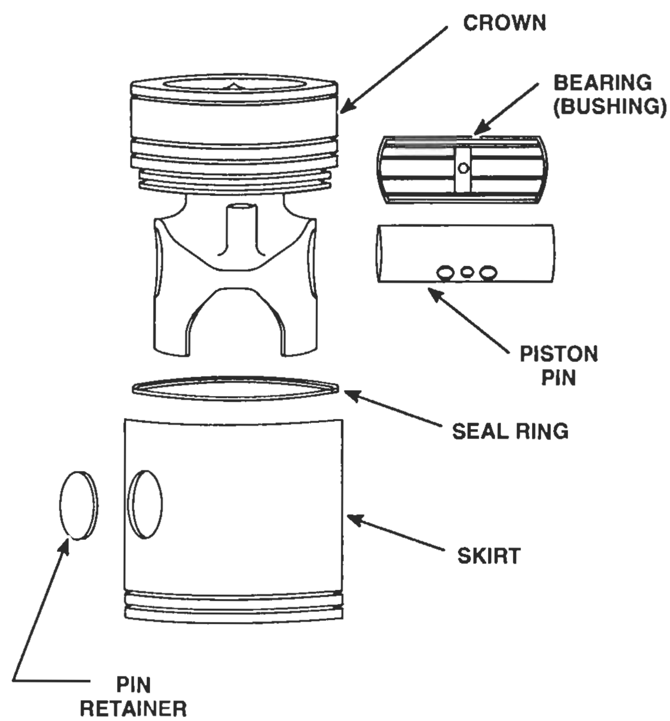


Figure 12. Crosshead Piston and Connecting Rod Components

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.

Detroit Diesel uses an 18.7:1 compression ratio piston (naturally aspirated and some turbocharged engines) or a 17:1 compression ratio piston (turbocharged engines). To aid identification of a piston (Figure 13.) fit the end of the gage between the top of the piston crown and the machined step below the third compression ring groove. A "GO" check identifies a 17:1 piston used in a turbocharged engine. A space of approximately .030 inch ("NO–GO") identifies a piston used in an 18.7:1 piston used in a naturally aspirated and some turbocharged engines.

NOTE: Crosshead pistons and trunk–type pistons must not be used together in an engine. The difference in weight of the pistons will affect engine balance.

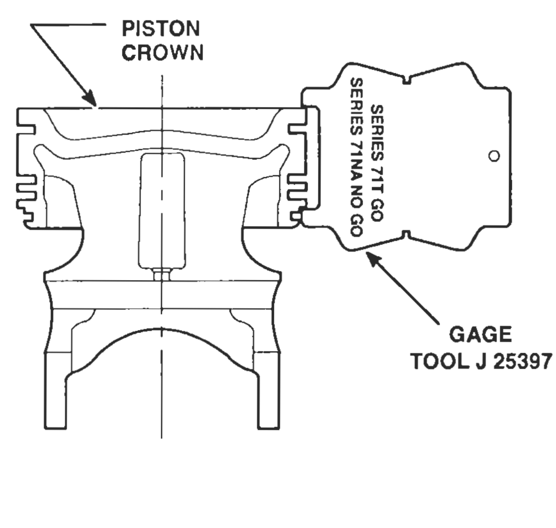


Figure 13. Piston Identification Tool

SECTION 1.6 – PISTON AND PISTON RINGS

PISTON RING INSPECTION

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

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

PISTON AND CONNECTING ROD REMOVAL

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

FLUOROELASTOMER (VITON) CAUTION

Under normal design conditions, fluoroelastomer (Viton) parts, such as O–rings and seals, are perfectly safe to handle. However, a potential hazard may occur if these components are raised to a temperature above 600°F (316°C) such as during a cylinder failure or engine fire. At temperatures above 600°F (316°C) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

CAUTION:

To avoid personal injury, wear goggles or a faceplate and neoprene or PVC gloves when handling fluoroelastomer O–rings or seals which have been degraded by excess heat. Make sure engine parts have cooled before handling them. If hydrogen fluoride condensate is expected, wash equipment and parts well with lime water (calcium hydroxide solution) before reusing. Discard gloves after handling degraded fluoroelastomer.

PISTON AND CONNECTING ROD DISASSEMBLY

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 (Figure 14.)
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.

Figure 14. Removing or Installing Piston Rings

5. Separate the piston skirt from the piston crown. Tool J 33048 will aid in disassembling the dome from the skirt of Series 71 crosshead piston assemblies using fluoroelastomer seal rings. After the piston pin is removed from the connecting rod and piston, 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. A neoprene–padded base 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).

SECTION 1.6 – PISTON AND PISTON RINGS

CLEANING

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use an approved chemical solvent that will not harm the tin–plate on the piston skirt. Do not use chemical solvent on the slipper bushing. If a chemical solvent is used, refer to the container for "Safe Use Instructions".

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. Micro Bead Glass Shot MS–M (.0029–.0058 inches) is recommended. Allowable air pressure is 80–100 lb/in.^{2} (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, because 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

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.

INSPECTION (CONT.)

Check the tapered fire ring groove width in the current piston crown with Tool J 24599 (Figure 15.) Slide the "NO–GO" wire (.106 inch 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 inch diameter) should be flush or protrude slightly from the fire ring groove.

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 Specifications – Section 1.0).

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).

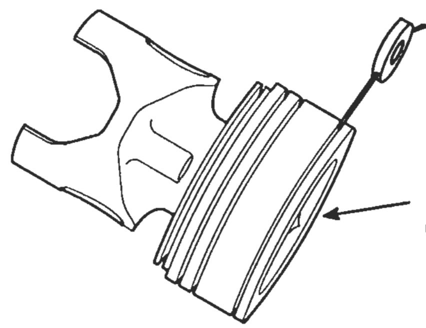


Figure 15. Checking Fire Ring Groove in Piston Crown

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 crosshead 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).

PISTON AND CONNECTING ROD ASSEMBLY

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 inch clearance between the edge of the bushing and the groove in the piston crown. The bearing must be installed before assembling the piston skirt and crown.
3. A new bushing with a shorter oil slot and modified I.D. was used effective with engine serial numbers 3A0101510, 4A0442750, 6A0451774. Interchangeability is not affected.
4. Lubricate the fluoroelastomer seal ring with engine oil.
5. The fluoroelastomer ring can be compressed by hand before the skirt is pushed into position on the piston crown. Excessive stretching should be avoided. 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.
6. Lubricate the piston pin with the engine oil/STP mix and install it (Figure 16.)

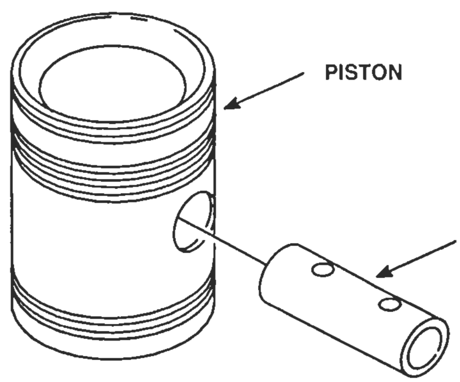


Figure 16. Piston Pin Installation

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

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

PISTON AND CONNECTING ROD ASSEMBLY (CONT.)

7. Install the spacers on the two 7/16–20 X 2 inch connecting rod to piston pin attaching bolts.
8. Apply a small amount of International Compound No. 2 or equivalent to the bolt threads and bolt head contact surfaces.
9. 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 (Figure 17.) Do not exceed this torque.

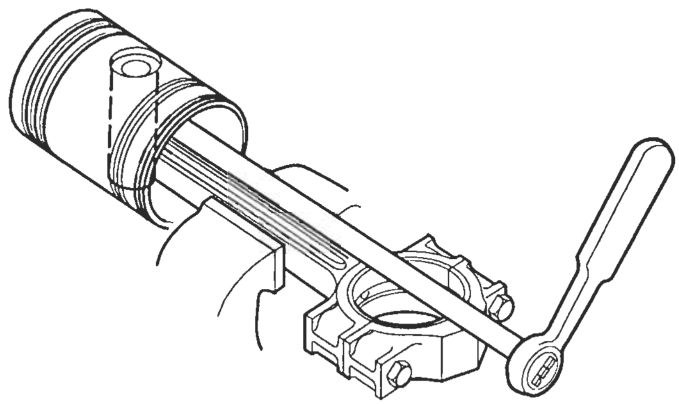


Figure 17. Tightening Connecting Rod to Piston Pin Bolts

10. Place a new piston pin retainer in position. Then, place the crowned end of installer J 23762 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston (Figure 18.)

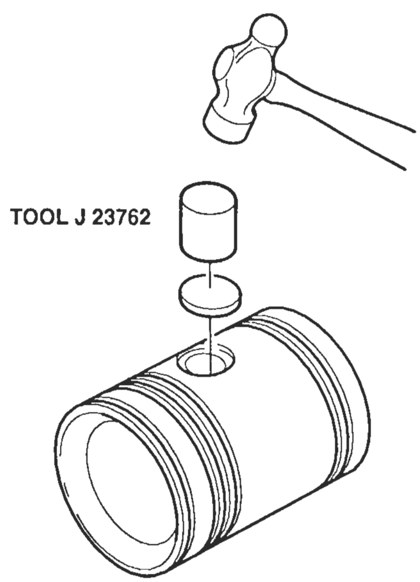


Figure 18. Installing Piston Pin Retainer

PISTON AND CONNECTING ROD ASSEMBLY (CONT.)

11. Install the second piston pin retainer in the same manner. Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers and inspect them to be sure they are not buckled and that they are fully seated in the counterbore. The width of the land should be even around the retainer.
12. 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 (Figure 19.) 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.

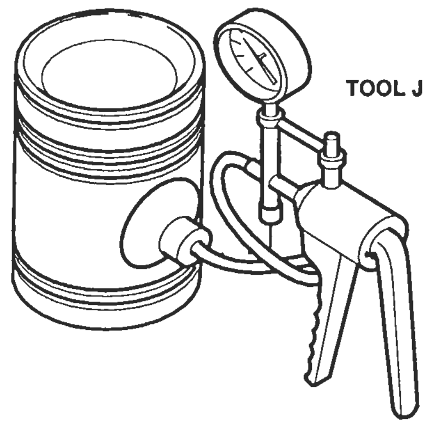


Figure 19. Checking Piston Pin Retainer for Proper Sealing

PISTON FITTING

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 Specifications – Section 1.0.

The piston–to–liner clearance, with new parts, will vary with the particular piston and cylinder liner (refer to Specifications – Section 1.0). A maximum clearance of .012 inch 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 (Figure 20.)

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.

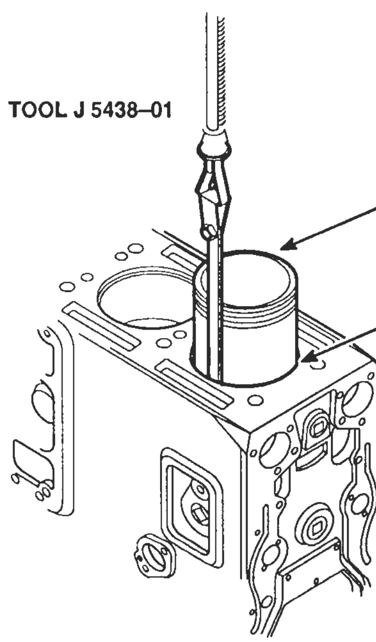


Figure 20. Measuring Piston–to–Liner Clearance

PISTON FITTING (CONT.)

Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be .001 inch greater than the thickness of the feeler gage used. For example, a .004 inch feeler gage will indicate a clearance of .005 inch 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.

PISTON RING FITTING

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

The top (fire) ring and the upper compression ring (second groove) are prestressed. Both are identified by a small indentation mark on the top side. The current piston crowns (18.7:1 and 17:1 compression ratio) have a tapered fire ring groove. To conform with this change, a tapered fire ring (Figure 21.) must be used. The former piston crown (17:1 compression ratio) had a rectangular fire ring groove. Only pistons with the tapered fire ring groove are available for service.

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

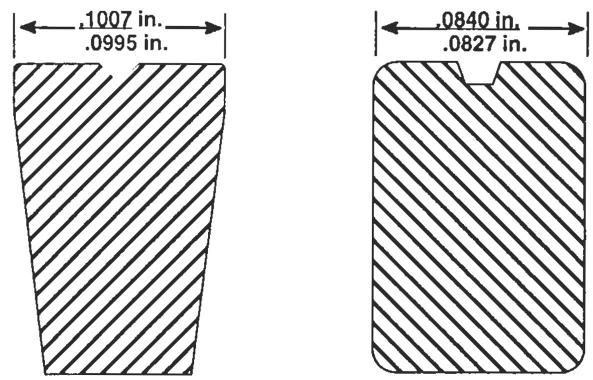


Figure 21. Fire Ring Comparison

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 (Figure 22.) (see Section 1.0).

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 inch.

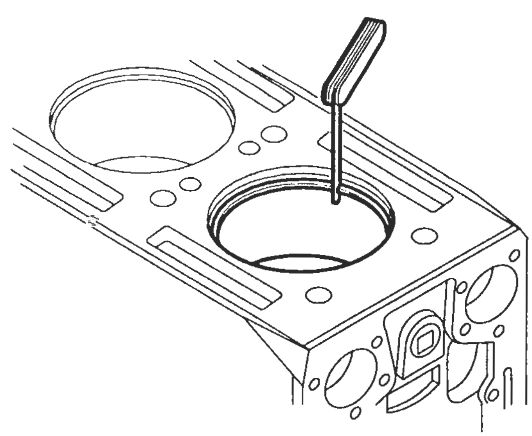


Figure 22. Piston Ring Gap Measurement

PISTON RING FITTING (CONT.)

Check the ring side clearance (Figure 23.) Ring side clearances are specified in Specifications – Section 1.0.

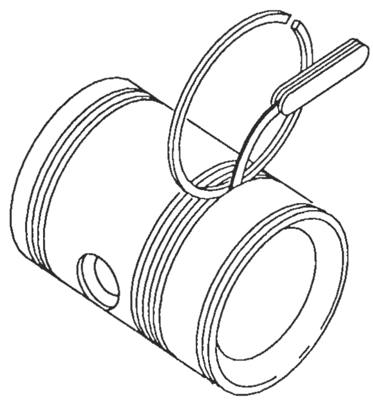


Figure 23. Measuring Piston Ring Side Clearance

PISTON RINGS INSTALLATION

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

COMPRESSION RINGS

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

OIL CONTROL RINGS

Install the oil control rings as follows:

1. Install the ring expanders (Figure 24. and Figure 25.) in the oil control ring grooves in the piston skirt. When installing the oil control rings, use care to prevent overlapping the ends of ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption. When peripheral abutment type ring expanders are used, install them with the legs of the free ends toward the top of the piston. With the free ends pointing up, a 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.

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OIL CONTROL RINGS (CONT.)

2. Install the oil control rings by hand. Start with the upper half (Figure 24.) of the top oil ring and align the gaps. The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.
3. Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

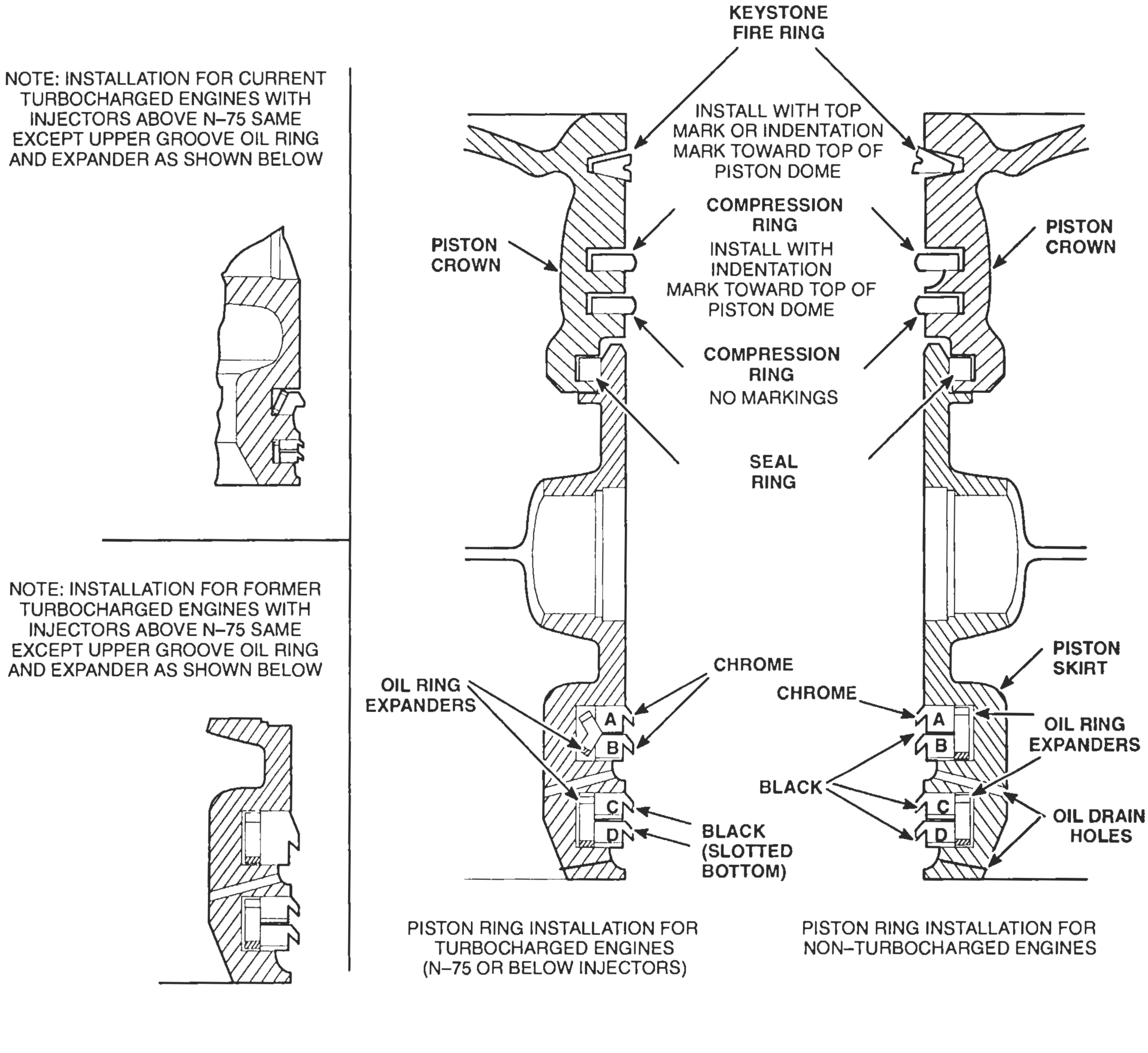

Figure 24. Piston Ring Installation Instructions

OIL CONTROL RINGS (CONT.)

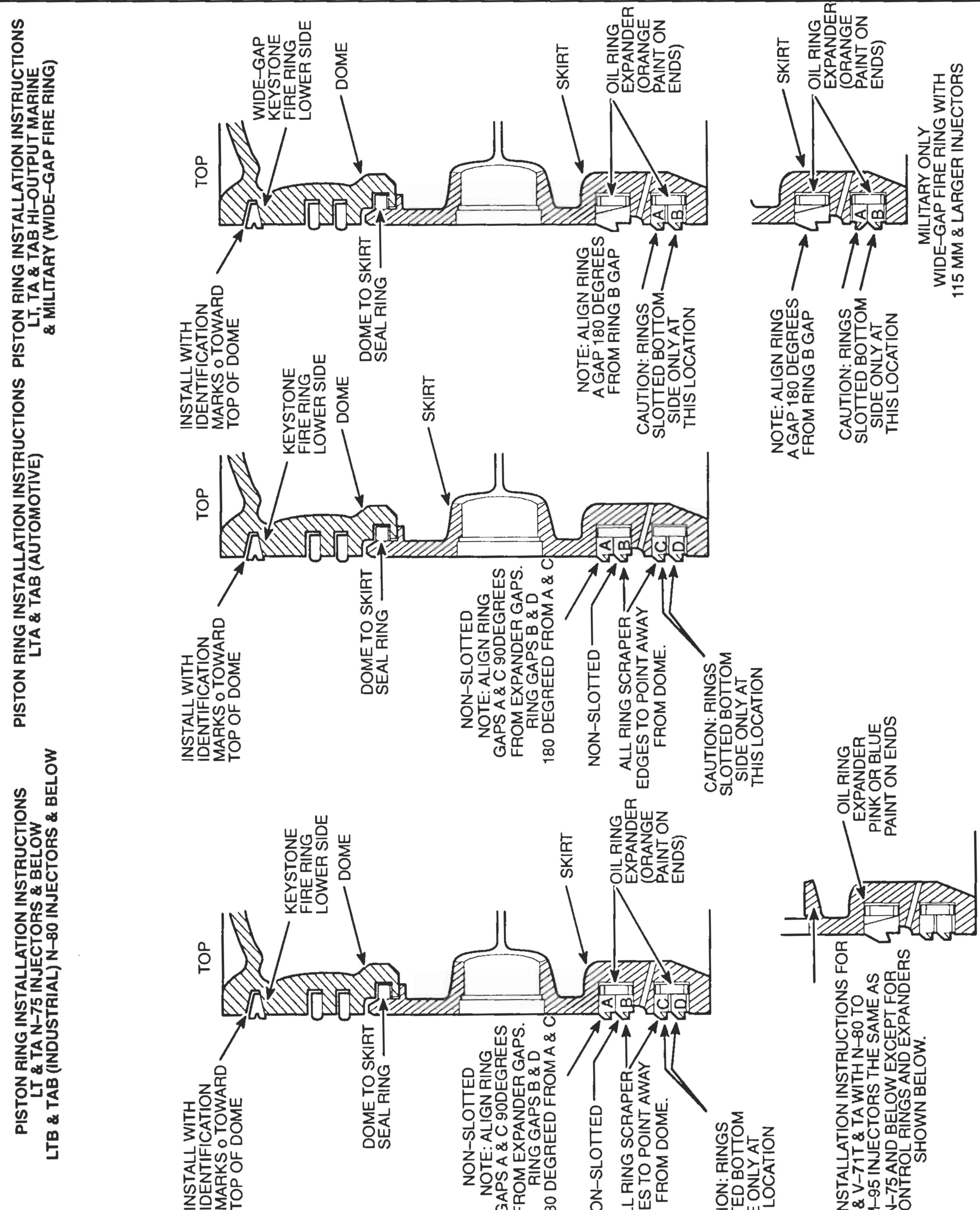

Figure 25. Piston Ring Installation Instructions (Turbocharged Engines)

OIL CONTROL RINGS (CONT.)

The 18.7:1 crosshead piston crown previously used for Inline 71 certified engines has now been replaced for all applications.

Former and new 18.7:1 crowns are similar, except:

1. The top compression ring groove on the new crown has a "J" relief machined in the bottom ring land (Figure 26.).
2. The keystone fire ring groove has more of an up–tilt than the fire ring groove on the former crown for improved ring face contact during cylinder firing.

This design difference improves ring sealing during engine operation, allowing more complete combustion of the air/fuel charge.

Former and new piston crowns are completely interchangeable and may be mixed in an engine. Only the new crown will be serviced. Cylinder kits which previously contained the former crown have been revised to add the new crown.

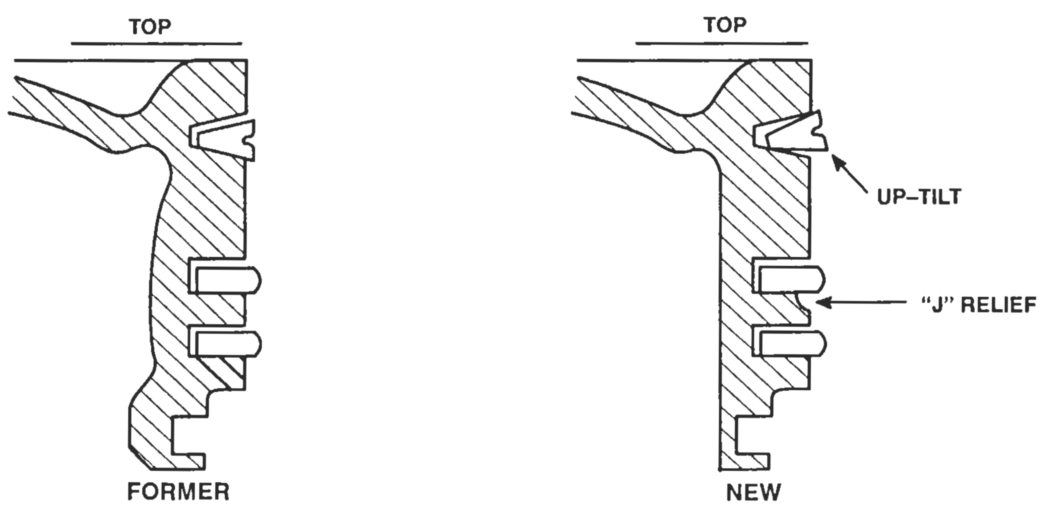

Figure 26. Former and New Piston Ring Crowns

3. The Series 71 wrap around core piston is an improvement over previous 71 pistons due to less complicated sand coring techniques used in manufacturing the casting. The reduction in sand cores reduces dimensional variation in the casting and provides more accurate location for machining resulting in more uniform wall thickness. The improved accuracy of the casting allows less stressed areas of the piston to be thinned and critical areas to be thicken as is the case with the 15% larger struts. The result is a longer life piston. The process leads to a drastically different piston cross section as shown in the figure above.

CONNECTING ROD

TRUNK–TYPE PISTON

Each connecting rod (Figure 1.) is forged to an "I" section with a closed hub at the upper end and a bearing cap at the lower end. The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head. An orifice is pressed into a counterbore at the lower end of the oil passage to meter the flow of oil.

A helically grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this cavity lubricates the piston pin bushings, and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle, orifice and the piston pin bushings pressed in place and bored to size. The replaceable connecting rod bearing shells are covered in Section 1.6.2.

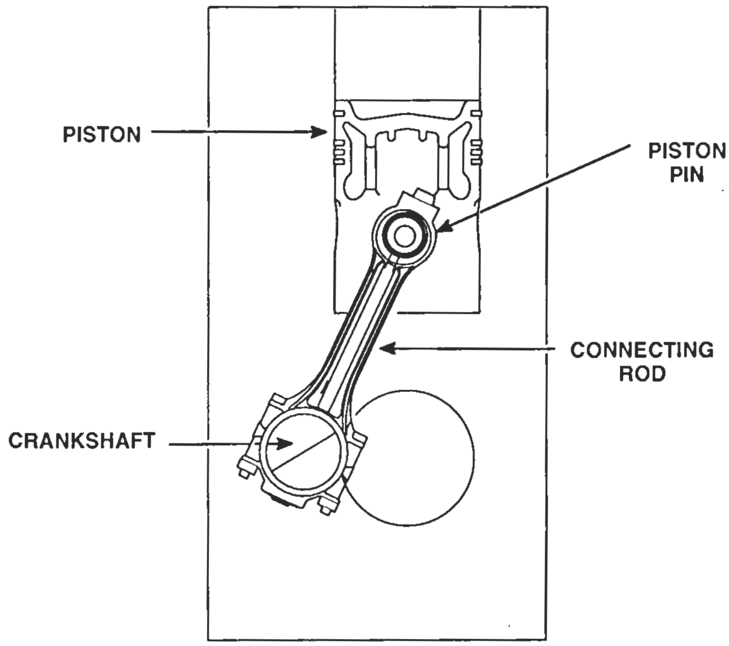

Figure 1. Connecting Rod

CONNECTING ROD TO PISTON DISASSEMBLY

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

INSPECTION

Clean the connecting rod and piston pin with a suitable solvent and dry them with compressed air. Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage and spray holes are not clogged. The connecting rod is shown in (Figure 2.)

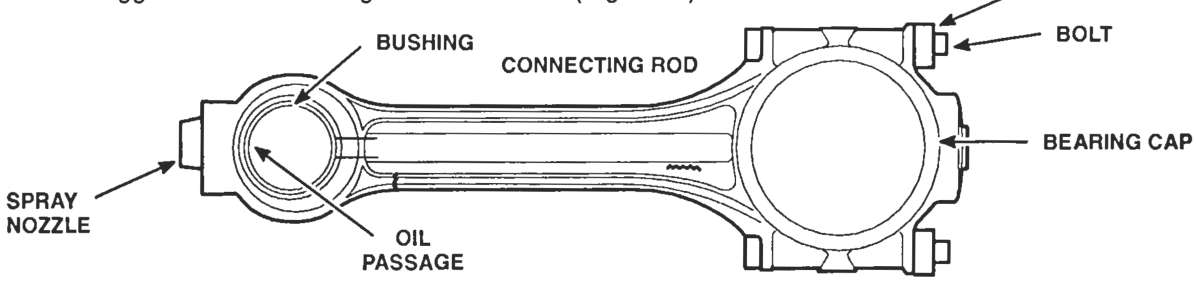

Figure 2. Connecting Rod Assembly

SECTION 1.6.1 – CONNECTING ROD

CONNECTING ROD INSPECTION (CONT.)

Visually check the connecting rod for twist or bending. Check for cracks (Figure 3.) by the magnetic particle method outlined in Section 1.3.

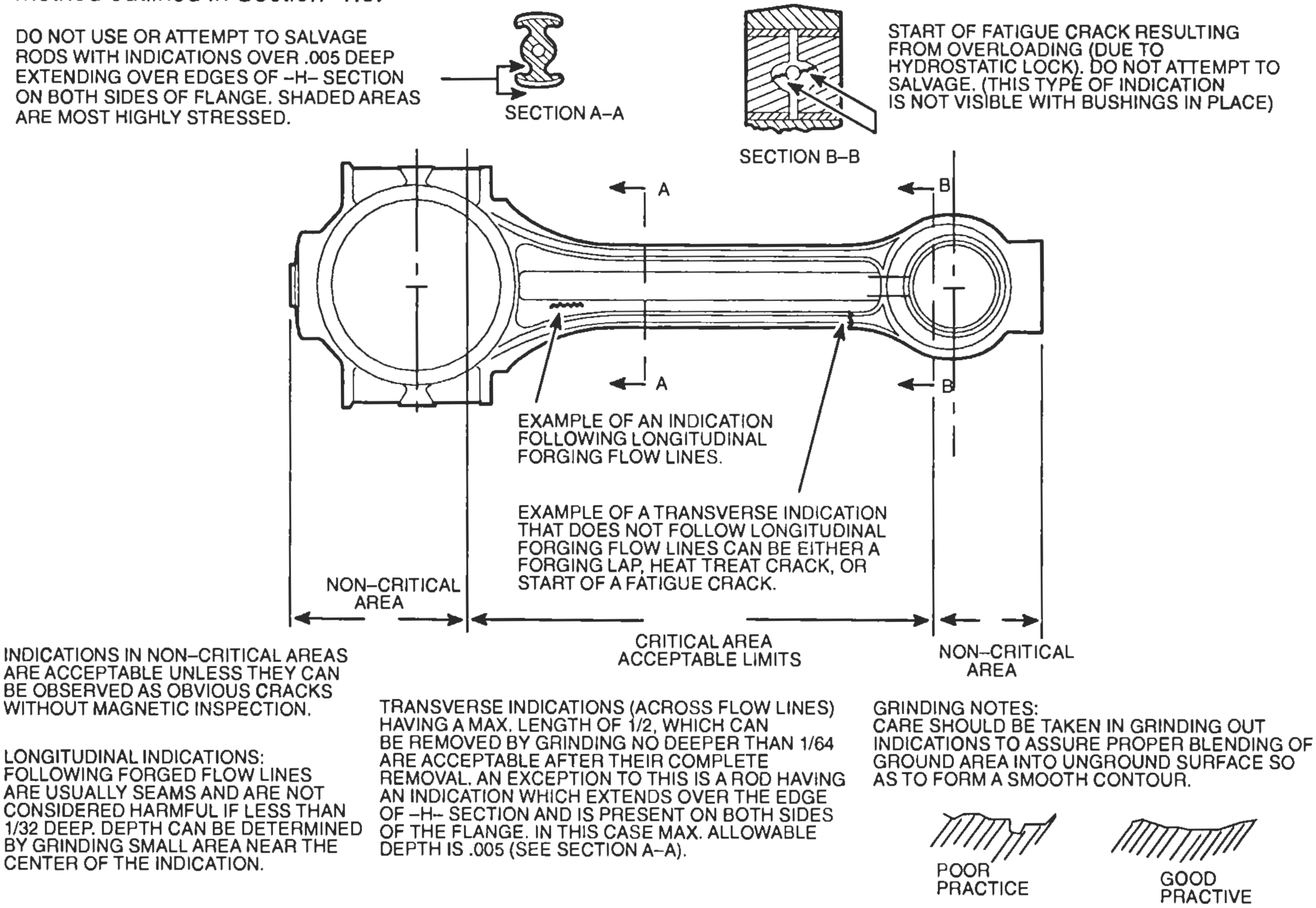

Figure 3. Magnetic Particle Inspection Limits for Connecting Rod

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). Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage and spray holes are not clogged.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Make sure the split line (cap to rod) is thoroughly cleaned to prevent trapped contaminants from adversely affecting bearing shell "crush". Check the connecting rod bushings for indications of scoring, overheating or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin, bushings and spray nozzle.

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

CONNECTING ROD INSPECTION (CONT.)

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

Turbocharged engines may use a piston pin which incorporates an oil hole (Figure 4.) to provide oil under pressure to the piston pin bushings. A similar piston pin is available as a service item for non–turbocharged engines.

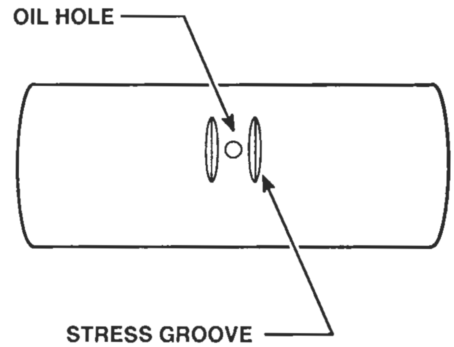

Figure 4. Piston Pin with Oil Hole

BUSHING REMOVAL

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

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

1. Clamp the upper end of the connecting rod in holder J 7632 (Figure 5.) so that the bore in the bushings is aligned with the hole in the base of the holder.
2. Place the bushing remover J 1513–3 in the connecting rod bushing, insert handle J 1513–2 in the remover and drive the bushings from the rod.

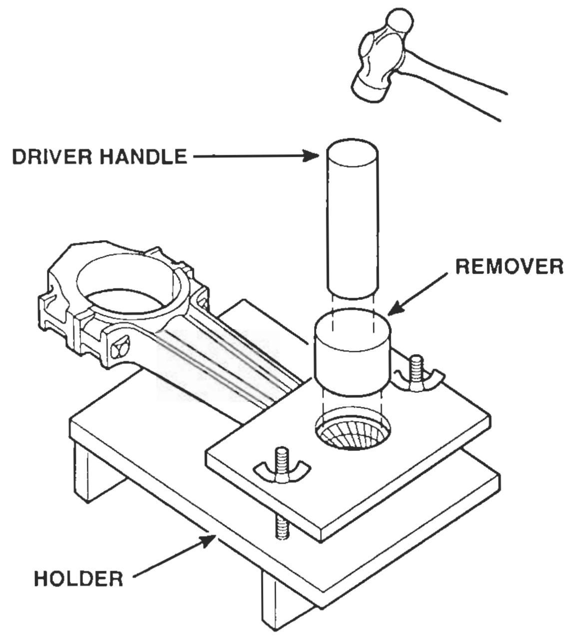

Figure 5. Removing or Installing Bushings with Holder

SPRAY NOZZLE AND ORIFICE REPLACEMENT

The connecting rod bushings must be removed before the spray nozzle or orifice can be replaced. Replace the spray nozzle as follows:

1. Remove the connecting rod bushings (refer to note above).
2. Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin, in the curved side of the tool, in the opening in the bottom of the spray nozzle.
3. Support the connecting rod and tool in an arbor press (Figure 6.)
4. Place a short sleeve directly over the spray nozzle. Then, press the nozzle out of the connecting rod.
5. Remove the tool.

The steel bushing–type orifice in the lower end of the drilled passage can be replaced, if necessary, at this time.

With the spray nozzle removed, insert a rod in the oil passage and drive the orifice from the lower end of the connecting rod.

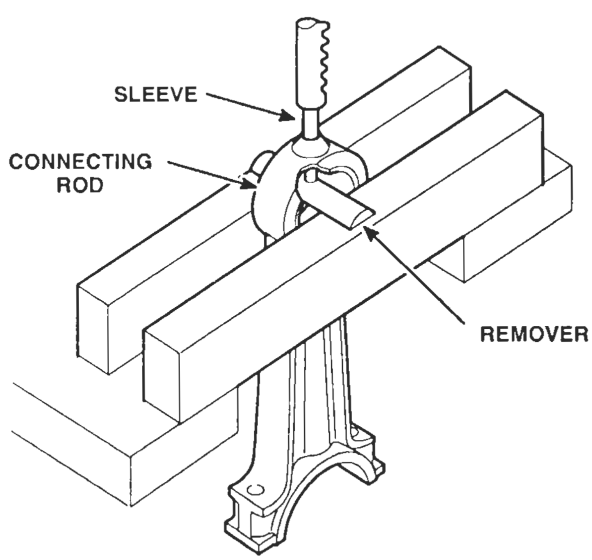

Figure 6. Spray Nozzle Removal

SPRAY NOZZLE AND ORIFICE REPLACEMENT (CONT.)

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

1. Start the new spray nozzle, with the holes positioned straight into the counterbore (Figure 7.) in the connecting rod.
2. Support the connecting rod in the arbor press, place a short 3/8 inch I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.
3. Install new bushings in the connecting rod.

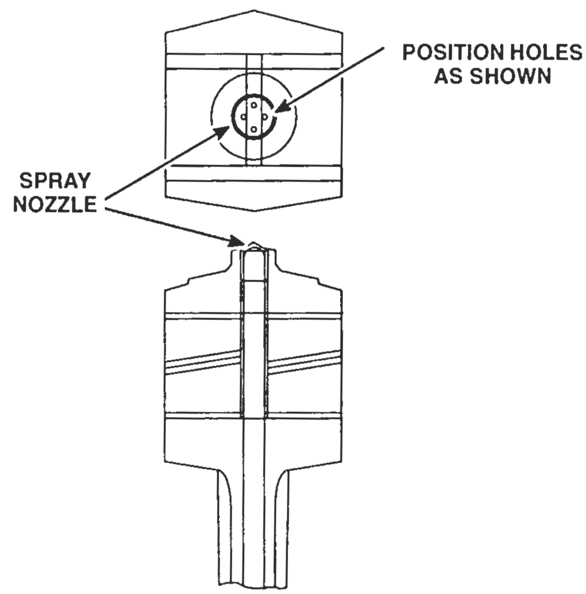

Figure 7. Spray Nozzle Hole Position

BUSHING INSTALLATION

A .812 inch long bushing is serviced for the connecting rod assembly used in all non–turbocharged engines. The .760 inch long vapor–blasted bushing used in turbocharged engines is not serviced separately.

Install connecting rod bushings as follows:

1. Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool.
2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Figure 8.)
3. Insert installer J 1513–6 in the bushing, then insert handle J 1513–2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.
4. Turn the connecting rod over in the holder and install the second bushing in the same manner.
5. The bushings must withstand an end load of 2000 pounds without moving after installation.

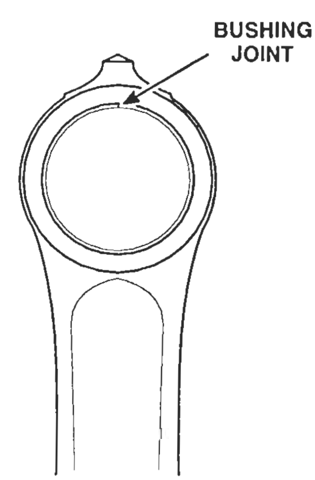

Figure 8. Location of Bushing Joint

BUSHING INSTALLATION (CONT.)

6. Ream the bushings to size, using tool set J 1686–03, as follows:

   a. Clamp reaming fixture J 29588–1 in a bench vise.

   b. Install arbor J 29588–10 with special bolt J 29588–2.

   c. Place the crankshaft end of the connecting rod on the arbor of the fixture (Figure 9.) and tighten the connecting rod cap nuts to 60–70 lb·ft (81–95 N·m) torque.

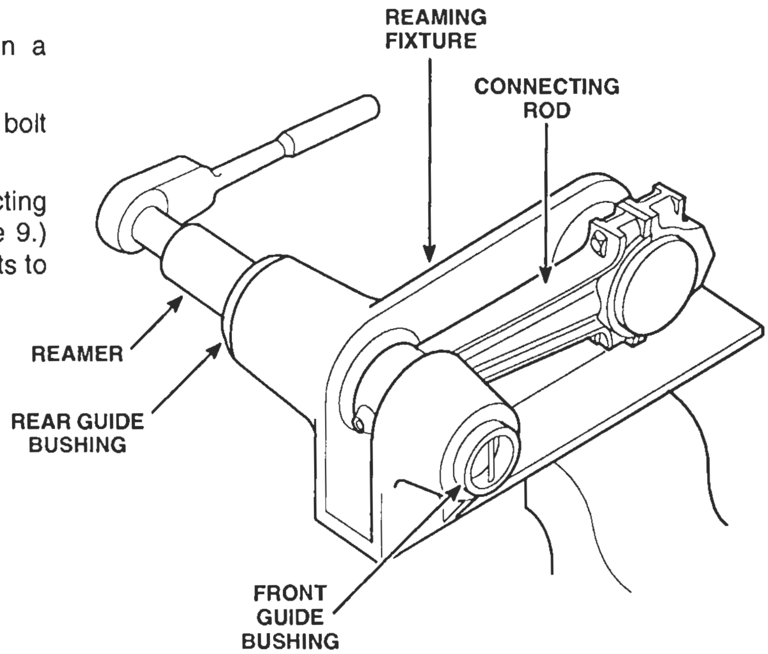

Figure 9. Reaming Bushings

   d. Slide the front guide bushing J 1686–11 (with the pin end facing out) in the fixture.

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

   f. Install the rear guide bushing J 1686–5 on reamer J 1686–20. Then slide the reamer and bushing into the fixture.

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

   h. Remove the reamer and the connecting rod from the fixture, blow out the chips and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.5025 to 1.5030 inches. This will provide a piston pin–to–bushing clearance of .0025 to .0034 inches with a new piston pin. A new piston pin has a diameter of 1.4996 to 1.5000 inches.

CONNECTING ROD TO PISTON ASSEMBLY

Apply clean engine oil to the piston pin and bushings. Assemble the connecting rod to the piston as follows:

1. Place the piston in the holding fixture (Figure 10.)
2. Place a new piston pin retainer in position. Then, place the crowned end of installer J 24107–01 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston.

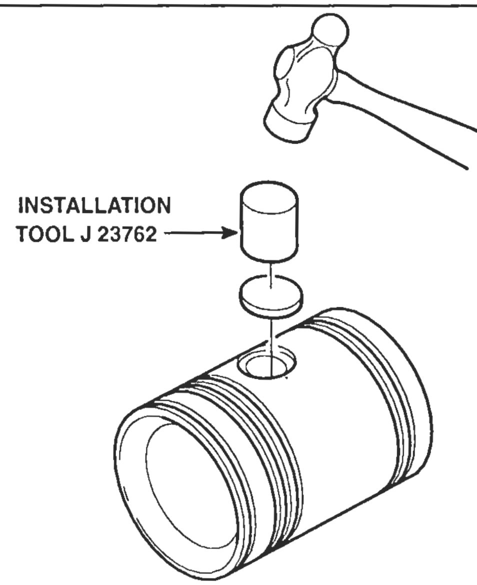

Figure 10. Piston Pin Retainer Installation

NOTE: Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

3. Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then, slide the piston pin in place. If the piston pin–to–bushing clearances are within the specified limits, the pin will slip into place without using force.
4. Install the second piston pin retainer as outlined in Steps 1 and 2.
5. After the piston pin retainers have been installed, check for piston pin end clearance by cocking the connecting rod and shifting the pin in its bushings.
6. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987 (Figure 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.

Figure 11. Checking Piston Pin Retainer for Proper Sealing

7. Install the piston rings on the piston as outlined in Section 1.6.
8. Install the piston and connecting rod assembly in the engine as outlined in Section 1.6.3.

CONNECTING ROD

CROSS–HEAD TYPE PISTON

The connecting rod (Figure 12.) 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 bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

Lubricating oil is forced through a drilled oil passage in the connecting rod to the piston pin and bushing. A service connecting rod includes the bearing cap and the attaching bolts and nuts.

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

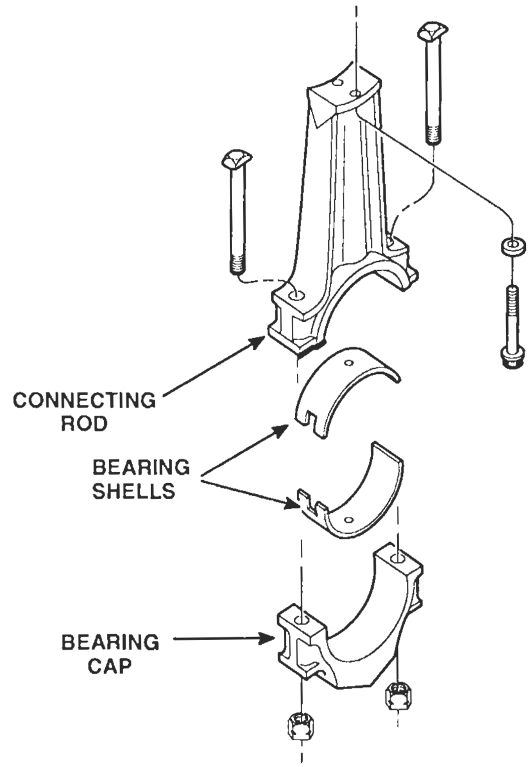

Figure 12. Connecting Rod Components

CONNECTING ROD DISASSEMBLY FROM PISTON

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

INSPECTION

Clean the connecting rod and piston pin with a suitable solvent and dry them with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (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 with the rod before reassembly.

NOTE: Never use crocus cloth on the bearing side of the pin.

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INSPECTION (CONT.)

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

1. Visually check for 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 (Figure 13.) by the magnetic particle method outlined in Section 1.3.

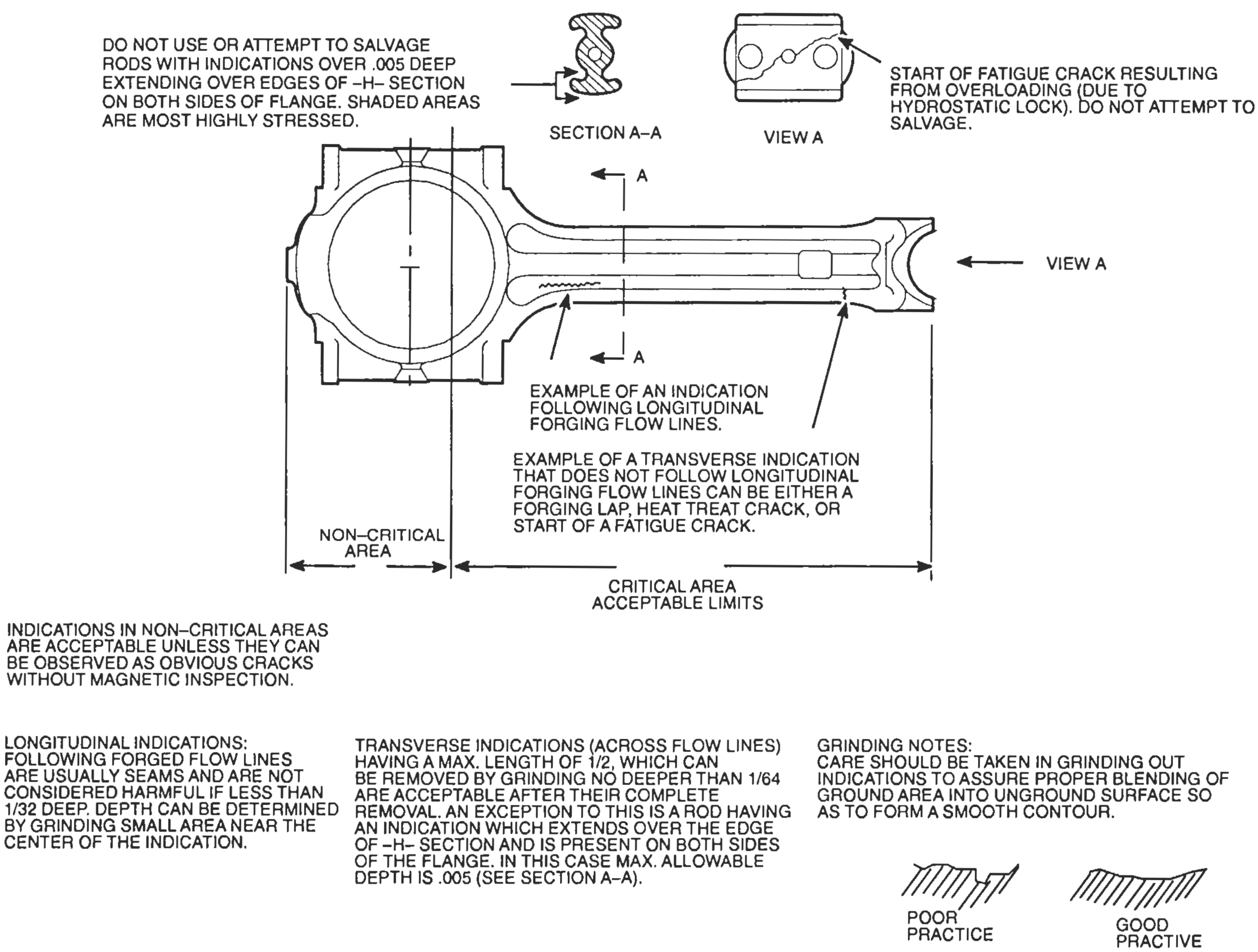


Figure 13. Magnetic Particle Inspection Limits for Connecting Rod

INSPECTION (CONT.)

2. Determine the average bore diameter of the rod, using a dial bore gage and master ring as follows (Figure 14.)

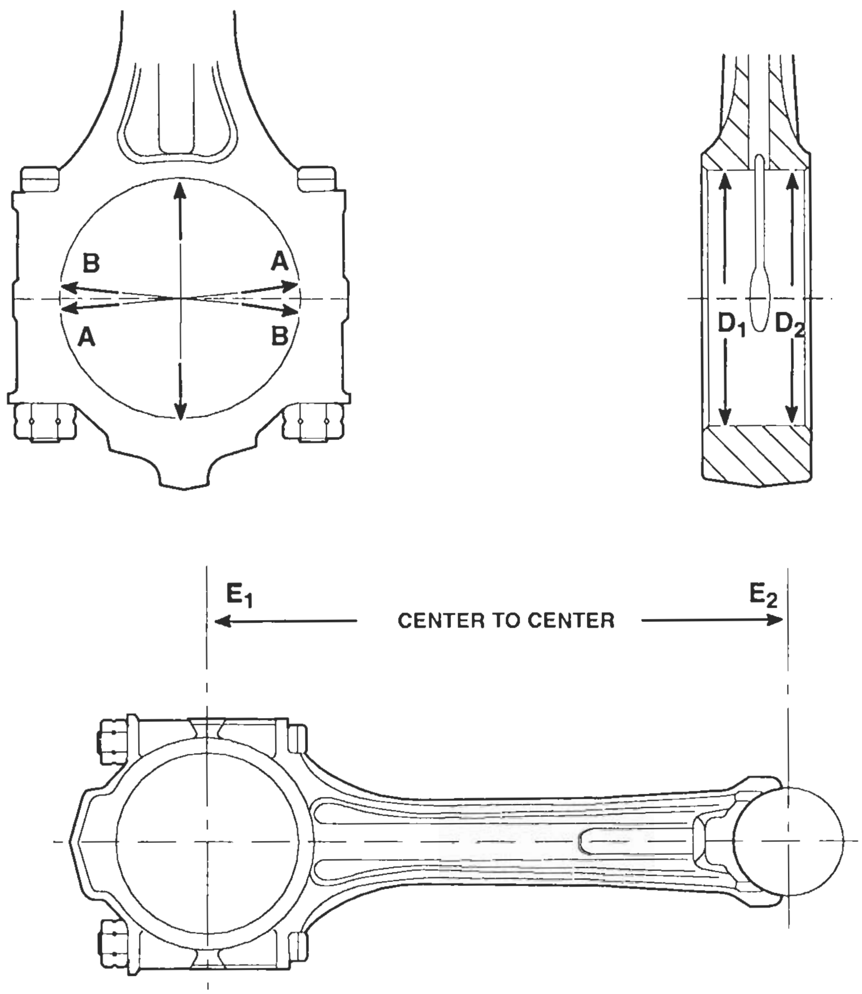


Figure 14. Dimensional Inspection of Cross–Head Piston Connecting Rod

INSPECTION (CONT.)

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.

c. Obtain the average of A and B to obtain size at split line.

$\frac{A + B}{2} = X$ which is the average of A + B

d. Measure C. The difference in the results of the measurements X and C gives the average bore out–of–round and can be .005 inch 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 inches.

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

3. Determine taper as follows:
   a. Subtract D1 from D2 to find the difference.
   b. The difference can be .0005 inch maximum.
4. Determine length by finding the distance between E1 and E2. Specifications: 10.121 to 10.126 inches.
5. 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 (Section 1.6.3). Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clear of obstructions.

CAUTION:
To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Make sure the split line (cap to rod) is thoroughly cleaned to prevent 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 inch or less. A new bushing is .087 to .088 inches thick. A new bushing with a shorter oil slot and modified I.D. is used, effective with engine serial numbers 3A0101510, 4A0278120 and 6A0451774.

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

INSPECTION (CONT.)

The new connecting rod has an improved oil passage drilled into it. This new "Y drilled" design (Figure 15.) increases the oil flow and allows for a larger bearing surface at the center of the connecting rod, which is the highest load area.

The new connecting rod design eliminates the need for a groove, as on the former connecting rod, by side drilling the rod at an angle to the center column hole, forming the "Y".

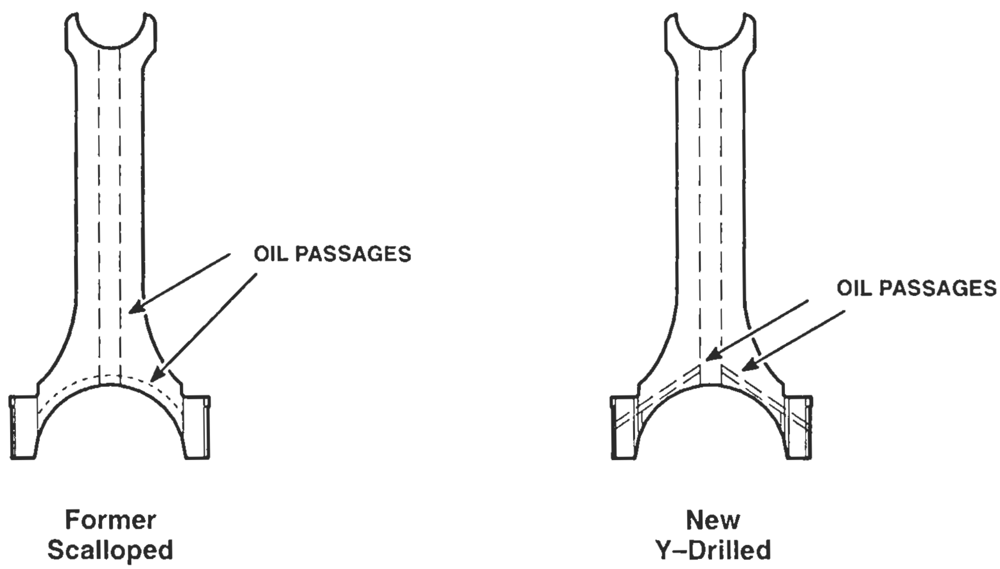


Figure 15. Former and New Connecting Rod Oil Passages

CONNECTING ROD TO PISTON ASSEMBLY

Refer to Section 1.6 for procedures to assemble the connecting rod to the piston.

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Figure 1.) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The upper and lower bearing shells are located in the connecting rod by a tang at the parting line at one end of each bearing shell.

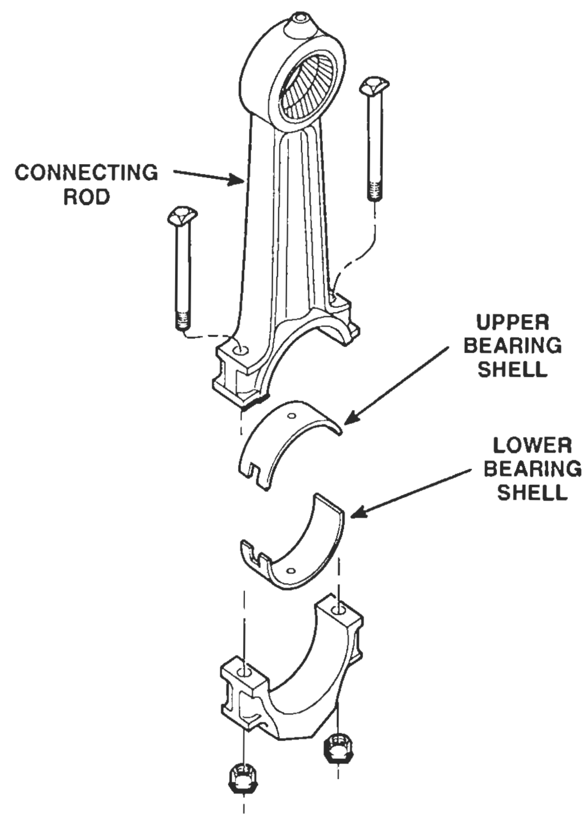


Figure 1. Connecting Rod and Bearing Shells

These bearings have an inner surface, called the matrix, of copper–lead or aluminum. A thin deposit of babbitt is then plated onto the matrix. This babbitt overlay has excellent resistance to friction, corrosion and scoring tendencies which, combined with the material of the matrix, provides improved load carrying characteristics. These bearings are identified by the satin silver sheen of the babbitt when new and a dull gray after being in service.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell is grooved midway between the bearing edges, part way up from each parting line, with an oil hole through the shell at the termination of each groove. The lower bearing shell has a continuous oil groove, extending from one parting line to the other, in line with that of the upper bearing shell. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings and spray nozzle through the oil passage in the connecting rod.

CONNECTING ROD BEARINGS (CONT.)

The new bearing (Figure 2.) has centrally located cutaway slots through the bearing ends, as opposed to the hole and groove of the former bearing. The new bearing may be used with the former connecting rod and will become the only available bearing for service. The new connecting rod must be used with the new bearing. If the former bearing is used with the new connecting rod, oil flow to the piston will be restricted, resulting in possible damage.

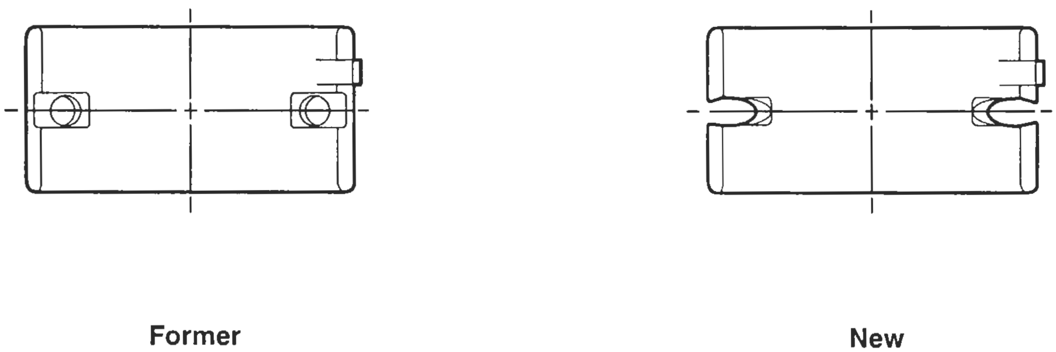


Figure 2. Connecting Rod Bearing Details

BEARING SHELL REMOVAL

The connecting rod bearing caps are numbered 1, 2, 3, etc., with matching numbers stamped on the connecting rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the oil pan.
2. Remove the lubricating oil pump and the pump inlet and outlet pipes.

NOTE: If shims are used between the oil pump body and the main bearing caps, save the shims so they may be reinstalled when installing the oil pump.

3. Remove one connecting rod bearing cap. Push the piston and rod 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.
5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

INSPECTION

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, chipping, cracking, loss of babbitt or signs of overheating. If any of these defects are present, the bearings must be discarded. However, babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are not detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

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

Measure the thickness (Section 1.3.4) of the bearing shells, using a micrometer and ball attachment J 4757. The minimum thickness of a worn standard connecting rod bearing shell should not be less than .1530 inch and, if either bearing shell is thinner than this dimension, replace both bearing shells. A standard bearing shell (Table 1) has a thickness of .1548 to .1553 inch.

Bearing Size	*New Bearing Thickness	Minimum Worn Thickness
Standard	.1548/.1553 inch	.1530 inch
.002 Undersize	.1558/.1563 inch	.1540 inch
.010 Undersize	.1598/.1603 inch	.1580 inch
.020 Undersize	.1648/.1653 inch	.1630 inch
.030 Undersize	.1698/.1703 inch	.1680 inch

*Thickness 90° from parting line of bearing.

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 (Section 1.0). The maximum connecting rod bearing–to–journal clearance with used parts is .006 inch.

Before installing the bearings, inspect the crankshaft journals (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 inch undersize for service with reground crankshafts. To determine the size bearings required (Section 1.3). Bearings which are .002 inch undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

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

CONNECTING ROD BEARING SHELL INSTALLATION

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

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.
2. Install the upper bearing shell — the one with the short groove and oil hole at each parting line — in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.
3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.
4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell — the one with the continuous oil groove — in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.
5. Install the bearing and cap and tighten the connecting rod bolt nuts to 60–70 lb·ft (81–95 N·m) torque (lubrite nut) or 65–75 lb·ft (88–102 N·m) torque (castellated nut).

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

6. Install the lubricating oil pump and the oil inlet and outlet pipes.

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

7. Install the oil pan, using a new gasket.
8. Fill the crankcase (Section 13.3) to the proper level on the dipstick.

If new bearings were installed, operate the engine on the run–in schedule (Section 13.2.1).

CYLINDER LINER

The replaceable type cylinder liner is accurately machined and heat treated to provide a long wearing scuff–resistant surface (Figure 1.) The flange at the top fits into a counterbore in the cylinder block and rests on a replaceable cast iron insert which permits accurate alignment of the cylinder liner.

When rebuilding a TA or TTA engine, always make sure that the correct cylinder liner is installed. The TA/TTA liner has a .95 inch port height, while the standard liner has a 1.05 inch port height. If the standard liner is installed in place of the TA liner, a small loss in power and an increase in smoke will result. This will also, put the TA and the TTA engines in direct violation of EPA (Environmental Protection Agency) standards.

NOTE: Do not use the short–oval port liners in an engine requiring long–oval port liners.

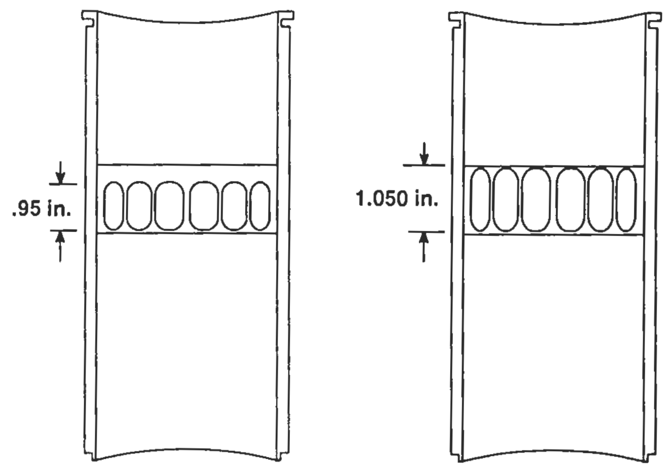


Figure 1. Cylinder Liners

The .95 inch port height liner can be identified as follows:

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

The liner is cooled by means of a water jacket in the cylinder block and by the scavenging air introduced into the cylinder through the air inlet ports around the liner. The air inlet ports 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.

CYLINDER LINER REMOVAL

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.

Remove a cylinder liner from a the iron block as follows:

1. Remove the piston and connecting rod assembly (Section 1.6).
2. Remove the cylinder liner with tool J 1918–02 as follows:
   a. Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then slide the upper puller clamp down against the top edge of the liner.
   b. With the tool in place, strike the upset head on the upper end of the puller rod a sharp blow with the puller weight, thus releasing the liner (Figure 2.)

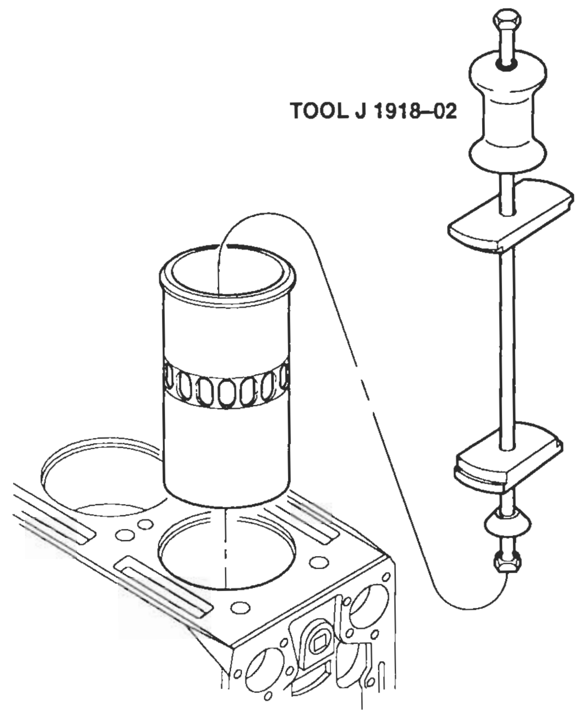


Figure 2. Cylinder Liner Removal

   c. Remove the tool from the liner. Then, remove the liner from the block.
   d. Remove the liner insert and shims (if used) from the counterbore in the block.
   e. Tag the liner, insert and shims.

If tool J 1918–02 is unavailable, tap the liner out with a hardwood block and hammer.

CYLINDER LINER INSPECTION

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for:

- Cracks
- Scoring
- Poor contact on outer surface
- Flange irregularities
- Inside Diameter
- Outside Diameter
- Out–of Round
- Taper

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

CYLINDER LINER INSPECTION (CONT.)

Excessive liner–to–block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant. Poor contact between the liner and the block bore may be indicated by stains or low pressure areas on the outer surface of the liner.

Examine the outside diameter of the liner for fretting. 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.

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. Replace the insert if there is evidence of brinelling.

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 affect piston ring seating.

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

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.

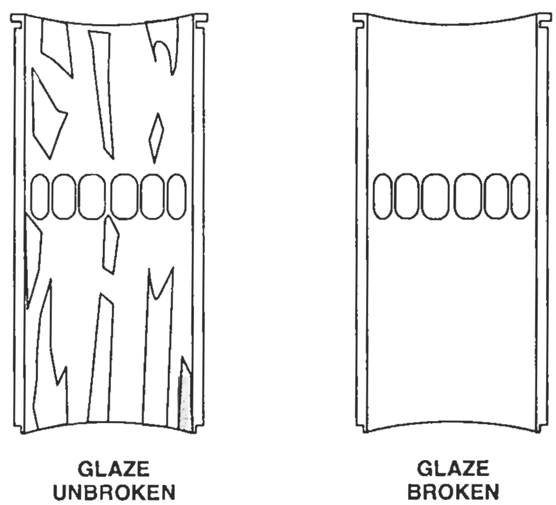


Figure 3. Glazed Cylinder Liner Surface

The hone J 5902–01, equipped with 120 grit stones J 5902–14, should be worked up and down the full length of the liner a few times 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 (Section 1.0).

SECTION 1.6.3 – CYLINDER LINER

LINER MEASUREMENTS

Measure the block bore and the outside diameter of the liner. If the liner–to–block clearance (with used parts) exceeds .0025 inch (cast iron block), it will be necessary to bore the block for an oversize liner as outlined in section 1.1.

Install the liner in the proper bore of the cylinder block. Measure the inside diameter of the liner at the various points (Figure 4.) Use cylinder bore gage J 5347–01, which has a dial indicator calibrated in .0001 inch increments. Set the cylinder bore gage on zero in master ring gage J 5580–1. Also, check the liner for taper and out–of–round. It is not necessary to measure the inside diameter or taper of a new liner.

NOTE: Dial bore gage master setting fixture J 23059–01 may be used in place of the master ring gage.

The piston–liner clearance must be within the specified limits (Section 1.0). Also, the taper must not exceed .002 inch and the out–of–round must not exceed .0025 inch on a used liner. If the out–of–round exceeds .0025 inch, rotate the liner 90° in the block bore and recheck.

Cylinder liners are available in .005, .010, .020 and .030 inches oversize on the outside diameter. When an oversize liner is installed, stamp the amount of oversize on top of the cylinder bore adjacent to the liner counterbore.

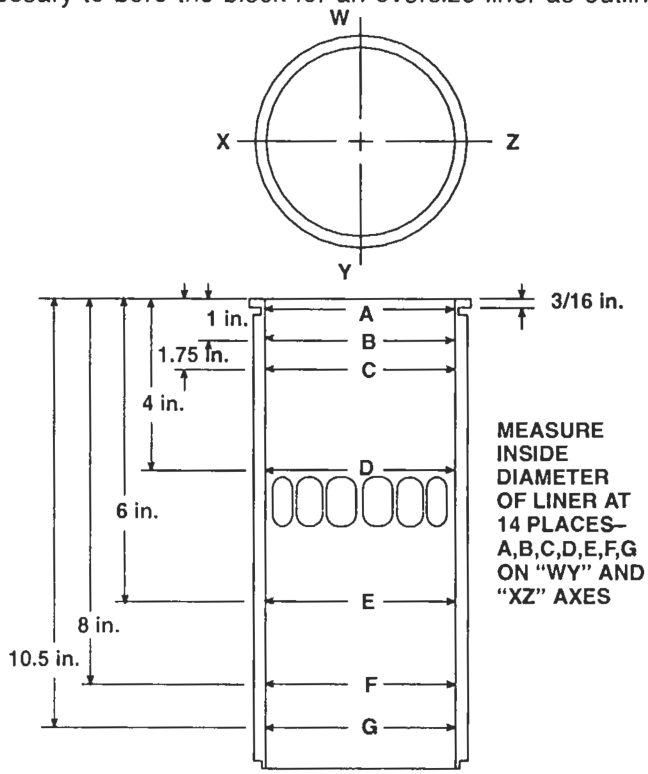


Figure 4. Cylinder Liner Measurement Diagram

NEW CYLINDER LINER SELECTION

The cylinder bores in a new cylinder block are classified as #1, #2 or #3 (Figure 5.) designating the specific size range for each bore and the appropriate cylinder liner that may be fitted to each bore. The classification number is stamped on the fire deck of the cylinder block adjacent to each cylinder bore.

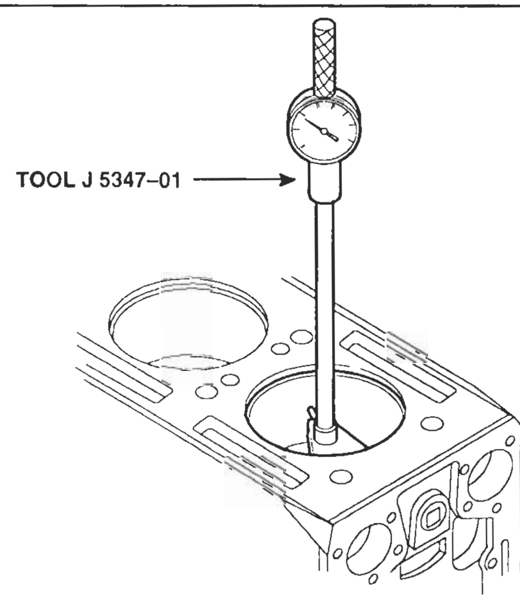


Figure 5. Checking Bore of Cylinder Liner

NEW CYLINDER LINER SELECTION (CONT.)

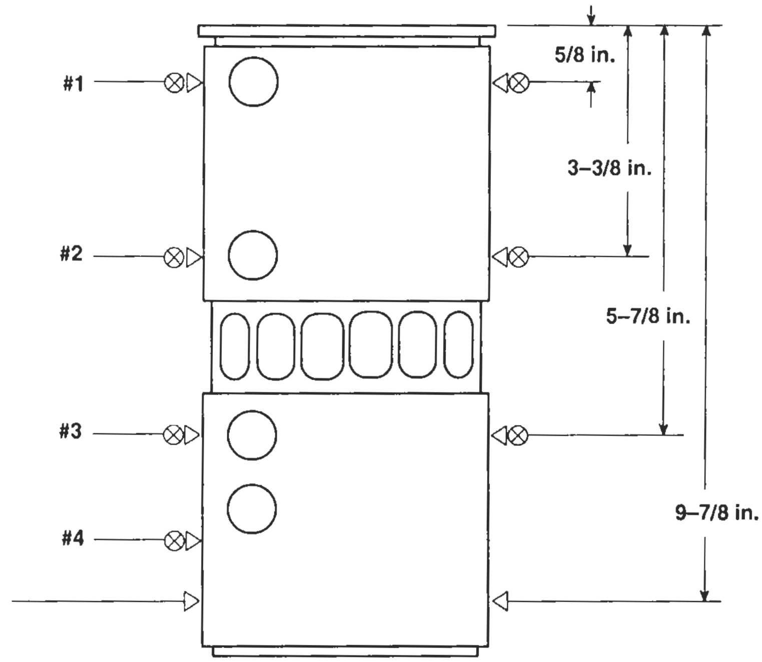
A new standard size cylinder liner is also classified as #1, #2, #3 or #4 (Figure 6.)

Although the block bores and liners should be measured to determine the liner–to–block clearance, the selection of a liner is narrowed down to only those in the appropriate classifications.

Before installing a liner in a used cylinder block, always lightly hone the block bore (Section 1.1).

STANDARD LINER (5113953) ONLY
LINER CLASSIFICATION IS IDENTIFIED BY THE POSITION OF THE ELECTRO–ETCHED STAMP WITH PART NO. AND PATENT NO. LOGO AS LISTED BELOW

CLASSIFICATION	STAMP POSITION	LINER SIZE
#1	BELOW FLANGE	4.6250–4.6255 in.
#2	ABOVE PORTS	4.6256–4.6260 in.
#3	BELOW PORTS	4.6261–4.6265 in.
#4	BELOW PORTS	4.6266–4.6280 in.



LINER CLASSIFICATION
LINER O.D. CLASSIFICATION IS MEASURED AT 3 POSITIONS MARKED <⊗

CYL. LINER O.D. IS MEASURED AT POSITIONS MARKED ▷

ALL MEASUREMENTS ARE AVERAGED FOR 360° ROTATION

Figure 6. Cylinder Liner Measurement Diagram

SECTION 1.6.3 – CYLINDER LINER

NEW CYLINDER LINER SELECTION (CONT.)

After honing the block bore, check the bore measurements to determine if a standard liner (classification #1, #2, #3 or #4) liner can be used (see Tables 1 and 2). A push fit between the liner and the block is desirable. If an adequate push fit cannot be obtained, it may be necessary to bore the block to receive an oversize liner.

When it becomes necessary to install an oversize liner, the same care in selective tolerance fitting must be adhered to. However, it may be more difficult to select an oversize liner since the size range is not broken down into classifications.

NEW CYLINDER LINER TO NEW CYLINDER BLOCK BORE FITS

CAST IRON BLOCKS

Classification Number Stamped Adjacent to Each Cylinder Bore	Cylinder Bore Classification Diameter (I.D.) (in.)	Linear (O.D.) Classification	Linear (O.D.) Diameter (in.)	Linear/Block Clearance (in.)
#0	4.6256/4.6259	#1	4.6250/4.6255	.0001/.0009
#1	4.6260/4.6265	#1 #2	4.6250/4.6255 4.6256/4.6260	.0005/.0015 .0000/.0009
#2	4.6266/4.6270	#2	4.6256/4.6260	.0006/.0014
#3	4.6271/4.6275	#3	4.6261/4.6265	.0006/.0014
#4	4.6276/4.6280	#4	4.6266/4.6280	.0006/.0015
METRIC				
#0	117.490/117.498 mm	#1	117.475/117.488 mm	.002/.023 mm
#1	117.500/117.513 mm	#1 #2	117.475/117.488 mm 117.490/117.500 mm	.012/.038 mm .000/.023 mm
#2	117.516/117.526 mm	#2	117.490/117.500 mm	.016/.036 mm
#3	117.528/117.593 mm	#3	117.503/117.513 mm	.015/.036 mm
#4	117.518/117.551mm	#4	117.515/117.551mm	.015/.038 mm

TABLE 1

OVERSIZE SERVICE CYLINDER LINERS

Service Liner Oversize (in.)	Liner Outside Diameter (in.)	Liner Outside Diameter (mm)	Liner/Block Clearance Req'd. After Boring Block (in.)
.005	4.6315 4.6300	117.640 117.602	.0005/.0015 (.013/.038 mm)
.010	4.6365 4.6350	117.767 117.729	.0005/.0015 (.013/.038 mm)
.020	4.6465 4.6450	118.021 117.983	.0005/.0015 (.013/.038 mm)
.030	4.6565 4.6550	118.275 118.237	.0005/.0015 (.013/.038 mm)

TABLE 2

NEW CYLINDER LINER SELECTION (CONT.)

In deciding whether boring is necessary or not, keep in mind that each bore in a used block must not be out–of–round or tapered more than .002 inches. If the average block bore is over 4.6285 inches, the cylinder block should be bored oversize.

To determine what size to bore the cylinder block for an oversize liner, each service liner used must be measured on the outside diameter for size in three places (under the flange, between the flange and the ports, and above the ports). The cylinder bore size will be determined by the average liner measurement taken at the three positions.

EXAMPLE:

Service liner O.D. measures 4.6280 inches.

O.D. size = 4.6280 inches
plus clearance = .0005
bore size = 4.6285 inches

Then, 4.6285 [+] .001 inches boring tolerance will allow a bore size of 4.6285 to 4.6295 inches and a possible liner–to–block clearance of .0005 to .0015 inches. The clearance tolerance is the dimensional difference between the liner O.D. and the block bore I.D.

CYLINDER LINER IN BLOCK BORE FITTING

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean.
2. Place a standard size cylinder liner insert (.1795–.1800 inches thick) in the block counterbore (Figure 7.)
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. If a new liner cannot be pushed in place, light honing of the block bore may be necessary to obtain the desired fit for best heat transfer.

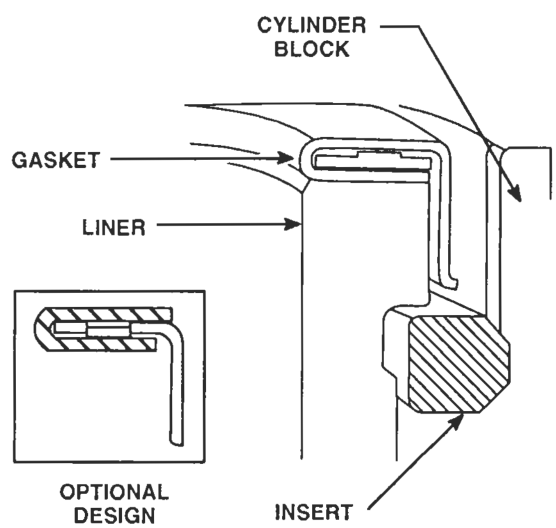


Figure 7. Cylinder Liner Mounting in Block

CYLINDER LINER IN BLOCK BORE FITTING (CONT.)

4. Install a cylinder liner hold–down clamp (Figure 8.)

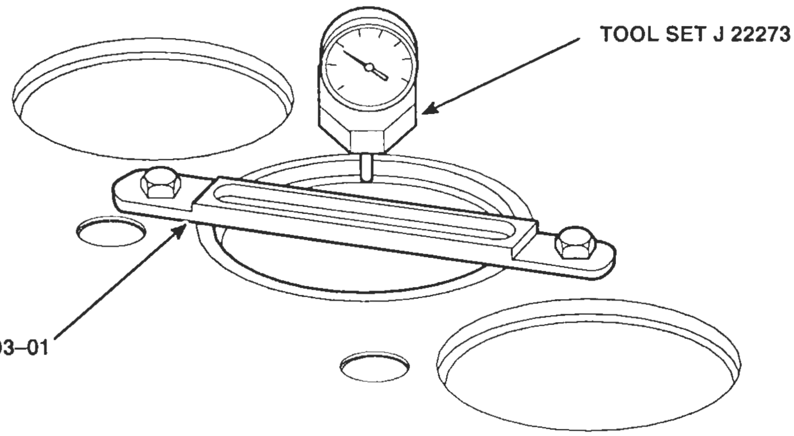


Figure 8. Checking Distance of Linear Flange Below Top Face of Block

5. Measure the distance from the top of the liner to the top of the block with a dial indicator. The liner flange must be .045 to .050 inches below the surface of the block. However, even though all of the liners are within these specifications, there must not be over .002 inch difference in depth between any two adjacent liners when measured along the cylinder longitudinal center line.

NOTE: A .002 inch thick shim is available for adjusting the liner height. The shim must be installed underneath the liner insert. Do not cut the shim for installation. Liner inserts which are .0015 inch thicker or thinner than standard are also available for service. In addition, the .004 and .008 inches thinner inserts which are provided for use with resurfaced cylinder blocks, can also be used to adjust the liner height.

6. Match–mark 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. The match–marks should be toward the blower side of the engine.
7. Remove the hold–down clamp and the cylinder liner.

NOTE: Do not remove the liner insert.

PISTON AND CONNECTING ROD INSTALLATION

1. With the piston assembled to the connecting rod and the piston rings in place as outlined in Sections 1.6 and 1.6.1, apply clean engine oil to the piston, rings and the inside surface of the piston ring compressor J 3272–03.

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 (Figure 9.)
5. Note the position of the match–mark 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 match–mark on the liner (Figure 9.)

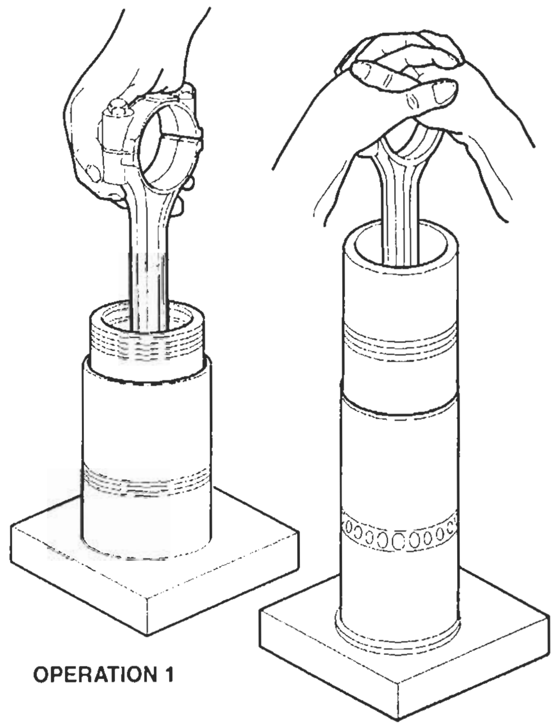


Figure 9. Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

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

CAUTION:

To avoid scraping knuckles or pinching fingers between the rod end and ring compressor walls, interlock fingers and place hands as shown when pushing down. This keeps fingers out of the ring compressor when the piston slides into the liner.

PISTON AND CONNECTING ROD INSTALLATION (CONT.)

NOTICE:

Do not force the piston into the liner. The peripheral abutment type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.
8. Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

CYLINDER LINER, PISTON AND CONNECTING ROD INSTALLATION

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

1. 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.
2. 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.
3. Install the upper bearing shell, the one with a short oil groove at each parting line, in the connecting rod. Lubricate the bearing shell with clean engine oil.
4. Position the piston, rod and liner assembly in line with the block bore (Figure 10.) so the identification number on the rod is facing the blower side of the engine and the match–marks 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.

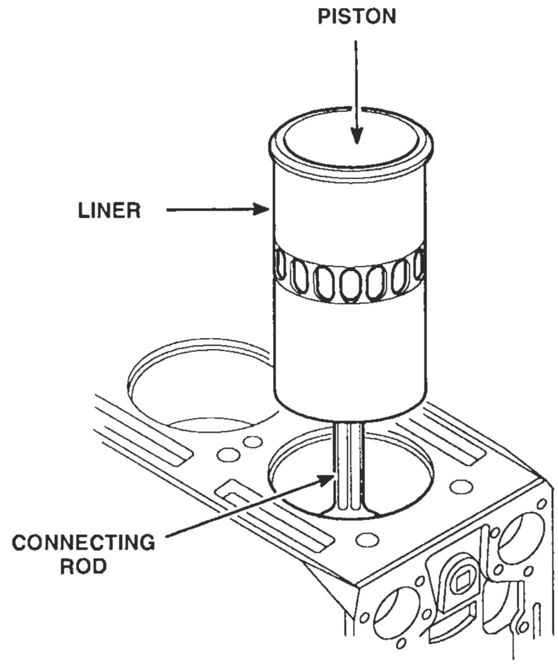


Figure 10. Piston, Rod and Liner Installation

5. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

CYLINDER LINER, PISTON AND CONNECTING ROD INSTALLATION (CONT.)

6. 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. Be sure the connecting rod bolt has not turned in the connecting rod before torque is applied to the nut. Tighten the connecting rod bolt nuts to 60–70 lb·ft (81–95 N·m) torque (lubrite nut) or 65–75 lb·ft (88–102 N·m) torque (castellated nut).

NOTE: The current connecting rod bolt is .200 inches longer than the former bolt. After the oil pump piping is installed, bar the engine over for a clearance check. In the event interference occurs, loosen the pipe or item involved and retighten it while holding it away from the point of interference.

7. Check the connecting rod side clearance. The clearance must be .006 to .012 inches.
8. Install the remaining liner, piston and rod assemblies in the same manner. Use hold–down clamps to hold each liner in place.
9. After all of the liners and pistons have been installed, remove the hold–down clamps.
10. Install new compression gaskets and water and oil seals (Section 1.2). Then install the cylinder head and any other parts which were removed from the engine.
11. After the engine has been completely reassembled, refill (Section 13.3) the crankcase to the proper level on the dipstick.
12. Close all of the drains and fill the cooling system.
13. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run–in schedule (Section 13.2.1).

ENGINE BALANCE AND BALANCE WEIGHTS

Both rotating and reciprocating forces are completely balanced in the engine. The eccentric rotating masses of the crankshaft and connecting rods are balanced by counterweights on the crankshaft cheeks.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple by virtue of an arrangement on the crankshaft in which reciprocating masses, though equal, are not opposite. This unbalanced couple, which tends to rock the engine from end to end, is balanced by an arrangement of rotating counterweights, mounted at the front and rear ends of the camshaft and balance shaft, which produce a couple equal and opposite in magnitude. Consequently the engine will operate smoothly and in balance throughout its entire speed range.

Each set of weights (weights on one shaft comprise a set) rotates in an opposite direction with respect to the other. When the two weights at either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the unbalanced couple; when they are in a horizontal plane, the centrifugal forces of these balance weights are opposite and are therefore cancelled. The front balance weights are eccentric in a direction opposite to the rear balance weights. Therefore, rotation will result in the desired couple effective only in a vertical plane.

The balance weights consist of two eccentric weights at each end of the engine. On three cylinder engines (through serial number 3A–48439), the weights at the rear are integral with the gears. On three cylinder engines effective with 3A–48440 and four cylinder and six cylinder engines, additional weights are attached to the gears.

The front balance weights are keyed to the front end of the camshaft and the balance shaft (Figure 1.) Balance weights are of one–piece construction.

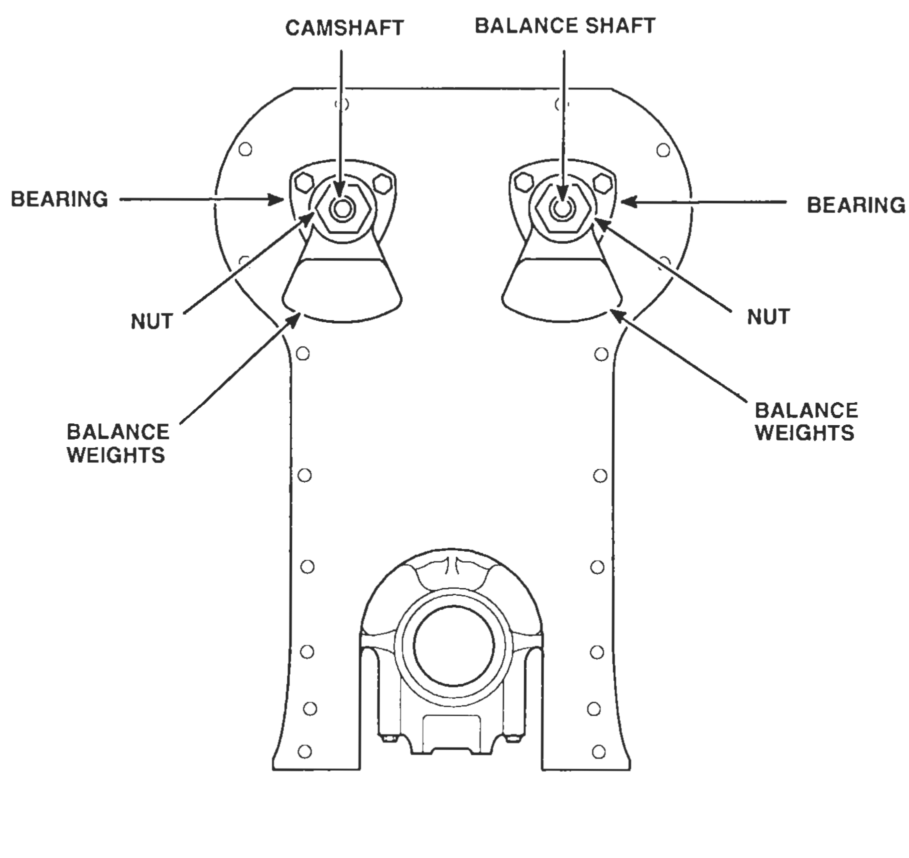


Figure 1. Front Balance Weight Mounting

REMOVE FRONT BALANCE WEIGHTS

1. Remove the balance weight cover.
2. Place a block of wood between the balance weights to prevent rotation (Figure 2.)
3. Loosen the balance weight retaining nuts on the camshaft and balance shaft with a 1–1/2 inch socket wrench and remove the nuts and internal tooth lock washers.

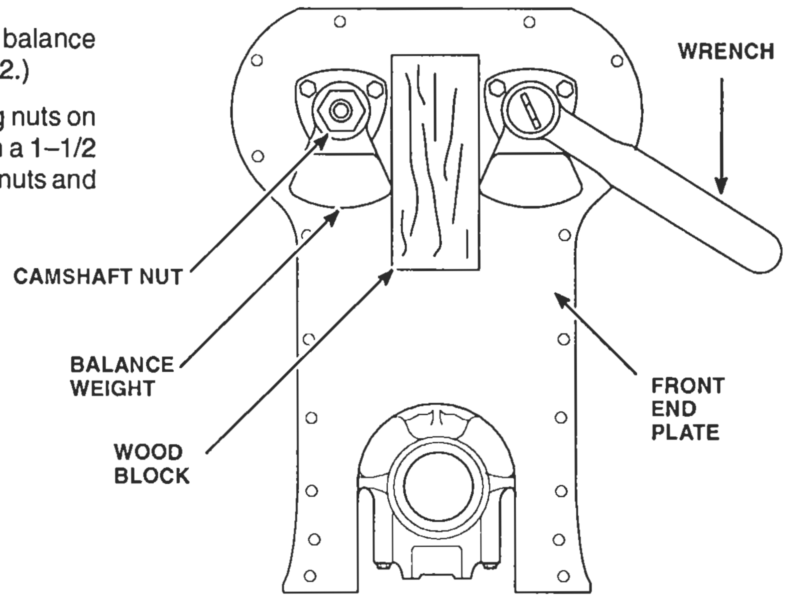


Figure 2. Nut Loosening on Camshaft or Balance Shaft

4. Force the balance weight off the end of each shaft with two heavy screwdrivers or pry bars between the heads of the bearing retaining bolts and the balance weight (Figure 3.)

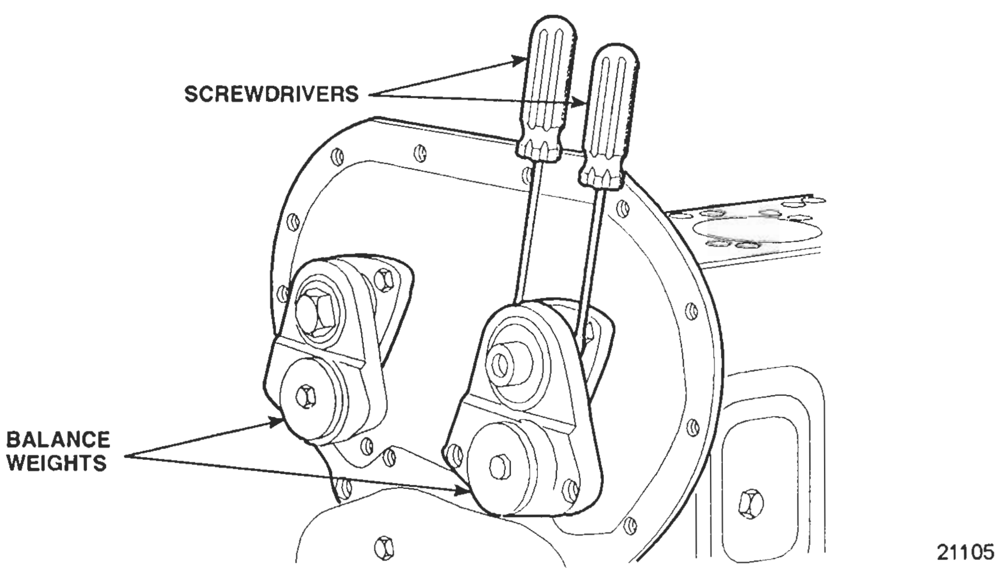


Figure 3. Removing Balance Weight

INSTALL FRONT BALANCE WEIGHTS

1. If thrust washers are used ("B" and "C" engines), apply heavy cup grease to the steel faces of the washers and install the washers up against the camshaft and balance shaft and bearings.
2. Install Woodruff keys in the keyways at the front end of the camshaft and the balance shaft.
3. Align the keyway in the balance weight hub with the key in the shaft and slide the balance weight on the camshaft.
4. Install the balance weight on the balance shaft in the same manner.
5. Slip an internal tooth lock washer over the end of each shaft. Start the nuts on both shafts.
6. Place a block of wood between the balance weights and tighten the retaining nuts to 300–325 lb·ft (407–441 N·m) torque.
7. Install the balance weight cover, using a new gasket.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN

A completely enclosed train of five helical gears is located at the rear end of the engine. A gear bolted to the crankshaft flange drives the camshaft and balance shaft gears, as well as the blower drive gear, through an idler gear mounted between the crankshaft and balance shaft gears on the RB, RC, LA and LD engines and between the crankshaft and camshaft gears on the RA, RD, LB and LC engines.

The camshaft gear and balance shaft gear mesh with each other and run at the same speed as the crankshaft gear. Since these two gears must be in time with each other, and the two as a unit in time with the crankshaft gear, the letter "O" is placed on one tooth of one of the gears with a corresponding mark at the root of the mating teeth of the other gear.

The camshaft and balance shaft gears are keyed to their respective shafts and held securely against the shoulder on the shaft by a nut. Viewing the engine from the flywheel or gear train end, the right–hand gear, whether on the balance shaft as shown on RA, RD, LA and LD engines or the camshaft as shown on RB, RC, LB and LC engines, has left–hand helical teeth (Figure 1.)

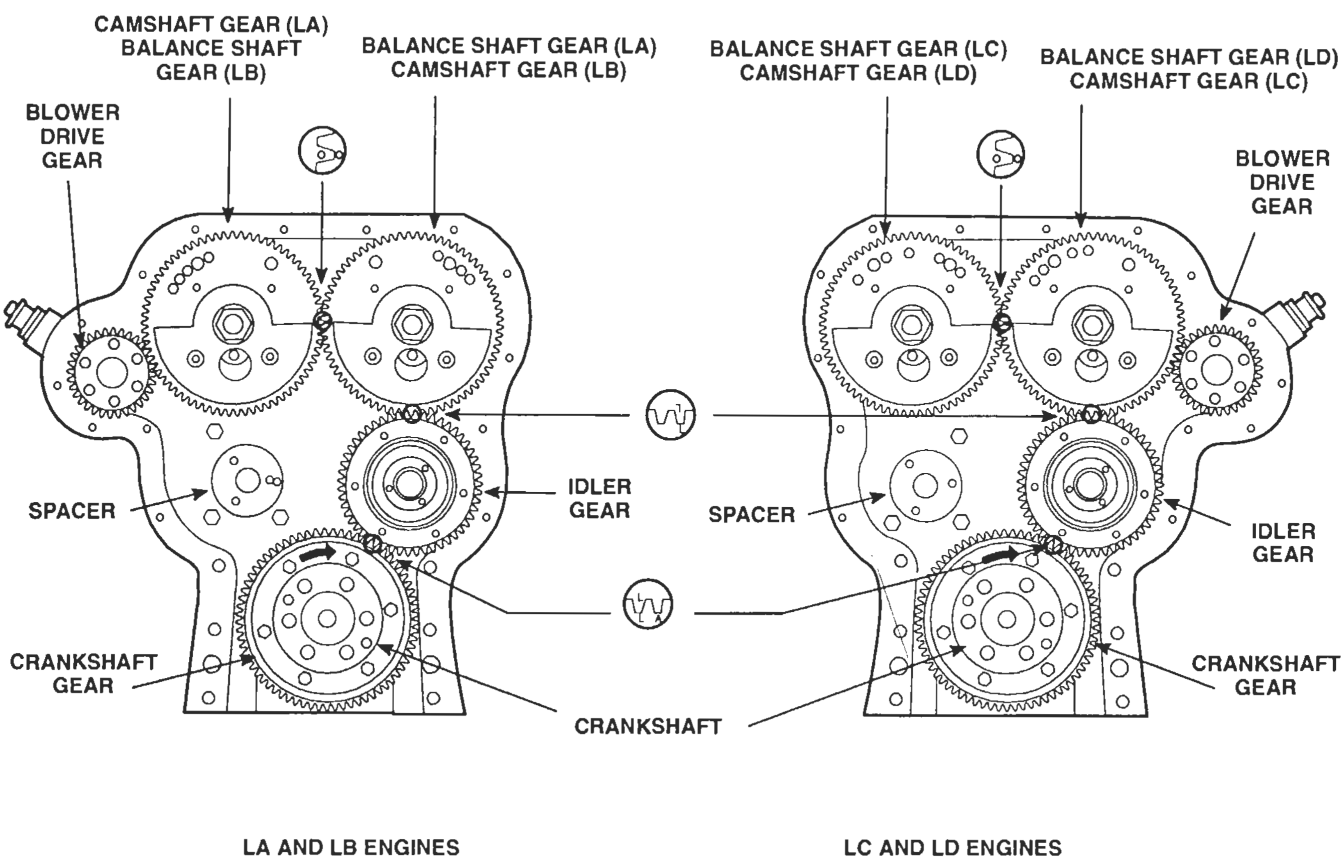


Figure 1. Gear Train and Timing Marks – Left–Hand Rotation Engines (Standard Timing Shown)

GEAR TRAIN (CONT.)

The idler gear rotates on a double–row, tapered roller bearing mounted on a stationary hollow hub. This hub is accurately located on the cylinder block end plate at the right–hand side of the LA, LB, LC and LD engines and at the left–hand side of the RA, RB, RC and RD engines as viewed from the gear train end.

A blower drive gear is located on the blower side to transmit power to the blower, governor, fuel pump and water pump.

Since the camshaft must be in time with the crankshaft, identification marks are located on two teeth of the idler gear with corresponding match marks stamped on the crankshaft gear and the camshaft gear.

However, the timing is advanced on certain engines by aligning the "A" on the crankshaft gear with "L" or "R" (depending upon engine rotation) on the idler gear (Figure 2.)

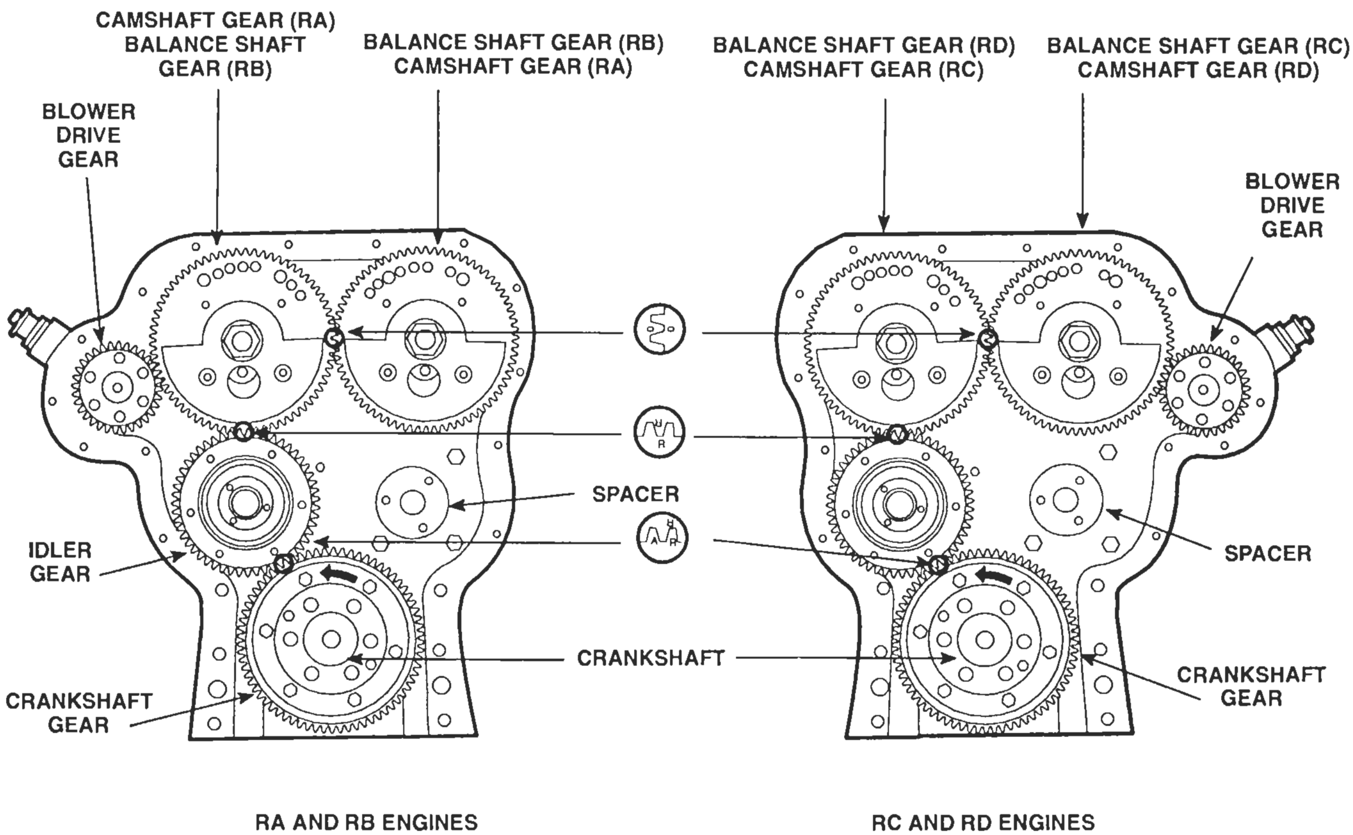


Figure 2. Gear Train and Timing Marks – Right–Hand Rotation Engines (Standard Timing Shown)

GEAR TRAIN (CONT.)

Before removing or replacing any of the gears, it is advisable to line up and make a sketch indicating the position of the timing marks. To do this, rotate the crankshaft until the timing marks are aligned on the camshaft gears. Then, check whether the "A", "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 (Table 1).

CAMSHAFT TIMING	
Standard Timing	Advanced Timing
All two – valve models	All four – valve models with N65 (brown tag), S70, HV7, S80, HV8, S90, HV9, N70, N80 injectors.
All four – valve models with 55E, S55, HV55, 60E, S60, DF6, HE6, 6E8, 6S8, HV6, N55, N60, N65 (white tag) injectors. All DDEC engines.	Except electric power generator and turbo-charged models.
All electric powered generator and turbocharged models.	

TABLE 1 – CAMSHAFT TIMING

Effective with engines 3–71–3858, 4–71–5786 and 6–71–10193, a new gear train with a 19° helix angle replaced the 41° helix gears. The number of teeth was also increased on the new gears (Table 2). Therefore, the gear train must be replaced only in complete sets. Only the 19° helix gears are available for service.

Gear	Number of Teeth	
	41°	19°
Crankshaft	62	78
Idler	54	68
Cam or Balance Shaft	62	78
Blower Drive	32	40

TABLE 2 – GEAR TEETH

Balance weights, one fastened to the inner face of each gear (camshaft and balance shaft) are important in maintaining perfect engine balance. These are in addition to the weights cast integral with the gears.

Gear train noise is usually an indication of excessive gear lash, scoring, pitting 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 is a result of too little gear lash.

Excessive wear and scoring may result from abrasive substances or foreign material in the oil, introduced in the engine by such means as removal of the valve rocker cover without first cleaning away the dirt.

The backlash of the original 41° helix gear trains was .003 to .005 inches. This was revised to .004 to .006 inches effective with engines 3–71–3917, 4–71–5785 and 6–71–10621 after the 19° helix cast iron gears came into use.

The backlash between the various mating gears in the current 19° helix steel gear train is from .003 to .008 inches with new parts and .010 inch with used parts.

Since the camshaft and balance shaft gears each have the same number of teeth as the crankshaft gear, they will turn at crankshaft speed. However, as the blower drive gear has only about half as many teeth as the camshaft or balance shaft gear, it turns at approximately twice the speed of the crankshaft.

SECTION 1.7.1 – GEAR TRAIN AND ENGINE TIMING

LUBRICATION

The gear train is lubricated by overflow oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of oil also spills into the gear train compartment from the camshaft and balance shaft end bearings and the idler gear bearing. The blower drive gear bearing is lubricated through an external pipe leading from the main cylinder block oil gallery to the gear hub bearing support. The idler gear bearing is pressure lubricated by oil passages in the idler gear hub which connect to the oil gallery in the cylinder block.

ENGINE TIMING

The correct relationship between the crankshaft and camshaft 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 camshaft gear can also be mounted in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the timing marks on the various gears will match.

An improperly timed engine may result in pre–ignition, uneven running and 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

Before performing the timing check, provide 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). Then, proceed as follows:

1. Clean and remove the valve rocker cover.
2. Select a cylinder for the timing check. A cylinder adjacent to one of the valve rocker cover bolt or stud holes should be chosen because the stud or bolt may be used to mount a dial indicator.
3. Remove the injector as outlined in Section 2.1 or 2.1.1.
4. Carefully, slide a rod, approximately 12 inch 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 inch graduations and with 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 that 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. Make sure that the indicator spindle is free in the injector tube and is free to travel at least one inch.

CHECK ENGINE TIMING (CONT.)

8. Attach a suitable pointer to the crankshaft front cover or engine front end plate (Figure 3.) The pointer should extend over the vibration damper (or crankshaft pulley).
9. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
10. Reset the dial indicator to zero. Turn the crankshaft until the indicator reading is .010 inch.
11. Scribe a line on the vibration damper (or crankshaft pulley) 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.
13. Set the dial to zero. Then, turn the crankshaft until the indicator reading is .010 inch.

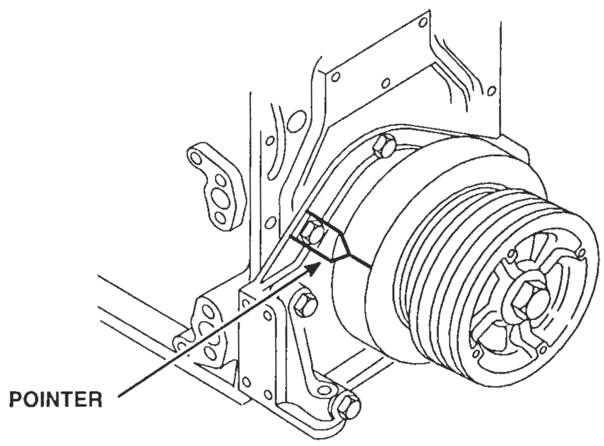


Figure 3. Pointer Installation for Marking Top–Dead–Center

14. Scribe a second line on the vibration damper (or crankshaft pulley) in line with the end of the pointer.
15. Scribe a third line halfway between the first two lines. This is top–dead–center. The three scribed lines are shown on the crankshaft pulley. Remove the indicator and rod from the engine.

NOTE: 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 or 2.1.1. Then adjust (see Section 14) the valve clearance and time the injector.

CHECK ENGINE TIMING (CONT.)

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 (Figure 4.) Then set the indicator 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.

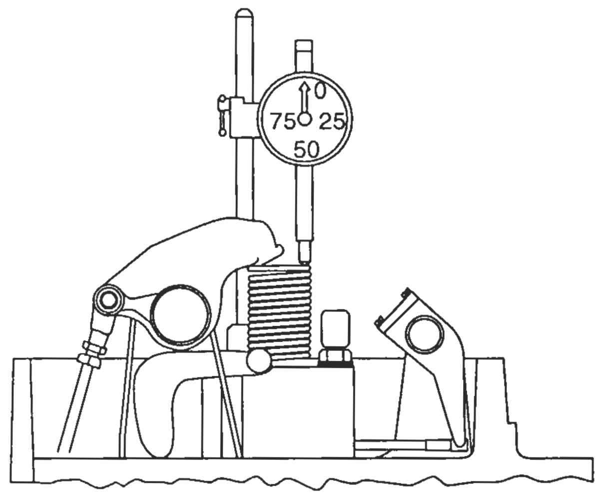


Figure 4. Checking Engine Timing by Measuring Injector Depression

18. Note the indicator reading. Compare it with the dimensions listed in Table 3.
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.

ENGINES	*INDICATOR READING		
	Correct	Ret"d 1–Tooth	Adv. 1–Tooth
(1) 3–71N, 4–71N & 6–71N	.228 in.	.198 in.	.248 in.
(2) 3–71N, 4–71N & 6–71N 6–71T & TT Auto (Pre–1979) 4–71T & 6–71T Industrial – Gen Set	.230 in.	.197 in.	.262 in.
4–71 DDEC	.161 in.	.126 in.	.197 in.
(1) 3–71N, 4–71N & 6–71N (Adv. Cam Timing)	.248 in.	.228 in.	.265 in.
(2) 3–71N, 4–71N, & 6–71N (Adv. Cam Timing)	.262 in.	.230 in.	.289 in.†
6–71T & TT Auto (1979 & later) 6–71TA & TTA Auto (1983 1/2 Federal) 6–71 DDEC	.189 in.	.157 in.	.222 in.
6–71TA–TTA Auto (1980 & later – California)	.144 in.	.111 in.	.177 in.

* Readings nominal – allowable tolerance ± .005 in.
† 3–71N – Via idler gear, 4–71N & 6–71N – Integrally advanced (gear train std. timed)
(1) High velocity type injector cam (Section 1.7.2)
(2) Low velocity type injector cam (Section 1.7.2)

TABLE 3 – INDICATOR READINGS

CAMSHAFT, BALANCE SHAFT AND BEARINGS

The camshaft and the balance shaft are located just below the top of the cylinder block (Figure 1.) and each may be located on either side of the engine as required by engine rotation and accessory arrangement. The camshaft actuates the exhaust valve and injector operating mechanism. The accurately ground cams ensure efficient, quiet cam follower roller action. They are also heat treated to provide a hard wear surface.

Both ends of the cam and balance shaft are supported by bearing assemblies, each consisting of a flanged housing and two bushings. In addition, intermediate two–piece bearings support the camshaft at uniform intervals throughout its length. The intermediate bearings are secured to the camshaft by lock rings, thereby permitting them to be inserted into the cylinder block with the shaft. Each intermediate bearing is secured in place, after the camshaft is installed, with a lock screw threaded into a counterbored hole in the top of the cylinder block.

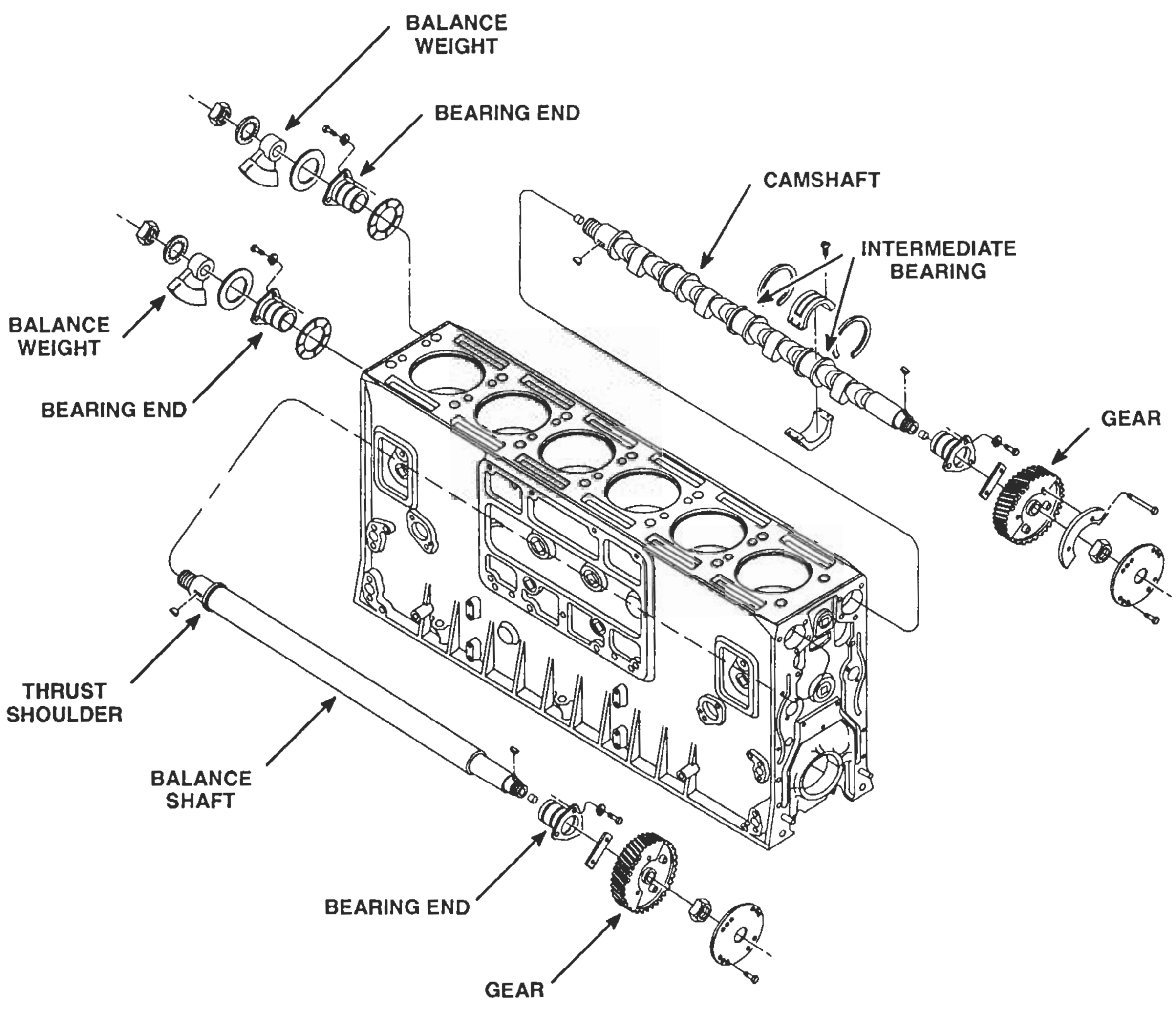


Figure 1. Camshaft and Balance Shaft Assemblies

SECTION 1.7.2 – CAMSHAFT, BALANCE SHAFT AND BEARINGS

The current engines are equipped with a low velocity, low lift injector cam lobe and a long closing ramp exhaust cam lobe design camshaft. Former engines were equipped with a high lift injector cam lobe camshaft. The two camshafts are interchangeable and only the current camshaft, which can be identified by the numeral "7" stamped on one end, is serviced.

On both the camshaft and the balance shaft, the gear thrust load is absorbed by two thrust washers, one on each end of the rear end shaft bearings of the "A" and "D" basic engines and at the front end of the "B" and "C" engines. The thrust washers bear against thrust shoulders on the shafts.

A helical drive gear with a counterweight is secured to each shaft with a Woodruff key (Figure 2.) nut, nut retainer, retainer bolts and lock washers. The drive gears are attached to the rear end of the shafts on all engines.

To help maintain engine balance, a balance weight is installed on the front end of each shaft.

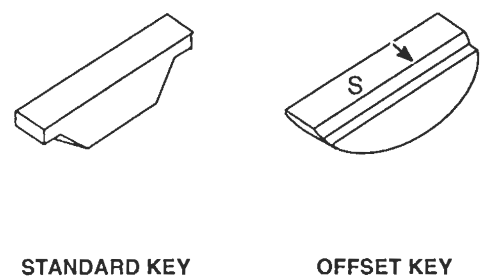


Figure 2. Woodruff Keys for Current Camshafts

ADVANCED TIMING CAMSHAFTS

Effective with four and six cylinder engines built approximately June, 1976 which require advanced timing in conjunction with N65 or larger fuel injectors are equipped with the current camshaft which also has the required advance timing incorporated into the camshaft.

The option data plate is marked to indicate whether an engine was built with the former standard camshaft with advanced gear timing or the current camshaft which has the required advance timing incorporated into the camshaft.

The required advanced timing built into the new (current) camshafts eliminate the need for installing the crankshaft gear one tooth advanced to the "A" position. This was accomplished by relocating the keyways at each end of the camshaft. Continue to use the standard (straight) Woodruff key with the new camshaft. When using the new camshaft make certain the gear train is not in the "A" position.

SERVICE

Only the new camshafts (which have the required advanced timing incorporated into the the camshaft and includes both the standard and offset Woodruff keys) are serviced. Use the new camshafts and straight key combination to service an advanced timed engine. Use the new camshafts and the offset key to service a standard timed engine. The offset key is identified with an S (standard) and an arrow stamped on the face of the key. With the keyways up, always install the offset keys with the arrow pointing inboard toward the center of the engine.

LUBRICATION

Lubricating oil is supplied under pressure to the bearings from the main oil gallery through a horizontal transverse passage at each end of the cylinder block, then up the connecting vertical passages in each corner of the block to the camshaft and balance shaft end bearings. The camshaft intermediate bearings are lubricated by the oil from the end bearings passing through the drilled passage in the shaft.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surface that mates with the upper halves of the bearings (Figure 3.) 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.

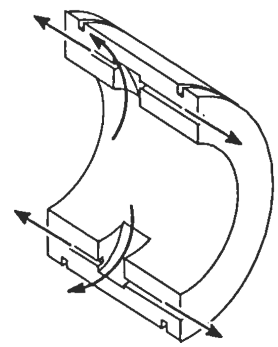


Figure 3. Camshaft Intermediate Bearing (Lower Half)

CAMSHAFT OR BALANCE SHAFT REMOVAL

Whenever an engine is being completely reconditioned or the camshaft, gears, bearings or thrust washers need replacing, remove the shafts from the engine as follows:

1. Drain the engine cooling system.
2. Remove all of the accessories and assemblies necessary to facilitate mounting the engine on an overhaul stand (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 head (Section 1.2).
5. Remove the flywheel and flywheel housing (see Sections 1.4 and 1.5).
6. Remove the front balance weight cover and place a wood block between the balance weights (Figure 4.) or wedge a clean rag between the camshaft and balance shaft drive gears at the rear of the engine.
7. Remove the gear nut retaining plates.

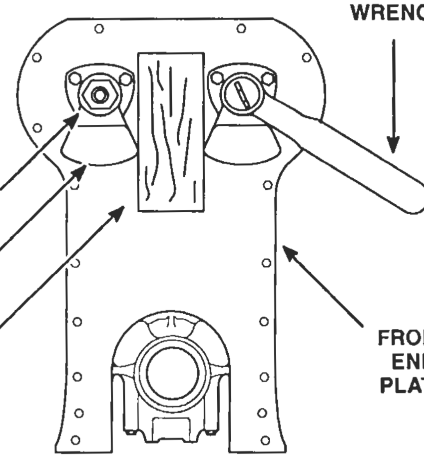


Figure 4. Loosening Nut on Camshaft or Balance Shaft

CAMSHAFT OR BALANCE SHAFT REMOVAL (CONT.)

8. Remove the gear retaining nuts on the gear end of the camshaft and the balance shaft. Remove the nut and lock washer from the balance weight end of each shaft.
9. Remove the front balance weights.
10. Remove the thrust washers between the bearings and the balance weight hubs on "B" and "C" engines.
11. Remove the lock screws that secure the camshaft intermediate bearings.
12. Rotate the gears as required to reveal the end bearing retaining bolts. Remove the bolts (Figure 5.)
13. Withdraw the camshaft bearing and gear assembly and the balance shaft and gear from the rear end of the cylinder block. If the thrust washers, located between the bearings and thrust shoulders at the front end of the shafts of the "B" and "C" engines, are not removed with the shafts, they should be pulled out when removing the bearings.
14. The cam and balance shaft front end bearings (and thrust washers on "B" and "C" engines) may be removed after taking out the bolts that hold the bearings to the end plate and cylinder block. If necessary, use a pry bar under the bearing flange.

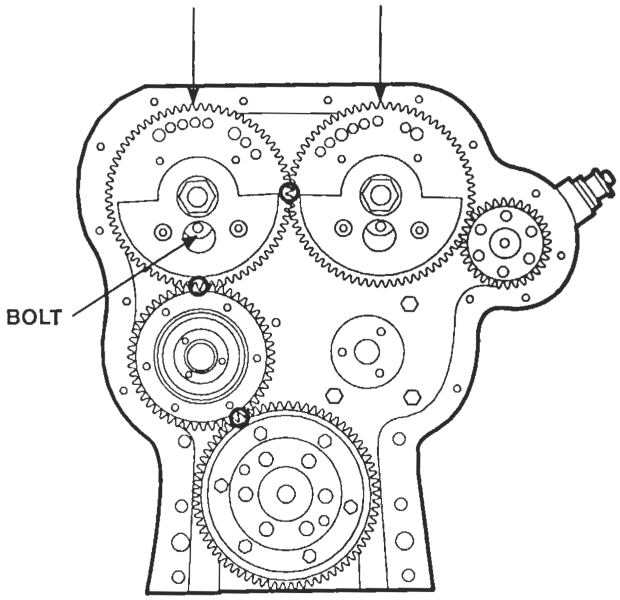


Figure 5. Removing or Installing Shaft Bearing Retainer Bolts

CAMSHAFT REMOVAL (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.

1. Drain the engine cooling system.
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 (see Section 1.2).
4. Remove the front balance weight cover and place a wood block between the balance weights.
5. Remove the gear nut retainer after removing the bolts. Remove the tachometer drive adaptor, if used.
6. Loosen and remove the nut at each end of the camshaft.
7. Remove the front balance weights.
8. Remove the thrust washer between the bearing and the balance weight hub ("B" and "C" engines only).
9. Remove the lock screws that secure the camshaft intermediate bearings.
10. Remove the three bolts that secure the camshaft bearing to the front end plate.

CAMSHAFT REMOVAL (FLYWHEEL HOUSING AND TRANSMISSION IN PLACE) (CONT.)

11. 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 (Figure 6.)
12. Turn the center screw of the puller clockwise to disengage the camshaft from the camshaft gear.

NOTE: 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 washer on "A" and "D" engines) securely in place and in alignment which will aid in the reinstallation of the camshaft.

13. Remove the front bearing from the camshaft and pull out the inner thrust washer ("B" or "C" engines). Then pull the camshaft and intermediate bearings from the cylinder block.

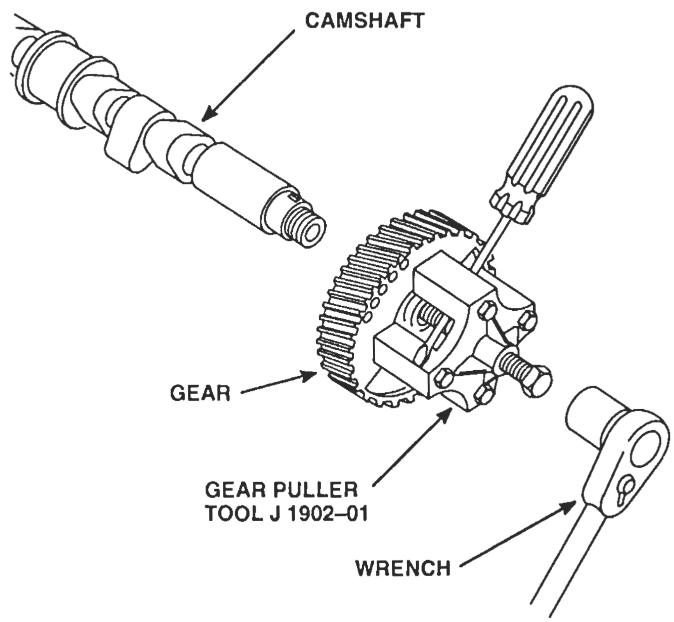


Figure 6. Removing Camshaft with Camshaft or Balance Shaft Gear Puller

DISASSEMBLE CAMSHAFT AND BALANCE SHAFT

1. Remove the gear from the shaft (Section 1.7.3).
2. Slide the rear bearing (and the thrust washer on the "A" and "D" engines) off of the shaft.
3. Remove the lock rings from the camshaft intermediate bearings and free the two halves of each bearing.
4. To facilitate the removal of any foreign material lodged behind the plugs, remove the end plugs from each camshaft 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 inch 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 inch drill (carboloy tip).
   e. Use the 1/4 inch drilled hole as a guide and drill the plug with a 5/16 inch drill (carboloy tip).
   f. Tap the drilled hole with a 3/8–16 tap.
   g. Thread the 3/8–16 adaptor J 6471–2 into the plug. Then, attach the slide hammer J 2619–5 to the adaptor. Remove the plug by striking the weight against the handle.
   h. Insert a .375 inch diameter steel rod into 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".

SECTION 1.7.2 – CAMSHAFT, BALANCE SHAFT AND BEARINGS

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 gallery and the oil holes with compressed air. Clean the gears, camshaft bearings and related parts with fuel oil and dry them with compressed air.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam followers (Section 1.2.1). Also, inspect the camshaft keyways and threads for damage.

If there is a doubt as to the acceptability of the camshaft for further service determine the extent of cam lobe wear as follows:

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gages (.0015–.0100) and a piece of square hard material 1/8 x 3/8 x 1 inch measure the flat on the injector rise side of the cam lobes (Figure 7.)
2. If the flats measure less than .003 inch in depth and there are no other defects the camshaft is satisfactory for service.
3. A slightly worn lobe still within acceptable limits, may be stoned and smoothed over with a fine crocus cloth.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Runout should not exceed .002 inch.

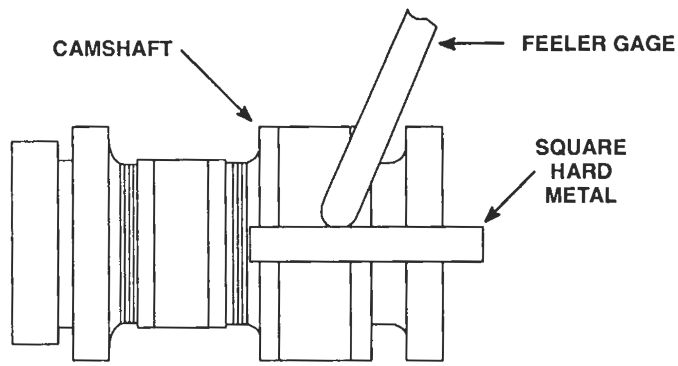


Figure 7. Checking Cam Lobe Wear

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, thoroughly clean it to remove the rust preventive and blow out the oil passages with compressed air.

Thrust washers are .119 to .122 inches thick. The clearance between the thrust washer and the thrust shoulder of the camshaft is .003 to .015 inch with new parts, or a maximum of .018 inch with used parts. Excessive clearance may be reduced by using thrust washers which are .005 inch or .010 inch oversize.

When the thrust surfaces of a camshaft or balance shaft are ground undersize, special care must be taken as follows:

1. Leave a .031 to .094 inch radius between the bearing surface of the thrust collar shoulder and the bearing surface of the camshaft (Figure 8.)
2. Leave a .010 to .030 inch radius between the bearing surface of the thrust collar shoulder and the bearing surface of the balance shaft.

Use a fillet radius gage to measure the specified radii.

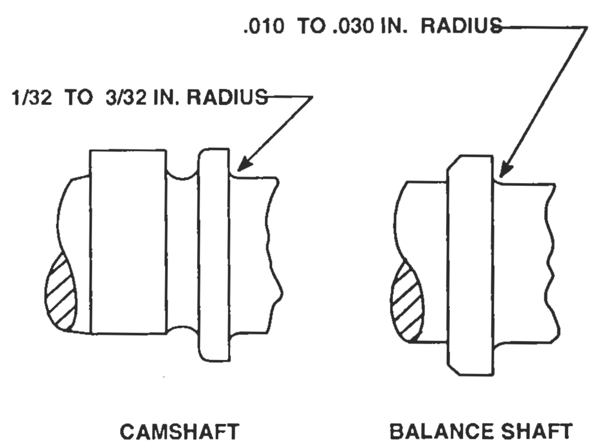


Figure 8. Camshaft and Balance Shaft Journal Fillets

DISASSEMBLE CAMSHAFT AND BALANCE SHAFT (CONT.)

Examine the faces of the shaft end bearings and any other surface which comes into contact with the thrust washers. Parts that are badly marred must be replaced; parts with slight scratches may be cleaned up with an oil stone. If a new camshaft is to be installed, thoroughly clean it to remove the rust preventive and blow out the oil passages with compressed air.

Inspect the bushings in the shaft end bearings. Replace the bushings or end bearing assemblies if they are worn excessively or the bushings have turned within the bearing. New bushings must be finished bored to a 20 rms finish after installation and tested for the correct press fit. The correct press fit is indicated if the bushing does not move when a 2000 pound end load is applied. This test is of special importance with engines that operate at high (2,300 r/min) speeds. The inside diameter of the bushings must be square with the rear face of the bearing within .0015 inch total indicator reading and concentric with the outside diameter of the bearing retainer within .002 inch total indicator reading. The bushings must project from .045 to .055 inch from each end of the bearing (Figure 9.)

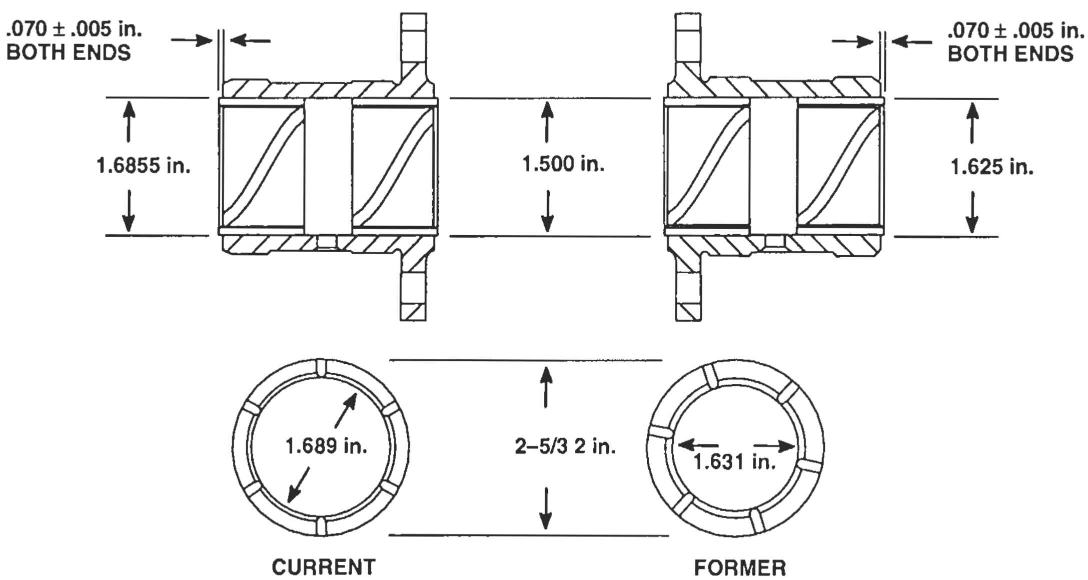


Figure 9. Comparison of End Bearings and Thrust Washers

The clearance between the camshaft and balance shaft end journals and the end bearing bushings is .002 to .004 inches with new parts or a maximum of .006 inch with used parts. End bearings are available in .010 or .020 inches undersize for use with shafts that are worn or have been reground and the clearances exceed the specified limits.

Replace excessively scored or worn camshaft intermediate bearings. The clearance between the camshaft journals and the intermediate bearings is .0025 to .005 inches with new parts or a maximum of .009 inch with worn parts. Camshaft intermediate bearings are available in .010 and .020 inches undersize for use with worn or reground shafts in which the clearances exceed the specified limits. Examine the intermediate bearing lock screws and the tapped holes in the block. Damaged holes in the cylinder block may be plugged, drilled and tapped. Discard lock screws with damaged threads.

ASSEMBLE CAMSHAFT AND BALANCE SHAFT

Assemble the camshaft and balance shaft (Figure 10.) as follows:

1. Coat the sides of the camshaft plugs with a light coating of Permatex Hi–Tack® or equivalent.

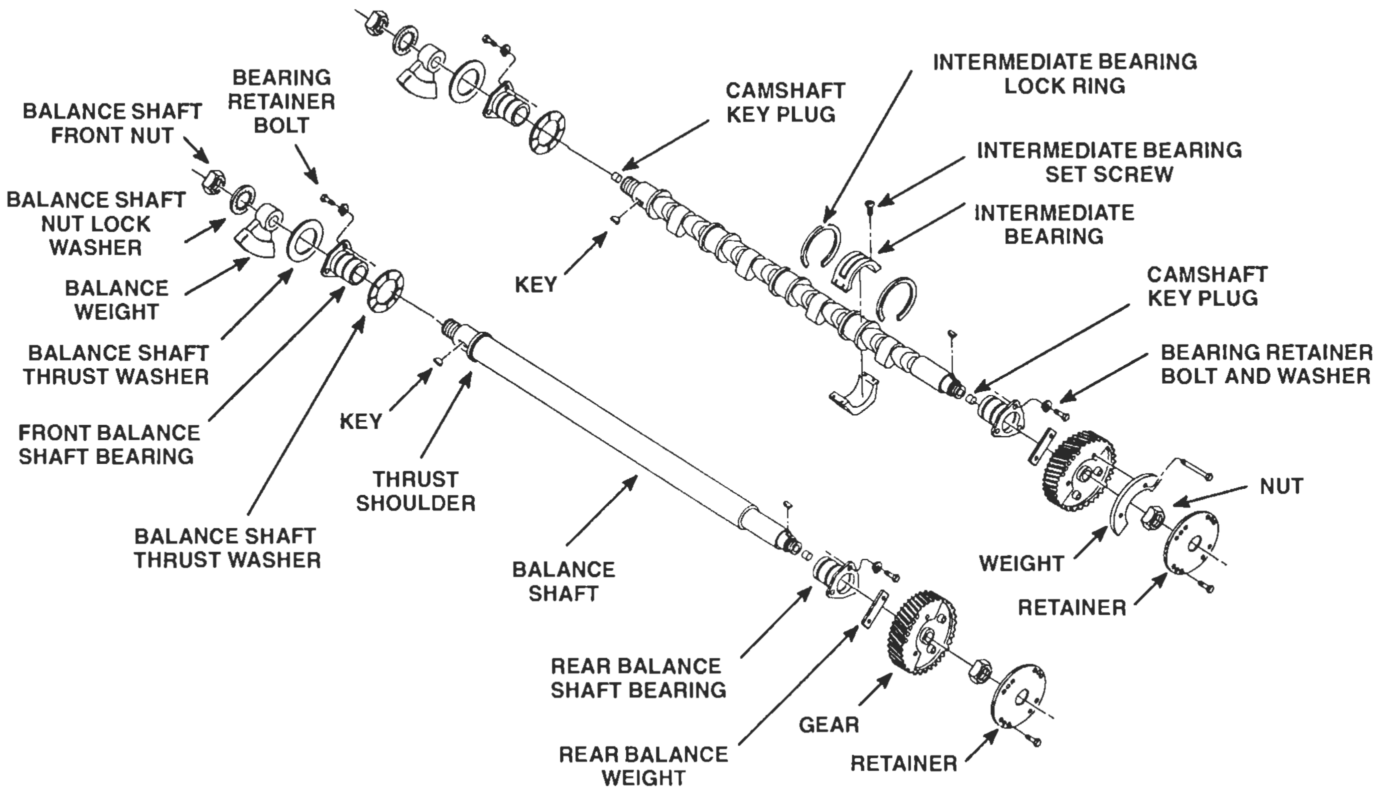


Figure 10. Typical Camshaft and Balance Shaft Parts

2. Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940 to 2.060 inches (Figure 11.)

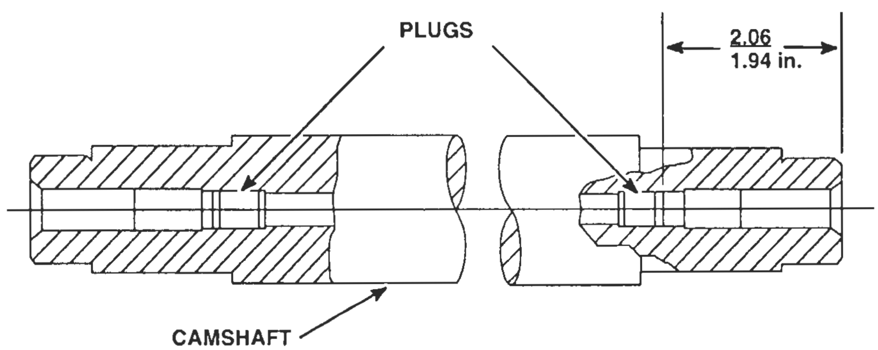


Figure 11. Camshaft Plug Installation

ASSEMBLE CAMSHAFT AND BALANCE SHAFT (CONT.)

3. Apply grease to the steel face of each end thrust washer. Then, place a thrust washer against each end of the camshaft and balance shaft rear bearings ("A" and "D" engines). Be sure the steel faces of the thrust washers are next to the bearing.

Effective with engines 3A–27384, 4A–59280, 6A–57745 and 8A–1446, the camshaft and balance shaft end bearings incorporated bushings with a larger outside diameter and greater wall thickness. To accommodate the larger bushing, the former bearings may be rebored to an inside diameter of 1.685–1.686 inches. The thrust washer used with this bearing must have a larger inside diameter.

4. Lubricate the rear camshaft and balance shaft bearing journals and slide the rear end bearings on each shaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.
5. Install the gears on the shafts.
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. Two intermediate bearing lock rings are used. The current ring can be identified by the wider gap. The wide gap ring MUST be used with the grooved type lower half bearings and can also be used with the former intermediate bearings.

INSTALL CAMSHAFT AND BALANCE SHAFT

1. Insert the front end of the camshaft into the opening on the blower side of the LA, LC, RA, and RC engines and on the opposite side of the LB, LD, RB and RD engines. Push the camshaft into the cylinder block until the camshaft gear teeth almost engage the teeth of the mating gear. Use care when installing the camshaft to avoid damaging the cam lobes. The right–hand gear (viewing the engine from the flywheel end), whether it is attached to the camshaft or the balance shaft, has left–hand helical teeth.
2. Align the timing marks on the mating gears (Section 1.7.1) and slide the camshaft gear in place.
3. Secure the camshaft rear end bearing to the cylinder block with the three bolts and lock washers. Rotate the camshaft gear, as required, to install the bolts through the hole in the gear web. Tighten the bolts to 35–40 lb·ft (47–54 N·m) torque.
4. Insert the balance shaft in the bore in the cylinder block and push it in until the teeth of the balance shaft gear almost engage the camshaft gear teeth.
5. Align the timing marks on the mating gears (Section 1.7.1) and slide the balance shaft gear into place.
6. Secure the balance shaft rear end bearing. Use the same procedure as outlined for the camshaft rear end bearing (Step 3).
7. Apply grease to the steel face of each thrust washer. Then, place a thrust washer against the inner end of the camshaft and balance shaft front end bearing ("B" and "C" engines). The steel face of the thrust washer must be against the bearing.
8. Install the camshaft and balance shaft front end bearings with the bolts and lock washers. Tighten the bolts to 35–40 lb·ft (47–54 N·m) torque.

NOTE: Install the front bearings with care to avoid dislodging the thrust washers. Do not hammer the bearings into the cylinder block.

9. Apply grease to the steel face of each thrust washer and place them so that the steel faces are against the outer end of the camshaft and balance shaft front bearings on "B" and "C" engines.

INSTALL CAMSHAFT AND BALANCE SHAFT (CONT.)

10. 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 (Figure 12.).

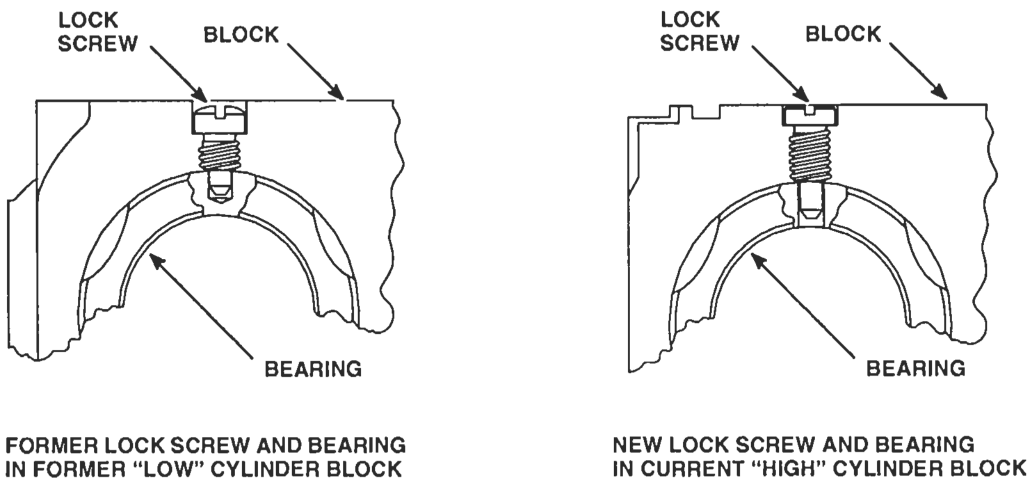


Figure 12. Camshaft Intermediate Bearing Lock Screws

11. Install the front balance weights on the shafts.
12. Place an internal tooth lock washer on the end of each shaft and start the nuts on both shafts.
13. Use a wood block between the balance weights or wedge a clean cloth between the camshaft and balance shaft gears to prevent their turning. Tighten the nuts to 300–325 lb·ft (407–441 N·m) torque.
14. Install the camshaft and balance shaft gear nut retainers with bolts and lock washers. Tighten the bolts to 35–39 lb·ft (47–53 N·m) torque.
15. Check the clearance between the thrust washer and the thrust shoulder of both the camshaft and balance shaft. The specified clearance is .003 to .015 inches with new parts or a maximum of .018 inch with used parts.
16. Check the backlash between the mating gears. The specified backlash between new gears is .003 to .008 inches or a maximum of .010 inch between worn gears.
17. Install the flywheel housing and other parts or assemblies that were removed from the engine, as outlined in their respective section of this manual.
18. Refill the cooling system.

INSTALL CAMSHAFT (FLYWHEEL HOUSING AND TRANSMISSION IN PLACE)

1. On the "A" and "D" engines, apply grease to the steel face of the thrust washer and install it with the steel face against the bearing.
2. 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 shaft in until it slides into the rear end bearing. Use care in the installation of the camshaft to prevent damage to the cam lobes. Install the woodruff keys in the current advanced timed camshafts.
3. Align the key in the shaft with the keyway in the camshaft drive gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

NOTICE:
On the "A" and "D" engines, make sure the thrust washer is in the correct position to prevent pushing the bushing into the bearing or damaging the bushing.

4. Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.
5. Install the front end bearing (and thrust washers on "B" and "C" engines) with the bolts and lock washers. Tighten the bolts to 35–40 lb·ft (47–54 N·m) torque. Apply grease to the steel faces of the thrust washers and insure that the steel faces are towards the bearing.
6. Install the balance weight on the front end of the camshaft.
7. Start the balance weight retaining nut and lock washer on the camshaft. Place a wood block between the balance weights. Tighten the gear retaining nut and the balance weight nut to 300–325 lb·ft (407–441 N·m) torque.
8. Align the holes in the camshaft intermediate bearings with the tapped holes in the top of the cylinder block (Figure 11.). Install and tighten the lock screws to 15–20 lb·ft (20–27 N·m) torque.
9. Reinstall the parts, accessories and assemblies that were removed from the engine as outlined in their respective sections in this manual.
10. Refill the cooling system.

CAMSHAFT AND BALANCE SHAFT GEARS

The camshaft and balance shaft gears, located at the flywheel end of the engine, mesh with each other and run at the same speed as the crankshaft (Figure 1.) Either one of the gears may be driven from the crankshaft timing gear, through an idler gear, depending upon engine rotation. Viewing the engine from the flywheel or gear train end, the right–hand gear, whether on the balance shaft (LA, LD, RA, RD engines) or camshaft (LB, LC, RB, RC engines), has left–hand helical teeth and the left–hand gear has right–hand helical teeth. The idler gear mates with the left–hand gear on right–hand rotation engines and with the right–hand gear on left–hand rotation engines.

Since the camshaft and balance shaft gears must be in time with each other, the letter "O" is stamped on one tooth of one of the gears with a corresponding mark at the root of the mating tooth of the other gear. Also, since these two gears as a unit must be in time with the crankshaft, identification marks (letter "R" or "L" for right–hand or left–hand rotation engines, respectively) are located on either the camshaft gear or balance shaft gear and the mating idler gear (Section 1.7.1).

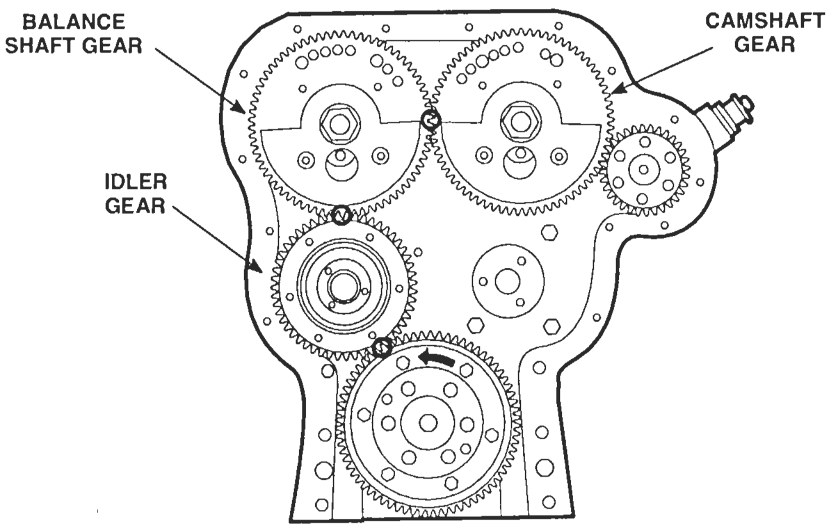


Figure 1. Camshaft and Balance Shaft Gears

The camshaft and balance shaft gears are keyed to their respective shafts and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut and prevents loosening of the nut. The retainer is attached to the gear by bolts threaded into tapped holes in the gear. These tapped holes are also utilized in mounting an accessory drive on the camshaft or balance shaft gear.

The same two gears are used as camshaft and balance shaft gears on three, four and six cylinder engines. A small balance weight is attached to the inner face of each gear. A different size weight is used on three, four and six cylinder engines. The three cylinder engine weight is secured to the gear with two 3/8–24 x 1–1/8 inch bolts, the four cylinder engine weight is secured with two 3/8–24 x 1–3/8 inch bolts and the six cylinder engine weight is secured with two 3/8–24 x 1–1/4 inch bolts. These weights are important in maintaining perfect engine balance.

NOTE: The current one–piece design balance weight used on the gears of six cylinder engines is interchangeable with the two–piece weight used on former 19° helix cast iron gears. However, the current and former design balance weights for four cylinder engine gears are not interchangeable.

SECTION 1.7.3 – CAMSHAFT AND BALANCE SHAFT GEARS

CAMSHAFT AND BALANCE SHAFT GEAR REMOVAL

1. Remove the camshaft and balance shaft from the engine (Section 1.7.2).
2. Support the camshaft suitably in the soft jaws of a bench vise, being careful not to damage the cams.
3. Remove the nut retaining the gear on the camshaft.
4. Back out the puller screw of tool J 1902–01 and attach the puller to the outer face of the gear with four bolts (Figure 2.)
5. Turn the puller screw down against the end of the shaft to remove the gear.
6. Remove the gear from the balance shaft in a similar manner.
7. If necessary, remove the two weight retaining bolts and remove the balance weights from each gear.
8. If necessary, remove the keys from the camshaft and balance shaft.

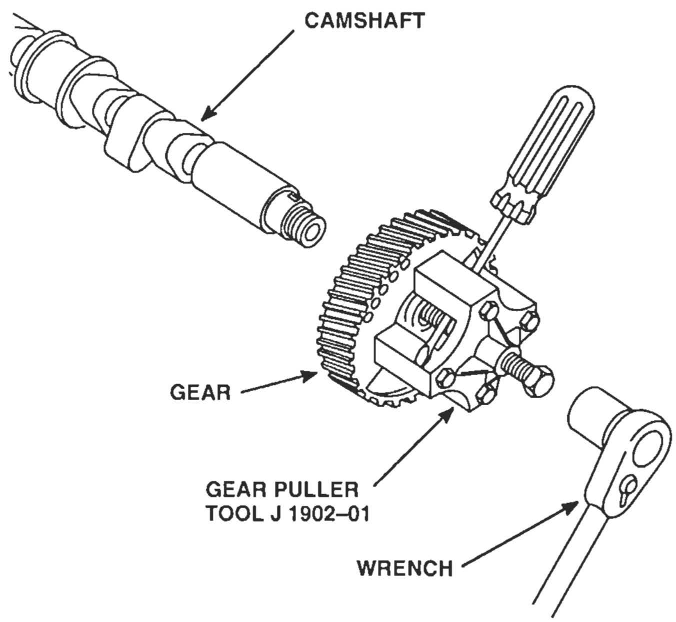


Figure 2. Removing Camshaft or Balance Shaft Gear

INSPECTION

Clean the gears with fuel oil and dry them with compressed air. Then, examine the gear teeth for evidence of scoring, pitting and wear. If severely damaged or worn, install a new gear. Also, check the other gears in the gear train.

CAMSHAFT AND BALANCE SHAFT GEAR INSTALLATION

1. Install the balance weights, if removed, on the gears.
2. Lubricate the shaft journals and place the camshaft and balance shaft end bearings in place, with the bolting flanges facing toward the gear ends of the shafts. If the engine being serviced is an “A” or “D” engine, install the thrust washers between the end bearings and the thrust shoulders of the shafts, and between the end bearings and the gears.

NOTE: Be sure the steel faces of the thrust washers are next to the bearings.

3. Install the Woodruff keys for the gears in both shafts.
4. Note that the teeth on one gear form a right–hand helix and on the other a left–hand helix. When viewing the engine from the flywheel end, the gear with right–hand helical teeth is located on the left–side and the gear with left–hand helical teeth is located on the right–side of the engine. With this in mind, rest on the non–gear end of the camshaft on a wood block and start the gear on the other end of the shaft by hand so the keyway aligns with the key and with the flat finished face of the gear away from the bearing.

CAMSHAFT AND BALANCE SHAFT GEAR INSTALLATION (CONT.)

5. Use gear installer J 1903 to drive the gears on the camshaft and balance shaft (Figure 3.)

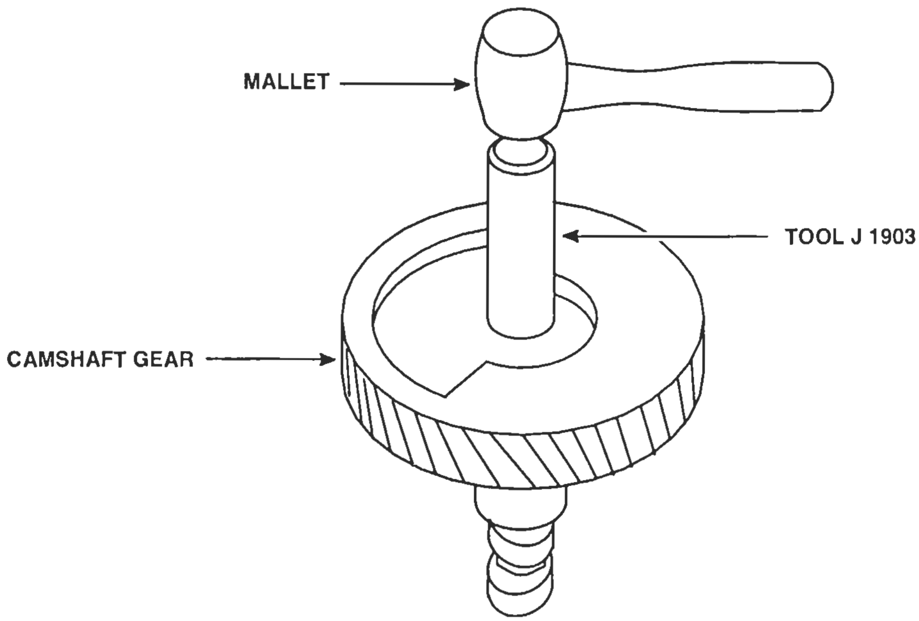


Figure 3. Replacing Camshaft Gear

6. Start the gear retaining nuts on their respective shafts by hand. Tighten the nuts after the shafts have been installed in the cylinder block.
7. Install the camshaft and balance shaft in the engine (Section 1.7.2).
8. With the shafts and the front balance weights installed, wedge a clean cloth between the camshaft and balance shaft gears and tighten the gear retaining nuts to 300–325 lb·ft (407–441 N·m) torque.
9. Secure the nuts with retainers, retainer bolts and lock washers.
10. Check the backlash between the mating gears. The backlash should be .003–.008 inches with new parts or .010 inch maximum with used parts.

IDLER GEAR AND BEARING ASSEMBLY

When replacing any part of the gear assembly a complete current roller bearing idler gear assembly must be used.

The idler gear is mounted on a double row, tapered roller bearing which, in turn, is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate. A hollow dowel serves a two–fold purpose; first, as a locating dowel it positions the hub and prevents it from rotating and, second, conducts oil under pressure from an oil gallery in the cylinder block through a passage in the gear hub to the roller bearing. The idler gear bearing consists of two cups, two cones and an outer and inner spacer ring.

The inner and outer cones of the idler gear bearing are pressed onto the gear hub and, therefore, do not rotate. Spacer rings or a spacer, separate the cones. The bearing cup(s) has a light press fit in the idler gear and is held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six bolts and three bolt locks on the other side.

A right–hand helix gear is provided for left–hand rotation engines, and a left–hand helix gear is provided for right–hand rotation engines (Section 1.7.1).

An idler gear hole spacer (dummy hub) is used on the side opposite the idler gear. No gasket is used between the idler gear hub or dummy hub and the flywheel housing. The flywheel housing bears against the inner races of the idler gear bearing and also against the dummy hub. Three self–locking bolts and steel washers are used to attach the flywheel housing at the idler gear and dummy hub locations. The washers seat in 7/8 inch spot faces at the flywheel housing attaching bolt holes, thus preventing oil leakage at these locations.

To minimize oil leakage into the flywheel housing, a idler gear spacer (dummy hub) is now being used in those engines not equipped with an integral idler gear spacer type flywheel housing (Figure 1.)

The flanged hex head bolts with a self locking sealing patch should be used with the spacer. Do not use a flat washer under the flanged head bolts.

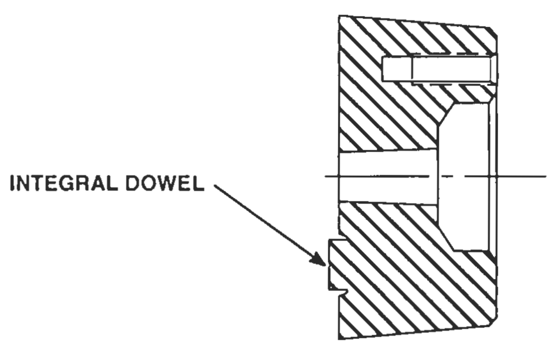


Figure 1. Idler Gear Spacer

REMOVE IDLER GEAR, HUB AND BEARING ASSEMBLY AND IDLER GEAR HOLE SPACER (FLYWHEEL HOUSING PREVIOUSLY REMOVED)

1. Remove the idler gear hub to cylinder block bolt and washer and withdraw the assembly from the cylinder block rear end plate.

NOTE: Before removing the idler gear check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure is applied by firmly grasping the rim of the gear with both hands and rocking 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. Remove the idler gear hole spacer (Section 1.7.1) in the same manner if the engine is being completely reconditioned.

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.

Disassemble the bearing as follows:

1. Remove the six bolts and three bolt locks which secure the bearing retainer to the idler gear, and remove the bearing retainer.

NOTE: The component parts of the idler gear bearing are matched and therefore, matchmark the parts during disassembly to ensure reassembly of the parts in their original positions.

2. Clean the idler gear and bearing assembly with fuel oil and dry it with compressed air.
3. Place the idler gear and bearing assembly in an arbor press with the bearing cone or inner race supported on steel blocks (Figure 2.) While rotating the gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacers.

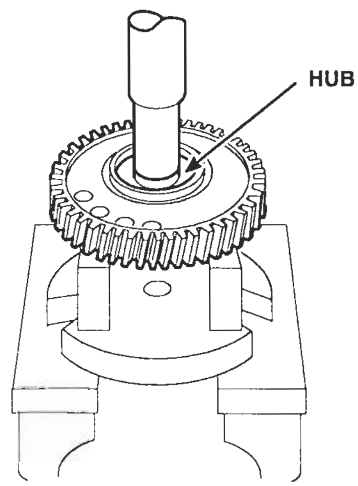


Figure 2. Pressing Hub Out of Bearing

4. Tap the bearing cups and spacer rings (current gear) or bearing cup and spacer (former gear) from the idler gear by using a brass drift alternately at four notches provided around the shoulder of the gear (Figure 3.)

NOTICE:

Use care to prevent the rollers from scattering. If this should occur, the bearing should not be reassembled and reused since the rollers were selectively mated to the bearing races when originally manufactured. A new bearing assembly must be used.

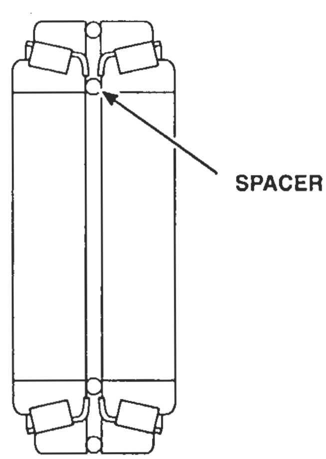


Figure 3. Idler Gear Bearing

INSPECTION

Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Inspect the bearings 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.

IDLER GEAR, HUB AND BEARING ASSEMBLY

CURRENT BEARING

Assemble the bearing components (Figure 4.) in their original positions (refer to identification marks made during disassembly) as outlined below:

NOTE: The idler gear bearing is a matched assembly. Do not mix components.

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.

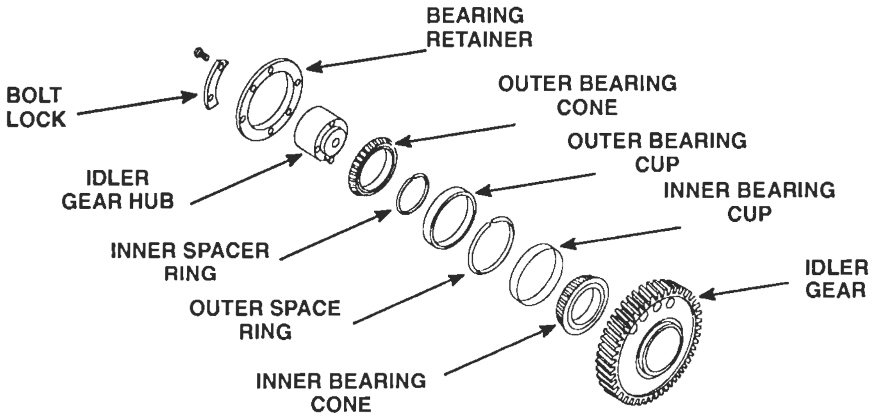


Figure 4. Idler Gear and Relative Parts

5. Lay the outer spacer ring on the face of the bearing cup.
6. 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.
7. 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.
8. 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.

IDLER GEAR, HUB AND BEARING ASSEMBLY (CONT.)

9. Position the gear with both cups over the hub and the inner bearing cone.
10. 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 (Figure 5.)
11. Before installing the gear and bearing assembly, check the pre–load.

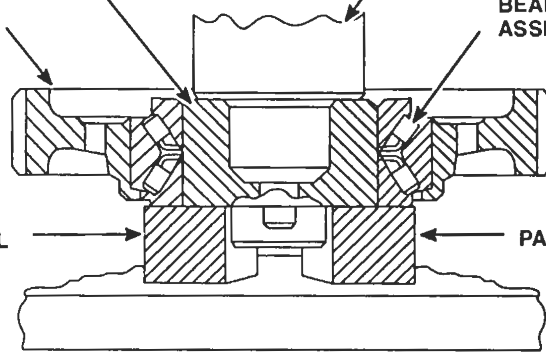


Figure 5. Pressing Hub into Bearing

CHECK BEARING PRE–LOAD

The rollers of the bearing are loaded between the bearing cup and bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be more tightly held between the cones and cup. In the idler gear bearings, a slight pre–load is applied by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre–loading is measured, in terms of pounds–pull, by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs, the pre–load should be measured as part of the operation.

The idler gear bearing 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 or balance shaft gears (depending upon engine rotation) 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 inches square (pre–load test plate) against the hub and cone as follows:

1. Mount the idler gear assembly on the engine.
2. Install the center bolt (1/2–13 x 2 1/2 inch bolt) and washer through the gear hub and into the cylinder block. Tighten the bolt to 80–90 lb·ft (108–122 N·m) torque.
3. Place steel plate against hub and bearing. Insert three 3/8–16 bolts through the plate and thread them into the hub. Tighten the bolts to 24–40 lb·ft (34–54 N·m) torque.

CHECK BEARING PRE–LOAD (CONT.)

4. Tie one end of a piece of lint–free 1/8 inch cord around a 1/8 inch round piece of wood (or soft metal stock). Place the wood between the teeth of gear, then wrap the cord around the periphery of the gear several times. Attach the other end of the cord to spring scale, J 8129. Maintain a straight, steady pull on the cord (Figure 7.) 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 ounces, the idler gear and bearing assembly are satisfactory for use.

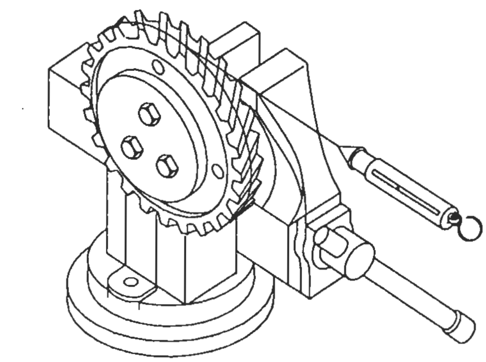
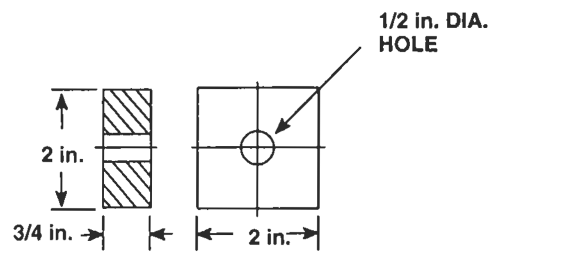
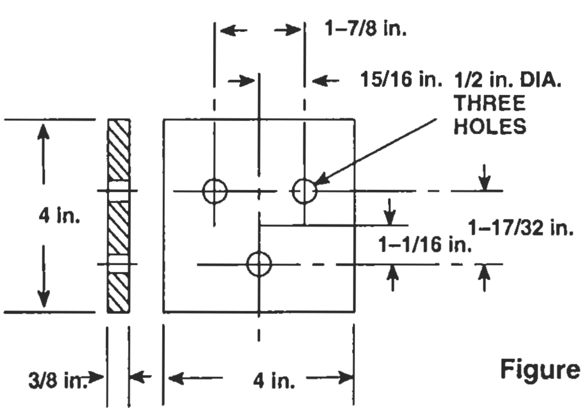


Figure 6. Checking Pre–Load of Idler Gear Bearing

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture, which may be held in a vise, can be used. Three plates (Figure 6.) a 1/2–13 x 2 3/4 inch bolt and a plain washer are used with a 1/2–13 inch 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 are for 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.





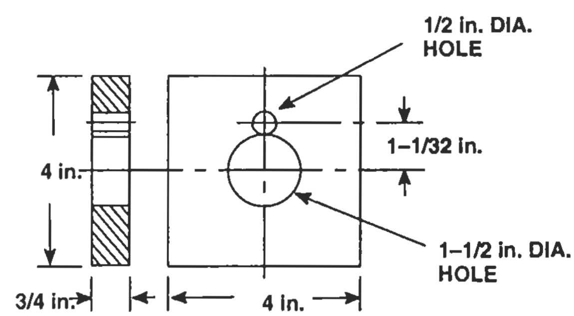


Figure 7. Plates for Bearing Test Fixture

CHECK BEARING PRE–LOAD (CONT.)

Check the pre–load as follows:

1. Attach the plates to the idler gear with 1/2–13 bolt, washers and nuts (Figure 8.) 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 vise.
4. Attach the cord to the idler gear and spring scale and check the pre–load as outlined in Step 4 of the previous method.

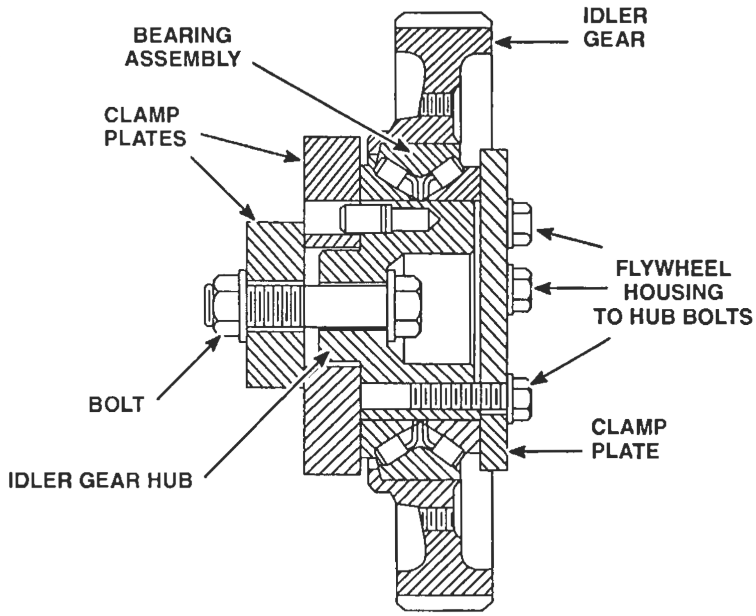


Figure 8. Fixture for Testing Bearing Pre–Load

If the scale reading is within the specified 1/2 to 4 lbs. but fluctuates more than the permissible 2 lbs. 11 ounces, the idler gear and bearing assembly must not be installed on the engine. Fluctuations in scale reading may be caused by the cones or races not being concentric to each other, damaged cones or races 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 should be replaced.

After the pre–load test is completed, remove the steel plates and install the bearing retainer as follows:

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.

NOTE: Do not use standard bolts and do not use the former bolt locks.

Idler gear assemblies which have a total length of 1.514 to 1.519 inch are to be used only on engines equipped with a cast iron flywheel housing. Idler gear assemblies with a total length of 1.509 to 1.514 inches are used on engines with an aluminum flywheel housing and may also be used with cast iron housings.

IDLER GEAR, HUB AND BEARING ASSEMBLY INSTALLATION

1. Position the crankshaft gear and either the balance shaft or camshaft gear (depending upon engine rotation) so that the timing marks will align with those on the idler gear (Section 1.7.1).
2. With these marks in alignment, start the idler gear into mesh with the crankshaft gear and either the camshaft or balance shaft gear, and simultaneously rotate the gear hub so that the hollow dowel at the inner face of the hub registers with the oil hole in the end plate.
3. Roll the idler gear into position, align the hollow dowel with the hole in the end plate, and gently tap the hub until it seals against the end plate. Thus, the hollow dowel in the hub will conduct oil through the end plate and into the hub where it flows through a drilled passage to the roller bearing.
4. After making sure that the hub is tight against the end plate, secure the idler gear assembly with a 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). 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.

NOTE: Current engines use a new idler gear hub and idler gear hole spacer (dummy hub) which requires 1/2–13 x 2–1/2 inch retaining bolts, replacing the 1/2–13 x 2 inch bolts formerly used.

6. Lubricate the idler gear and bearing liberally with clean engine oil.
7. Check the backlash between the mating gears. The backlash must be .002 to .008 inches between new gears and must not exceed .010 inch between used gears.
8. No gasket is used between the roller bearing type idler gear assembly and the flywheel housing.

NOTE: Make sure the oil passage in the cylinder block is plugged at the dummy hub location.

9. Install the flywheel housing (Section 1.5).

CRANKSHAFT TIMING GEAR

The crankshaft timing gear is bolted to the flange at the rear end of the crankshaft and drives the camshaft gear (LB, LC, RA and RD engines) or balance shaft gear (LA, LD, RB and RC engines) through an idler gear.

Since the camshaft must be in time with the crankshaft, timing marks are located on two teeth of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (Section 1.7.1).

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 and lock washers securing the gear to the crankshaft.
4. Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then remove the gear with a suitable puller (Figure 1.)

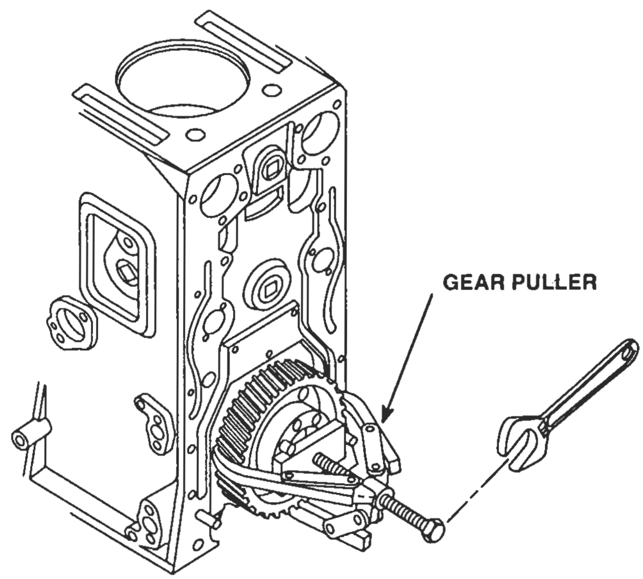


Figure 1. Crankshaft Timing Gear Removal

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 lb/in^2 (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.

CRANKSHAFT TIMING GEAR INSTALLATION

1. Position the gear on the rear end of the crankshaft with the flat finished hub of the gear facing toward the cylinder block and with all six 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 ("L" or "R") on the crankshaft gear tooth with the corresponding mark on the idler gear (Section 1.7.1).

NOTE: When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

3. Start the six 3/8–24 inch bolts with lock washers 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 N·m) torque.
4. Check the backlash with the mating gear. The backlash should be .003 to .008 inches with new gears or .010 inch maximum with used gears.
5. Install a new crankshaft rear oil seal sleeve if required (Section 1.3.2).

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

The blower drive gear is mounted on the blower drive gear support and in addition to driving the blower, drives the governor, water pump and fuel pump. The drive is cushioned by a spring–loaded flexible coupling which insures a uniform rotation of the blower rotors (Figure 1.)

The left–hand helix blower drive gear is driven by the camshaft gear on LA and RA engines and the balance shaft gear on LB and RB engines. The right–hand helix blower drive gear is driven by the camshaft gear on LC and RC engines, and the balance shaft gear on LD and RD engines (Section 1.7.2).

NOTE: The 39 tooth and the 40 tooth blower drive gears are interchangeable, however, the governor will have to be adjusted to compensate for the change in the governor drive speed.

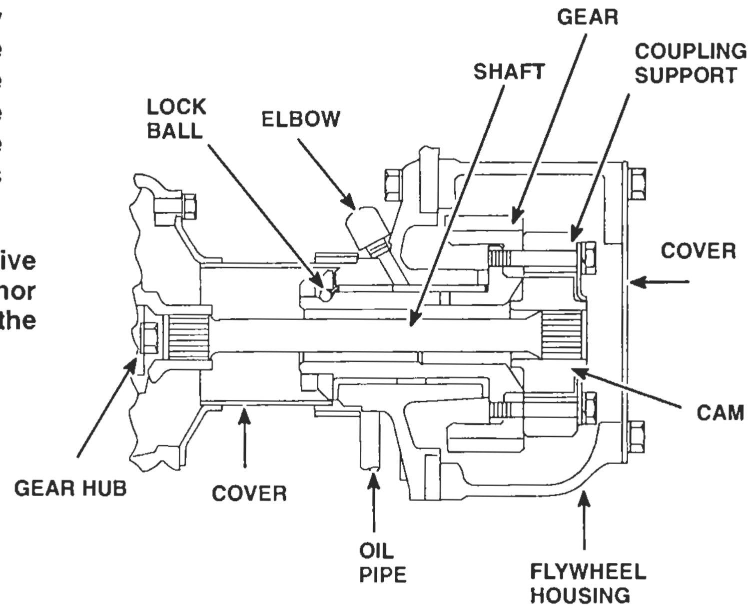


Figure 1. Blower Drive Gear and Support Assembly

A new blower drive support assembly has replaced the former assembly (Figure 2.) The new and former blower drive assemblies are different in that the flanged bearing, which also served as a thrust surface, has been replaced by a new bearing. The inner bearing of the new assembly protrudes slightly from the inner face of the support to facilitate installation of and to serve as a pilot for the thrust washer.

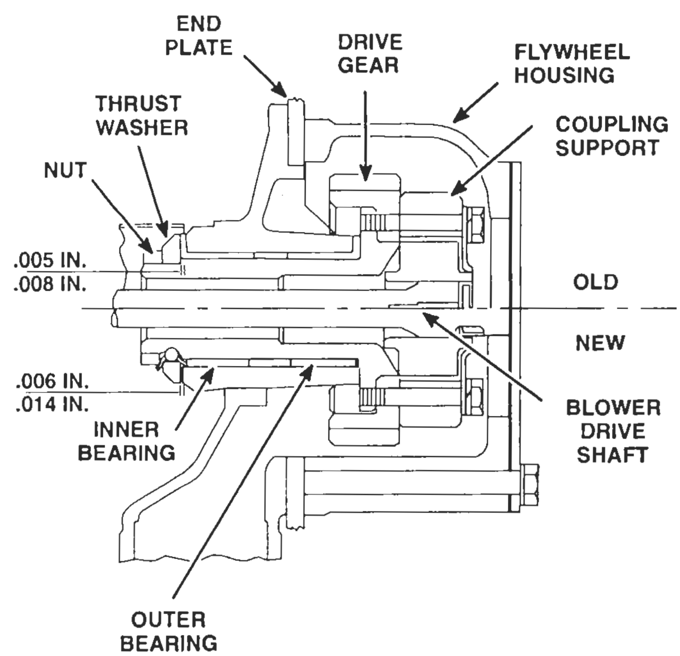


Figure 2. Blower Drive Support Assembly

SECTION 1.7.6 – BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

REMOVE AND INSTALL BLOWER DRIVE SHAFT

If the blower drive shaft is not broken, it may be removed as follows:

1. Remove the six bolts that secure the flywheel housing small hole cover.
2. Remove the snap ring (Figure 3.) and pull the blower drive shaft out of the drive assembly.

NOTE: Some shafts have a tapped hole in the end which can be used as an aid in removing the shaft.

If the blower drive shaft is broken and it is not possible to remove all of the pieces, it will be necessary to remove the blower (Section 3.4).

A broken drive shaft indicates an unusual loading which may have been caused by a bearing failure or other malfunction. Inspect the blower drive, blower rotors and the housing before replacing the drive shaft (Section 3.4).

Reverse Steps 1 and 2 for the installation of the blower drive shaft.

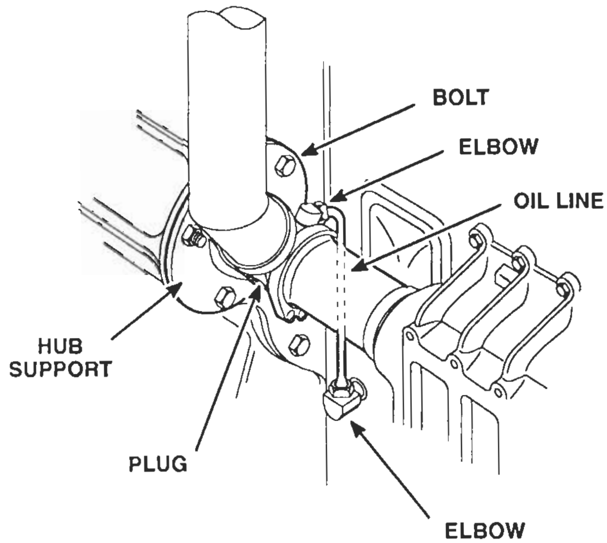


Figure 3. Blower Drive Shaft Mounting

REMOVE BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY (FLYWHEEL HOUSING REMOVED)

Removal of the flywheel housing (Sections 1.5 and 1.5) is not necessary when removing the blower drive gear. However, an inspection of the gear train is advisable when any one of the gears requires service.

Before removing the blower drive gear, the blower drive shaft must be removed as previously outlined.

1. Remove the blower (Section 3.4).
2. Remove the blower drive oil line (Figure 4.)
3. Straighten the ears on the lock washer and loosen the drive gear hub nut.
4. Remove the blower drive support attaching bolts.
5. Loosen the blower drive support by tapping it lightly and withdraw the support from the cylinder block rear end plate. Take care to prevent damage to the blower drive gear teeth. Discard the gasket.

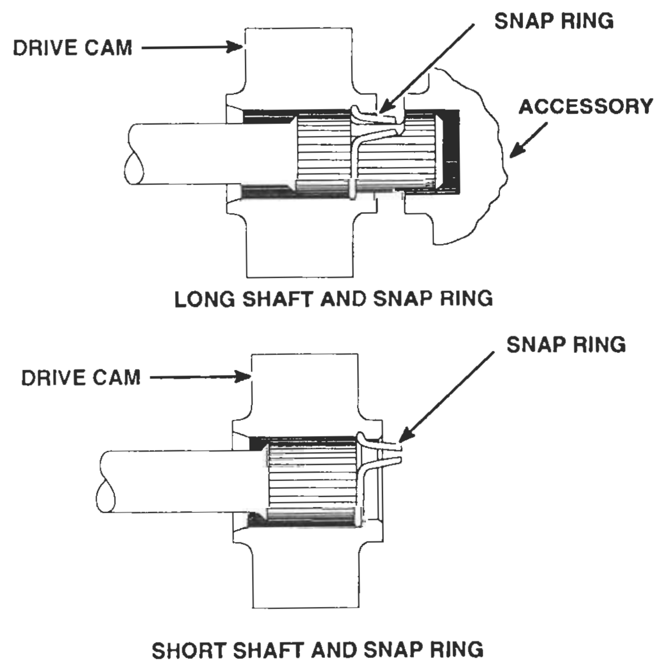


Figure 4. Blower Drive Gear and Support Mounting

DISASSEMBLE BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

1. Secure the blower drive gear and support assembly in a vise with soft jaws.
2. Take out the drive coupling bolts and remove the retainer and coupling support (Figure 5.)
3. Remove the drive gear hub nut, lock washer, lock ball and thrust washer and withdraw the blower drive gear hub.
4. Remove the thrust washer from the blower drive gear hub.
5. Press the gear hub out of the blower drive gear.

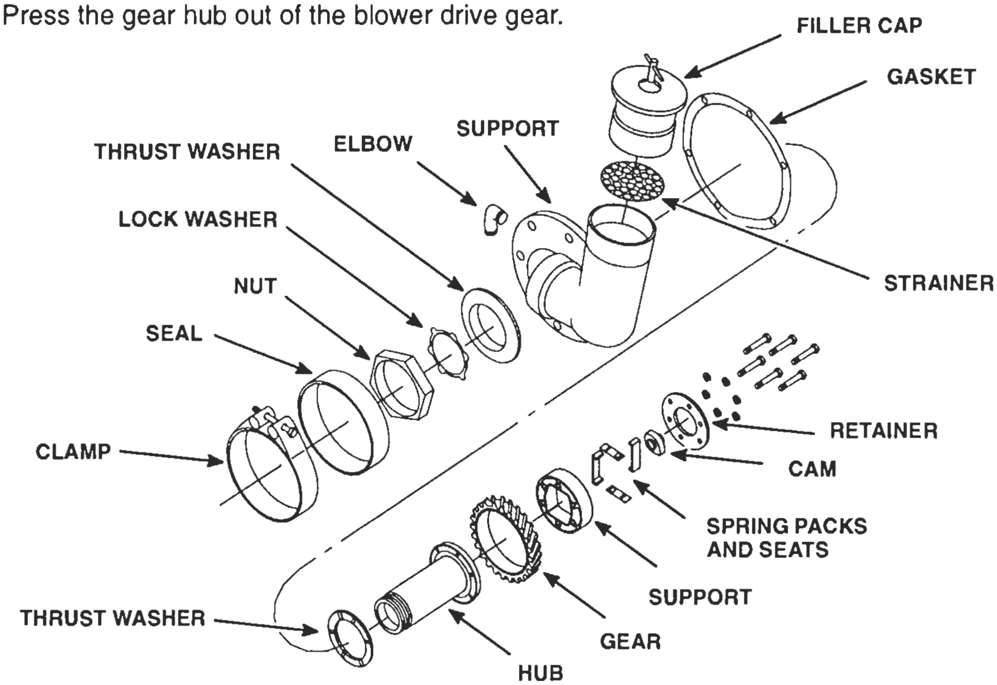


Figure 5. Blower Drive Gear Parts

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 lb/in^2 (276 kPa) air pressure.

Ensure that the oil grooves, oil holes, and cavities are free of dirt.

Replace the thrust washers if they are worn or scored.

If the bearings are worn or scored excessively the drive gear hub support or bearings will have to be replaced. These bushing type bearings are diamond bored to an inside diameter of 1.6260 to 1.6265 inches, after installation in the hub.

The clearance between the bearings and the hub is .0010 to .0025 inches with new parts and a maximum of .0050 inch with used parts.

INSPECTION (CONT.)

The bearing on the gear end protrudes .045 to .055 inches above the surface of the face to facilitate the installation of the blower drive thrust washer. The other bearing is installed with the end flush to .030 inch below the surface of the face of the support. Replacement bearings must withstand a 2000 lb. end load without moving, also the bearing bores must be square with the inner and outer faces of the support within .001 inch total indicator reading.

Replace the blower drive shaft if the serrations are worn or damaged.

Inspect the blower drive coupling support, cam, spring seats and spring packs. Replace worn or damaged parts.

The blower drive couplings incorporate spring seats which prevent pressure and wear from the spring packs on the coupling, thereby, prolonging the life of the coupling. Shorter springs are required for use with the spring seats. When a spring replacement is necessary, the new springs and spring seats, available in a kit, must be installed.

Examine the blower drive gear. If the teeth are excessively worn, scored or pitted, the gear must be replaced.

ASSEMBLE BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

Assembly the blower drive gear and support assembly as follows:

1. Secure the blower drive gear support in a vise with soft jaws.
2. Press the drive gear hub into the drive gear.
3. Lubricate the drive gear hub, bearings in the support, thrust surfaces and blower drive thrust washer with engine oil.
4. Place the thrust washer on the protruding bearing in the gear side of the support and insert the blower drive gear hub and gear assembly.
5. Locate the lock ball in its place on the drive gear hub and slide the hub thrust washer into position over the lock ball. The thrust washer must be installed with the tapered face toward the threads on the hub.
6. Install a new lock washer and finger tighten the nut on the hub. Install two bolts into the threaded holes in the drive gear hub. Place a suitable holding bar across the bolts to keep the hub from rotating and tighten the hub nut to 50–60 lb·ft (68–81 N·m) torque. Bend the ears of the lock washer against the nut to lock the nut in place. Remove the two bolts.
7. Assemble the blower drive coupling.
   a. Place the drive coupling support on wood blocks (Figure 6.)
   b. Install the spring end seats and place the spring seats in each corner of the drive coupling support.
   c. Apply engine oil to the drive coupling springs (there are 21 leaves in each spring pack) and insert them in the coupling support.
   d. Place the blower drive cam on the installer J 1471, insert the round end of the tool between the spring packs and press the cam into position.

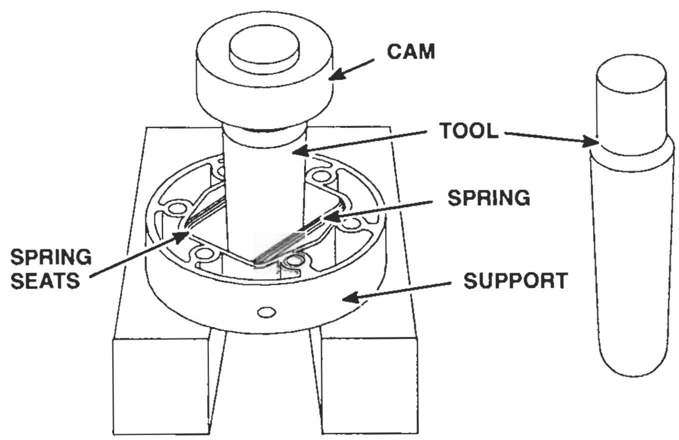


Figure 6. Inserting Blower Drive Cam

ASSEMBLE BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY (CONT.)

8. Place the coupling support against the drive gear with the blower drive shaft ring groove in the cam facing away from the drive gear. Then, place the drive coupling retainer against the coupling support with the flared edge away from the support. Revolve the coupling assembly on the hub flange until the cam lobes are in line with the oil grooves in the gear hub to ensure proper lubrication (Figure 7.)
9. Install the drive coupling bolts.

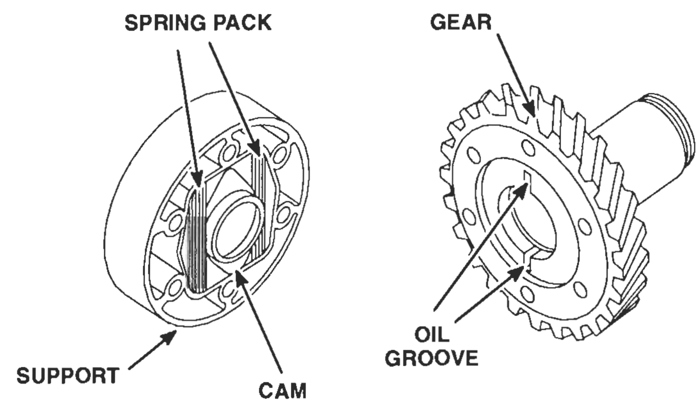


Figure 7. Relation of Blower Drive Cam to Oil Grooves in Gear Hub

INSTALL BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

1. Check the clearance between the drive support and gear hub thrust washer before installing the blower drive gear support assembly. The clearance must be .006 to .014 inches.
2. Place a new gasket on the mounting face of the hub support.
3. Attach the blower drive gear and support assembly to the cylinder block rear end plate with the two 3/8–24 x 7/8 inch bolts.
4. Connect the oil line.
5. Install the blower as outlined in Section 3.4 and secure the seal and clamp.
6. Insert the blower drive shaft into the blower rotor gear hub. The end without the groove for the ring must be inserted first.
7. Lock the drive shaft in place by installing the ring in the groove provided in the coupling cam.
8. Reinstall the flywheel and flywheel housing (Sections 1.4 and 1.5) and install the remaining bolts that secure the blower drive gear and support assembly.

ACCESSORY DRIVES

Accessory drives have been provided at the rear of the engines to accommodate both gear–driven and belt–driven accessories.

For the possible accessory drive location and rotation of the drive at a particular position (Figure 1.)

The drive for direct gear–driven accessories, such as a raw water pump, is made up of a spacer (when used), accessory drive plate and drive coupling.

The drive plate and spacer (when used) are bolted to the camshaft or balance shaft gear. The accessory is bolted to the flywheel housing and driven by a drive coupling which is splined to both the accessory shaft and accessory drive plate.

Belt–driven accessories, such as battery–charging generators or air compressors, are driven off the camshaft or balance shaft gears by a drive hub and pulley or a spacer (when used), accessory drive plate, drive shaft, accessory driven retainer assembly and pulley, accessory drive retainer assembly and pulley.

POSITION	DRIVE RATIO
1	1.1
2	1.1
*4 (blower)	1.95:1 OR 2:1
*5 (blower)	1.95:1 OR 2:1

*Depends on engine application

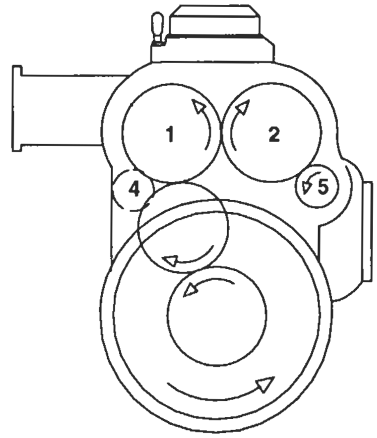


Figure 1. Accessory Drive Locations

In the first arrangement, the drive hub is bolted to the camshaft or balance shaft gear. The oil seal retainer is bolted to the flywheel housing and the pulley is keyed to the drive hub shaft which extends through the oil seal retainer.

In the second arrangement, the spacer (when used) and accessory drive plate are bolted to one of the balance gears. The accessory drive shaft is splined to the drive plate at one end and supported by a bearing in the accessory drive retainer at the other end. The accessory drive retainer, which also incorporates an oil seal, is bolted to the flywheel housing. The pulley is keyed to the drive shaft which extends through the drive retainer assembly.

On some coach engines, a step–up gear is attached to the camshaft gear with six allen head bolts and lock washers to drive the battery–charging alternator. The alternator mounting adaptor is attached to the flywheel housing. Two set screws are used to adjust and hold a clearance (maximum .002 inch runout) between the outer flange of the step–up gear and the alternator adaptor.

REMOVE ACCESSORY DRIVE

Remove the gear–driven type accessory drive (Figure 2.) as follows:

1. Remove any external piping or connections to the accessory.
2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.
3. Remove the drive coupling.

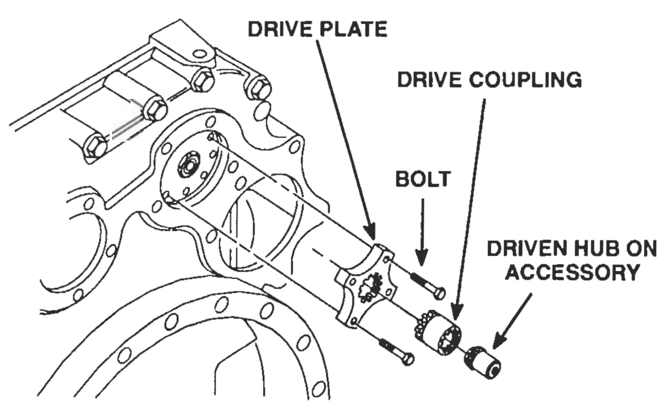


Figure 2. Accessory Drive

SECTION 1.7.7 – ACCESSORY DRIVES

REMOVE ACCESSORY DRIVE (CONT.)

4. Place a clean lint free cloth in the flywheel housing opening underneath the accessory drive plate to prevent the bolts from accidently falling into the gear train. Remove the lock wires if used. Then remove the four bolts (and lock washers if used) attaching the accessory drive plate and spacer (when used) to the balance gear and remove the plate and spacer.

Remove the drive assembly for the belt–driven type accessory as follows:

1. Remove any external piping or connections to the accessory.
2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and the accessory.
3. Remove the bolt and washer (Figure 3.) that retains the pulley on the drive shaft.
4. Use a suitable gear puller to remove the pulley from the drive shaft. Remove the Woodruff key.
5. Remove the five bolts and lock washers which attach the drive retainer assembly to the flywheel housing. Remove the retainer assembly.
6. Remove the accessory drive shaft, drive plate and spacer (when used), or drive hub, in a manner similar to that outlined in Steps 3 and 4 under removal of the direct gear–driven type accessory drive.

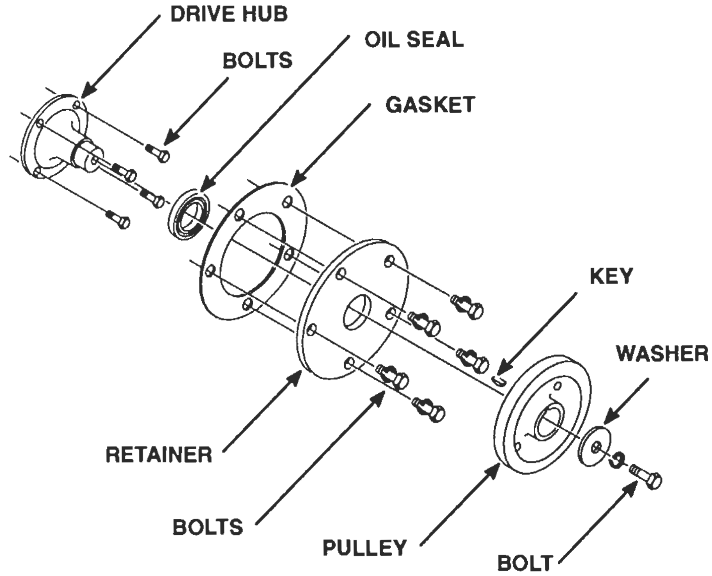


Figure 3. Accessory Drive Components for Belt Driven Accessory (Drive Hub Type)

7. Remove the snap ring and ball bearing from the accessory drive shaft retainer assembly (Figure 4.)

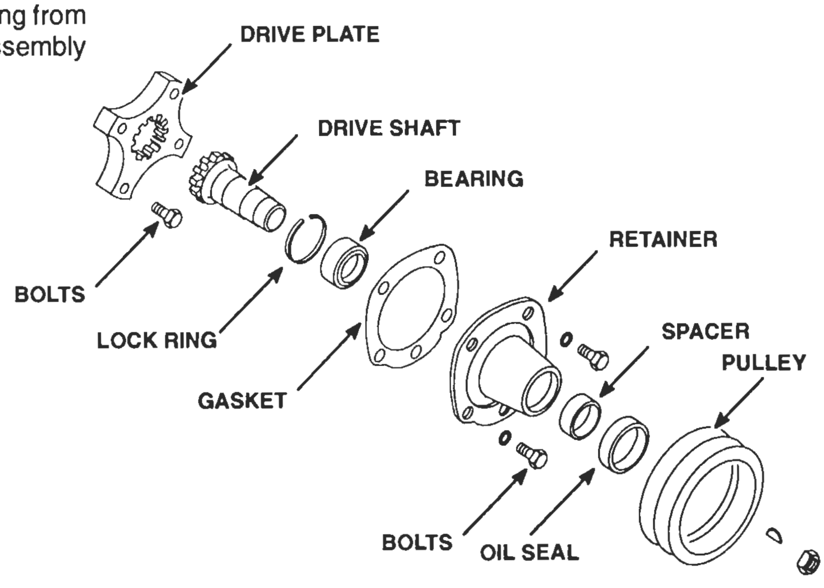


Figure 4. Accessory Drive Components for Belt–Driven Accessory (Drive Plate Type)

INSPECTION

Clean the accessory drive parts with clean fuel oil (except shielded bearings) and dry them with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Examine the gear teeth of the drive shaft, drive coupling or drive plate for wear. If worn excessively, replace with new parts.

Inspect the ball bearing used to support the accessory drive shaft. Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the outside of the bearing clean, then hold the inner race and revolve the outer race slowly by hand. If the bearing is worn or does not roll freely, replace it.

Inspect the accessory drive hub for grooving at the area of contact with the lip of the oil seal. If the hub is grooved to a point where the effectiveness of the oil seal is lost, a ring–type oil seal spacer is available which serves to reposition the seal and provide a new sealing surface (Figure 5.)

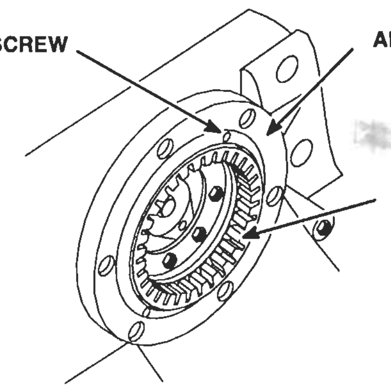


Figure 5. Step–Up Gear Drive Mounting

INSTALL ACCESSORY DRIVE

1. Remove the old gasket material from the flywheel housing. Use care so that no gasket material falls into the gear train compartment.
2. Insert a clean, lint free cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate and spacer (Figure 6.) (when used) or accessory drive hub, with the tapped holes in the balance gear. Then secure the plate and spacer (when used), or drive hub, with four bolts (and lock washers or lock wire, if used).

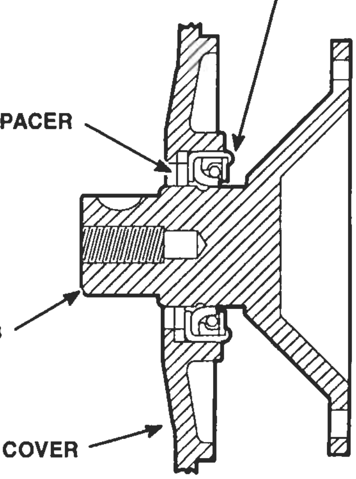
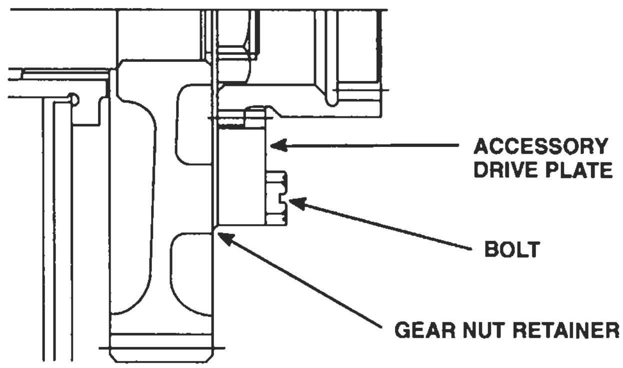


Figure 6. Location of Oil Seal Spacer

INSTALL ACCESSORY DRIVE (CONT.)

3. If an accessory drive plate is used (Figure 7.) then align the bolt holes in the accessory drive plate (and spacer, if used) with the tapped holes in the camshaft gear. Secure the drive plate (and spacer) with the four special shoulder bolts (and lock washers, if used). Tighten the bolts to 45–50 lb·ft (61–68 N·m) torque.



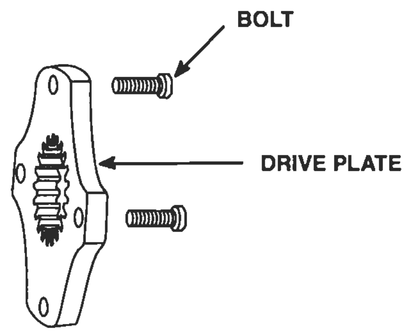


Figure 7. Current Design of Accessory Drive Plates and Spacers

4. If a gear–driven accessory is used, install the drive coupling 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; rotate it, if necessary, to align the teeth of the driven hub with those in the drive coupling. Then secure the accessory to the flywheel housing with bolts and lock washers.
5. If a belt–driven accessory is used, 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. Then 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 N·m) torque.
   e. Install the key in the shaft. Then start the pulley on the shaft and tap it in place. Install the 3/4–16 retaining nut. Tighten the nut to 120–140 lb·ft (163–190 N·m) 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.

NOTE: When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot (Section 15.1).

INSTALL ACCESSORY DRIVE (CONT.)

6. If an accessory drive hub is used, proceed as follows:

   a. Align the bolt holes in the drive hub with the tapped holes in the balance gear. Then secure the drive hub to the gear with four shoulder bolts. Tighten the bolts to 45–50 lb·ft (61–68 N·m) 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 N·m) 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 in place. Install the plain washer, lock washer and bolt. Tighten the bolt to 35 lb·ft (47 N·m) 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.

NOTE: When installing or adjusting the 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 (refer to Section 15.1).

7. If the flywheel housing small hole covers were removed, install them as outlined in Section 1.5.

BALANCE WEIGHT COVER

The front balance weight cover encloses the front engine balance weights and also serves as a support for various equipment such as the cooling fan support bracket or heat exchanger.

The balance weight cover requires no servicing. However, when an engine is being completely reconditioned or the camshaft, balance shaft or front balance weights need replacing, the balance weight cover must be removed.

REMOVE COVER

1. Drain the cooling system.
2. Loosen the hose connections between the radiator (or heat exchanger) and the engine.
3. Remove the radiator (or heat exchanger).
4. Remove the fan, fan hub and adjusting bracket.
5. Remove the fifteen bolts, lock washers and plain washers (Figure 1.) which secure the balance weight cover to the cylinder block and the front end plate. Remove the cover and gasket.
6. Remove all traces of the old gasket material from the cover and the end plate.

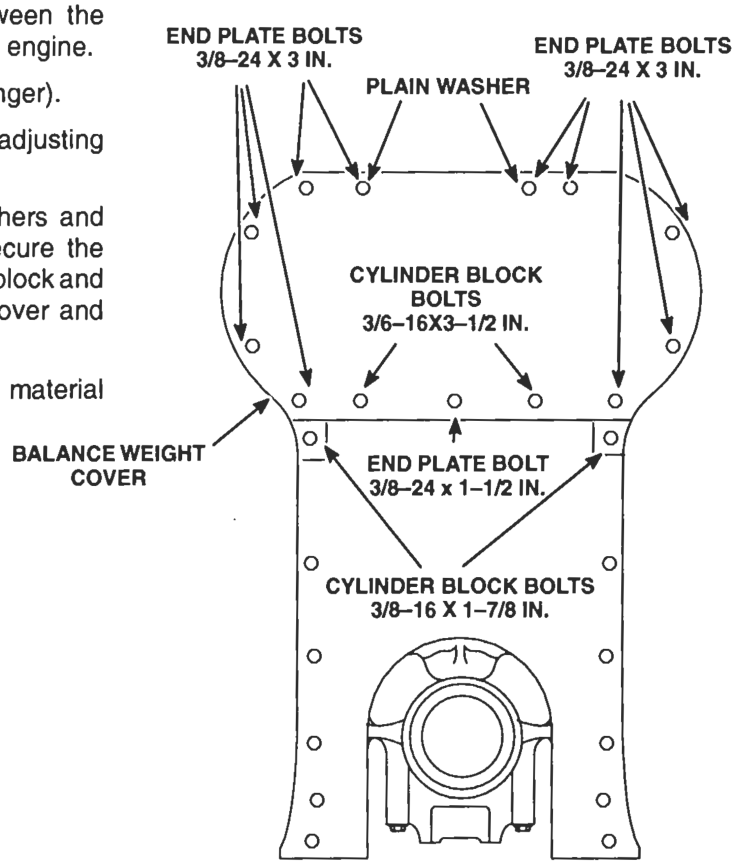


Figure 1. Balance Weight Cover Mounting

SECTION 1.7.8 – BALANCE WEIGHT COVER

INSTALL COVER

1. Affix a new gasket to the balance weight cover.
2. Install the cover in place and install the fifteen attaching bolts, lock washers and plain washers finger tight.
3. Tighten the bolts (Figure 2.) to 25–30 lb·ft (34–41 N·m) torque.
4. Install the various sub–assemblies that were previously removed.

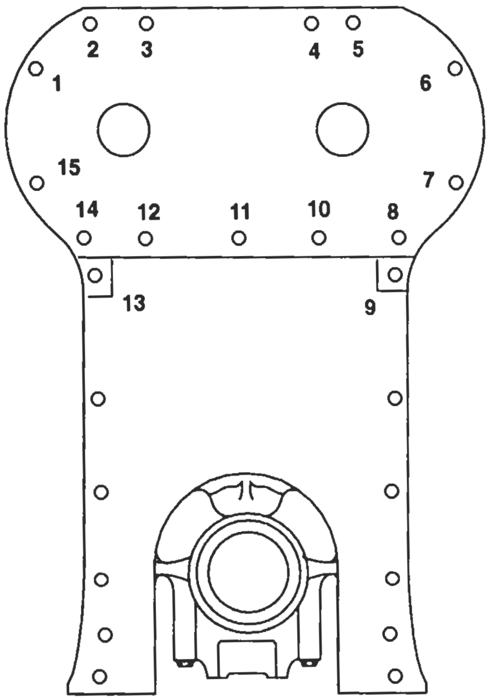


Figure 2. Balance Weight Cover Bolt Tightening Sequence

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

REWORKING EARLY CYLINDER BLOCK FOR 71E OR 71T ENGINES

The current service replacement cylinder blocks are applicable to all Series 71 engine models, including the 71E or 71T engines. The distance from the top surface of the current blocks to the top of the air inlet port opening is 3–63/64 inches.

This dimension was 4–19/64 inches on earlier service cylinder blocks. The larger port opening is required on 71E and 71T engines due to the increased port height of the cylinder liners used in these engine models. The port height of a service replacement block may be checked by inserting a 71E or 71T cylinder liner into the block bore and inspecting the liner ports through the hand hole in the side of the block.

The air inlet ports may be enlarged on an early block by grinding a small amount of metal from the port area (Figure 1.) This requires careful workmanship to avoid exceeding the dimensions shown. A 71E or 71T cylinder liner may be used as a gage to check the grinding operation.

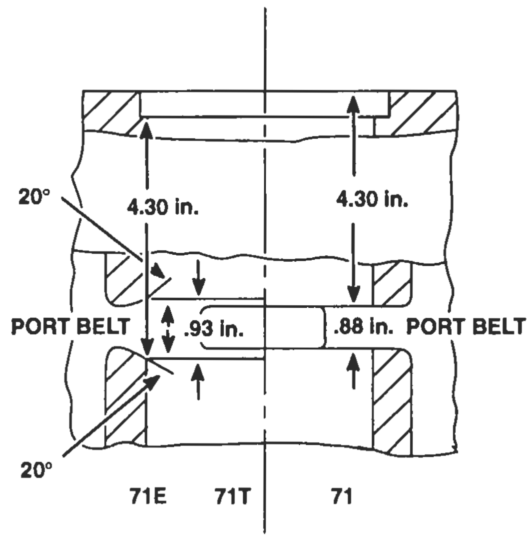


Figure 1. Cylinder Block Air Inlet Port Machining

ALUMINUM CYLINDER BLOCK

The aluminum cylinder block, used on certain engines, has been revised by enlarging the camshaft intermediate bearing lock screw holes. This change requires 3/8–24 x .620 inch lock screws in place of the 1/4–28 x .715 inch lock screws formerly used. The upper halves of the camshaft intermediate bearings have also been revised by enlarging the lock screw hole.

When replacing the aluminum block on engines prior to serial numbers 4A–79662 and 6A–76745, new camshaft intermediate bearing sets and new lock screws must also be used with the new block.

IN–FRAME OVERHAUL

Polyethylene plastic plugs (J 34698) help prevent solvent and debris from entering the crankcase while cleaning the airbox during in–frame overhaul or cylinder kit replacement.

INSTALLATION OF STAINLESS STEEL INSERTS IN ALUMINUM BLOCK

To minimize electrolytic action between the aluminum cylinder block and the cast iron cylinder head and fresh water pump, stainless steel inserts have been added to the water inlet and outlet holes in the current cylinder blocks.

Inserts are available and may be added to early aluminum cylinder blocks by following the instructions for machining and installation (Figure 2.)

The outer diameter of the inserts must be coated with a sealant such as Perfect Seal No. 3 or equivalent at installation.

To further minimize electrolytic action, a cast iron water manifold replaces the aluminum manifold. However, the aluminum heat exchanger inlet elbow and a revised aluminum inlet elbow spacer are used with the cast iron manifold.

The current cast iron cylinder head applicable to an engine with an aluminum block incorporates copper plated water nozzles, and the protective coating formerly applied to the internal surfaces has been discontinued. When a current cylinder head is to be installed on an early aluminum block, it is recommended that the water hole inserts be added to the block or a water filter be added to the unit. The filter will not stop electrolytic action, but will tend to retard it slightly.

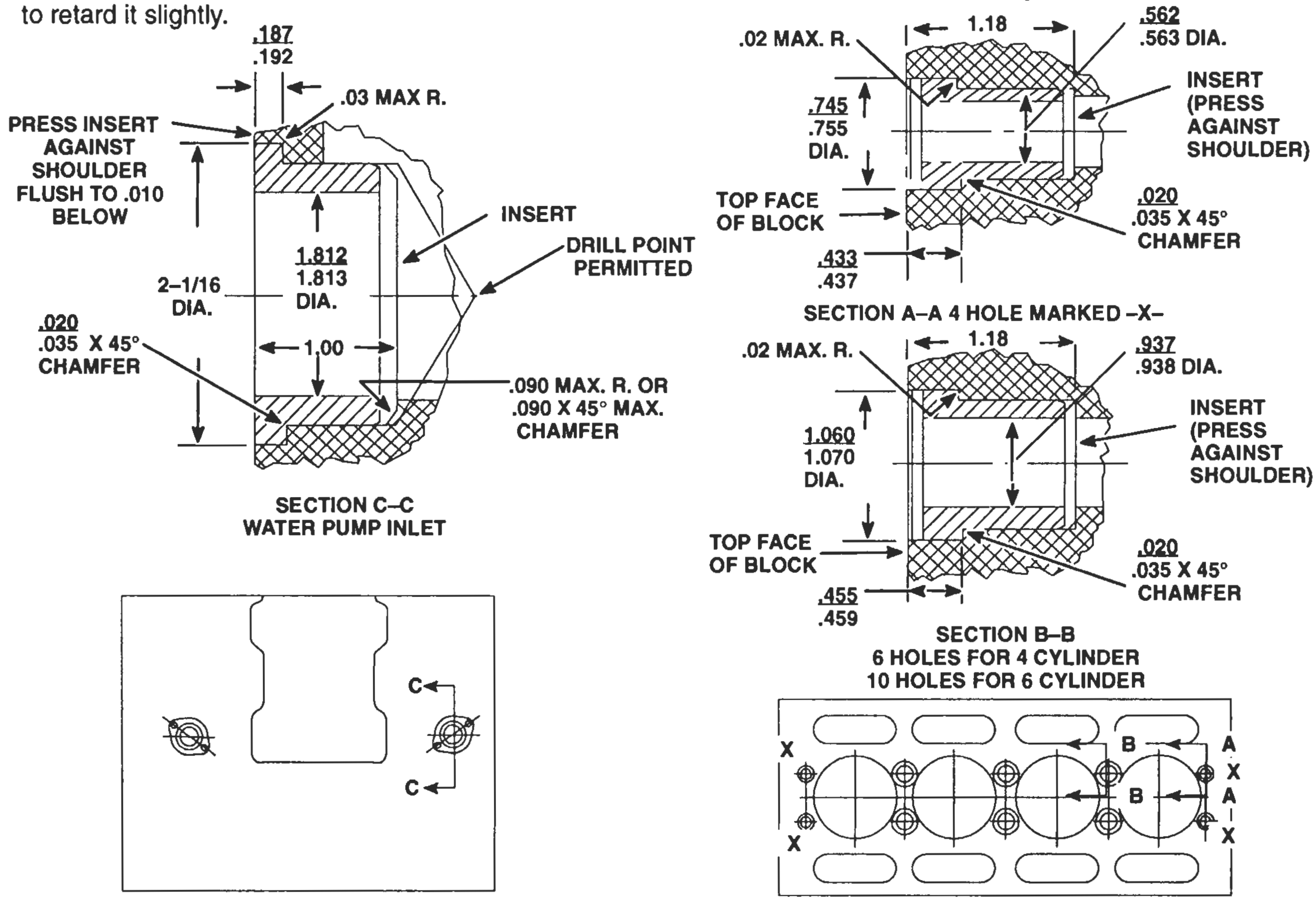


Figure 2. Installation of Water Hole Inserts in Aluminum Cylinder Block

AIR BOX DRAIN TUBE CONVERSION AIR BOX FLOOR CHECK VALVE

If replacement of the air box floor check valve becomes necessary, engines should be converted to the external, open air box drain system. Use this procedure:

1. Remove the two check valves from the floor of the air box at the No. 2 and No. 5 cylinder positions.
2. Apply 3M No. 971 Scotch–Grip Industrial Sealer, or equivalent, to the threads of two 3/4–14 inch pipe plugs and install in the bottom drain opening.
3. Remove one of the plugs from either of the air box drain openings located at opposite ends of the block.
4. Install the components (Section 1.1.2).

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. Series 71 cylinder heads that have the expansion slot (dogbone–shaped cavity) completely filled in with weld will have an increased probability of cracking in the valve area. Cylinder heads repaired in this manner should not be used. The expansion slot was designed into the cylinder head to relieve the stresses due to high operating temperatures.

WELDING ENGINE CYLINDER HEADS (CONT.)

6. Cylinder heads that have been welded should be checked for acceptability (Sections 1.2 through 1.2.2). 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.

NOTICE:

Secondary damage to other engine components could result from not checking these components.

CHECKING BEARING CLEARANCES

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

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 inches, type PR–1 (red) has a range of .002 to .006 inches and type PB–1 (blue) has a range of .004 to .009 inches.

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.

NOTE: 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 inch off center.
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 (Figure 3.) The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

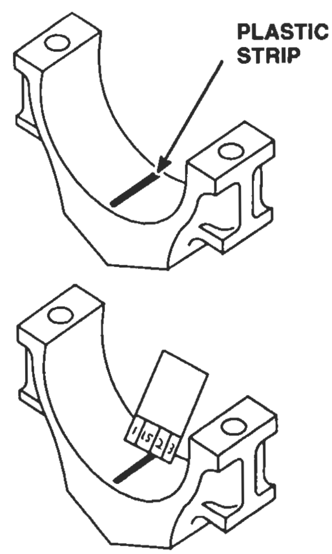
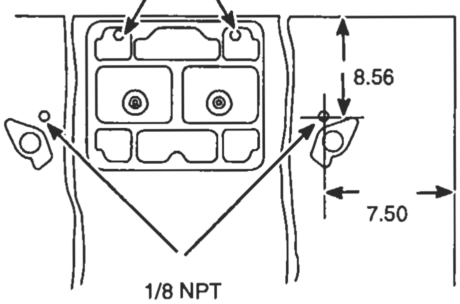


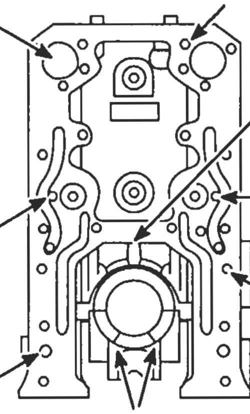
Figure 3. Measuring Bearing–to–Crankshaft Clearance with Plastic Strip

PISTON AND CYLINDER LINER USAGE (TRUNK TYPE)

1. The "N" pistons are .030 inches longer than the "E" pistons and approximately .155 inches longer than the special "E" piston. In addition, the fire ring turbocharged piston is .125 inches longer than the non–firing ring turbocharged piston. These dimension differences dictate that pistons cannot be mixed in an engine. To do so would result in misfiring and a rough idle condition which could ultimately result in cylinder liner scuffing.
2. The "E" and "turbo" cylinder liner has .900 inch long ports compared to 1.055 inch long ports in the oval port liner and .703 inch long ports in the standard two valve port liner. These port dimension differences prohibit mixing of cylinder liners in an engine which would result in a timing differential and compression ratio changes.
3. Only the oval port cylinder liners can be used with 18.7:1 compression ratio pistons. In addition, only oval port cylinder liners can be used with fire ring turbocharged pistons. The standard port cylinder liner should be used only with the non–fire ring two valve piston.
4. Crown valve injectors can be used with the 18.7:1 pistons. Crown Valve and needle valve injectors must not be mixed in an engine.
5. When converting to "N" pistons, it is important that the exhaust valve protrusion be measured carefully to assure that when fully closed the exhaust valves do not protrude more than .006 inches above the cylinder head fire deck. Only the "thin" exhaust valve inserts (for two valve or four valve heads) which are .247/.251 inches thick can be used with the "N" piston.

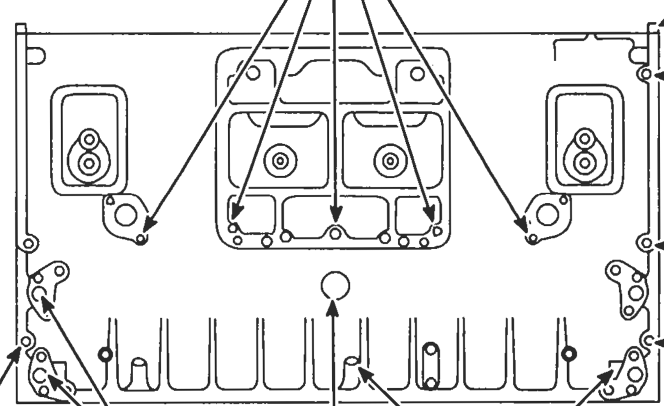
CYLINDER BLOCK PLUGGING CHARTS (LD & RD ENGINES)





*=Apply Loctite J 26558–92 Pipe Sealer or Equivalent Prior to Installation.

STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

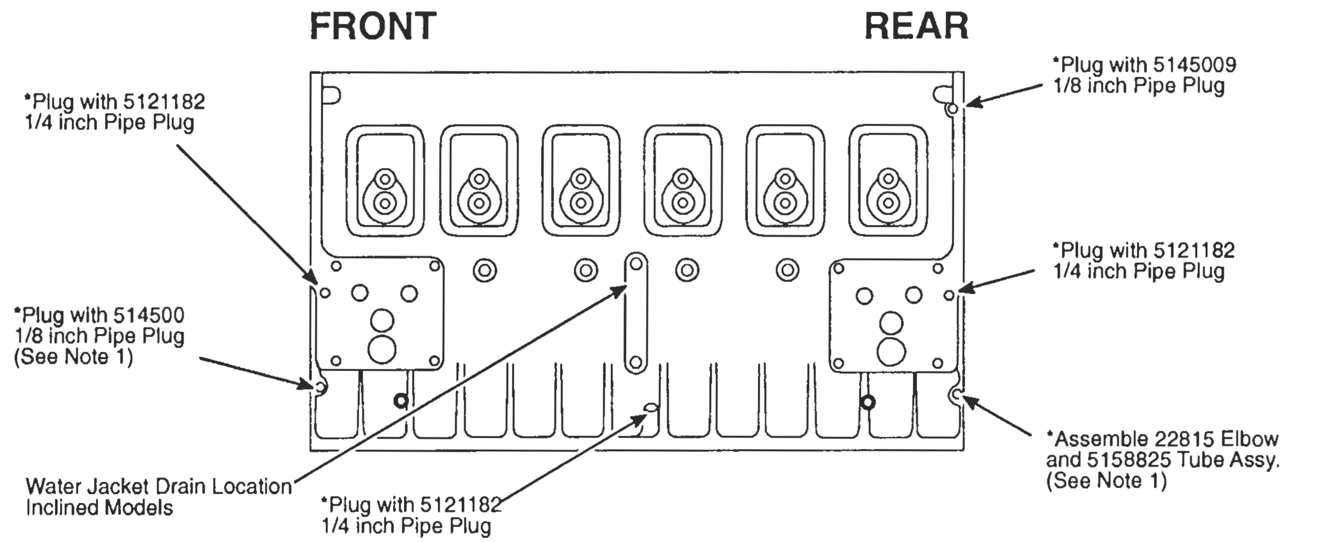


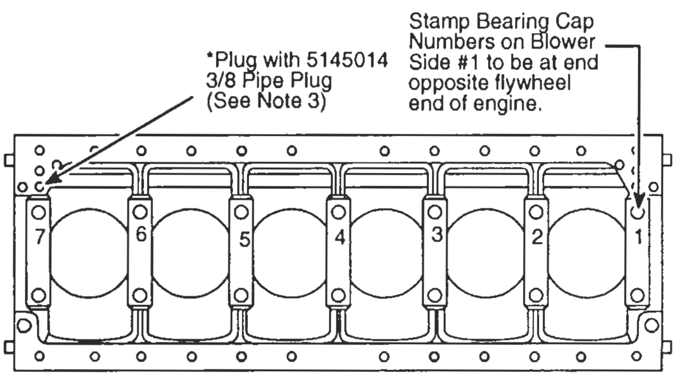
NOTES:

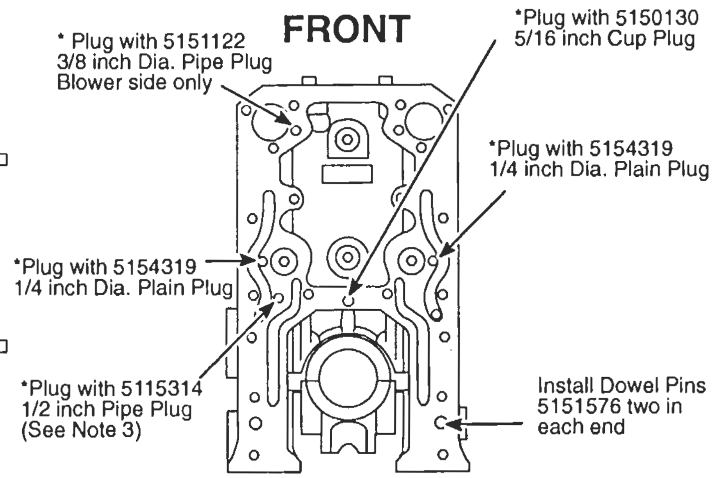
(1) Assemble 225815 elbow and 5158825 tube assy. to the front of the block for LD engine of Model 24001B and RD engine Model 24002B. Assembly 5145014 plugs to rear of block on aforementioned engines. On truck engines, assemble 225815 elbow and 5158825 tube assy. to the front and to the rear on the blower side. Assemble 5145009 plugs on the opposite side of the block.

(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

CYLINDER BLOCK PLUGGING CHARTS (LD & RD ENGINES) (CONT.)

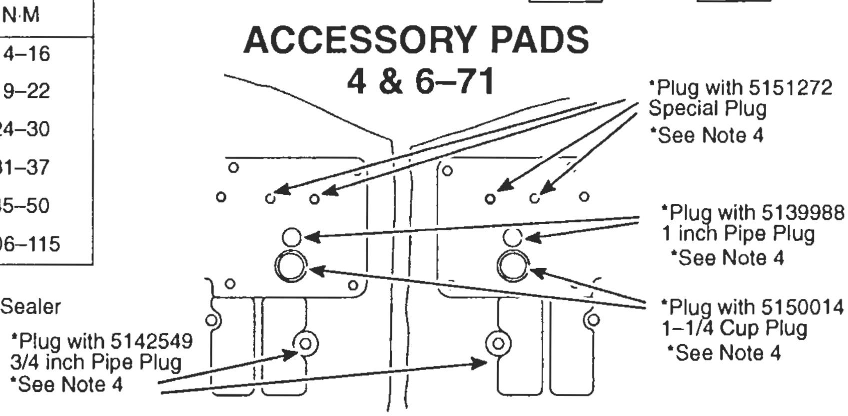






STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
1/8	10–12	14–16
1/4	14–16	19–22
3/8	18–22	24–30
1/2	23–27	31–37
3/4	33–37	45–50
1	78–85	106–115

*=Apply Loctite J 26558–92 Pipe Sealer or Equivalent Prior to Installation.



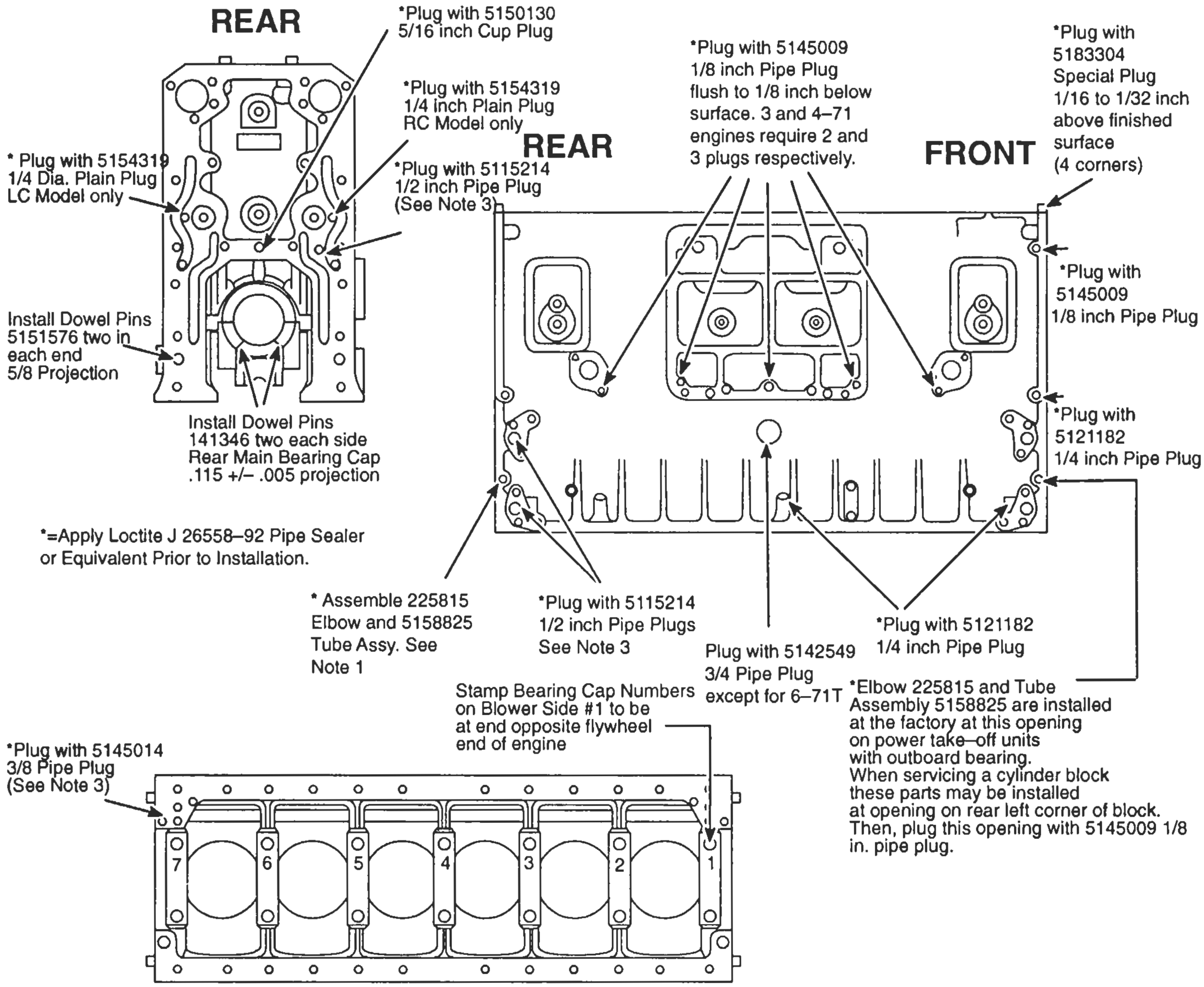
NOTES:

(1) Assemble 225815 elbow and 5158825 tube assy. to the front of the block for LD engine of Model 24001B and RD engine Model 24002B. Assembly 5145014 plugs to rear of block on aforementioned engines. On truck engines, assemble 225815 elbow and 5158825 tube assy. to the front and to the rear on the blower side. Assemble 5145009 plugs on the opposite side of the block.

(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

(4) Do not install plugs when crankcase breather is to be installed on accessory pad.

CYLINDER BLOCK PLUGGING CHARTS (LC & RC ENGINES)



STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

NOTES:

(1) Assemble 225815 elbow and 5158825 tube assy. to the front of the block for LD engine of Model 24001B and RD engine Model 24002B. Assembly 5145014 plugs to rear of block on aforementioned engines. On truck engines, assemble 225815 elbow and 5158825 tube assy. to the front and to the rear on the blower side. Assemble 5145009 plugs on the opposite side of the block.

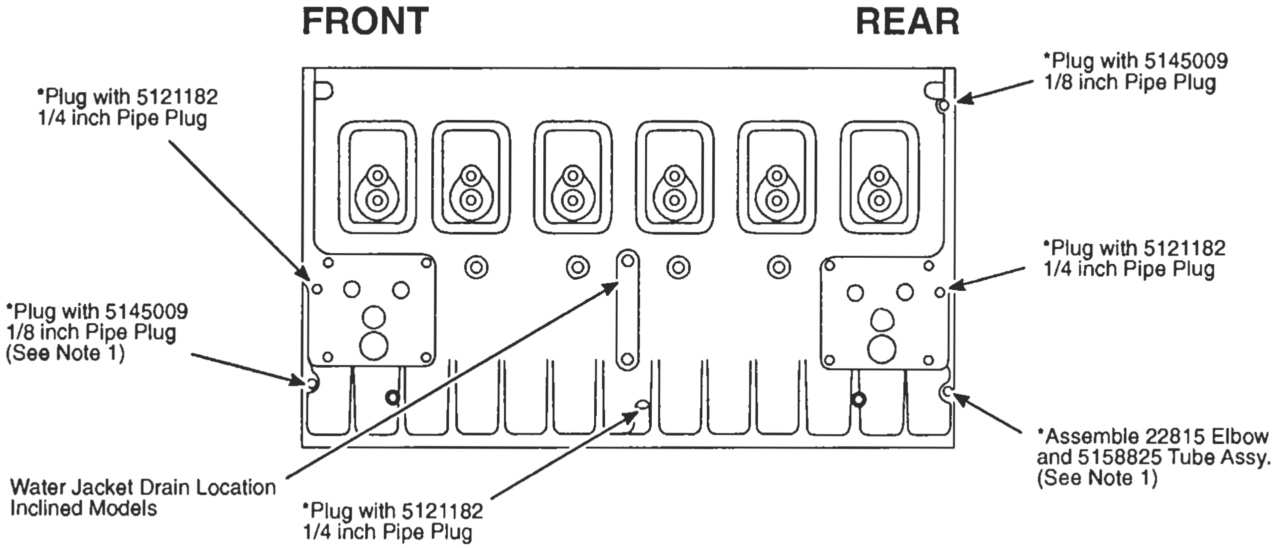
For single engine generator units assemble 225815 elbow and 5171500 tube assembly on the front of the block on the handhole cover side. Assemble 225815 elbow and tube assembly 5171500 (for 3–cyl.) 5171501 (for 4–cyl) or 5171502 (for 6–cyl) to the rear on the same side of the block. The front and rear tubes should then be connected to the common drain tank. Assemble 5145009 plugs in the two corresponding holes on the opposite side of block.

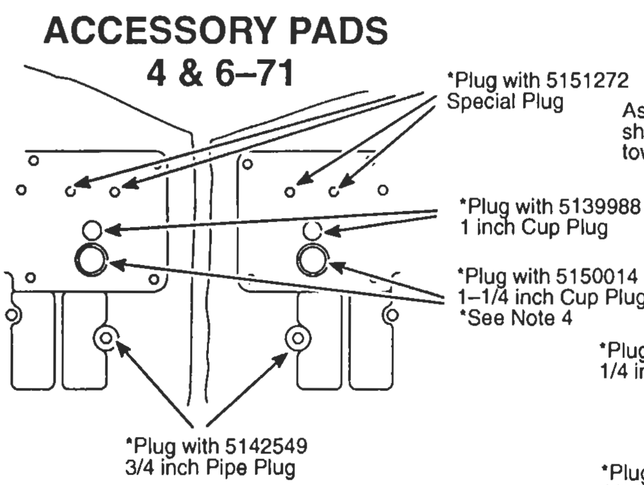
Each engine of Model 12201 and 12202 units requires 2 elbows 225815 and tube assemblies 5171502 (rear) on the blower side of block. For these twin generator units, 2 plugs 5145009 are, therefore, used on the handhole cover side of the block.

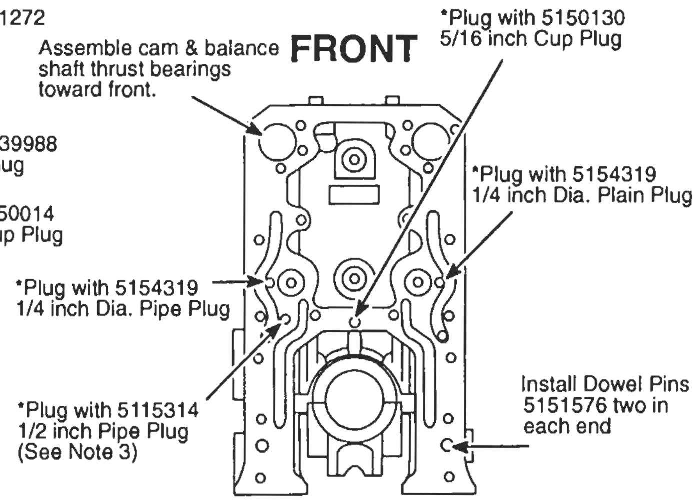
(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

 May, 1994

CYLINDER BLOCK PLUGGING CHARTS (LC & RC ENGINES) (CONT.)







*=Apply Loctite J 26558–92 Pipe Sealer
or Equivalent Prior to Installation.

STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

NOTES:

(1) Assemble 225815 elbow and 5158825 tube assy. to the front of the block for LD engine of Model 24001B and RD engine Model 24002B. Assembly 5145014 plugs to rear of block on aforementioned engines. On truck engines, assemble 225815 elbow and 5158825 tube assy. to the front and to the rear on the blower side. Assemble 5145009 plugs on the opposite side of the block.

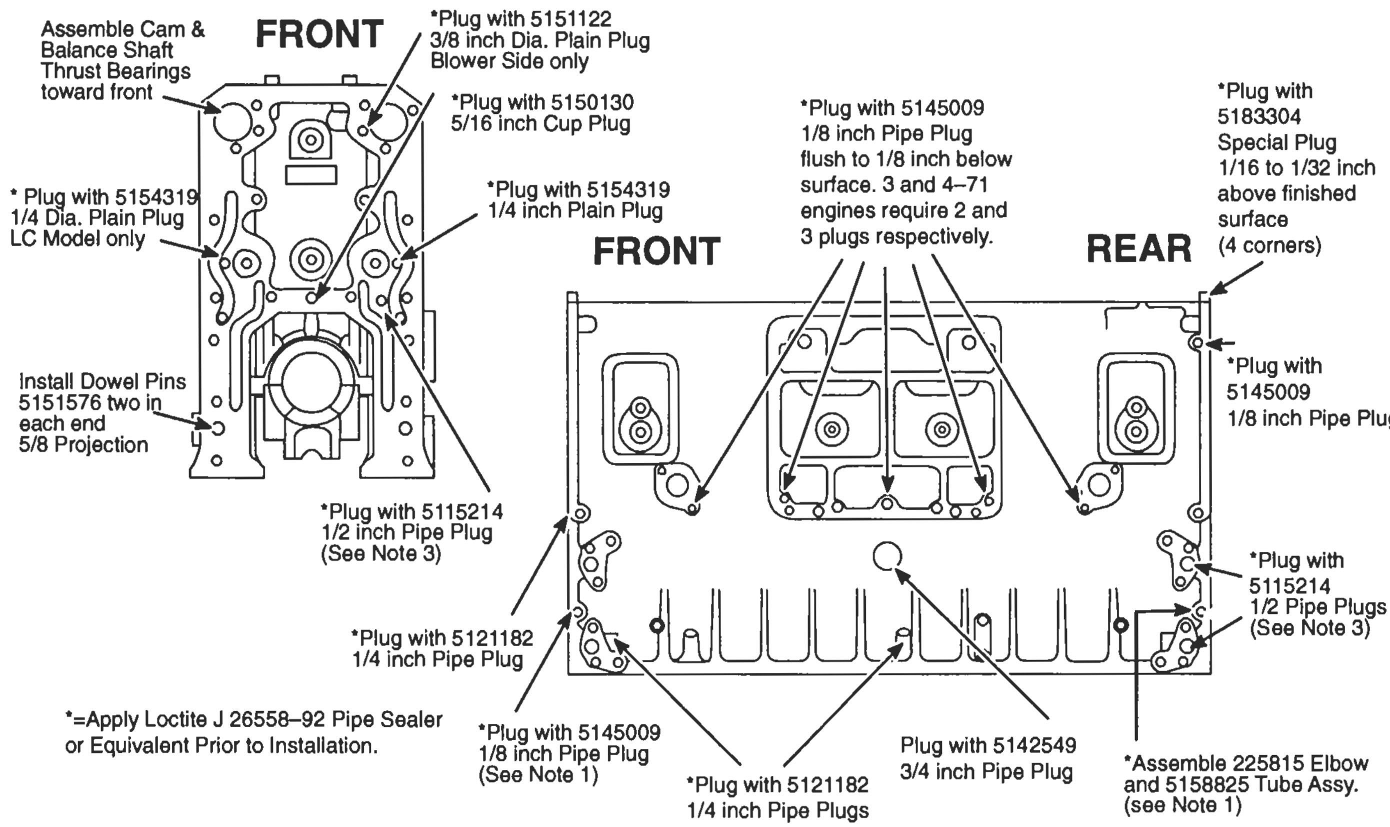
For single engine generator units assemble 225815 elbow and 5171500 tube assembly on the front of the block on the handhole cover side. Assemble 225815 elbow and tube assembly 5171500 (for 3–cyl.) 5171501 (for 4–cyl) or 5171502 (for 6–cyl) to the rear on the same side of the block. The front and rear tubes should then be connected to the common drain tank. Assemble 5145009 plugs in the two corresponding holes on the opposite side of block.

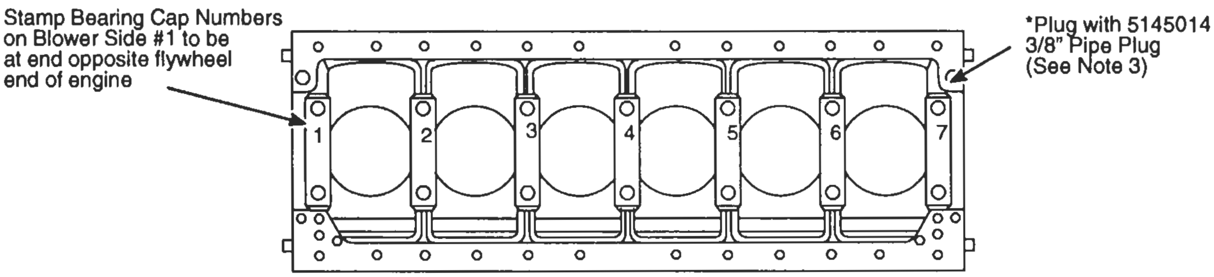
Each engine of Model 12201 and 12202 units requires 2 elbows 225815 and tube assemblies 5171502 (rear) on the blower side of block. For these twin generator units, 2 plugs 5145009 are, therefore, used on the handhole cover side of the block.

(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 517334 and plug 5145014 in bottom of block by 5173333 when assembling an aluminum cylinder block.

(4) Do not install plugs when crankcase breather is to be installed on accessory pad.

CYLINDER BLOCK PLUGGING CHARTS (LB & RB ENGINES)





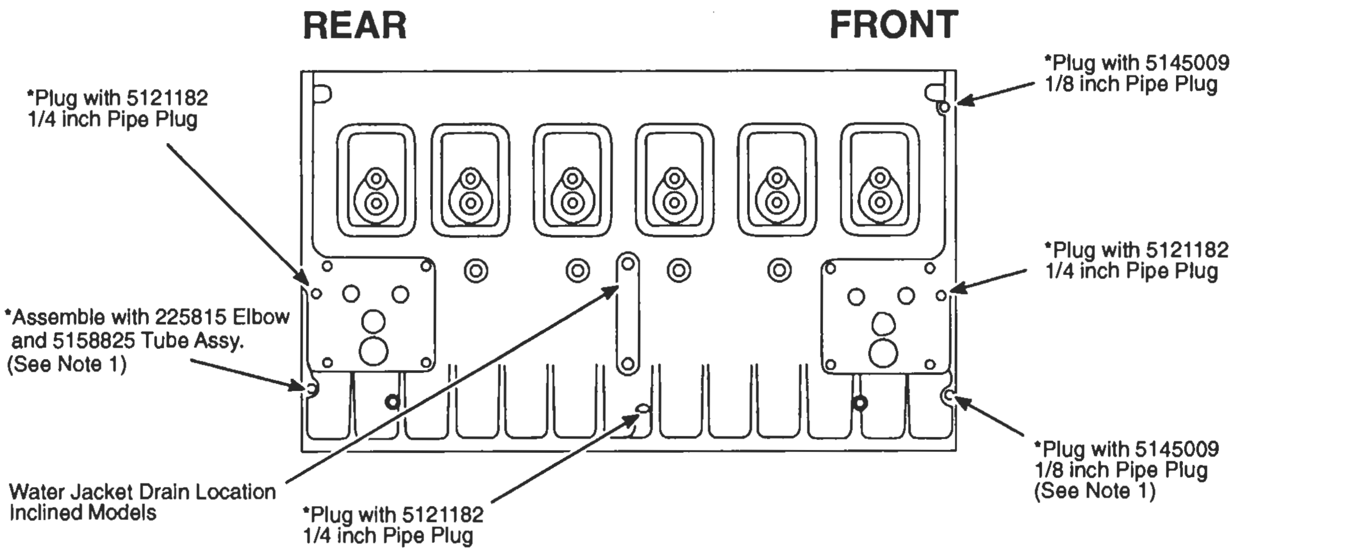
STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
1/8	10–12	14–16
1/4	14–16	19–22
3/8	18–22	24–30
1/2	23–27	31–37
3/4	33–37	45–50
1	78–85	106–115

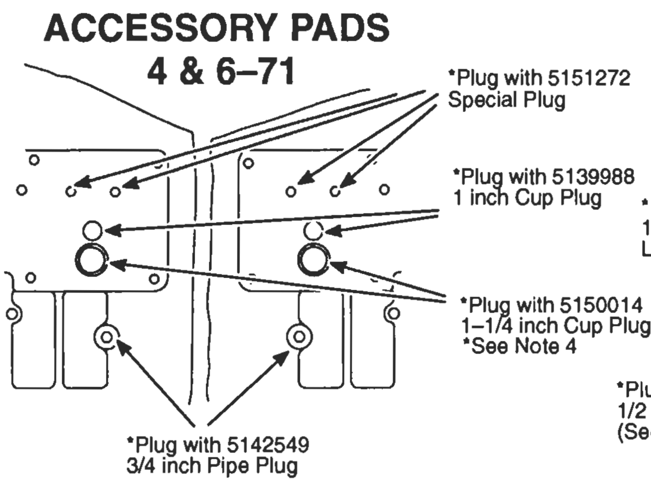
NOTES:

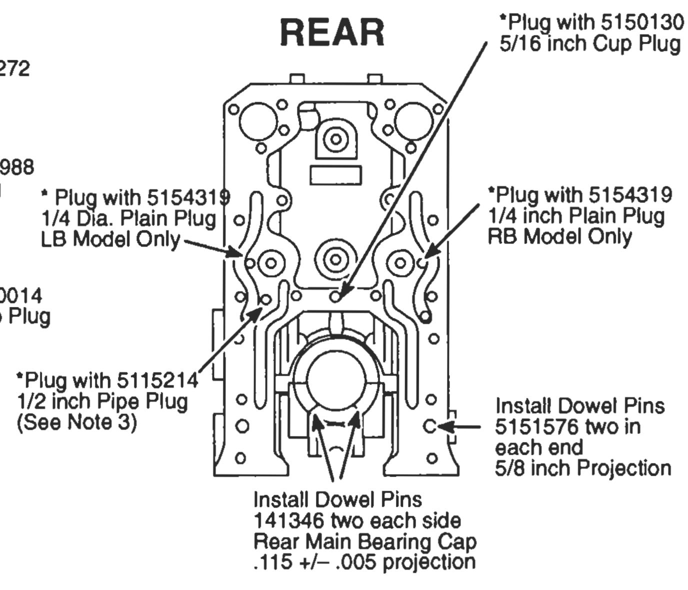
(1) Assemble 225815 elbow and 5158825 tube assy. to the front of the block for LD engine of Model 24001B and RD engine Model 24002B. Assembly 5145014 plugs to rear of block on aforementioned engines. On truck engines, assemble 225815 elbow and 5158825 tube assy. to the front and to the rear on the blower side. Assemble 5145009 plugs on the opposite side of the block.

(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

CYLINDER BLOCK PLUGGING CHARTS (LB & RB ENGINES) (CONT.)







*=Apply Loctite J 26558–92 Pipe Sealer
or Equivalent Prior to Installation.

NOTES:

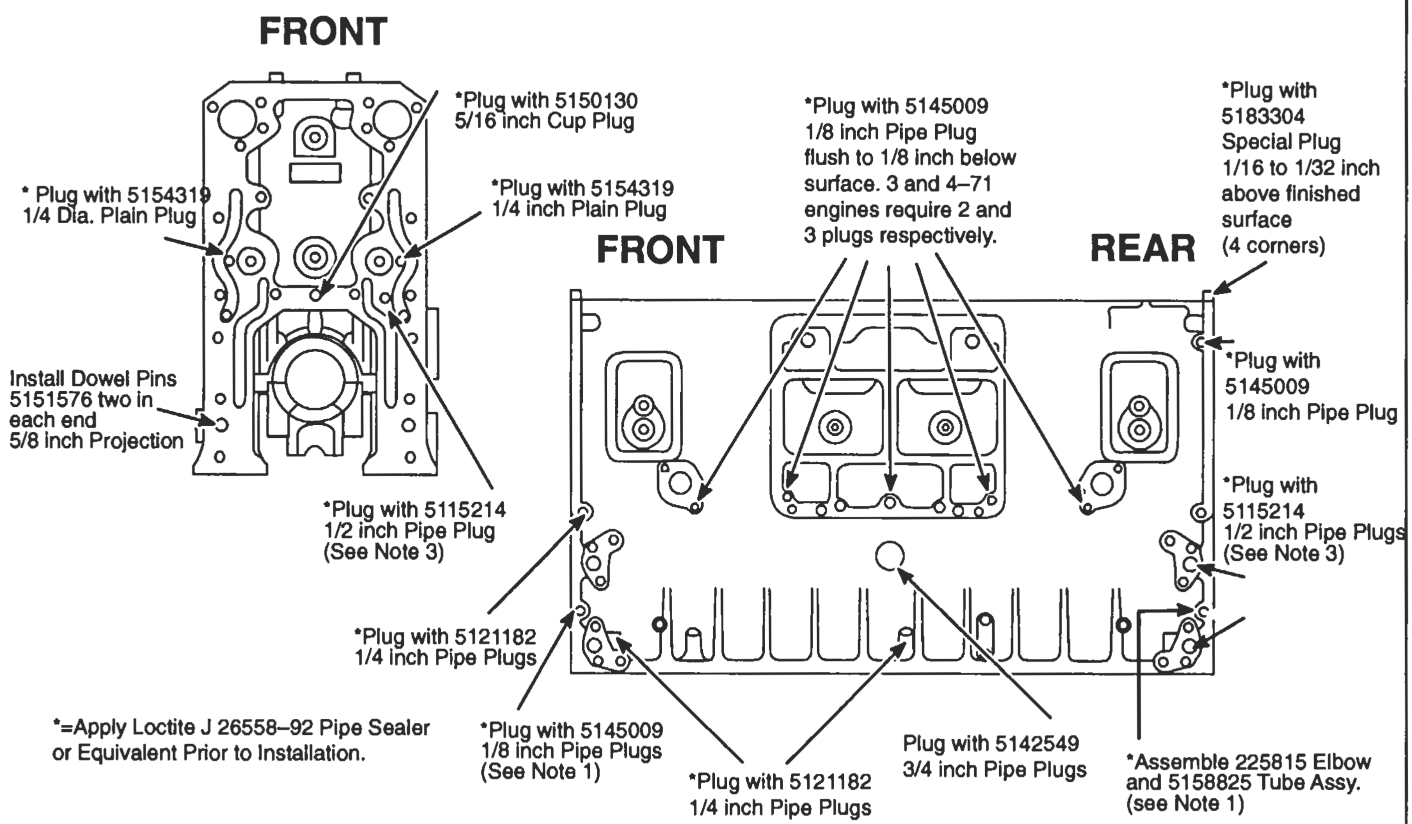
(1) Assemble 225815 elbow and 5158825 tube assy. to the front of the block for LD engine of Model 24001B and RD engine Model 24002B. Assembly 5145014 plugs to rear of block on aforementioned engines. On truck engines, assemble 225815 elbow and 5158825 tube assy. to the front and to the rear on the blower side. Assemble 5145009 plugs on the opposite side of the block.

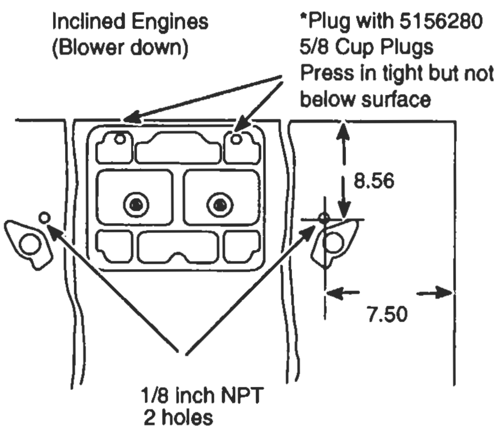
(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

(4) Do not install plugs when crankcase breather is to be installed on accessory pad.

STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

CYLINDER BLOCK PLUGGING CHARTS (LA & RA ENGINES)





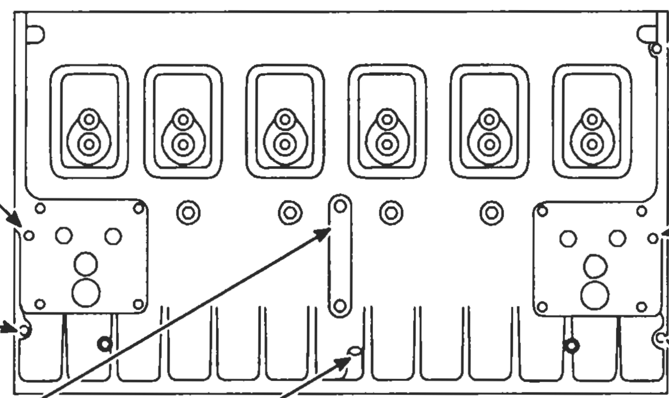
STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
1/8	10–12	14–16
1/4	14–16	19–22
3/8	18–22	24–30
1/2	23–27	31–37
3/4	33–37	45–50
1	78–85	106–115

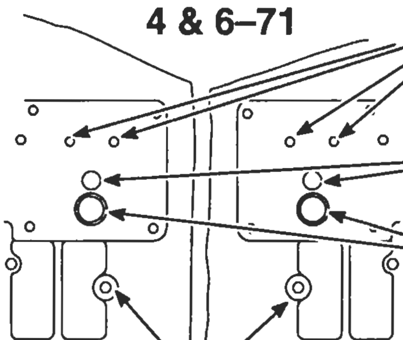
NOTES:

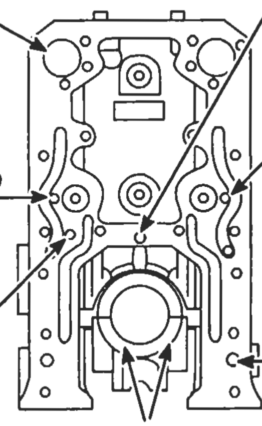
(1) On coach engines, assemble 225815 elbow and 5158825 tube assy. on thr front and to the rear of block, both on the blower side. On RA engine of model 12004B, assemble 225815 elbow and 5158825 tube assembly on each side and to the front of the block. For the LA engine of Model12201, assemble 225815 elbow and 5171502 tube assembly to the front and the rear of blcok, both on the blower side. On the aforementioned engines, assemble a 5145009 plug into each of the two remaining corresponding holes.

(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

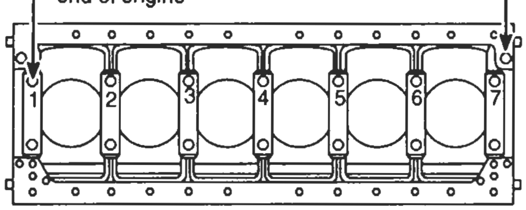
CYLINDER BLOCK PLUGGING CHARTS (LA & RA ENGINES) (CONT.)







*=Apply Loctite J 26558–92 Pipe Sealer or Equivalent Prior to Installation.



STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

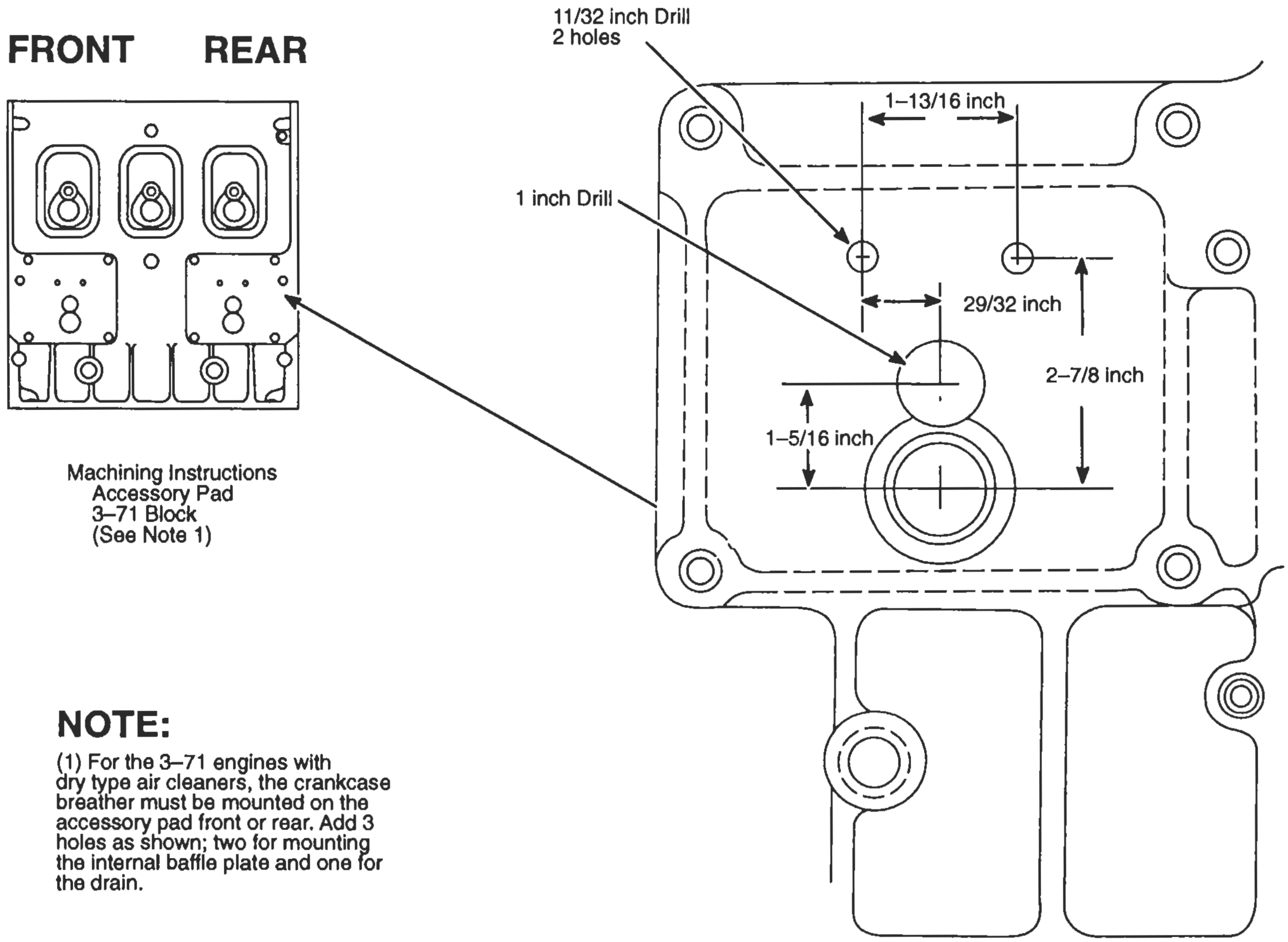
NOTES:

(1) On coach engines, assemble 225815 elbow and 5158825 tube assy. on thr front and to the rear of block, both on the blower side. On RA engine of model 12004B, assemble 225815 elbow and 5158825 tube assembly on each side and to the front of the block. For the LA engine of Model12201, assemble 225815 elbow and 5171502 tube assembly to the front and the rear of blcok, both on the blower side. On the aforementioned engines, assemble a 5145009 plug into each of the two remaining corresponding holes.

(3) Replace oil cooler pad and oil gallery end plugs 5115214 by plug 5173334 and plug 5145014 in bottomof block by 5173333 when assembling an aluminum cylinder block.

(4) Do not install plugs when crankcase breather is to be installed on accessory pad.

ACCESSORY PAD MACHINING CHART (3–71)



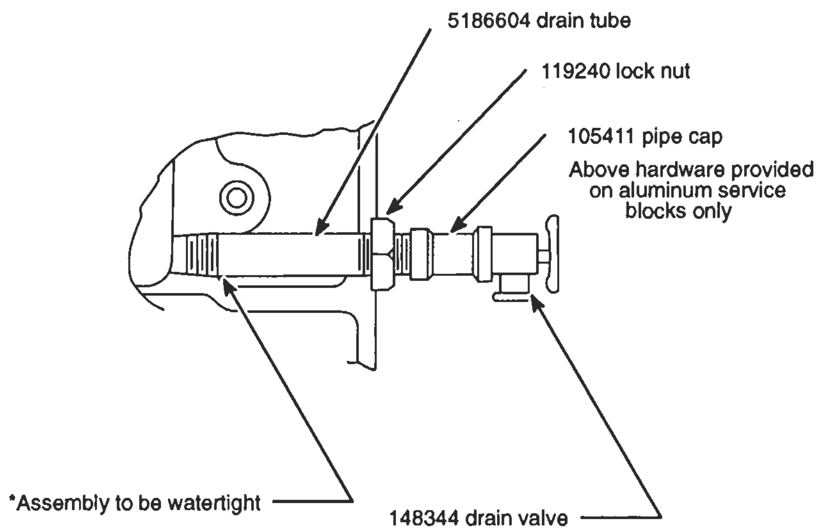
Machining Instructions
Accessory Pad
3–71 Block
(See Note 1)

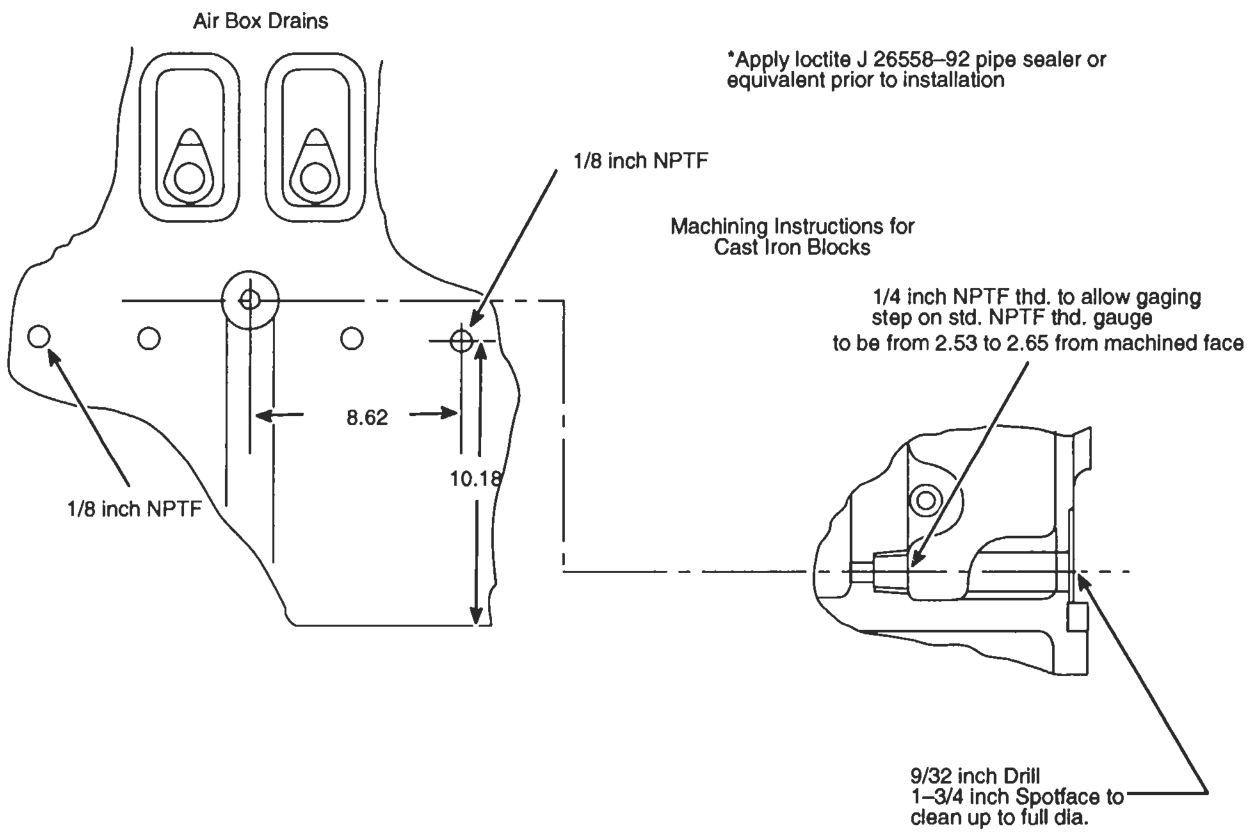
NOTE:

(1) For the 3–71 engines with dry type air cleaners, the crankcase breather must be mounted on the accessory pad front or rear. Add 3 holes as shown; two for mounting the internal baffle plate and one for the drain.

 May, 1994

WATER JACKET DRAIN CHART (HORIZONTAL ENGINES)





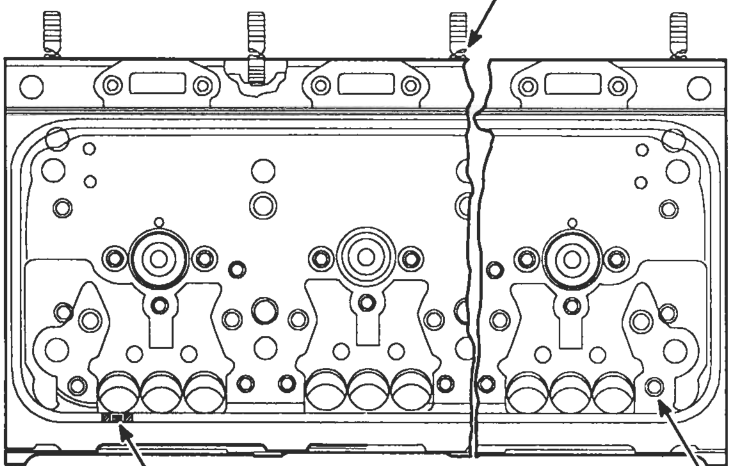
CYLINDER HEAD PLUGGING CHARTS (2–VALVE)

* Apply Loctite J 26558–92 pipe sealer with teflon or equivalent prior to installation.

STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

NOTICE: Do not over torque teflon wrapped pipe plugs.

*Install Exhaust Manifold Studs to 25–40 lb·ft (34–54 N·m) Torque



*Install 3/8–16 inch plugs flush to 1/16 inch above surface 4 places

*Install fuel manifold connectors and washers

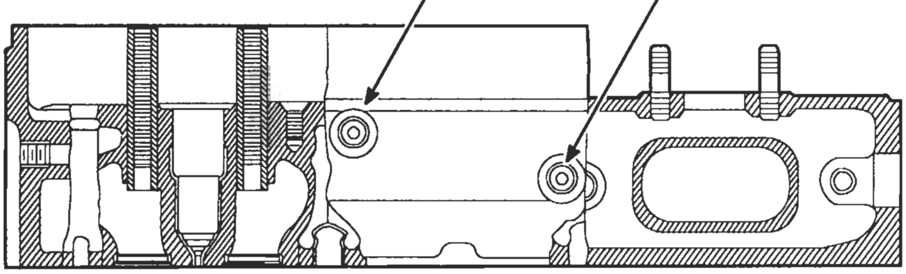
*1/4 inch NPTF (in manifold)

*5/8–18 inch (in filter)

To assemble hose and fittings:
1. Cut hose to required length. Lubricate inside of hose and outside of nipple.
2. Push nose on fitting underneath protective cap.

*Install flexible manifold inlet hose in convenient location. Install special 1/4 inch pipe plugs in all other end and side positions

*Install restricted (R) orifice connector in convenient location in fuel manifold outlet

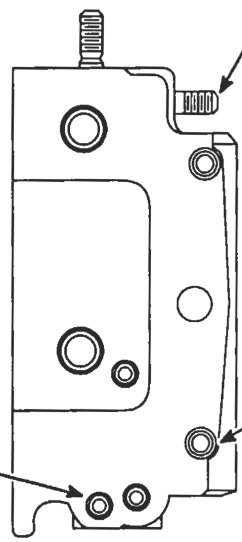


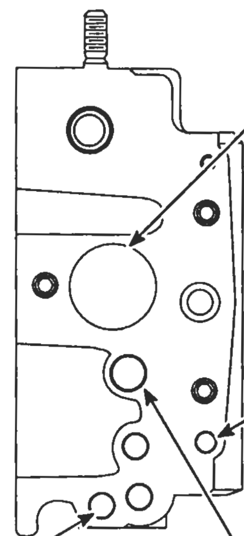
CYLINDER HEAD PLUGGING CHARTS (2–VALVE) (CONT.)

* Apply Loctite J 26558–92 pipe sealer with teflon or equivalent prior to installation.

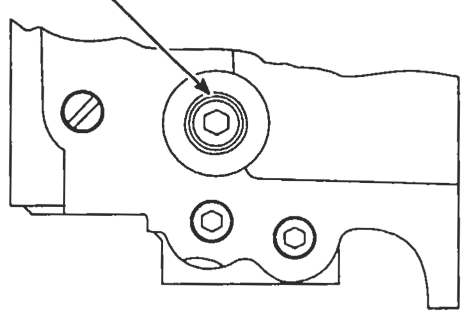
STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
1/8	10–12	14–16
1/4	14–16	19–22
3/8	18–22	24–30
1/2	23–27	31–37
3/4	33–37	45–50

NOTICE: Do not over torque teflon wrapped pipe plugs.





New style head end view (opposite) 3–71 & 6–71 inline



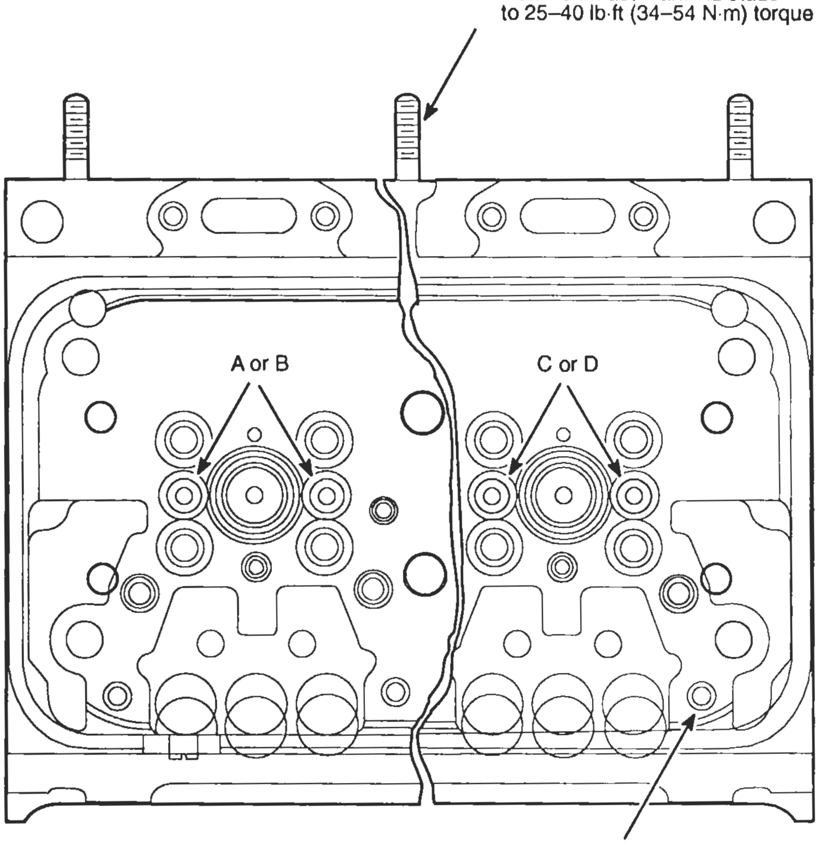
New style head end view (opposite) 3–71 inline

CYLINDER HEAD PLUGGING CHARTS (4–VALVE)

* Apply Loctite J 26558–92 pipe sealer with teflon or equivalent prior to installation.

STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
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

NOTICE: Do not over torque teflon wrapped pipe plugs.

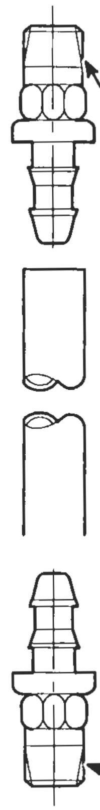


A–Use with three spring design (spring under bridge)

B–Two spring design (no spring under bridge)

C–Use with .581 I.D. valve spring

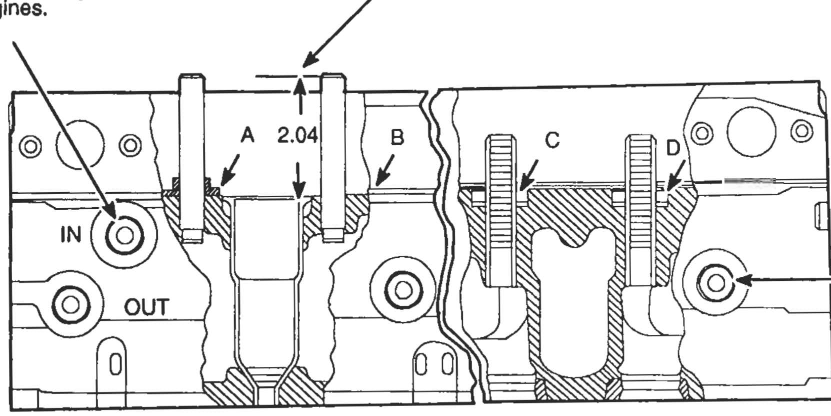
D–Use with .645 I.D. valve spring



To assemble hose and fittings:
1. Cut hose to required length. Lubricate inside of hose and outside of nipple.
2. Push nose on fitting underneath protective cap.

*Install special1/4 inch pipe plugs in all manifold end and side positions except fuel inlet and outlet positions convenient for assembly for 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.

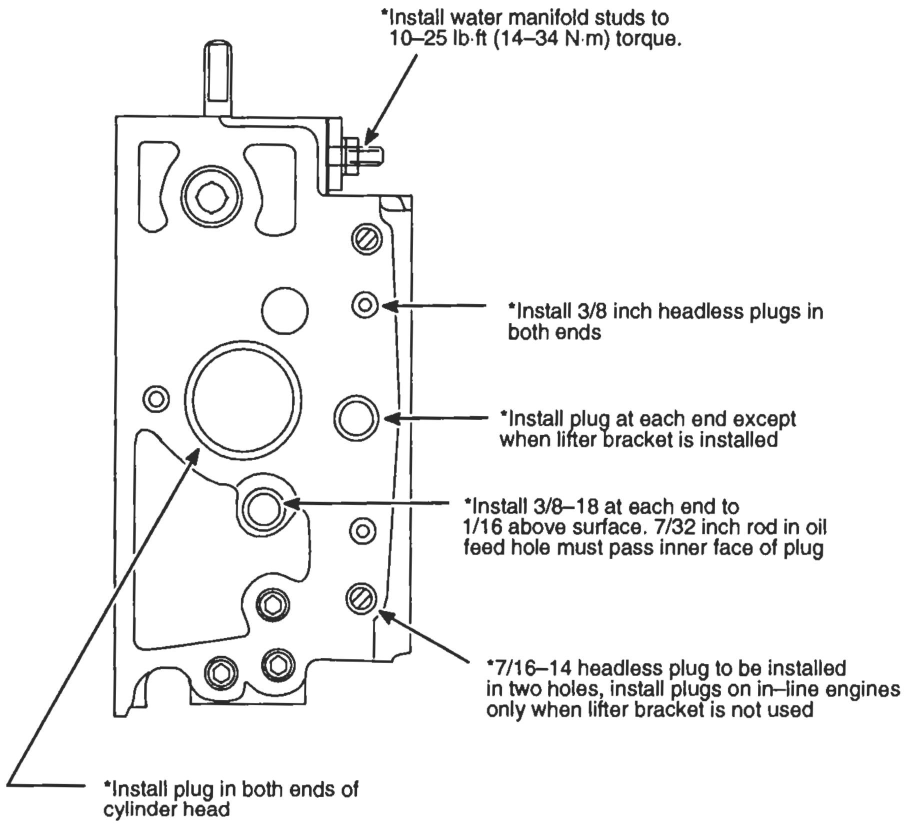
NOTICE: Use .1065 inch connector (marked R10) with 90CMM injectors. Use .080" connector (marked R80, R08 or R8) with all other injectors.

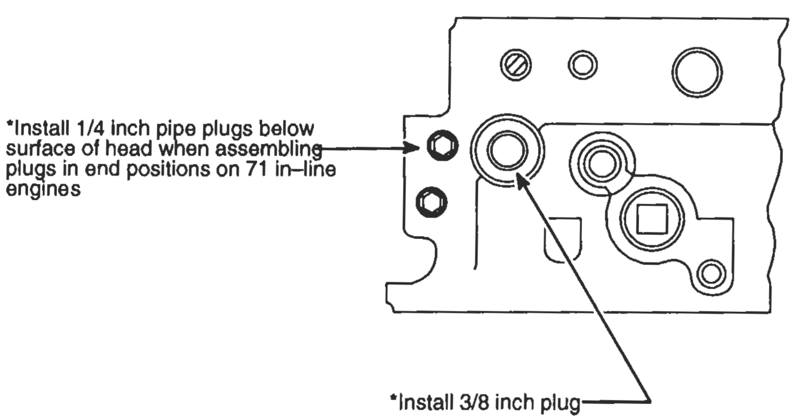
CYLINDER HEAD PLUGGING CHARTS (4–VALVE) (CONT.)

* Apply Loctite J 26558–92 pipe sealer with teflon or equivalent prior to installation.

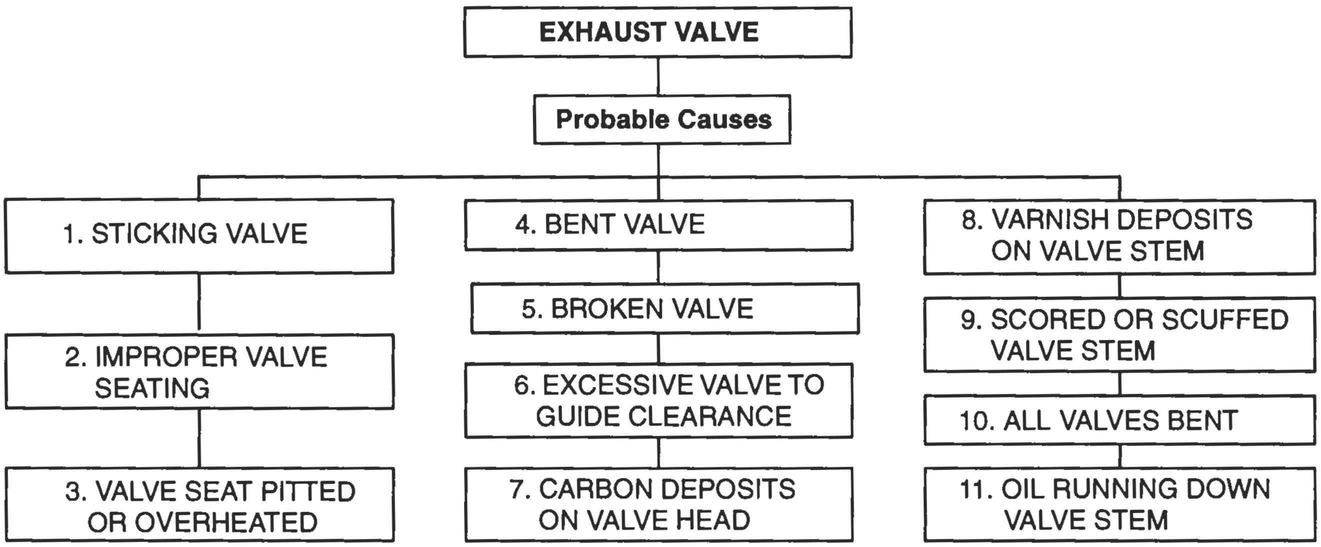
STANDARD PIPE PLUG TORQUE		
SIZE	LB·FT	N·M
1/8	10–12	14–16
1/4	14–16	19–22
3/8	18–22	24–30
1/2	23–27	31–37
3/4	33–37	45–50

NOTICE: Do not over torque teflon wrapped pipe plugs.





TROUBLESHOOTING



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 the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean–up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.
8. Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.
9. Check for a bent valve stem or guide, metal chips or dirt, or for lack of lubrication. Clean up the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap does not scrape the valve stem.
10. Check for a gear train failure or for improper gear train timing.
11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this Chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the 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 (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
CYLINDER BLOCK			
Block bore:			
Diameter (cast iron block)	4.6256	4.6270	
Out–of–round		0.0010	0.0020
Taper	0.0010	0.0020	
Cylinder liner counterbore:			
Diameter	5.0460	5.0510	
Depth (cast iron high block)	0.4770	0.4795	
Main bearing bore			
Inside diameter (vertical axis)	3.8120	3.8130	
Top surface of block:			
Centerline main bearing bore to block top	16.1840	16.1890	16.176 min.
Flatness—transverse (3, 4 and 6 cyl.)			0.0030
Flatness—longitudinal (3 cyl.)			0.0060
Flatness—longitudinal (4 cyl.)			0.0070
Flatness—longitudinal (6 cyl.)			0.0090
Depth of counterbores (top surface):			
Cylinder head seal strip groove	0.0920	0.1070	
Large water holes (between cylinders)	0.1100	0.1200	
Small water holes (at ends)	0.0880	0.0980	
Combination water and oil holes	0.0880	0.0980	
CYLINDER HEAD			
Flatness—transverse (3, 4 and 6 cyl.)			0.0040
Flatness—longitudinal (3 cyl.)			0.0055
Flatness—longitudinal (4 cyl.)			0.0080
Flatness—longitudinal (6 cyl.)			0.0100
Surface Finish (with 1mm dia. stylus)		90AA	
Distance between top deck and fire deck	3.5560	3.5680	3.5360
Water nozzles	0.0100 recess	0.0030 prot.	
Cam follower bores	1.0620	1.0630	1.0650
ROCKER ARMS AND SHAFTS			
Diameter—rocker shaft	0.8735	0.8740	
Diameter—inside (rocker arm bushing)	0.8750	0.8760	
Clearance—shaft–to–bushing	0.0010	0.0025	0.0040

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
CAM FOLLOWERS			
Diameter	1.0600	1.0610	
Clearance—follower–to–head	0.0010	0.0030	0.0060
Rollers and pins:			
Clearance—pin–to–bushing	0.0013	0.0021	0.010 Horiz.
Side clearance—roller to follower	0.0110	0.0230	0.0230
EXHAUST VALVES			
Stem diameter (2–valve)	0.3417	0.3425	0.3405
Stem diameter (4–valve)	0.3100	0.3105	0.3090
Valve head–to–cylinder head:			
30° (2–valve and 4–valve)	0.023 recess	0.006 prot.	0.038 recess
VALVE GUIDES			
Height above cylinder head:			
2–valve	1.5938	1.5938	
4–Valve (chamfered guide)	0.8800	0.8800	
4–valve (machined guide)	0.6900	0.6900	
Diameter—inside (2–valve)	0.3445	0.3455	0.3465
Diameter—inside (4–valve)	0.3125	0.3135	0.3140
Clearance—valve–to–guide (2–valve)	0.0020	0.0038	0.0060
Clearance—valve–to–guide (4 valve)	0.0020	0.0035	0.0050
VALVE BRIDGE GUIDES			
Height above cylinder head (4–valve)	2.0400	2.0400	
EXHAUST VALVE SEAT INSERTS			
Seat width—31° (2–valve)	0.0625	0.0937	0.0937
Seat width—31° (4–valve)	0.0468	0.0937	0.0937
Valve seat runout		0.0020	0.0020
CRANKSHAFT			
Journal diameter—main bearing	3.4985	3.5002	
Journal diameter—conn. rod bearing	2.7485	2.7502	
Journal out–of–round		0.00025	0.0010
Journal taper		0.0006	0.0006
+Runout on journals—total indicator reading:			
3 cylinder (mounted on No. 1 and No. 4 journals):			
At No. 2 and No. 3 journals		0.0020	
4 cylinder (mounted on No. 1 and No. 5 journals):			
At No. 2 and No. 4 journals		0.0020	
At No. 3 journal		0.0040	
6 cylinder (mounted on No. 1 and No. 7 journals):			
At No. 2 and No. 6 journals		0.0020	
At No. 3 and No. 5 journals		0.0040	
At No. 4 journal		0.0060	
Thrust washer thickness	0.1190	0.1220	
End play (end thrust clearance)	0.0040	0.0140	0.0180

+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 inch total indicator reading. When the runout on adjacent journals is in the same direction, the difference must not exceed .003 inch 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 inch total indicator reading or .002 inch on each journal.

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
MAIN BEARINGS			
Inside diameter (vertical axis)	3.5014	3.5034	
Bearing–to–journal clearance	0.0014	0.0044	0.0060
Bearing thickness 90° from parting line	0.01548	0.1553	0.153
TRUNK TYPE PISTON AND RINGS (71)			
Piston:			
Height (centerline of bushing to top)	3.5130	3.5180	
Diameter (above compression rings)	4.2190	4.2220	
Diameter (at skirt)	4.2433	4.2455	
Clearance—piston skirt–to–liner (long port)	0.0040	0.0078	0.0120
Clearance—piston skirt–to–liner (short port)	0.0040	0.0083	0.0120
Out–of–round		0.0005	
Taper		0.0005	
Compression rings:			
Gap	0.0180	0.0430	0.0600
Clearance—ring–to–groove:			
No. 1 (top)	0.0095	0.0130	0.0220
No. 2	0.0075	0.0110	0.0150
No. 3 and 4	0.0055	0.0090	0.0130
Oil control rings:			
Gap	0.0080	0.0230	0.0430
Clearance—ring–to–groove	0.0015	0.0055	0.0080
TRUNK TYPE PISTONS AND RINGS (71E)			
Piston:			
Height (centerline of bushing to top):			
Two valve head engine	3.3880	3.3930	
Four valve head engine	3.5130	3.5180	
Diameter (above compression rings):			
Two valve head engine	4.2217	4.2247	
Four valve head engine (60 cmm inj.)	4.2230	4.2260	
Four valve head engine (70 cmm inj.)	4.2190	4.2220	
Diameter (at skirt):			
Two valve head engine	4.2433	4.2455	
Four valve head engine (60 cmm inj.)	4.2433	4.2455	
Four valve head engine (70 cmm inj.)	4.2418	4.2440	
Clearance—piston skirt–to–liner:			
Two valve head engine	0.0040	0.0078	0.0120
Four valve head engine (60 cmm inj.)	0.0040	0.0078	0.0120
Four valve head engine (70 cmm inj.)	0.0055	0.0093	0.0120
Out–of–round		0.0005	
Taper		0.0005	
Compression rings:			
Gap (top–fire ring)	0.0230	0.0380	0.0600
Gap (No. 2, 3 and 4)	0.0180	0.0430	0.0600
Clearance—ring–to–groove:			
No. 1 (top, fire ring)	0.0040	0.0070	0.0100
No. 2	0.0095	0.0130	0.0220
No. 3	0.0075	0.0110	0.0150
No. 4	0.0055	0.0090	0.0130

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
TRUNK TYPE PISTONS AND RINGS (71E) (Cont.)			
Oil control rings:			
Gap	0.0080	0.0230	0.0430
Clearance—ring–to–groove	0.0015	0.0055	0.0080
TRUNK TYPE PISTONS AND RINGS (71M)			
Piston:			
Height (centerline of bushing to top)	3.5130	3.5180	
Diameter (above compression rings)	4.2230	4.2260	
Diameter (at skirt)	4.2418	4.2440	
Clearance—piston skirt–to–liner	0.0055	0.0093	0.0120
Out–of–round		0.0005	
Taper		0.0005	
Compression rings:			
Gap (top–fire ring)	0.0230	0.0380	0.0600
Gap (No. 2, 3 and 4)	0.0180	0.0430	0.0600
Clearance—ring–to–groove:			
No. 1 (top–fire ring)	0.0040	0.0070	0.0100
No. 2	0.0095	0.0130	0.0220
No. 3	0.0075	0.0110	0.0150
No. 4	0.0055	0.0090	0.0130
Oil control rings:			
Gap	0.0080	0.0230	0.0430
Clearance—ring–to–groove	0.0015	0.0055	0.0080
TRUNK TYPE PISTONS AND RINGS (71N)			
Piston:			
Height (centerline of bushing to top)	3.5430	3.5480	
Diameter (above compression rings)	4.2225	4.2255	
Diameter (at skirt)	4.2428	4.2450	
Clearance—piston skirt–to–liner	0.0045	0.0083	0.0120
Out–of–round		0.0005	
Taper		0.0005	
Compression rings:			
Gap (top–fire ring)	0.0230	0.0380	0.0600
Gap (No. 2, 3 and 4)	0.0180	0.0430	0.0600
Clearance—ring–to–groove:			
No. 1 (top–fire ring)	0.0040	0.0060	0.0100
No. 2	0.0100	0.0130	0.0220
No. 3 and 4	0.0040	0.0070	0.0130
Oil control rings:			
Gap	0.0080	0.0230	0.0430
Clearance	0.0015	0.0055	0.0080
TRUNK TYPE PISTONS AND RINGS (71T)			
Piston:			
Height (centerline of bushing to top)	3.3880	3.3930	
Diameter (above compression rings)	4.2197	4.2227	
Diameter (at skirt)	4.2413	4.2435	
Clearance—piston skirt–to–liner	0.0060	0.0098	0.0120
Out–of–round		0.0005	
Taper		0.0005	

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
TRUNK TYPE PISTONS AND RINGS (71T) (Cont.)			
Compression rings:			
Gap	0.0180	0.0430	0.0600
Clearance—ring–to–groove:			
No. 1	0.0095	0.0130	0.0220
No. 2	0.0075	0.0110	0.0150
No. 3 and 4	0.0055	0.0090	0.0130
Crankcase seal ring:			
Gap	0.0050	0.0400	0.0400
Clearance	0.0100	0.0150	0.0170
Oil control rings:			
Gap (two rings in lower groove)	0.0050	0.0140	0.0340
Gap (one ring in upper groove)	0.0050	0.0140	0.0340
Clearance (two rings in lower groove)	0.0015	0.0055	0.0080
Clearance (one ring in upper groove)	0.0010	0.0035	0.0060
PISTON PINS (TRUNK PISTONS)			
Length	3.6050	3.6200	
Diameter	1.4996	1.5000	1.4980
Clearance—pin to piston bushing	0.0025	0.0034	0.0100
Clearance—pin to conn. rod bushing	0.0025	0.0034	0.0100
Clearance—end (pin–to–retainer—retainer with lock ring)	0.0160	0.0640	0.0640
Piston bushing—inside diameter	1.5025	1.5030	1.5050
CROSS HEAD PISTONS AND RINGS			
Piston crown:			
Saddle–to–crown distance:			
N piston (18.7:1 compr. ratio)	2.7030	2.7100	
T piston (17:1 compr. ratio)	2.6730	2.6800	
Diameter:			
At top	4.2226	4.2256	
Below both compression rings	4.2389	4.2423	
Above and below seal ring groove	3.8850	3.8970	
Above and below bearing saddle	3.2360	3.2370	
Compression rings:			
Gap (top–fire ring)	0.022	0.037	0.0600
Gap (No. 2 and 3)	0.018	0.0430	0.0600
Clearance—ring–to–groove:			
*Top (Keystone fire ring)	0.0010	0.0050	0.0070
No. 2 (rectangular section)	0.0100	0.0130	0.0220
No. 3 (rectangular section)	0.0040	0.0070	0.0130
Seal ring:			
Gap (in skirt counterbore)	0.0020	0.0210	0.0270
Clearance	0.0005	0.0030	0.0040

*Measured with Keystone fire ring flush with outside diameter of piston crown.

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
CROSS HEAD PISTONS AND RINGS (Cont.)			
Piston skirt:			
#Diameter	4.2414	4.2424	
Clearance—skirt–to–liner	0.0045	0.0083	0.0120
Seal ring bore	3.9200	3.9240	3.9260
Piston pin bore	1.5030	1.5040	1.5040
Oil control rings:			
Gap (two rings in lower groove) (71N & T)	0.0080	0.0230	0.0430
Gap (two rings in upper groove) (71N)	0.0080	0.0230	0.0430
Gap (one ring in upper groove) (71T)	0.0050	0.0140	0.0340
Gap (two rings in upper groove) (71T)	0.0080	0.0230	0.0430
Clearance (lower groove)	0.0015	0.0055	0.0080
Clearance (upper groove)	0.0010	0.0035	0.0060
PISTON PINS (CROSS–HEAD PISTON)			
Length	3.6150	3.6240	
Diameter	1.4996	1.5000	1.4980
Slipper bearing (bushing):			
Thickness at center	0.0870	0.0881	0.0860
Clearance (edge of bushing to groove in piston)	0.0005	0.0105	0.0120
CONNECTING ROD			
Inside diameter (upper bushing)	1.4985	1.5000	1.5000
Normal side clearance	0.0060	0.0120	
CONNECTING ROD BEARINGS			
Inside diameter (vertical axis)	2.7514	2.7534	
Bearing–to–journal clearance	0.0014	0.0044	0.0060
Bearing thickness 90° from parting line	0.1548	0.1553	0.153 min.
CYLINDER LINER			
Outside diameter	4.6252	4.6265	
Inside diameter	4.2489	4.2511	
Clearance—liner–to–block:			
High	0.0000	0.0020	0.0025
Out–of–round—inside diameter		0.0030	0.0025
Taper—inside diameter		0.0013	0.0020
Depth of flange BELOW block	0.0450	0.0500	0.0500
Variation in depth between adjacent liners		0.0020	0.0020
Insert thickness	0.1795	0.1800	
CAMSHAFT			
Diameter (at bearing journals):			
Front and rear	1.4960	1.4965	
Center and intermediate	1.4975	1.4985	
Runout center bearing (mounted end bearings)		.0020	
Shaft diameter at gear	1.1875	1.1885	
End thrust	0.0030	0.0150	0.0180
Thrust washer thickness	0.1190	0.1220	

#Diameter above and below the piston pin may be 4.2414 inches.

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
BALANCE SHAFT			
Shaft diameter at bearings	1.4970	1.4975	
Shaft diameter at gear	1.1875	1.1885	
Length—thrust bearing end journal	2.8740	2.8760	
End thrust	0.0030	0.0150	0.0180
Thrust washer thickness	0.1190	0.1220	
CAMSHAFT AND BALANCE SHAFT BEARINGS			
Inside diameter:			
Front and rear	1.5000	1.5010	
Center and intermediate	1.5010	1.5030	
Clearance—bearing–to–shaft:			
Front and rear	0.0025	0.0040	0.0060
Center and intermediate	0.0025	0.0050	0.0090
Outside diameter:			
Front and rear	2.1875	2.1880	
Center and intermediate	2.1840	2.1860	
Diameter of cylinder block bore	2.1875	2.1887	
Clearance—bearings–to–block:			
Front and rear	0.001 press.	0.0005 loose	
Intermediate (extruded)	0.0015	0.0065	
Intermediate (die cast)	0.0015	0.0105	
CAMSHAFT AND BALANCE SHAFT GEARS			
Inside diameter	1.1875	1.1880	
Clearance—gear–to–shaft	0.0015 press.	0.0000	
Backlash	0.0030	0.0080	0.0100
IDLER GEAR			
Backlash	0.0030	0.0080	0.0100
Pre–load—Variation on pull 2 lbs. 11 oz.	1/2 lb.	4 lbs.	
CRANKSHAFT TIMING GEAR			
Inside diameter	4.7490	4.7510	
Clearance—gear–to–shaft	0.001 press.	0.001 loose	
Backlash	0.0020	0.0050	0.0100
BLOWER DRIVE GEAR			
Backlash	0.0030	0.0080	0.0100
Gear–to–hub fit	0.0005 press.	0.001 loose	
Support–to–end plate	0.0005 press.	0.0025 loose	
Inside diameter (support bushing)	1.6260	1.6265	
Hub diameter (at bearing)	1.6240	1.6250	
Hub–to–support bushing clearance	0.0010	0.0025	0.0050
Hub–to–cam clearance	0.0020	0.0070	
End thrust (current bearing)	0.0060	0.0140	
End thrust (former flanged bearing)	0.0050	0.0080	0.0100

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. (lb/in^2)
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	(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
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
Flywheel housing bolts	3/8–16	25–30		34–41
Front accessory drive pulley bolt	3/8–16	25		34
Front end plate bolt (2 bolts water jacket plug)	3/8–16	20–25		27–34
Idler gear hub and spacer bolts	3/8–16	40–45		54–61
Injector clamp bolts	3/8–16	20–25		27–34
Oil pan bolts (upper)	3/8–16	15–20		20–27
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
Blower drive support bolts and nuts	3/8–24	25–30		34–41
*Balance weight–to–camshaft gear bolt	3/8–24	15–18		20–24
Balance weight–to–camshaft gear locknut	3/8–24	25–30		34–41
Balance weight–to–camshaft gear plain nut	3/8–24	18–22		24–30
Balance weight–to–camshaft gear slotted nut	3/8–24	28–32		38–43
Camshaft intermediate bearing lock screw	3/8–24	15–20		20–27
Crankshaft front cover bolts	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 hole)	3/8–24	30–35		41–47
Fuel pipe nuts (uncoated)	3/8–24	—	160	18.3
Fuel pipe nuts (Endurion®)	3/8–24	—	130–160	14.7–18.1
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	—	160–200	18.1–22.6
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.)

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
Stabilizer bolts	7/16–14	70–75		95–102
Connecting rod nut (castellated)	7/16–20	65–75		88–102
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
#Fuel manifold connectors (Nylon insert)	7/16–20	30–35		41–47
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)	1/2–13	30–35		41–47
Generator drive bearing retaining bolt	1/2–13	30–35		41–47
Generator drive oil seal retaining bolt	1/2–13			
Idler gear hub and dummy hub bolt	1/2–13	80–90		108–122
+Rocker shaft bolts	1/2–13	90–100		122–136
**Camshaft gear bolt (right–bank–300M)	9/16–18	180–190		244–258
**Flywheel bolts (see Sect. 1.4)	9/16–18			
**Cylinder head bolts	5/8–11	170–180		237–244
**Main bearing bolts (asm.)	5/8–11	190–200		258–272
**Main bearing bolts (bolting)	5/8–11	165–175		224–238
**Cylinder head nuts	5/8–11	175–185		238–251
Rear Accessory drive pulley nut (blower driven)	3/4–16	120–140		163–190
Rear Accessory drive pulley nut (cam driven)	3/4–16	150–170		204–231
Crankshaft end bolt	1–14	290–310		393–421
Camshaft nut	1 1/8–18	300–325		407–441
Blower drive gear hub nut	1 7/16–16	50–60		68–81
Left bank accessory drive gear nut	1 7/16–16	50–60		68–81

*Stake nut after tightening.

#Lubricate before assembling to cylinder head.

+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).

 May, 1994

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	9–22	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 inch Dryseal PTF thread	†Assemble with max. .0625 inch protrusion from surface
Cylinder head (side)	3/8–16 inch	Assembly flush to .0625 inch protrusion from surface
Cylinder head (top)	1/2 inch PTF–SAE short	Flush to 1.1250 inch recessed
Cylinder head (end)	3/4 inch Dryseal PTF–SAE short	Flush to .1250 inch recessed
Water hole plug	1 inch NPTF thread	Assemble 2.000 to 2.250 inch below machined surface
Core hole plug	1 3/4–16 inch	150–180 lb·ft (204–244 N·m)
Oil drain plug (Nylon washer)	18mm	25–35 lb·ft (34–37 N·m)

*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.

SPRING SPECIFICATIONS

SPRING	REPLACE WHEN LOAD IS LESS THAN:
Cam follower (11 coils – .177 wire)	172 lbs. @2.1250 inch
Cam follower (11 1/2 coils – .162 wire)	133 lbs. @2.1094 inch
Exhaust valve (two–valve cylinder head)	25 lbs. @2.2000 inch
§Exhaust valve (8 3/4 coils – .148 wire)	25 lbs. @1.8000 inch

*Four–valve cylinder head.

SERVICE TOOLS

TOOL NAME	TOOL NO.
CYLINDER BLOCK	
Cylinder Bore Plug Set	J 34698
Cylinder Checking Gage And Master Ring Set	J 9353
Cylinder Hone Set (2 1/2 to 5 3/4 inches)	J 5902–01
Dial Bore Gage Master Setting Fixture	J 23059–01
Dial Indicator Set	J 22273–01
Diesel Engine Parts Dolly	J 6387
Engine Overhaul Stand	J 29109
Engine Overhaul Stand Adaptor Plate	J 8196
Engine Overhaul Stand Adaptor Plate	J 33850
Pipe Plug Remover/Installer (1/8 Dia.)	J 34650
Special Plug Remover	J 21996–01
Loctite “Chisel” Gasket Remover	PT–7275
CYLINDER HEAD	
Cam Follower Service Fixture	J 33421–22
Load Cell Kit, Cam Follower Roller Fixture	J 33421–25
Cylinder Head Holding Plate Set	J 3087–01
Cylinder Head Pressure Checking Tool	J 28454
Feeler Gage Set (.0015 to .015 inches)	J 3172
Feeler Stock (.0015 inch)	J 23185
Guide Studs	J 9665
Push Rod Remover (Set of 3)	J 3092–01
Slide Hammer	J 2619–01
Socket (Fuel Line Nut)	J 8932–01
Spring Tester	J 22738–02
Valve Bridge Holding Fixture	J 21772
Valve Bridge Guide Remover (Broken)	J 7453
Valve Bridge Guide Remover Set (Press Fit)	J 7091–01
Valve Bridge Guide Installer (Press Fit)	J 7482
Valve Bridge Guide Remover And Installer (Threaded – 4 Valve Head)	J 6846
Valve Guide Cleaner	J 5437
Valve Guide Installer (2–valve Head)	J 9530
Valve Guide Installer (Machined 4–valve Head)	J 21520
Valve Guide Oil Seal Installer	J 35373
Valve Guide Remover (2–Valve Head)	J 267
Valve Guide Remover (4–Valve Head)	J 6569
Valve Seat Grinder (Model V.I.P.)*	J 7040–A
–Valve Seat Dial Gage	J 8165–2
–Valve Seat Grinder	J 8165–1A
Valve Seat Grinder Adaptor Set (2–Valve Head)	J 8165–8
Valve Seat Grinder Adaptor Set (4–Valve Head)	J 6390–02
Valve Seat Insert Installer (2–Valve Head)	J 1736
Valve Seat Insert Installer (4–Valve Head)	J 6568
Valve Seat Insert Remover (31° 2–Valve Head)	J 23479–271
Valve Seat Insert Remover (4–Valve Head)	J 23479–471

*Consists Of Single Dash (–) Items Below:

SERVICE TOOLS (CONT.)

TOOL NAME	TOOL NO.
Valve Spring Checking Gage	J 25076–B
Valve Spring Compressor	J 7455–A
CRANKSHAFT	
Crankshaft Front Oil Seal Installer	J 9783
Crankshaft Oil Seal Expander	J 22425–A
Crankshaft Pulley And Rubber Mounted Balancer Puller	J 5356
Crankshaft Rear Oil Seal Installer	J 9727–A
Crankshaft Rear Oil Seal Expander (Oversize Seal)	J 4195–01
Crankshaft Rear Oil Seal Service Sleeve Installer	J 4194–01
Dial Indicator Set	J 5959–01
Driver Handle	J 3154–1
Driver Handle	J 8092
Micrometer Ball Attachment	J 4757
Universal Bar Type Puller	J 24420–B
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	
Crankshaft Oil Seal Expander	J 22425–A
Crankshaft Oil Seal Expander (O.S. Seal)	J 4195–01
Driver Handle	J 8092
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 Bushing Reamer Set	J 29588–71
Connecting Rod Holding Fixture	J 7632
Connecting Rod Spray Nozzle Remover	J 8995
Crosshead Piston Dome Disassembly Tool	J 33048
Cylinder Checking Gage And Master Ring Set	J 9353
Cylinder Hone Set (2 1/2 to 5 3/4 inch range)	J 5902–01
Cylinder Liner Hold–Down Clamp	J 21793–B
Cylinder Liner Remover Set	J 1918–02
Dial Bore Gage Setting Fixture	J 23059–01
Dial Indicator Set	J 22273–01
Feeler Gage Set	J 3172
Fire Ring Groove Gage (cross–head piston)	J 24599
Micrometer Ball Attachment	J 4757
Piston and Connecting Rod Bushing Installer and Remover Set	J 1513–02
Piston Bushing Reamer Set	J 3071–B

SERVICE TOOLS (CONT.)

TOOL NAME	TOOL NO.
Piston Bushing Reaming Fixture	J 5273
Piston Crown Identification Gage (cross–head)	J 25397–A
Piston Pin Alignment Tool	J 24285
Piston Pin Retainer Installer (Trunk–type piston)	J 24107–01
Piston Pin Retainer Installer (Cross–head piston)	J 23762
Piston Pin Retainer Leak Detector (Plastic)	J 23987–B
Piston Pin Retainer Leak Detector (all metal design)	J 35134
Piston Ring Compressor	J 3272–03
Piston Ring Remover and Installer	J 8128
Piston to Liner Feeler Gage Set	J 5438–01
Seal Ring Compressor (Cross–head piston)	J 23453
CAMSHAFT	
Accessory Drive Hub Oil Seal Aligning Tool	J 21166
Blower Drive Cam Installer	J 1471
Camshaft Gear Puller	J 1902–01
Camshaft Gear Puller Adaptor Plate Set	J 6202–01
Camshaft and Oil Pump Gear Replacer	J 1903
Dial Indicator and Attachment Set	J 5959–01
Slide Hammer Set	J 6471–02
Spring Scale	J 8129

FUEL SYSTEM

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FUEL SYSTEM

The fuel system (Figure 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 in several places in the side of the cylinder head. This aids installation of the fuel lines.

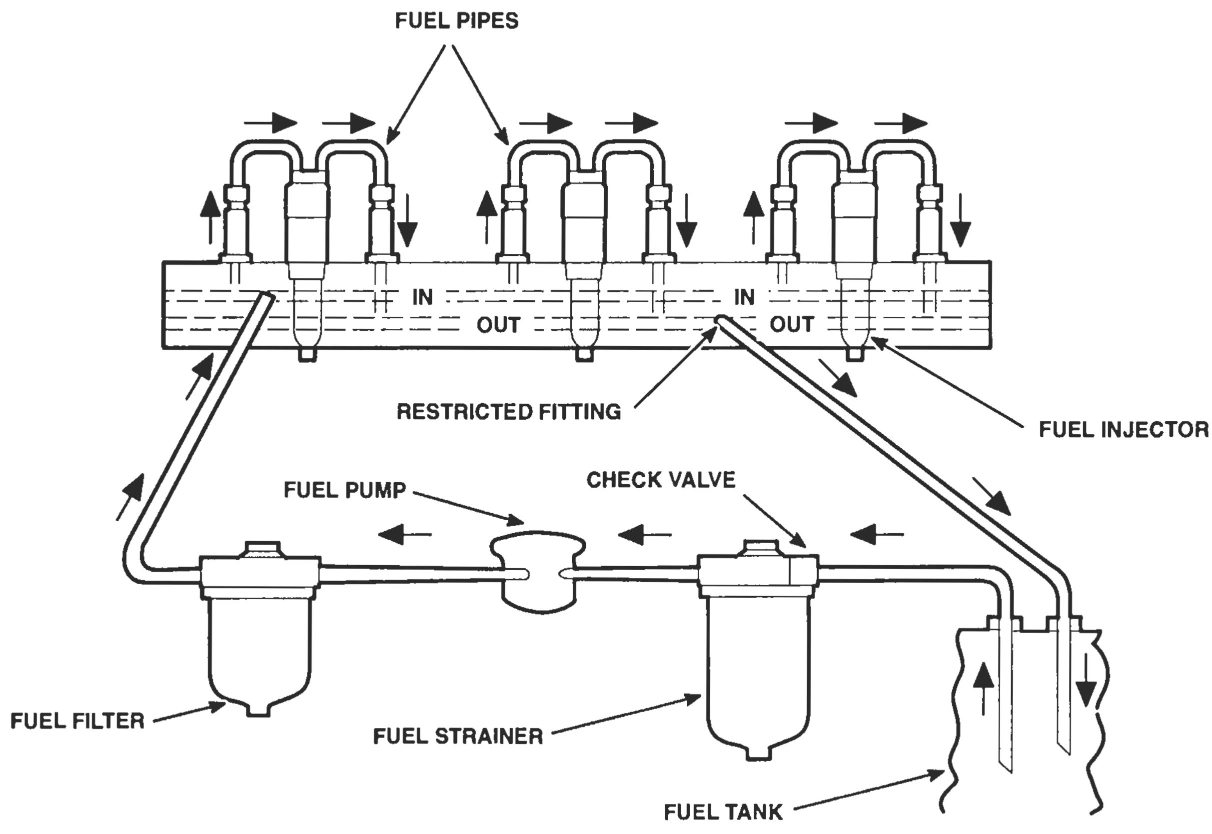

Figure 1. Schematic Diagram of Fuel System

ELECTRONIC UNIT INJECTOR

The Electronic Unit Injector (EUI) is a lightweight, compact unit that injects diesel fuel directly into the combustion chamber. The amount of fuel injected and the beginning of injection timing is determined by the Electronic Control Module (ECM). The ECM sends a command pulse which activates the injector solenoid.

The EUI performs four functions:

- Creates the high–fuel pressure required for efficient injection.
- Meters and injects the exact amount of fuel required to handle the load.
- Atomizes the fuel for mixing with the air in the combustion chamber.
- Permits continuous fuel flow for component cooling.

Engine combustion is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder. Metering and timing of the fuel is accomplished by the ECM which actuates the solenoid poppet valve to stop the free flow of fuel through the injector. When the solenoid poppet valve closes, fuel is trapped in the injector body and under the plunger. The continuous fuel flow through the injector prevents air pockets in the fuel system and cools those injector parts subjected to high combustion temperatures.

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

OPERATION

Fuel enters the injector through the fuel crossover pipe located at the back of the injector (Figure 1.)

Excess fuel oil returns through a crossover pipe to the fuel tank.

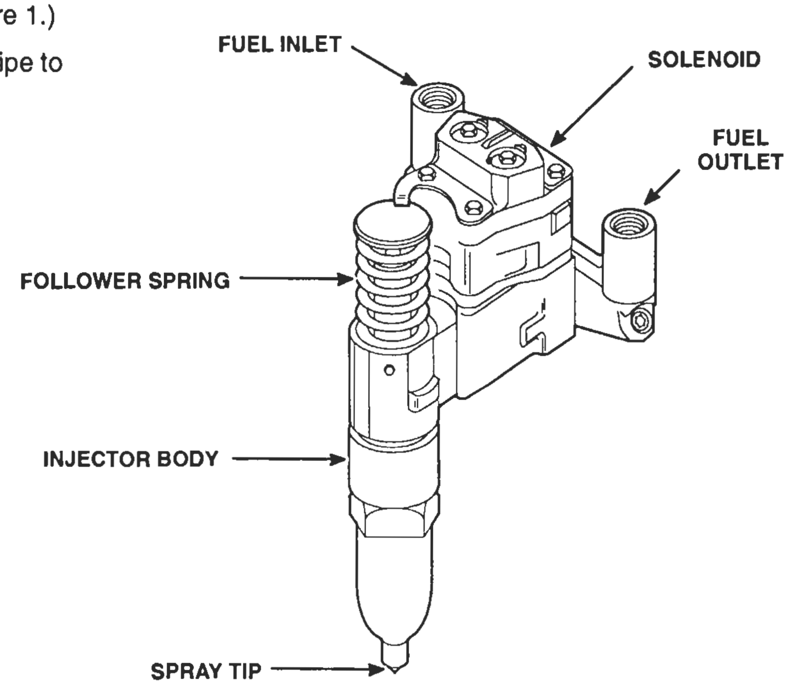

Figure 1. Electronic Unit Injector

OPERATION (CONT.)

After entering the nut cavity, the fuel passes through a drilled passage into the poppet control valve and plunger area (Figure 2.)

The plunger operates up and down in the body bore of the injector. The motion of the injector rocker arm is transmitted to the plunger and follower that bears against the follower spring.

As the piston moves approximately two–thirds of the way up in the cylinder on the compression stroke, the injector cam lode begins to lift causing the injector rocker arm to push down on the follower and the plunger. Just before injection begins, the ECM sends an electric pulse which turns on the injector solenoid. The energized solenoid creates a magnetic force which pulls the armature up, closing the poppet valve and trapping fuel under the plunger and passages leading down to the needle valve. The fuel pressure increases as the plunger continues its downward stroke.

A flat disk check valve is built into the injector fuel passages between the plunger and the tip. This check valve normally has no effect on the injection process but will function to prevent cylinder gases from blowing back into the injector and fuel system.

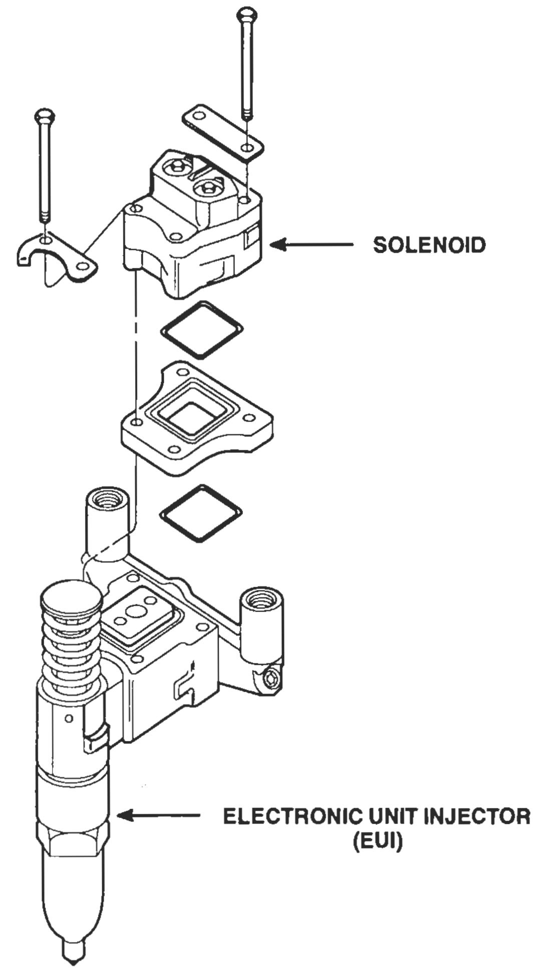

Figure 2. Electronic Unit Injector Components

This fuel pressure acts on the needle valve. When it creates a force high enough to overcome the valve spring force holding the needle on its seat, the needle valve moves up, allowing the high pressure fuel to spray into the combustion chamber. The high pressure of the fuel passing through the small holes in the tip creates a finely atomized spray for combustion within the cylinder.

After the "Pulse Width" time has passed, the ECM turns off the current to the injector solenoid. The de–energized solenoid allows a spring to open the poppet valve, permitting the trapped fuel to spill down, dropping the pressure within the injector. When the pressure is low enough the needle valve closes and ends injection.

OPERATION (CONT.)

The beginning of injection and metering of the fuel in relation to the crankshaft position are controlled by the ECM. Injection begins soon after the poppet valve is closed. The valve closing point information, known as the «response time feedback, is returned to the ECM. This information is used to monitor and adjust injection timing, thus removing injector–to–injector variation influences on timing. The amount of fuel injected depends on the Pulse Width stored in the calibration which determines how long the poppet valve remains closed; the larger the Pulse Width the longer the valve is closed and the more fuel is injected.

When the injector rocker arm has completed its downward travel the injector follower spring returns it to the starting position. As the plunger moves up fuel enters the injector pumping cavity for another injection cycle. The constant circulation of fuel through the injector renews the fuel supply in the chamber and aids the cooling of the injector.

INJECTOR REMOVAL

NOTE: The solenoid can be replaced without removing the injector. See Section 2.1, Page 5.

To remove the injector, complete the following steps:

1. Clean and remove the valve rocker cover (Section 1.2.4).
2. Remove the fuel inlet and outlet crossover lines from the injector and fuel stand pipes installed in the head. Use caution so as not to damage pipes during removal.
3. Remove the two rocker shaft thru–bolts. Push the rocker shaft assembly back, away from the injector.
4. Loosen the injector wire terminal screws two full turns and remove the terminal wires. Do not remove the screws from the injector. The wire terminals have keyhole slots to fit over the screw head. Turning the screws too far will damage the threads in the injector solenoid housing.
5. Lift the injector from its seat in the cylinder head by inserting a pry bar under the injector body as shown in Figure 3.

NOTICE:

Extreme care should be used when handling an Electronic Unit Injector (EUI) to avoid costly damage by dropping or otherwise mishandling the EUI.

6. Cover the injector hole in the cylinder head to keep out foreign material. Remove carbon from the injector exterior in the area where the tip joins the nut, using wire buffing wheel No. J–7944. Avoid wire brushing the spray holes to prevent damage.
7. Clean the exterior of the injector with clean solvent and dry it with compressed air.

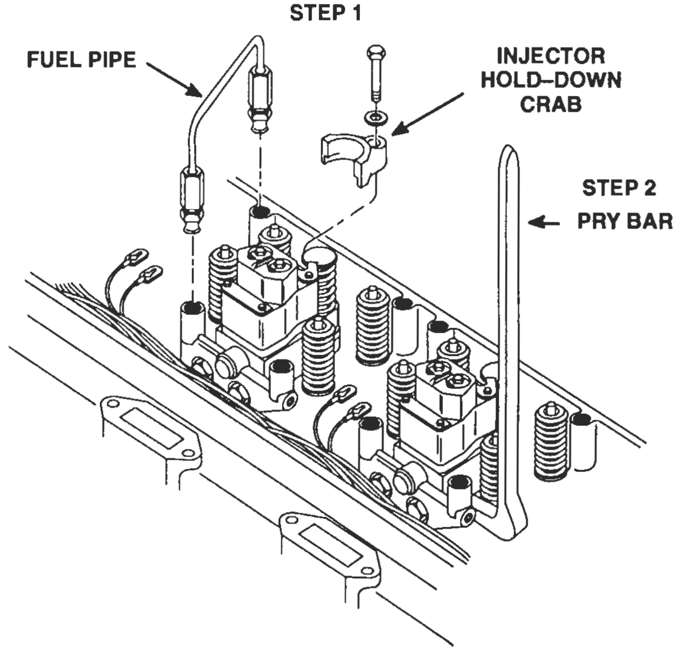

Figure 3. Removing EUI

SOLENOID REPLACEMENT

The injector solenoid is serviceable and may be replaced without removing the injector from the engine.

1. Loosen the injector wire terminal screws two turns and remove terminal wires.
2. Loosen four hex head screws and remove old solenoid (Figure 4.) Discard solenoid, load plate, follower retainer, and screws. *Do not reuse old screws.*
3. Remove spacer and seals from injector body. Discard seals, but *do not discard spacer.* The spacer is a matched component with the armature and *must remain* with its respective injector.
4. Install new seal in spacer groove and position spacer on body with seal facing down (Figure 4.) Seal may be retained in groove with small quantity of grease.
5. Install new seal in solenoid groove and install solenoid on spacer.
6. Install new screws through load plate and follower retainer, solenoid, and spacer. Thread screws into body.

NOTICE:

Do not reuse old load plate, follower retainer, screws or screw washers (if used), since this may result in solenoid and/or screw damage.

7. Tighten all screws until heads contact retainer and load plate with a slight force (less than 5 lb·in (0.6 N·m) torque in the sequence shown (Figure 5.)
8. Tighten screws to 19 lb·in torque in the sequence shown (Figure 5.)
9. Etch last four digits of injector part number on the load plate (Figure 5.)
10. After solenoid installation, pressurize the fuel system to check for fuel leaks.

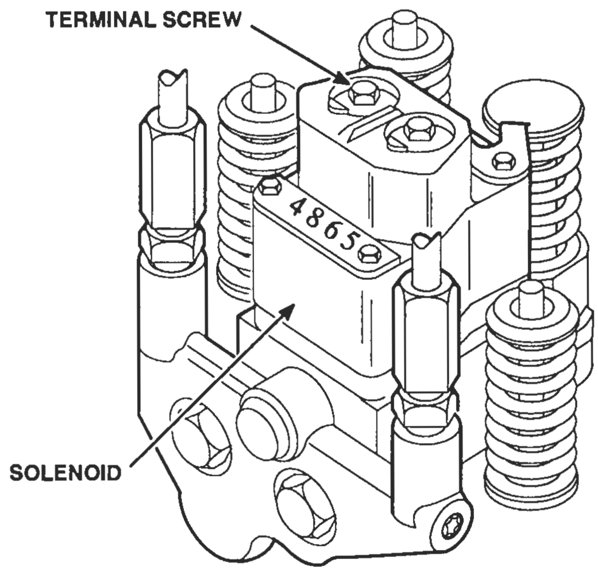

Figure 4. EUI Injector Solenoid Location

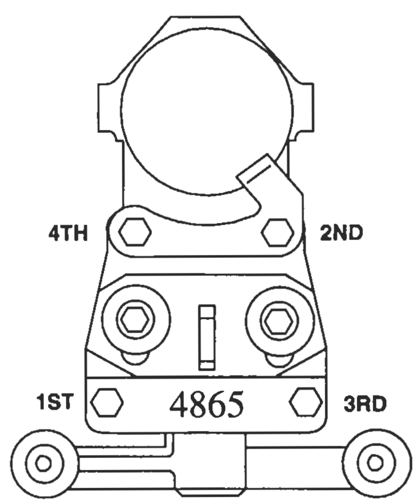

Figure 5. EUI Solenoid Torque Sequence

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INJECTOR INSTALLATION

1. Insert the injector into its respective injector tube bore. Visually align the injector body for equal clearance between valve springs (there is no locating dowel pin on the underside of the Electronic Unit Injector). After locating the injector, press down on the top of the injector body with the heel of your hand to seat it in the injector tube (Figure 6.)

NOTICE:
Care should be used when handling the EUI to avoid damage.

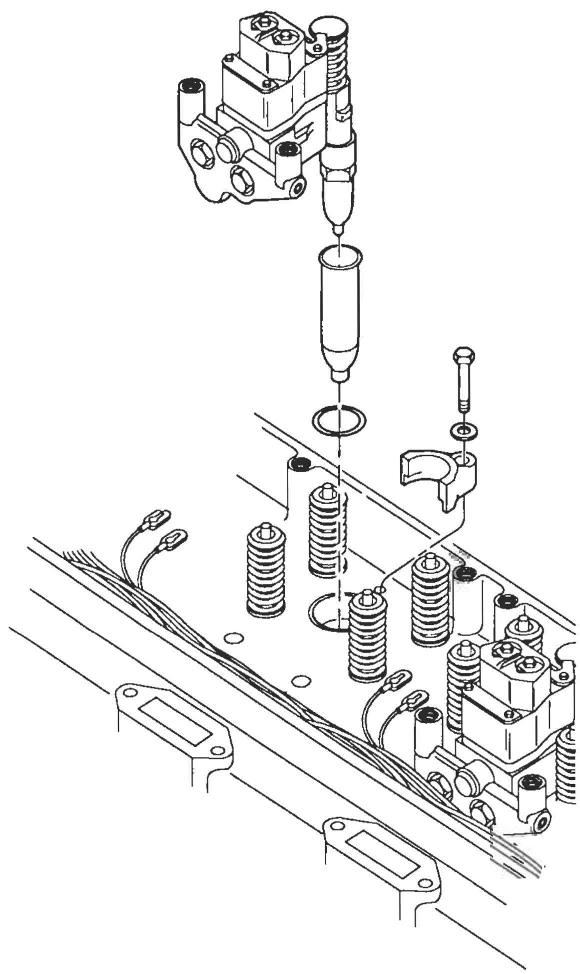


Figure 6. Electronic Unit Injector Installation

INJECTOR INSTALLATION (CONT.)

2. Tighten injector crab bolt to 20–25 lb·ft.
3. Tighten the rocker shaft bolts to 90–100 lb·ft.
4. Tighten the jumper tube nuts to 145 lb–in. (Be sure the "O" ring seal is in place at each end of the tube.)

   – Time the injector to: 1.460 in. (Tool J–1853)
5. Refer to section 14.1 and adjust valve clearances.
6. Install the EUI terminal wires by positioning the keyhole in the terminal over the screw in the injector solenoid housing. Pull the terminal end down so that the screw rests in the smaller slot in the terminal. Tighten the screws to 12–17 lb·in. Do not bend the terminals down after installation (Figure 7.)

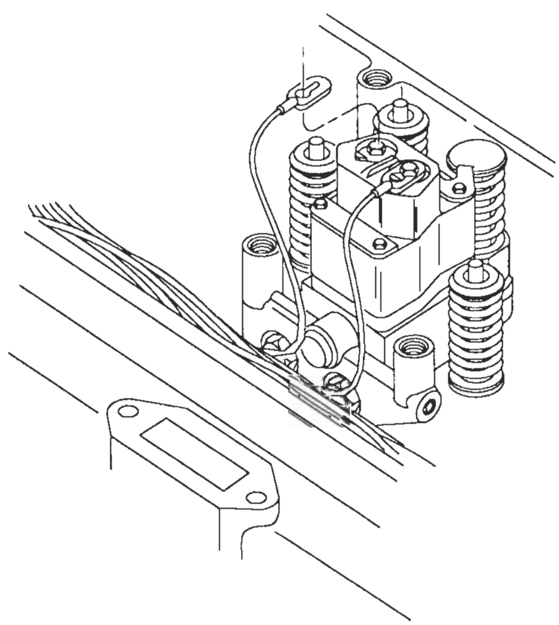


Figure 7. EUI Terminal Installation

7. Install the rocker arm shafts, with rocker arms in place, as outlined in Section 1.2.1.
8. Refer to Section 14.1 and adjust the intake and exhaust valve clearances and injector height.
9. Refer to Section 1.2.4 and install the valve rocker cover.
10. Continue engine assembly.

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)–NEEDLE VALVE

The fuel injector 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 (Figure 1.)

The fuel injector performs four functions (Times – Atomizes – Meters – Pressurizes):

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

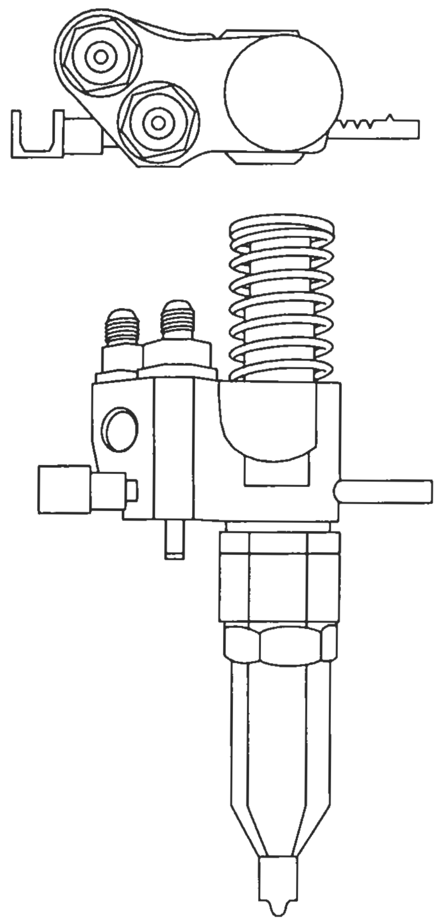


Figure 1. Fuel Injector Assembly

FUEL INJECTOR (CONT.)

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 (Figure 2.)

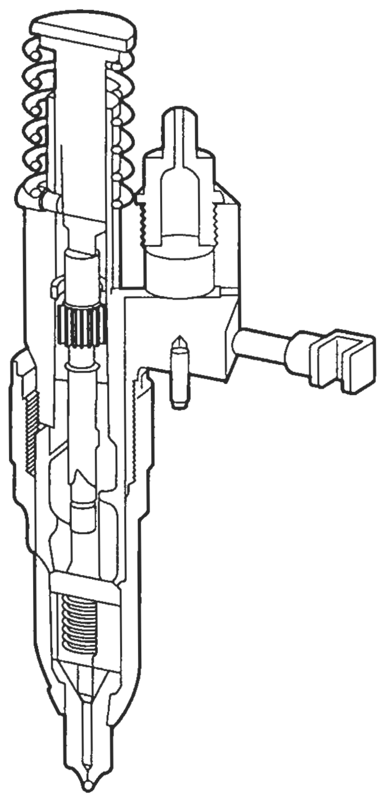


Figure 2. Cutaway View of Fuel Injector

FUEL INJECTOR (CONT.)

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. The fuel metering (Figure 3.) from no–load to full–load is by rotation of the plunger in the bushing.

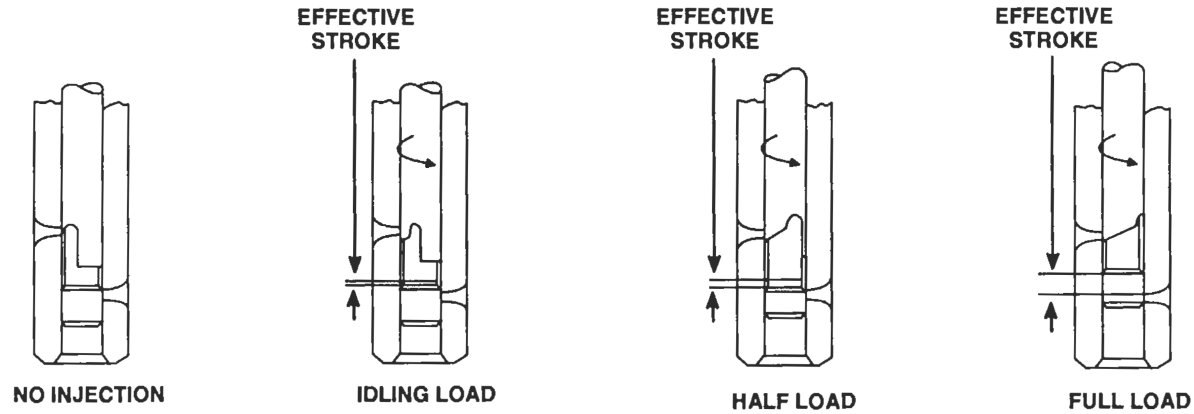


Figure 3. No Load to Full Load Fuel Metering

The phases of injector operation (Figure 4.) by the vertical travel of the injector plunger are shown below. The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers. Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes.

Each injector control rack 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.

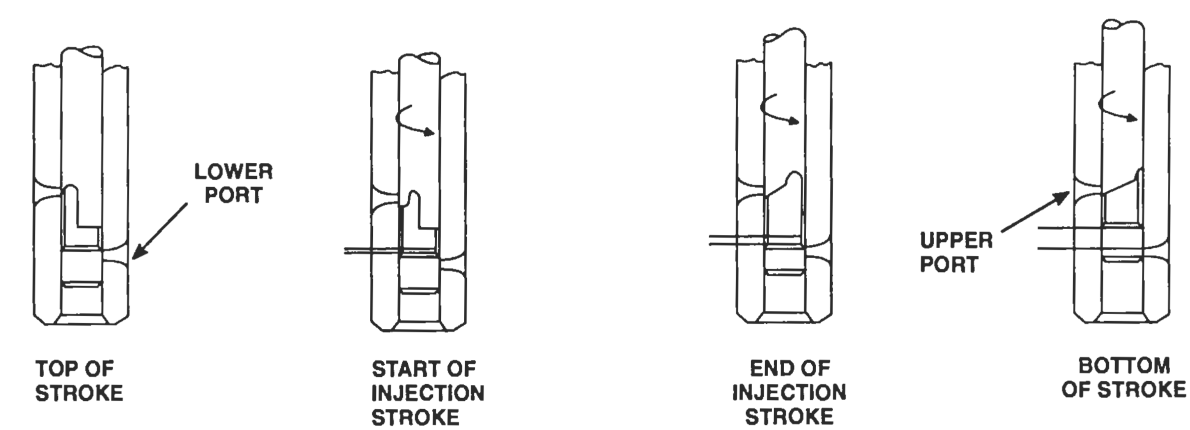


Figure 4. Phases of Injector Operation Through Vertical Travel of Plunger

SECTION 2.1.1 – FUEL INJECTOR

OPERATION

Fuel under low pressure enters the injector at the inlet side through a filter cap and filter positioned over the racks. 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 (Figure 5.) In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

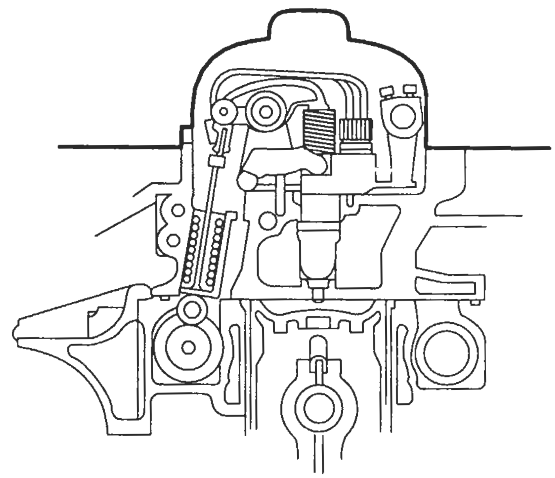


Figure 5. Fuel Injector Mounting

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.

OPERATION (CONT.)

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. Previous Figure 3 shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this no injection position to full injection position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

GENERAL INSTRUCTIONS FOR INJECTOR CARE AND OVERHAUL

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first–class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water–free fuel are the keys to trouble–free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions are 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.

SECTION 2.1.1 – FUEL INJECTOR

GENERAL INSTRUCTIONS FOR INJECTOR CARE AND REMOVAL (CONT.)

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 (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.

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.

REMOVE INJECTOR (CONT.)

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 (Figure 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.
7. Lift the injector from its seat in the cylinder head.
8. Cover the injector hole in the cylinder head to keep foreign material out.
9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

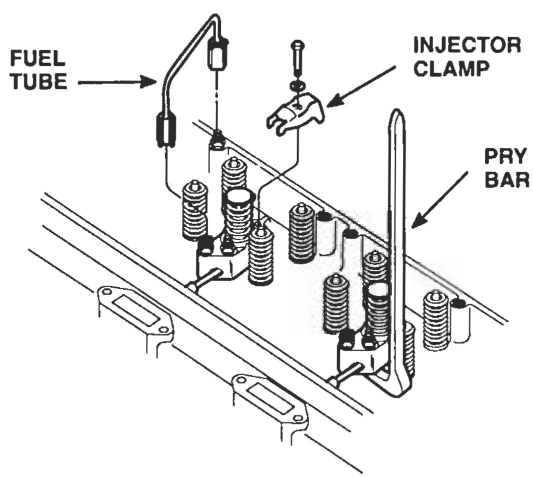


Figure 6. Removing Injector from Cylinder Head

INSPECT AND TEST PRIOR TO REUSE

This inspection and test procedure 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 lb/in^2 (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrosion.
   - Follower spring and injector body
   - Body nut and spray tip
   - Injector rack and filter caps
2. Inspect the following parts for wear or abrasion deterioration.
   - Top of the follower and Follower spring
   - Injector body and 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 (Figure 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.

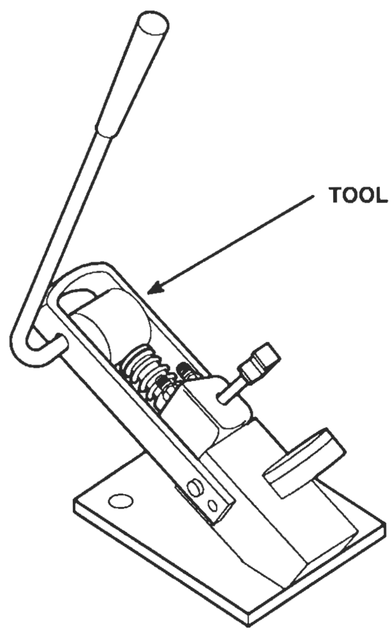


Figure 7. Checking Rack for Freeness In Tester

4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

DISASSEMBLE INJECTOR

1. Support the injector upright in injector holding fixture J 22396 (Figure 8.) and remove the filter caps, gaskets and filters.

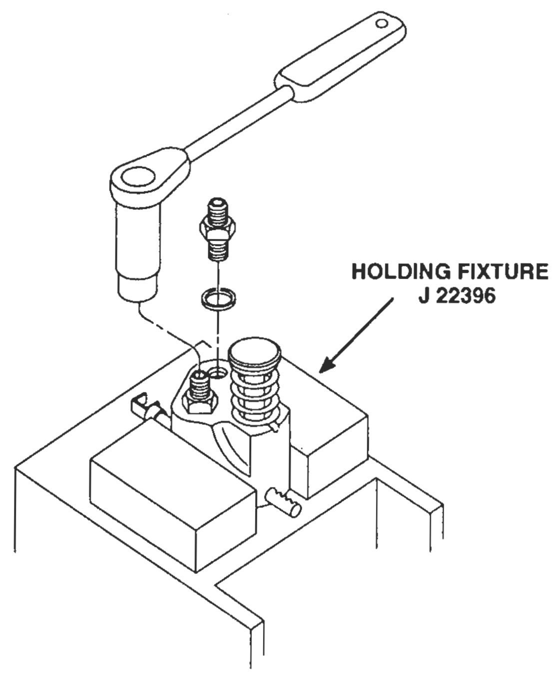
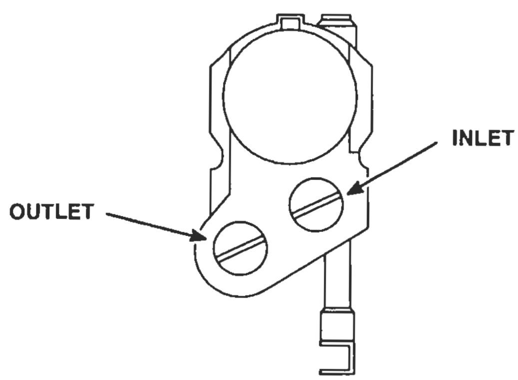


Figure 8. Removing Filter Cap

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 (Figure 9.)



OFFSET INJECTOR

FILTER REQUIRED IN
INLET SIDE ONLY
(ABOVE CONTROL RACK)

Figure 9. Filter in Injector Body Location

DISASSEMBLE INJECTOR (CONT.)

2. Compress the follower spring (Figure 10.) Then raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

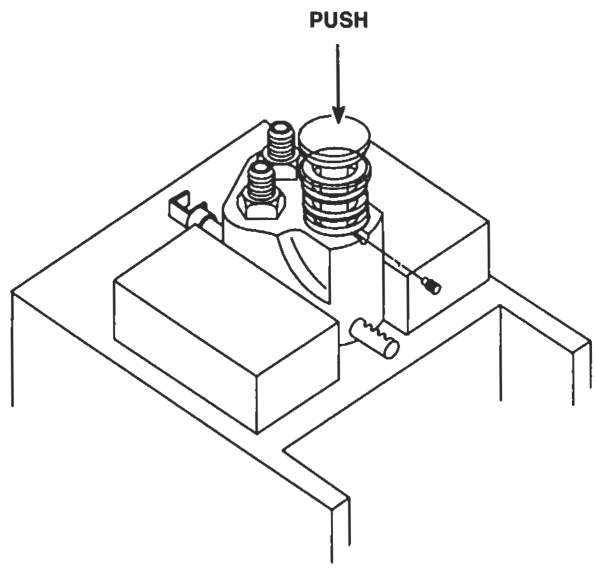


Figure 10. Removing Injector Follower Stop Pin

3. Remove the plunger follower, plunger and spring (Figure 11.) as an assembly.

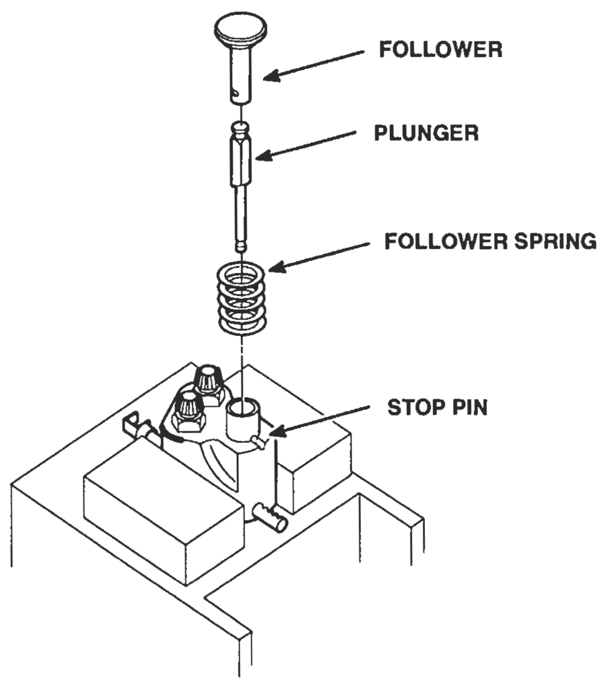


Figure 11. Removing or Installing Plunger Follower, Plunger and Spring

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DISASSEMBLE INJECTOR (CONT.)

4. Using socket J 4983–01, loosen the nut on the injector body (Figure 12.)
5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip, spring cage, valve spring, spring seat, check valve cage and check valve.

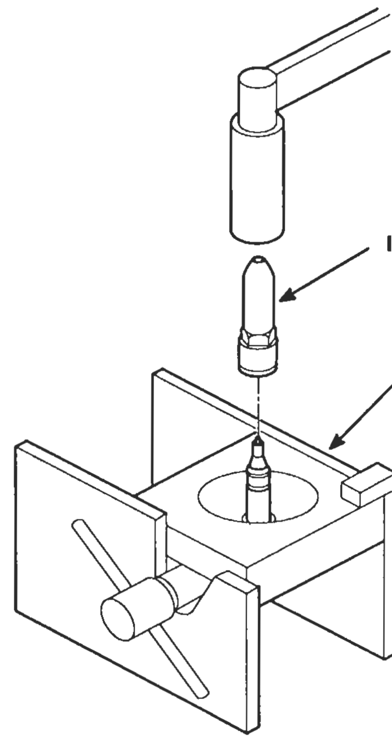

Figure 12. Removing Injector Nut

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 (Figure 13.)

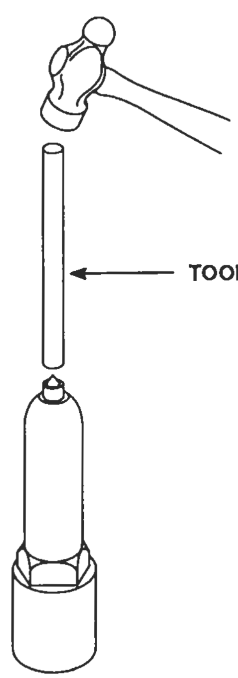

Figure 13. Removing Spray Tip from Injector Nut

SECTION 2.1.1 – FUEL INJECTOR

DISASSEMBLE INJECTOR (CONT.)

6. Remove the spill deflector (Figure 14.) Then lift the bushing straight out of the injector body.
7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.
8. Withdraw the injector control rack from the injector body. Also remove the seal ring from the body.

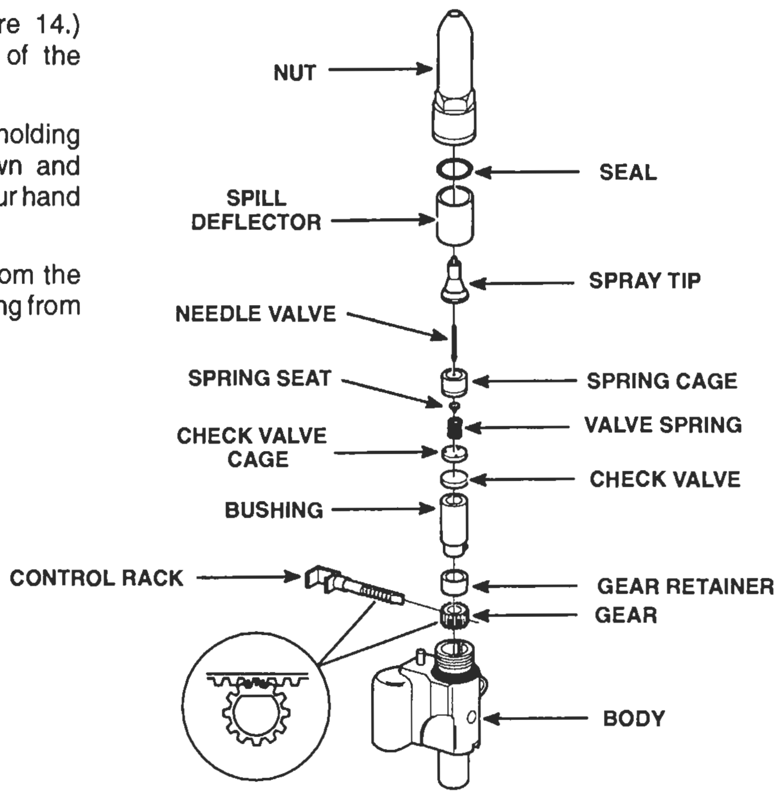

Figure 14. Injector Rack, Gear, Spray Tip and Valve Parts

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 lb/in^2 (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 minutes in a suitable solution prior to the external cleaning and buffing operation.

CLEAN INJECTOR PARTS (CONT.)

Clean the spray tip with tool J 24838 (Figure 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.

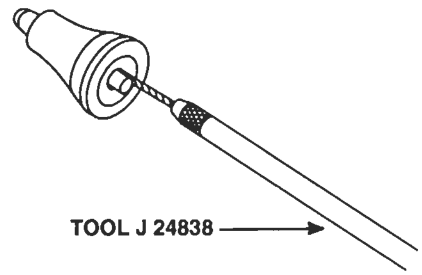

Figure 15. Cleaning Injector Spray Tip

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298–1 and the proper size spray tip cleaning wire. Use wire J 21460–01 to clean .0055 inch diameter holes and wire J 21461–01 to clean .006 inch diameter holes (Figure 16.)

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16 inch with stone J 8170. Allow the wire to extend 1/8 inch 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 3,000 r/min. 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.

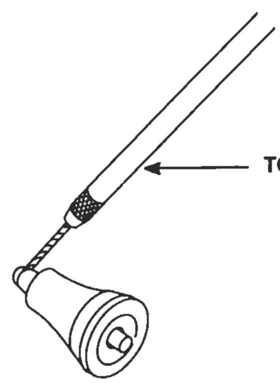

Figure 16. Cleaning Spray Tip Orifices

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.

CLEAN INJECTOR PARTS (CONT.)

9. 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.
10. Carefully insert reamer J 21089 in the injector body (Figure 17.) Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the injector body 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.

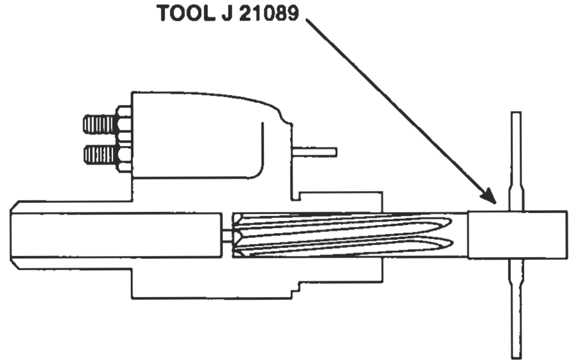

Figure 17. Cleaning Injector Body Ring

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 (Figure 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 container with clean test oil. Keep the parts of each injector assembly together.

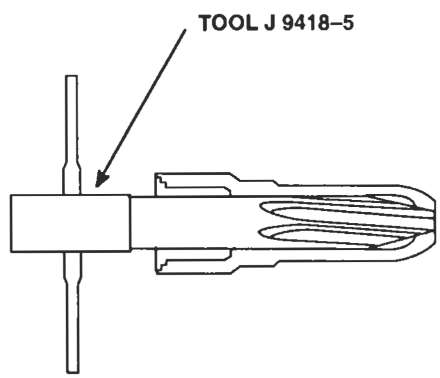

Figure 18. Cleaning Injector Nut Lower End

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INSPECT INJECTOR PARTS (VISUAL AND DIMENSIONAL)

NOTE: 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:
   a. Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002 inch (Figure 19.)
   b. 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 inch wear on the top or if there is any other visible damage or wear.
2. Follower Spring:
   a. Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.
   b. 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.
   c. Check the follower spring tension with spring Tester J 29196.
   d. The injector follower spring .142 inch diameter wire has a free length of approximately 1.504 inch and should be replaced when a load of less than 70 lbs. will compress it to 1.028 inch.

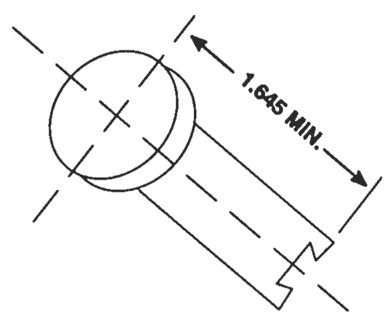

Figure 19. Injector Follower

3. Injector Body:
   a. 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:
   a. 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:
   a. 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.
   b. The notch in the clevis should be .3125 to .3145 inches. A .250 inch 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
   a. Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

INSPECT INJECTOR PARTS (VISUAL AND DIMENSIONAL) (CONT.)

7. Plunger and Bushing Assembly:

NOTICE:

Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

8. Bushing:
   a. Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring and the condition of the dowel pin and check for corrosion or varnish (Figure 20.)

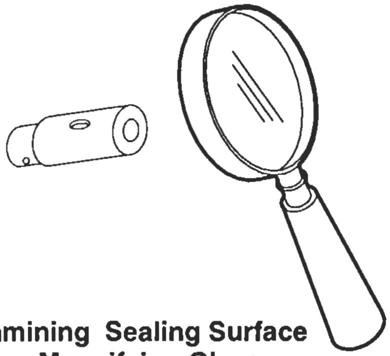

Figure 20. Examining Sealing Surface with a Magnifying Glass

9. Plunger:
   a. Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Figure 21.)
10. Check Valve:
    a. Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.
11. Check Valve Cage:
    a. Inspect the check valve cage for cracks and scratches on the lapped surfaces or for corrosion, varnish and wear.

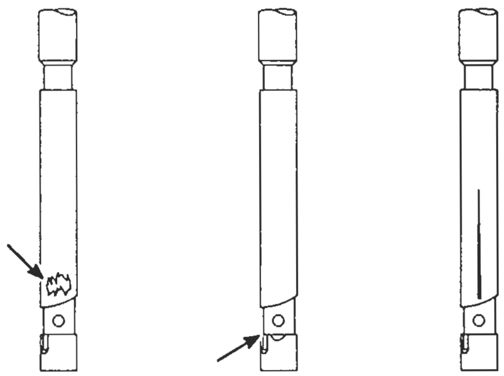

Figure 21. Unusable Injector Plungers

12. Valve Spring:
    a. 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.

NOTE: 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 inch I.D.). A no. 15 (.180 inch) 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 (Figure 31.) The high V.O.P. spring seat can be distinguished from the standard spring seat by its smaller diameter post and the groove on the end of this post. To ensure proper operation, the high V.O.P. spring and seat must be used together. Do not mix injectors containing standard springs and seats with injectors having high V.O.P. springs and seats in the same engine.

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INSPECT INJECTOR PARTS (VISUAL AND DIMENSIONAL) (CONT.)

13. Spring Seat:
    a. Check the surfaces for wear.
14. Spring Cage:
    a. 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.
15. Spray Tip:
    a. 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.
16. Needle Valve:
    a. Check the spray tip needle valve for erosion at the seat shoulder, scratches and overheating (discolored).
17. Nut:
    a. 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.
18. Spill Deflector:
    a. Inspect both ends of the spill deflector for sharp edges or burrs.
19. Part Thickness:
    a. Check the minimum thickness of the parts (Table 1).

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199 inches
Check Valve Cage	.163 – .165 inches
Check Valve	.022 inches
Valve Spring Cage	.602 inches

INSPECT INJECTOR PARTS (VISUAL AND DIMENSIONAL) (CONT.)

20. Needle Valve Lift:

    a. Measure the needle valve lift, using tool J 9462–02 (Figure 22.) as follows:

    b. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

    c. 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.

    d. 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 inches. If it exceeds .018 inches, the tip assembly must be replaced. If it is less than .008 inches, inspect for foreign material between the needle valve and the tip seat.

    e. 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.

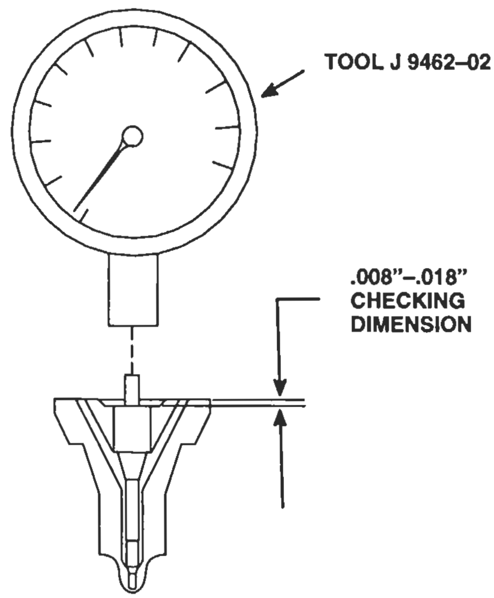

Figure 22. Checking Needle Valve Lift

21. Classify Spray Tip:

    a. Match the plunger/bushing assembly with the proper spray tip using Flow Gage J 25600–A (Section 2.0).

    b. The method of identifying Series 71 mechanical unit injector tips has been changed. A two–digit “generic code” number is stamped in the tip counterbore is now used in place of the last four digits of the part number (Figure 23.)

    c. The two–digit code is **the specific flow category for the given number of holes in the tip**. The larger the number, the greater the possible tip flow. Thus, individual injector output can be adjusted upward or downward by using a tip with a larger or smaller flow category number.

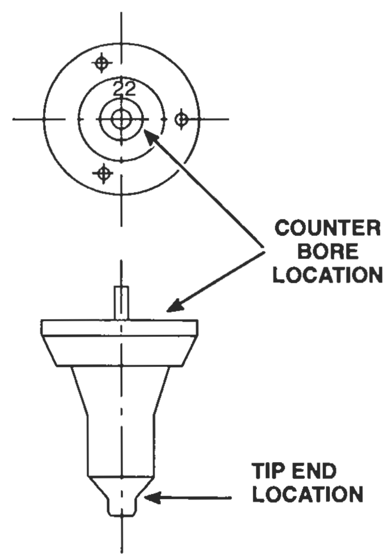

Figure 23. Spray Tip Classification

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:
   a. Resurface or replace if worn beyond dimensional limits.
2. Follower Spring:
   a. Reuse unless damaged, worn or won't meet test specifications.
3. Body:
   a. Lap bushing seat.
   b. Reblue.
   c. Repair damaged threads.
   d. Replace body if the clamp radius is badly worn or if the threads are less than 90% good.
4. Filter Caps:
   a. Recondition tapered seat.
   b. Clean and deburr hole.
   c. Reblue.
   d. Replace if the threads or sealing surfaces are damaged.
5. Control Rack:
   a. Deburr teeth – check for straightness.
   b. Replace if the teeth show significant wear.
6. Gear and Gear Retainer:
   a. Deburr.
   b. Replace if cracked or significantly worn.
7. Bushing:
   a. Replace if scored, cracked or if residue cannot be removed.
   b. Lap the check valve seat (sealing) surface.
8. Plunger:
   a. Clean – remove varnish.
   b. Replace if scored, chipped or scratched.
9. Check Valve:
   a. Lap both flat (sealing) surfaces.
   b. Replace if scratched, cracked or badly worn.
10. Check Valve Cage:
    a. Lap both flat sealing surfaces.
    b. Replace if cracked or too thin (Table 1).

RECONDITION INJECTOR (CONT.)

11. Valve Spring:
    a. Replace. Do not reuse unless there is absolutely no wear or damage.
12. Spring Seat:
    a. Replace if there is a hole worn in the rounded end where the needle quill touches.
13. Spring Cage:
    a. Lap both flat (sealing) surfaces.
    b. Replace if cracked or too thin (Table 1) or if the needle has worn a pocket around the small hole.
14. Spray Tip:
    a. Regrind seat.
    b. Lap flat sealing surface.
    c. Regrind the needle conical seat.
    d. Replace if beyond flow limits i.e., eroded spray holes.
15. Nut:
    a. Remove carbon from the seat and tapered inside diameter.
    b. Reblue.
    c. Replace if the threads are damaged more than 10% or if the small inside diameter is badly eroded.
16. Spill Deflector:
    a. Remove burrs.
    b. Reuse if the ends are smooth and even and the deflector is not cracked.
    c. Normally, new parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solidified 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 (Figure 24.) Lapping the surface of a new current spray tip is not recommended.

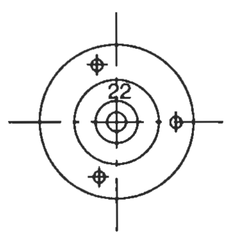

Figure 24. Spray Tip Sealing Surface Identification

LAPPING INJECTOR PARTS

If necessary, lap the sealing surfaces (Figure 25.) 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.

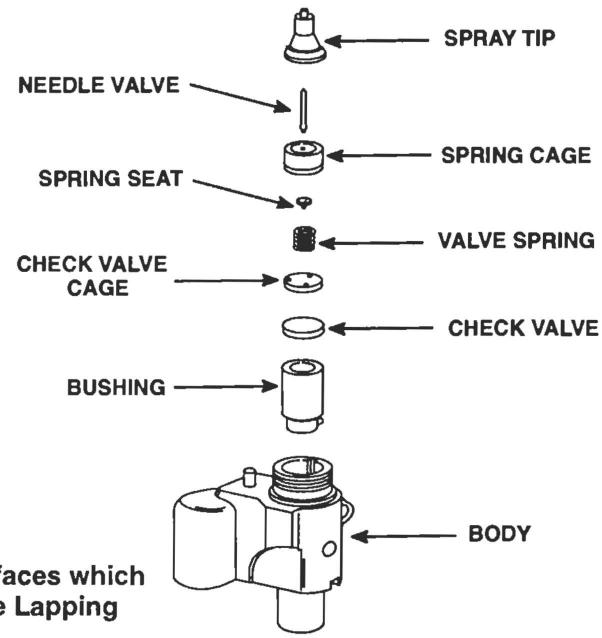

Figure 25. Sealing Surfaces which may Require Lapping

3. Place the part to be lapped flat on the block (Figure 26.) 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.

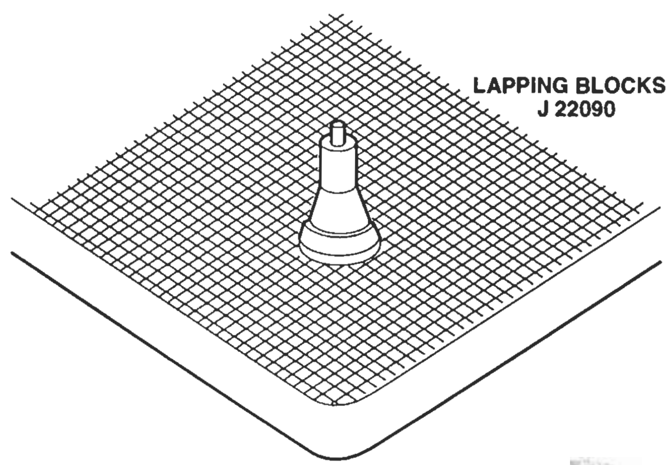

Figure 26. Lapping Spray Tip on Lapping Blocks

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

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. 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 in the top of the body (Figure 27.) The stainless steel wire mesh pellet is installed dimple end down, slotted end up.

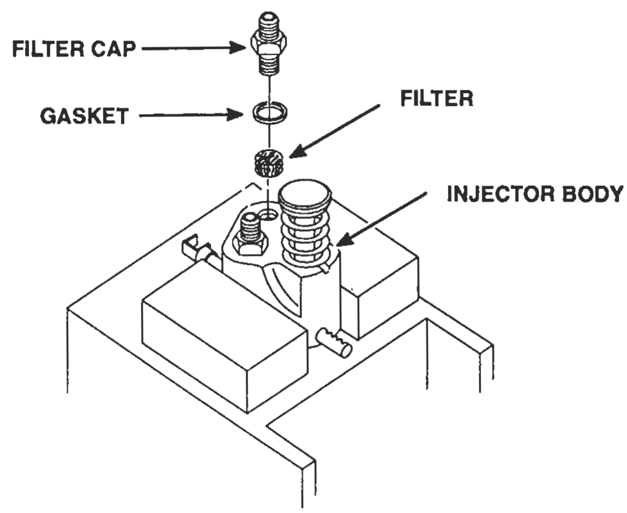

Figure 27. Details and Location of Injector Filters and Caps

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 (Figure 28.)

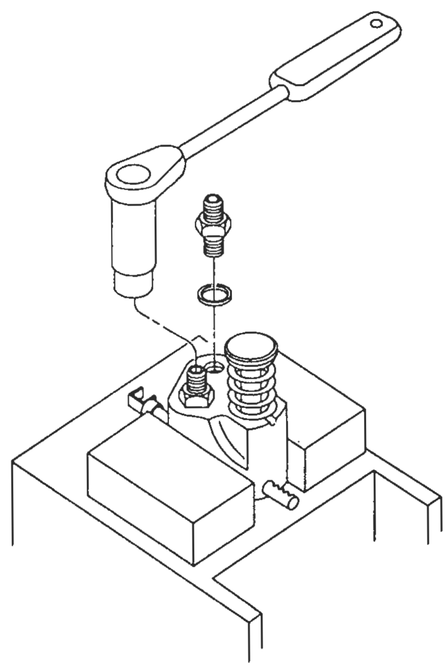

Figure 28. Location of Filter in Injector Body

ASSEMBLE INJECTOR (CONT.)

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 inches deep socket (Figure 29.)
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.
7. Remove the protector (J 29197).
8. Slide the control rack into the injector body.

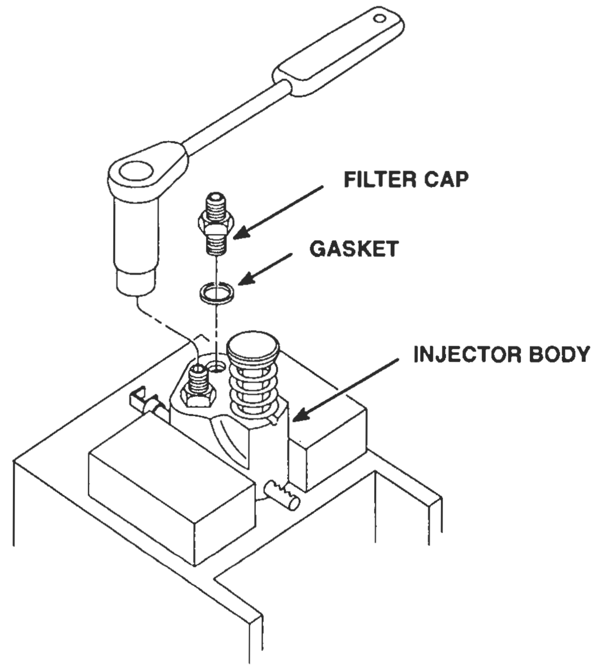

Figure 29. Installing Filter Cap

9. Note the marked teeth on the control rack and (Figure 30.) 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.
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 inch 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.

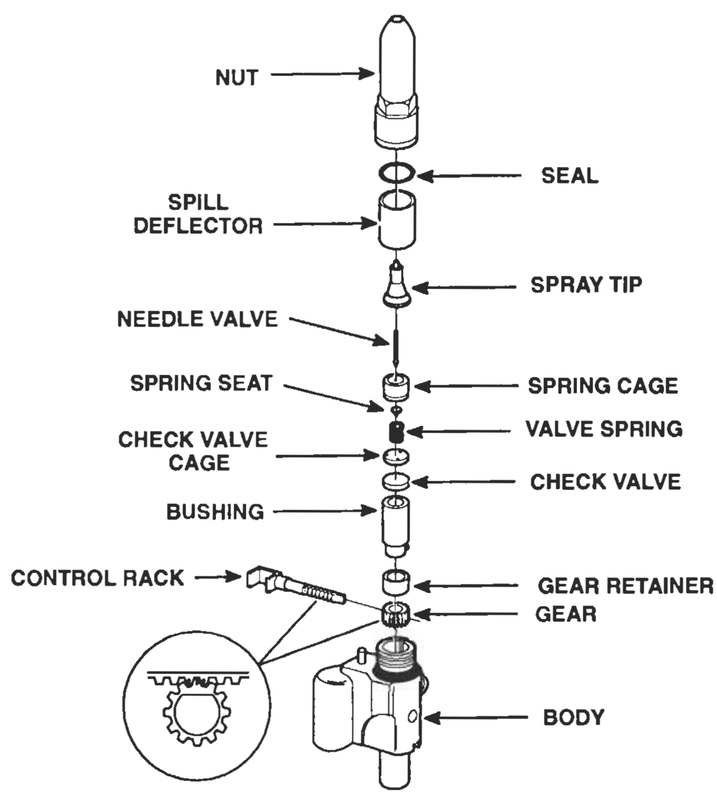

Figure 30. Injector Rack, Gear, Spray Tip and Valve Assembly

SECTION 2.1.1 – FUEL INJECTOR

ASSEMBLE INJECTOR (CONT.)

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 (Figure 31.) Then place the spray tip assembly on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

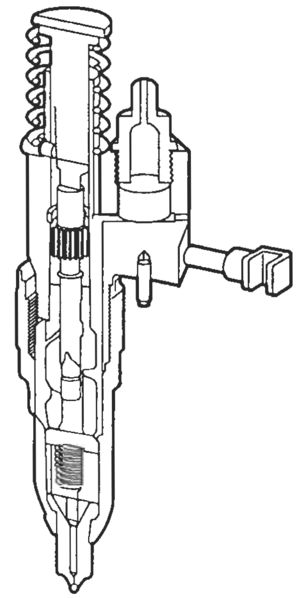

Figure 31. Cutaway View of Fuel Injector

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 (Figure 32.)
21. 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.

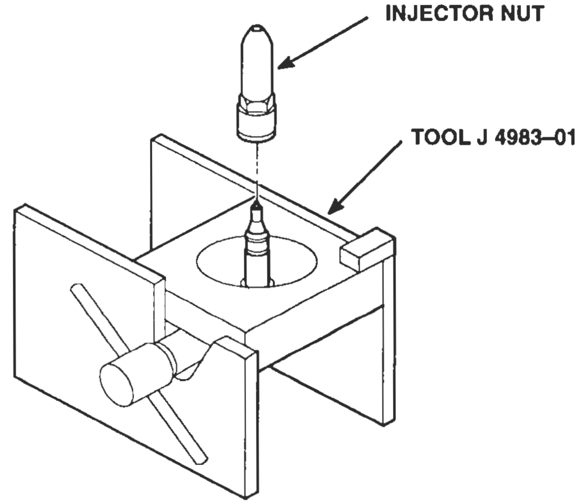

Figure 32. Tightening Injector Nut

ASSEMBLE INJECTOR (CONT.)

22. Use socket J 4983–01 and a torque wrench to tighten the injector nut to 75–85 lb·ft (102–115 N·m) torque (Figure 33.)
23. 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.

NOTE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

24. Turn the injector over and push the rack all the way in.
25. Place the follower spring on the injector body.

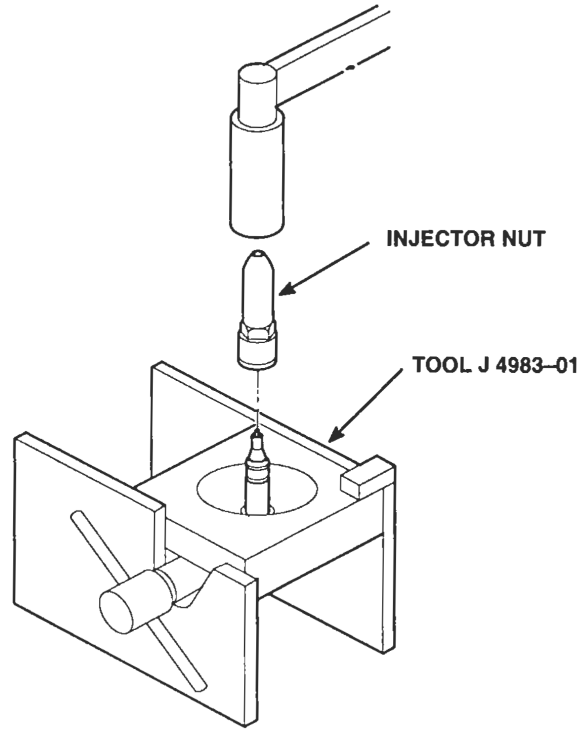

Figure 33. Tightening Injector Nut with Torque Wrench using Tool J 4983–01

26. Place the stop pin (Figure 34.) on the injector body so that the follower spring rests on the narrow flange of the stop pin.
27. Slide the head of the plunger into the follower.
28. Align the slot in the follower with the stop pin hole in the injector body.
29. Align the flat side of the plunger with the flat in the gear.
30. 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.

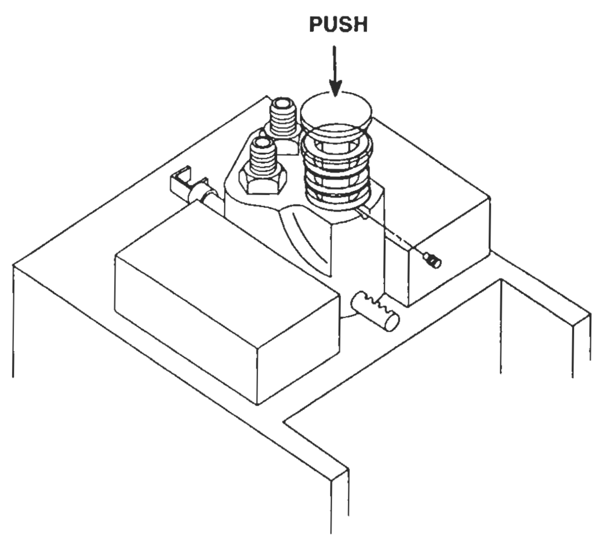

Figure 34. Installing Injector Follower Stop Pin

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 (Figure 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.
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 patten 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.

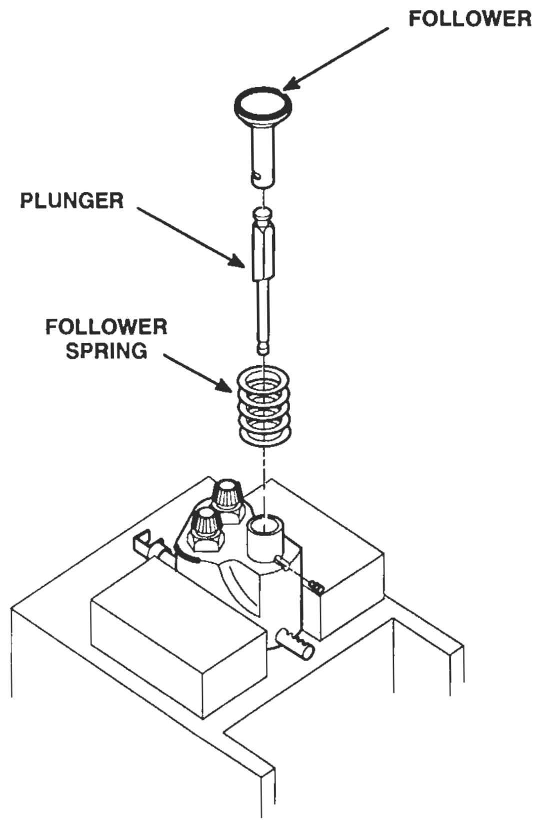

Figure 35. Injector in Position for Testing on Tester J 23010–A

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 (Figure 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 lb/in.^{2} (689–1378 kPa), check for injector nut seal ring leaks. Then, increase the gage reading to 1,500–2,000 lb/in.^{2} (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 1,500 lb/in.^{2} to 1,000 lb/in.^{2} (10,335 kPa to 6,890 kPa). This should not occur in less than seven 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 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 to the up (horizontal) position.

CHECK RACK FREENESS AND SPRAY TIP CONCENTRICITY

Place the injector in Tester J 29584 (Figure 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.

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.

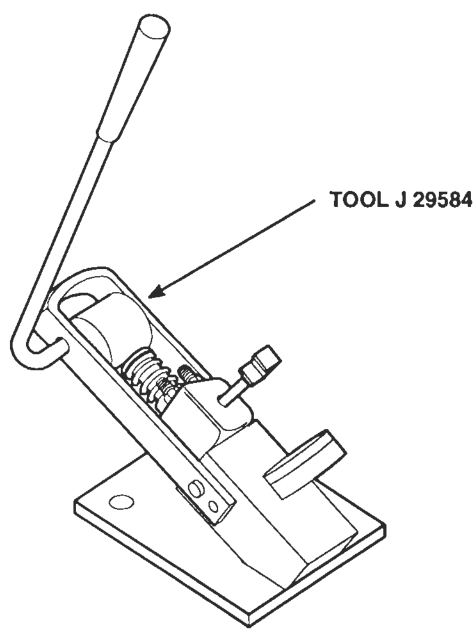

Figure 36. Checking Rack for Freeness

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 29584 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 inch, 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. 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.

NOTE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0 – Specifications.

NOTE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. 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. Fuel pipes with O–ring seals may be reused if they are not bent, twisted, restricted, or otherwise damaged. When installing reusable lines, replace them in the same location and on the same connections from which they were removed. Do not reuse flared end fuel pipes.
6. To help insure more consistent fastening, tighten fuel pipe nuts on new or reusable 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 lb·in).

NOTE: Because of their low friction surface, Endurion®–coated nuts on fuel jumper lines must be tightened to 130–160 lb·in (14.7–18.1 N·m) torque. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion®–coated nuts on the same cylinder head.

INSTALL INJECTOR (CONT.)

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).

Jumper Line Usage	Torque
Endurion®–coated	130–160 lb·in. (14.7–18.1 N·m)
Uncoated	160 lb·in. (18.1 N·m)
Jacobs Brakes*	120 lb·in. (13.6 N·m)
Load limiting devices	160 lb·in. (18.1 N·m)
O–ring sealed fuel pipes	160–200 lb·in. (18.1–22.6 N·m)

*Not serviced. Available from Jacobs Manufacturing Company

Jumper Line Nut Torque

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.

7. 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.

NON–BLUED INJECTOR BODIES, VALVE NUTS, FILTER CAPS

Effective with 1988–built engines, the valve nuts, bodies and filter caps on Series 71 and fuel injectors are no longer blued.

To avoid body–to–nut distortion or filter cap damage during injector assembly, the torque specifications have been changed:

VALVE NUTS

Tighten injector valve nuts as follows:

Non–blued nut on non–blued body	50 lb·ft (68 N·m) torque
Blued nut on blued body	80 lb·ft (108 N·m) torque
Non–blued nut on blued body or blued nut on non–blued body*	65 lb·ft (88 N·m) torque

FILTER CAPS

Tighten injector filter caps as follows:

Non–blued nut on non–blued body	62 lb·ft (84 N·m) torque
Blued nut on blued body	70 lb·ft (95 N·m) torque
Non–blued nut on blued body or blued nut on non–blued body*	62 lb·ft (84 N·m) torque

NOTE: Only nominal torque values are given. The torquing process (accurate torque wrench, operator technique, etc.) should be good enough to yield a range of ± 10% of the nominal.

NOTE: The different torque values for blued, non–blued, and mixed components compensate for the different thread friction/lubrication characteristics of each combination.

***NOTE: Mixing blued and non–blued components is not recommended because of inconsistent product appearance.**

FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket (Figure 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.

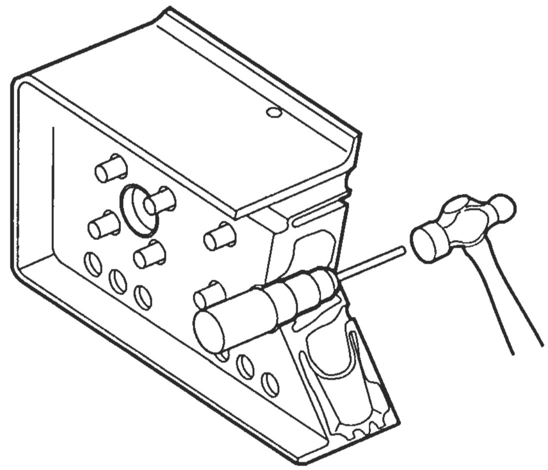

Figure 1. Removing Injector Tube with Tools J 5286–4C and J 5286–5

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 inches vs. 1.180–1.183 inches) 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 inside diameter of the new tube does not require reaming. Reaming is only necessary at the small inside diameter 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.

NOTE: Ethylene glycol base antifreeze is recommended for use in all Detroit Diesel engines. Methyl alcohol base antifreeze is not recommended because of its effect on the fluoroelastomer seal rings in the cylinder head.

SECTION 2.1.4 – FUEL INJECTOR TUBE

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 sensitive 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.
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. 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 inches (Figure 2.).

INSTAL INJECTOR TUBE (CONT.)

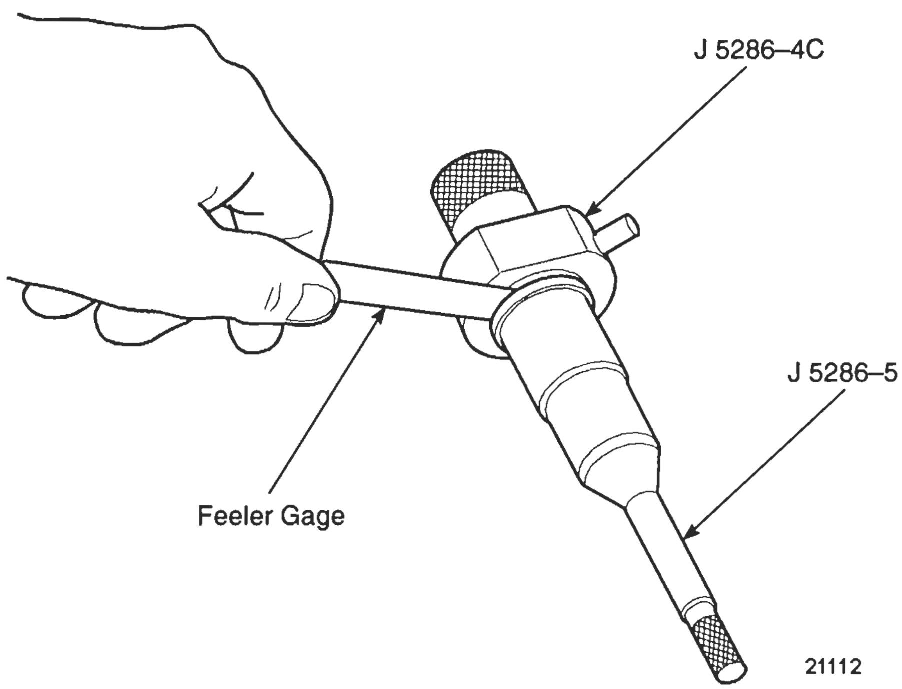

Figure 2. Measuring Tube Clearance With Feeler Gage

INSTALL INJECTOR TUBE (CONT.)

3. Slip the injector tube into the injector bore and drive it in place (Figure 3.) 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.
4. During installation the tube will stretch slightly before the tool contacts the flange, thus allowing the tool to properly install the tube. If there is no clearance at the flange, the tube will buckle slightly during installation until the tool contacts the tube at the lower end. The buckling causes compressive stress which will result in tube cracking during engine operation and subsequent engine damage.

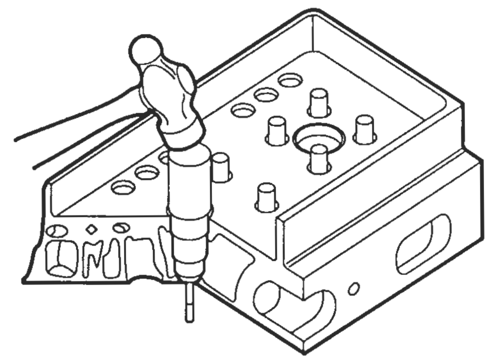

Figure 3. Install Injector Tubes with Tools J 5286–4C and J 5286–5

5. 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 (Figure 4.)
   b. Then, using a socket and torque wrench, apply approximately 30 lb·ft (41 N·m) torque on the upsetting die.
   c. Remove the installing tools and ream the injector tube as outlined below.

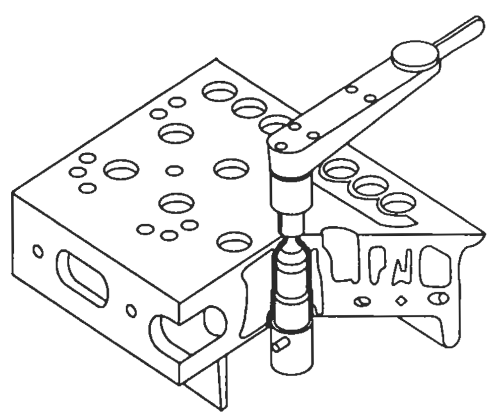

Figure 4. Upsetting Injector Tube with Tools J 5286–4C and J 5286–6

 May, 1994

REAM INJECTOR TUBE

After an injector tube has been installed in a cylinder head, it must be finished in three operations:

First, hand reamed, (Figure 5.) to receive the injector body nut and spray tip.

Second, spot–faced to remove excess stock at the lower end of the injector tube.

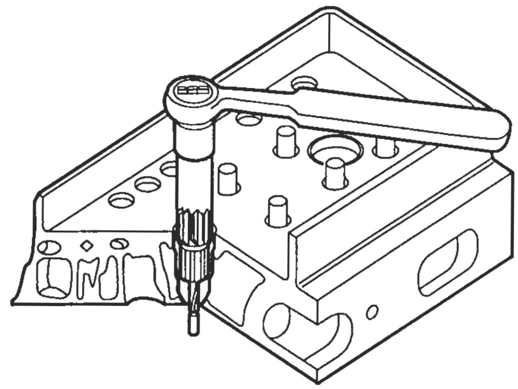

Figure 5. Reaming Injector Tube for Injector Body Nut and Spray Tip with Tool J 22525–1

Third, hand reamed, (Figure 6.) 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.

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. Clean out all of the chips.

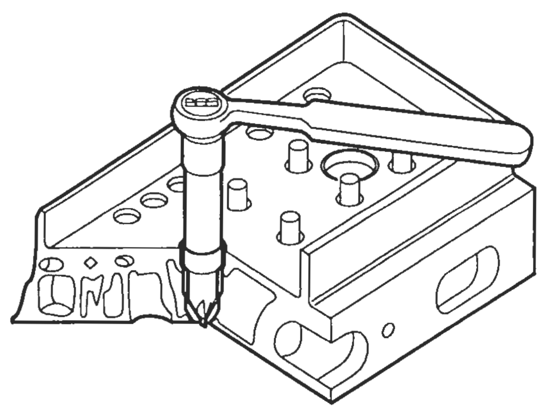

Figure 6. Reaming Injector Tube for Injector Nut with Tool J 5286–9

REAM INJECTOR TUBE (CONT.)

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 inch 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 (Figure 7.)

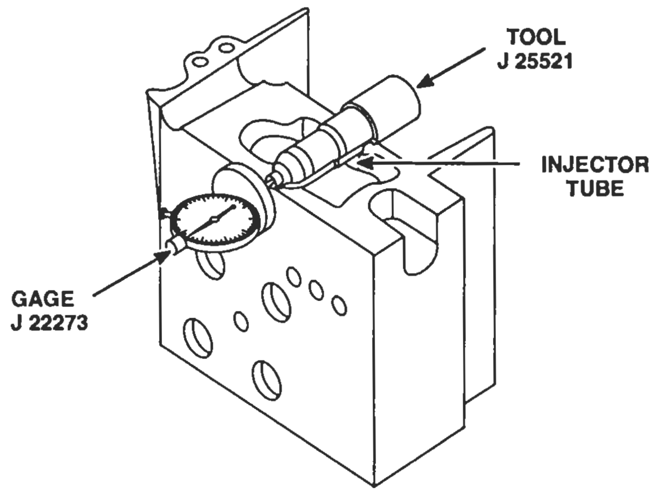

Figure 7. Measuring Relationship of Bevel Seat of Injector Tube to Fire Deck of Cylinder Head

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 inch with the fire deck of the cylinder head (Figure 8.)

NOTE: Any fire deck resurfacing work must be done prior to final injector tube seat gaging. Refer to Section 1.2 for resurfacing instructions.

With the first reaming operation completed and the injector tube spot–faced, wash the interior of the injector tube with clean solvent and dry it with compressed air. Then, perform the second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286–9 into the injector tube until it contacts the bevel seat.
b. Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.
c. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

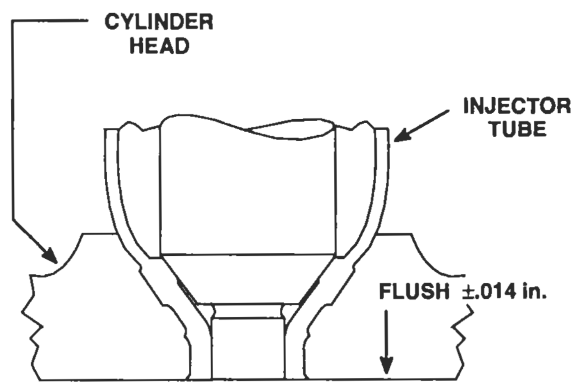

Figure 8. Measuring Relationship of Gage to Fire Deck of Cylinder Head

REAM INJECTOR TUBE (CONT.)

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 inch with the fire deck of the cylinder head. Then, wash the interior of the injector tube with clean solvent and dry it with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

FUEL PUMP

The positive displacement gear–type fuel pump (Figure 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.

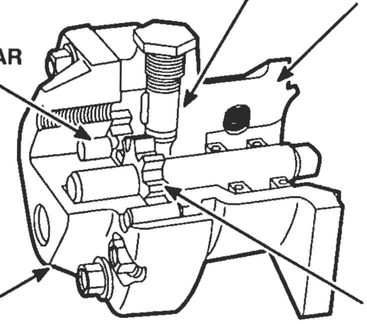

Figure 1. Fuel Pump Assembly

The fuel pump is attached to the rear end plate cover of the blower assembly with three nylon patch bolts which prevents the oil in the blower cover from seeping out around the bolt threads. The pump is driven off the end of the blower lower 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 (Figure 2.)

On certain applications, the fuel pump is attached to a special flywheel housing large hole cover. It is driven off of the balance shaft gear by means of a drive coupling fork attached to the end of the pump drive shaft and mating with a drive adaptor bolted to the balance shaft gear.

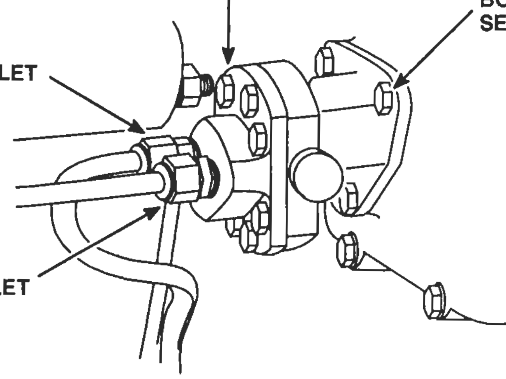

Figure 2. Fuel Pump Drive Mounting

Fuel pumps are furnished in left–hand or right–hand rotation, according to the engine model, and are stamped "LH IN" or "RH IN". The left–hand pumps are used on LA–LB–RA–RB engines while the right–hand pumps are used on LC–LD–RC–RD engines. These pumps are not interchangeable, nor can a pump made for one rotation be rebuilt for the other rotation since the relief valve can be installed in only one position in the pump body.

Certain engine applications use a high–capacity fuel pump with 3/8 inch wide gears to increase fuel flow and reduce fuel spill temperature. The high–capacity fuel pump and the standard fuel pump with 1/4 inch wide gears may not be completely interchangeable; therefore, when replacing a standard pump with a high–capacity pump, the appropriate fuel lines and connections must be used.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal–to–metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

FUEL PUMP (CONT.)

The fuel pump body is recessed to provide running space for the pump gears (Figure 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.

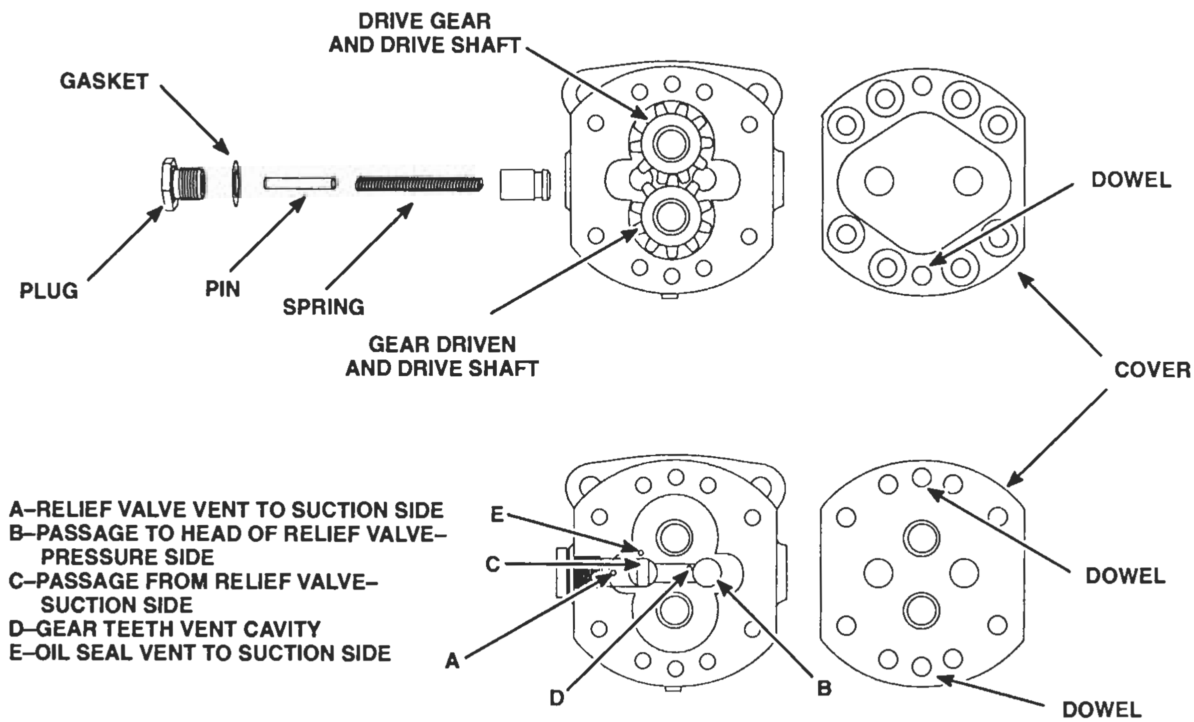

Figure 3. Fuel Pump Valve and Rotation

Pressurized fuel contacts the relief valve through hole "B" and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole "C" when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole "C". The cavity "D" provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the blower timing gear compartment. A small hole "E" 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.

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FUEL PUMP (CONT.)

A material lip type seal is used in the fuel pumps. The fuel pump seal is made of a polyacrylate material. The fuel pumps will have the seals installed with the lips of the seals facing in the opposite direction of each other (Figure 4.)

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

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.

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 lb/in.^{2} (448 kPa).

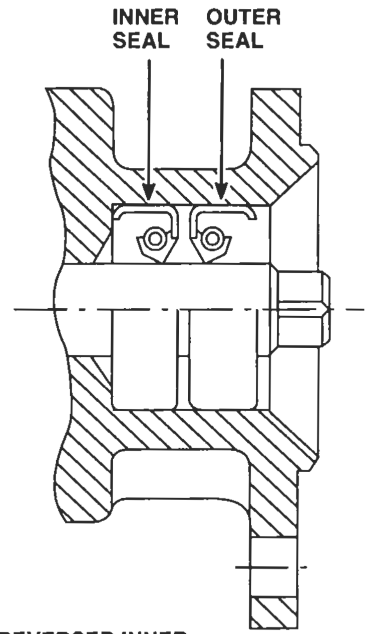


Figure 4. Fuel Pump Oil Seal Locations

OPERATION

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65 to 75 lb/in.^{2} (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold (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, using wrench J 4242, and withdraw the pump from the blower.
4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

DISASSEMBLE FUEL PUMP

With the fuel pump removed from the engine and mounted in holding fixture J 1508–10 (Figure 5.) disassemble the pump as follows:

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.
2. Withdraw the drive shaft, drive gear and gear retaining ball as an assembly from the pump body.
3. Press the drive shaft just far enough to remove the steel locking ball. Then, invert the shaft and gear assembly and press the shaft from the gear. Do not misplace the steel ball. Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surface.
4. Remove the driven shaft and gear as an assembly from the pump body. Do not remove the gear from the shaft. The driven gear and shaft are serviced only as an assembly.
5. Remove the relief valve plug and copper gasket.
6. Remove the valve spring, pin and relief valve from the valve cavity in the pump body.
7. If the oil seals need replacing, remove them with oil seal remover J 1508–13 (Figure 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.

NOTE: Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

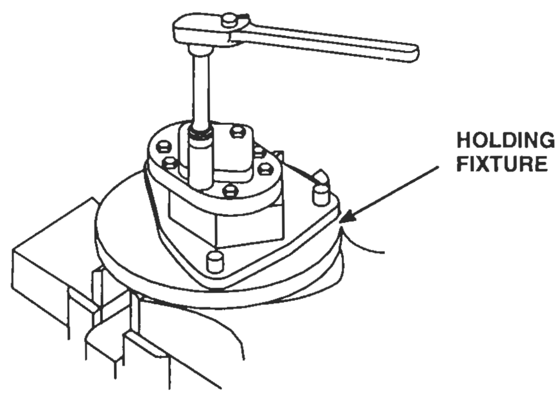


Figure 5. Removing Pump Cover

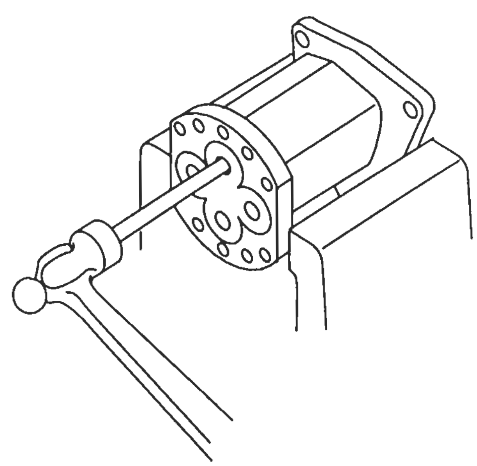


Figure 6. Removing Oil Seals

INSPECTION

Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts, if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together.

Any scratches or slight damage may result in pressure leaks. Also, check for wear at areas contacted by the gears and shafts. Replace the pump cover or body, if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Current standard fuel pumps (with 1/4 inch wide gears) incorporate a 1/8 inch shorter pump body with three drain holes, a 1/8 inch shorter drive shaft and a cover with a 3/8 inch inlet opening. When replacing a former pump, a 3/8 x 1/4 inch reducing bushing is required for the inlet opening and the **unused drain holes must be plugged.**

ASSEMBLE FUEL PUMP

Assemble the pump as follows:

1. Lubricate the lips of the oil seals (Figure 7.) 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.

NOTE: When replacing the former nitrile fuel pump seals with the current polyacrylate seals, install them in a reversed order.

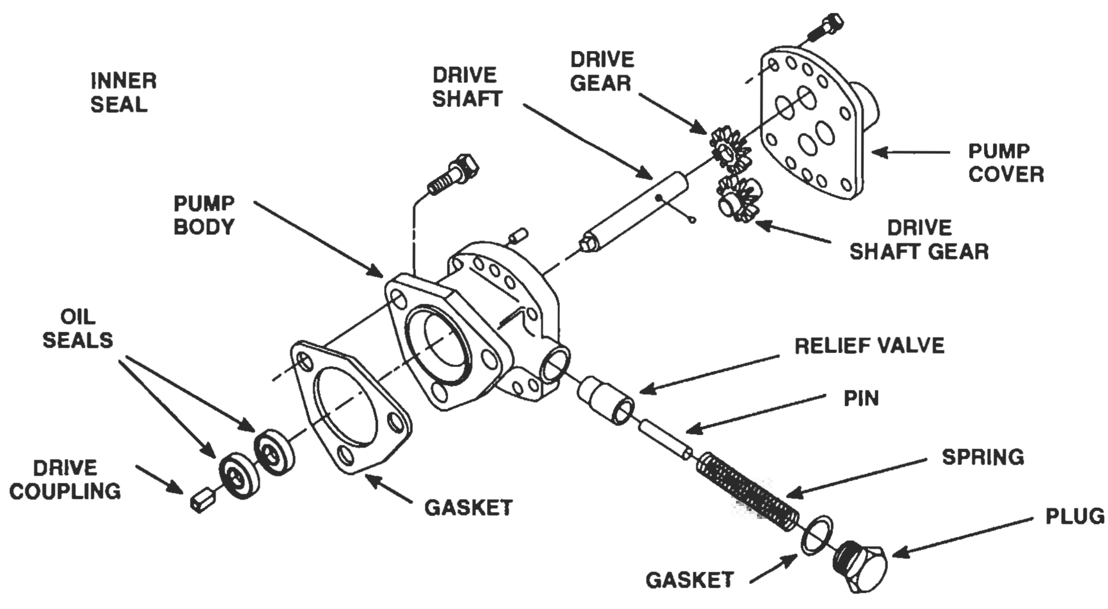


Figure 7. Fuel Pump Components

ASSEMBLE FUEL PUMP (CONT.)

b. With the pump body supported on wood blocks, insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange (Figure 8.) Then, drive the seal in until it bottoms.

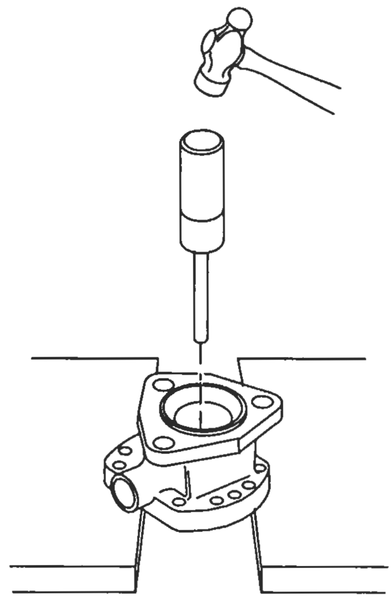


Figure 8. Installing Inner Oil Seal

c. Place the shorter end of the adaptor J 1508–9 over the pilot and against the shoulder of the installer handle. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then, insert the pilot of the installer handle into the pump body and drive the seal in until the shoulder of the adaptor contacts the pump body (Figure 9.) 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.

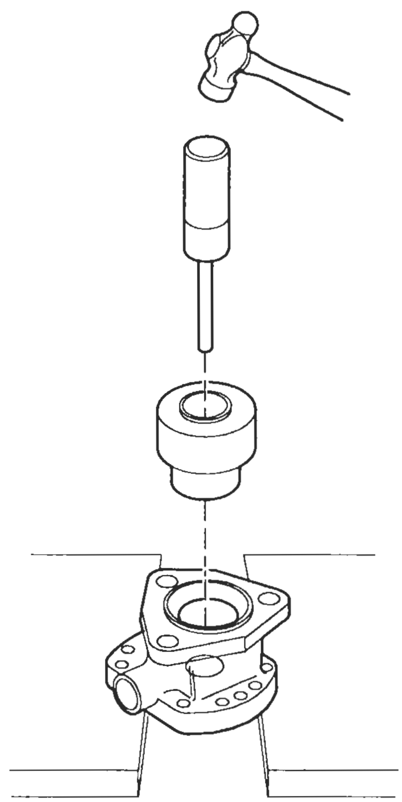


Figure 9. Installing Outer Seal

ASSEMBLE FUEL PUMP (CONT.)

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 (Figure 10.)
5. Place the driven shaft and gear assembly in the pump body.

NOTE: The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

6. Lubricate the gears and shafts with clean engine oil.
7. Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then, place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

NOTICE:

The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal–to–metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

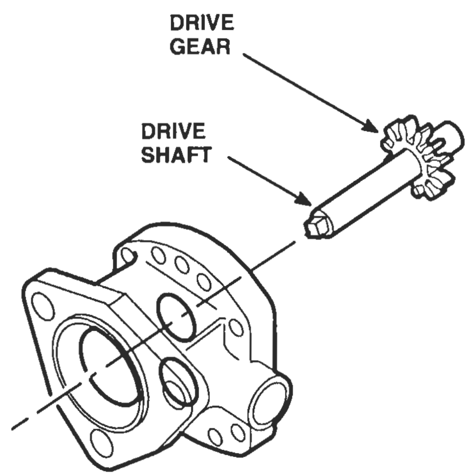


Figure 10. Installing Drive Shaft Gear Assembly

ASSEMBLE FUEL PUMP (CONT.)

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.
9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.
10. Install 1/8 inch 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 left–hand pump is used on "A" and "B" engines and the right–hand pump is used on "C" and "D" engines. The pumps are not interchangeable and cannot be rebuilt to operate in an opposite direction.

The pump must always be installed with the inlet opening in the pump cover (marked "LH IN" or "RH IN") on the side toward the cylinder block. The pump is driven by a drive disc at the rear of the blower lower rotor. 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 blower, being certain that the drive coupling fork registers with the slots in the drive disc on the blower rotor shaft.
3. Secure the pump to the blower with three nylon patch bolts.

NOTE: To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

4. If removed, install the fuel inlet and outlet fittings in the pump cover.
5. Before installing inlet or outlet fittings in the fuel pumps, coat the threads lightly with Gasoila, Permatex II or an equivalent non–hardening sealant. To prevent sealant from entering the fuel system, do not apply sealant to the first two threads of the fittings. Tighten the fittings until 1/2 inch of the threads are engaged. Continue to tighten the fitting until alignment of the fitting is achieved. Do not tighten the fitting past the 3/4 inch thread engagement point.

NOTICE:

Do not install fittings with Teflon® tape or paste, since this can result in fuel pump cover damage (cracking) before the required torque is reached.

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), (Figure 1.) are used to remove impurities from the fuel. The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density–type element is capable of filtering out particles of 30 microns (a micron is approximately .00004 inch). The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper–type element can remove particles as small as 10 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.

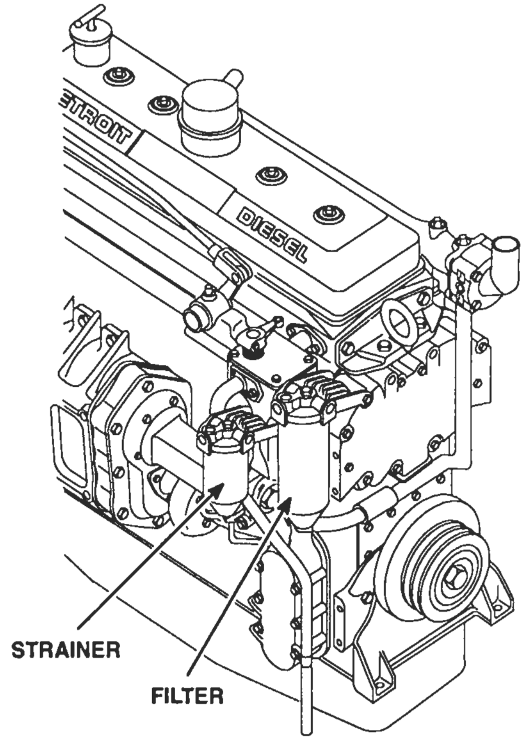


Figure 1. Fuel Filter and Fuel Strainer Mounting

The filter and strainer consist basically of a shell, a cover, and a replaceable filtering element. The assembly is made oil tight by a shell gasket, a cover nut or bolt, and a cover nut or bolt gasket.

The central stud is a permanent part of the shell and, when the unit is assembled, extends up through the cover where the nut or bolt holds the assembly together.

A filter element sets over the central stud inside the shell and is centered in the shell by the stud.

The current cover assemblies are visibly different by a cast letter "P" (primary) that has been added to the top of the strainer cover and the letter "S" (secondary) that has been added to the top of the filter cover.

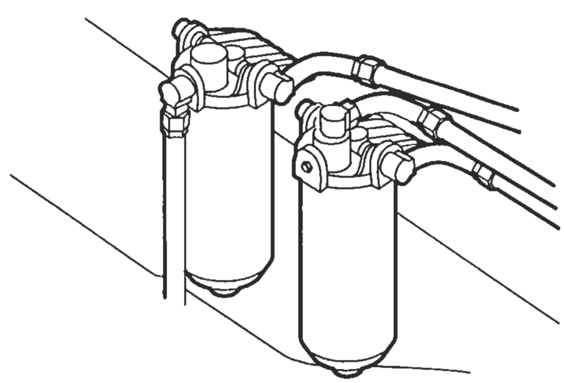


Figure 2. Fuel Filter and Fuel Strainer Mounting

SECTION 2.3 – FUEL STRAINER AND FILTER

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.

REPLACE FUEL STRAINER OR FILTER ELEMENT

The procedure for replacing an element is the same for the fuel strainer(Figure 3.) or fuel filter (Figure 4.). Replace the element as follows:

NOTE: Only filter elements designed for fuel oil filtration should be used to filter the fuel.

1. With the engine stopped, place a container under the strainer or filter and open the drain cock. Loosen the cover 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.

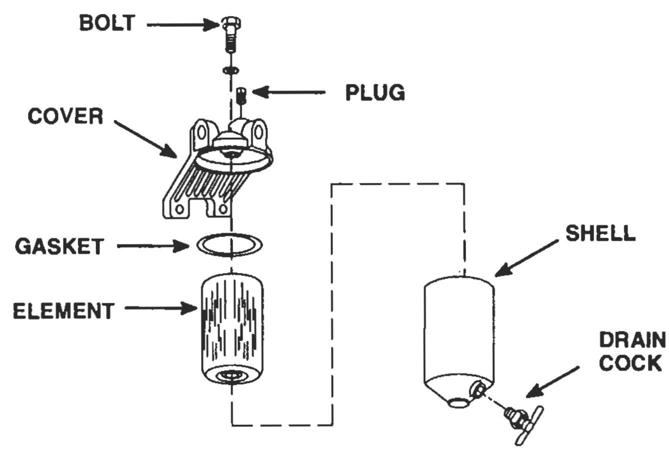


Figure 3. Fuel Filter and Fuel Strainer Part Locations

REPLACE FUEL STRAINER OR FILTER ELEMENT (CONT.)

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.
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.

NOTE: 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.

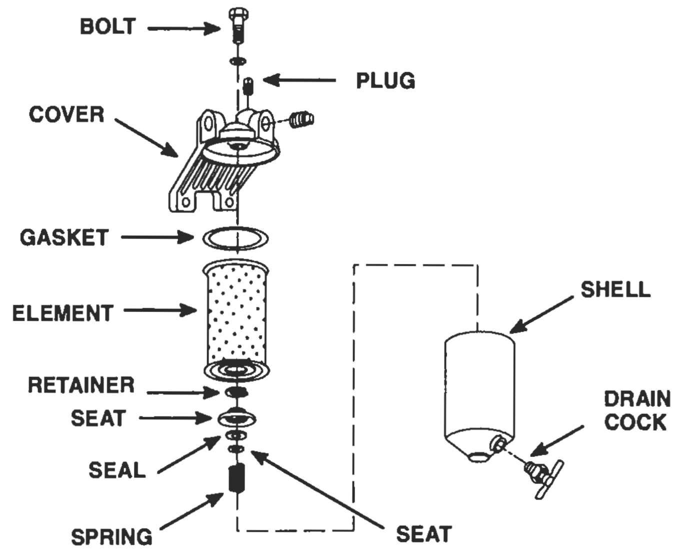


Figure 4. Fuel Filter Details and Parts

SECTION 2.3 – FUEL STRAINER AND FILTER

REPLACE FUEL STRAINER OR FILTER ELEMENT (CONT.)

The current strainer and filter elements include the element, the cover gasket and cover bolt gasket. The strainer element also includes both the former and current bolt gaskets.

6. Place a new element over the center stud and push it down against the element seat. Make sure the drain cock is closed, then fill the shell about two–thirds full with clean fuel oil.

NOTE: Thoroughly soak the density–type strainer element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

7. 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 (Figure 5.) is used on certain engines. 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.

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.

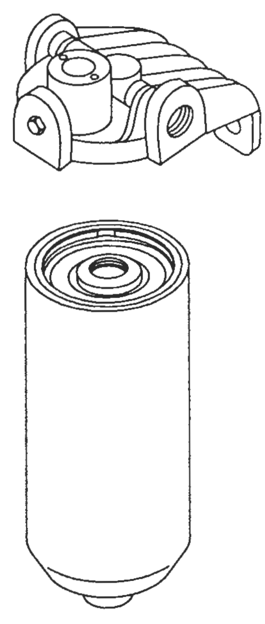


Figure 5. Typical Spin–On Filter Details and Mounting

FILTER REPLACEMENT

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 MANIFOLD

The fuel injectors are supplied with fuel oil through pipes connected to the fuel inlet manifold. Excess fuel oil is returned to the fuel tank from the fuel injectors through pipes connected to the fuel outlet manifold. The fuel inlet and outlet manifolds are an integral part of the cylinder heads (Figure 1.) Since there are inlet and outlet passages provided opposite each injector position in the side of the head as well as at each end, greater flexibility is permitted in the installation of the fuel lines to the fuel manifolds. The fuel passages are identified by the words "IN" (top manifold) and "OUT" (bottom manifold) cast in several places in the side of the cylinder head.

The fuel manifold connectors are assembled to the integral fuel manifold cylinder head, using special steel sealing washers, and tightened to 40–45 lb·ft (54–61 N·m) torque.

A special fitting with a restricted opening is used in the fuel outlet manifold to maintain the proper pressure within the fuel system. Refer to Section 13.2 for the size of restriction used.

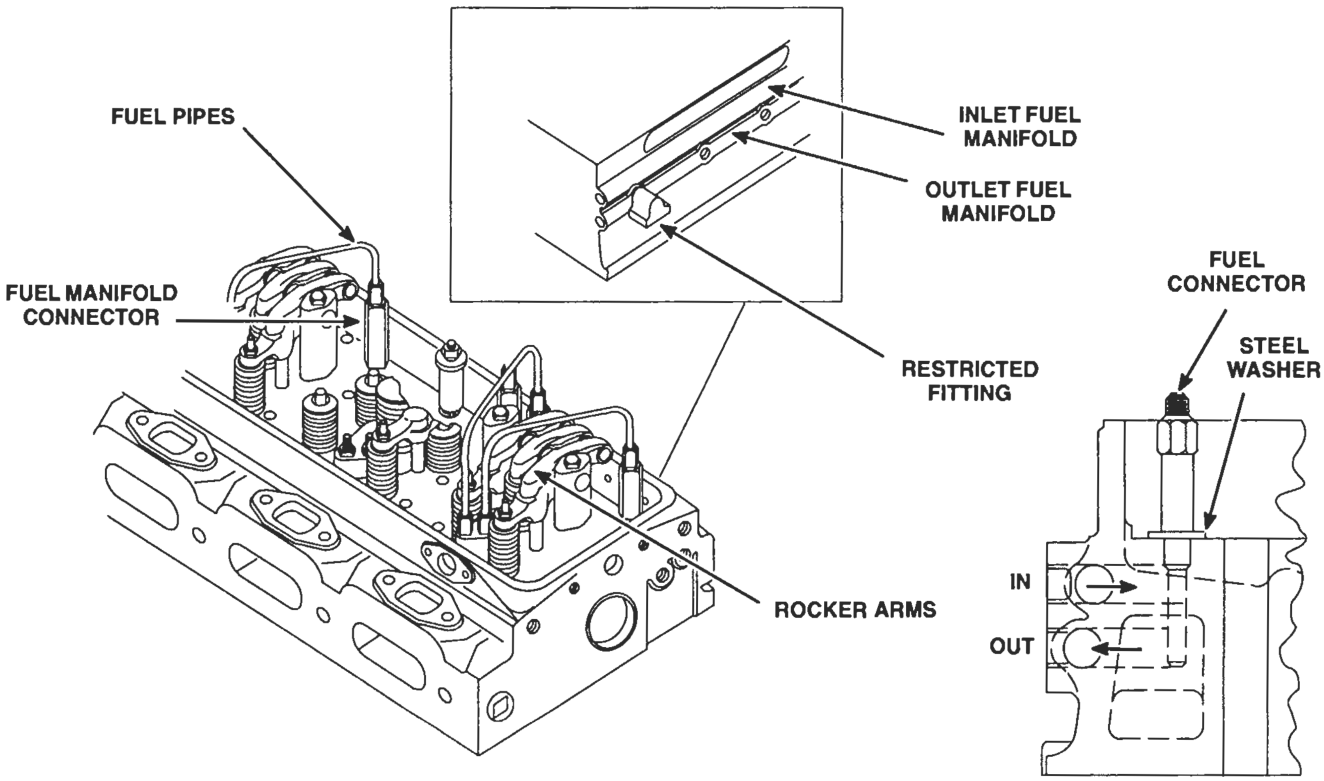


Figure 1. Cylinder Head with Integral Fuel Manifolds

SERVICE

NOTICE:

The direction of flow of the fuel will, in most cases, be reversed when replacing a cylinder head with the external fuel manifolds by one with the integral manifolds. Therefore, replace the filters before the injectors are reinstalled in the replacement head. Otherwise, damage to the injectors will result due to foreign particles in the filter entering the injector.

FUEL COOLERS

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 (Figure 1.) 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.

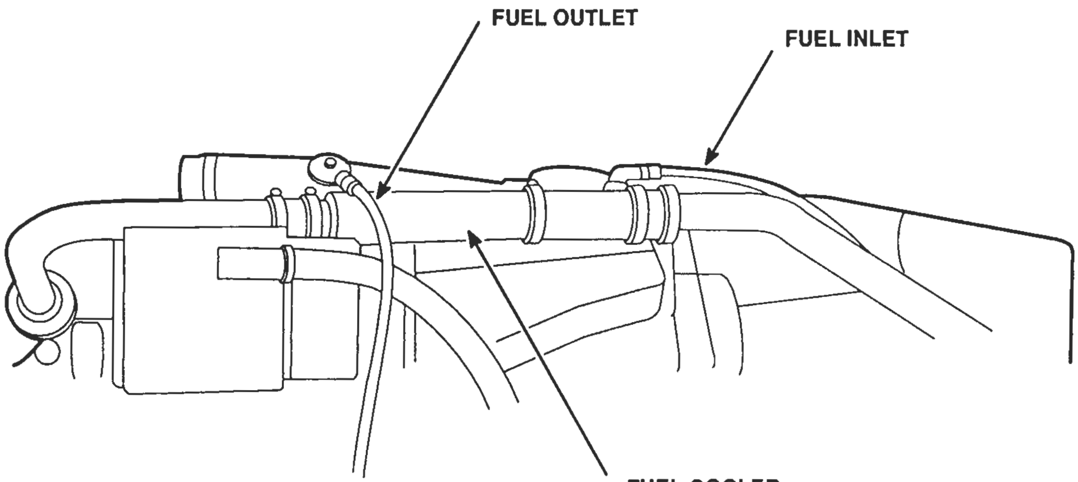


Figure 1. Fuel cooler Mounting

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 liters) of a solution composed of 1/3 muriatic acid and 2/3 water. The cleaning action is evident by the bubbling and foaming.

Watch the process carefully 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.

SECTION 2.5.1 – FUEL COOLER

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 inch pipe plug and attaching an air hose to the other opening. Apply approximately 100 lb/in.^{2} (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.

ELECTRONIC ENGINE CONTROL

The Detroit Diesel Electronic Control System (DDEC) controls the timing and amount of fuel injection by the electronic unit injectors (EUI). The system also monitors several engine functions using electrical sensors which send electrical signals to the Electronic Control Module (ECM). The ECM then computes the incoming data and determines the correct fuel output and timing for optimum power, fuel economy and emissions. The ECM also has the ability to display warnings or shut down the engine completely (depending on option selection) in the case of damaging engine conditions, such as low oil pressure, low coolant, or high oil temperature.

The replaceable PROM is an EEPROM in the DDEC II ECM. The ECM has isolator mounts for both vibration and electrical isolation. The engine mounted system simplifies vehicle wiring for greater reliability.

The DDEC system is self–diagnostic. It can identify faulty components and other engine–related problems by providing the technician with a diagnostic code.

The replacement of DDEC components is based on indicated diagnostic codes leading to faulty components. Refer to DDEC Troubleshooting Guide 6SE489 (DDEC II) or 6SE492 (DDEC III) for more complete information on diagnosis of components and system problems.

DETROIT DIESEL ELECTRONIC CONTROL (DDEC III) (4–71 ONLY)

ADDED FEATURES OF DDEC III

- More powerful microprocessor
- Increased memory
- Additional inputs and outputs
- Faster data resolution
- Future SAE guidelines
- New manufacturing techniques
- 24V capability
- Cruise control
- Vehicle speed limiting
- Vehicle overspeed with fuel
  - Logs engine hours above set limit
  - No warning light
- Vehicle overspeed without fuel
  - Logs engine hours above set limit
  - No warning light
- Engine overspeed
  - Logs code above 2500 RPM
- All diagnostic codes are engine hour stamped
- SAE standard diagnostic codes
- Flash diagnostic codes
  - Active codes on stop engine light (red)
  - Inactive codes on check engine light (yellow)
- MPSI Diagnostic Data Reader (DDR) with new cartridge
  - DDEC II & DDEC III compatible
- Alpha numeric password setting with DDR
  - Maximum, minimum and rating security
- Standard SAE 6–pin round diagnostic connector
- Reprogram ECM through DDR connector
- Multiple horsepower ratings
  - Three single ratings
  - One cruise power rating
- Program rating with DDR or personal computer
- Password security for rating selection with DDR

DETROIT DIESEL ELECTRONIC CONTROL (DDEC III) (CONT.)

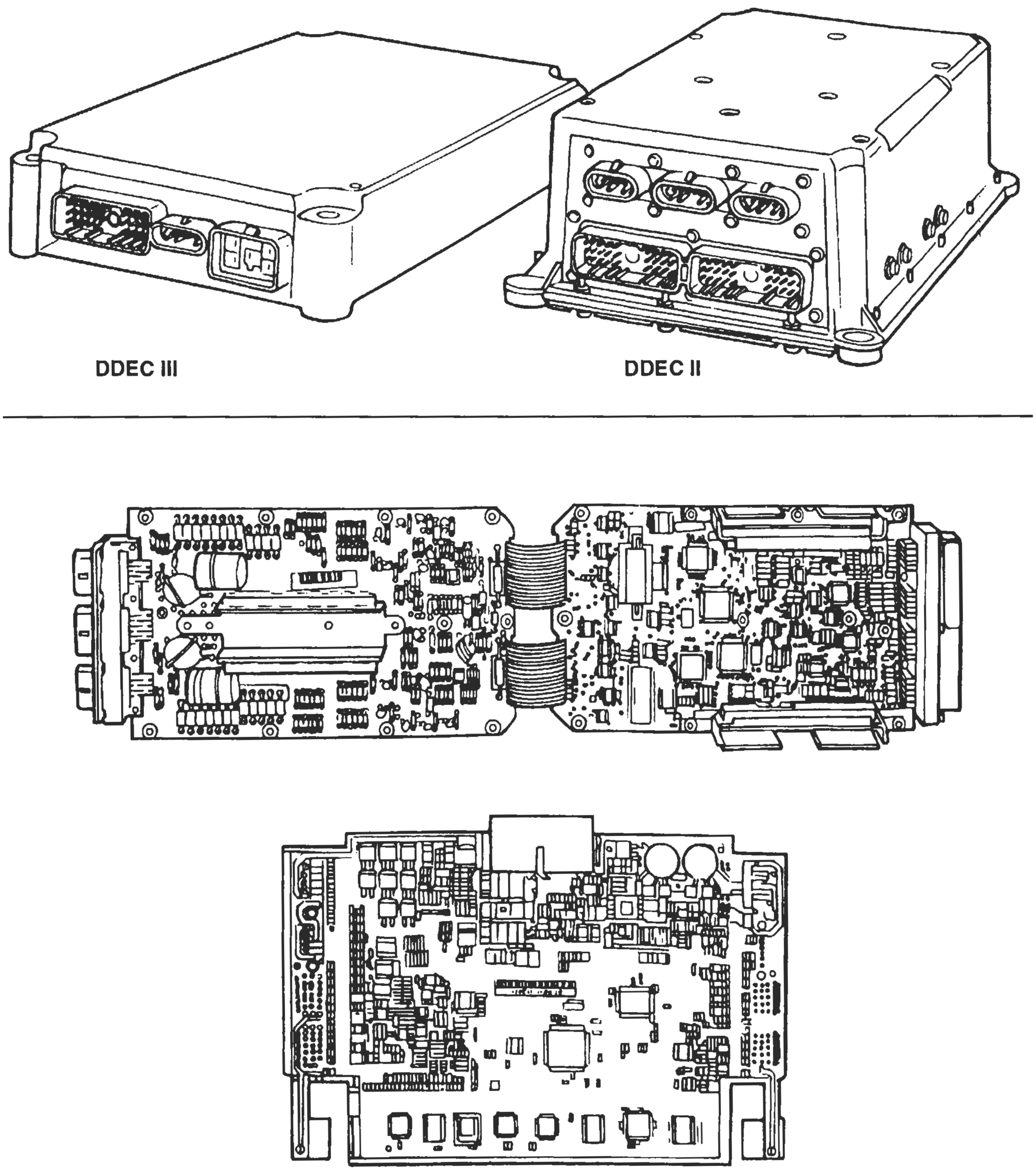


Figure 1. DDEC III Electronic Control Module (ECM)

DETROIT DIESEL ELECTRONIC CONTROL (DDEC III) (CONT.)

SAE Standard Communications

- SAE J 1587 protocol on J 1708 hardware
  - Diagnostics
  - Electronic dashes
  - Data hub
- SAE J 1922 protocol on J 1708 hardware
  - Traction control systems
  - Transmission controls
- SAE J 1939 high speed data link
  - ECM communications on multi–block engines
  - Vehicle controls

Fan Controls

- Inputs
  - Coolant temperature
  - Oil temperature
  - Air temperature
  - Air conditioning
- Outputs
  - Single on/off fan clutch
  - Dual on/off fan clutch
  - 2–speed single fan clutch
  - Modulated fan clutch

Engine Brake Control

- Eliminates OEM engine brake module
- Compatible with cruise control
  - Engine brake will go on and off without disabling cruise control (Auto only)
- Engine fan braking
  - Requires fan and engine brake controls
  - Fan turn on when engine brake is on high
- In cruise control, engine brake operates electronically (Auto only)
  - MPH activating speeds are set with DDR
- Cruise control, engine brake operates manually (Auto only)

PROGRAMMING WITH DDR

- Password
- Droop
- Active HP rating
- Cruise control
- Engine brake
- Cruise auto control
- Vehicle speed limiting
- Vehicle speed sensor
- VSG cruise switch
- Idle timer shutdown
- Engine protection
- Vehicle ID number (VIN)
- Idle adjustment
- Progressive shifting

DETROIT DIESEL ELECTRONIC CONTROL (DDEC III) (CONT.)

DDEC II vs. DDEC III

Engine Hardware	DDEC II	DDEC III
Sensors	**Standard** Oil Temperature Oil Pressure Coolant Level Turbo Boost Throttle Position Timing Reference Synchronous Reference Fuel Temperature **Optional** Coolant Temp (Bus) Fuel Pressure Pressure Governor (Firetruck) Bypass Blower (Alt. Fuels)	**Standard** Oil Temperature Oil Pressure Coolant Level Turbo Boost Throttle Position Timing Reference Synchronous Reference Fuel Temperature Air Temperature **Optional** Coolant Temp (Bus) Fuel Pressure Pressure Governor (Firetruck) Bypass Blower (Alt. Fuels)
Electronic Foot Pedal Assembly	3 Wires	3 Wires
Coolant Level Sensor	Coolant Probe Coolant Module	Coolant Probe Only
Diagnostic Request Stop Engine Override	2 Switches	1 Combined Switch
Communications	Vehicle Interface Harness SAE J 1587/J 1922	Vehicle Interface Harness SAE J 1587 Communications Harness SAE J 1922, SAE J 1939
Engine Harness	6 Pin Connector 16 Ga. Wire 4 Power 2 Ground	5 Pin Square Connector 12 Ga. Wire (Eliminates Splicing) 2 Power 2 Ground 1 Clean Ground

DIAGNOSTIC PROCEDURES

Before attempting any diagnosis of the system, read Section 2, "Basic Knowledge Required," and Section 3, "Testing the DDEC System," of the DDEC Troubleshooting 6SE489. Basic mechanical checks should be made beforehand to verify that the problem is definitely related to the electrical portion of the system. If the basic mechanical checks fail to locate the problem, start the electrical diagnosis with the Troubleshooting Charts as described in the DDEC Troubleshooting Guide 6SE489 (Figure 1.)

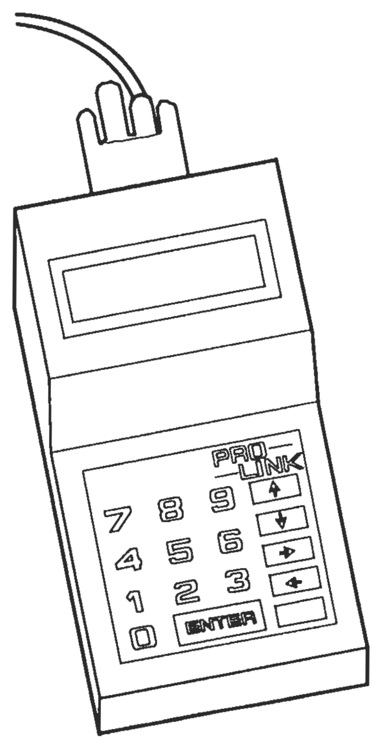


Figure 1. J 38500 DDEC Reader

DIAGNOSTIC PROCEDURES (CONT.)

If the diagnostic reader is not available, the following procedure can be used to read the fault codes using the "Check Engine" light on the dashboard of the vehicle (Figure 2.)

If the vehicle is equipped with an OEM supplied diagnostic switch, hold the switch in the on position. This should be done with the ignition on and the engine not running.

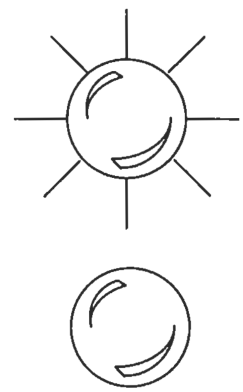


Figure 2. Dashboard Warning Lights

If there is no diagnostic switch, locate the 12–pin Diagnostic Data Link (DDL) connector under the dash of the vehicle (Figure 3.) Using the jumper wire from the Kent–Moore Diagnostic Jumper Wire Kit, J 35751, or equivalent, connect pin A to pin M.

These methods will cause the "Check Engine" light to begin flashing a code when the ignition is turned to the "ON" position. Code 25, for example, would be two flashes followed by a pause, followed by five more flashes. This code would indicate no trouble codes logged since the last system check. This flashing code will be repeated until the diagnostic switch is turned "OFF" or the jumper wire is removed from pins A and M.

CAUTION:

If the vehicle is equipped with an OEM supplied diagnostic switch, the switch must NOT be switched on when operating the vehicle. If this is done, the diagnostic mode line will be grounded, and the throttle will be forced to the idle position, affecting vehicle operation. The throttle will also go to idle if pins A and M in the Diagnostic Data Link (DDL) connector are jumpered together as shown in Figure 3. This condition will not occur when a diagnostic reader is used.

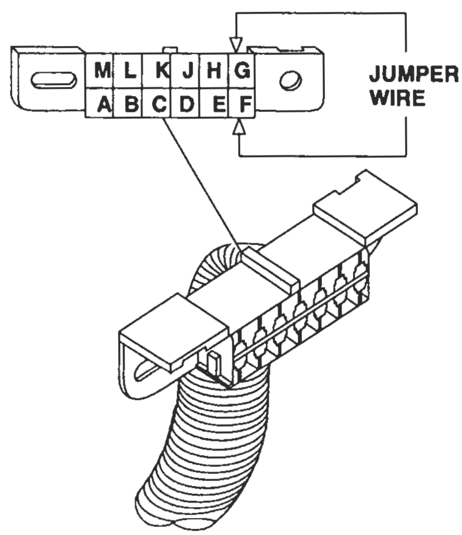


Figure 3. Diagnostic Data Link (DDL) Connector

DIAGNOSTIC PROCEDURES (CONT.)

If a code other than 25 is read, refer to the correct chart as instructed by the DDEC Troubleshooting Guide 6SE489 for repair instructions.

Fault codes can be cleared from the DDEC II system only by using a diagnostic reader. Follow the instructions supplied with the reader to clear the fault codes.

Following are basic replacement procedures for the DDEC components. Components should NOT be replaced unless a defective unit has been concluded by the DDEC Troubleshooting Guide, 6SE489.

NOTE: Before beginning any repair procedures, the ignition switch must be in the "OFF" position.

ELECTRONIC CONTROL MODULE (ECM) DDEC II

The DDEC II Electronic Control Module (ECM) is a microprocessor. It is the control center of the DDEC II system (Figure 1.)

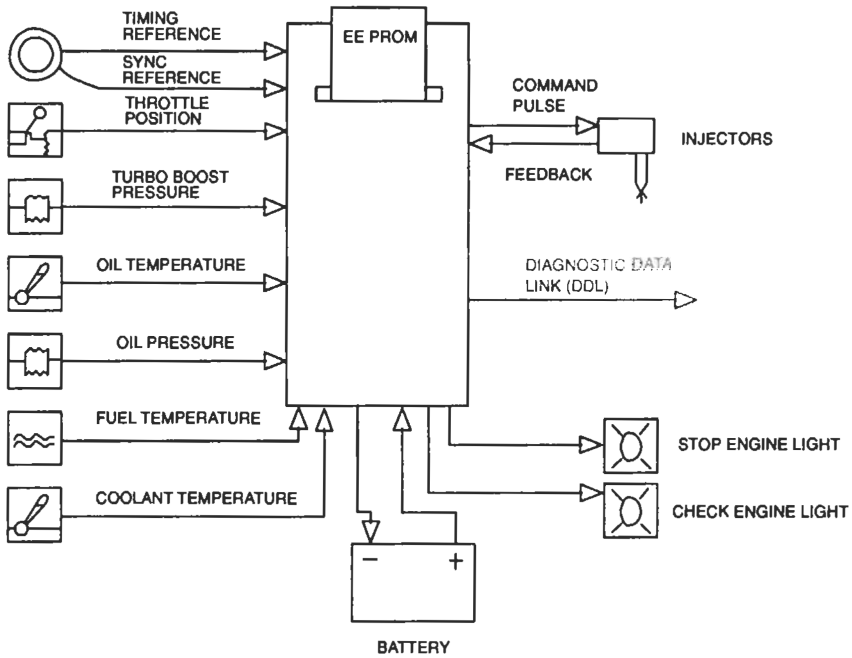


Figure 1. Schematic Diagram of DDEC II

The DDEC II ECM is packaged in a die–cast aluminum housing with sealed connectors (Figure 2.) It is mounted to the left side of the engine block.

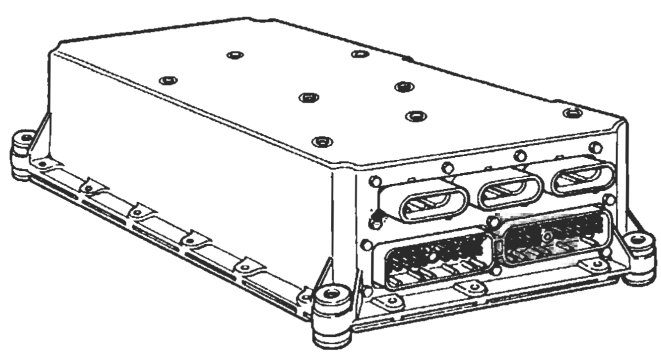


Figure 2. Electronic Control Module

ECM REMOVAL–(DDEC II)

1. Disconnect the fuel line (at the secondary fuel filter) that runs from the ECM cold plate. Position the line over a suitable container to collect any fuel coming from the system.
2. Disconnect the inlet and return lines from the ECM cold plate and fuel connector block.

NOTICE:

The connector block must be held securely with a wrench while loosening fuel lines to prevent damage to the block.

3. Remove the five wire harness connections at the ECM.

NOTE: Carefully disengage the lock tab on the power harness and injector harness connectors when removing.

4. Remove the thru–bolts holding the ECM to the engine.
5. Remove the ECM and cold plate from the engine.
6. Remove the screws securing the cold plate to the ECM. Remove the cold plate from the ECM.

ECM INSTALLATION (DDEC II)

1. Reverse the removal procedure for installation.
2. Use Loctite 262, or equivalent, on the cold plate–to–ECM screws. Tighten to 84–106 lb·in (9.5–12 N·m) torque.
3. Inspect the ECM isolators for damage and replace if required.

NOTE: The ECM isolators must be reinstalled.

4. Tighten the ECM–to–engine bolts to 17–20 lb·ft (23–27 N·m). Tighten the ECM connector hold–down screws to 21–26 lb·in (24–30 kg·cm) torque.
5. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code except code 25 is obtained, refer to the DDEC II Troubleshooting Guide 6SE489.
6. Start the engine, and check for fuel leaks.

ELECTRONIC FOOT PEDAL ASSEMBLY (EFPA)

The Electronic Foot Pedal Assembly (EFPA) connects the accelerator pedal to a Throttle Position Sensor (TPS). The Throttle Position Sensor (TPS) is a device that sends an electrical signal to the Electronic Control Module (ECM) that varies in voltage according to the amount the pedal is depressed. The system is installed in the space normally occupied by the mechanical foot pedal. The Electronic Foot Pedal Assembly (EFPA) has maximum and minimum stops that are built into the unit during manufacture.

A typical EFPA is shown in (Figure 1.) The EFPA assembly is supplied by the vehicle manufacturer.

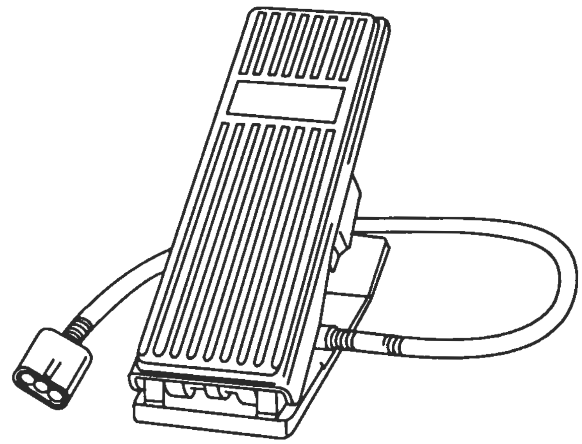


Figure 1. Electronic Foot Pedal Assembly (EFPA)

TURBO BOOST SENSOR (TBS)

The Turbo Boost Pressure Sensor is a pressure sensor that sends an electrical signal to the ECM (Figure 1.) The ECM uses this information to compute the amount of air entering the engine. Fuel supply is regulated by the TBS information to control engine smoke. The TBS is non–serviceable and must be replaced as an assembly. No adjustment is required.

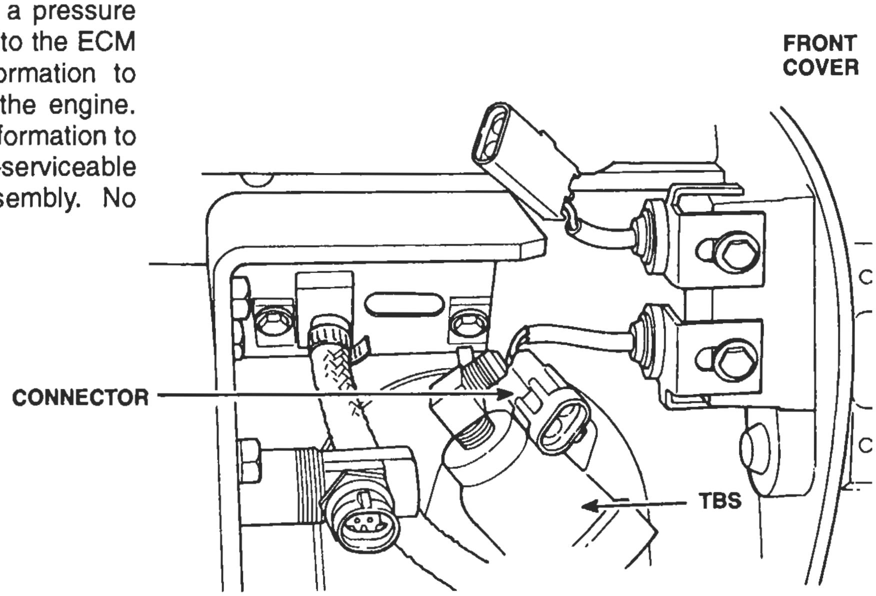


Figure 1. Turbo Boost Pressure Sensor (TBS)

TBS REMOVAL

1. Remove the clamp on the air pressure line at the sensor body. Pull the hose off.
2. Disengage the locking tang on the connector body. Grasp the terminal body and gently pull it from the sensor.
3. Loosen and remove the two nut and bolt assemblies holding the sensor to the bracket and remove the sensor.

TBS INSTALLATION

1. The TBS is an electronic device. Use care during installation.
2. Reverse the removal procedure for installation.
3. Carefully route hose from the connector at the blower inlet manifold. Do not allow loops or kinks or sags in the hose.
4. Torque the bolts to **no more than** 21–26 in·lb (24–30 kg·cm) torque.
5. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any other code other that 25 appears, refer to the DDEC Troubleshooting Guide 6SE489.

OIL PRESSURE SENSOR (OPS)

The Oil Pressure Sensor (OPS) is installed into the main engine oil gallery. A typical location is the left rear corner of the cylinder block (Figure 1.)

The OPS sends an electrical signal to the ECM telling it what the engine oil pressure is at any given speed. A low oil pressure signal exceeding seven seconds is used by the ECM to begin the stop engine or warning function. The OPS is non–serviceable and should be replaced as a unit. No adjustment is required.

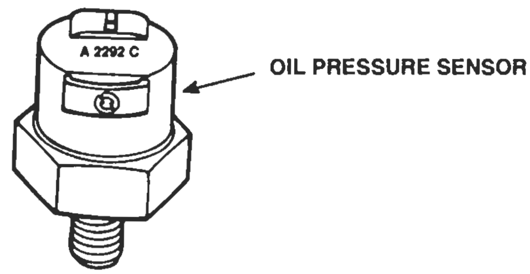


Figure 1. Oil Pressure Sensor (OPS)

OPS REMOVAL

1. Disengage the locking tang on the three–wire connector. Grasp the body of the connector and gently pull it free of the OPS.
2. Use the appropriate wrench on the hex end of the OPS to unscrew it from the engine.

OPS INSTALLATION

1. The OPS is an electronic device. Use care on installation.
2. Reverse the removal procedure for installation.
3. Use Loctite Pipe Sealant with Teflon J 26558–92 (or equivalent) on all but the first two threads of the OPS to prevent leaks.
4. Turn the ignition to the “ON” position. Observe or read any diagnostic codes. If any code other than 25 is obtained, refer to the DDEC Troubleshooting Guide 6SE489.

OIL TEMPERATURE SENSOR (OTS)

The Oil Temperature Sensor (OTS) is installed into the main engine oil gallery. A typical location is the left rear corner of the cylinder block as shown in Figure 1. The OTS sends an electrical signal to the ECM indicating engine oil temperature. The ECM uses this information to modify engine speed for better cold weather starts and faster warm–ups. Oil temperatures exceeding specification for two seconds or more will begin the stop engine or warning function. The OTS is non–serviceable, and is replaced as a unit. No adjustment is required.

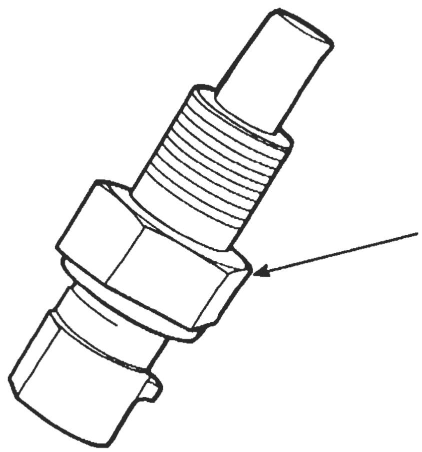


Figure 1. Engine Oil Temperature Sensors (OTS)

OTS REMOVAL

1. Disengage the locking tang on the two–wire connector. Grasp the body of the connector and gently pull it from the socket.
2. Use the appropriate wrench on the hex portion of the sensor and unscrew it.

OTS INSTALLATION

1. The Oil Temperature Sensor is an electronic device. Use care in the installation process.
2. Reverse the removal procedure for installation.
3. Use Loctite Pipe Sealer with Teflon J 26558–92 (or equivalent) on all but the first two threads of the OTS to prevent leaks.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the DDEC Troubleshooting Guide 6SE489.

SYNCHRONOUS REFERENCE SENSOR (SRS)

The Synchronous Reference Sensor (SRS) is an electronic component that is mounted to the back side of the front end plate (Figure 1.)

The sensor portion of the SRS extends through a hole in the end plate, and is positioned very near the pulse wheel. A bolt, inserted through a hole in the SRS bracket, secures the SRS assembly to the end plate. The SRS connector is black in color.

The SRS references firing position for the number one piston.

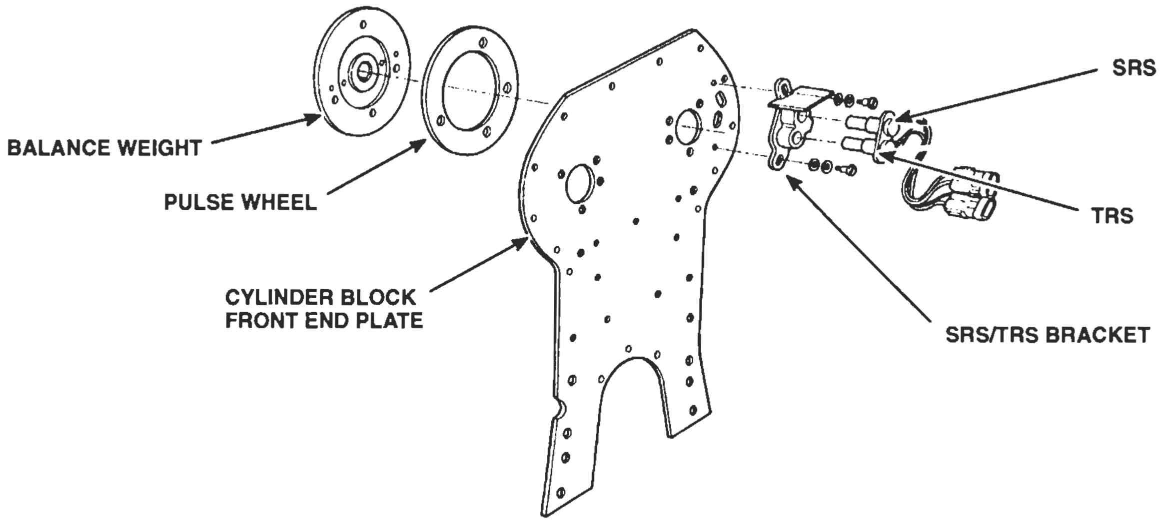


Figure 1. SRS Location

The SRS sends a signal to the ECM. This signal is generated by a raised metal pin on the rear of the pulse wheel (Figure 2.)

The pin passes by the SRS as the number one piston reaches approximately 45° before Top–Dead–Center.

The SRS is a non–serviceable item and is replaced as a unit. No adjustment is required.

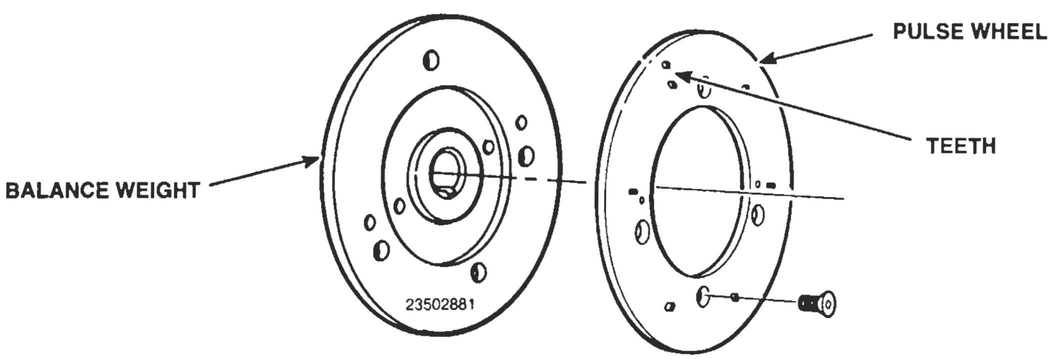


Figure 2. Pulse Wheel

SECTION 2.6.6 – SRS

SRS REMOVAL

1. Disengage the locking tang on the SRS connector. Grasp the connector bodies and gently pull them apart.
2. Using a socket and long extension, remove the SRS bolt.
3. Remove the SRS by pulling it straight out of the gear case.

SRS INSTALLATION

1. The SRS is an electronic component. Use care upon installation. The O–ring on the sensor may be coated with clean engine oil for ease of installation.
2. Insert the SRS into the gear case and index the hole in the bracket with the hole in the gear case.
3. Insert the SRS bolt and tighten it to 22–28 lb·ft (30–38 N·m) torque.
4. Plug the connectors together, making sure the locking tang clicks into place.
5. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the DDEC Troubleshooting Guide 6SE489.

TIMING REFERENCE SENSOR (TRS)

The Timing Reference Sensor (TRS) is an electronic component that is mounted to the back side of the front end plate (Figure 1.)

The sensor portion of the TRS extends through an opening in the end plate, and is positioned near the pulse wheel. A bolt, inserted through a hole in the TRS bracket, secures the TRS assembly to the end plate. The TRS connector is gray in color.

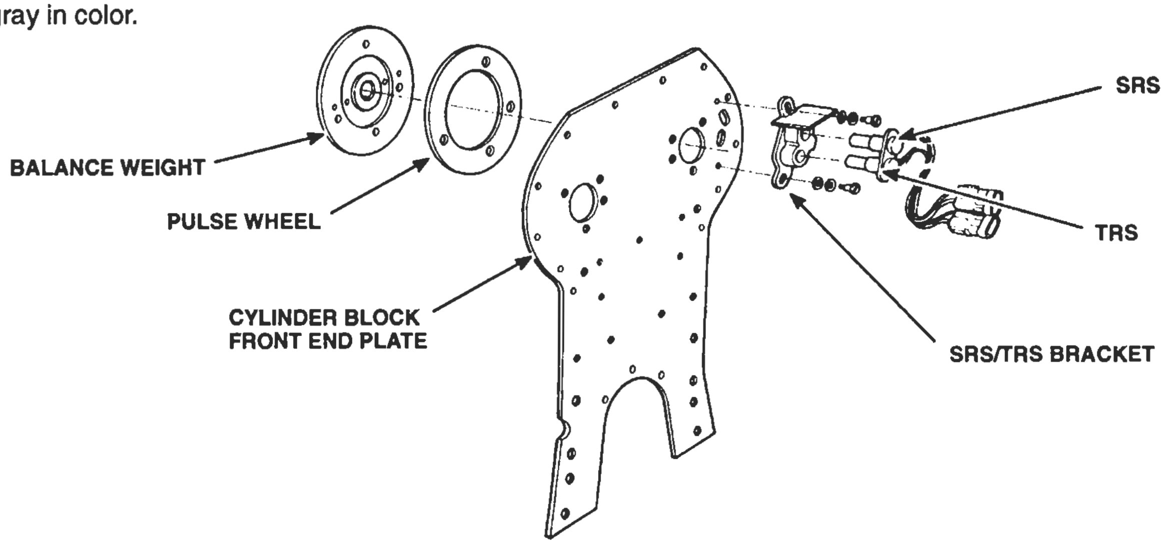


Figure 1. Timing Reference Sensor

The TRS sends a signal to the ECM. As the pulse wheel rotates (Figure 2.) a pin passes by the TRS as each cylinder reaches 10° before Top–Dead–Center. These signals are used by the ECM to determine injector solenoid operation times.

The TRS is a non–serviceable component and is replaced as a unit. No adjustment is required.

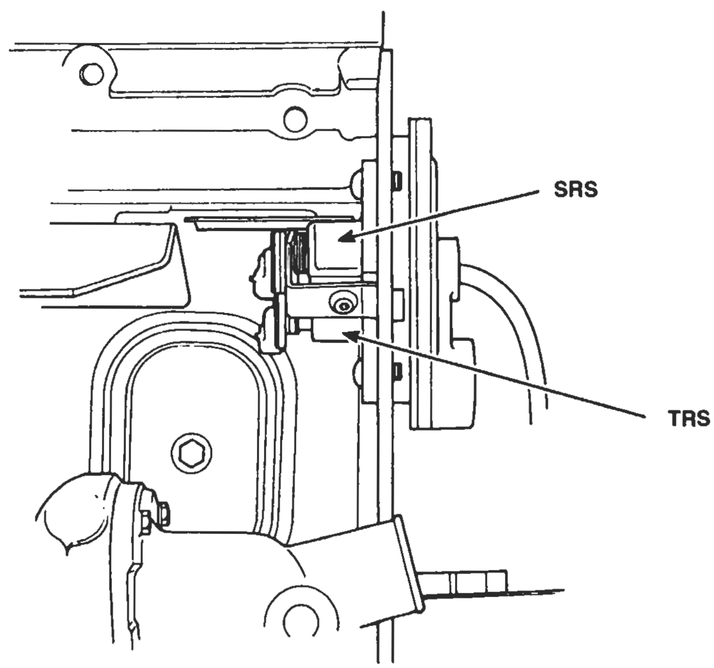


Figure 2. Timing Reference Sensor Assembly

TRS INSTALLATION

1. The TRS is an electronic component. Use care upon installation. The O–ring on the sensor may be coated with clean engine oil for ease of installation.
2. Insert the TRS into the gear case and index the hole in the bracket with the hole in the gear case.
3. Insert the TRS bolt and tighten it to 22–28 lb·ft (30 to 38 N·m).
4. Plug the connectors together, making sure the locking tang clicks into place.
5. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the DDEC Troubleshooting Guide 6SE489.

SRS/TRS REMOVAL AND TIMING

1. Loosen and remove the front cover (Refer to Section 1.7.8).
2. Remove any hoses or fuel lines necessary to gain access to the sensors.
3. Disengage the locking tang on the SRS connector. Grasp the connector bodies and gently pull them apart. Repeat this procedure for the TRS.
4. Remove the SRS/TRS retaining screw and clip.
5. Remove the sensor assembly.
6. If a pulse wheel or engine front end plate has been removed or replaced, loosen the two sensor–retaining socket head screws.

SRS/TRS INSTALLATION

Use the tools shown in (Figure 3.) (DDEC Tool Kit) to perform the following operations:

1. Install the sensors assembly and retaining clip.
2. Install, **but do not tighten**, the retaining clip screw.

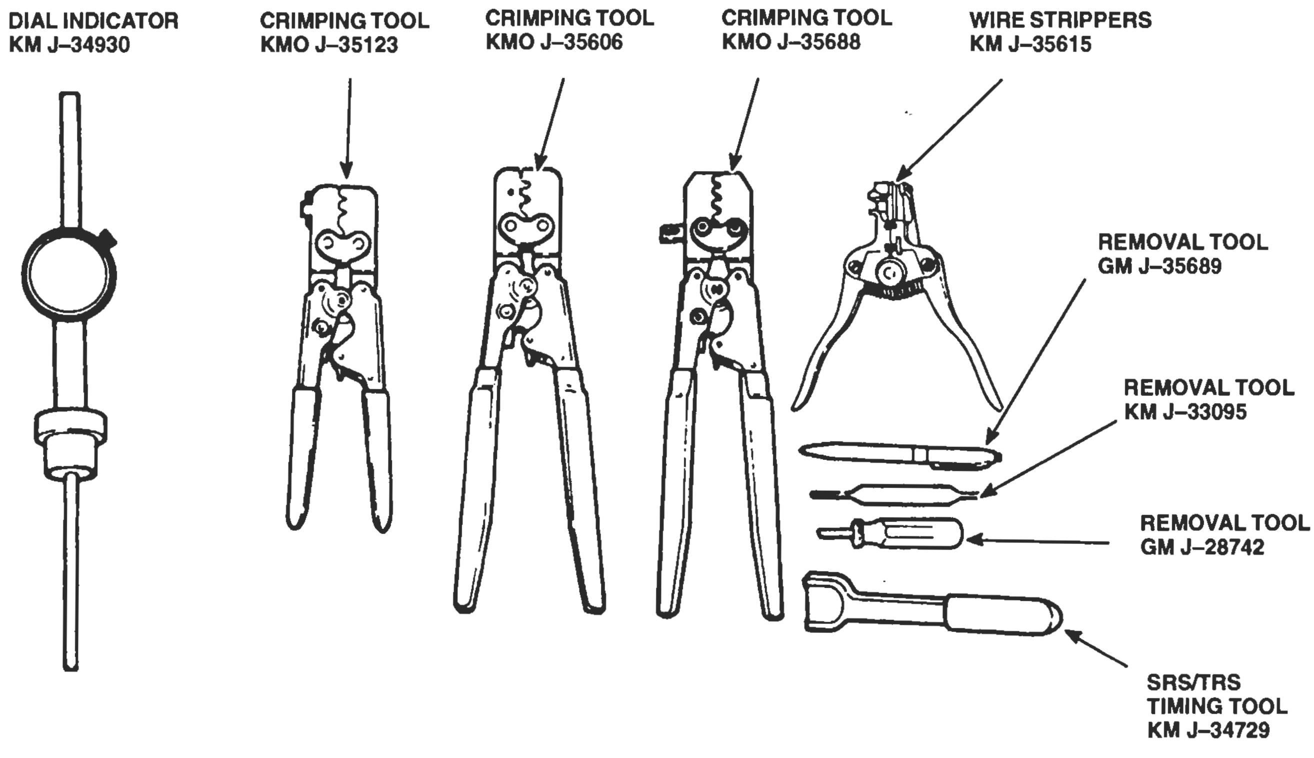


Figure 3. SRS/TRS Installation Tools

SRS/TRS ADJUSTMENT

Whenever a sensor assembly is replaced, it must be aligned in relationship to the pin on the Pulse Wheel upon installation. Use the following instructions for sensor alignment.

1. Refer to Electronic Unit Injector Replacement in this manual and remove the following injector:
   a. #4 for right rotation engines
   b. #1 for left–hand rotation engines
2. Position the piston for this cylinder at top dead–center, using Crankshaft Position Timing Tool, Kent–Moore tool J34930, as follows:
   a. Install the slotted spacer on the chain between the dial indicator and the top of the holder. Tighten the clamp screw.

NOTICE:

Failure to insert the spacer could result in damage to the dial indicator if the piston is already at the top of the travel when the tool is installed.

   b. Insert a dial indicator tool into the injector bore, install injector hold–down crab and tighten the bolt.
   c. Turn the crankshaft slowly in the direction of rotation and note indicator movement. Stop turning when the dial hand just stops.
   d. Turn the crankshaft slowly, opposite the direction of rotation, until the dial indicator hand just starts to move. The piston is now at top–dead center.
   e. Before piston downward travel can be measured, the dial indicator must be "zeroed". Loosen the clamp screw and remove the slotted spacer. Lower the dial indicator until the two smaller indicator hands are at "0" and the large hand is near "0" (Figure 4.)

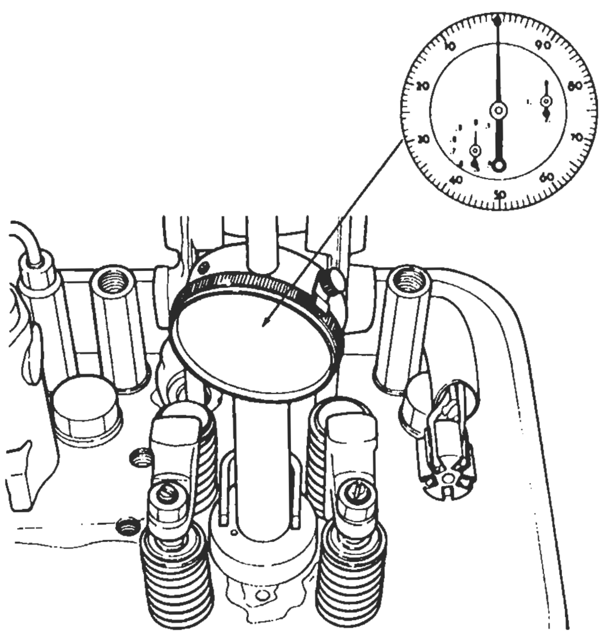


Figure 4. Dial Indicator Calibration

SRS/TRS ADJUSTMENT (CONT.)

f. Tighten the clamp screw and zero the large hand by turning the outer ring of the dial face. Tighten the bezel screw so the outer ring will not turn.

3. Turn the crankshaft slowly, in the direction of rotation, until the dial indicator pointer reads exactly 1.077 inches of piston travel (Figure 5.)

CAUTION:

If the crankshaft pulley retaining bolt has loosened during the timing procedure, tighten it to the specified torque upon completion of the SRS/TRS positioning procedure following the instructions in Section 1.3.7.

At this point, the pin on the rear of the Pulse Wheel, located at the rear of the balance weight, are in the proper location for positioning the sensors. The sensor bracket must be positioned correctly in relation to the engine front end plate. Use SRS/TRS Timing Tool No. J34729 to accomplish this task.

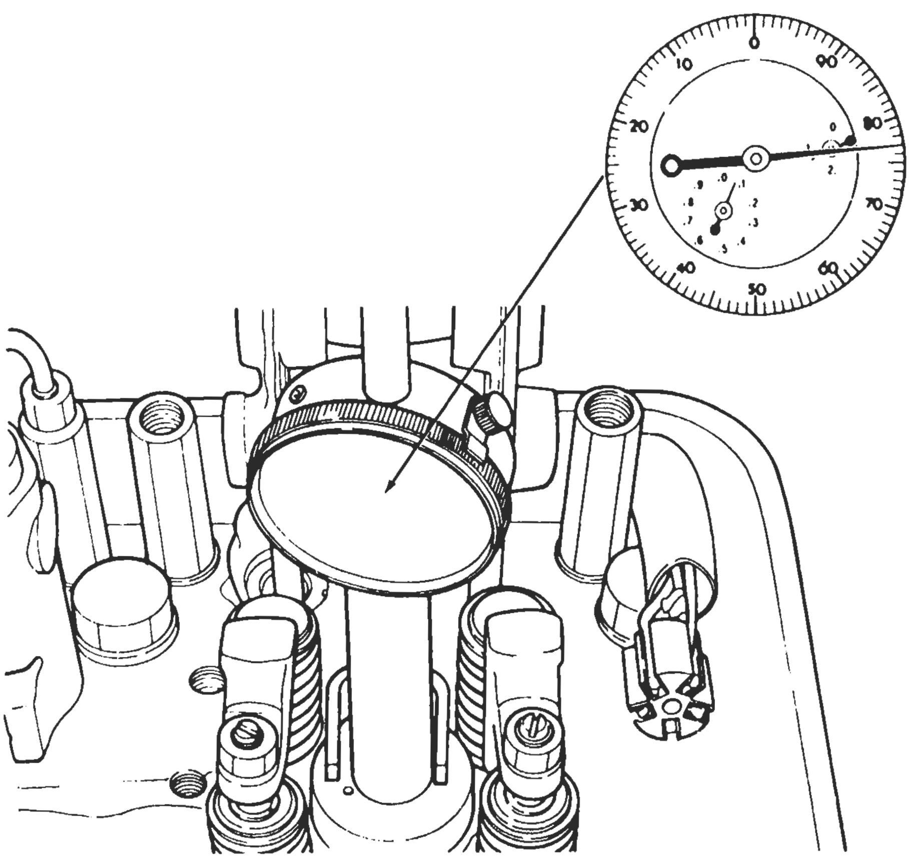


Figure 5. 1.077 Inches Piston Travel

SRS/TRS ADJUSTMENT (CONT.)

To align the sensor bracket:

1. Tap the end of the balance weight with a fiber mallet or rubber hammer to make up the balance shaft end play.
2. Insert the SRS/TRS Timing Tool between the double teeth on the Pulse Wheel, and the TRS so that the groove at the rear of the tool slides over the teeth in the Pulse Wheel (Figure 6.)

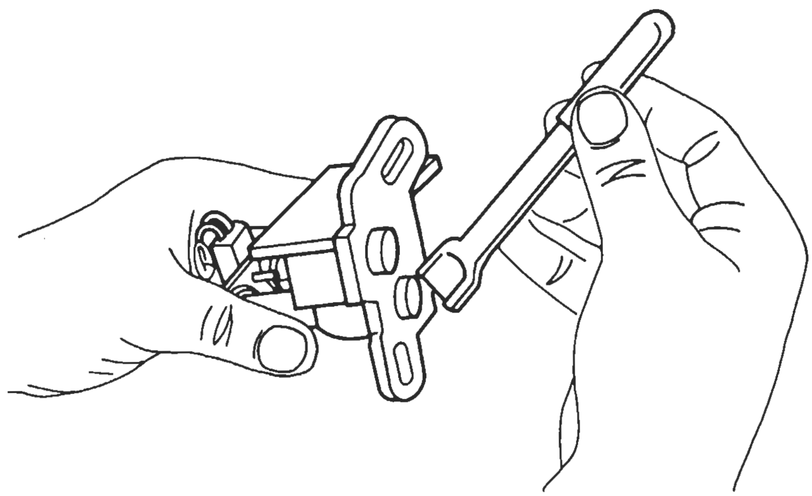


Figure 6. SRS/TRS Timing Tool Insertion

3. This operation is necessary if the sensor bracket has loosened from its original mounting position. If the sensor bracket has not loosened, go to Step 5. Position the SRS/TRS bracket so that the round end of the TRS is located in the half moon position at the front of the Timing Tool (Figure 7.)

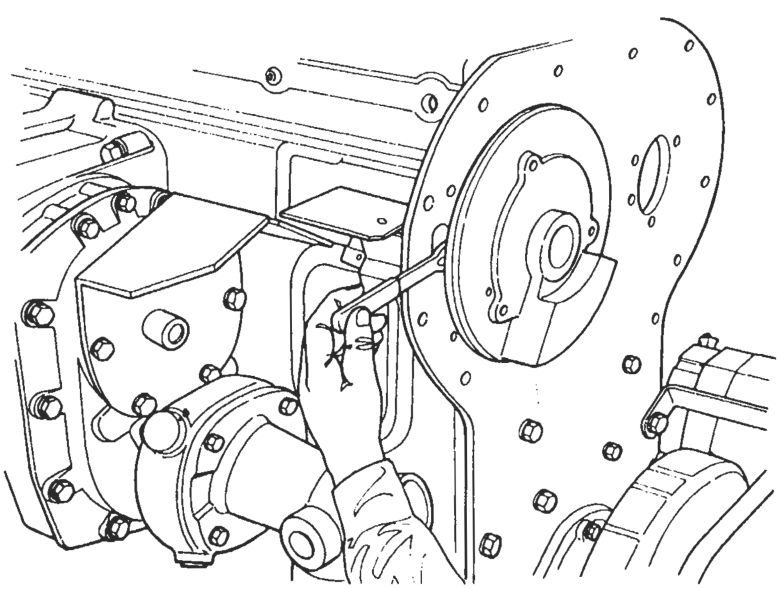


Figure 7. Tightening Sensor Bracket Mounting

SRS/TRS ADJUSTMENT (CONT.)

4. Tighten the two Allen bolts securing the SRS/TRS bracket to the engine front end plate.
5. Push gently on the end of the TRS so that the timing tool is in direct contact with the TRS and the raised metal teeth of the Pulse Wheel (Figure 8.)

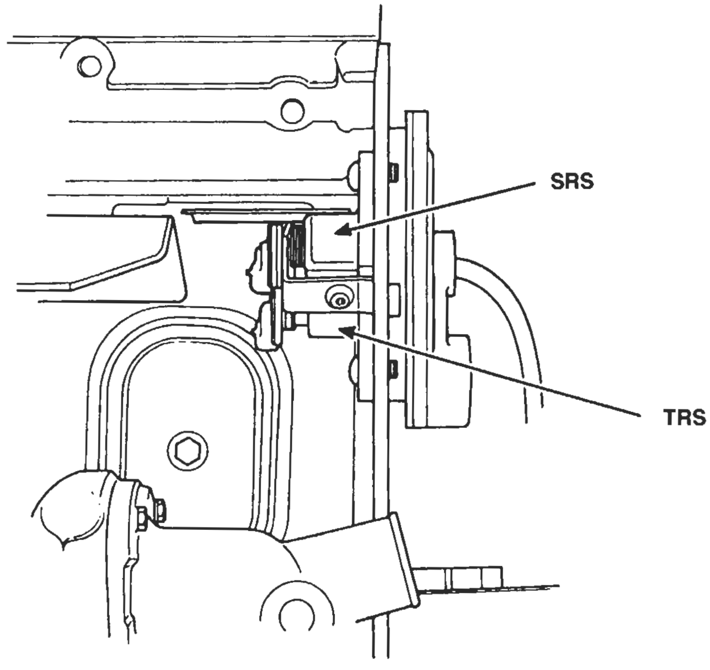


Figure 8. Installing SRS/TRS

6. Tighten the sensor retaining clip socket head screw. If this adjustment has been done correctly, the resulting air gap between the pulse wheel teeth and the end of the sensor will be .020 inches (±.002).
7. Loosen and remove the injector crab hold–down bolt. Remove the injector crab.
8. Install the front cover and related parts using the appropriate sections of this service manual.

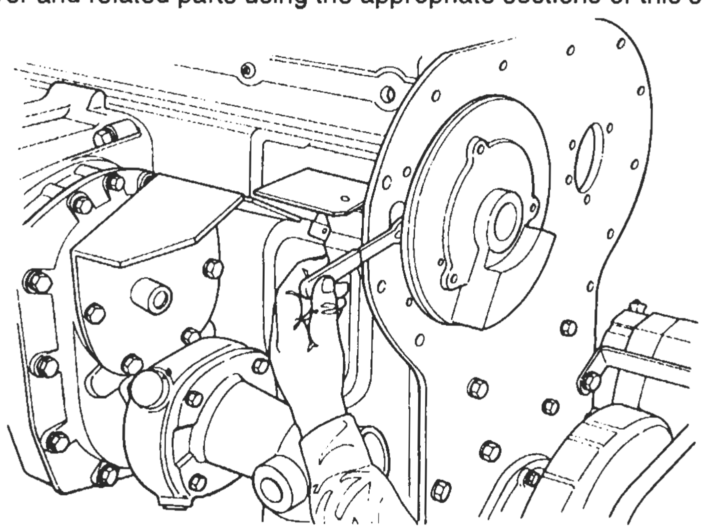


Figure 9. Tightening Sensor Bracket Mounting

CYLINDER BLOCK FRONT END PLATE

DDEC equipped Series 71 engines utilize a new design front end plate that incorporated holes used for mounting the SRS/TRS and bracket assembly (Figure 10.)

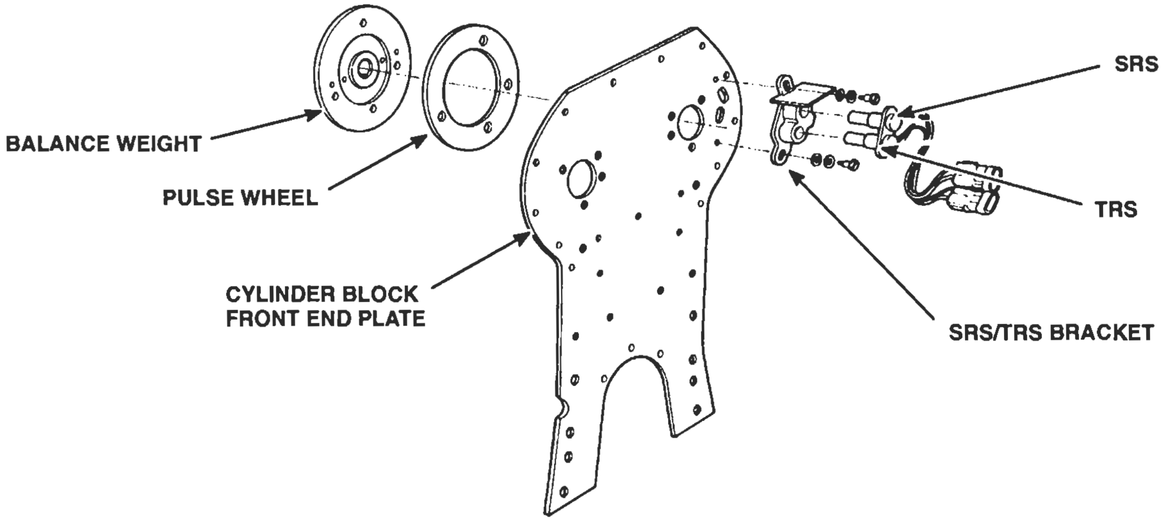


Figure 10. SRS/TRS Cylinder Block Front End Plate

CYLINDER BLOCK FRONT END PLATE REMOVAL

With the exception of sensor mounting bracket, DDEC equipped engine front end plates are removed and replaced in the same manner as mechanically governed engines. Refer to Section 1.1.1 for removal and installation instructions.

PULSE WHEEL

The Pulse Wheel is a metal disc that is mounted to the rear of the right balance weight (Figure 11.)

The raised metal pin generates a signal in the Synchronous Reference Sensor (SRS) and Timing Reference Sensor (TRS). These signals are used by the ECM to locate the piston position for injector solenoid operation.

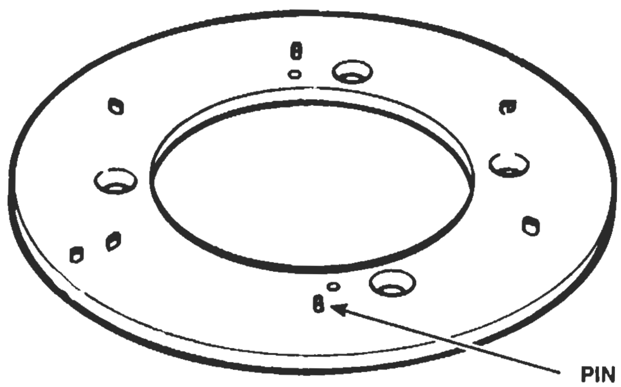


Figure 11. Pulse Wheel

PULSE WHEEL REMOVAL

The replacement of the Pulse Wheel will require adjustment of the Synchronous Reference Sensor (SRS) and Timing Reference Sensor (TRS). Refer to instructions in the SRS/TRS Replacement Section.

Use the following instructions to replace the pulse wheel:

1. Loosen and remove the front cover.
2. Loosen and remove the nut and washer that secures the balance weight to the shaft.
3. Attach puller J24420–A to the pulse wheel.

NOTICE:
Never pry on the pulse wheel to remove it. This may bend the pulse wheel or damage the teeth.

PULSE WHEEL REMOVAL (CONT.)

4. Use adaptor J7932 between the end of the camshaft and the pullet screw to protect the end of the cam (Figure 12.)

NOTE: Be careful not to loose the Woodruff key.

5. Remove the four Allen–type flat head screws that retain the pulse wheel to the balance weight. Remove the pulse wheel.

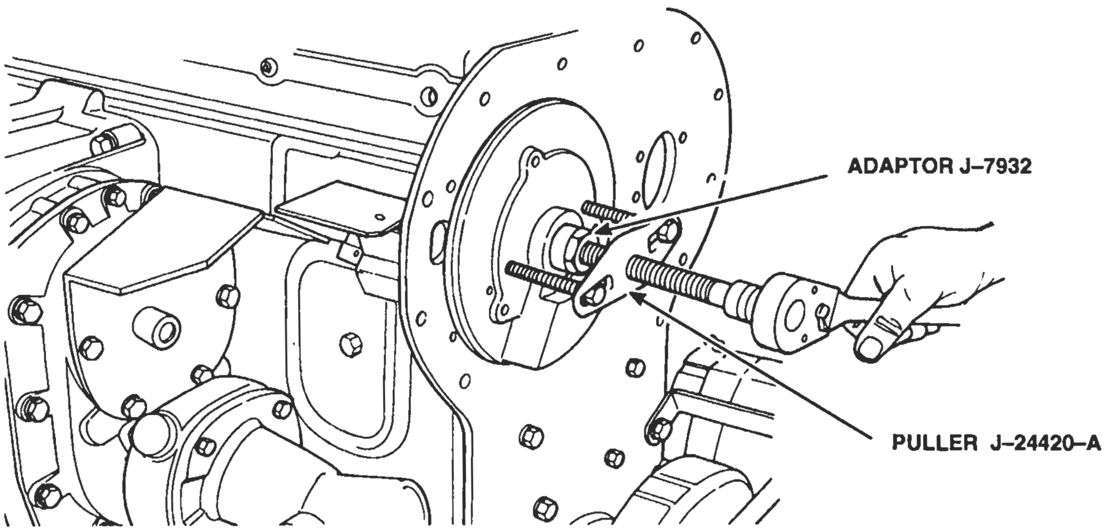


Figure 12. Pulse Wheel Removal

PULSE WHEEL INSTALLATION

1. Locate the two small holes in the pulse wheel over the dowels in the rear of the balance weight.
2. Use Loctite 262, or equivalent, on the four Allen–type flat head screws and secure the pulse wheel to the balance weight.
3. If removed, replace the Woodruff key to the slot in the balance shaft. Index the slot in the balance weight to the Woodruff key and start the wright on the end of the shaft.
4. Use a fiber mallet or plastic hammer to tap the balance weight onto the end of the balance shaft.
5. Install the nut and lockwasher to the end of the balance shaft and tighten to 300–325 lb·ft (407–441 N·m) torque.
6. Adjust the SRS/TRS to the pulse wheel air gap following the instructions in the SRS/TRS Section in the Service manual.
7. Install the front cover.

COOLANT LEVEL SENSOR (CLS)

The Coolant Level Sensor (CLS) is a two piece sensor (Figure 1.) The sensor probe (supplied by the vehicle manufacturer) is mounted in the top tank or overfill tank. The sensor module is mounted on the vehicle. The module sends an electrical signal to the ECM to indicate coolant level. Low coolant will activate the stop engine function or warning function. Both the CLS sensor probe and module are non–serviceable and should be replaced as necessary.

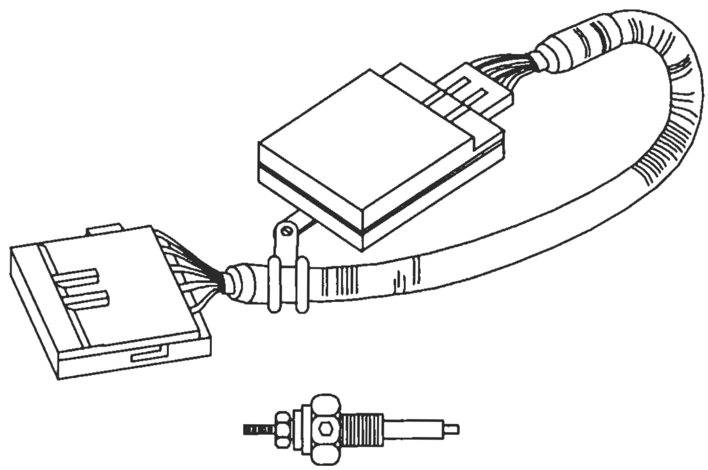


Figure 1. Two Piece Coolant Level Sensor (CLS)

CLS PROBE REMOVAL

1. Open the drain cock at the bottom of the radiator and drain the coolant into an appropriate container. Remove only as much coolant as is necessary to clear the CLS probe.
2. Remove ground wire screw and ground wire from side of probe. Loosen and remove nut from sensor lead of probe. Remove sensor lead.
3. Use the appropriate wrench on the hex portion of the sensor and unscrew it from the radiator.

CLS PROBE INSTALLATION

1. Reverse procedure for installation.
2. Refer to Section 5 and fill the cooling system.
3. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the DDEC Troubleshooting Guide 6SE489.
4. Start the engine and check for leaks.

CLS MODULE REMOVAL

1. Disengage the locking tang on the CLS module connector. Grasp the connector bodies and gently pull them apart.
2. Remove module from vehicle.

CLS MODULE INSTALLATION

1. The CLS module is an electronic component. Use care upon installation.
2. Reverse the removal procedure for installation.

FUEL PRESSURE SENSOR (FPS)

The Fuel Pressure Sensor (FPS) is installed into the secondary fuel filter (Figure 1.) The Fuel Pressure Sensor (FPS) is not used in all applications. The FPS sends an electrical signal to the ECM telling it what the engine fuel pressure is at any given speed.

The FPS is non–serviceable and should be replaced as a unit. No adjustment is required.

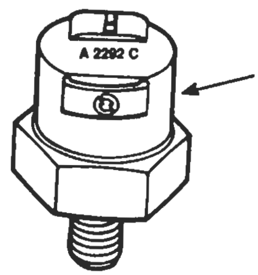


Figure 1. Engine Fuel Pressure Sensor

FPS REMOVAL

1. Disengage the locking tang on the three–wire connector. Grasp the body of the connector and gently pull it free of the FPS.
2. Use the appropriate wrench on the hex end of the FPS to unscrew it from the filter.

FPS INSTALLATION

1. The FPS is an electronic device. Use care on installation.
2. Reverse the removal procedure for installation.
3. Use Loctite Pipe Sealant with Teflon J–26558–92 (or equivalent) on all but the first two threads of the FPS to prevent leaks.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 is obtained, refer to the DDEC Troubleshooting Guide, 6SE489.

FUEL TEMPERATURE SENSOR (FTS)

The Fuel Pressure Sensor (FPS) is installed into the secondary fuel filter (Figure 1.) The FPS sends an electrical signal to the ECM telling it what the engine fuel pressure is at any given speed.

The FPS is non–serviceable and should be replaced as a unit. No adjustment is required.

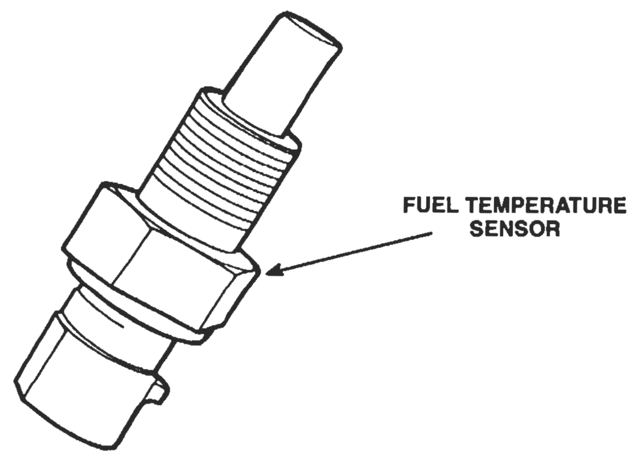


Figure 1. Engine Fuel Temperature Sensor

FTS REMOVAL

1. Disengage the locking tang on the three–wire connector. Grasp the body of the connector and gently pull it free of the FPS.
2. Use the appropriate wrench on the hex end of the FPS to unscrew it from the filter.

FTS INSTALLATION

1. The FPS is an electronic device. Use care on installation.
2. Reverse the removal procedure for installation.
3. Use Loctite Pipe Sealant with Teflon J–26558–92 (or equivalent) on all but the first two threads of the FPS to prevent leaks.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 is obtained, refer to the DDEC Troubleshooting Guide, 6SE489.

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 the upper blower rotor. The following types of mechanical governors are used:

1. Limiting Speed Mechanical Governor.
2. Variable Speed Mechanical Governor.
3. Constant 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.

Constant speed mechanical governors are used on engines which require a constant speed of predetermined value. There is no intermediate or manually controlled range between high and low engine speeds. The only requirement is to control the idle speed and maintain a constant operating speed.

Each type of governor has an identification plate located on the control housing, containing the governor assembly number, type, idle speed range and manufactured date. The maximum engine speed, not shown on the identification plate, is stamped on the option plate attached to the valve rocker cover.

CHECK GOVERNOR OPERATION

Governor difficulties are usually indicated by speed variations of the engine; however, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, check the engine as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.
2. Check the engine to be sure that all of the cylinders are firing properly (refer to Section 15.2). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in Section 2.1 or 2.1.1.
3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

CHECK GOVERNOR OPERATION (CONT.)

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

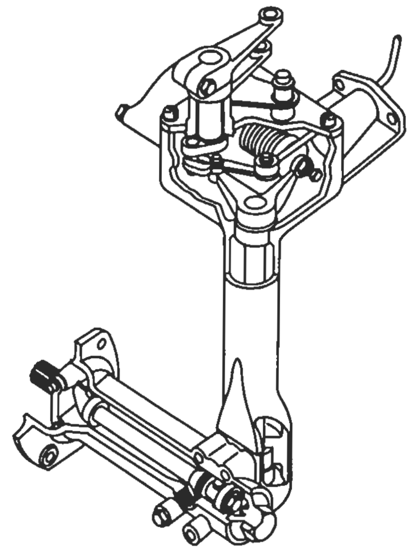
1. If an injector rack sticks or moves too hard, it may be due to the injector hold–down clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20–25 lb·ft (27–34 N·m) torque.
2. An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in Section 2.1 or 2.1.1.
3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in Section 14.
4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no–fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in Section 14.
5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.
6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

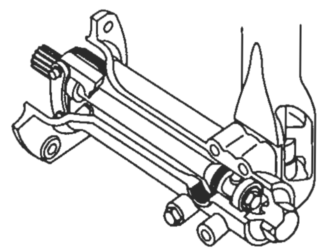
LIMITING SPEED MECHANICAL GOVERNOR

The limiting–speed mechanical governor (Figure 1.) may be either a single weight or a double weight–type governor and it performs the following functions:

1. Controls the engine idling speed.
2. Limits the maximum operating speed of the engine.



SINGLE WEIGHT GOVERNOR



DOUBLE WEIGHT GOVERNOR

Figure 1. Limiting Speed Mechanical Governor

The governor is mounted on the front end of the blower and is driven by the upper blower rotor. The governor consists of three subassemblies:

1. Control Housing Cover.
2. Control Housing.
3. Weights and Housing.

The governor provides full fuel 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.

Governors dated March, 1975 or later in turbocharged engines include a starting aid screw threaded into the governor housing. Only the governor housing with the external starting aid screw is serviced. If the starting aid screw is not required, back it out as far as possible to make it ineffective.

A tamper–resistant single weight limiting–speed governor is provided for highway vehicle engines (refer to Section 2.0).

SECTION 2.7.1 – LIMITING SPEED MECHANICAL GOVERNOR

OPERATION (SINGLE WEIGHT GOVERNOR)

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of 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 determined 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.

OPERATION (DOUBLE WEIGHT GOVERNOR)

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and operating shaft to the operating shaft lever. One end of 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 of the low speed weights operates against the low speed spring. As the engine speed increases, the centrifugal force of the low speed weights compresses the low speed spring until the weights are against their stops, thus limiting their travel, at which time the low speed spring is fully compressed and the low speed cap is against the high speed 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.

A fuel rod, connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

OPERATION (DOUBLE WEIGHT GOVERNOR) (CONT.)

The engine idle speed is determined by the centrifugal force of the low speed weights required to balance out tension on the low speed spring.

Adjustment of the engine idle speed is accomplished by changing the tension on the low speed spring by means of the idle adjusting set screw. Refer to Section 14.3 for the idle speed adjustment.

The maximum no–load speed is determined by the centrifugal force of the high speed weights 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

Surplus oil returning from the cylinder head provides lubrication for the parts in the governor control housing, the riser thrust bearings, and the weight shaft end bearing. Oil picked up from a reservoir in the blower front end plate by a slinger attached to the lower rotor shaft, provides lubrication for the governor weights and weight carrier.

Pressure lubrication has been provided for the weight housing bearings on the current engines. The oil tube is attached between the oil gallery in the cylinder block and the governor weight housing.

REMOVE GOVERNOR FROM ENGINE

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If after performing these checks the governor fails to control the engine properly, it should be removed and reconditioned.

1. Disconnect the linkage attached to the governor control levers (Figure 2.)
2. Remove the breather tube.
3. Remove four screws and lock washers and lift the governor cover and gasket from the governor housing.
4. Disconnect the fuel rod from the differential lever and the injector control tube lever.
5. Disconnect the oil tube at the governor weight housing or cover and remove the cover, if used.
6. Remove the two governor–to–cylinder head bolts.
7. Remove the control housing from the cylinder head and weight housing.
8. Use tool J 4242 to remove the six governor weight housing–to–blower bolts, then withdraw the housing from the blower.

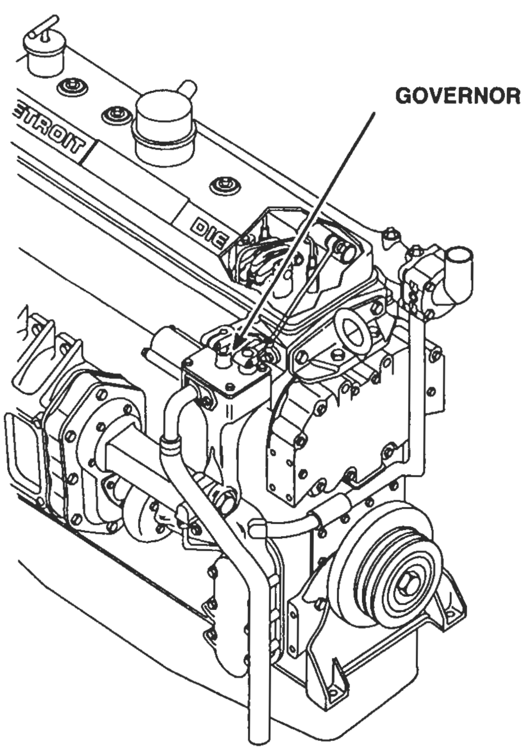


Figure 2. Typical Limiting Speed Governor Mounting

DISASSEMBLE GOVERNOR

1. Disassemble the governor cover:

   a. Remove the plug from the throttle shaft (Figure 3.)

   b. Loosen the speed control lever bolt, and lift the speed control lever from the throttle shaft.

   c. Remove the tapered pin from the shutdown lever. Lift the lever and the seal ring retainer from the throttle shaft. Withdraw the throttle shaft from the cover.

   d. Remove the cam retainer and plain washer from the cam pin. Lift the cam and the stop lever, if used, off the pin.

   e. Remove the seal ring from the governor cover.

   f. Wash the cover assembly (containing needle 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.

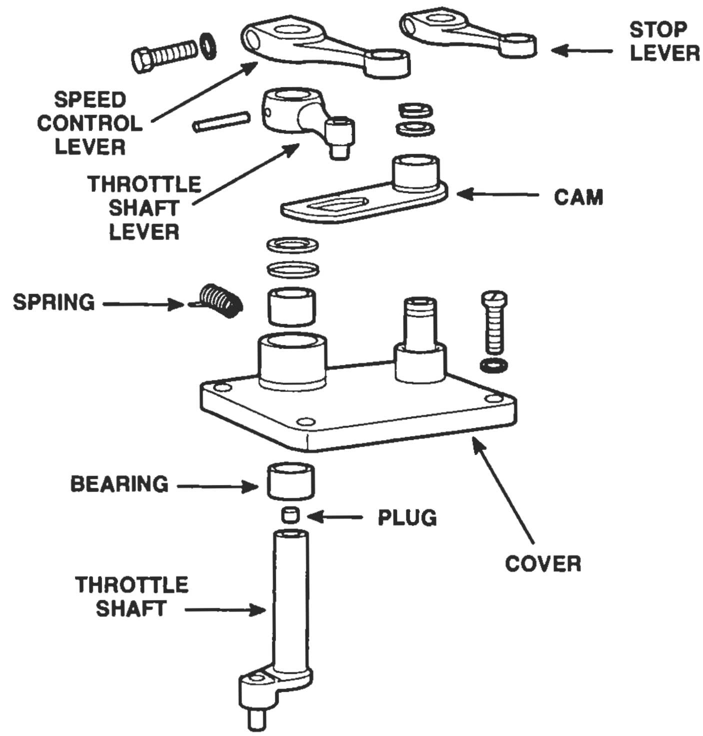


Figure 3. Governor Cover and Components

   g. If needle bearing removal is necessary, place the inner face of the cover over the opening in the bed of the press. Place remover J 21967–01 on top of the bearing and press both bearings out of the cover (Figure 4.)

2. Disassemble the governor control housing (single and double weight governors):

   a. Place the control housing in a soft–jawed vise.

   b. Remove two bolts and withdraw the high speed spring retainer cover.

   c. Loosen the lock nut with tool J 5345–5. Remove the high speed spring retainer, idle adjusting set screw, high speed spring, spring plunger, low speed spring, spring seat, and spring cap as an assembly.

   d. Remove the spring retainer and washer, then lift the differential lever from the pin of the operating shaft lever.

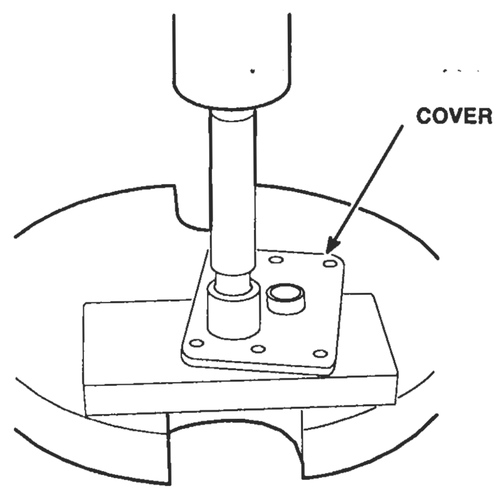


Figure 4. Needle Bearing Removal from Governor Cover

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DISASSEMBLE GOVERNOR (CONT.)

e. Remove the expansion plug (Figure 5.) out of the lower end of the control housing.

f. Remove the bearing retaining screw, flat washer, and lock washer.

g. Loosen the operating fork set screw, if used.

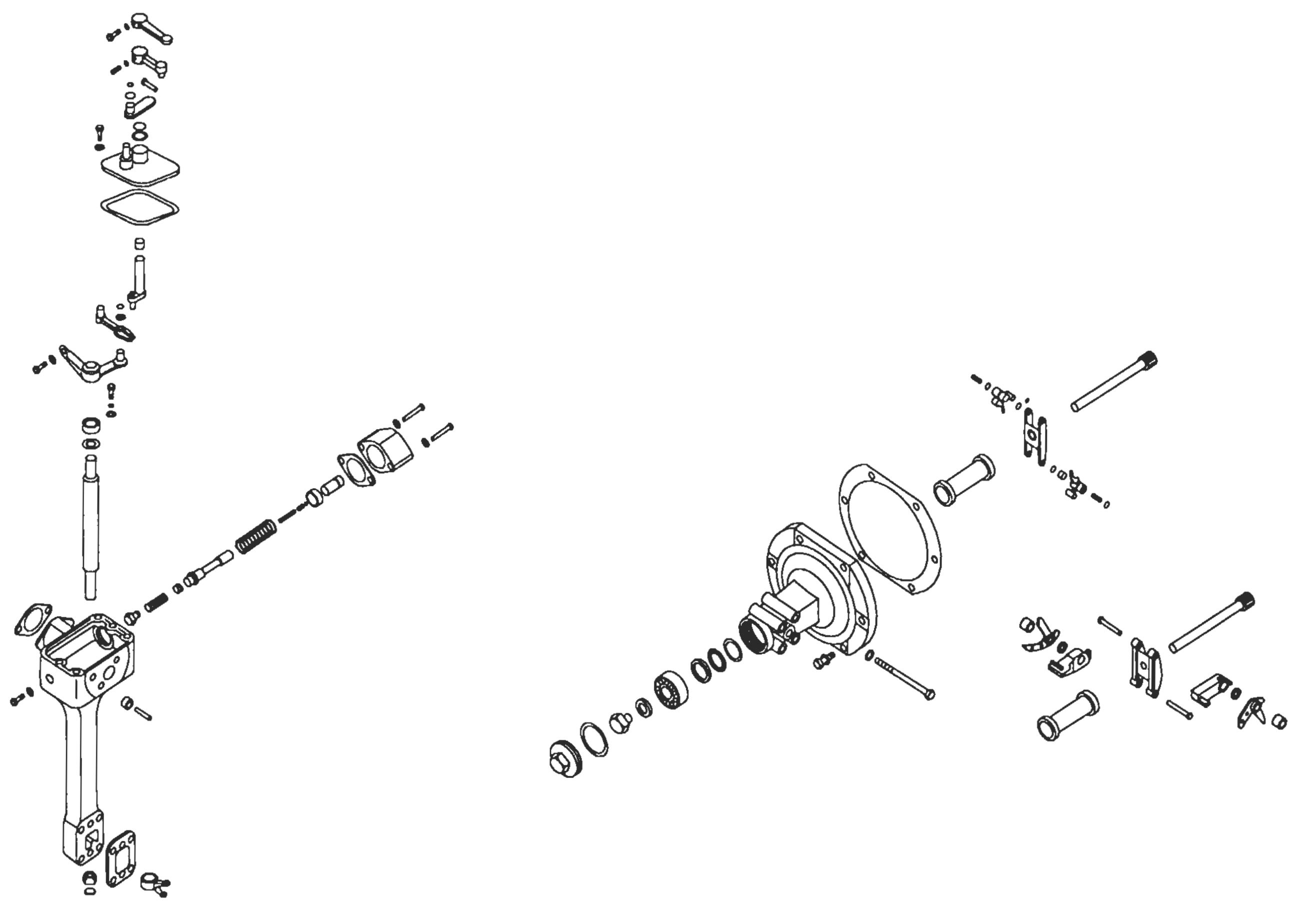

Figure 5. Limiting Speed Governor Components

DISASSEMBLE GOVERNOR (CONT.)

h. Support the control housing (Figure 6.) Press the operating shaft from the operating fork using a brass rod. Withdraw the operating shaft, operating lever, and bearing as an assembly from the control housing.

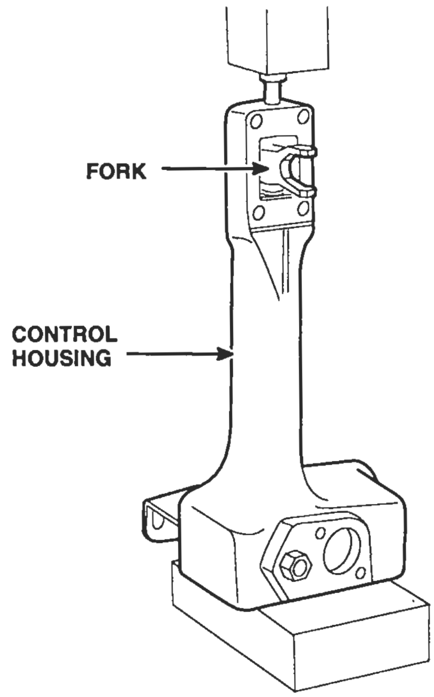

Figure 6. Operating Fork Removal from Operating Shaft

i. Support the operating shaft and lever on the bed of the press (Figure 7.) Press the shaft from the operating lever and bearing with a brass rod.

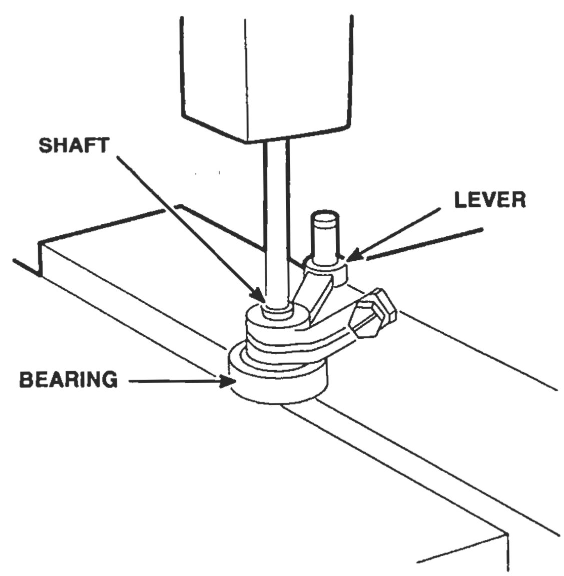

Figure 7. Operating Shaft Removal from Operating Lever

DISASSEMBLE GOVERNOR (CONT.)

3. Disassemble the governor weight housing:
   a. Place the weight housing in a soft–jawed vise. Remove the plug and gasket.
   b. Straighten the tang of the lock washer and remove the bearing retaining bolt.
   c. Thread a 5/16–24 x 3 inch bolt into the tapped end of the weight shaft. Support the weight housing on the bed of the press (Figure 8.) and press the shaft from the bearing.
   d. Slide the riser thrust bearing and governor riser from the shaft.

This bearing is specially designed to absorb thrust loads; therefore looseness between the mating parts does not indicate excessive wear.

   e. Remove the bearing from the weight housing.

NOTE: The weight shaft end bearing should be discarded on removal as it becomes brinnelled during the disassembly process.

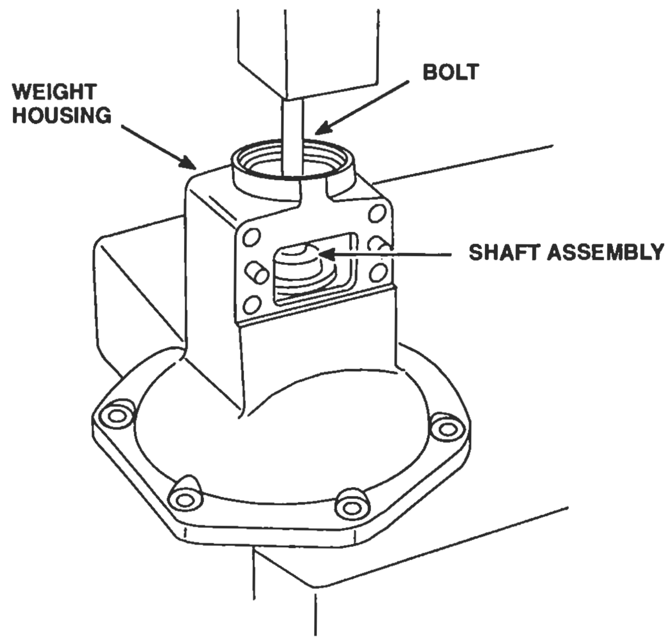

Figure 8. Removing Governor Weight and Shaft Assembly

   f. Mark the weights and carrier with a center punch for identification. Also note position of the thin washers between the weights so that the parts can be replaced in their original position.
   g. If removal of the weights from the carrier is necessary on the current double weight governors, refer to (Figure 9.) and remove the retainers from the weight pin. Press the pin from the low speed weights. The high speed weight is not a press fit.

Remove the second pair of weights in the carrier in the same manner as described above.

NOTE: If necessary the needle bearing in the high speed weights may be removed at this time.

   h. If required, the weight carrier may be pressed from the governor weight shaft and a new carrier installed.

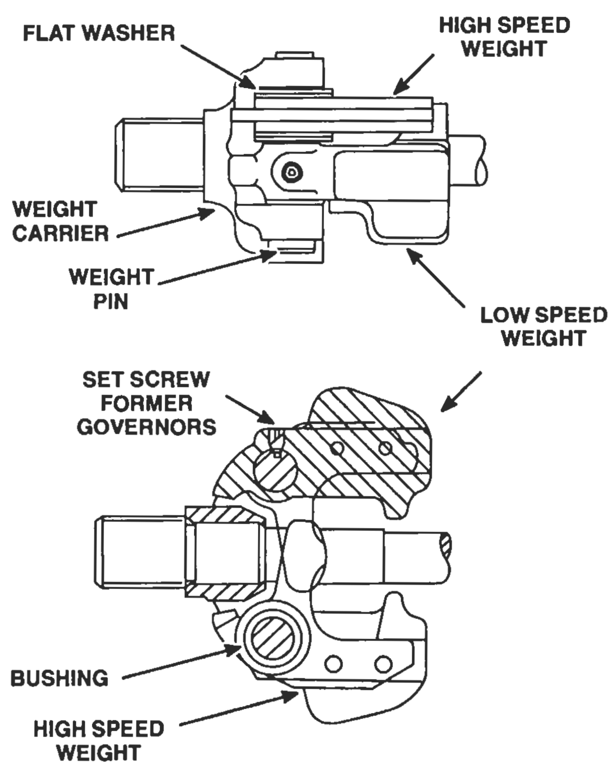

Figure 9. Cross Section of Double Weight Governor

INSPECTION

Clean all the parts with fuel oil, and dry them with compressed air.

Revolve the ball bearings slowly by hand. Replace bearings which indicate rough or tight spots. Also replace bearings which are corroded or pitted.

Examine the riser thrust bearings for excessive wear, flat spots, or corrosion. If any of these conditions exist, install a new riser and bearing assembly.

Inspect the weight carriers, weights and retaining pins for wear.

Inspect the bushings in current weights and replace if worn excessively. In former weights inspect the needle bearings for wear and replace if necessary.

Inspect the operating shaft and bushing for excessive wear. If excessive wear is noted, a new bushing and shaft must be installed.

ASSEMBLE GOVERNOR COVER

1. If the needle bearings were removed from the governor cover, place the governor cover on the bed of an arbor press with the inner face of the cover down. Start the upper bearing straight into the bearing bore of the cover with the number on the bearing up. Insert the bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Figure 10.)
2. Turn the cover over and start the second bearing, number side up, in the bearing bore. Press the bearing in flush with the cover with tool J 21068.

NOTE: Do not use impact tools to install needle bearings.

1. Apply lubricant to the retaining pin and place the cam over the pin with the boss of the cam up. Install the stop lever, if used.
2. Place the washer over the pin and secure it with the spring retainer.
3. Install the plug in the throttle shaft.
4. Pack the needle bearings with grease. Then slide the throttle shaft assembly through the bearings.
5. Insert the seal ring over the shaft and into the counterbore against the upper bearing. Place the retainer over the shaft and against the seal ring.
6. Start the throttle shaft lever over the throttle shaft with the holes in the lever and shaft for tapered pin in alignment.

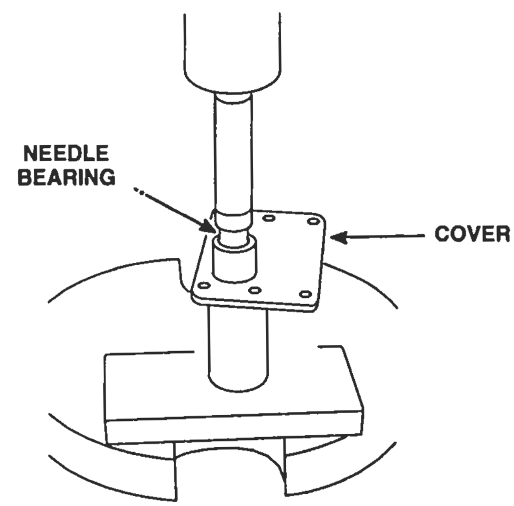

Figure 10. Installing Needle Bearings on Governor Covers

ASSEMBLE GOVERNOR COVER (CONT.)

7. Support the lower end of the throttle shaft on the bed of an arbor press, then place a sleeve on the throttle lever and align the slot in the cam with the pin in the throttle lever. Press the lever down on the shaft until the hole in the lever is in line with the hole in the shaft.
8. Insert the tapered pin in the hole of the lever, then support the lever and cover assembly on a steel block and drive the pin into place.
9. Position the speed control lever on the throttle shaft and tighten the retaining bolt.
10. Attach one end of the spring in the small hole of the cam.

ASSEMBLE GOVERNOR CONTROL HOUSING

1. Place the washer over the short finished end of the operating shaft. Start the bearing over the end of the shaft. Support the opposite end of the shaft on the bed of a press. Press the bearing on the shaft tight against the washer with a sleeve which has the same diameter as the bearing inner race.
2. With the pivot pin in the operating lever up, start the lever over the end of the shaft with the flat on the shaft registering with the flat surface in the lever. Press the lever on the shaft tight against the bearing.
3. Lubricate the bearing and operating shaft bushing in the housing with clean engine oil. Insert the lever and operating shaft assembly in the control housing.
4. Position the operating fork over the lower end of the operating shaft so the finished side of the fork finger will rest against the thrust bearing when assembled.
5. Support the operating shaft and control housing in an arbor press with the upper end of the operating shaft resting on a steel block. Align the flat in the operating fork with the flat on the operating shaft, then place a sleeve over the end of the shaft and rest it on the fork. Bring the ram of the press down on the sleeve and press the fork straight down and tight against the shoulder on the shaft.
6. Tighten the fork set screw, if used.
7. Apply a good quality sealant around the periphery of the expansion plug and press the plug into the lower end of the control housing.
8. Place a lock washer and flat washer over the retaining screw. Thread the screw in the control housing to secure the operating shaft bearing.
9. Place the differential lever over the pivot pin of the operating lever. Install a plain washer and spring retainer.

ASSEMBLE GOVERNOR SPRINGS, PLUNGERS, AND ADJUSTING SCREWS

1. Thread the locknut on the buffer screw and thread the buffer screw into the control housing.
2. Thread the locknut on the high speed spring retainer approximately 1 1/2 inch. Place the high speed spring over the high speed spring plunger with the close wound coils inside of the spring retainer.
3. Insert the plunger and spring assembly in the high speed spring retainer. Thread the set screw approximately 1.00 inch into the tapped end of the plunger. Thread the locknut over the set screw.
4. Insert the low speed spring in the low speed spring cap and the small end of the spring seat in the opposite end of the low speed spring.
5. Insert the low speed spring seat and low speed spring and cap assembly in the high speed spring plunger with the spring seat against the shoulder of the set screw.
6. Start the governor high speed spring assembly into the opening of the control housing and thread the high speed spring retainer in the housing approximately 1.00 inch.
7. Installation of the high speed spring retainer cover is not required until after the governor has been installed on the engine and the tune–up procedures outlined in Section 14 have been completed.

ASSEMBLE GOVERNOR WEIGHT HOUSING

1. Assemble the weights.

Single Weight Governor:

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.

g. If removed, install the starting aid screw.

Double Weight Governor:

a. With current governors, 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.

b. 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 inch with the weight pressed in position.

NOTE: To maintain this clearance insert a .004–.012 inch shim between the low speed weight and carrier while pressing the pin into position.

ASSEMBLE GOVERNOR WEIGHT HOUSING (CONT.)

c. Remove the shim and install the second weight pin retainer.

d. Install the second pair of weights in the carrier in the same manner as described above.

NOTE: Before applying the sealant to a new set screw immerse the set screw in Loctite Primer T or equivalent.

2. Assemble the weight shaft and carrier assembly:

   a. Slide the riser over the weight shaft and against the finished surfaces of the governor weights.

   b. Assemble the riser thrust bearing on the weight shaft with the bearing race with the smallest inside diameter against the thrust riser. Incorrect installation of the bearing will result in erratic operation of the governor.

   c. Insert the weight carrier and shaft assembly in the weight housing.

   d. Support the splined end of the shaft on the bed of an arbor press. Start the shaft end bearing in the housing and over the end of the shaft with the numbered side of the bearing facing away from the shaft. Press the new bearing in place using a 1 3/8 inch diameter metal bar flat on the ends which bear against both the inner and outer races of the bearing.

NOTICE:

The former bearing had thrust capacity in one direction only. Be sure to install the former bearing so that the thrust shoulder is toward the governor weights. Otherwise, the force exerted by the weights will pull the inner race and ball assembly away from the outer race and result in damage to the bearing and erratic governor operation.

   e. Place the washer over the bearing retaining bolt. Thread the bolt into the tapped end of the shaft and tighten it. Bend the tang on the washer against the head of the bolt.

   f. 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 with either the flat or point of the head on a horizontal line.

INSTALL GOVERNOR

1. Affix a new gasket to the governor weight housing. Start the splined end of the weight shaft in the upper blower rotor and position the housing against the blower end plate.
2. Place a new copper gasket on each weight housing–to–blower bolt and thread the bolts into the blower end plate, finger tight only.
3. Place a new gasket over the dowels and against the side of the weight housing facing the engine.

NOTE: Check the dowel pins for excessive protrusion. The specified protrusion is 3/32 inch.

4. Move the thrust bearing assembly and riser toward the weight end of the shaft.
5. Position the lower end of the control housing over the dowel pins in the weight housing.

ASSEMBLE GOVERNOR WEIGHT HOUSING (CONT.)

The finished surface of the operating fork must be placed against the outer side of the thrust bearing.

NOTICE:

For ease in assembling the governor control housing (four or six cylinder engine) to the interim weight housing (no identification mark) (Figure 11.) Install a special bolt (3/8–24 x 3/4 or 7/8 inch) from which the outer 1/2 of thread down to a diameter of 5/16 to 1/4 inch has been removed, as a tool in the 1/8 NPTF oil hole to prevent the thrust bearing from moving too far forward in the weight housing. The current weight housing has two ribs cast on the inner surface of the housing to prevent any part of the riser thrust bearing from sliding forward to where the operating fork could be inserted on the wrong side of one or more parts of the bearing.

6. Affix a new gasket to the governor control housing, then attach the governor control housing to the cylinder head with two bolts. Tighten the bolts.
7. Tighten the governor–to–blower bolts with wrench J 4242.
8. Affix a new gasket to the weight housing cover (former governors only) and place the cover in position. Install the four weight housing–to–control housing bolts with lockwashers and tighten the bolts.
9. Connect the oil tube to the restricted fitting on the weight housing or cover (if used).
10. Position the fuel rod over the differential lever pin. Place a flat washer over the pin and secure it with the retainer.
11. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.
12. Place a new gasket on the governor control housing and mount the governor cover on the housing with the pin on the throttle shaft registering with the machined slot in the differential lever.
13. Install the four cover screws with lock washers. Connect one end of the cam spring to one of the cover screws.

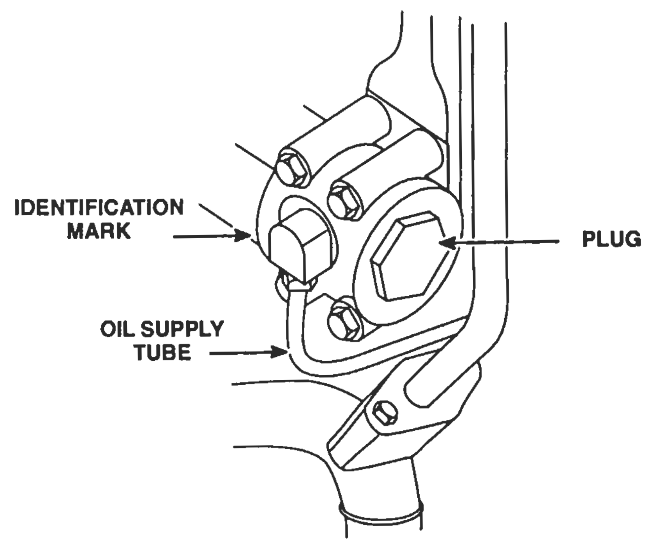

Figure 11. Governor Weight Housing Current Four and Six Cylinder Engines

ASSEMBLE GOVERNOR WEIGHT HOUSING (CONT.)

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 over–speeding engine can result in engine damage which could cause personal injury.

14. Connect the throttle linkage.
15. Attach the breather tube to the governor housing.
16. Perform the engine tune–up as outlined in Section 14.3.

LIMITING SPEED MECHANICAL GOVERNOR (DUAL HIGH SPEED RANGE)

The limiting–speed mechanical double weight dual high–speed range governor is similar to the limiting speed–governor shown in Figure 1. in Section 2.7.1 except the spring and piston assemblies.

The dual range governor is used on highway vehicle engines that require a high maximum speed part of the time and a low maximum speed the remainder of the time.

Due to the governors dual speed feature, it permits a high engine speed in the lower gear ratios for maximum vehicle acceleration while providing a conservative vehicle speed in the high gears. The valve for controlling the high and low speed ranges of the governor is usually connected to the transmission. Shifting the transmission from a lower gear to a high gear will automatically shift the governor from its high maximum speed range to the low maximum speed range.

This two speed operation is accomplished by the use of air pressure behind a piston (Figure 1.) to increase the tension (Figure 2.) on the governor high speed spring. 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.

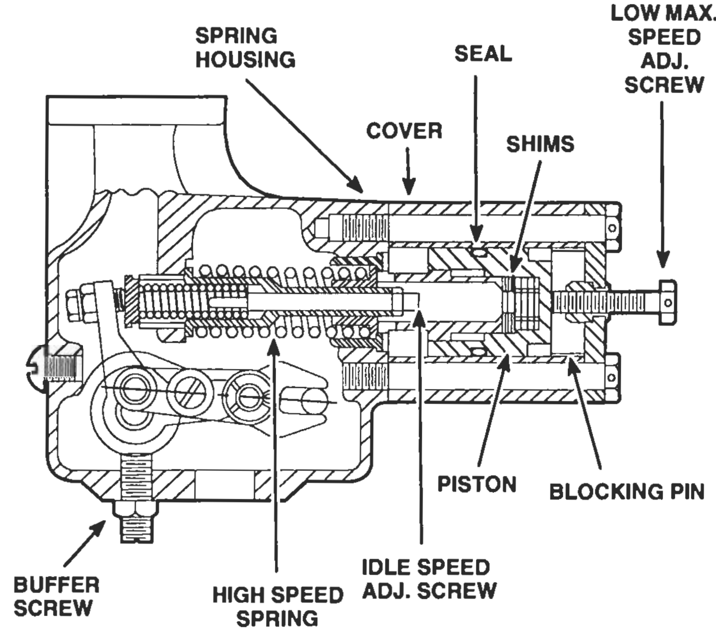

Figure 1. Spring and Piston Assembly of Current Dual Range Governor

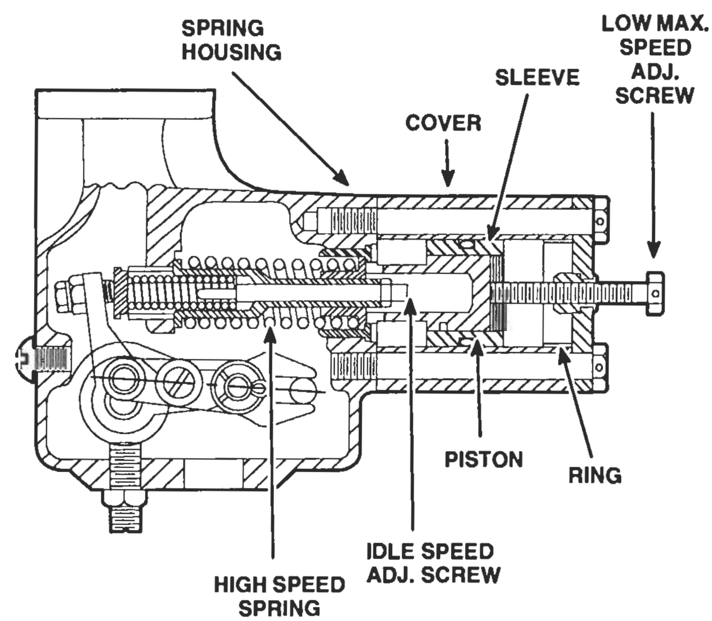

Figure 2. Spring and Piston Assembly of Former Dual Range Governor

SECTION 2.7.1.2 – LIMITING SPEED GOVERNOR

LUBRICATION

Surplus oil returning from the cylinder head provides lubrication for the parts in the governor control housing, the riser thrust bearings and the weight shaft end bearing. Oil picked up from a reservoir in the blower front end plate by a slinger attached to the lower rotor shaft provides lubrication for the governor weights and weight carrier.

Pressure lubrication has been provided for the weight housing bearings on current engines. The oil tube is attached between the oil gallery in the cylinder block and the weight housing.

REMOVE GOVERNOR FROM ENGINE

Governor operation should be checked as outlined in Section 2.7 before the governor is removed from the engine. If after performing these checks the governor fails to control the engine properly, it should be removed and reconditioned.

1. Disconnect the linkage (Figure 3.) attached to the governor levers.
2. Remove the breather tube.
3. Remove four screws and lock washers and lift the governor cover and gasket from the control housing. Discard the gasket.
4. Disconnect the fuel rod from the differential lever and the injector control tube lever.
5. Disconnect the oil tube at the governor weight housing, or cover and remove the cover, if used.
6. Remove both governor–to–cylinder head bolts.
7. Remove the governor control housing from the cylinder head and governor weight housing.
8. Remove six weight housing–to–blower bolts, using wrench J 4242, and withdraw the housing from the blower.

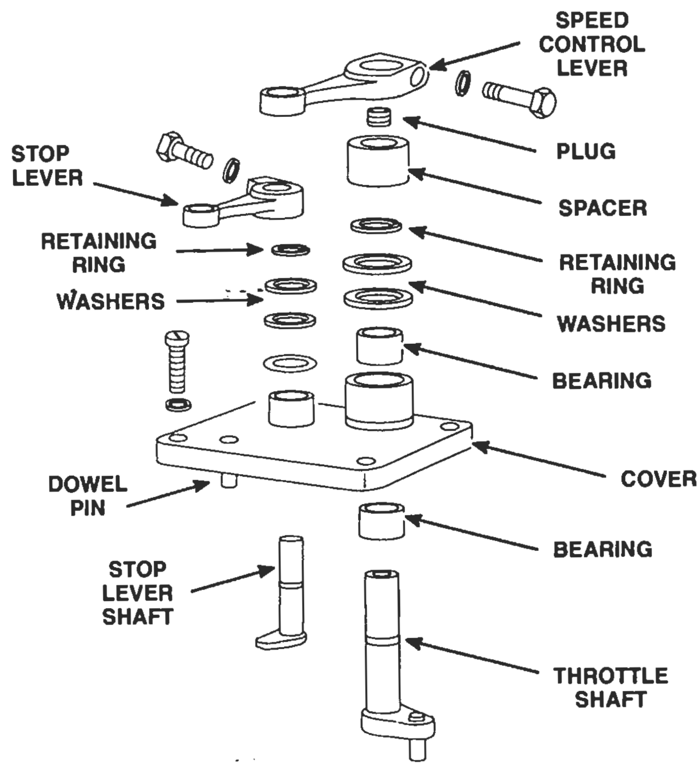

Figure 3. Exploded View of Governor Cover

DISASSEMBLE GOVERNOR COVER

1. Loosen the lever bolts and remove the speed control lever and stop lever from their respective shafts.
2. Remove the plug from the throttle shaft.
3. Remove the seal retaining ring and spacers from the stop lever shaft and withdraw the shaft from the cover.
4. Remove the seal ring from the governor cover.
5. Remove the spacer (if used), the retaining ring and washers from the throttle shaft and withdraw the shaft from the cover.
6. Wash the cover assembly thoroughly in clean fuel oil and inspect the needle bearings for wear or damage. If bearing removal is necessary, place the inner face of the cover over the opening in the bed of the press. Place remover tool J 21967–01 on top of the bearing (Figure 4.) and press both bearings out of the cover.

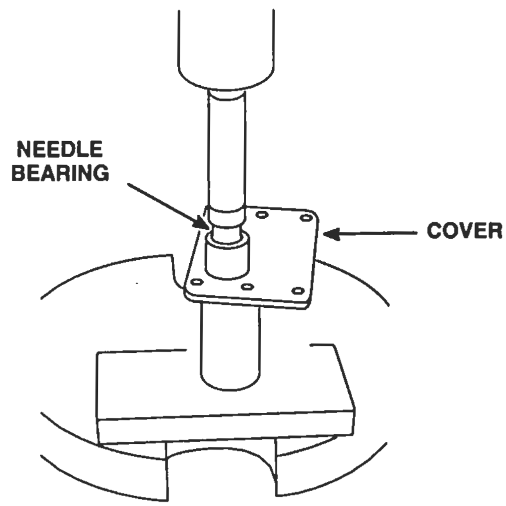

Figure 4. Needle Bearing Removal from Governor Cover

DISASSEMBLE GOVERNOR CONTROL HOUSING

1. Remove the two bolts securing the spring housing cover and withdraw the cover, piston, sleeve and low maximum speed adjustment screw as an assembly.

NOTICE:
The governor has 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.

2. Remove the spring retainer and washer, then lift the differential lever from the pin of the operating shaft lever
3. Remove the expansion plug from the lower end of the control housing.
4. Remove the bearing retaining screw, washer and lock washer.
5. Loosen the operating fork set screw, if used.
6. Support the control housing as shown in Figure 6 in Section 2.7.1. Press the operating shaft from the operating fork with a brass rod. Withdraw the shaft, lever and bearing as an assembly from the control housing.
7. Support the operating shaft and lever on the bed of the press (Figure 7 in Section 2.7.1). Press the shaft from the operating lever and bearing with a brass rod.

DISASSEMBLE GOVERNOR WEIGHT HOUSING

1. Place the weight housing in a soft jawed vise. Remove the plug and gasket (Figure 5.)
2. Straighten the tang on the lock washer and remove the bearing retaining bolt.
3. Thread a 5/16–24 x 3 inch bolt into the tapped end of the weight shaft. Support the weight housing on the bed of the press as shown in Figure 8 in Section 2.7.1. Press the shaft from the bearing.
4. Slide the riser thrust bearing and governor riser from the shaft.

NOTE: This bearing is specially designed to absorb thrust loads; therefore, looseness between the mating parts does not indicate excessive wear.

5. Remove the bearing from the weight housing.

NOTE: The weight shaft end bearing should be discarded on removal as it becomes brinnelled during the disassembly process.

6. Mark the weights and carrier with a center punch for identification. Also note the position of the thin washer between the weights so that the parts can be replaced in their original position.

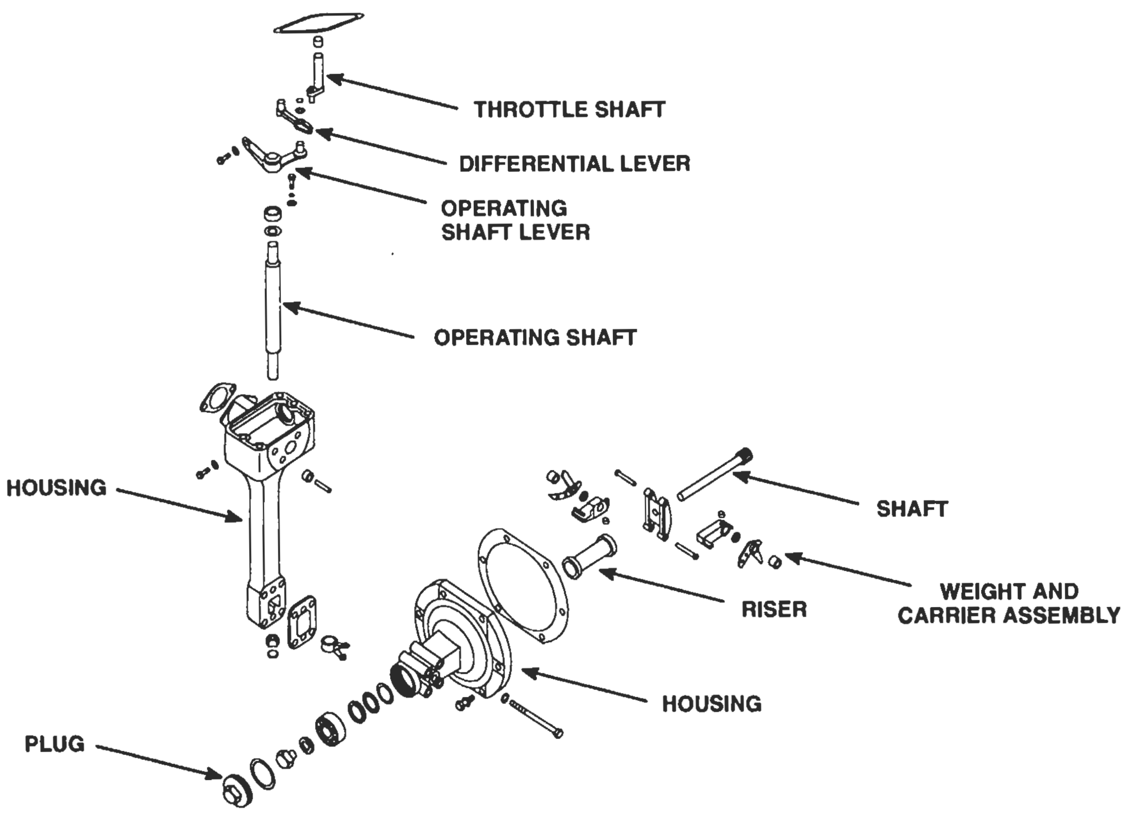

Figure 5. Exploded View of Governor Control and Weight Housing

DISASSEMBLE GOVERNOR WEIGHT HOUSING (CONT.)

7. If removal of the weights from the carrier is necessary on the double weight governor, (Figure 6.) remove the retainer from the weight pin. Press the pin from the low speed weights. The high speed weight is not a press fit.

NOTE: If necessary the needle bearing assembly in the high speed weights may be removed at this time.

8. If required, the weight carrier may be pressed from the governor weight shaft and a new carrier installed.

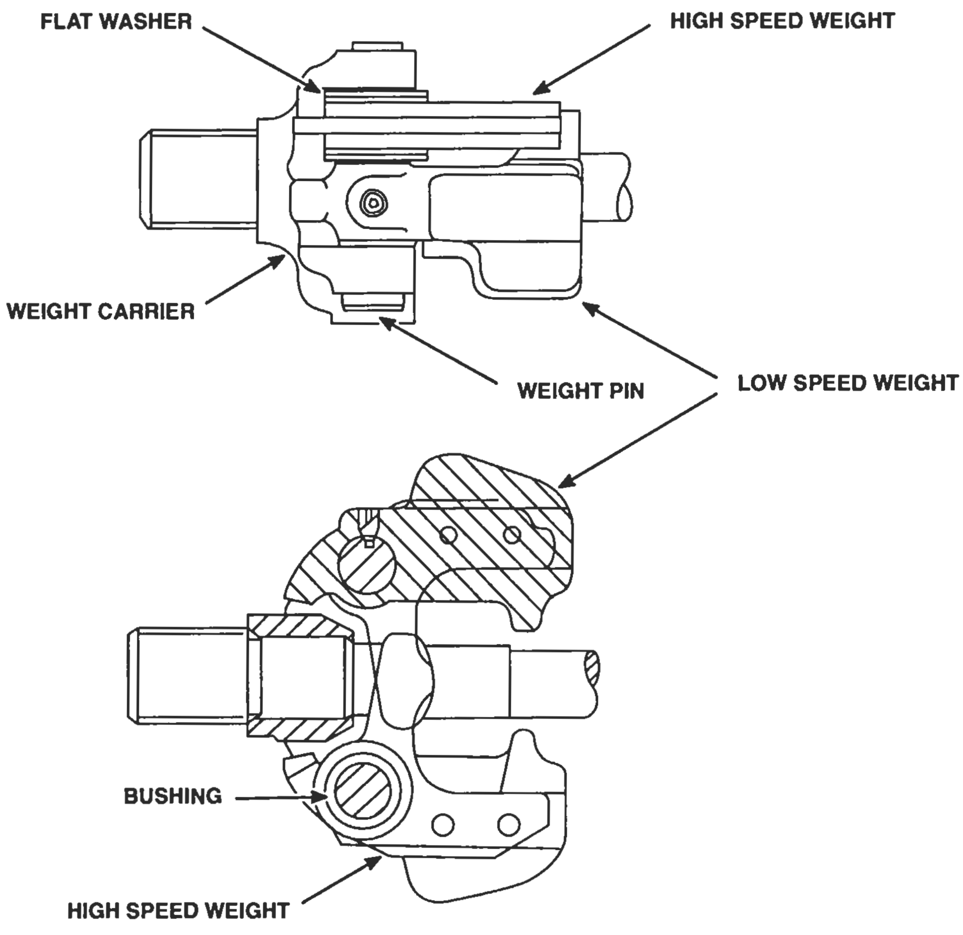

Figure 6. Cross Section of Governor Weight for Double Weight Governor

SECTION 2.7.1.2 – LIMITING SPEED GOVERNOR

INSPECTION

Clean all of the parts with fuel oil and dry them with compressed air.

Revolve the ball bearings slowly by hand. Replace the bearings which indicate rough or tight spots. Also replace the bearings which are corroded or pitted.

Examine the riser thrust bearings for excessive wear, flat spots, or corrosion. If any of these conditions exist, install a new riser and bearing assembly.

Inspect the weight carriers, weights and retaining pins for wear.

Inspect the bushings in the weights and replace them if they are worn excessively.

Inspect the operating shaft and bushing for excessive wear. If excessive wear is noted, install a new bushing and shaft.

ASSEMBLE GOVERNOR COVER

If the needle bearings were removed from the governor cover, place the governor cover on the bed of an arbor press with the inner face of the cover down. Start the upper bearing straight into the bearing bore of the cover with the number on the bearing up. Insert bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Figure 7.)

Turn the cover over and start the second bearing, number side up, in the bearing bore. Press the bearing in flush with the cover with tool J 21068.

NOTE: Do not use impact tools to install needle bearings.

9. Install the plug in the throttle shaft.
10. Pack the needle bearings with grease. Then slide the throttle shaft assembly through the bearings.
11. Install two retaining washers and retaining ring on the throttle shaft.
12. Install the spacer on the shaft (slip fit) against the retainer washers and over the snap ring.
13. Lubricate the stop lever shaft with engine oil and slide the shaft through the cover.
14. Install a new seal ring over the shaft and in the cover, then install two seal retaining washers and a retaining ring.
15. Install the stop lever and speed control lever and tighten the clamping bolts.

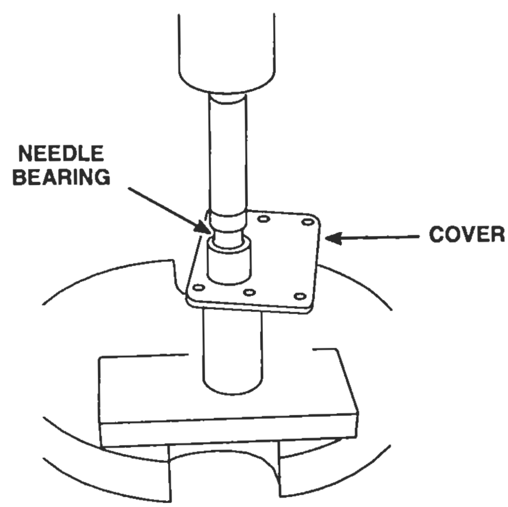

Figure 7. Install Needle Bearings in Governor Cover

ASSEMBLE GOVERNOR CONTROL HOUSING

1. Place the washer over the short finished end of the operating shaft. Start the bearing over the end of the shaft. Support the opposite end of the shaft on the bed of a press. Press the bearing on the shaft tight against the washer with a sleeve which has the same diameter as the bearing inner race.
2. With the pivot pin in the operating lever up, start the lever over the end of the shaft with the flat on the shaft registering with the flat surface in the lever. Press the lever on the shaft tight against the bearing.
3. Lubricate the bearing and operating shaft bushing in the housing with clean engine oil. Insert the lever and operating shaft assembly in the control housing.
4. Position the operating fork over the lower end of the operating shaft so the finished side of the fork finger will rest against the thrust bearing when assembled as shown in Figure 1 of 2.7.1.
5. Support the operating shaft and control housing in an arbor press with the upper end of the operating shaft resting on a steel block. Align the flat in the operating fork with the flat on the operating shaft, then place a sleeve over the end of the shaft and rest it on the fork. Bring the ram of the press down on the sleeve and press the fork straight down and tight against the shoulder on the shaft. Tighten the fork set screw, if used.
6. Apply a good quality sealant around the periphery of the expansion plug and press the plug into the lower end of the control housing.
7. Place a lock washer and flat washer over the retaining screw. Thread the screw in the control housing to secure the operating shaft bearing.
8. Place the differential lever over the pivot pin of the operating lever. Install a plain washer and spring retainer.

ASSEMBLE GOVERNOR SPRINGS, PLUNGERS AND ADJUSTING SCREWS

1. Thread the lock nut on the buffer screw and thread the buffer screw into the governor control housing.
2. Thread the idle speed adjusting screw into the high speed spring plunger, then thread the lock nut on the end of the adjusting screw.
3. Slip the high speed spring, spring guide, and governor spring retainer over the end of the plunger.
4. Insert the low speed spring seat, low speed spring, and spring cap in the other end of the plunger.
5. Slip the low speed spring end of the assembly through the control housing. Then thread the high speed spring retainer into the control housing, using tool J 1652–01.
6. Apply Perfect Seal No. 3 sealant or equivalent on the threads of the piston sleeve, then thread the sleeve into the piston until the sleeve extends approximately .781 inch from the piston.
7. Install a seal ring in the groove of the piston.
8. Position the blocking ring in the spring housing so the opening in the ring is in line with the threaded hole. If the spring housing did not incorporate a blocking ring, the installation of a blocking ring is recommended. This ring will prevent the piston and seal ring from sliding out the cover end of the spring housing, and possible damage to the seal ring by the sharp edges of the threaded hole.
9. Lubricate the inside surface of the spring housing with an all–purpose grease and insert the piston and sleeve assembly inside the spring housing at the end opposite to the pipe plug boss.
10. Use a new gasket at each end of the spring housing and attach the cover to the end of the housing (end with the boss for the pipe plug) and install the spring housing on the control housing.
11. Install the low maximum speed adjustment screw and lock nut in the spring housing cover.

ASSEMBLE GOVERNOR WEIGHT HOUSING (DOUBLE WEIGHT)

1. 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. 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 inches with the weight pressed in position.

NOTE: To maintain this clearance insert a .004–.012 inches shim between the low speed weight and carrier while pressing the pin into position.

Remove the shim and install the second weight pin retainer. Install the second pair of weights in the carrier in the same manner as described above.

Place the low speed weight on the pin and slide the pin through.

Place two flat washers on the pin next to the low speed weights.

Install the high speed weights on their shafts after installing the needle bearings.

Place the high speed weight on the pin and slide the pin through the weight.

Place two more flat washers on the pin between the high speed weights and the carrier. Slide the pin through the washers and into the carrier.

Align the indentation in the pin with the set screw hole in the low speed weights. Apply a sealant such as Loctite grade C or CV or equivalent on the threads of each set screw. Insert the set screws and tighten them to 20 lb·in (2.26 N·m) minimum. Be sure to stake each set screw in two places after tightening the screws.

NOTE: Before applying the sealant apply a Loctite primer to the set screws.

2. Slide the riser over the shaft and against the finished surfaces of the governor weights as shown in Figure 1 in Section 2.7.1.
3. Assemble the riser thrust bearing on the weight shaft with the bearing race having the smaller inside diameter against the thrust riser. Incorrect installation of the bearing will result in erratic operation of the governor.
4. Insert the weight carrier and shaft assembly in the weight housing.
5. Support the splined end of the shaft on the bed of an arbor press. Start the shaft end bearing in the housing and over the end of the shaft with the numbered side of the bearing facing away from the shaft. Press the new bearing in place using a 1 3/8 inch diameter metal bar flat on the ends which will bear against both the inner and outer races of the bearing.
6. Place the washer over the bearing retaining bolt. Thread the bolt into the tapped end of the shaft and tighten it. Bend the tang on the washer against the head of the bolt.
7. 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 with either flat or point of head on a horizontal line.

INSTALL GOVERNOR

1. Affix a new gasket to the governor weight housing. Start the splined end of the weight shaft in the upper blower rotor and position the housing against the blower end plate.
2. Place a new copper gasket on each weight housing–to–blower bolt and thread the bolts into the blower end plate, finger tight only.
3. Place a new gasket over the dowels and against the side of the weight housing facing the engine.
4. Move the thrust bearing assembly and riser toward the weight end of the shaft.
5. Position the lower end of the control housing over the dowel pins in the weight housing.

The finished surface of the operating fork must be placed against the outer side of the thrust bearing as shown in Figure 1 in Section 2.7.1.

NOTICE:

The weight housing has two ribs cast on the inner surface of the housing to prevent any part of the riser thrust bearing from sliding forward to where the operating fork could be inserted on the wrong side of one or more parts of the bearing.

6. Affix a new gasket to the governor control housing. Then attach the governor control housing to the cylinder head with two bolts. Tighten the bolts.
7. Tighten the governor–to–blower bolts with wrench J 4242.
8. Install the four weight housing–to–control housing bolts with lock washers. On former engines affix a new gasket–to–the weight housing cover, then place the cover in position and install the four weight housing to control housing bolts with lock washers. Tighten the bolts.
9. Connect the oil tube to the restricted fitting on the weight housing, or cover if used.
10. Refer to Figure 1 in Section 2.7.1 and position the fuel rod over the differential lever pin. Place a flat washer over the pin and secure it with the retainer.
11. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.
12. Place a new gasket on the governor control housing and mount the governor cover on the housing with the pin on the throttle shaft registering with the machined slot in the differential lever.

INSTALL GOVERNOR (CONT.)

13. Install the four cover screws with 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 over–speed will result if the injector racks cannot be positioned at no–fuel with the governor stop lever. An over–speeding engine can result in engine damage which could cause personal injury.

14. Connect the throttle linkage.
15. Attach the breather tube to the governor housing.
16. Tune–up the engine as outlined in Section 14.3.2.

LIMITING SPEED MECHANICAL GOVERNOR (VARIABLE LOW–SPEED)

The variable low–speed limiting speed mechanical governor is used on 6–71 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 governor is a single–weight type and provides an idle speed range of 500 to 1,800 r/min.

The governor is mounted on the front end of the blower and is driven by the upper blower rotor.

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 (Figure 1.) is turned to the speed required within the above range to operate the auxiliary equipment.

For the air operated governor, 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.

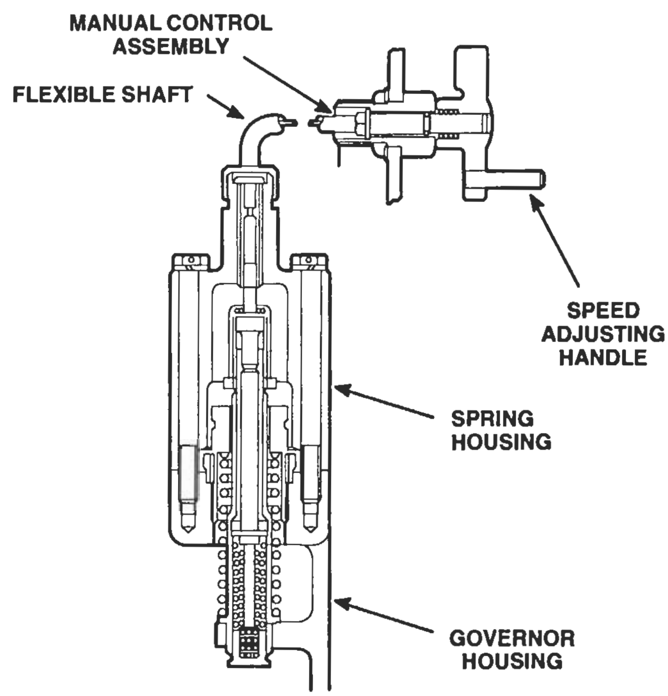

Figure 1. Cable Operated Governor Spring Housing

SECTION 2.7.1.3 – VARIABLE SPEED LIMITING SPEED GOVERNOR

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 GOVERNOR
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 as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.
2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket.
3. Remove the adjusting coupling from the adjusting shaft.
4. Hold the adjusting lock nut with a wrench and back off the retainer and adjusting shaft.
5. Unscrew the adjusting shaft from the retainer.
6. Unscrew the idle 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.

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:

N: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

ASSEMBLE GOVERNOR

NOTE: During assembly, lubricate all spring housing components and needle bearing assemblies with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1, then assemble the spring housing and components.

To assure a 500 r/min idle speed for certain on highway vehicle engines, the spring seat chamfer has been removed from the low–speed spring plunger and cap. The internal chamfer has been removed from both ends of the coil of the outer low–speed spring. A high idle condition could be the result if an unchamfered spring did not seat properly.

NOTICE:

A chamfered spring should not be used with an unchamfered plunger and cap, because a severe wear condition will result.

1. Thread the spring retainer lock nut on the high–speed spring retainer approximately 1–1/2 inches.
2. Place the high–speed spring on the high–speed spring plunger.
3. Insert the high–speed spring and plunger assembly in the high–speed spring retainer.
4. Insert the low–speed spring plunger into the high–speed spring plunger.
5. Place the inner and outer springs in the lower end of the high–speed spring plunger, over the low–speed spring plunger.
6. Install the low–speed spring cap over the end of the inner low–speed spring and into the end of the high–speed spring plunger and install the assembly in the governor housing.

NOTE: Place the spring housing gasket in position before installing the assembly.

7. Thread the idle speed adjusting lock nut on the threaded end of the high–speed spring plunger approximately 1/2 inch.
8. Screw the adjusting shaft into the adjusting shaft retainer all the way.
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.

SECTION 2.7.1.3 – VARIABLE SPEED LIMITING SPEED GOVERNOR

INSTALL GOVERNOR

Install the governor as outlined in Section 2.7.1, then connect the manual control flexible shaft to the governor spring housing.

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 (Figure 2.) as follows:

1. Clamp the flange of the governor housing in a vise equipped with soft jaws.

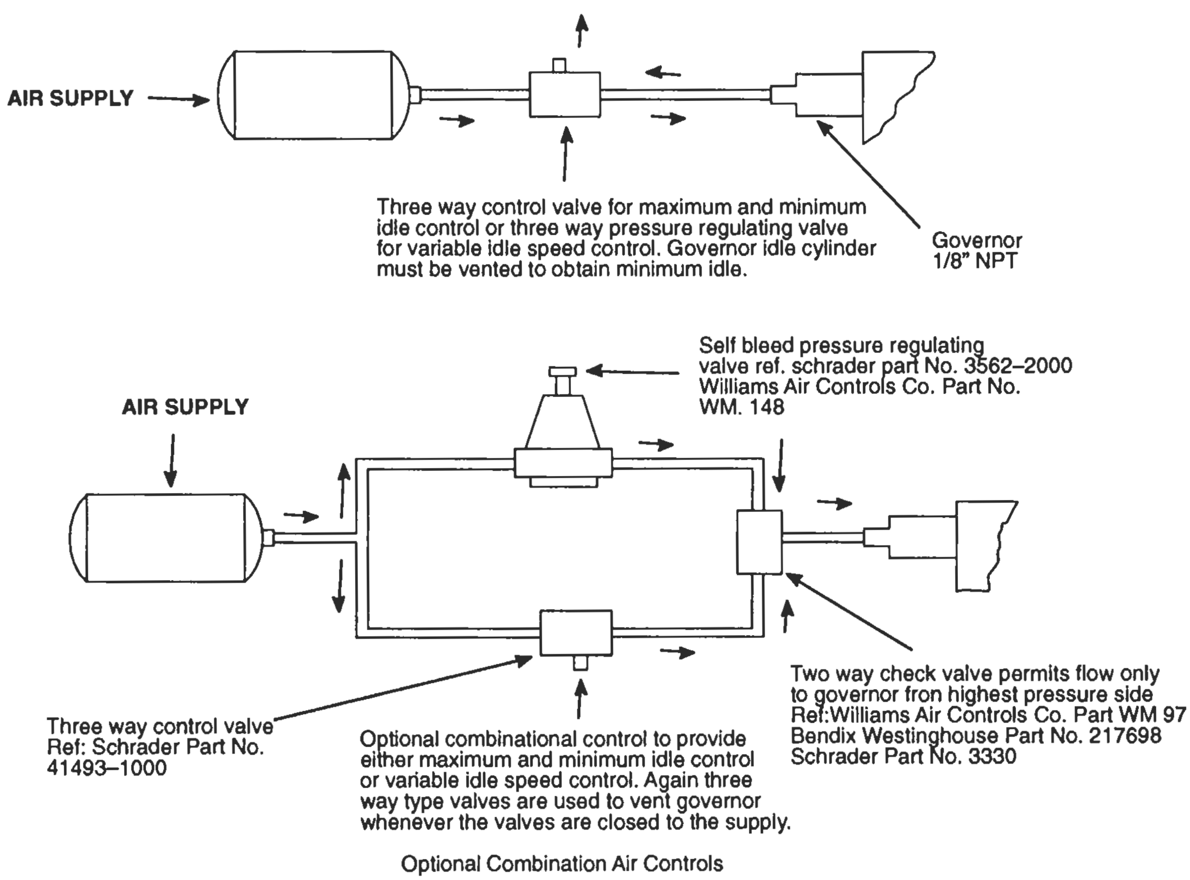

Figure 2. Air Operated Variable Low Speed Limiting Governor and Air Controls

DISASSEMBLE GOVERNOR (CONT.)

2. Remove the two bolts and lock washers securing the spring housing to the governor housing and withdraw the spring housing and gasket. Discard the gasket.
3. Loosen the 5/16–24 idle speed jam nut and remove the idle speed adjusting screw, seal ring and nut as an assembly. Discard the seal ring.
4. Hold the 1/2–20 jam nut on the high–speed spring plunger with a wrench and unscrew the air cylinder cap, retainer ring, pin, piston, air cylinder and seal ring as an assembly from the end of the high–speed spring plunger.
   a. Disengage the retainer ring from the air cylinder and remove the air cap and piston from the air cylinder.
   b. Remove the seal ring from the piston. Discard the seal ring.
5. Unscrew the high–speed spring retainer lock nut and remove the high–speed spring retainer, plunger and spring along with the low–speed spring plunger, inner and outer springs and low–speed spring cap as an assembly from the governor housing.
6. Remove the high–speed spring retainer and spacer assembly and spring from the high–speed spring plunger. Remove the low–speed spring cap from the opposite end of the high–speed spring plunger and remove the low–speed spring plunger along with the inner and outer low–speed springs.

INSPECT 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:

N: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

SECTION 2.7.1.3 – VARIABLE SPEED LIMITING SPEED GOVERNOR

ASSEMBLE GOVERNOR

NOTE: During assembly, lubricate all spring housing components with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

Assemble the governor as outlined in Section 2.7.1, then assemble the spring housing and components as follows:

1. Thread the spring retainer lock nut on the high–speed spring retainer approximately 1–1/2 inches.
2. Place the high–speed spring on the high–speed spring plunger.
3. Insert the high–speed spring and plunger assembly in the high–speed spring retainer.
4. Insert the low–speed spring plunger into the high–speed spring plunger.
5. Place the inner and outer springs in the lower end of the high–speed spring plunger, over the low–speed spring plunger.
6. Install the low–speed spring cap over the end of the inner low–speed spring and into the end of the high–speed spring plunger and install the assembly in the governor housing.

NOTE: Place the new spring housing gasket in position before installing the assembly.

7. If removed, thread the 1/2–20 high–speed spring jam nut on the threaded end of the plunger approximately 1/2 inch.
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.

NOTE: Be sure and lubricate the bore of the spring housing with grease as stated in the above note.

INSTALL GOVERNOR

Install the governor as outlined in Section 2.7.1, then connect the air controls to the governor spring housing.

Adjust the governor as outlined in Section 14.3.3.

LIMITING SPEED MECHANICAL GOVERNOR (FAST IDLE CYLINDER)

The double–weight limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover (Figure 1.) An engine shutdown air cylinder, if used, is also mounted on the governor cover.

For operation and adjustment of the fast idle air cylinder, refer to Section 14.3.4.

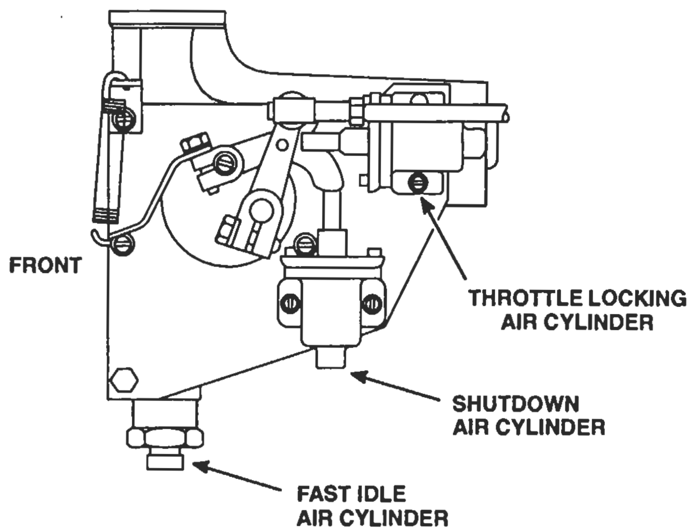

Figure 1. Governor with Fast Idle Cylinder

LUBRICATION

The governor is lubricated in the same manner as the limiting speed governor (Section 2.7.1).

CHECK GOVERNOR OPERATION

Governor difficulties should be checked in the manner outlined in Section 2.7. If, after making the checks, the governor fails to control the engine or auxiliary equipment properly, it should be removed and reconditioned.

REMOVE GOVERNOR FROM ENGINE

1. Release any air in the system and disconnect the air hoses from the air cylinders.
2. Remove the governor by following the procedure outlined in Section 2.7.1.

SECTION 2.7.1.4 – LIMITING SPEED GOVERNOR (FAST IDLE)

DISASSEMBLE GOVERNOR

1. Disassemble the governor as outlined in Section 2.7.1.
2. Disassemble the fast idle cylinder (Figure 2.) as follows:
   a. Pull the plunger out of the buffer spring and cylinder.
   b. Clamp the air cylinder in a vise equipped with soft jaws.
   c. Apply pressure on the end of the air inlet plug and remove the plug retaining ring from the groove in the air cylinder.
   d. Pull the air inlet plug and seal ring assembly from the air cylinder. Remove the seal ring from the groove in the plug.
   e. Insert a 3/32 inch diameter steel rod in the plunger opening in the air cylinder and push the piston, seal ring, dual idle spring and spring follower out of the air cylinder as an assembly. Then remove the air cylinder spring from the cylinder.
   f. Remove the seal ring from the groove in the piston. Apply pressure on the spring follower and remove the follower retaining ring from the groove in the piston. Remove the follower and spring.

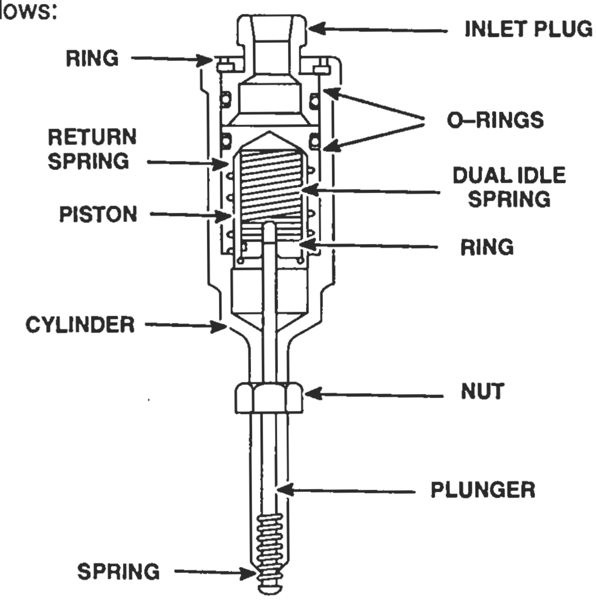

Figure 2. Fast Idle Cylinder

INSPECTION

Wash all of the governor components in clean fuel oil and dry them with compressed air. Then inspect them as outlined in Section 2.7.1.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Examine the fast idle air cylinder components for wear or any defects. Replace worn or damaged parts.

ASSEMBLE GOVERNOR

1. Assemble the governor as outlined in Section 2.7.1.
2. Assemble the fast idle cylinder as follows:
   a. Insert the dual idle spring inside of the fast idle air cylinder. Place the spring follower, with the small diameter end down, inside of the spring. Apply pressure on the spring follower and compress the spring enough to expose the retaining groove. Then install the retaining ring in the groove.
   b. Install a new seal ring in the groove in the piston. Then install the air cylinder spring over the small diameter end of the piston.
   c. Lubricate the seal ring on the piston with engine oil. Then insert the piston and spring assembly, with the small diameter end of the piston first, straight into the air cylinder spring seats on the shoulder in the cylinder.

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 govemors. 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 r/min 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 (Figure 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 r/min to the desired setting.

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 the housing with engine oil. Install the piston in the housing bottoming the piston on its stop.
4. Slide the housing and piston assembly over the spring retainer and idle speed screw.

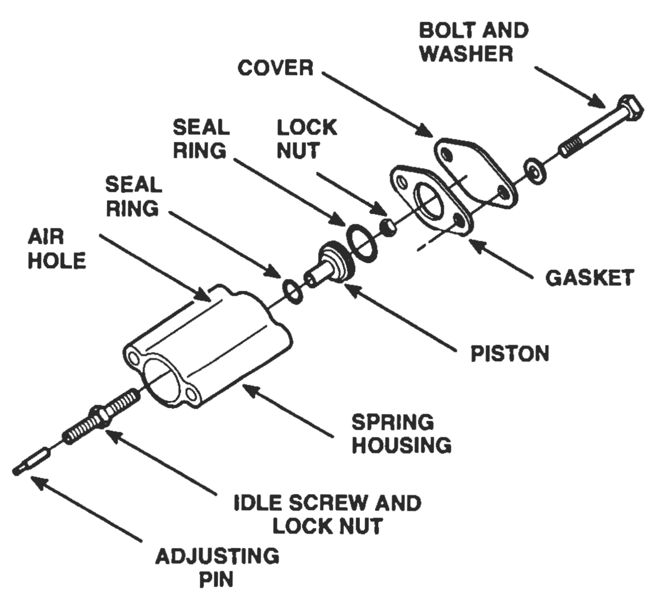

Figure 1. Air Operated Variable High Speed Limiting Speed Mechanical Governor Components

INSTALL CONTROL HOUSING (CONT.)

5. Install the idle screw self–locking nut and make the following adjustments:
   a. Place a .010 inch 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 (Figure 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 inch bolts. Tighten bolts.

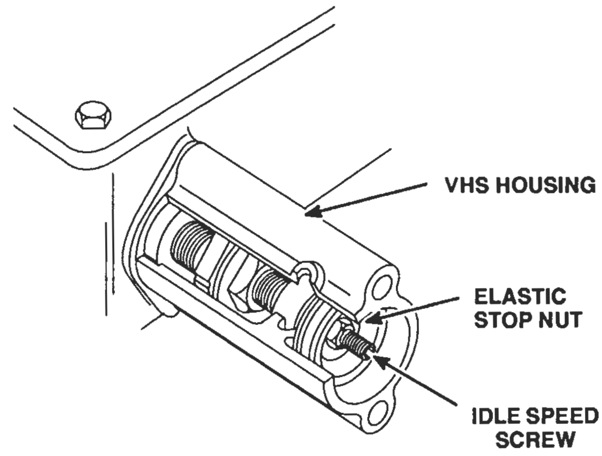

Figure 2. Elastic Stop Nut Adjustment

Install the air cylinder (throttle lock) 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 when full air pressure is applied (Figure 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.

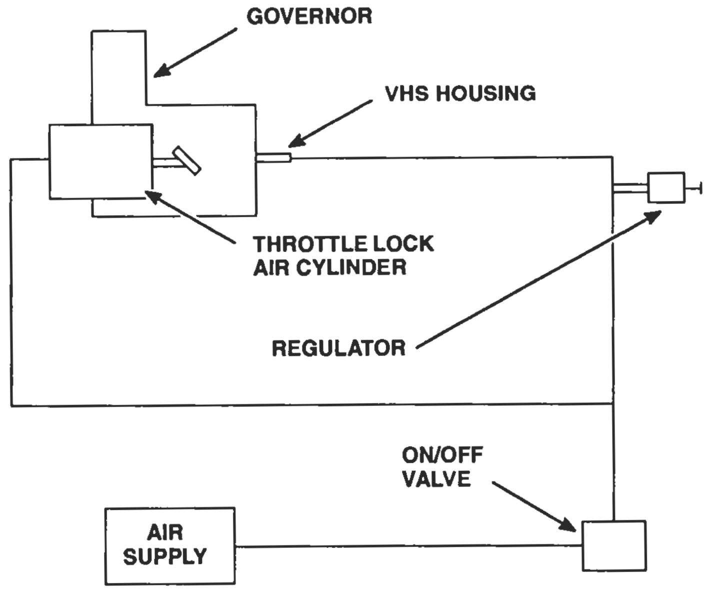

Figure 3. Limiting Speed Mechanical Governor Schematic (Variable High Speed)

INSTALL CONTROL HOUSING (CONT.)

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 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.

d. Install a new seal ring in the groove of the air cylinder air inlet plug.

e. Lubricate the seal ring with engine oil. Then insert the air inlet plug straight into the air cylinder and against the piston.

f. Clamp the air cylinder in a vise equipped with soft jaws. Apply pressure on the end of the air inlet plug and compress the spring enough to expose the retaining ring groove. Then install the retaining ring.

g. If removed, thread the lock nut on the air cylinder. Then insert the plunger through the buffer spring and into the air cylinder.

7. Install the fast idle air cylinder assembly in the governor housing buffer screw hole.

INSTALL GOVERNOR

1. Install the governor on the engine as outlined in Section 2.7.1.
2. Install the throttle locking and engine shutdown air cylinders.
3. Connect the air hoses to the air cylinders.
4. Adjust the governor as outlined in Section 14.3.4.

VARIABLE SPEED MECHANICAL GOVERNOR

The variable speed mechanical governor performs three functions:

1. Controls the engine idle speed.
2. Limits the maximum no–load speed.
3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single weight governor is mounted on the front of the blower and is driven by the upper blower rotor.

The governor consists of four subassemblies:

4. Control Housing Cover.
5. Control Housing.
6. Weight and Housing.
7. Variable Speed Spring Housing and Shaft.

OPERATION

Two manual controls are provided on the variable speed governor: a stop lever for starting and stopping, and a speed control lever (Figure 1.) For starting, the stop lever is moved to the run position, which holds the injector control racks near the full–fuel position. Upon starting, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion, which is transmitted through the riser and operating shaft to the operating shaft lever. One end of the operating lever bears against the variable speed spring plunger, while the other end provides a changing fulcrum on which the differential lever pivots.

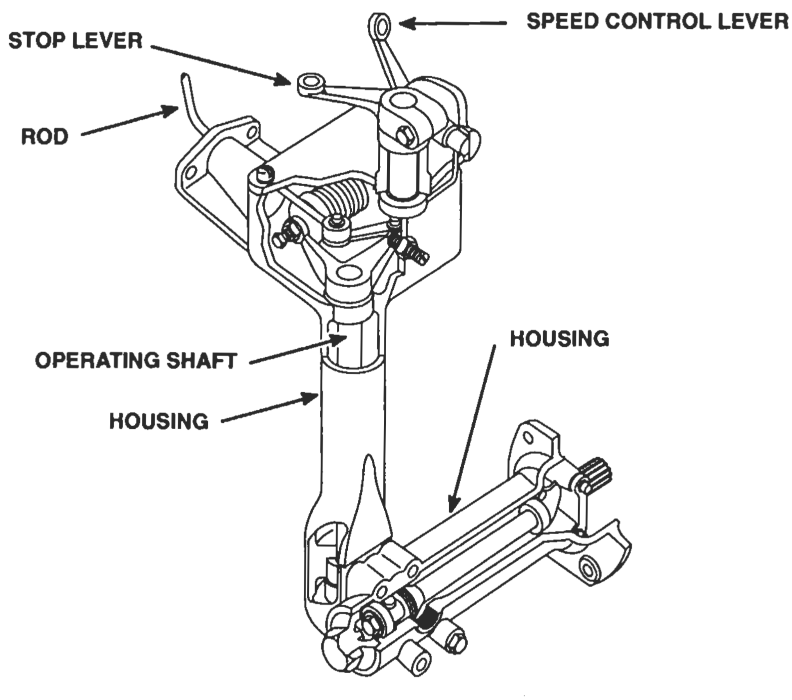

Figure 1. Variable Speed Mechanical Governor

OPERATION (CONT.)

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving governor weights and tension on the variable speed spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

A fuel rod connected to the differential lever and injector control tube lever provides a means for the governor to change the fuel settings of the injector control racks.

The engine idle speed is determined by the centrifugal force required to balance out the tension on the variable speed spring in the low speed range.

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 for 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, as required. Refer to Section 14.4 for maximum no–load speed adjustment.

LUBRICATION

Surplus oil returning from the cylinder head provides lubrication for the parts in the governor control housing, the riser thrust bearings, and the weight shaft end bearing. Oil picked up from a reservoir in the blower front end plate by a slinger attached to the lower rotor shaft provides lubrication for the governor weights and weight carrier.

Pressure lubrication has been provided for the weight housing bearings on current engines. The oil tube is attached between the oil gallery in the cylinder block and the governor weight housing.

REMOVE GOVERNOR

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 throttle control rod (Figure 2.) and booster spring from the speed control lever.
2. Remove the breather tube.
3. Remove the four cover screws and lift the governor cover with the stop lever and retraction spring (current engine), and cover gasket from the governor housing.
4. Disconnect the fuel rod from the differential lever and injector control tube lever.
5. Disconnect the oil tube at the governor weight housing, or cover, if used.
6. Remove the two governor–to–cylinder head bolts.
7. Remove the control housing from the cylinder head and weight housing.
8. Use wrench J 4242 and remove the six governor weight housing–to–blower bolts, then withdraw the housing from the blower.

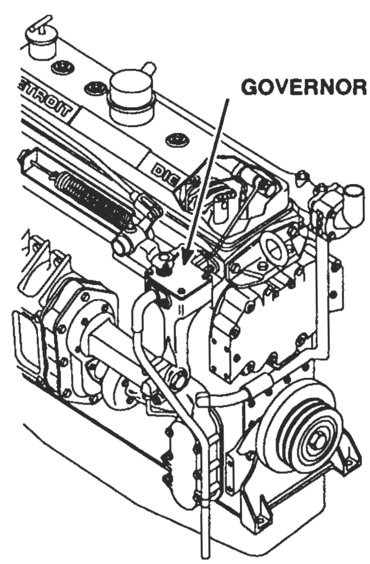

Figure 2. Variable Speed Governor Mounting

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DISASSEMBLE GOVERNOR

With the cover removed from the control housing, disassemble the governor as follows:

1. Disassemble the governor cover (Figure 3.)
   a. Loosen the clamping bolt and remove the stop lever from the shaft. Remove the lever torsion retraction spring (current engine).
   b. Remove the control shaft lock ring and seal retainer. Withdraw the control shaft from the cover.
   c. Remove the seal ring from the governor cover.
   d. Wash the cover assembly.

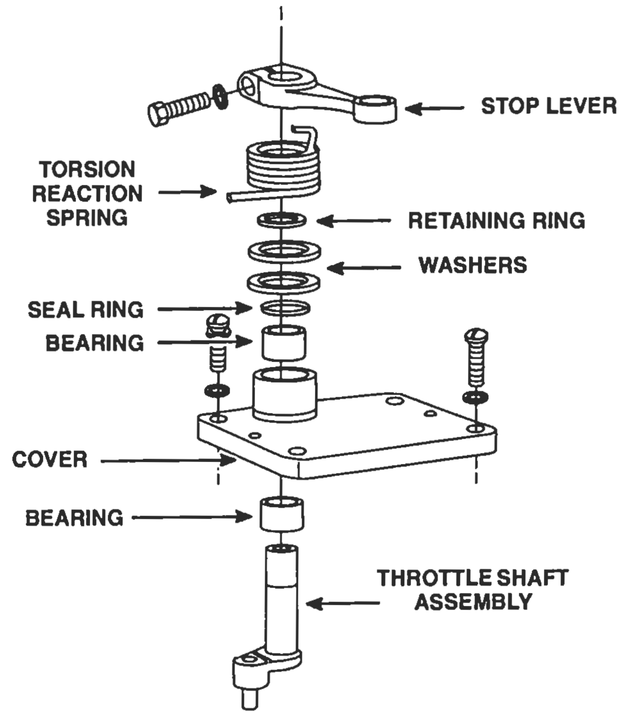

Figure 3. Governor Cover and Components

   e. If needle bearing or bushing removal is necessary, place the inner face of the cover over the opening in the bed of an arbor press (Figure 4.) Place remover J 21967–01 on top of the bearing or bushing and under the ram of the press, then press both bearings or bushing out of the cover.

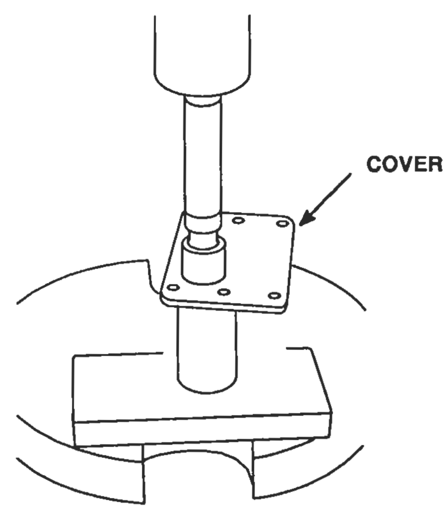

Figure 4. Removing Bearings from Cover

DISASSEMBLE GOVERNOR (CONT.)

2. Disassemble the governor control housing.
   a. Place the control housing in the soft jaws of a vise (Figure 5.)
   b. Remove two bolts and lock washers and withdraw the variable speed spring housing, spring plunger, and spring as an assembly. Withdraw the spring plunger from the plunger guide.
   c. Remove the spring retainer and washer. Lift the differential lever off the pin of the operating shaft lever.

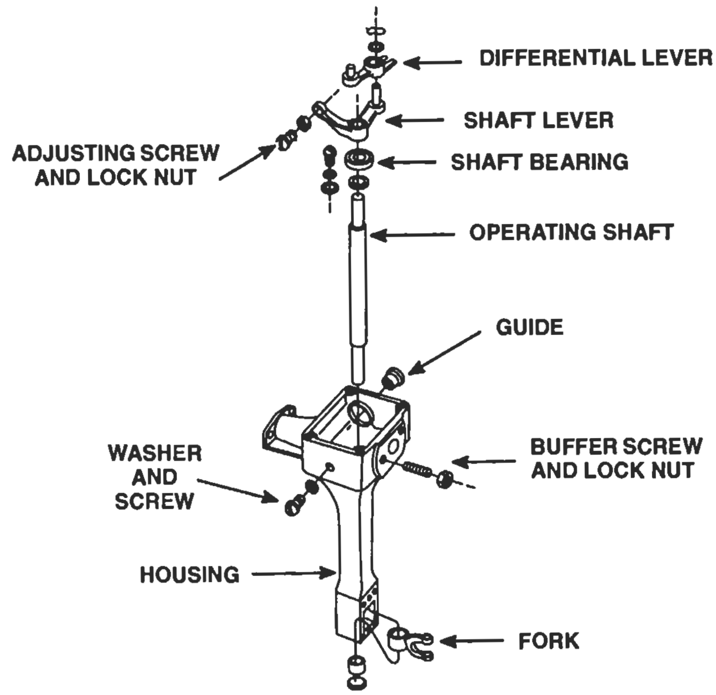

Figure 5. Governor Housing and Components

   d. Remove the variable speed spring plunger guide (Figure 6.) Remove the bearing retaining screw, flat washer and lock washer.
   e. Remove the expansion plug out of the lower end of the control housing.
   f. Loosen the operating fork set screw, if used.

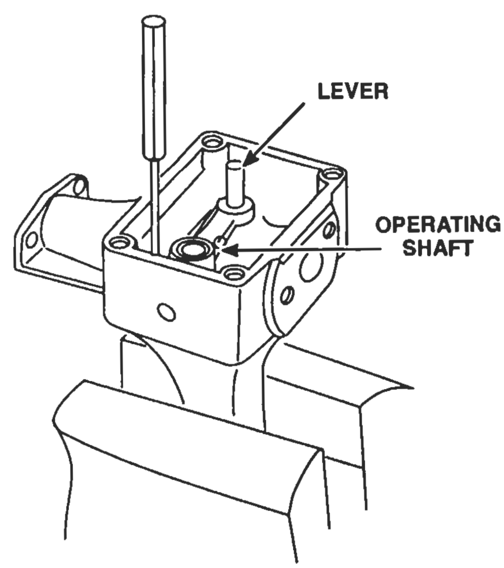

Figure 6. Removing Variable Speed Spring Plunger Guide

DISASSEMBLE GOVERNOR (CONT.)

g. Support the control housing bottom side up on the bed of the press. Use a brass rod and press the operating shaft from the operating fork (Figure 7.) Withdraw the operating shaft, operating lever and bearing as an assembly from the control housing.

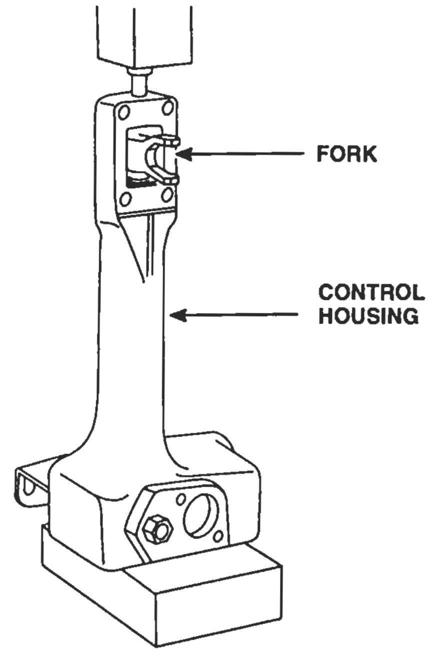

Figure 7. Removing Operating Shaft from Operating Fork

h. Support the operating shaft and lever on the bed of the press as shown in Figure 8. Use a brass rod and press the shaft from the operating lever and bearing.

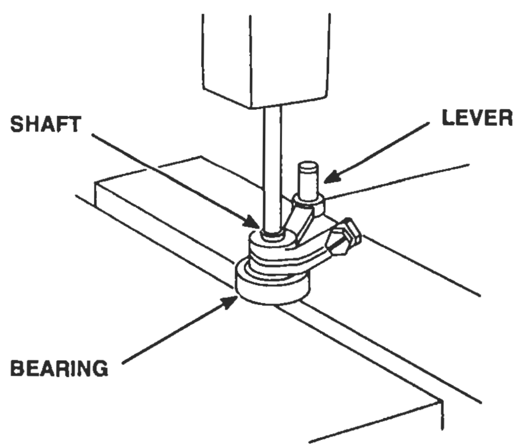

Figure 8. Removing Operating Shaft from Operating Lever

SECTION 2.7.2 – VARIABLE SPEED MECHANICAL GOVERNOR

DISASSEMBLE GOVERNOR (CONT.)

3. Disassemble the governor weight housing.
   a. Place the weight housing in the soft jaws of a vise (Figure 9.) Remove the end plug and gasket.
   b. Straighten the tang of the lock washer and remove the bearing retaining bolt.

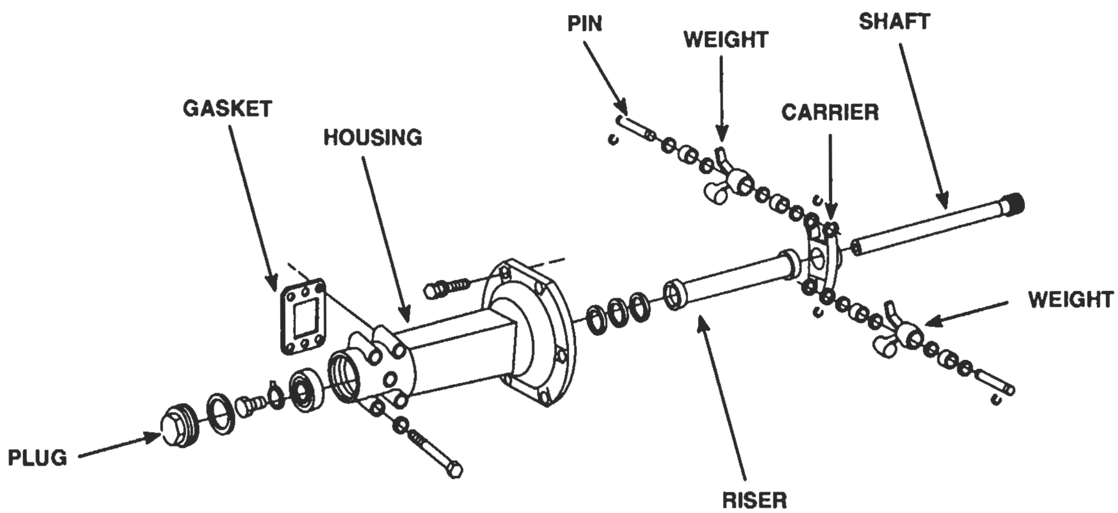

Figure 9. Governor Weight Housing Components

DISASSEMBLE GOVERNOR (CONT.)

c. Thread a 5/16–24 x 3 inch bolt into the tapped end of the weight shaft. Support the weight housing on the bed of the press as shown in Figure 10. Then press the shaft from the bearing.

d. Slide the riser thrust bearing and governor riser from the shaft.

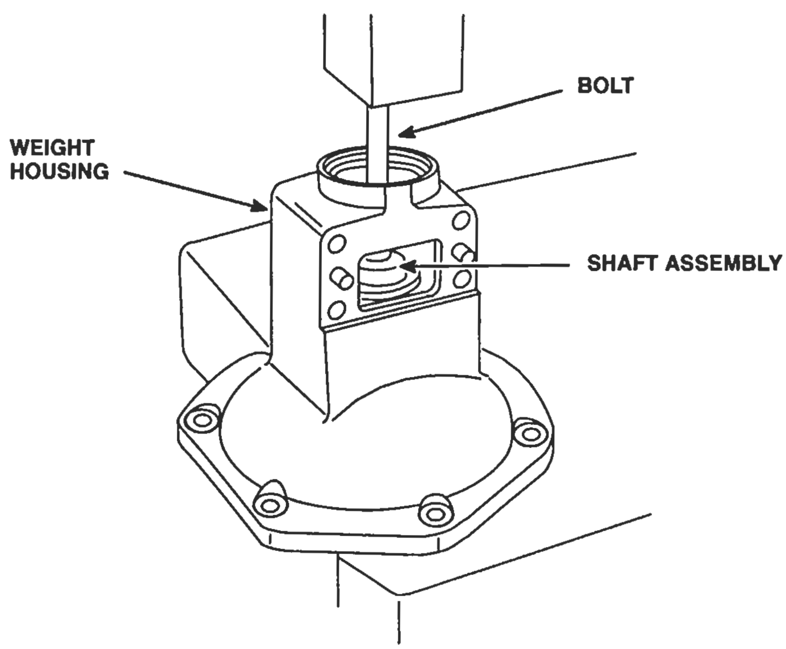

Figure 10. Removing Governor Weight and Shaft Assembly

DISASSEMBLE GOVERNOR (CONT.)

This bearing is specially designed to absorb thrust load; therefore looseness between the mating parts does not indicate excessive wear.

e. Remove the bearing from the weight housing.

NOTE: The weight shaft end bearing should be discarded on removal as it becomes brinnelled during the disassembly process.

f. Use tool J 4880 and remove one lock ring from each weight pin. Withdraw the pins, flat washers and governor weights.

g. If required, the weight carrier may be pressed from the governor weight shaft and a new carrier installed.

4. Disassemble the governor variable speed spring housing.

a. Withdraw the variable speed spring stops, spring plunger and shims from the spring housing.

b. Loosen the bolt and withdraw the speed control lever from the speed control lever shaft. Remove the Woodruff key from the shaft.

c. Remove the plain washer and seal from the shaft.

d. On the current spring housing, remove one screw and lock washer and remove the spring housing cover and gasket. Then remove the set screw from the spring lever.

e. Support the spring housing on the bed of the press with the shaft up. Use a brass rod and press the shaft, plug and bearing from the housing. Remove the bearing from the shaft and the spring lever from the housing.

f. If required, the second bearing may be pressed from the housing.

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 lb/in^2 (276 kPa) air pressure.

Inspect all of the governor components and replace worn or damaged parts. Revolve the operating shaft bearing and the governor weight shaft bearing slowly by hand; replace the bearings if rough or tight spots are detected.

Inspect the operating shaft and shaft bushing for excessive wear. If excessive wear is noted, a new bushing and shaft must be installed. Examine the riser thrust bearing for excessive wear, flat spots or corrosion. If any of these conditions exist, a new thrust bearing assembly must be installed.

Inspect the needle bearing or bushing and the control lever shaft for excessive wear or flat spots. If one or both conditions exists, new bearings and control shaft must be installed.

The bushing contained in the current cover assemblies is not serviced. When replacement is necessary, use needle bearings.

Inspect the spring lever shaft and bearings for excessive wear or flat spots at the bearing surface. If one or both conditions exist, a new shaft and bearings must be installed.

INSPECTION (CONT.)

When installing a new bearing in the spring housing lever assembly, note that the roller type bearing rides on a hardened bearing pin and is a press fit in the spring lever.

Also, when installing the roller–type bearing, the pressed–in pin must be below the surface of the lever and staked in three places on both sides.

Examine the weight carrier pins and bearings for excessive wear and flat spots. If either of these conditions exist, new parts must be installed.

Check the finished surface of the governor weights for flat spots. If flat spots are noted, new weights should be installed.

ASSEMBLE GOVERNOR COVER

1. If new needle bearings are to be installed in the governor cover, place the governor cover on the bed of an arbor press with the inner face of the cover down. Start a new needle bearing straight into the bearing bore of the cover with number on the bearing up. Then insert bearing installer J 21068 in the bearing and press the bearing in until the shoulder on the tool contacts the cover (Figure 11.)
2. Reverse the governor cover on the bed of the press (inner face of cover up). Start the second bearing straight into the bore of the cover with the bearing number up. Press the bearing in flush with the cover with tool J 21068.

NOTE: Do not use impact tools to install needle bearings.

3. Pack the needle bearings with grease. If the cover contained a bushing which was not removed, lubricate it with clean engine oil. Insert the throttle shaft through the bearing or bushing.
4. Insert a seal ring over the throttle shaft and into the counterbore against the upper bearing. Place the retainer over the shaft and against the seal ring.
5. Locate the lock ring in the groove of the throttle shaft.
6. Place the torsion retraction spring over the cover hub with the hooked end up. Then place the stop lever on the shaft and tighten the clamping bolt. (Refer to Governor Installation).

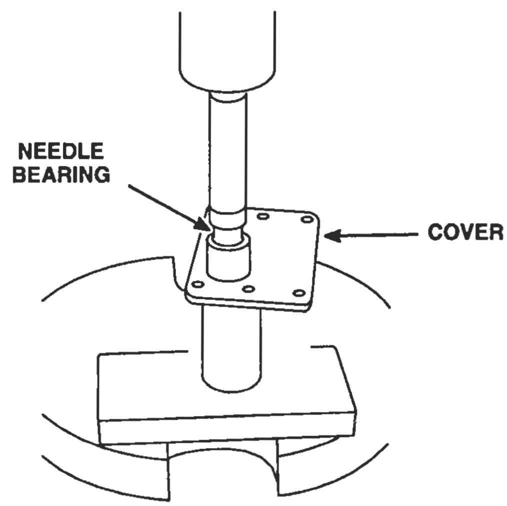

Figure 11. Installing Needle Bearing in Governor Cover

ASSEMBLE GOVERNOR CONTROL HOUSING

1. Place the bearing washer over the short, finished end of the operating shaft. Start the bearing over the end of the shaft. Support the opposite end of the shaft on the bed of the press. Using a sleeve having the same diameter as the bearing inner race, press the bearing on the shaft tight against the washer.
2. With the pivot pin in the operating lever up, start the lever over the end of the shaft with the flat on the shaft registering with the flat surface in the lever. Press the lever on the shaft tight against the bearing.
3. Lubricate the bearing and operating shaft bushing in the housing with clean engine oil. Insert the lever and operating shaft assembly in the control housing.
4. Position the operating fork over the lower end of the operating shaft so the finished side of the fork fingers will rest against the thrust bearing.
5. Support the operating shaft and control housing on the bed of an arbor press with the upper end of the shaft resting on a steel block. Align the flat in the operating fork with the flat on the shaft, then place the sleeve over the end of the shaft and rest it on the fork. Press the fork straight down tight against the shoulder on the shaft.
6. Tighten the fork set screw (if used).
7. Place the differential lever over the pivot pin of the operating lever. Install the plain washer and spring retainer.
8. Place the lock washer and the flat washer over the bearing retaining screw. Thread the screw in the control housing tight to secure the bearing.
9. Insert the variable speed spring plunger guide in the control housing.
10. Apply a good quality sealant around the outer periphery of the expansion plug and tap the plug into the lower end of the control housing.

ASSEMBLE GOVERNOR WEIGHT HOUSING

1. Install the lock ring in the groove of the weight pin. Place the flat washer over the pin and against the lock ring.
2. Start the pin through the opening in the weight carrier. Place the second washer over the pin and against the projecting arm of the weight carrier.
3. Position the governor weight between the projecting arms of the weight carrier. Push the pin through the governor weight. Place the third flat washer over the pin and against the weight.
4. 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 the second lock ring in the groove of the weight carrier pin.
5. Install the second governor weight as outlined in Steps 1 through 4.
6. Slide the riser over the shaft and against the finished surfaces of the governor weights.
7. Assemble the riser thrust bearing on the weight shaft with the bearing race having the smaller inside diameter against the thrust riser. Incorrect installation of the bearing will result in erratic operation of the governor.
8. Insert the weight carrier and shaft assembly in the weight housing.

ASSEMBLE GOVERNOR CONTROL HOUSING (CONT.)

9. Support the splined end of the shaft on the bed of an arbor press. Start the shaft end bearing in the housing and over the end of the shaft with the numbered side of the bearing facing away from the shaft. Press the new bearing in place using a 1 3/8 inch diameter metal bar flat on the ends which will bear against both the inner and outer races of the bearing.
10. Place a washer over the bearing retaining bolt. Thread the bolt into the tapped end of the shaft and tighten it. Bend the tang of the washer against the head of the bolt.
11. 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 end 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 with either the flat or the point of the head on a horizontal line.

ASSEMBLE VARIABLE SPEED SPRING HOUSING

1. Lubricate the speed control lever shaft needle bearings (Figure 12.) 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.

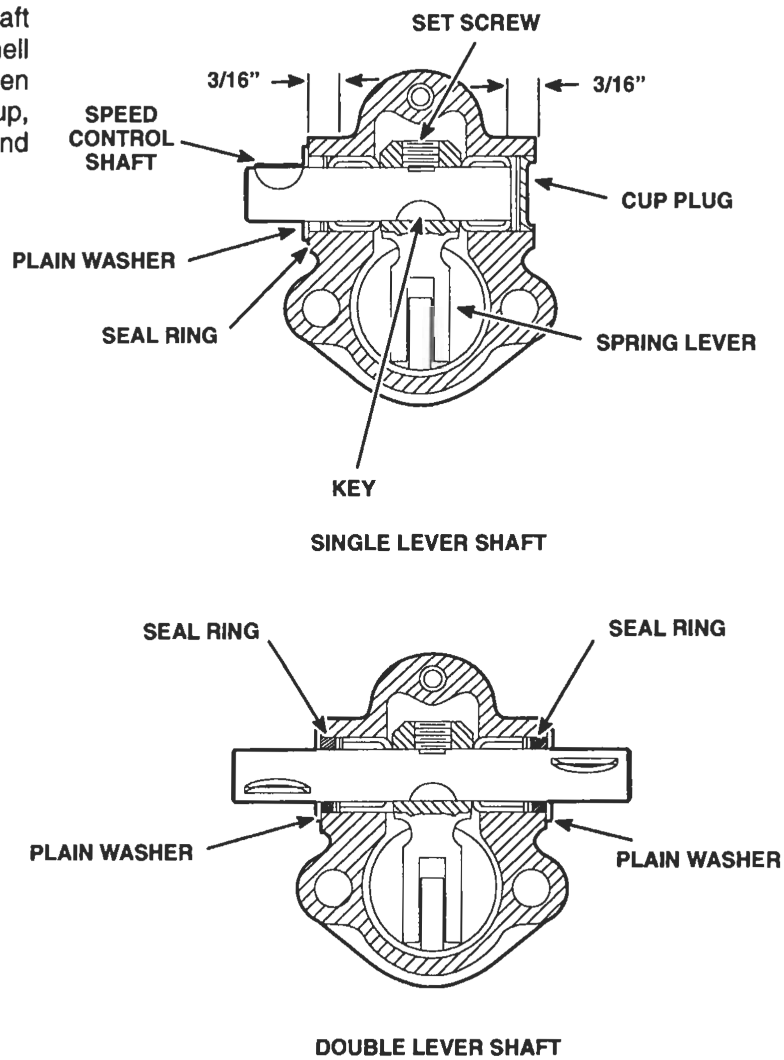

Figure 12. Cross Section of Governor Variable Speed Spring Housing

ASSEMBLE VARIABLE SPEED SPRING HOUSING (CONT.)

2. Install the needle bearing pilot rod J 9196–2 in the installer body J 9196–1 and secure it in place with the retaining screw (Figure 13.).

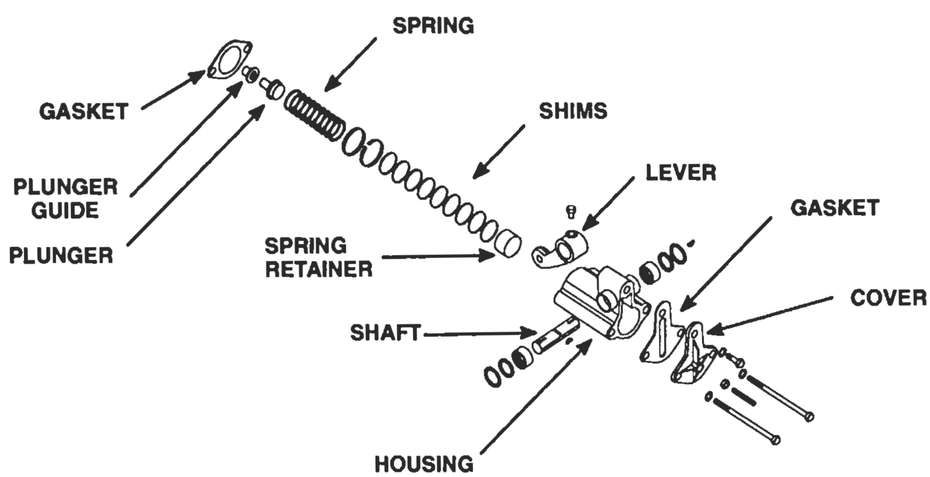

Figure 13. Variable Speed Spring Housing and Shaft Details and Relative Location of Parts

3. Place the pilot rod end of the bearing installer assembly in the bearing. Support the spring housing, bearing and installer on a short sleeve on the bed of an arbor press (Figure 14.) then press the bearing in the housing until the shoulder on the installer contacts the housing.

NOTE: When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

4. If removed, install the spring lever Woodruff key in the center keyway in the speed control lever shaft.

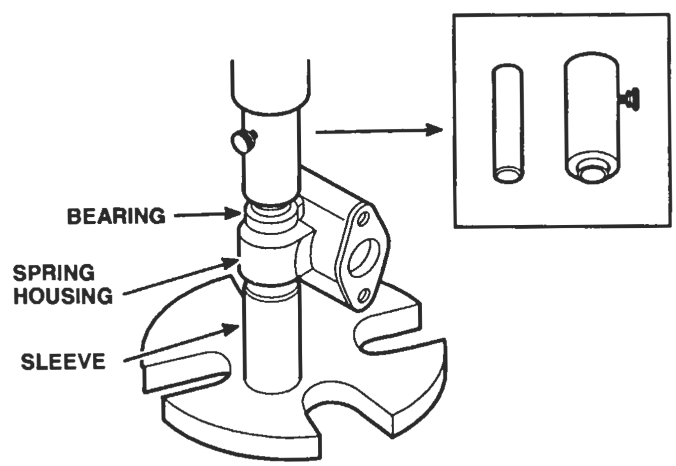

Figure 14. Installing Speed Control Shaft Bearings in Spring Housing

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ASSEMBLE VARIABLE SPEED SPRING HOUSING (CONT.)

5. Place the spring lever assembly between the bearing bores inside the spring housing with the arm (roller end) of the lever facing out.
6. Insert the correct end of the single or double lever–type speed control lever shaft 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.
7. Thread the set screw into the spring lever, making sure the point of the screw is seated in the flat on the shaft.
8. 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.
9. 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, then press the bearing in the housing until the shoulder on the installer contacts the housing.
10. 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.
11. Clamp the spring housing assembly in a bench vise equipped with soft jaws. Then tighten the spring lever retaining set screw to five to seven lb·ft (seven to ten N·m) torque.
12. Stake the edge of the spring lever set screw hole with a small center punch and hammer to retain the set screw in the lever. Then install the plug in the former spring housing.
13. 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.
14. 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.
15. 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.
16. If removed, thread the lock nut on the idle speed adjusting screw. Then, thread the idle speed adjusting screw into the spring housing cover approximately 1.00 inch.

ASSEMBLE VARIABLE SPEED SPRING HOUSING TO THE CONTROL HOUSING

1. Insert the small end of the spring plunger in the plunger guide. Insert the solid stop in the governor control housing.
2. Place the spring retainer in the spring housing, with the closed end of the retainer against the spring lever. If shims were used, place them inside of the spring retainer. Insert the split stop in the spring housing and against the spring retainer.

NOTE: Be sure to use shims with an .344 inch inside diameter. Either spring retainer may be used with shims which have a .750 inch inside diameter. However, do not use the .344 inch inside diameter shims with a spring retainer which has only one air bleed hole.

3. Insert the variable speed spring in the spring plunger with the tightly wound end of the spring against the shims.
4. Insert the bolts through the spring housing. Place a new gasket over the bolts and against the housing.
5. Place the spring housing in position against the control housing with the spring plunger engaged in the end of the variable speed spring. Thread the bolts in the control housing and tighten them securely.

INSTALL GOVERNOR

1. Affix a new governor–to–blower gasket to the governor weight housing. Start the splined end of the weight shaft into the upper blower rotor and position the housing against the blower end plate.
2. Place a new copper gasket on each weight housing–to–blower bolt and thread the bolts into the blower end plate, finger tight only.
3. Place a new gasket over the dowels and against the side of the weight housing facing the engine.
4. Move the thrust bearing assembly and riser toward the weight end of the shaft.
5. Position the lower end of the control housing over the dowel pins of the weight housing.

The finished surface of the operating fork must be placed against the outer side of the thrust bearing.

NOTICE:

For ease in assembling the governor control housing (four or six cylinder engine) to the interim weight housing (no identification mark), install a special bolt (3/8–24 x 3/4 or 7/8 inch), from which the outer 1/2 inch of thread down to a diameter of 5/16 inch to 1/4 inch has been removed, as a tool in the 1/8″ NPTF oil hole to prevent the thrust bearing from moving too far forward in the weight housing. The weight housing has two ribs cast on the inner surface of the housing to prevent any part of the riser thrust bearing from sliding forward to where the operating fork could be inserted on the wrong side of one or more parts of the bearing.

INSTALL GOVERNOR (CONT.)

6. Use a new gasket and attach the governor control housing to the cylinder head with two bolts. Tighten the bolts.
7. Tighten the governor–to–blower bolts with tool J 4242.
8. Place the cover in position. Install the four weight housing–to–control housing bolts with lock washers and tighten the bolts.
9. Connect the oil tube to the restricted fitting on the weight housing, or cover if used.
10. Position the fuel rod over the differential lever pin. Place a flat washer over the pin and secure it with a retainer.
11. Attach the fuel rod to the injector control tube lever with a pin and cotter pin.
12. Place a new gasket on the governor control housing and mount the governor cover on the housing with the pin on the lever shaft registering with the machined slot in the differential lever.
13. Secure the cover to the governor housing with three regular screws, one special screw and lock washers.
14. Hook the torsion retraction spring to the special cover screw and the stop lever.

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.

15. Perform an engine tune–up as outlined in Section 14.4.

CONSTANT SPEED MECHANICAL GOVERNOR

The horsepower requirements of an engine vary continually due to fluctuating loads. Therefore, some means must be provided to control the amount of fuel required to hold the engine speed reasonably constant during such fluctuations. To accomplish this control, a mechanical governor of the constant speed type has been provided.

The constant speed mechanical governor (Figure 1.) has a speed range of 1,200–2,000 r/min at full load. Upon starting, the engine will automatically attain approximately 50 r/min more than the pre–determined speed.

As load is applied, the engine speed drops until it reaches the desired speed at full load. This speed can be adjusted by moving the high speed spring retainer. Other style governors can be adjusted by the use of shims behind the governor spring.

A spring on top of the governor holds the governor control lever in the run position. A cable from the instrument panel, when pulled, overcomes the spring and draws the injector racks to the no–fuel position (through the governor), thus stopping the engine.

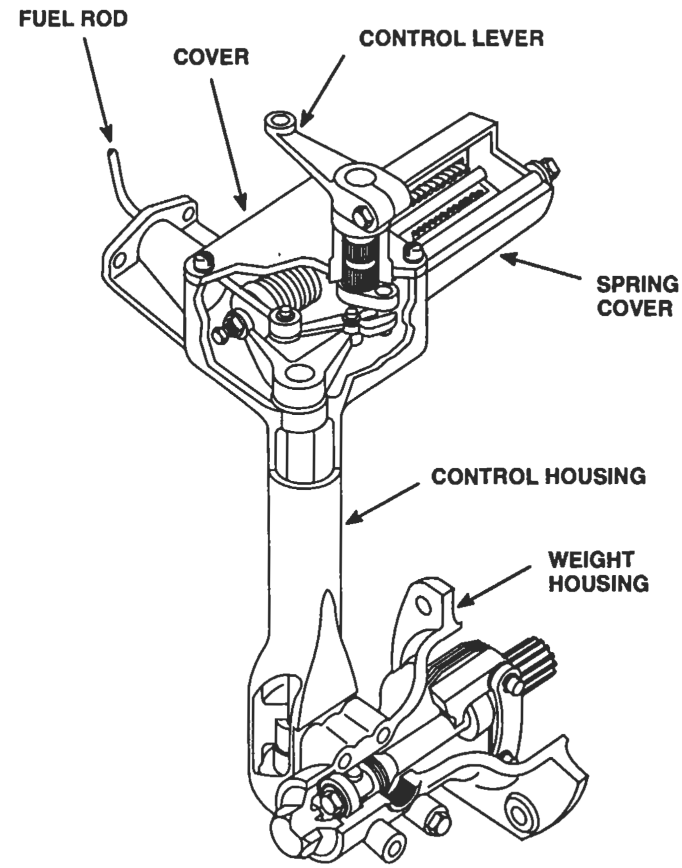

Figure 1. Constant Speed Governor

CONSTANT SPEED MECHANICAL GOVERNOR (CONT.)

The centrifugal force of the revolving flyweights is converted into linear motion which is transmitted through the riser and the operating shaft to the operating shaft lever, one end of which is the spring seat while the other end provides a changing fulcrum on which the differential lever pivots. A fuel rod, connected to the differential lever and injector control tube lever, provides a means for the governor to change the fuel settings of the injector control racks.

The centrifugal force of the governor weights is opposed by the governor spring. Load changes create an unbalanced force between the revolving governor weights and the tension of the spring. When the two forces are equal, the engine speed stabilizes. Whenever the centrifugal force of the revolving weights overcomes the tension of the spring, the injector racks will be moved toward the no–fuel position. Also, whenever the centrifugal force of the weights allows the spring to expand, the injector racks will move toward the full–fuel position.

When governor difficulties are encountered which would necessitate the removal, disassembly, cleaning and inspection, assembly and installation of the constant speed mechanical governor, refer to Section 2.7.1 for the proper procedure.

When engine tune–up is necessary, refer to Section 14.6.

MECHANICAL OUTPUT SHAFT GOVERNOR

The Pierce mechanical output shaft governor is used on certain engines equipped with a torque converter, to regulate the speed of the output shaft. The front mounted output shaft governor is mounted at the front of the engine and is driven by a flexible shaft from the torque converter output shaft and is connected through linkage to the engine governor (Figure 1.)

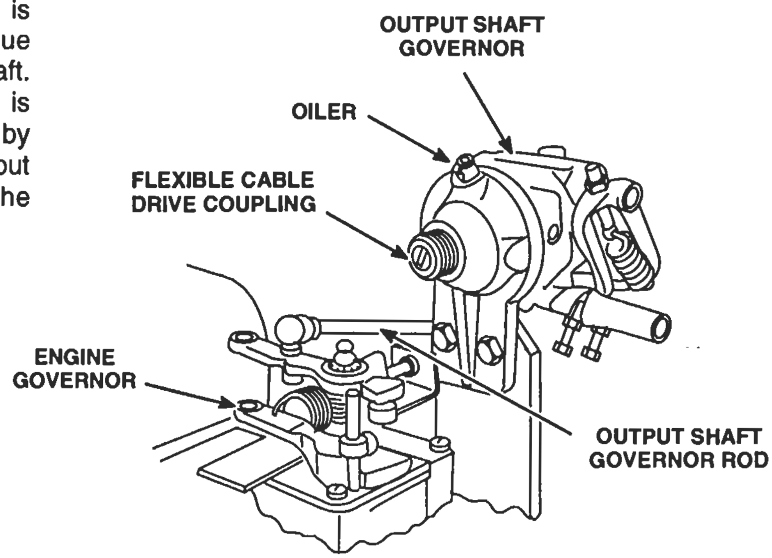

Figure 1. Front Mounted Output Shaft Governor

The rear mounted output shaft governor is mounted on the torque converter and is driven through a drive adaptor by the output shaft and is connected through linkage to the engine governor (Figure 2.) The mechanical limiting–speed governor on the engine regulates the maximum and idle speeds of the engine while the output shaft governor has control of the engine speed in the intermediate speed range between maximum and idle engine speed.

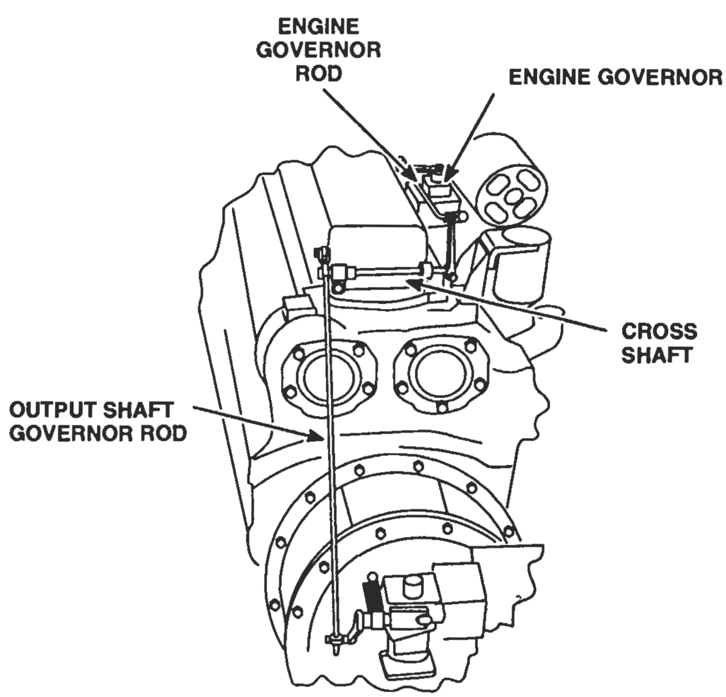

Figure 2. Rear Mounted Output Shaft Governor

MECHANICAL OUTPUT SHAFT GOVERNOR (CONT.)

The flyweights on the output shaft governor are driven through the operating spider and shaft assembly by the governor drive adaptor. A shoulder on the flyweights bears against the riser that transmits the motion of the flyweights, through the riser thrust bearing, to the operating fork. The operating fork is attached to the rocker shaft that rides in the rocker shaft ball bearings. Pinned to the rocker shaft is the spring lever and the rocker shaft lever. Connected to the spring lever is the speed adjusting spring that is in turn connected through the eyebolt to the speed adjusting spring lever. The speed adjusting spring lever is mounted on the speed adjusting shaft and is controlled by the engine operator when establishing and desired engine speed. Two screws (minimum and maximum output shaft speed adjusting screws) limit the travel of the speed adjusting shaft and thus the minimum and maximum output shaft speed settings. The linkage that operates the engine governor throttle is connected to the rocker shaft lever. The movement of the rocker shaft lever increases or decreases the speed of the engine.

LUBRICATION

The output shaft governor is lubricated by engine oil that is contained within the governor housing. The movement of the governor weights throws the oil to all parts in the governor requiring lubrication.

With the output shaft stopped, fill the governor sump through the hinged cap oiler until the oil begins to drip out of the oil level hole. When the sump is full, the oil will drip from the oil level hole. The plug should be installed and tightened sufficiently to prevent oil leakage.

NOTE: Care should be taken to remove all dirt or foreign material from the governor openings before filling or checking the oil level.

The bearing surfaces of the speed adjusting shaft should be lubricated by a hand oiler with engine oil. Rod end ball joints are sealed assemblies and do not require lubrication. The throttle control lever and the levers surrounding its shaft should be lubricated with all purpose grease through the grease fitting.

DISASSEMBLY

After removing the governor and before removing any parts from the governor, wash the entire unit with clean fuel oil and dry it with compressed air. Then inspect for worn or damaged parts that can be repaired or replaced without complete disassembly. The output shaft governor may be disassembled. To disassemble, proceed as follows:

1. Remove the two socket head screws (Figure 3.) and lock washers that secure the speed adjusting shaft bracket to the governor body. Unhook the speed adjusting spring from the speed adjusting spring lever and the spring lever while removing the bracket.
2. Remove the speed adjusting shaft bracket retaining snap ring from the speed adjusting shaft using snap ring pliers J 4880. Remove the washer and slide the bracket from the shaft.
3. If desired, note the position of the speed adjusting spring lever on the speed adjusting shaft and, using a small punch, drive out the 5/32″ roll pin that retains the lever to the speed adjusting shaft. After removing the roll pin, it will then be necessary to tap the end of the shaft with a soft hammer to facilitate the removal of the lever. The minimum and maximum speed adjusting screws may be removed from the speed adjusting spring lever, if desired.

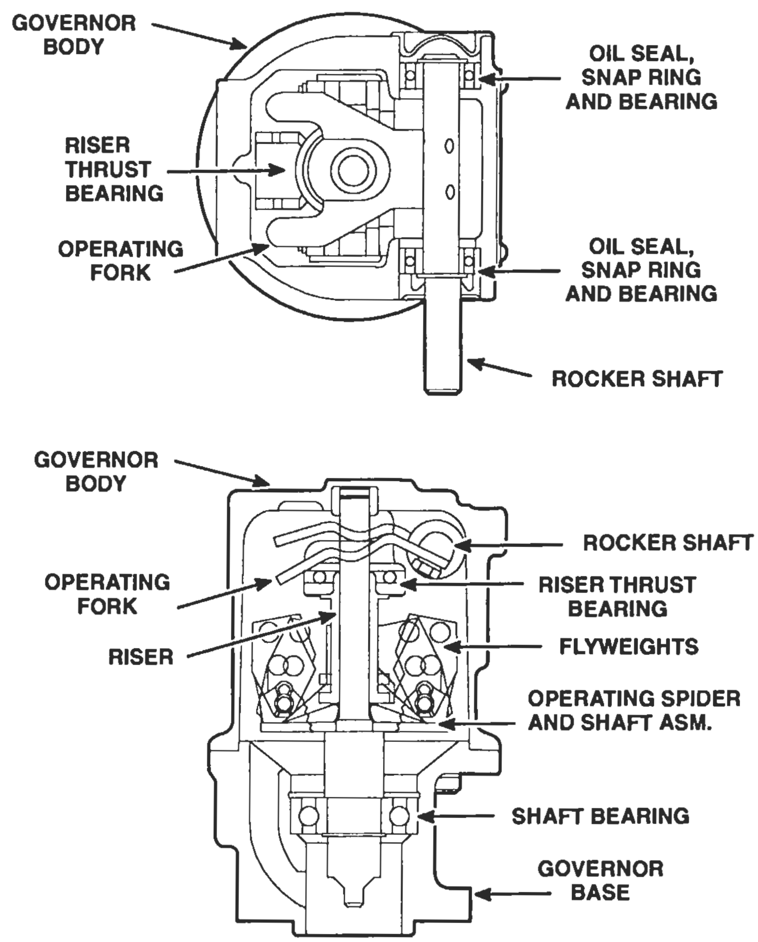

Figure 3. Governor Cross–Section

4. Remove the four socket head screws and lock washers that secure the governor base to the body. Remove the body–to–base gasket. Remove the riser and thrust bearing from the governor operating spider and shaft assembly.
5. Remove the two bolts and lock washers that secure the operating fork to the rocker shaft.
6. Drive lightly against the lower edge of the oil seal plug with a small punch to force the upper edge of the plug outward. Then place a screwdriver behind the plug and force it out of the governor body.
7. Remove the bearing retaining snap ring from the rocker shaft.
8. Tap the end of the rocker shaft gently and withdraw the shaft from the governor body. If the governor body is placed in a vise, care must be taken not to overtighten the vise as this could distort the aluminum body.
9. Remove the rocker shaft inner and outer bearings. The outer bearing may have to be tapped slightly to free it from the governor body.

SECTION 2.7.4 – MECHANICAL OUTPUT SHAFT GOVERNOR

DISASSEMBLY (CONT.)

10. Remove the snap ring, rubber oil seal (Figure 4.) and oil seal retainer from the governor rocker shaft.
11. Use a small punch and drive out the 5/32 inch roll pins that secure the spring lever and rocker shaft lever to the rocker shaft after noting the relationship of the levers on the shaft. Then tap the end of the rocker shaft with a soft hammer to facilitate the removal of the levers from the shaft.
12. Secure the governor base in an inverted position in a vise and remove the lower bearing retaining snap ring using tool J 4880.
13. Tap the splined end of the operating spider and shaft assembly lightly to loosen the shaft from the bearing. Remove the operating spider and shaft assembly.
14. Invert the governor base in the vise and remove the internal snap ring retaining the upper bearing.
15. Gently press the bearing out of the counterbore in the governor base.
16. Remove the eight hair pin clips that secure the weights on their supporting pins. Then using a 5/32 inch punch, gently tap out the four flyweight supporting pins.
17. Carefully support the lower side of the riser thrust bearing in an arbor press. Then using a 7/16 inch rod, gently press the riser from the inner race of the bearing. Use extreme care to prevent damage to the bearing shoulder of the riser.
18. Remove the nut and washer from the tachometer connection and remove the connection from the inside governor body.

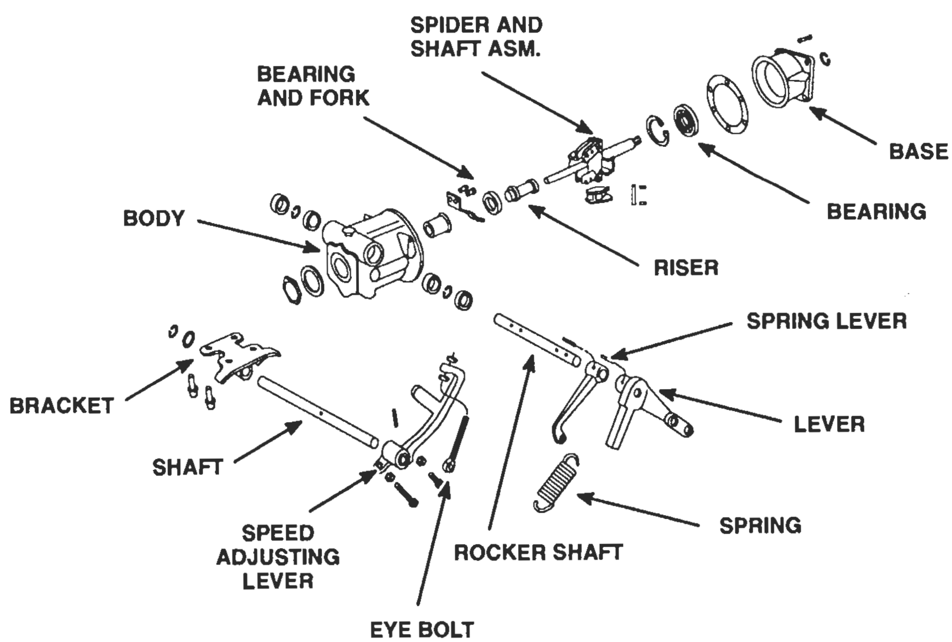

Figure 4. Output Shaft Governor and Components

INSPECTION

After the governor assembly has been disassembled, thoroughly clean each piece in fuel oil and dry with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Inspect the rocker shaft bearings for excessive wear. Replace them, if necessary.

Inspect the operating shaft bearing for excessive wear.

Inspect the rubber oil seal on the governor rocker shaft. The slightest wear on this part can cause oil leakage. It is recommended that when overhauling a governor, a new oil seal be installed.

Inspect the tachometer connection for wear to either the bushing or oil seal. If either part appears worn or damaged excessively, replace the entire connecting assembly.

Inspect all of the retaining snap rings to determine if they have been damaged at the time of disassembly. Replace them, if necessary.

Inspect the riser bearing surface of the flyweights for excessive wear or a flat spot. If either condition exists, new weights must be installed. The flyweights must work freely on their supporting pins for satisfactory governor operation.

Inspect the governor operating fork for excessive wear or distortion. If either condition exists, install a new fork.

Inspect the governor body for distortion or damage to the bearing seating surfaces and replace it, if necessary.

ASSEMBLY

After all of the parts have been cleaned and inspected, assemble the governor as follows:

1. Place the governor base on a bench, bottom side down, and press the bearing into the base with the stamped side of the bearing inner race facing downward.
2. Install the upper bearing retainer internal snap ring into the base.
3. Replace the flyweights by positioning the operating shaft and spider assembly in a vertical position and install the supporting pins from left to right through the spider and weights. Retain the supporting pins with the hair pin clips at each end.
4. Lubricate the governor spider and operating shaft assembly lightly at the bearing end and, using an arbor press force the shaft gently until it seats on the inner race of the bearing.
5. Install the lower bearing retainer snap ring.
6. Insert the tachometer connector into the governor body and retain it securely with the washer and nut.
7. Slide the spring lever and the rocker shaft lever on the rocker shaft, if removed, and pin the levers to the shaft with new 5/32 inch roll pins.
8. Place the oil seal retainer (lip out) and the oil seal (lip in) on the governor rocker shaft. Install the outer bearing retainer snap ring on the governor rocker shaft, taking precaution against damaging the bearing surface.

ASSEMBLY (CONT.)

9. Place the outer rocker shaft bearing on the rocker shaft with the stamped side of the bearing facing (outward) the snap ring.
10. Place the governor body on a bench, with the name plate up and the body to base gasket surface facing the technician, then insert the rocker shaft into the governor body from the left side until the bearing seats in the bore of the body.
11. Press the rubber oil seal into the governor body. Gently tap around the circumference of the oil seal retainer until it is firmly in place.
12. Place the inner rocker shaft bearing in place on the shaft and gently press it into the governor body with its stamped side outward.
13. Install the inner bearing retainer snap ring on the rocker shaft and install a new oil seal plug, pressing it firmly into the governor body.
14. Place the governor operating fork in the governor body on the flat section of the rocker shaft and securely tighten the retaining bolts.
15. Slide the speed adjusting spring lever, if removed, on the speed adjusting shaft and pin it securely, using a new 5/32 inch roll pin. Install the minimum and maximum speed adjusting screws, if removed.
16. Slide the speed adjusting shaft through the speed adjusting shaft bracket and install the washer and snap ring.
17. Support the riser in a vertical position on an arbor press and place the thrust riser bearing in position on the riser, with the protruding race of the bearing facing upward. Then carefully press the bearing down until it is seated on the shoulder of the riser.
18. Install the riser on the operating spider and shaft assembly.
19. Install a new body–to–base gasket and assemble the governor base to the body using four socket head screws, with the oil drain hole boss in the governor base on the lever side of the governor.
20. Place the governor on a bench with the name plate downward. Hook the speed adjusting spring to the adjusting spring speed lever and rocker shaft spring lever.
21. Install the two socket head screws in the two lower holes of the speed adjusting shaft bracket and fasten them securely to the governor body.
22. Install the governor.

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 (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 rod connected to the injector control tube lever, 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 retighten 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 realign the control tube supporting brackets, then tighten the bolts to correct this condition. Reposition the injector racks after realigning the support brackets.
   e. Replace an injector control tube return spring which has been bent or otherwise distorted. When the injector control tube and the injector racks are free from bind, the control tube will return to the no–fuel position by action of the return spring.

NOTE: Never stretch or tamper with an injector control tube return spring to change its tension. Use a new spring.

   f. Check for bind in the pin which connects the fuel rod to the injector control tube lever. If necessary, remove the pin and polish it with fine emery cloth.

CHECK GOVERNOR OPERATION (CONT.)

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. 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.
   c. If the speed variations are large and erratic and unaffected (except, perhaps, in magnitude) by changes in the speed droop adjustment, or if the governor fails to control the speed at all, replace or overhaul the governor.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

To be certain whether the governor or engine is at fault, install a new governor (with the same part number) and check the performance of the engine.

SG HYDRAULIC GOVERNOR

The governors are a hydraulic type with a speed droop stabilization mechanism (Figure 1.). 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. Move the droop adjusting bracket in to decrease the governor droop and move it in the opposite direction to increase the governor droop.

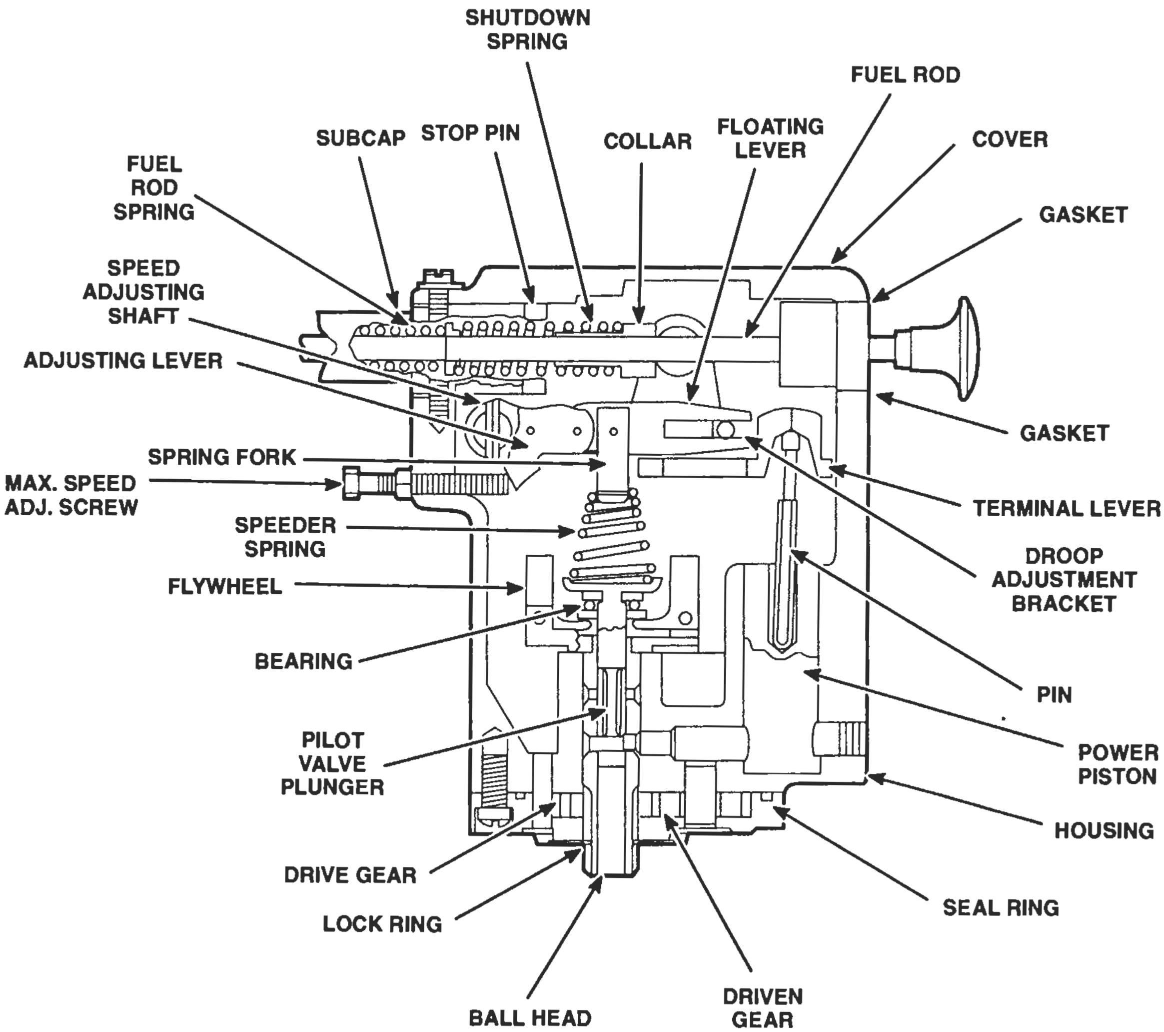

Figure 1. Hydraulic Governor Assembly

SECTION 2.8.1 – SG HYDRAULIC GOVERNOR

SG HYDRAULIC GOVERNOR (CONT.)

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 (Figure 2.).

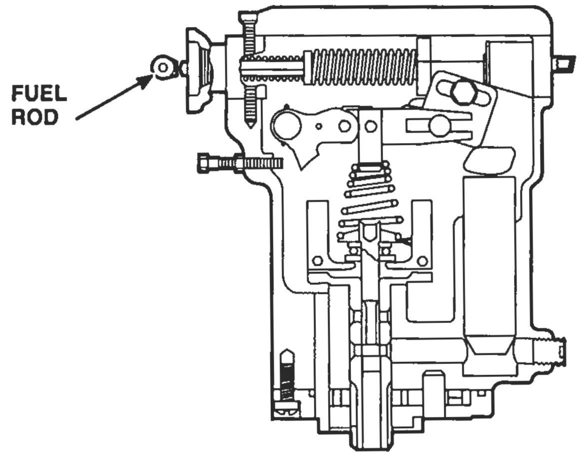

Figure 2. Hydraulic Governor Assembly

The governor is connected to the fuel injectors by a fuel rod attached to a lever on the injector control tube (Figure 3.).

The governor is driven by the upper blower rotor through an integral horizontal drive shaft and bevel gear and an integral vertical driven shaft and bevel gear, both mounted on ball bearings and retained in the drive housing (Section 2.8.3).

When starting a cold engine, considerable 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 not desired, the starting time can be shortened by pressing in on the fuel rod knob. The inward movement of this knob takes the control of the injector fuel racks away from the governor.

The engine can be stopped, regardless of the governor, by pulling out on the fuel rod knob.

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 lubricating oil pressure failure. Should the engine fail to supply oil to the governor, the servo–piston will drop, letting the fuel rod return to the no–fuel position.

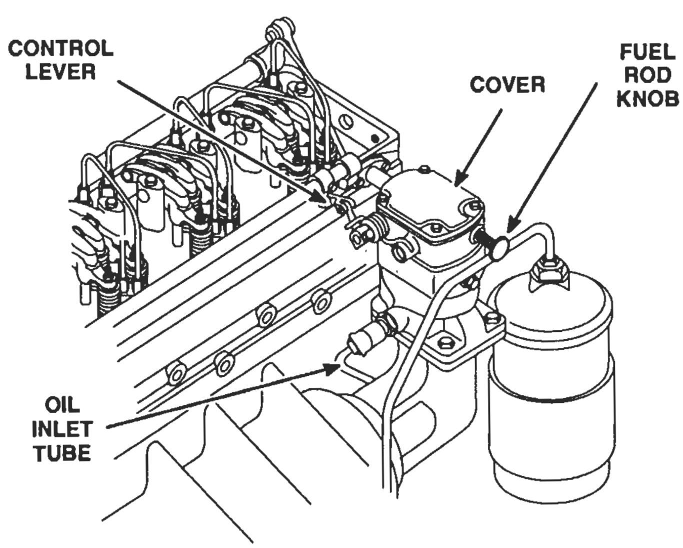

Figure 3. Hydraulic Governor Mounting

OPERATION

5. With the engine operating, oil from the engine lubricating system is admitted to the space around the pump gear. The gears raise the oil pressure to a value determined by the relief valve plunger which opposes the relief valve plunger.
6. The oil pressure is maintained in the annular space between the under cut portion of the pilot valve plunger and the bore in the ball head. For any given throttle setting, the speeder spring has a definite compression 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, thus producing a constant speed condition (Figure 4.)

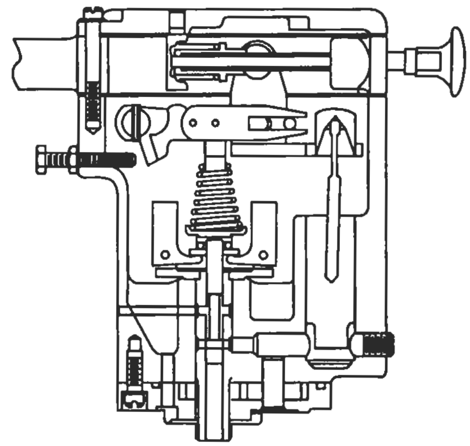

Figure 4. Stable Position of Governor Mechanisms When Engine Load is Constant

7. 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 the lower end of the power piston and force the piston and the floating lever upward (Figure 5.) 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.

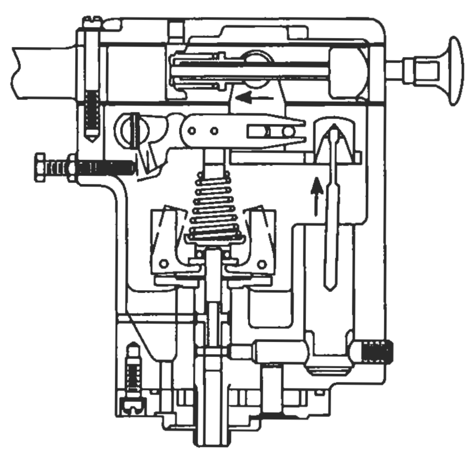

Figure 5. Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

OPERATION (CONT.)

8. As the power piston and floating lever rise, the compression load on the speeder spring is reduced, allowing the flyweights to again move out to their normal vertical position.
9. With the governor weights in a vertical position, the land on the pilot valve plunger will again cover the ports in the ball head, thus 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.
10. The governor reaction as the load on the engine is decreased and the engine speed increases is shown in Figure 6.

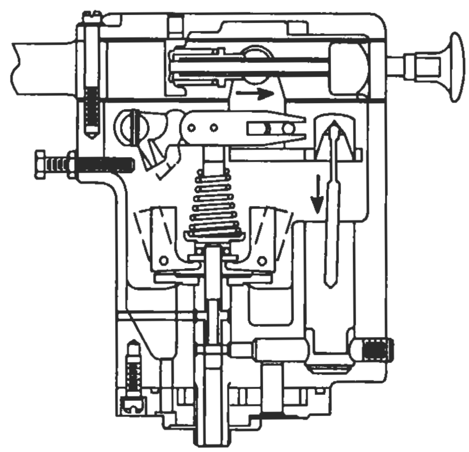

Figure 6. Position of Governor Mechanisms as Load Decreases and Engine Speed Tends to Increase

LUBRICATION

Oil seeping past the power piston and the pilot valve plunger is vaporized by the revolving governor flyweights, thus 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. Oil that collects on the floor of the governor housing passes through a drilled passage into the governor drive housing, providing lubrication for the governor drive and driven shaft beveled gears and their bearings.

The surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and the cylinder block.

REMOVE GOVERNOR

1. Disconnect the fuel rod from the injector control tube lever.
2. Remove the valve rocker cover.
3. Remove the end of the retracting spring from the control lever. Then remove the cotter pin and pin securing the control link to the control lever.

Remove the end of the former retracting spring from the pin securing the throttle link to the control lever. Then remove the pin.

4. Disconnect the oil inlet tube assembly from the governor oil inlet plug (current governor) or from the relief valve assembly (former governor).
5. On a governor equipped with a synchronizing motor, tag and disconnect the wires from the motor.
6. Remove the three cover screws, then lift the governor cover and gasket from the governor housing. Remove the two subcap–to–cylinder head bolts. Remove the two subcap retaining screws (Figure 7.)
7. Lift up on the subcap assembly until a definite snap indicates that the fuel rod and collar have been freed from the terminal lever cross pin. Remove the subcap assembly, pulling the fuel rod out of the hole in the cylinder head and throttle control rod mounting bracket.
8. Remove the four bolts or nuts and lock washers, then lift the governor away from the drive housing. Remove the gasket.

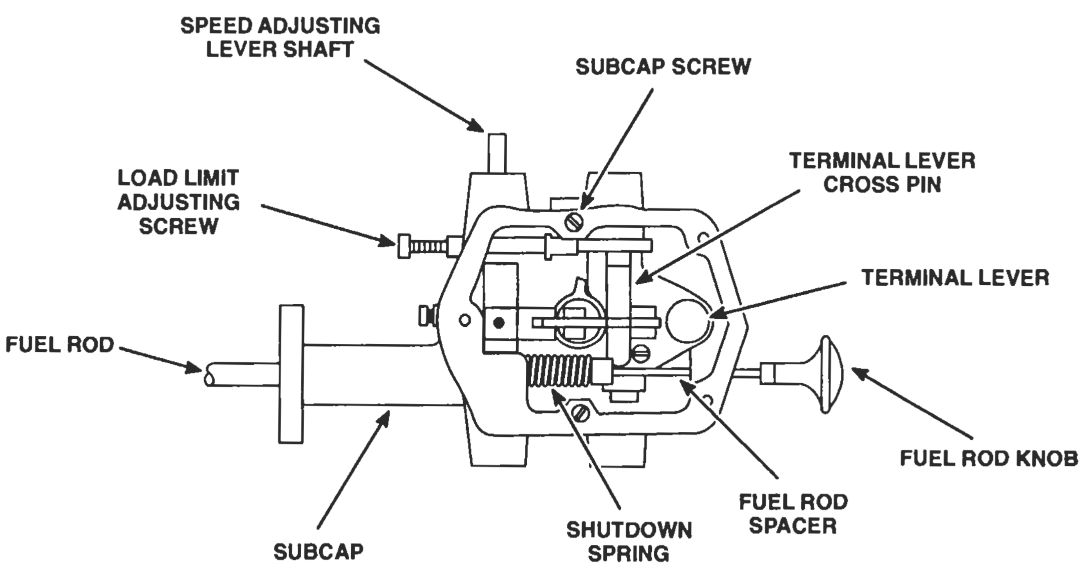

Figure 7. Top View of Current Governor with Cover Removed

DISASSEMBLE GOVERNOR

Before removing any parts from the governor, wash the unit thoroughly in clean fuel oil, dry it with compressed air and inspect it for worn or damaged parts that may be repaired or replaced without completely disassembling the governor.

Governor disassembly need be carried out only as far as necessary to correct the difficulties which interfere with proper governor operation.

Refer to Figure 8. for the location of the governor parts.

Disassemble the governor subcap as follows:

1. Loosen the fuel rod knob locknut and remove the knob and nut from the fuel rod.
2. Slide the fuel rod gasket off of the fuel rod and pull the spacer out of the subcap and off of the fuel rod.
3. Pull the fuel rod out of the subcap and remove the fuel rod collar, shutdown spring, fuel rod disc and the fuel rod spring from the subcap.
4. Loosen the load limit adjusting screw locknut and remove the load limit screw, nut and copper washer from the subcap.
5. If necessary, remove the fuel rod oil seal and the subcap plug from the subcap.
6. Examine the fuel rod bushing in the subcap. If the bushing is worn or damaged, press it out of the subcap with an arbor press.

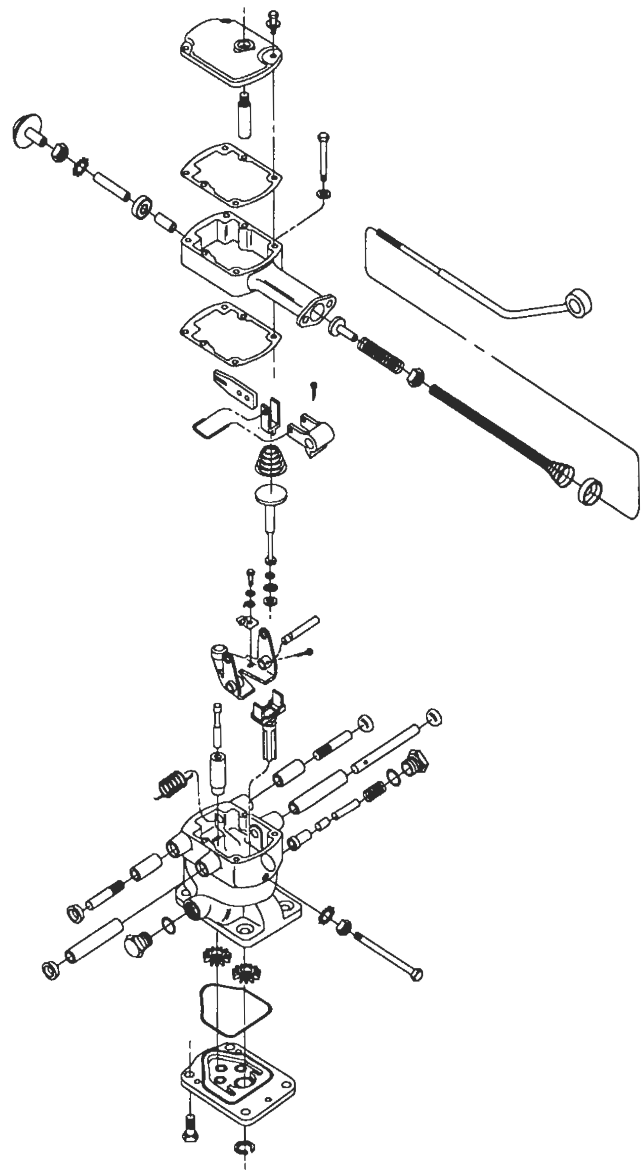

Figure 8. Hydraulic Governor Details and Relative Location of Parts

 May, 1994

CURRENT GOVERNOR

1. Remove the terminal lever cross pin from the arms of the terminal lever.
2. Remove the nut, lock washer and bolt securing the governor control lever to the speed adjusting shaft; then remove the lever and the retracting spring from the shaft.
3. If necessary, remove the oil inlet elbow from the governor housing oil inlet plug.
4. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws (Figure 9.)
5. On a governor equipped with a synchronizing motor, remove the end of the speed adjusting lever retracting spring from the hole in the side of the speed adjusting lever, using a pair of small nose pliers.
6. Loosen the maximum speed adjusting screw locknut and remove the adjusting screw from the governor housing.

NOTE: If the maximum speed adjusting screw is not removed, the speed adjusting lever spring pin will hit the screw when it is being removed from the adjusting lever.

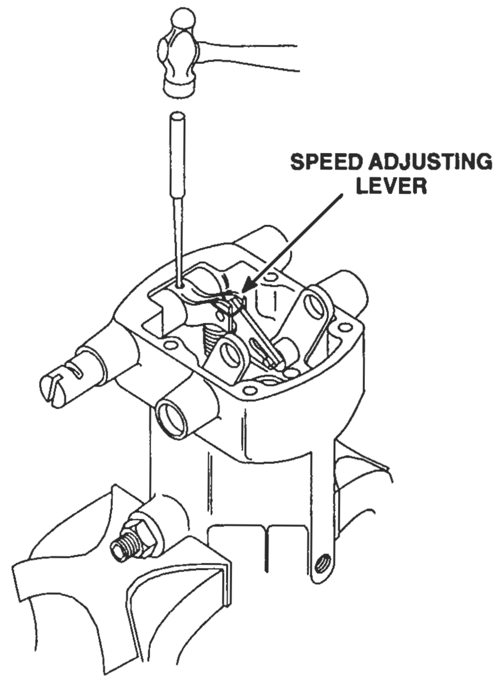

Figure 9. Removing Speed Adjusting Lever Roll Pin

7. Remove the speed adjusting lever roll (spring) pin from the speed adjusting lever and the lever shaft with a small punch and hammer.
8. 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.
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 speed adjusting floating lever and the terminal lever.

CURRENT GOVERNOR (CONT.)

10. Lift the speed adjusting lever, floating lever, spring fork, speeder spring and pilot valve plunger as an assembly from the governor housing (Figure 10.)
11. Remove the pilot valve plunger thrust bearing and the roll spring pin from the governor housing.
12. On a governor equipped with a synchronizing motor, slide the speed adjusting lever retracting spring off of the speed adjusting shaft bushing and remove it from the housing.
13. If necessary, the speed adjusting lever, floating lever, spring fork), speeder spring and pilot valve plunger and spring seat assembly may be disassembled as follows:
    a. Straighten the bent end of the wire pin securing the speed adjusting lever and spring fork to the speed adjusting floating lever.
    b. Pull the pin out of the speed adjusting lever, floating lever and spring fork with a pair of pliers.
    c. Insert a small screwdriver between the spring and fork and pry the speeder spring from the spring fork.
    d. Work a small screwdriver around and under the speeder spring and remove the spring from the pilot valve plunger and spring seat assembly.
14. Remove the two cotter pins securing the terminal lever to the terminal lever shafts.

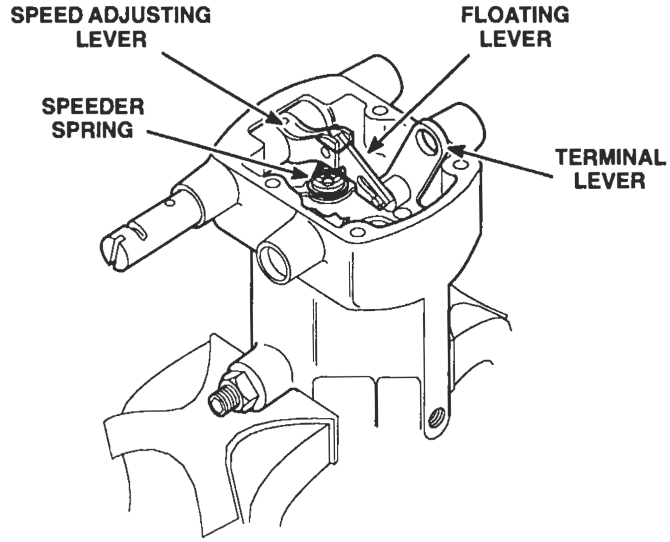

Figure 10. Removing Speed Adjusting Lever, Floating Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly

CURRENT GOVERNOR (CONT.)

15. Place a 1/4 inch brass rod, approximately 5 inch long, against the inner end of the terminal lever shaft. Then drive the governor housing cup plug out of the boss at the side of the housing (Figure 11.)

NOTE: Use care when removing the cup plugs.

16. Remove the remaining governor housing cup plug from the boss in the opposite side of the housing in the same manner as outlined in Step 15.
17. Push the terminal lever shafts out of the terminal lever and housing with the brass rod. Then lift the terminal lever out of the housing. Remove the terminal lever–to–power piston pin from the piston.
18. Remove the governor housing from the bench vise. Turn the governor upside down and remove the power piston from the housing.

NOTE: It may be necessary to tap the face of the governor housing lightly against a wood block to jar the piston out of the housing.

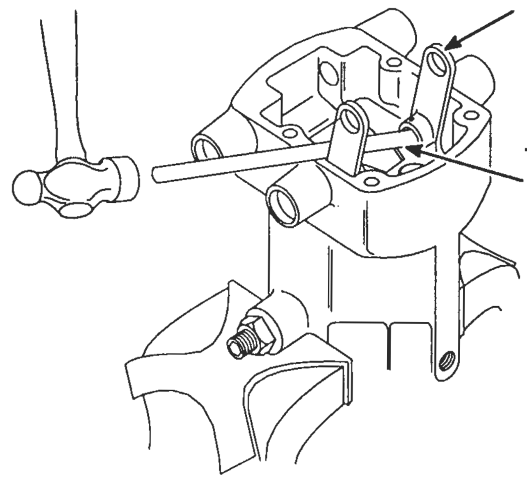

Figure 11. Removing Cup Plug From Governor Housing

19. Place the housing, bottom side up, on a bench.
20. Remove the lock ring from the groove in the shaft of the ball head with a pair of snap ring pliers. Then remove the ball head and flyweight assembly from the housing.
21. Remove the three screws securing the governor base to the governor housing.
22. 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.
23. Remove the oil pump drive and driven gears from the governor base or housing.
24. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise. Remove the oil inlet plug, gasket, relief valve plunger sleeve retaining spring and relief valve plunger spring from the governor housing.
25. Remove the dummy hole plug and gasket from the opposite side of the governor housing. Then insert a small brass rod through the dummy hole opening and push the relief valve plunger and the relief valve plunger sleeve out of the governor housing. Catch the plunger and sleeve by hand when removing them.

NOTE: The relief valve plunger incorporates an No. 8–32 thread to facilitate the removal of the plunger from the housing, if required, without removing and disassembling the governor.

26. If necessary, remove the speed adjusting lever shaft hole plug in the governor housing by inserting a 1/4 inch brass rod through the shaft opening and tap the cup plug out of the housing with a hammer.
27. If necessary, remove the speed adjusting shaft oil seal from the governor housing.

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 lb/in^2 (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 stoning flat areas and rounding off the edges of the plunger.

Examine the oil pump gears and the driven gear bushing for excessive wear and damage.

Examine the power piston and its cylinder (bore) in the governor housing for scoring and burrs. If slightly scored, the areas may be cleaned up with a fine india stone. Care must be used to prevent stoning flat areas and rounding off the edges of the piston.

Examine the ends of the power piston–to–terminal lever pin for wear and scoring. If slightly scored, clean the ends up with a fine india stone. Also, check the pin seats in the terminal lever and power piston for wear and scoring.

Examine the ends of the terminal lever cross pin and the holes in the terminal lever for wear and scoring.

Examine the outside diameter of the ball head and its bore in the governor housing for scoring and burrs. If slightly scored, the areas may be cleaned up with a fine india stone. Care must be used to prevent flat areas and rounding off the edges of the ball head. The current pilot valve plunger has two oil holes to provide additional lubrication to the pilot valve thrust bearings.

NOTE: The pilot valve plunger, power piston and ball head assembly must operate freely in their respective bores.

Examine the pilot valve thrust bearing for excessive wear and flat spots.

Inspect the finished radius (thrust bearing contact surfaces) of the flyweights for excessive wear or flat spots. The flyweights must operate freely on their support pins for satisfactory governor operation.

Inspect the terminal lever and speed adjusting lever shaft bushings in the governor housing. If scored or wom excessively, replace the bushings.

Examine the face of the fuel rod collar where it contacts the terminal lever cross pin for scoring and wear.

Examine the speed adjusting floating lever, spring fork, speed adjusting lever and spring fork pins for scoring and 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 plunger in the former governors did not incorporate four relief holes and the sleeve and washer were separate pieces. Do not mix the former and current plunger and sleeve in a governor.

Inspect the bushings in the terminal lever and speed adjusting shaft sleeve in a former governor.

Check the speed adjusting lever retracting spring for fractured coils.

Examine the shutdown and fuel rod springs for fractured coils.

Inspect the fuel rod bushing and oil seal for excessive wear.

Replace all of the governor parts that are excessively worn or damaged.

ASSEMBLE GOVERNOR

Assemble the governor as follows:

1. If removed, install new speed adjusting lever and terminal shaft bushings in the governor housing to the specified dimensions (Figure 12.)
2. Lubricate the two oil pump gears and and place them in their respective positions in the governor base.
3. Place a new seal ring in the groove of the governor base, with the wide side of the seal down in the groove.
4. Set the governor housing on the base with the dowels in the base registering with the holes in the housing and the driven gear stud in the housing registering with the hole in the driven gear. Press the housing down against the base seal ring.
5. Lubricate the outside diameter of the ball head with engine oil. Then insert the end of the ball head and flyweight assembly straight into and through the bore of the governor housing, drive gear and base.

NOTE: It is important when installing the drilled driven gear stud that it be installed with the mark on the stud pointing towards the relief valve side of the governor. Also, that the shaft of the arrow is parallel to a line through the center of the governor and the relief valve.

6. Insert three screws through the governor base and thread them into the governor housing. Turn the ball head assembly while tightening the screws to make sure the ball head assembly revolves freely.

If a bind exists, loosen the screws, tap the sides of the base lightly with a plastic hammer and tighten the screws again. Revolve the ball head assembly again and check for bind. Repeat if necessary until all parts rotate freely.

NOTE: To install a current design governor base on a former design housing or a former design base on a current design housing, No. 3 taper dowel pins must be used. Refer to Figure 13. for fabrication of tools necessary to properly align the base and the housing and proceed as follows:

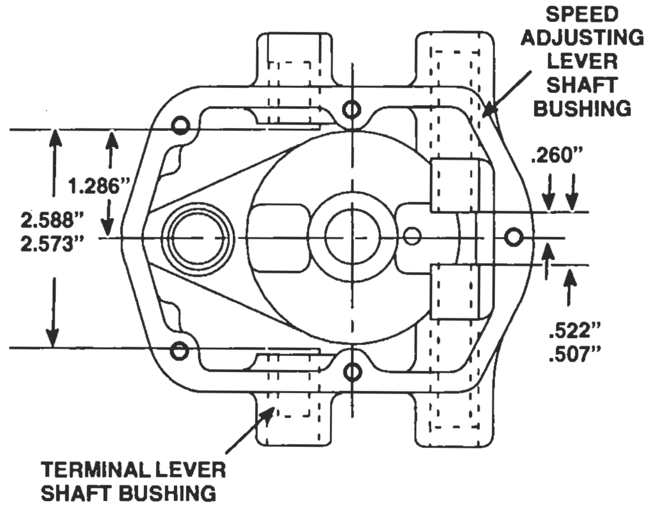

Figure 12. Location of Speed Adjusting Lever and Terminal Lever Shaft Bushing in Governor Housing

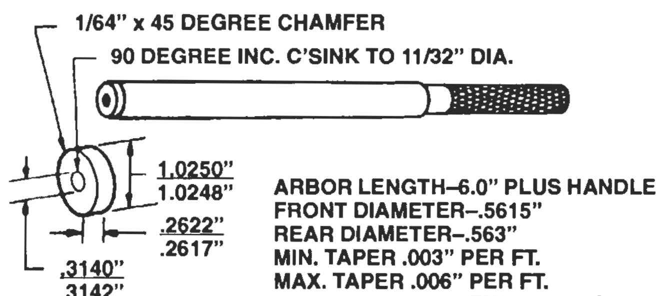

Figure 13. Fabrication of Governor Housing–to–Base Alignment Tool

ASSEMBLE GOVERNOR (CONT.)

a. Position the dummy gear over the idler gear stud.

b. Position the base against the governor housing and align them with the tapered arbor.

c. Enlarge the dowel pin holes to .200–.212 inch diameter and taper ream to allow for a No. 3 tapered pin. Always drill from the base to the housing and be sure the tapered pin is flush with the bottom of the governor mounting flange.

7. Install the ball head lock ring in the groove of the ball head shaft with a pair of snap ring pliers.

8. Install the relief valve plunger (Figure 14.), plunger sleeve, plunger retaining spring, sleeve retaining spring, oil inlet plug and dummy plug in the governor housing as follows:

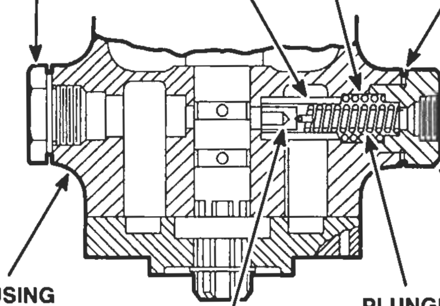

Figure 14. Location of Relief Valve Plunger, Plunger Sleeve, Springs, Oil Inlet Plug and Dummy Plug in Governor

a. Lubricate the outside diameter of the relief valve plunger and plunger sleeve with engine oil. Then insert the relief valve plunger inside of the plunger sleeve.

b. Determine the type of governor being assembled, right–hand or left–hand, then insert the relief valve plunger and sleeve assembly straight into the proper opening in the side of the governor housing with the tapped hole in the relief valve plunger facing out, and push it in against the shoulder in the housing.

c. Place the relief valve plunger spring and the plunger sleeve retaining spring in the housing and against the plunger and sleeve.

d. Place a gasket on the oil inlet plug, then place the plug over the ends of the springs and thread it into the governor housing.

e. Place a gasket on the dummy hole plug and thread it into the opening in the opposite side of the governor housing.

f. Clamp the bottom (square portion) of the governor housing between the soft jaws of a bench vise. Then, tighten the oil inlet plug and dummy hole plug securely.

9. Lubricate the power piston with engine oil, then insert the piston, small end down, straight into the piston bore in the governor housing and push it in until it bottoms.

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ASSEMBLE GOVERNOR (CONT.)

10. Install the terminal lever, terminal lever shafts, cotter pins and cup plugs in the governor housing as follows:

    a. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

    b. Lubricate one of the terminal lever shafts with engine oil. Place the terminal lever in between the ends of the two bushings inside of the governor housing. Then insert the serrated end of the shaft into the bushing in the housing with the cotter pin holes in the shaft and terminal lever in alignment (Figure 15.) Push the shaft into the lever until the two holes are in alignment.

    c. Install a cotter pin through the terminal lever and shaft and bend the ends over against the side of the terminal lever.

    d. Install the second terminal lever shaft in the housing and terminal lever at the opposite side of the governor housing in the same manner as outlined in Steps b and c.

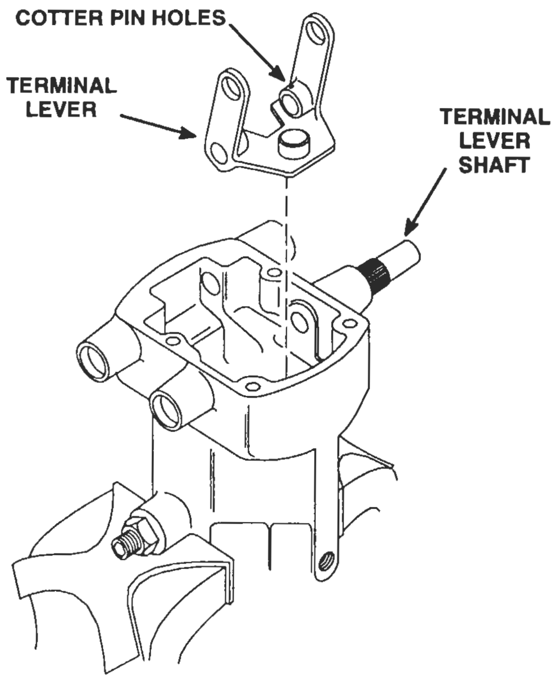

Figure 15. Installing Terminal Lever Shaft in Governor Housing and Terminal Lever

    e. Apply a thin coat of sealing compound to the outside diameter of a new governor housing cup plug. Start the plug, open end out, straight into one of the shaft openings, then press the plug in flush with the outside face of the housing boss.

    f. Install the second new governor housing cup plug in the boss at the opposite side of the housing in the same manner as described in Step e.

11. Lubricate the terminal lever–to–power piston pin with engine oil. Raise the edge of the terminal lever and insert the pin in the hole in the power piston, then lower the terminal lever down on the pin.

12. If disassembled, the speed adjusting lever, floating lever, spring fork, speeder spring and the pilot valve plunger may be assembled as follows:

    a. Place the non–slotted end of the speed adjusting floating lever in the slot on the speed adjusting lever so the pin holes are in alignment.

    b. Insert the long end of the speed adjusting lever–to–floating lever wire pin through the pin hole in the speed adjusting lever and floating lever.

    c. Place the speed adjusting floating lever in the slot of the spring fork with the pin holes in alignment, then insert the short end of the wire pin through the hole in the spring fork and the floating lever.

    d. Push the wire pin in against the speed adjusting lever and spring fork and bend the protruding end of the pin over toward the slotted end of the floating lever.

    e. Press the lower end of the spring fork into the small end of the speeder spring. Then insert the opposite end of the spring in the spring seat of the pilot valve plunger.

SECTION 2.8.1 – SG HYDRAULIC GOVERNOR

ASSEMBLE GOVERNOR (CONT.)

13. Remove the governor housing from the bench vise and place it on its side, oil inlet plug side up, on a work bench with the top of the housing facing out.

14. On a governor equipped with a synchronizing motor, place the speed adjusting lever retracting spring over the speed adjusting lever shaft bushing in the governor housing, with the hooked end of the spring over the slot between the two shaft bushings (Figure 16.)

15. Lubricate the pilot valve plunger thrust bearing with engine oil and place it over the end of the pilot valve plunger with the smallest (outside diameter) bearing race next to the spring seat.

16. Lubricate the pilot valve plunger with engine oil. Then hold the thrust bearing against the spring seat and insert the assembly in the governor housing with the speed adjusting lever facing the two bushings inside the housing. 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.

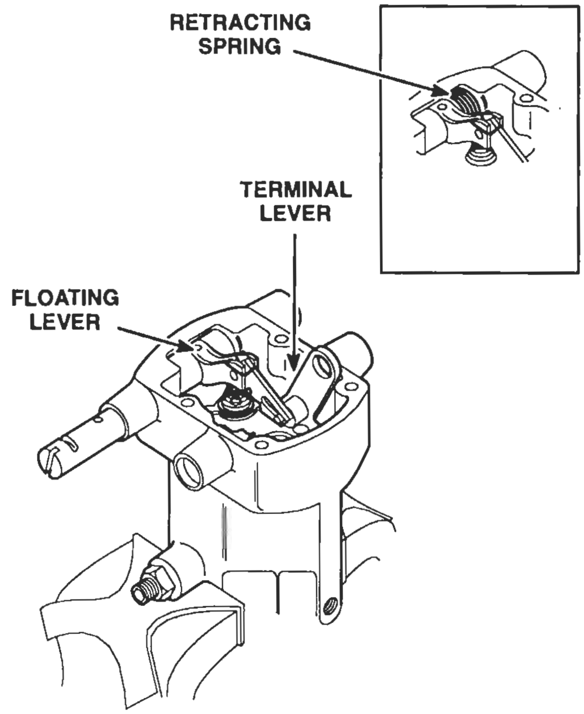

Figure 16. Installing Speed Adjusting Lever, Floating Lever, Speeder Spring and Pilot Valve Plunger Assembly

17. Install the speed adjusting lever shaft, roll (spring) pin and cup plug in the governor housing as follows:

    a. Clamp the governor housing and base assembly in a bench vise equipped with soft jaws.

    b. Lubricate the speed adjusting lever shaft with engine oil. Rotate the shaft so the machined slot in the outside diameter of the shaft is in the same position it was in at the time of removal. Then insert the shaft in the shaft bushing in the housing from the oil inlet plug side, with the roll pin hole in the shaft and lever in alignment (Figure 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.

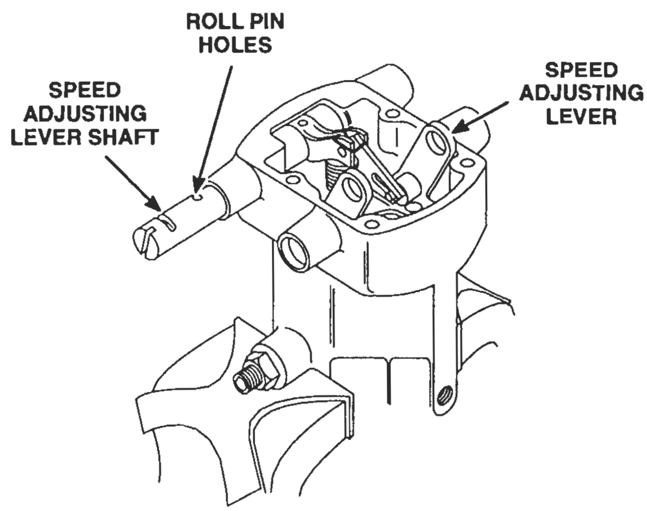

Figure 17. Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever

NOTE: 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.

ASSEMBLE GOVERNOR (CONT.)

d. Start the speed adjusting lever roll (spring) pin straight into the pin hole in the lever; then, tap the pin through the lever and shaft until it is flush with the top of the lever.

e. On a governor equipped with a synchronizing motor, rotate the speed adjusting lever retracting spring clockwise around the shaft bushing and insert the hooked end of the spring in the small hole in the side of the speed adjusting lever with a pair of small nose pliers.

f. If removed, apply a thin coat of sealing compound to the outside diameter of the speed adjusting lever shaft cup plug. Start the plug, open end out, straight into the boss in the opposite side of the governor housing, then press the plug in flush with the edge of the boss.

g. If removed, apply a thin coat of sealing compound to the outside diameter of the speed adjusting shaft oil seal. Place the oil seal, lip of seal facing in, over the end of the speed adjusting shaft and start it in the bore in the housing, then press the seal in flush with the edge of the boss.

18. Place the flat side of the speed droop adjusting bracket against the top (bolting) surface of the terminal lever, with the pin in the bracket in the slot of the speed adjusting floating lever. Secure the bracket to the terminal lever with a flat washer, lock washer and screw.

19. If removed, thread the locknut on the maximum speed adjusting screw. Place the copper washer on the adjusting screw, then thread the screw approximately half way in the governor housing.

20. Install the terminal lever cross pin through the pin holes of the terminal lever, with the fuel rod slot in the pin facing up.

ASSEMBLE GOVERNOR SUBCAP

1. If removed, press a new fuel rod bushing in the subcap, flush with the bottom of the counterbore. Then press a new fuel rod oil seal, with the lip of the seal facing out, straight in and against the bottom of the counterbore in the subcap.

2. If removed, apply a thin coat of sealing compound to the outside diameter of a new governor subcap cup plug. Start the plug, open end out, straight into the plug opening; then, press the plug in against the shoulder in the bore of the subcap.

3. Insert the threaded end of the fuel rod through the hole in the cup plug in the projecting end of the subcap.

4. Place the large end of the fuel rod spring over the threaded end of the fuel rod and push it in against the cup plug in the subcap.

5. Place the fuel rod disc, large outside diameter end first, over the threaded end of the fuel rod and against the fuel rod spring.

6. Place the shutdown spring over the end of the fuel rod and over the end of the fuel rod disc.

7. Place the fuel rod collar, small outside diameter end first, over the end of the fuel rod and inside the shutdown spring.

8. Push the fuel rod through the bushing in the subcap, then slide the fuel rod space over the end of the fuel rod and through the bushing in the subcap.

9. Push the fuel rod through the spacer until the threads on the end of the fuel rod are through the spacer. Then, install the gasket, locknut and fuel rod knob on the end of the fuel rod.

10. If removed, thread a locknut on the load limit screw. Place the copper washer over the end of the load limit screw, then thread the screw into the subcap until the end protrudes approximately 1/8 inch through the second boss inside the subcap.

INSTALL GOVERNOR

Proceed as follows:

1. Loosen the six governor drive housing–to–blower cover bolts.
2. Affix a new gasket to the top of the governor drive housing.
3. Position the governor over the drive housing with the maximum speed adjusting screw facing the cylinder head. 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 rest the governor housing on the gasket.
4. Install the four governor to to drive housing bolts and lock washers. Tighten the bolts to 13–17 lb·ft (18–23 N·m) torque.
5. Affix a new subcap–to–governor housing gasket to the top face of the housing.
6. Affix a new gasket to both sides of the throttle control rod mounting bracket, then place the bracket over the end of the throttle rod.
7. Start the fuel rod through the opening in the throttle control rod mounting bracket and the cylinder head.

Push in on the fuel rod knob and at the same time lower the subcap down on the governor housing so that the fuel rod enters the slot in the terminal lever cross pin and the fuel rod collar rests in the front side of the collar adjacent to the side of the terminal lever.

8. Install the two subcap–to–governor housing screws and lock washers. Tighten the screws securely.
9. Insert the two bolts and lock washers through the subcap bolting flange and throttle control rod mounting bracket and thread them into the cylinder head. Tighten the bolts to seven–nine lb·ft (10–12 N·m) torque. Then tighten the governor drive housing to blower cover bolts to 13–17 lb·ft (18–23 N·m) torque.
10. If removed, install the oil supply tube elbow in the governor oil inlet plug. Then attach the oil inlet tube assembly to the elbow.
11. Place the control lever retracting spring over the end of the speed adjusting shaft with the hooked end of the spring facing out.
12. Place the control lever over the end of the speed adjusting shaft and install the bolt, lock washer and nut. Tighten the nut to seven–nine lb·ft (10–12 N·m) torque.
13. Place the throttle link over the end of the control lever and install the link pin and cotter pin, if used.
14. Place the straight end of the retracting spring on top of the boss at the side of the housing. Then, hook the opposite end of the spring over the control lever.
15. Connect the fuel rod to the injector rack control tube lever with a pin and a cotter pin.
16. Pour approximately one pint of engine lubricating oil in the top of the governor to provide initial governor lubrication.
17. Affix a new gasket to the top of the governor subcap. Place the governor cover on top of the gasket and install the three screws and lock washers. Tighten the screws securely.
18. On a governor equipped with a synchronizing motor, connect the wires to the motor.
19. 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 PSG hydraulic governor is the isochronous hydraulic type with speed droop stabilization (Figure 1.) Hydraulic action is transmitted by oil which is admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The 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, providing the load is within the rated capacity of the power generator.

The mechanical connection of the governor to the fuel injectors is by means of a fuel rod attached to a lever on the injector control tube.

The governor operates in such a manner that fuel supplied to the injectors is decreased by action of a fuel rod spring and increased by the opposing action of the hydraulic operated power piston. Admission of oil under the power piston is controlled by the vertical movement of the pilot valve plunger. This plunger is in turn, controlled by the flyweights. The flyweight ball head is mounted on the pilot valve bushing.

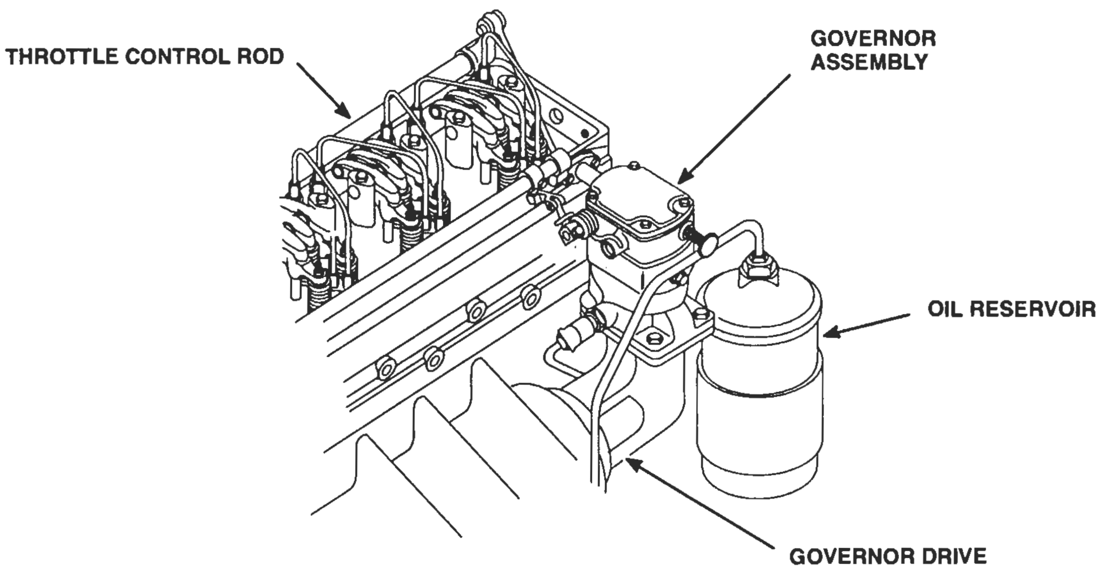

Figure 1. Typical PSG Hydraulic Governor Mounting

Rotation of the governor is accomplished by the upper blower rotor through an integral horizontal drive shaft and bevel gear and an integral vertical driven shaft and bevel gear both mounted on ball bearings and retained in a drive housing.

In starting a cold engine, considerable time is required for the lubricating oil pressure to become sufficient to operate the governor and thus move the injector control racks to the full–fuel position so the engine can start. Since this delay in starting is considered objectionable, the starting time can be shortened by pressing in on the knob which is threaded on the fuel rod and projects from the side of the governor subcap. The inward movement of this knob takes the control of the injector fuel racks away from the governor.

The engine can be stopped in a similar manner, regardless of the governor, by pulling out on the fuel rod knob.

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 lubricating oil pressure failure. Should the engine fail to supply oil to the governor, the power piston will drop, thus allowing the fuel rod 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 drive and driven oil pump gears. The gears raise the oil pressure to a value determined by the spring in the relief valve opposing the relief valve plunder. The oil, now under pressure, is maintained in the annular space between the undercut portion of the pilot valve plunger and the bore in the pilot valve bushing (Figure 2.)

For any given throttle setting, the speeder spring has a definite compression value which is opposed by the centrifugal force of the flyweights. When these two forces are equal, the control land on the pilot valve plunger covers the lower ports in the pilot valve bushing.

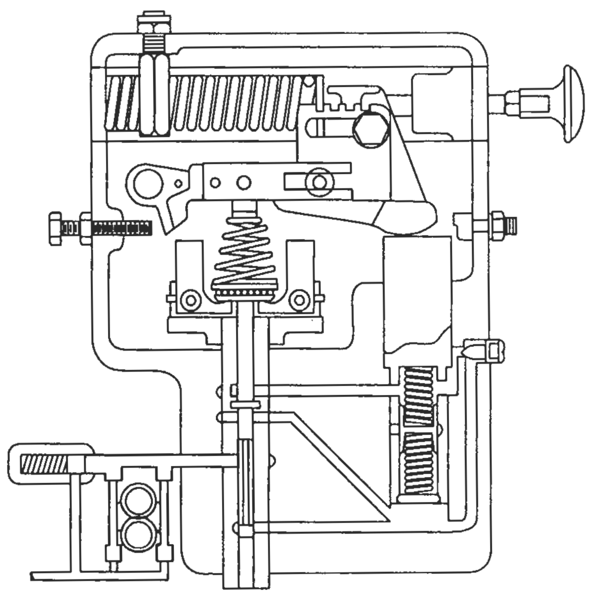

Figure 2. Stable Position of Governor when Load on Engine is Constant

OPERATION (CONT.)

Under these conditions equal oil pressures are maintained on both sides of the buffer piston and tension on the two buffer springs is equal. Also, the oil pressure is 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 engine speed remains constant.

Assume that a load increase (Figure 3.) 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 power piston causing it to rise. This upward motion of the power piston will be transmitted through the terminal lever and the fuel rod to the injector control tube, causing the fuel setting of the engine to be increased.

Oil, forcing the power piston upward also forces the buffer piston upward because the oil pressure on the two sides of the buffer piston are unequal.

This upward motion of the piston compresses the buffer spring and relieves the pressure on the lower buffer spring.

The oil cavities above and below the buffer piston are common to the receiving compensating land on the pilot valve plunger. Since the high pressure is below the compensating land, the pilot valve plunger is forced upward, centering the flyweights and causing the control land of the pilot valve to close off the regulating port; thus the upward movement of the power piston stops when it has moved far enough to make the necessary fuel correction.

Oil passing through the compensating needle valve equalizes the pressures 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.

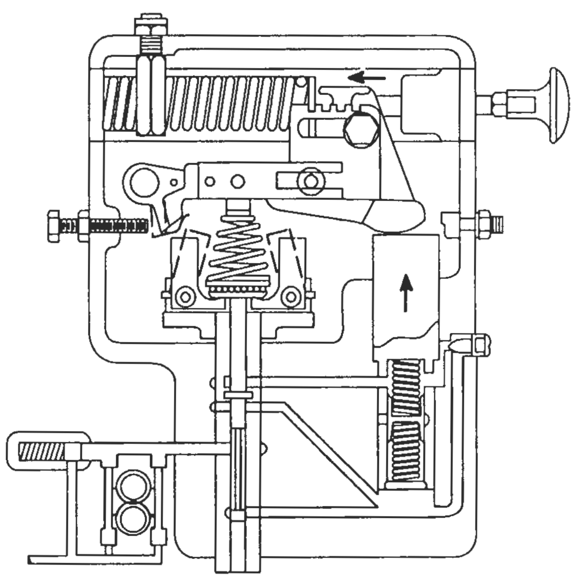

Figure 3. Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

OPERATION (CONT.)

The governor reaction changer as the load on the engine is decreased and engine speed returns to normal (Figure 4.) With a load decrease the engine speed will momentarily increase and the flyweights will move outward thus raising the pilot valve plunger.

This allows 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 power piston which is transmitted through the terminal lever to the fuel rod, resulting in a fuel correction to the injectors.

The compensating mechanism described produces stable operation by permitting the governor to move instantaneously in response to a load change and 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 control lever. Movement of the 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.

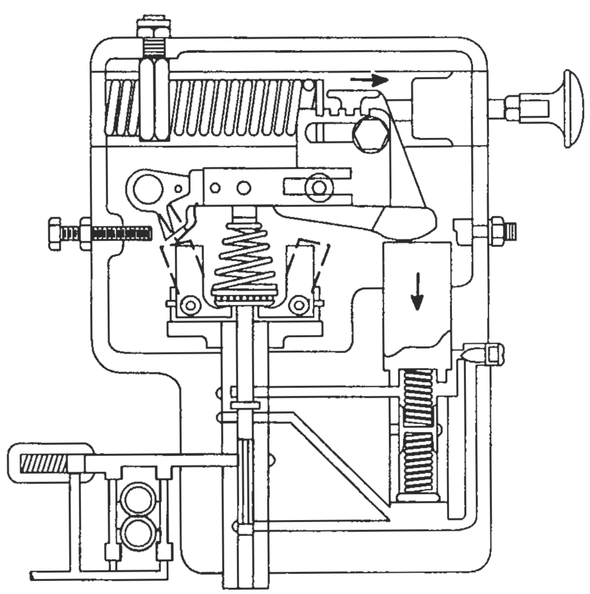

Figure 4. Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

LUBRICATION

Oil passes up through a drilled passage in the pilot valve plunger and is directed at the thrust bearing from where it is vaporized by rotation of the flyweights, resulting in sufficient lubrication of the upper moving parts. Governor pump gears, pilot valve plunger, power piston and buffer piston are all exposed to pressurized oil. Oil which collects on the floor of the governor passes through a drilled passage into the governor drive housing, thus lubricating the governor drive shaft, drive shaft bearing, driven shaft and driven shaft bearing.

Surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and cylinder block.

REMOVE GOVERNOR FROM ENGINE

1. Remove the cotter pin and withdraw the clevis pin that holds the fuel rod to the injector control tube lever.
2. Disconnect the oil pressure line at the governor relief valve.
3. Remove the clevis pin and separate the throttle control link from the control lever.
4. Remove the two subcap–to–cylinder head attaching bolts.
5. Remove the three governor cover bolts and separate the cover and cover gasket from the subcap.
6. Remove the two bolts holding the governor subcap to the governor housing.
7. Lift up on the subcap assembly until a definite snap indicates that the fuel rod has been freed from the terminal lever. Remove the subcap assembly, pulling the fuel rod out of the hole in the cylinder head. Remove the two gaskets.
8. Remove the four bolts and lock washers that secure the governor housing to the governor drive housing and then lift the governor away from the drive housing. Remove the gasket.

INSTALL GOVERNOR ON ENGINE

With the subcap removed from the governor housing, install the governor as follows:

1. Loosen the six governor drive–to–blower attaching bolts with tool J 4242.
2. Place a new gasket on the governor drive housing. Hold the governor so that the relief valve points toward the blower and position the governor over the drive housing. Turn the ball head assembly slightly to align the splines on the pilot valve bushing with the splines in the driven shaft sleeve. Then, set the governor down on the drive housing.
3. Secure the governor to the drive housing with four bolts and lock washers. Tighten the bolts uniformly. On earlier units, the governor was attached to the drive housing by four studs, lock washers and nuts.
4. Affix a new gasket to the top bolting flange of the governor housing.
5. Affix a new gasket on the subcap adaptor and between the cylinder head and the throttle control shaft bracket. Start the fuel rod through the hole in the control shaft bracket and cylinder head and lower the subcap assembly down on the governor housing. At the same time, press in on the fuel knob to allow the fuel rod to enter the slotted position of the terminal lever and the fuel rod collar to rest against the front working face of the terminal lever.
6. Secure the subcap to the governor housing with two bolts.
7. Install two bolts through the subcap adaptor, throttle control shaft bracket and into the cylinder head. Tighten the bolts securely.
8. Pour approximately one pint (1/2 liter) of lubricating oil in the governor housing for initial governor lubrication.
9. Connect the oil line to the relief valve.
10. Place a new gasket on top of the subcap and install the cover. Insert three bolts through the governor cover and subcap and into the governor housing. Tighten the bolts securely.
11. Connect any governor control linkage previously removed.
12. Tighten the six governor drive–to–blower attaching bolts with tool J 4242.

HYDRAULIC GOVERNOR DRIVE

The governor drive assembly consists of an integral horizontal drive shaft and bevel gear and an integral vertical driven shaft and bevel gear, both mounted on ball bearings and contained in a governor drive housing (Figure 1.)

A second bearing is used on the horizontal drive shaft on six cylinder engines to provide additional support.

Drive to the horizontal shaft is through serrations on the shaft engaging with serrations in the upper blower rotor shaft. The governor proper is driven through splines on the lower end of the ball head registering with splines in the upper end of the driven shaft sleeve.

The bearing on the horizontal shaft is retained by two bolts, flat washers, and lock washers and on the vertical shaft by two set screws, flat washers, and lock washers. The drive housing flange at the drive shaft is gasketed and bolted to the blower front end cover, while the governor is gasketed and bolted to the drive housing at the driven shaft opening.

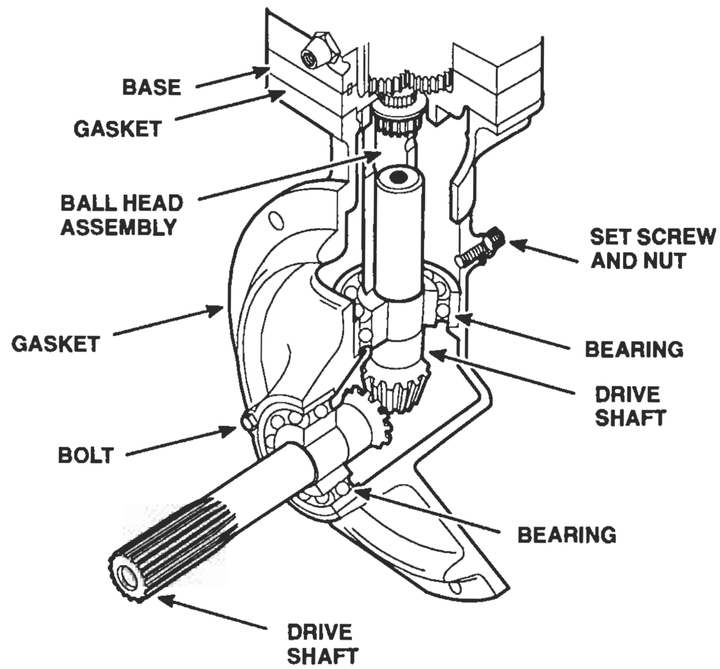

Figure 1. Governor Drive Assembly

LUBRICATION

Gears and bearings of the governor drive assembly are lubricated by surplus oil from the governor which spills over the moving parts and then returns to the engine crankcase through connecting drilled passages in the blower front end plate and cylinder block.

If the governor fails to control the engine speed properly, the fault may lie in the governor drive. To function properly, the clearance between the bevel gears of the drive and driven shafts should not be less than .001 inch or exceed .003 inch.

SECTION 2.8.3 – HYDRAULIC GOVERNOR DRIVE

REMOVE GOVERNOR DRIVE

1. Remove the governor.
2. Remove the six drive housing to blower bolts and plain washers and withdraw the housing assembly from the blower.

DISASSEMBLE GOVERNOR DRIVE

1. Remove the two bearing retaining bolts (Figure 2.) and two set screws.
2. Withdraw the horizontal drive shaft and bearing as an assembly from the drive housing.

The horizontal drive shaft in hydraulic governors used on six cylinder engines is supported in two bearings separated by a spacer; therefore, remove the shaft, bearings, and spacer as an assembly.

3. Withdraw the driven shaft, bearing and sleeve as an assembly from the drive housing.
4. If inspection of the drive and driven shaft bearings, as outlined below, indicate they should be replaced, rest the bearing on the bed of an arbor press and press the shaft from the bearing, using a brass bar between the ram of the press and the shaft.

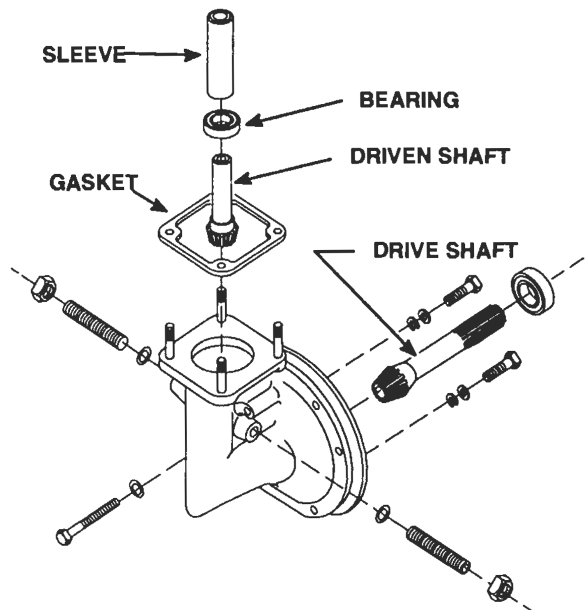

Figure 2. Governor Drive Components

INSPECTION

After the governor drive has been disassembled, wash all 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 lb/in^2 (276 kPa) air pressure.

Examine the gear teeth of the drive and driven shafts for chipping or scoring and, if either of these conditions exists, replace the shafts.

Revolve the bearings by hand to check for excessive wear, bind, or rough spots. If any of these conditions exist, install new bearings.

Slight end play is not objectionable in single row annular ball bearings, since they are built with that characteristic.

If inspection reveals the bearings are in good condition, lubricate them with clean engine oil prior to using.

ASSEMBLE GOVERNOR DRIVE

1. With the drive bearing properly supported on the bed of an arbor press, press the drive shaft into the bearing and against the shoulder on the shaft.
2. Start the driven bearing on the driven shaft followed by the sleeve, then with the sleeve properly supported on the bed of an arbor press, and using a brass bar between ram and gear, press the shaft into the bearing and sleeve.
3. Lower the driven shaft assembly into the governor drive housing from the top with the bearing resting on the shoulder in the housing.
4. Start a nut and flat washer on each retaining screw and thread the screws into the governor housing until they bottom on the outer race of the bearing.
5. Install the horizontal drive shaft assembly in the governor housing with the drive bearing resting in the counterbore provided and with the teeth of the horizontal drive gear in mesh with the teeth on the vertical driven gear.
6. Place a lock washer and flat washer over each bearing retaining bolt and thread the bolts into the governor housing to secure the bearing.

INSTALL GOVERNOR DRIVE

1. Affix a new gasket to the bolting flange of the governor drive housing, then start the serrations of the horizontal drive shaft into mesh with the serrations of the upper blower rotor shaft.
2. Set the drive housing in position against the blower end cover and attach it to the cover with six holes and plain washers. Do not tighten the bolts until the governor has been attached securely to the drive housing and the cylinder head.
3. Install the governor assembly.

HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover (Figure 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.

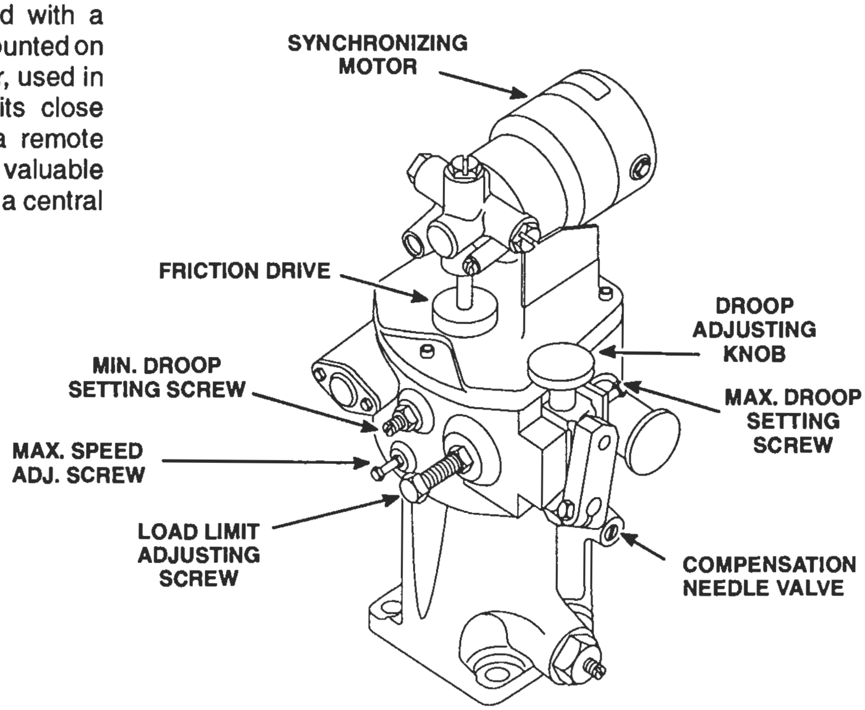

Figure 1. Typical Synchronizing Motor Mounting

The motor is connected to the source of electrical supply through a two–way switch (Figure 2.)

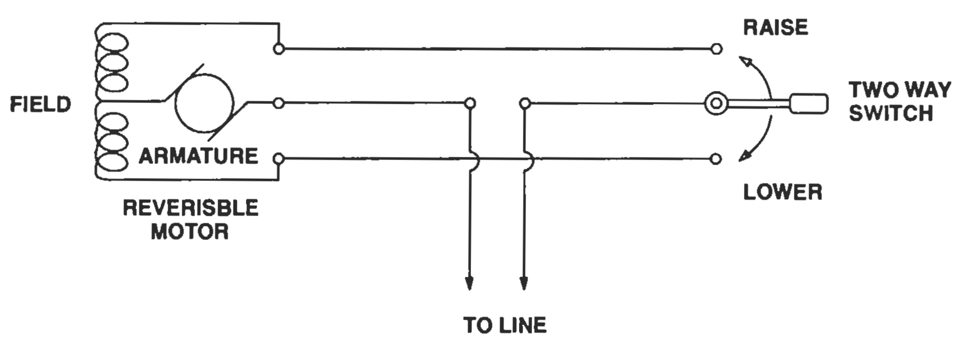

Figure 2. Synchronizing Motor Wiring Diagram

HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR (CONT.)

The friction drive components are assembled to the drive shaft of the current type synchronizing motor and extend down through the governor cover. The speed adjusting screw of the friction drive is threaded into the governor cover and bears directly on the speed adjusting lever (Figure 3.)

The former type synchronizing motor was assembled off–center on the governor cover with the motor drive shaft extending down to a point near the governor speed adjusting shaft. The friction drive components were assembled to the governor speed adjusting shaft and the driving worm pinion was assembled to the end of the motor drive shaft. The speed adjusting shaft was splined to conform with the internally splined speed adjusting lever of the governors using the former type synchronizing motor.

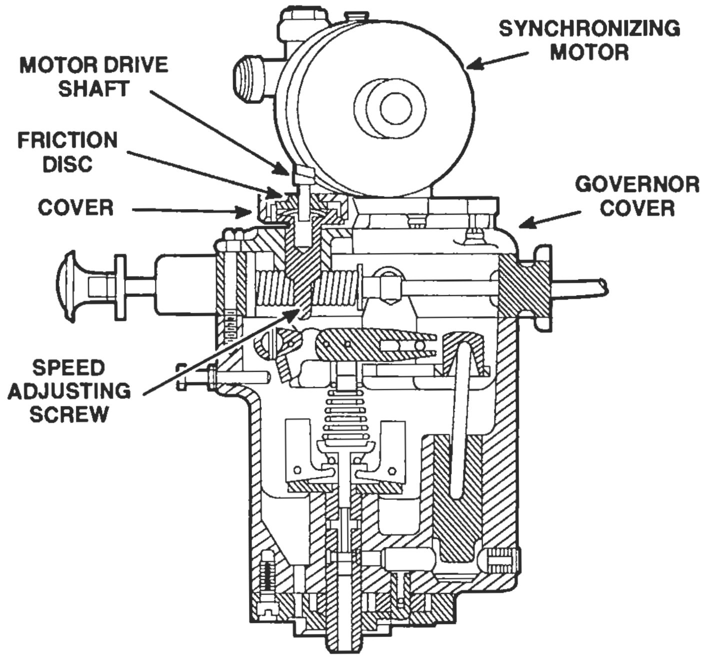

Figure 3. Friction Drive Assembly

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.

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 or slip–clutch must be strong enough to permit the motor to carry the speed adjusting lever up against the maximum speed adjusting screw without slipping, yet it must be loose enough to slip after the lever contacts the screw.

FUEL INJECTOR CONTROL TUBE

The fuel injector control tube assembly is mounted on the cylinder head and consists of a control tube, injector rack control levers, a return spring and injector control tube lever mounted in two bracket and bearing assemblies attached to the cylinder head.

The injector rack control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no–fuel position. The injector control tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to Section 14 for positioning of the injector rack control levers.

Certain engines use a spring–loaded injector control tube assembly (Figure 1.) similar to the above except it has a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector, 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.

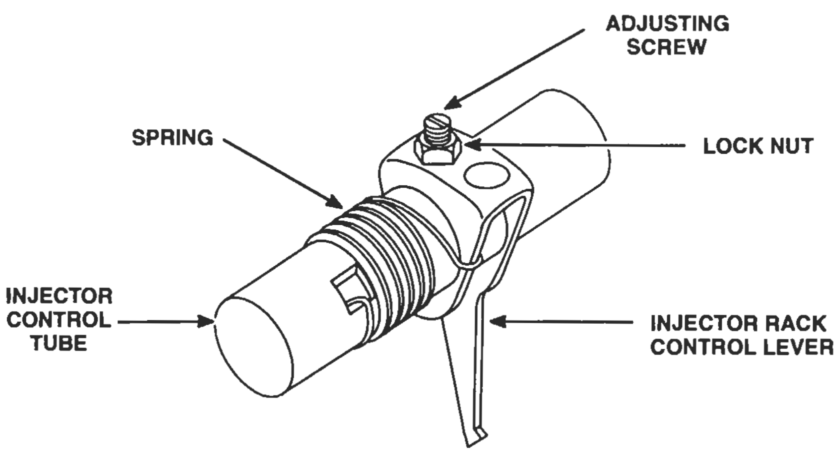

Figure 1. Injector Control Tube and Rack Lever (Spring–Loaded)

NOTE: Do not replace the spring–loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shutoff valve. However, when the spring–loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to .6290 inch and install a 5/8 inch cup plug at each end of the housing.

Engine shut down (normal or emergency) is accomplished on the spring–loaded fuel injector control tube (one screw design) by pulling the governor shutdown lever to the no–fuel position. With the two screw design injector control tube and lever assembly, emergency engine shutdown is accomplished by tripping the air shutoff valve in the air inlet housing. Normal shut down is accomplished by pulling the governor shutdown lever to the no–fuel position.

Adjustment of the single screw and locknut on each injector rack control lever can be performed the same as for the two screw design rack control lever as outlined in Section 14.

SECTION 2.9 – FUEL INJECTOR CONTROL TUBE

REMOVE INJECTOR CONTROL TUBE

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.
2. Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

DISASSEMBLE INJECTOR CONTROL TUBE

The injector control tube, one mounting bracket, a spacer and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the disassembly and assembly procedure for these items is not included in the following:

1. Remove the bracket from the injector control tube.
2. Loosen the adjusting screws or adjusting screw and locknut at each injector rack control lever.
3. With the spring–loaded injector control tube, disconnect the yield springs at each rack lever, then roll the yield springs out of the slots and notch of the control tube.
4. Disconnect the return spring from the bracket and front or rear rack lever.
5. Then, remove the yield springs and/or return spring and rack levers from the control tube.

INSPECTION

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

Examine the control tube, control lever, control tube rack control levers and brackets for excessive wear, cracks or damage and replace them, if necessary. The bearing in the bracket is not serviced separately. Examine the yield springs and/or return spring and replace them if worn or fractured.

ASSEMBLE INJECTOR CONTROL TUBE

With all of the parts cleaned and inspected and the necessary new parts on hand (Figure 2.) and assemble as follows:

1. Two Screw design injector control tube.

Install the rack control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

One Screw and Locknut design injector control tube.

Install the rack control levers with the levers facing the front bracket position and the R. H. helix yield springs.

Then, install the odd (L. H. helix) yield spring and rack control lever with the lever facing the front bracket position.

Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R. H. helix yield springs) in the control tube. Then, turn the adjusting screws and locknuts into the notch and slots far enough to position the levers on the control tube.

2. On both designs, install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the front bracket.

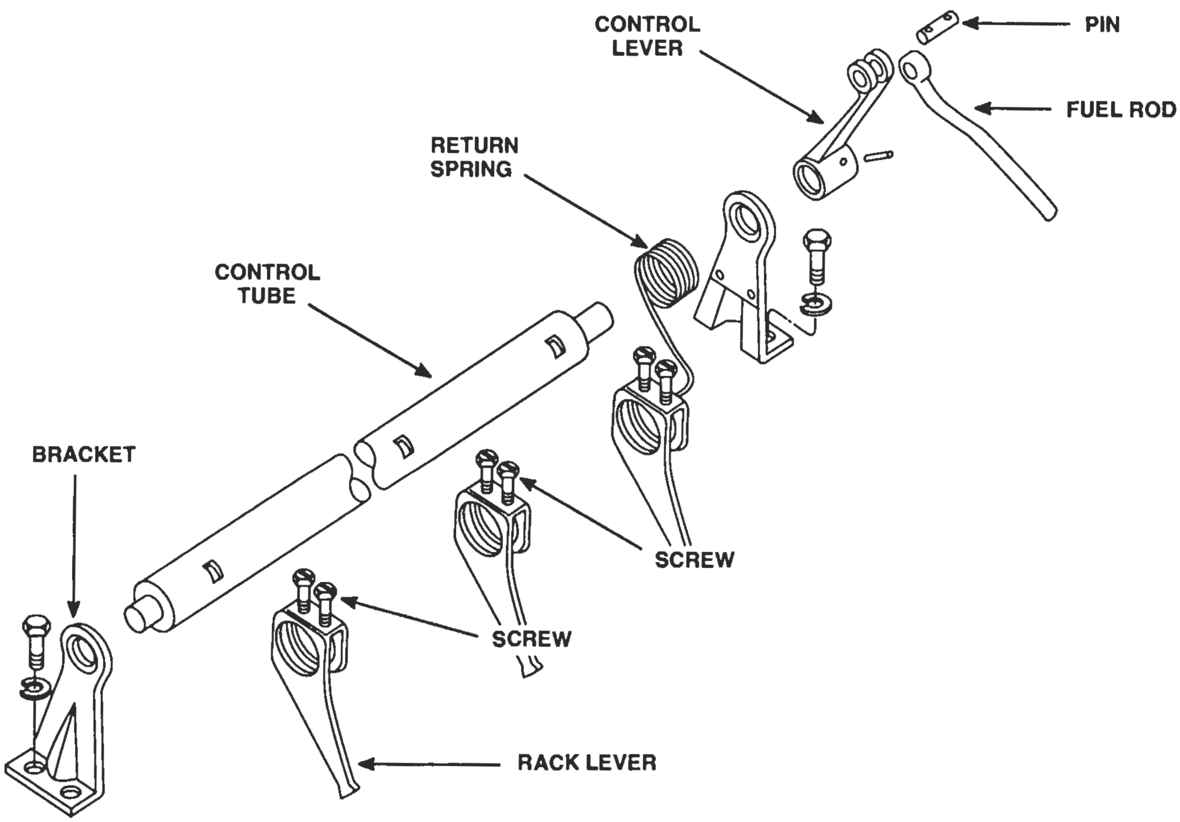

Figure 2. Injector Control Tube Assembly (Non–Spring Loaded)

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 inches long piece of 1/2 inch wide, 1/8 inch thick bar stock (Figure 3.)

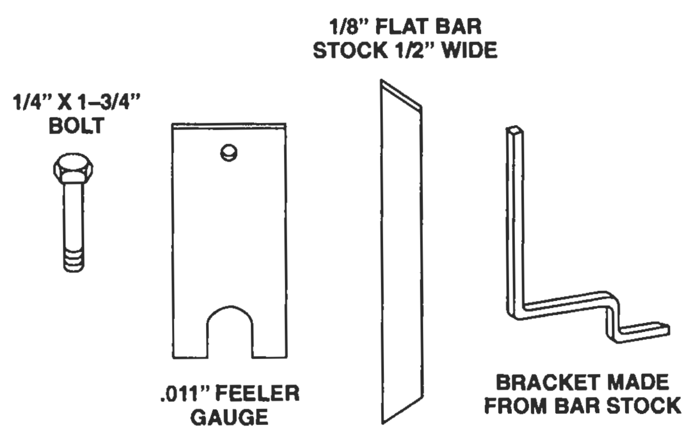

Figure 3. Fabricate Indexing Bracket

3. Secure the indexing bracket to the control tube with a hose clamp (Figure 4.)
4. Insert a 1/4 x 1–3/4 inch 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.

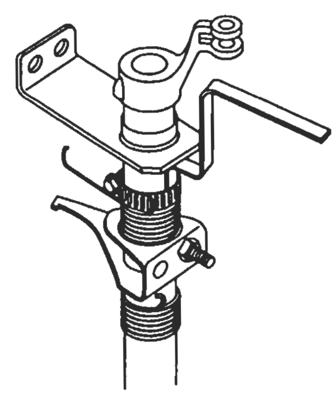

Figure 4. Secure Indexing Bracket to Control Tube

INDEXING A NEW REPLACEMENT CONTROL LEVER TO THE INJECTOR CONTROL TUBE (CONT.)

5. Remove the pin from the control lever and press the old lever off the control tube (Figure 5.)

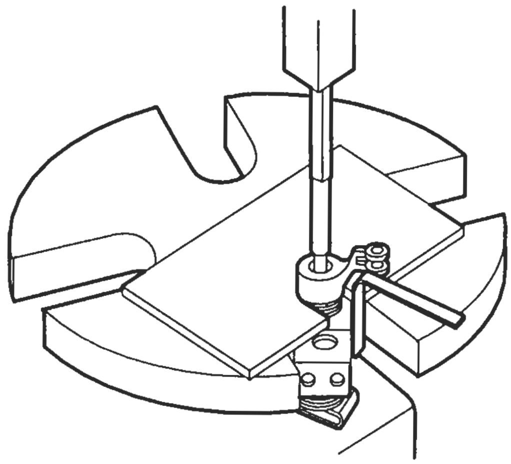

Figure 5. Press Old Lever Off Control Tube

6. Reinsert the 1/4 x 1–3/4 inch 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 (Figure 6.) Place a .011 inch 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.
7. Position the control tube on the table of a drill press and drill a 1/8 inch 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.
8. Clean the control tube thoroughly and install on the engine. Adjust the injector racks as outlined in Section 14.3.

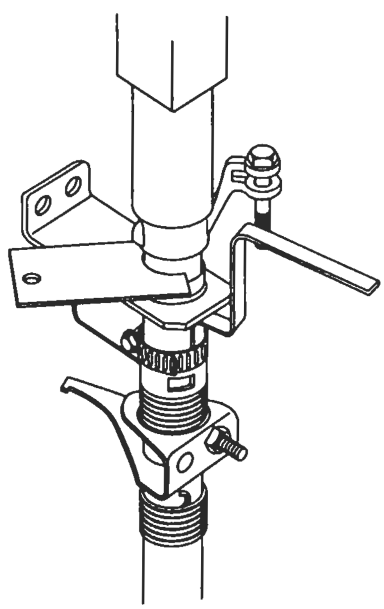

Figure 6. Installing New Lever

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 inch 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.
5. Refer to Section 14 and position the injector rack control levers. Be sure the injector rack control levers can be placed in a no–fuel position before restarting the engine.

CAUTION:

Loss of shutdown control could result in a runaway engine which could cause personal injury.

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

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 (Figure 1.) Position it on the clamping post and tighten the thumb screw into the lower detent position (Figure 3.)
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 inch diameter hole at the far right of the adaptor plate onto the 3/8 inch 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.
6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

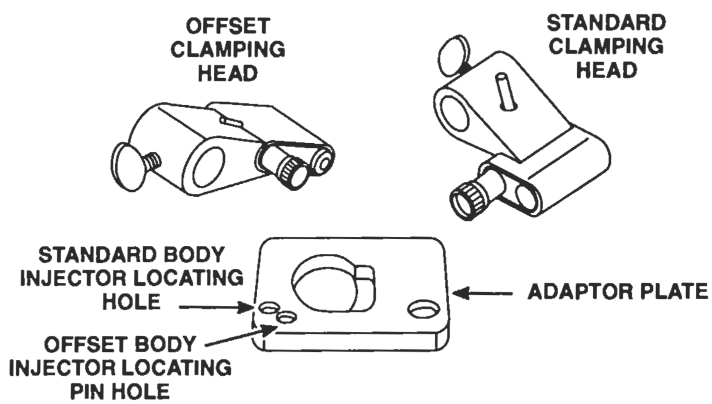

Figure 1. Injector Tester J 23010–A Clamping Heads

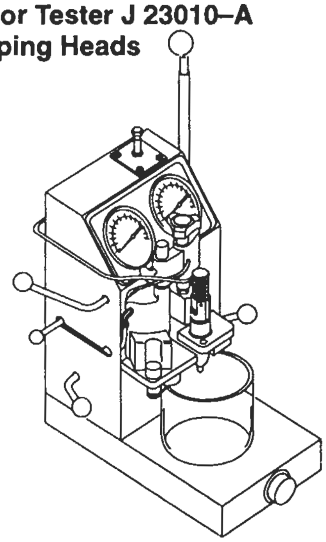

Figure 2. Injector Installed in Tester J 23010–A with Clamping Head

CLAMPING THE FUEL INJECTOR

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)

Align the clamping head seals over the injector filter caps (Figure 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.

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.

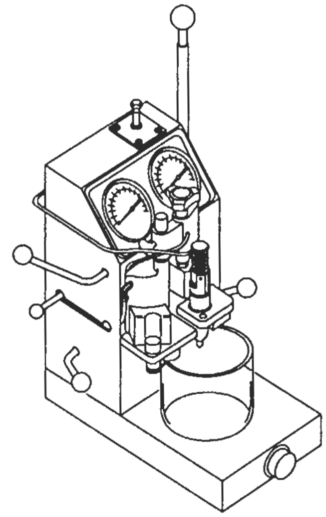

Figure 3. Injector in Position for Testing with J 23010–A

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 lb/in.^{2} (689–1,378 kPa). Check for injector nut seal ring leaks. Then, increase gage reading to 1,500–2,000 lb/in.^{2} (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 1,500 to 1,000 lb/in.^{2} (10,335 kPa to 6,890 kPa). This should not occur in less than seven 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 (Figure 4.)
4. Turn the gage damping valve knob clockwise to the closed position, then open the valve 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.

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.

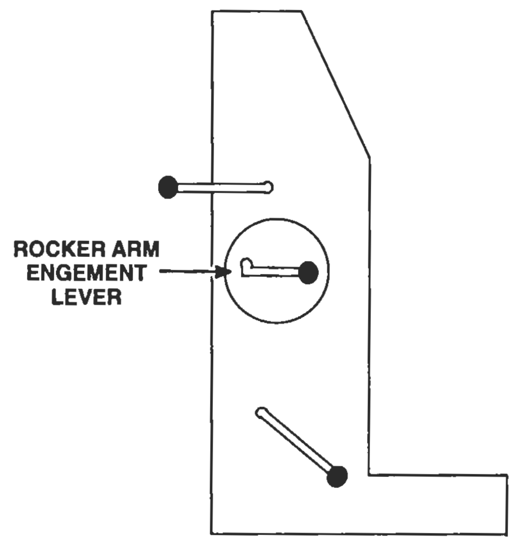

Figure 4. Position of Rocker Arm Engagement Lever

UNCLAMPING THE INJECTOR

1. Open the Thru–Flow valve to release pressure in the system.
2. Move lever 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 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 2,400–2,500 lb/in.^{2} (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 (Figure 5.)

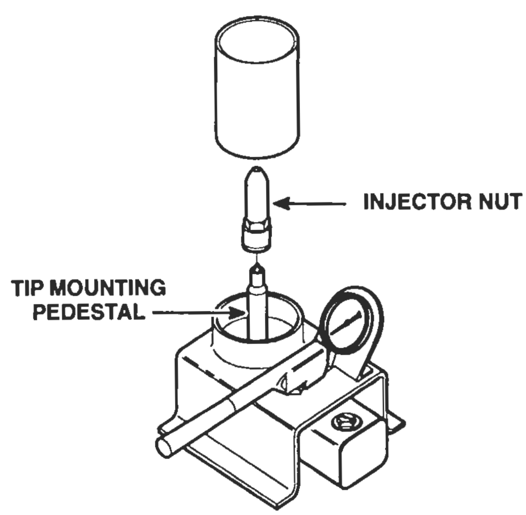

Figure 5. Installing Injector Nut

INJECTOR SPRAY TIP TESTER (J 22640–A) (CONT.)

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 (Figure 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 2,200 and 3,300 lb/in.^{2} (15,158 and 22,737 kPa) except for the L–40 injector needle valve and spring which should open between 1,700 and 2,300 lb/in.^{2} (11,713 and 15,847 kPa). When using the high V.O.P. spring, the oil delivery will occur at 2,900–3,900 lb/in.^{2} (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.

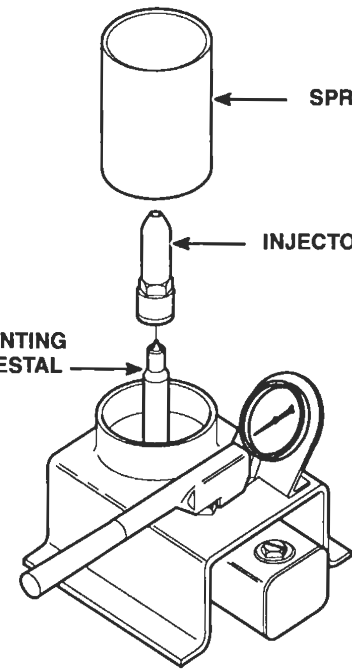

Figure 6. Tester J 22640–A with Shield Installed

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 1,500 lb/in.^{2} (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 permissible.

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 (Figure 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 (Figure 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.

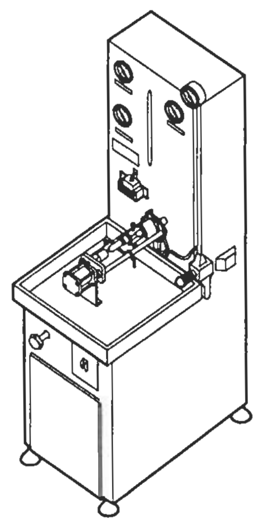

Figure 7. Injector in Calibrator J 22410–A

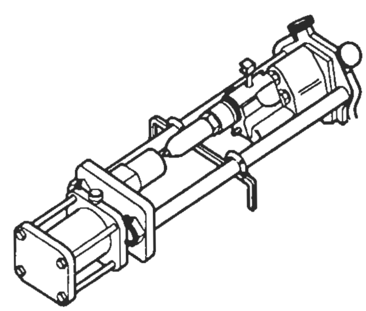

Figure 8. Position of Calibrator Fuel Flow Pipes

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CHECK INJECTOR OUTPUT (CONT.)

Set the counter (Figure 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.

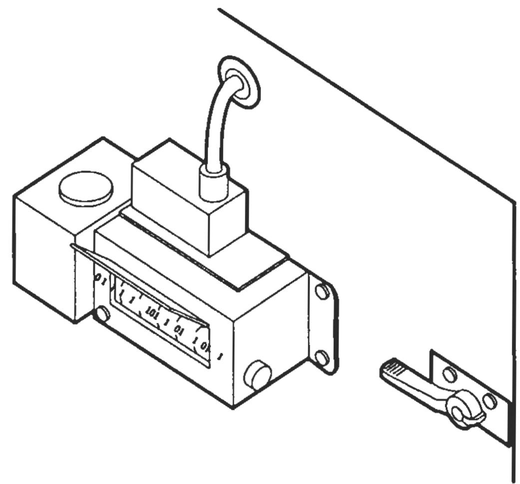

Figure 9. Setting Calibrator Stroke Counter

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.
9. Shut the calibrator off when two consecutive tests show the same output. Usually, three tests are sufficient.

CHECK INJECTOR OUTPUT (CONT.)

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 6 for the cause and remedy. See Injector Calibrator Readings for different factors that may affect the injector calibrator output reading.

INJECTOR	CALIBRATOR J 22410	INJECTOR	CALIBRATOR J 22410
	Min.Max.		Min.Max.
71N5	50 55	7A50	53 58
N55	53 58	7A55	56 61
N60	57 62	7A60	60 65
N65 (white tag)	64 69	7A65	66 71
N65 (brown tag)	64 69	7A70	72 77
NH65	70 72	7A75	75 80
N70	71 76	B55	53 58
N75	75 80	B60	57 62
N80	81 86	B65	64 69
N90	87 93	71B5	50 55
M95	97 103	B55E	53 58
7E50	50 55	7B5E	50 55
7E55	53 58	71C5	50 55
7E60	57 62	C55	53 58
7E65	63 68	C60	57 62
7E75	75 80	C65	64 69
7G65	67 72	C70	71 76
7G70	72 77	7C70	71 76
7G75	77 82	7C75	75 80

TABLE 1 – INJECTOR CALIBRATIONS

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

Several factors affect the injector calibrator output readings. The four major items are:

1. **Operator Errors:** If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of one or two points will result (Figure 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 two to six 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.

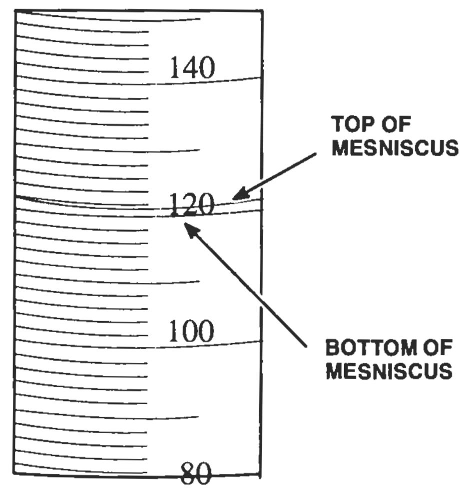

Figure 10. Checking Fuel Output

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 Figure 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.

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

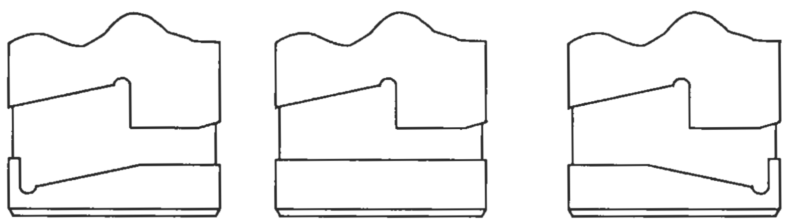

Figure 11. Injector Plunger Types

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 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 result 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 lb/in.^{2} (276 kPa), but not more than 150 lb/in.^{2} (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.

REGULATED PRESSURE ADJUSTMENT

1. Set all toggle valves in the closed position (Figure 12.)
2. Open the calibrating valve approximately four 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 three 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.

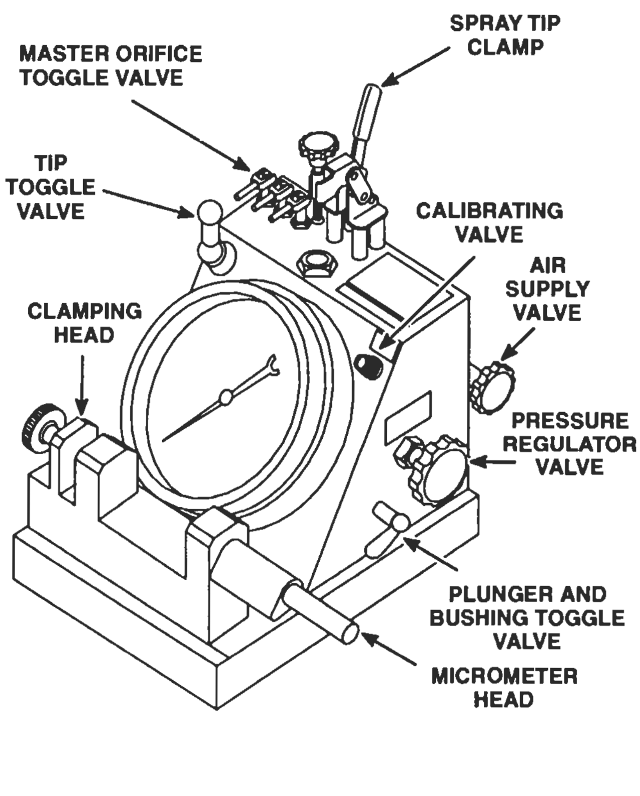

Figure 12. Plunger/Bushing and Tip Flow Gage J 25600–A

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 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. 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 (Figure 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.

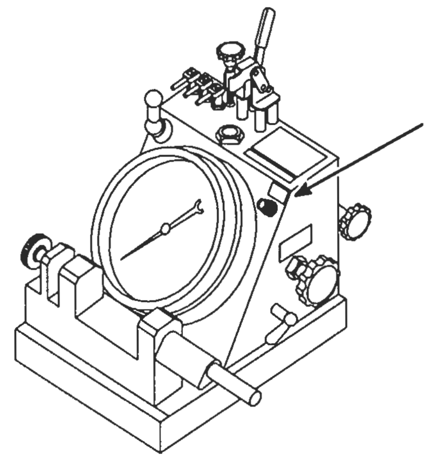

Figure 13. Adjusting the Calibrating Valve

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. Refer to the chart for the flow values.
3. Remove the needle valve, if installed, and clamp the spray tip on the unit (Figure 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.

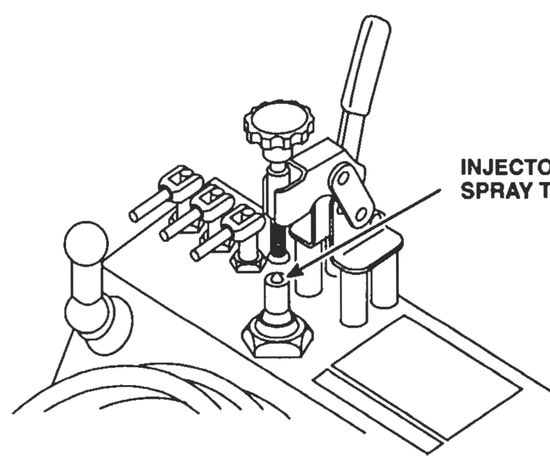

Figure 14. Spray Tip Installed in Tester

TIP STAMP	NOMINAL FLOW VALUE	MASTER ORIFICE CALIBRATION
6–.006	22	
7–.007	69	
8–.0055	26	A
8–.006	48	
9–.0055	48	
9–.0058	69	

PLUNGER/BUSHING EFFECTIVE STROKE MEASUREMENT

The objective of flowing 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 required. 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 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.
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, (the 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 (Figure 15.) To check in full–fuel position, the rotate bushing until the bushing pin contacts the rear locating surface.
6. Adjust the spring loaded bottom 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.

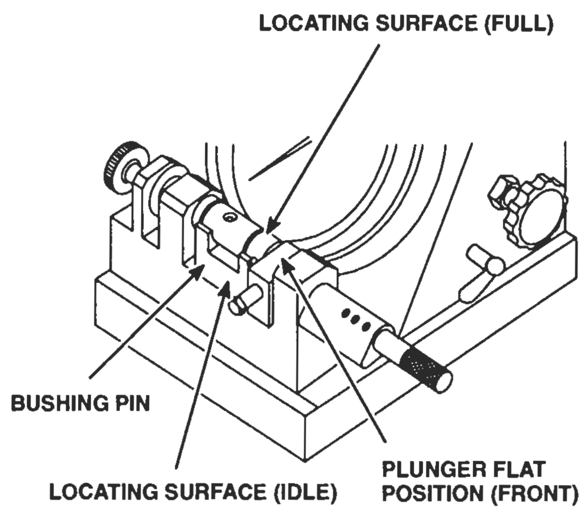

Figure 15. Cradle Mounted on Fixture

PLUNGER/BUSHING EFFECTIVE STROKE MEASUREMENT (CONT.)

7. Hold the plunger against the micrometer and rotate the carriage adjustment screw until the plunger almost closes the port (Figure 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.

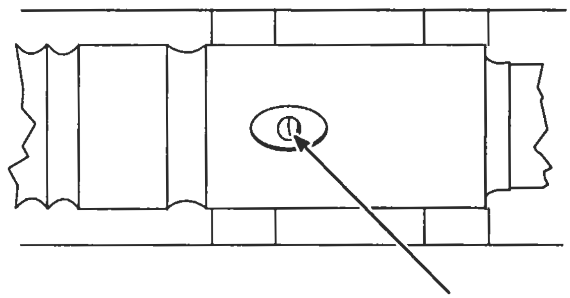

Figure 16. End of Plunger Shown in Port

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. The 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/bushings 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 (Figure 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.

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.

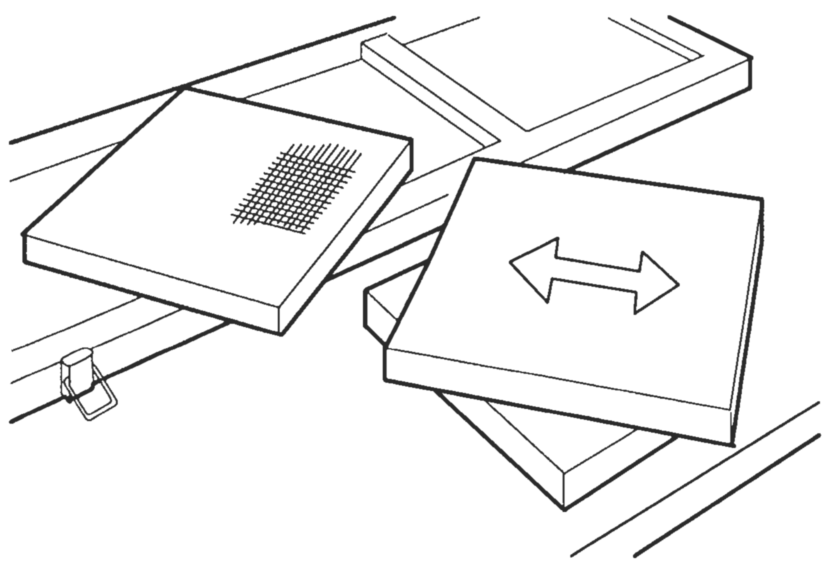

Figure 17. Refinish Lapping Blocks

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.

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 (Figure 18.) and appears in the advanced or retarded position, disassemble the injector and correct the rack–to–gear timing.

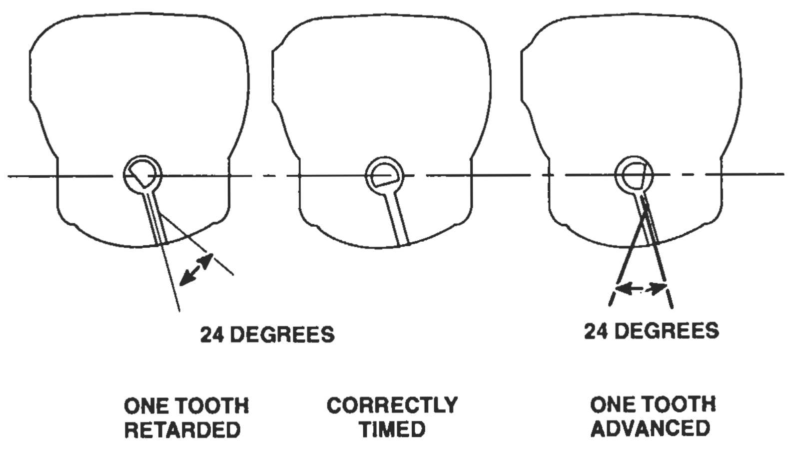

Figure 18. Injector Tack–to–Gear Timing

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 to the recommended torque. 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.

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 to twenty 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 lb/in.^{2} or 413–552 kPa) to the inlet of the secondary 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 lubricating 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 lubricating 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 lubricating 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 lb/in.^{2} (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 lb/in.^{2} (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.

CHECK FOR LEAKS (CONT.)

Method 3.

Use while the engine is operating at 400–600 r/min.

Apply an outside fuel source capable of 60–80 lb/in.^{2} (413–552 kPa) to the outlet side of the secondary filter. Pour lubricating 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 lb/in.^{2} (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.

NOTE: With the engine at rest as in Method 2, all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity resulting in droplets of fuel 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 lubricating 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 (Section 2).

POINTS TO REMEMBER

Lubricating 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 spillage 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 lubricating oil filter changes.

HYDRAULIC GOVERNOR RETRACTING SPRING

The retracting spring was installed for standardization in hydraulic governors used on the Series 71 engines (Figure 19.) The retracting spring hooked in the side of the speed adjusting lever and was incorporated to permit the governor on some applications to reach and hold low speeds by exerting force upward on the speed adjusting lever and, at the same time remove tension from the governor speeder spring.

The retracting spring is required in comparatively few applications, and has been removed from all of the hydraulic governor assemblies, except the governor assemblies equipped with synchronizing motors.

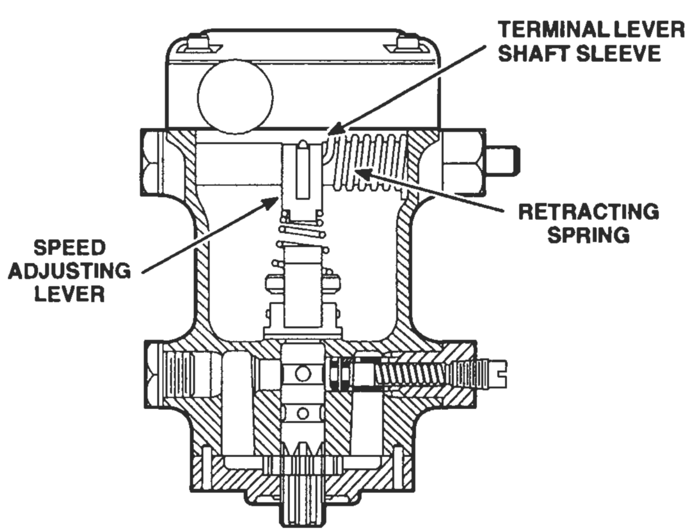

Figure 19. Hydraulic Governor Retracting Spring Installation

HYDRAULIC GOVERNOR RETRACTING SPRING (CONT.)

The current hydraulic governor control lever retracting springs used on hydraulic governors are shown in Figure 20. The extension type retracting spring has been replaced by two new torsion type retracting springs, one for "A" model engines and one for "C" model engines.

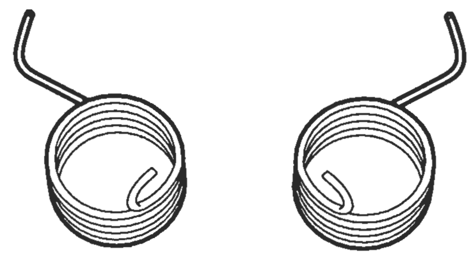

Figure 20. Hydraulic Governor Control Lever Retracting Springs

LOW–SPEED STOP SCREW AND GOVERNOR COVER

More accurate alignment of the low–speed stop screw and the speed adjusting shaft lever has been accomplished by relocation of the low–speed stop screw in the cover of all hydraulic governors (Figure 21.) except the SGT dual hydraulic governor.

This improved alignment more effectively limits the travel of the speed adjusting shaft lever, thus preventing the lever from traveling beyond the stop position, and also eliminates the possibility of unseating the speeder spring from the spring seat. Also, to provide a more positive seating shoulder for the low–speed stop screw, the governor cover has been revised to provide a flat seating surface (Figure 22.) The low–speed stop screw has been reduced in size at its lower end so as to contact the speed adjusting lever with greater accuracy.

The current and former design stop screws and covers are not interchangeable.

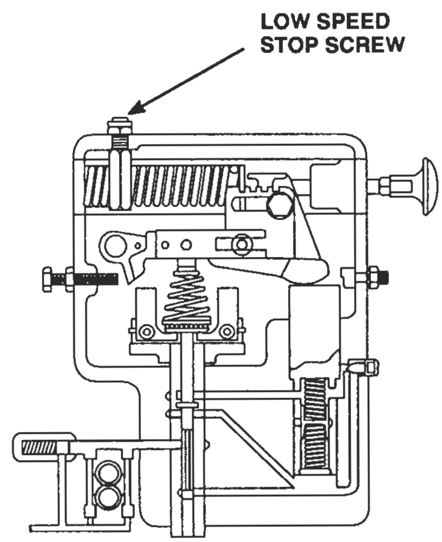

Figure 21. Hydraulic Governor Low–Speed Stop Screw

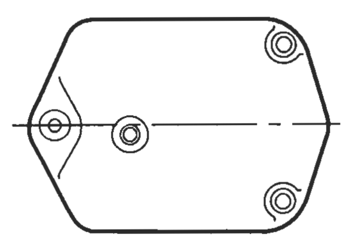

Figure 22. Hydraulic Governor Cover

 May, 1994

TAMPER–RESISTANT GOVERNOR FOR HIGHWAY VEHICLE ENGINES

A tamper–resistant single weight limiting speed "TT" governor is provided for highway vehicle engines.

This governor incorporates a special high–speed spring housing and a break–off head governor cover screw, designed to make unauthorized governor adjustments difficult.

The governor spring housing has one inch of additional metal resembling two bosses cast on the bolt head of the housing (Figure 23.) 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 and cylinder head. In addition the head of the break–off head screw must be drilled out to permit removal of the governor cover.

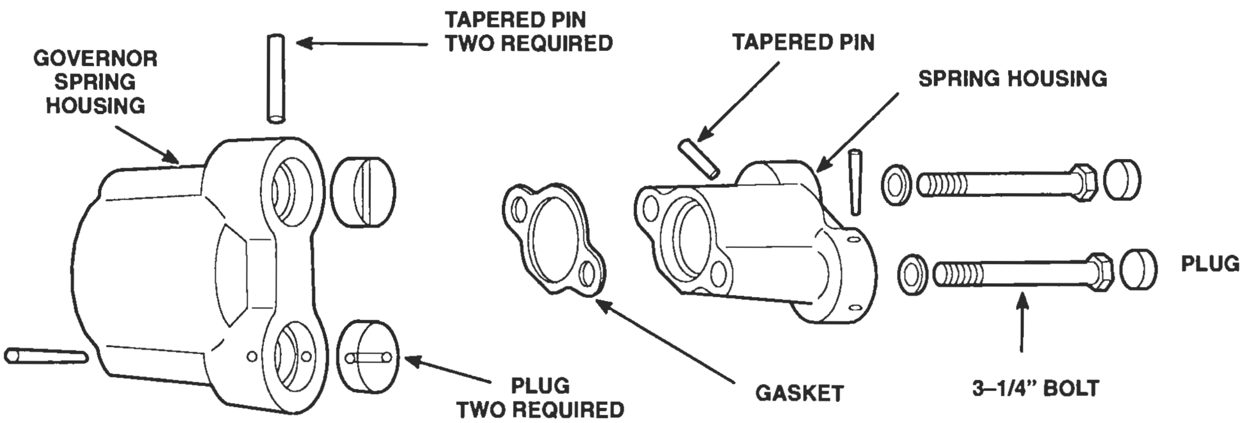

Figure 23. Tamper Resistant Governor Components

The governor is not normally tamper–resistant as furnished on the engine by the factory. The spring housing retainer bolts are removable and the break–off head governor cover screw has not been broken off. This is to permit governor adjustments that maybe necessary before the engine is placed in service.

To make the governor tamper–resistant install two plugs and two tapered pins and break off the head of the cover break–off head screw by over–tightening.

Install the tamper–resistant plugs and pins in the counterbores of the spring housing as follows:

a. Install the inboard plug with the drilled passage in the vertical position and the larger opening up.

b. Install the outboard plug with the drilled passage horizontal and the larger opening away from the engine.

c. Drive the tapered pins, small end first, into the drilled passages in the top and side of the spring housing until the pins are below flush and firmly in place.

d. Turn the governor cover brake–off head screw by tightening the screw until the head separates.

TROUBLESHOOTING FUEL PUMP

The fuel pump is so constructed as to be inherently trouble free. By using clean, water–free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel supply valve is open. Also, check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

1. Disconnect the fuel return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Figure 24.)
2. Start and run the engine at 1,200 r/min and measure the fuel flow. Refer to Section 13.2 for the specified quantity per minute.
3. Immerse the end of the fuel hose in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

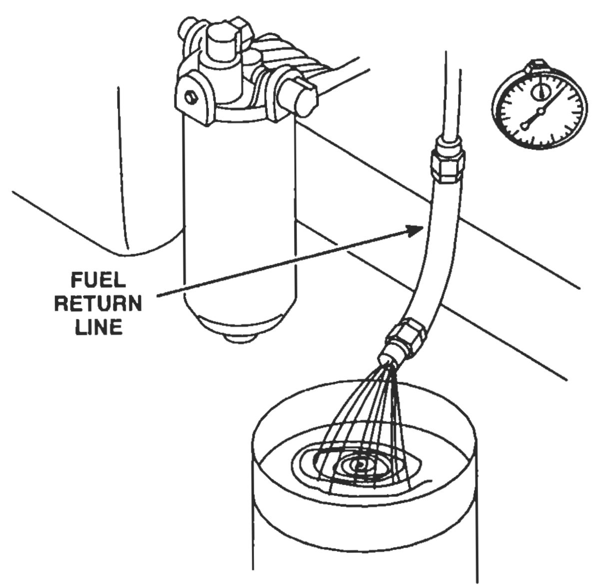

Figure 24. Measuring Fuel Flow

CHECKING FUEL FLOW (CONT.)

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 1,200 r/min to check the fuel flow. If the flow is still unsatisfactory, perform Step "b" below.
   b. Replace the element the fuel filter. If the flow is still unsatisfactory, do as instructed in Step "c".
   c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screwdriver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.
2. Perform cylinder cut out with the D.D.R. on DDEC engines.
3. Stop the engine and remove the fuel pipe between the fuel return manifold and the injector.
4. 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 r/min 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.**

Inline 71 engines with single weight systems may require 90 psi (621 kPa) or more and double weight systems need 70 lb/in.^{2} (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 lb/in.^{2} (0–827 kPa).

2. **An interaction between the idle circuit and the high speed circuit.**

All engines supplied by DDC with the VHS feature installed as original equipment have a compatible governor which will allow control from no–load to within 100 r/min of idle. Minimum certified idle values should not be violated. The following chart shows the minimum control speed of the heavy weight governors with various idle speeds and idle springs.

Single weight governors capable of accepting the VHS are also capable of reducing the minimum r/min to within 100 r/min of idle.

Normal Idle of:	500	550	600	650	750
Min. Control w/Blue Stripe Idle Spring	500	550	850	1100	1200
w/Green or yellow Stripe Idle Spring	650	850	1100	1300	NA

AIR–OPERATED VARIABLE HIGH SPEED GOVERNORS (CONT.)

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 the 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 acquiring 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 (Section 2.7.1.5).

4. **Engine overshoot.**

This usually relates to the non–synchronized engagement of the throttle lock and the regulated air supply to the VHS housing. A variable orifice (needle valve type) in one of the air supply lines will provide capability for synchronization as follows:

In cases of overshoot, the variable orifice is installed in the supply line to the throttle lock.

In case of undershoot, the variable orifice is installed in the regulated air pressure line to the VHS housing.

5. **Lowered idle or no–load.**

Usually caused by air from the air supply leaking into or being trapped in the VHS housing. Any pressure in the VHS housing will lower both the no–load and idle. Recheck the air plumbing.

6. **Lack of normal power.**

The elastic stop nut is screwed in too tight, pulling the high–speed plunger off its seat. This will cause low power but no change in the no–load r/min. 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

LOW OR HIGH VALVE OPENING PRESSURE

LOW VALVE OPENING PRESSURE

Probable Causes

1. WORN OR ERODED NEEDLE VALVE OR VALVE SEAT IN SPRAY TIP
2. WORN OR DAMAGED NEEDLE VALVE QUILL
3. WORN OR DAMAGED NEEDLE VALVE SPRING SEAT
4. WORN OR BROKEN VALVE SPRING
5. DIRT OR FOREIGN MATERIAL IN INJECTOR.

HIGH VALVE OPENING PRESSURE

Probable Causes

6. CARBON OR FOREIGN MATERIAL IN SPRAY TIP
7. CARBON IN SPRAY TIP ORIFICES

SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.
2. Replace the spring seat.
3. Replace the valve spring.
4. Disassemble the injector and clean all of the parts.
5. Remove the carbon in the spray tip with the tip reamer J 9464–01 which is especially designed and ground for this purpose.
6. 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

INSUFFICIENT INJECTOR HOLDING TIME

Probable Causes

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 ERODED NEEDLE VALVE SEAT IN SPRAY TIP
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

INCORRECT INJECTOR OUTPUT

Probable Causes

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 outlines 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 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 parts.
12. Assemble the gear with the 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 corrective output.

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

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. (lb/in^2)
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	C.I. ENGINE TORQUE (lb·ft)	TORQUE (N·m)	ALUM ENGINE TORQUE (lb·ft)	TORQUE (N·m)
Limiting speed low weight set screw	10–32	20 in·lb	2.26	–	–
Variable speed spring lever set screw	5/16–24	5–7	7–10	–	–
Injector clamp bolt	3/8–18	20–25	27–34	20–25	27–34
Injector clamp stud	3/8–16	10–25	14–34	10–25	14–34
Fuel pipe nut (Endurion® coated)	3/8–24	130–160 lb·in	14.7–18.1	130–160 in·lb	14.7–1
8.1					
Fuel pipe nut (uncoated)	3/8–24	160 lb·in	18.3	160 lb·in	18.3
Fuel pipe nut (load limiting device)	3/8–24	160 lb·in	18.3	160 lb·in	18.3
Fuel pipe nut (Jacobs Brake)	3/8–24	120 lb·in	13.6	120 lb·in	13.6
Fuel pipe nut (with O–ring seal)	3/8–24	160–200lb·in	18.1–22.6	160–200lb·in	18.1–2
2.6					
Injector clamp nut	3/8–24	20–25	27–34	20–25	27–34
Fuel manifold connector nut	7/16–20	30–35	41–47	30–35	41–47
*Fuel manifold connector (nylon insert)	7/16–20	30–35	41–47	30–35	41–47
*Fuel manifold connector (steel washer)	7/16–20	40–45	54–61	–	–
†Rocker arm bracket bolt	1/2–13	90–100	122–136	–	–
Injector Filter Caps					
Non–blued cap on non–blued body	5/8–24	62	84	62	84
Blued cap on blued body	5/8–24	70	95	70	95
Non–blued cap on blued body or blued cap on non–blued body	5/8–24	62	84	62	84
Injector filter Cap (O–ring sealed fuel pipe)	1/2–20	70	95	70	95
Injector Nut (needle valve)					
Non–blued cap on non–blued body	15/16–24	50	68	50	68
Blued cap on blued body	15/16–24	80	108	80	108
Non–blued cap on blued body or blued cap on non–blued body	15/16–24	65	88	65	88

*Lubricate before assembly.

†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 brackets.

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Auxiliary Injector Tester ("N")	J 22640–A
Field Modification	J 22640–51
Fuel Pipe Socket	J 8932–01
Torque Wrench (Calibrated In Inch–Pounds)	J 24405
Fuel System Primer	J 5956
Injector Body Reamer	J 21089
Injector Body Thread Reconditioning Set	J 22690
Injector Calibrator	J 22410
Injector Nut Seal Ring Installer	J 29197
Injector Service Set (Includes *Tools)	J 1241–07
Injector Service Set ("N") – Includes #Tools)	J 23435–C
*Deburring Tool	J 7174
#*Fuel Hole Brush	J 8152
#*Injector Nut Socket Wrench	J 4983–01
#*Injector Nut And Seat Carbon Remover Set	J 9418
#*Injector Spray Tip Driver	J 1291–02
*Injector Tip Cleaner	J 1243–01
#*Pin Vise	J 4298–1
#*Rack Hole Brush	J 8150
#*Spray Tip Carbon Remover	J 24838
*Spray Tip Seat Remover	J 4986–01
*Spray Tip Wire (.005I)	J 21459–01
#*Spray Tip Wire (.0055I)	J 21460–01
#*Spray Tip Wire (.006I)	J 21461–01
#*Wire Sharpening Stone	J 8170
Injector Test Oil (5, 15, 30 And 55 Gal.)	J 26400
Injector Tester	J 9787
Injector Tester	J 23010–B
Injector Tip Concentricity Gage	J 29584
Injector Vise And Rack Freeness Tester	J 22396
Injector Vise Jaws (Offset Body)	J 8912
Injector Vise Jaws (Standard Body)	J 1261
Lapping Block Set	J 22090–A
Master Injector Calibrating Kit	J 35369
Polishing Compound ("N" Injectors)	J 23038
Polishing Stick Set ("N" Injectors)	J 22964
Spray Tip Flow Gage	J 25600–B
Field Modification Kit	J 25600–103
Spray Tip Gage ("N" Injectors)	J 9462–02
Spring Tester	J 22738–02
Wire Brush (Brass)	J 7944

SERVICE TOOLS (CONT.)

TOOL NAME	TOOL NO.
INJECTOR TUBE	
Cylinder Head Holding Plates	J 3087–01
Injector Protrusion Gage	J 25521
Injector Tube Service Tool Set	J 22525–B
Injector Tube Service Tool Set (Power Equip.)	J 22515–B
Injector Tube Swaging Tool	J 28611–A
FUEL PUMP	
Fuel Pump Tool Kit	J 34607
Fuel Pump Tool Set	J 1508–E
Fuel Pump Wrench	J 4242
Fuel System Primer	J 5956
MECHANICAL GOVERNOR	
Spanner Nut Socket	J 5345–12
Elastic Stop Nut Adjustment Tool	J 28598–A
Governor Cover Bearing Installer	J 21068
Governor Cover Bearing Remover/Installer	J 21967–01
Governor Housing Repair Kit	Pt 7150
High–speed Spring Retainer Nut Wrench	J 1652–01
Variable Speed Spring Housing Bearing Installer	J 9196
HYDRAULIC GOVERNOR	
Governor Speeder Spring Wrench (PSG Governor)	J 4873–01
Needle Bearing Installer (SGX Governor)	J 21068
Snap Ring Pliers (External Type) (PSG Governor)	J 4880
Snap Ring Pliers (Internal Type) (PSG Governor)	J 5403
MISCELLANEOUS	
Reader, Dual Diagnostic Data Link (DDDL)	J 36380

Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank. All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. Refer to Section 13.2 for the size fitting required.

AIR INTAKE SYSTEM

CONTENTS

Air Intake System 3
Air Cleaner 3.1

Air Silencer 3.2

Air Shutdown Housing 3.3

Blower 3.4

Turbocharger (Airesearch) 3.5
Turbocharger Intercooler 3.5.2
Turbocharger Aftercooler 3.5.3

Shop Notes – Troubleshooting – Specifications – Service Tools 3.0

AIR INTAKE SYSTEM

In the scavenging process used in the 71 Inline engine, 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, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air enters the blower from the air cleaner or air silencer and is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows (Figure 1.) The continuous discharge of fresh air from the blower creates an air pressure of approximately 7 lb/in.^{2} (48 kPa) in the air chamber of the cylinder block at maximum engine speed. The air sweeps through the intake ports which start to open as the piston approaches the end of its downward travel and closes after the compression stroke begins.

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.

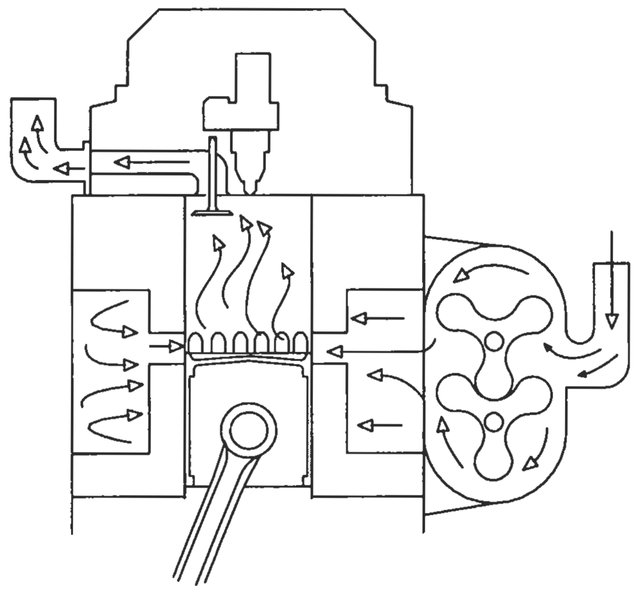

Figure 1. Blower and Engine Air Flow

Turbocharging the 4–71 and 6–71 engines is accomplished by introducing a turbocharger in series with the blower of the air system (Figure 2.) The expanding exhaust gases turn a single–stage turbine wheel which drives an impeller which supplies air under pressure to the blower. Even though the blower speed is considerably reduced through an additional pair of gears in the blower gear train, the air box pressure nearly doubles by the increase in air flow. This results in more efficient engine breathing, quieter operation and more complete combustion and scavenging cycles.

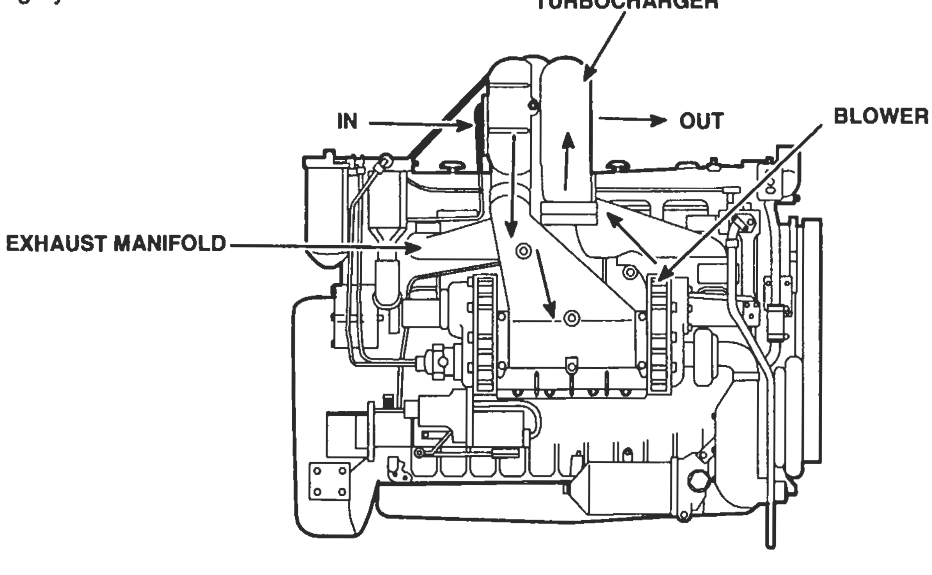

Figure 2. Turbocharger and Blower Air Flow

AIR CLEANER

The air cleaner is designed to remove foreign matter from the air and 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 out of an engine cannot be over–emphasized since clean air is 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 mounting varies in accordance with the air cleaner installation and the engine units on which they are attached. The light duty oil wetted–type oil bath type and the dry type air cleaners are mounted on the air inlet housing. Heavy duty air cleaners are remotely mounted from the air inlet housing and are connected to it by air tight ducts.

AIR CLEANER MAINTENANCE

Although the air cleaner is highly efficient, this efficiency depends upon proper maintenance and periodic servicing.

Damaged gaskets, loose hose connections or leaks in the duct work, which permit dust–laden air to completely bypass the cleaner and enter the engine directly, will lower the efficiency of the air cleaner. If the air cleaner is not serviced periodically, the engine will not receive a sufficient amount of clean air.

No set rule for servicing an air cleaner can be given since it depends upon the type of air cleaner, the condition of the air supply and the type of application. An air cleaner operating in severe dust will require more frequent service than an air cleaner operating in comparatively clean air. The most satisfactory service period should be determined by frequently inspecting the air cleaner under normal operating conditions, then setting the service period to best suit the requirements of the particular engine application.

The following maintenance procedure will assure efficient air cleaner operation.

1. Keep the air cleaner tight on the air intake pipe to the engine.
2. Keep the air cleaner properly assembled so the joints are oil and air tight.
3. Repair any damage to the air cleaner or related parts immediately.
4. Inspect and clean or replace the air cleaner element as operating conditions warrant. With the dry type air cleaner, it is possible to clean and reuse the element several times as long as the paper is not ruptured in the process. In an oil bath type cleaner keep the oil at the level indicated on the air cleaner sump. Overfilling may result in oil being drawn through the element and into the engine carrying dirt into the cylinders and also resulting in excessive engine speed.
5. After servicing the air cleaner, remove the air inlet housing and clean accumulated dirt deposits from the blower screen and the inlet housing. Keep all air intake passages and the air box clean.
6. To obtain air tight rubber hose connections, use new hoses and clamps in their place where necessary.
7. Carefully inspect the entire air system periodically. Enough dust–laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.

SECTION 3.1 – AIR CLEANER

LIGHT DUTY OIL BATH–TYPE AIR CLEANER

The light duty oil bath type–air cleaner consists basically of a wire screen element supported inside a cylindrical housing which contains an oil bath directly below the element (Figure 1.) Air drawn through the cleaner passes over the top of the oil bath. The air stream direction reverses when the air impinges on the oil in the sump and is then directed upwards by baffles. During this change in the direction of air flow, much of the foreign matter is trapped by the oil and is carried to the sump where it settles out. The air passes upward through the metal–wool elements where more dust and the entrained oil are removed. A second change of air direction at the top of the cleaner directs the air downward through the center tube and into the blower inlet housing.

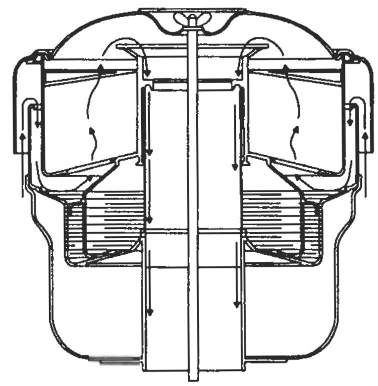

Figure 1. Light Duty Oil Bath Type Air Cleaner

AIR CLEANER SERVICE (LIGHT DUTY)

To service the light duty air cleaner, loosen the wing bolt and remove the cleaner from the air inlet housing. The cleaner may then be separated into two sections. The upper section contains the metal–wool elements and the lower section is made up of the oil sump, removable baffle and the center tube.

The upper shell and metal–wool elements may be cleaned by soaking the entire section in kerosene or fuel oil.

This will loosen the oil and dust in the elements and facilitate flushing out the dirt. The oil should be emptied from the sump, the baffle removed, and the sump and baffle cleaned in kerosene or fuel oil to remove all sediment. A lint–free cloth should be pushed through the center tube of the cleaner before the baffle is installed and the sump refilled to the oil level mark with clean engine oil. Never use cotton waste to wipe the center tube. Use the same viscosity and grade of oil that is used in the engine crankcase. All gaskets and sealing surfaces should be checked and cleaned to ensure air–tight seals.

After the filter element has been thoroughly drained of the flushing fluid, the cleaner should be assembled. However, before installing the cleaner on the engine, the air inlet housing and blower inlet screen should be checked for the presence of dirt accumulations. If the service period has been too long, or dust–laden air has been leaking past the seals, the inlet housing and screen will be dirty. This will serve as a good check on the maintenance of the air cleaner installation. When installing the cleaner and its seal on the inlet housing, be sure that the cleaner seats properly, then tighten the wing bolt securely until the cleaner is rigidly mounted.

HEAVY DUTY OIL BATH–TYPE AIR CLEANER

In all heavy duty air cleaners air is drawn through the air inlet hood, which acts as a cleaner and down through the center tube (Figure 2.) At the bottom of the tube, the direction of air flow is reversed and oil is picked up from the oil reservoir cup. The oil laden air is carried up into the separator screen where the oil which contains the dirt particles is separated from the air by collecting on the separator screen.

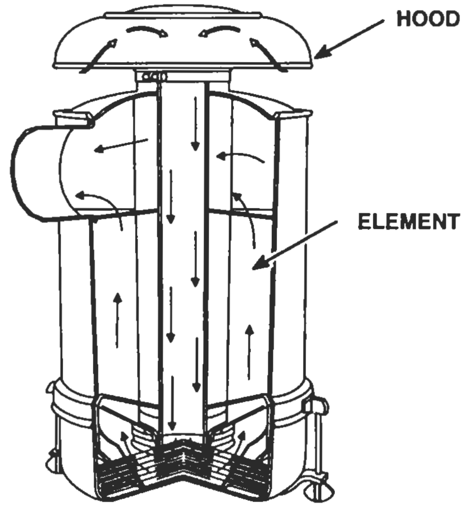

Figure 2. Heavy Duty Oil Bath Type Air Cleaner

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 (Figure 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.

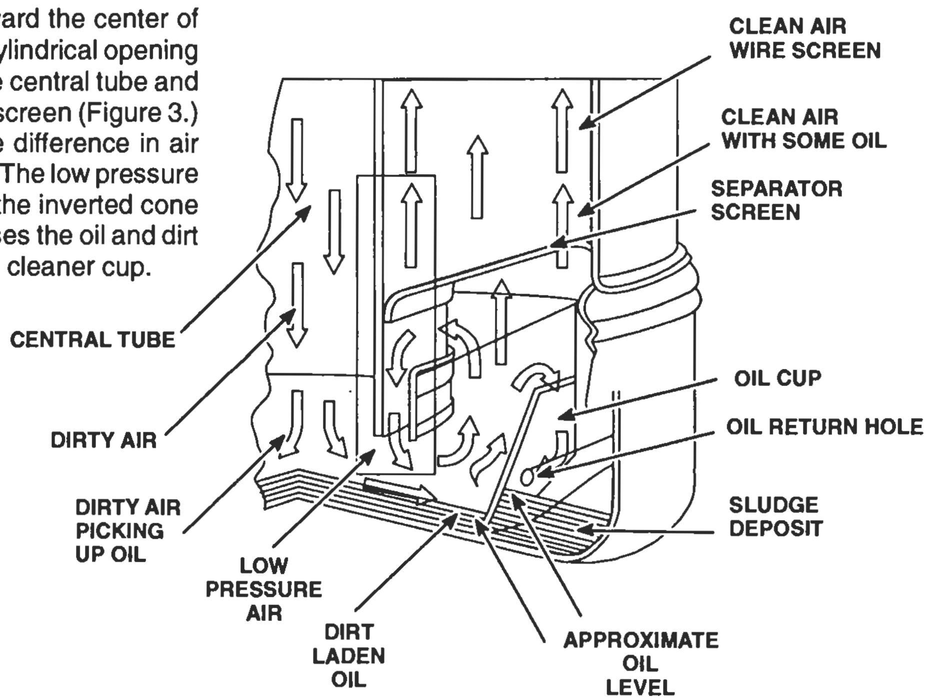

Figure 3. Air Flow Through Heavy Duty Oil Bath Air Cleaner

HEAVY DUTY OIL BATH–TYPE AIR CLEANER (CONT.)

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 pan. The clean air then leaves the cleaner through a tube at the side and enters the blower through the air inlet housing.

An air inlet hood or pre–screener must be used with the heavy duty air cleaners depending upon operating conditions. This equipment normally requires cleaning more frequently than the main air cleaner. The usual installation employs an air inlet hood which serves only to prevent rain, rags, paper, leaves, etc., from entering the air cleaner. The smaller cleaners use a spherical–shaped hood. Air enters the hood through a heavy screen which forms the lower portion of the hood and the air is reversed in the hood and pulled downward into the air cleaner. The hood is mounted on the air cleaner inlet tube and is held in place by the fit of the hood in the inlet tube.

The larger cleaners use a dome–shaped hood. A heavy screen inside the dome guards against large pieces of foreign material entering the cleaner. The hood is mounted on the air inlet tube of the cleaner and is secured to it by a screw–clamp. As previously mentioned, the hoods serve only to prevent rain and large pieces of foreign material from entering the cleaner. The openings in the hoods should be kept clear to prevent excessive restriction to air flow.

A pre–screener should be used on the inlet tube of the air cleaner instead of the inlet hood for those operations in which the air cleaner elements load up with lint or chaff. The purpose of the pre–screener is to remove as much of the lint or chaff as possible before the air enters the cleaner.

AIR CLEANER SERVICE (HEAVY–DUTY)

The air inlet hoods used on heavy–duty air cleaners are not intended to do any cleaning. However, some dirt will collect on the heavy screens and in the hood itself. Therefore, it will be necessary to remove the hood occasionally for cleaning by brushing or with compressed air.

Some applications may be equipped with a pre–screener. The pre–screener catches the lint and chaff on the screen surrounding the shell. This screen can be removed by unhooking the retaining springs and cleaned by brushing or with compressed air. The shell can be cleaned, if necessary by wiping it with a clean cloth. The pre–screener may then be assembled and installed on the cleaner inlet tube.

Although the pre–screener will remove most of the lint and chaff from the air, some may still find its way into the main cleaner. Therefore it is essential that the fixed element of the main cleaner be checked each time the cleaner is serviced to prevent excessive lint deposits.

When the oil sump is removed on some heavy–duty air cleaners, a tray–type screen attached to the tube will be visible. It may be removed by loosening the wing nuts and rotating the tray so that it unlocks from the tube. On other heavy duty models, the tray rests on the lip of the inner oil cup of the sump and is not retained by wing nuts.

The efficiency of the tray–type oil bath air cleaner can be greatly reduced unless the fibrous material caught in the tray is removed. It is extremely important that the tray be cleaned regularly and properly.

If a tray is plugged with lint or dirt, wash the tray in a solvent or similar washing solution and blow out with high velocity compressed air or steam. An even pattern of light should be visible through the screens when a clean tray is held up to the light.

It is advisable to have a spare tray on hand to replace the tray that required cleaning. Having an extra tray available makes for better servicing and the plugged tray can be cleaned thoroughly at leisure.

Check for dirt accumulation in the air cleaner center tube. Remove dirt by passing a clean cloth through the center tube. Some tubes have a restricted portion at the lower end and care must be taken not to damage this end.

Check the oil sump for any dirt accumulation in both the inner and outer cups and clean if necessary.

At some regular period of engine service, remove the entire air cleaner from the engine and clean the fixed element. This can be done by passing a large quantity of clean solvent through the air outlet and down into the element. When clean, allow element to dry thoroughly before installing cleaner.

AIR CLEANER SERVICE (HEAVY DUTY) (CONT.)

When all of the components have been cleaned, the cleaner is ready for assembly. The removable screen should be installed and the oil sump should be filled with clean engine oil to the indicated level and installed on the cleaner. Care should be exercised that all gaskets and joints are tight. All connections from the cleaner to the engine should be checked for air leaks to prevent any air bypassing the air cleaners.

If it is found that unfiltered air is being admitted into the engine through the duct work of an air cleaner installation, the following procedure may be used for finding air leaks in an air duct system. The air cleaning system does not have to be dismantled which will save time.

To make this check, it is necessary that suitable plugs be provided to block the air cleaner system inlet and outlet. The air cleaner inlet plug should contain a suitable air connection and shutoff valve to maintain two pounds pressure in the air duct system. The outlet plug need only be of sufficient size to form a completely air–tight seal at the outlet end of the system. Then check the system as follows:

1. Remove the air inlet hood or pre–screener.
2. Insert the plug (with the fitting for the air hose) in the air cleaner inlet to form an air–tight seal.
3. Insert the other plug in the outlet end of the system to form an air–tight seal.
4. Attach an air hose to the plug in the air cleaner inlet and regulate pressure not to exceed 2 $lb/in.^2$ (14 kPa).
5. Brush a soap solution on all air duct connections. Any opening which would allow dust to enter the engine can then be detected by the escaping air causing bubbles in the soapsuds solution. All leaks thus discovered should be remedied until the system checks "air–tight".
6. Remove plugs and install air inlet hood or pre–screener.

A rotational type service program may be followed on heavy duty air cleaner installations that use a main and after cleaner in accordance with the following procedure. The heaviest cleaning job is imposed upon the main cleaner.

1. Remove and clean the sump and removable screen of the main cleaner.
2. Check all joints and tubes of the main cleaner and ensure that they are air–tight.
3. Install the cleaned removable screen on the main cleaner.
4. Remove the sump of the after cleaner and install it on the main cleaner.
5. Remove and clean the removable screen of the after cleaner.
6. Check all joints and tubes of the after cleaner and ensure that they are air–tight.
7. Install the remaining screen and sump on the after cleaner.

The design and function of heavy duty air cleaners is such that the fixed elements tend to be self–cleaning. However, it may be occasionally necessary to remove the entire cleaner from its mountings and clean the elements. If the fixed elements require too much frequent cleaning, it is advisable to relocate the air intake to provide a cleaner air supply.

Proper selection of air cleaners and good air cleaner maintenance go "hand–in–hand" to provide long engine life and trouble–free operations.

SECTION 3.1 – AIR CLEANER

DRY–TYPE AIR CLEANER

The Donaldson dry–type air cleaners 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 replacement element assembly.

The dust is swept through a space in the side of the baffle and collects in the lower portion of the body or dust cup. The dust remaining in the clean air is removed by the element.

The dry type air cleaner cannot be used where the atmosphere contains oil vapors or fumes from the breather can be picked up by the air cleaner.

AIR CLEANER SERVICE (DRY TYPE)

The air cleaner should be serviced as operating conditions warrant (Section 15.1).

Under no engine operating conditions should the maximum allowable air intake restriction (Section 13.2) be exceeded. Check restriction with a water manometer (Section 13.2.1). In addition, inlet restriction should be adjusted for high altitude conditions. A clogged air cleaner element will cause excessive intake restriction, reduce air supply to the engine, decrease performance and higher valve and cylinder temperatures.

Disassemble the cleaner (Figure 4.) 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.

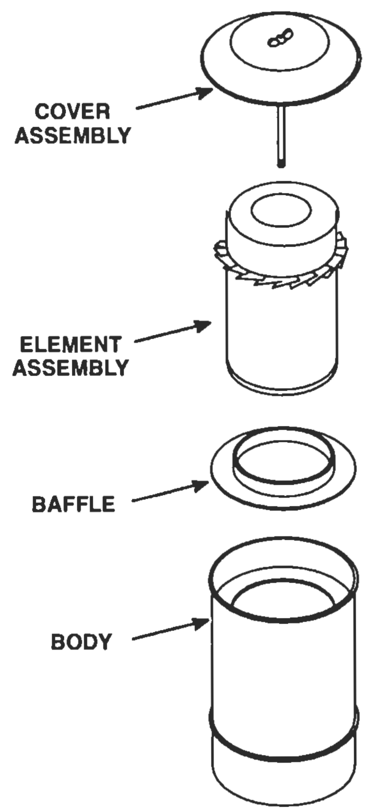

Figure 4. Dry Type Air Cleaner

AIR CLEANER SERVICE (DRY–TYPE) (CONT.)

Disassemble the cleaner (Figure 5.) 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.

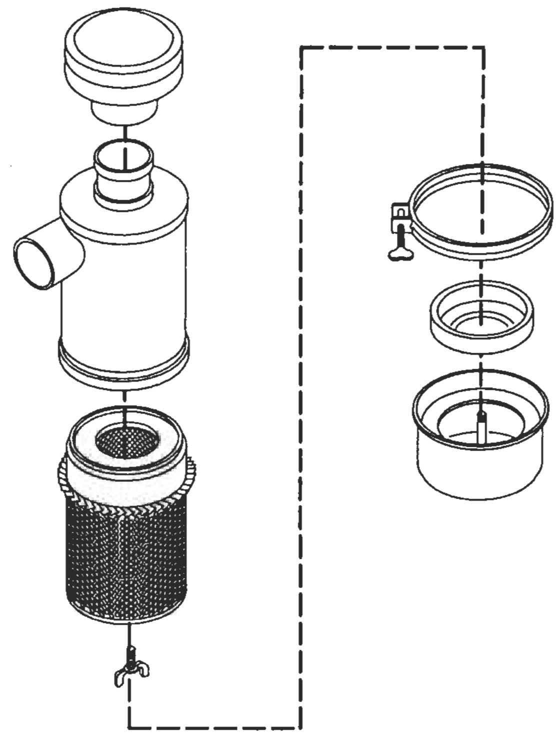

Figure 5. Dry Type Air Cleaner (Heavy Duty)

Extra heavy duty air cleaners (Figure 6.) can also be used.

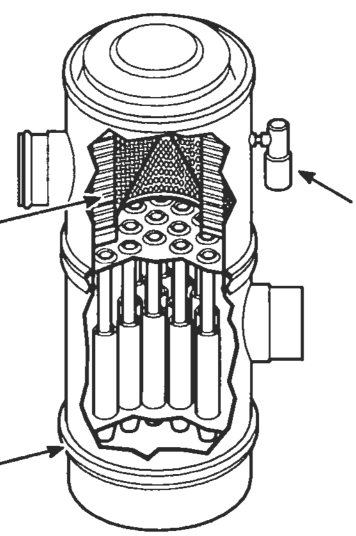

Figure 6. Dry Type Air Cleaner (Extra Heavy Duty)

AIR CLEANER MAINTENANCE

Although the air cleaner is highly efficient, this efficiency depends upon proper maintenance and periodic servicing.

Damaged gaskets, loose hose connections or leaks in the ductwork permit dust–laden air to completely bypass the cleaner and enter the engine. If the air cleaner is not serviced periodically, the engine will not receive a sufficient amount of clean air.

Servicing intervals of an air cleaner depends upon the quality of the available air supply. An air cleaner operating in severe dust will require more frequent service than an air cleaner operating in comparatively clean air. The most satisfactory service period should be determined by monitoring the air inlet restriction, then setting the service period to best suit the requirements of the particular engine.

Under no engine operating conditions should the inlet restriction exceed 20 inches of water (5.0 kPa). A clogged air cleaner element will cause excessive intake restriction and reduced air supply to the engine.

Dry–type air cleaner elements should be replaced after one year of service, or when the maximum allowable air intake restriction has been reached, whichever occurs first.

Cleaning and/or reusing dry paper type air cleaner elements is not recommended unless the cleaning method used removes clogging without damage to the element. Inspection and cleaning of elements must be done in accordance with the air cleaner manufacturer's recommendations, if any. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

The following maintenance procedure will ensure efficient air cleaner operation:

1. Keep the air cleaner housing tight on the air intake pipe.
2. Be sure the correct filter replacement is used.
3. Keep the air cleaner properly assembled so the joints are strictly air tight.
4. Repair any damage to the air cleaner or related parts immediately.
5. Inspect and clean or replace the air cleaner elements as operating conditions warrant.
6. Carefully inspect the entire system periodically. Enough dust–laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.
7. Do not use oil in the bottom of the air cleaner body.

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

The air silencer is attached to the air intake side of the blower rotor housing (Figure 1.) A perforated sheet metal partition divides the silencer into two sections. The inner portion forms an air duct the entire length of the silencer. Air enters this duct from both ends and flows toward the outlet opening at the center and then into the blower. The outer portion is filled with sound absorbent, flame–proof, felted cotton waste.

A blower screen is used between the air silencer and the blower housing to prevent foreign objects from entering the blower.

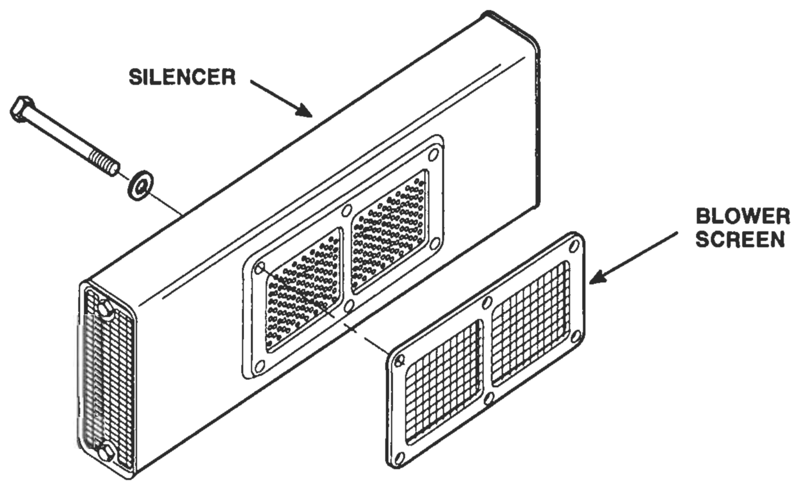

Figure 1. Blower Air Inlet Silencer Assembly

REMOVE AND INSTALL AIR SILENCER

The air silencer requires no service. However, it must be removed to clean or to replace the blower screen or to service the blower. Remove the silencer as follows:

1. Remove the bolt that retains the breather pipe to the air silencer.
2. Support the silencer and remove the six attaching bolts and washers. Remove the silencer and blower screen from the blower.
3. Clean or replace the blower screen.
4. Place the washers over the six silencer attaching bolts. Slide the bolts through the bolt holes in the silencer.
5. Place the blower screen and gasket assembly over the projecting bolts with the screen side of the assembly toward the blower and position the silencer against the blower housing. Tighten the bolts.

SECTION 3.2 – AIR SILENCER

TURBOCHARGER AIR SILENCER

The air silencer used on the air inlet side of the turbocharger consists of an inner and outer cover. A fiberglass insulation pad and a perforated sheet metal screen located against the inner wall of each cover absorb the sound of the incoming air. Three through bolts hold the covers, insulation pads and screens together. They are used to attach the silencer assembly to the compressor of the turbocharger assembly.

Air is drawn into a passage formed between the inner and outer covers of the silencer and flows into the turbocharger compressor through the outlet opening in the inner cover. A perforated steel screen surrounds the silencer and prevents any large objects from entering the silencer.

SERVICE

Very little service, other than an occasional cleaning of the silencer is required. However, the silencer must be removed when service operations are performed on the turbocharger. Remove the silencer as follows:

1. Loosen the three attaching bolts and withdraw the silencer assembly.
2. Unhook the spring that holds the ends of the screen together (two bolts and lock washers are used in place of the spring on earlier silencers).
3. Remove the three bolts from the silencer and disassemble the entire silencer.
4. Clean and inspect the silencer components. If the covers on the earlier type silencer need replacing, the entire silencer must be replaced.
5. Reassemble the silencer (Figure 2.)
6. Install the silencer on the compressor side of the turbocharger.

NOTICE:

Tighten the bolts evenly and only enough to secure the silencer to the turbocharger. Excessive torque may disrupt alignment of the turbocharger.

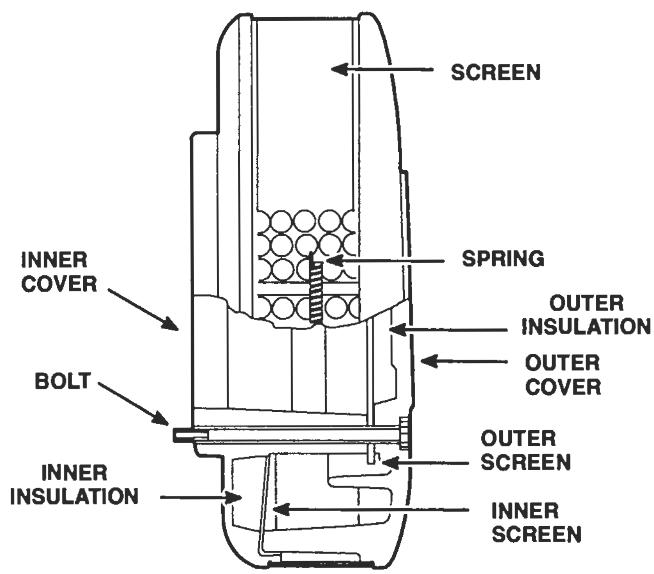

Figure 2. Turbocharger Air Inlet Silencer

AIR SHUTDOWN HOUSING

The air shutdown housing is mounted on the side of the blower and serves as a mounting for the air cleaner or for air cleaner ducting. The air shutdown housing contains an air shutdown valve(s) that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut down (Section 7.4.1).

REMOVE AIR SHUTDOWN HOUSING

1. Remove the air cleaner or air cleaner ducts.
2. Disconnect the Bowden wire or cable assembly from the air shutoff cam pin handle (shutdown control nut on early engines).
3. Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shutdown housing gasket from the blower.

DISASSEMBLE AIR SHUTDOWN HOUSING

If necessary, the air shutoff valve assembly may be disassembled after the air shutdown housing has been removed from the blower.

Disassemble the air shutoff valve (Figure 1.) assembly as follows:

1. Use a small punch to remove the pin from the air shutoff valve shaft. Remove the washer from the shaft. Remove and discard the seal ring from the housing.
2. Remove the pins that secure the air shutoff valve(s) to the shaft.

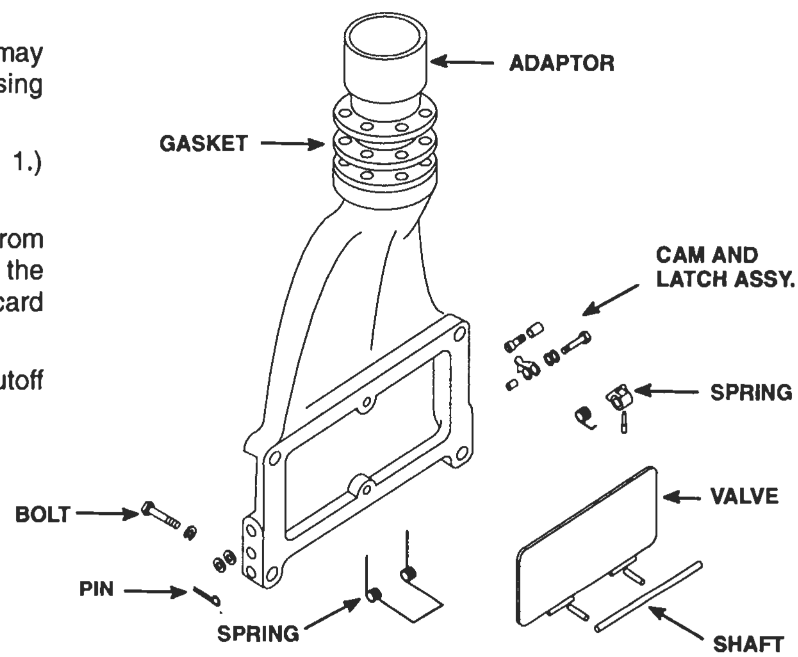

Figure 1. Cam and Latch Type Air Shutdown Housing Components

CAM AND LATCH TYPE

1. Note the position of the air shutoff valve spring and the valve. Then withdraw the shaft from the housing to release the valve(s) and spring in the housing. Remove and discard the seal ring from the housing.
2. Remove the bolt, lock washer and plain washer from the housing and remove the latch, latch spring and spacer.

SECTION 3.3 – AIR SHUTDOWN HOUSING

INSPECTION

Clean the blower screen and all parts thoroughly with fuel oil and dry them with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

Inspect the parts for wear or damage. The face of the air shutoff valve(s) must be perfectly flat to assure a tight seal when it is in the shutdown position.

ASSEMBLE AIR SHUTDOWN ASSEMBLY (CAM AND LATCH TYPE)

The holes for the cam pin handle and the retaining pins must be drilled at the time a new service shaft or air shutoff valve(s) are assembled (Section 3.0). Proceed as follows:

1. Place the valve(s) and spring in position in the housing and slip the shaft in place. The shaft must extend .760 inch from the side of the housing where the shutdown latch is assembled. Then install the pins which retain the valve(s) to the shaft.
2. Lubricate with engine oil and install a new seal ring at each end of the shaft.
3. Install the cam and cam pin handle on the shaft.
4. Install a washer and retaining pin at the other end of the shaft.
5. Assemble the spacer and spring on the latch. Then slip the attaching bolt through the lock washer, plain washer, latch and spacer. Attach the latch assembly to the housing and tighten the bolt.
6. After assembly, check for .015 to .040 inch shaft end play.

INSTALL AIR SHUTDOWN HOUSING

Before attaching the shutdown assembly to the blower, place a steel straight–edge lengthwise on the finished face of the housing bolting flange (Figure 2.) and close the valves against the straight–edge. The finished pads at each end of both valves must be flush against the straight–edge when it is moved from the top to the bottom of the inlet housing flange. Now turn the straight–edge crosswise on the housing flange and draw it from end–to–end. Both the upper and lower finished pads of the valves must be flush against the straight–edge throughout the length of the valves.

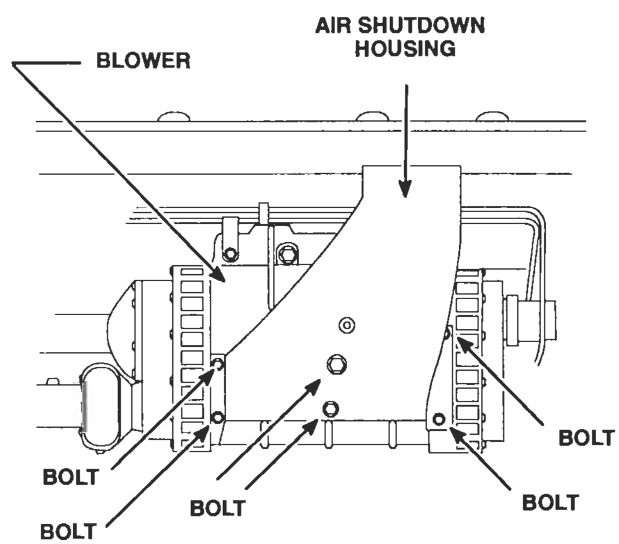

Figure 2. Air Shutdown Housing Mounting Bolt Location

INSTALL AIR SHUTDOWN HOUSING (CONT.)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

NOTE: 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.

2. Mount the air shutdown housing together with the striker plate gasket and striker plate (if used) on the blower with bolts and lock washers and tighten the bolts to 16–20 lb/in.^{2} (22–27 N·m) torque.

NOTE: The 3/8–16 x 3–1/4 inch bolt and the 3/8–16 x 2 inch bolt must be installed properly. The four 1–5/8 inch bolts are installed in the four corner bosses of the housing.

3. Connect the Bowden wire or cable assembly to the air shutoff cam handle pin.
4. Start and run the engine at idle speed and no load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valve(s) and the striker plate. Reposition the valve(s) if necessary.
5. Install the air cleaner or air cleaner ducts.

6–71 TA, TTA ENGINE BLOWER BYPASS VALVE MAINTENANCE

The air inlet housings on Inline 6–71 turbocharged–aftercooled automotive engines are equipped with blower bypass valves. The original valves used an aluminum piston with a single seal ring (Figure 3.) A steel piston with two seal rings replaced the aluminum piston, effective with engine serial number 6A0449864. To insure the continued efficient operation of these valves, the piston bores must be lubricated with Parker Super 0–Ring Lube (or equivalent high temperature silicone grease) at the following intervals:

If the valve has an aluminum piston (one groove, one 0–ring seal), lubricate every 30,000 miles.

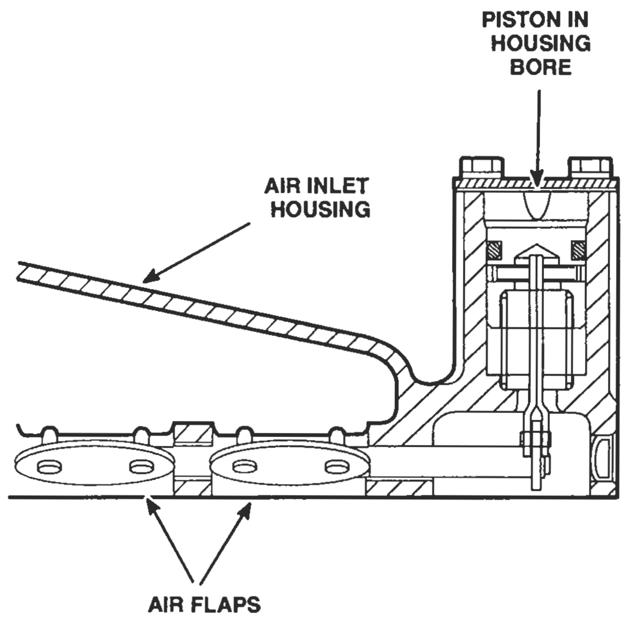

Figure 3. Air Inlet Housing Valve Tower

6–71TA, TTA ENGINE BLOWER BYPASS VALVE MAINTENANCE (CONT.)

If the valve has a steel piston (Figure 4.) (two grooves, two 0–ring seals), lubricate every 100,000 miles.

NOTICE:

Failure to lubricate the piston bore can result in premature seal wear, metal–to–metal piston/bore contact, and valve sticking, causing low power and black smoke at low engine speed.

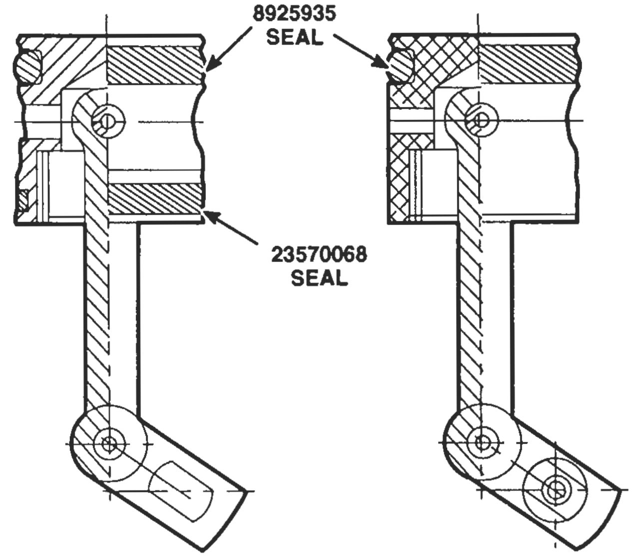

Figure 4. Former and Current Piston and Link Assemblies

LUBRICATE BYPASS VALVE PISTON BORE

1. Loosen the four 5/16 inch bolts on the air inlet housing valve tower and remove the cover and gasket.
2. Push the bypass valve piston to the bottom of the bore.
3. Lightly coat the bore with Parker Super O–Ring Lube (or equivalent). Move the piston up and down to evenly distribute the grease.
4. Using a new cover gasket, replace the cover and reinstall the four bolts. Tighten to 13 – 17 $lb/in.^2$ (18 – 23 N·m) torque.

To insure continued efficient engine operation, DDC recommends replacing the former piston with the new at time of major overhaul or earlier if valve sticking or valve bore scoring is experienced.

NOTICE:

Before installing a new steel piston, check the valve bore for scoring or any rough ridges. Installing a piston in a scored bore can lead to rapid seal wear and eventual valve sticking. Remove scored or rough areas carefully with crocus cloth wet with fuel oil. Clean the valve bore thoroughly after this operation.

LUBRICATE BYPASS VALVE PISTON BORE (CONT.)

Effective with engine serial number 6A0450228, a 5/16 x 1 inch slotted spring pin (Figure 5.) was installed in the valve tower air transfer passage to block off the air bleed hole and improve the operation of the steel piston. DDC recommends installing the spring pin in all previously built engines which have the steel piston or whenever the aluminum piston is replaced by the steel.

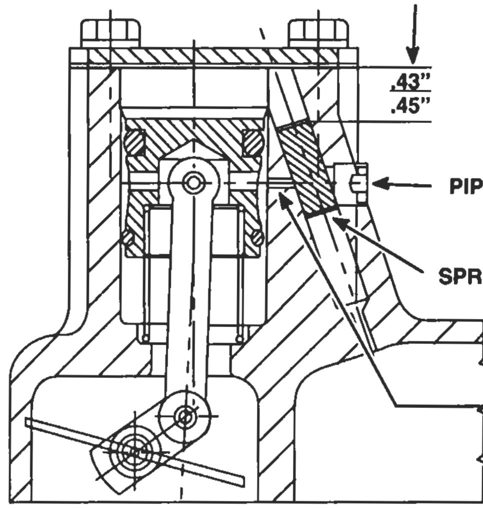

Figure 5. Valve Tower Cross–Section View Showing Spring Installed

INSTALL STEEL PISTON AND SPRING PIN

1. Remove the air inlet housing (Section 3.3).
2. Remove the four valve tower bolts and lock washers.
3. Remove the screw holding the piston link in place from the end of the shaft.
4. The piston is spring–loaded so very carefully slide the piston link off the shaft.
5. Remove the piston and link assembly with the spring.
6. Remove the 1/8 inch pipe plug from the side of the valve tower and position the spring pin in the valve tower air transfer passage so that the slotted side faces the pipe plug hole and the closed side faces the piston. Use a suitable blunt pin punch and drive the pin into the air transfer passage to a depth of .43 to .45 inches below the machined surface of the tower.
7. Visually check to make sure the pin slot faces the plug hole and the pin extends below the bottom of the hole. Replace the pipe plug.
8. Install the new O–Ring seals in the proper locations on the new steel piston.
9. Lightly coat the valve bore with Parker Super O–Ring Lube or an equivalent high temperature silicone grease. Coat the O–Ring seals with the same lubricant and press some into the piston grooves.
10. Install the new piston and link assembly with the spring. Be careful to avoid any dirt contamination.
11. Slide the link onto the shaft and secure it with the screw and washer. Tighten the screw to 20 – 22 lb/in.^{2} (2.26 – 2.49 N·m) torque.
12. Cycle the valve manually several times to ensure proper operation and to evenly distribute the grease in the piston bore.

INSTALL STEEL PISTON AND SPRING PIN (CONT.)

13. Use a new gasket and replace the valve cover plate and reinstall the four bolts and lock washers. Tighten the bolts to 13 – 17 lb/in.^{2} (18 – 23 N·m) torque.
14. Reinstall the air inlet housing on the engine (Section 3.3).

NOTE: To ensure efficient valve operation, the valve bore with the new steel piston must be lubricated every 100,000 miles with Parker Super O–Ring Lube or an equivalent high temperature silicone grease.

BLOWER

The blower is designed especially for efficient diesel operation and 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 the housing bolted to the cylinder block. To provide continuous and uniform displacement of air, the rotor lobes are made with a helical (spiral) form.

Two timing gears are located on the drive end of the rotor shafts and space the rotor lobes with a close tolerance. Since the lobes of the upper and lower rotors do not touch at any time, no lubrication is required.

Oil seals located in the blower end plates prevent air leakage and also keep the oil used for lubricating the timing gears and rotor shaft bearings from entering the rotor compartment. Lip type oil seals are installed in the blower end plates.

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 pre–loaded radial and thrust ball bearing at the gear end.

The upper blower rotor is driven by the blower drive shaft which is coupled to the upper rotor timing gear by means of a flexible drive hub.

A flexible coupling, formed by an elliptical cam driven by two bundles of leaf springs which ride on four semi–cylindrical supports and spring seats is attached to the blower drive gear (Figure 1.) and prevents the transfer of torque fluctuations to the blower.

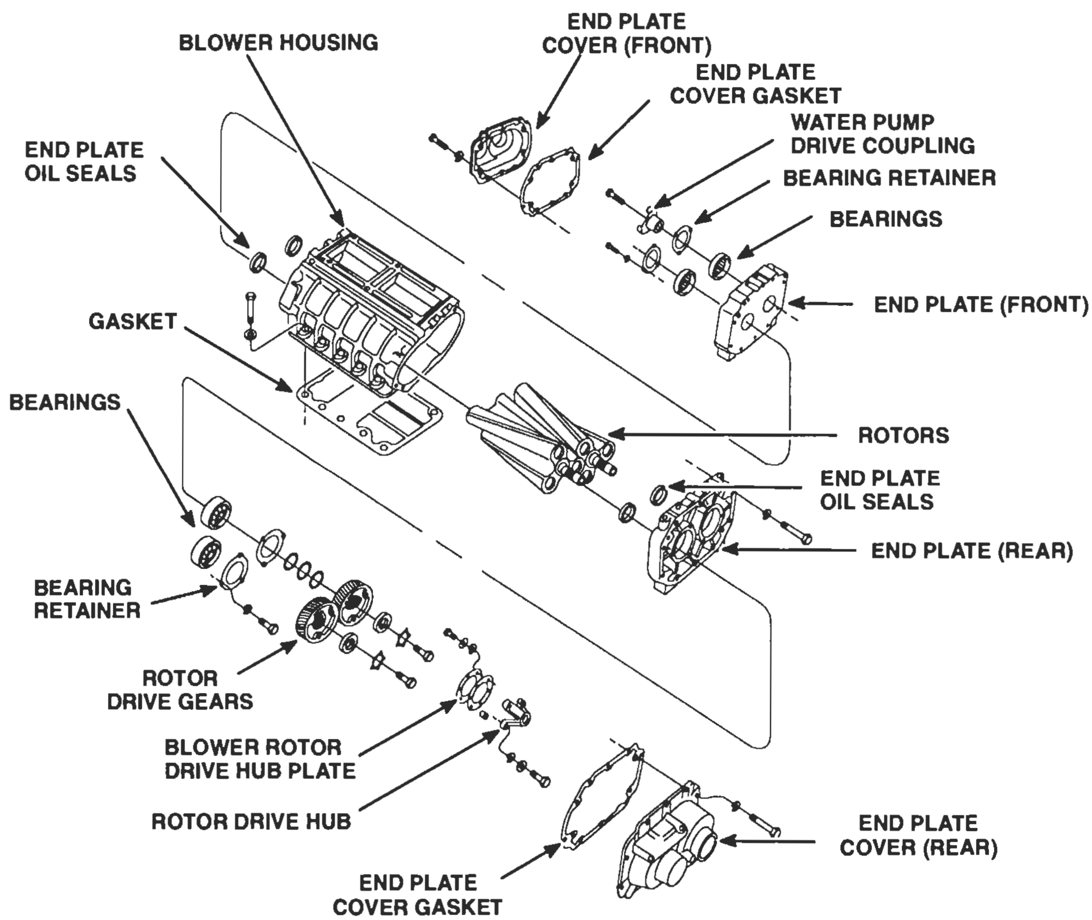

Figure 1. Blower Drive Assembly and Accessories

SECTION 3.4 – BLOWER

BLOWER (CONT.)

The former 71E and 71N engines used a 1.69:1 ratio blower and the former 71T engines used a 1.55:1 ratio blower. Early engines employ a 2.00:1 ratio standard blower.

Currently a standard and a small diameter rotor blower are used on Inline 71 engines. The small diameter rotor blower with a 2.00:1 blower–to–engine speed ratio is employed in the 71E and 71N engines and a 1.95:1 blower–to–engine speed ratio is employed in the 71T engines.

The ratio between the blower speed and the engine speed, and the number of teeth in the blower drive gears and reduction gears is shown in Table 1.

Engine Type	Blower Type	Ratio Blower to Engine Speed	No. Teeth (Blower Drive Gear)	No. Teeth (Reduction Gear)
CURRENT 71N AND 71T ENGINES				
71	Standard	2.00:1	39	No Gear
71N	Small Dia. Rotor	2.00:1	39	No Gear
71T	Small Dia. Rotor	1.95:1	40	No Gear
71T, 71TTA	Small Dia, Rotor+	1.65:1	40	No Gear
71	Large Bearing*	2.00:1	39	No Gear
FORMER 71, 71E, 71N AND 71T ENGINES				
71E, 71N	Standard	1.69:1	39	33 (Drive) 39 (Driven)
71T	Standard	1.55:1	39	45 (Drive) 58 (Driven)

* 1.95:1 ratio – Two valve head engine
+ 1979 vehicle engine

TABLE 1

BLOWER (CONT.)

Reduced blower speed on the former 71E, 71N and 71T reduction blowers is accomplished by the use of an additional pair of gears mounted on the rotor shafts. The upper drive gear is mounted on a double row ball bearing and is driven by the blower drive shaft by means of a flexible drive hub attached to the gear (Figure 2.) The drive gear mates with a lower driven gear that is meshed to the lower blower rotor shaft. Since the lower rotor (timing) gear is also meshed to the lower rotor shaft, it drives the upper rotor (timing) gear.

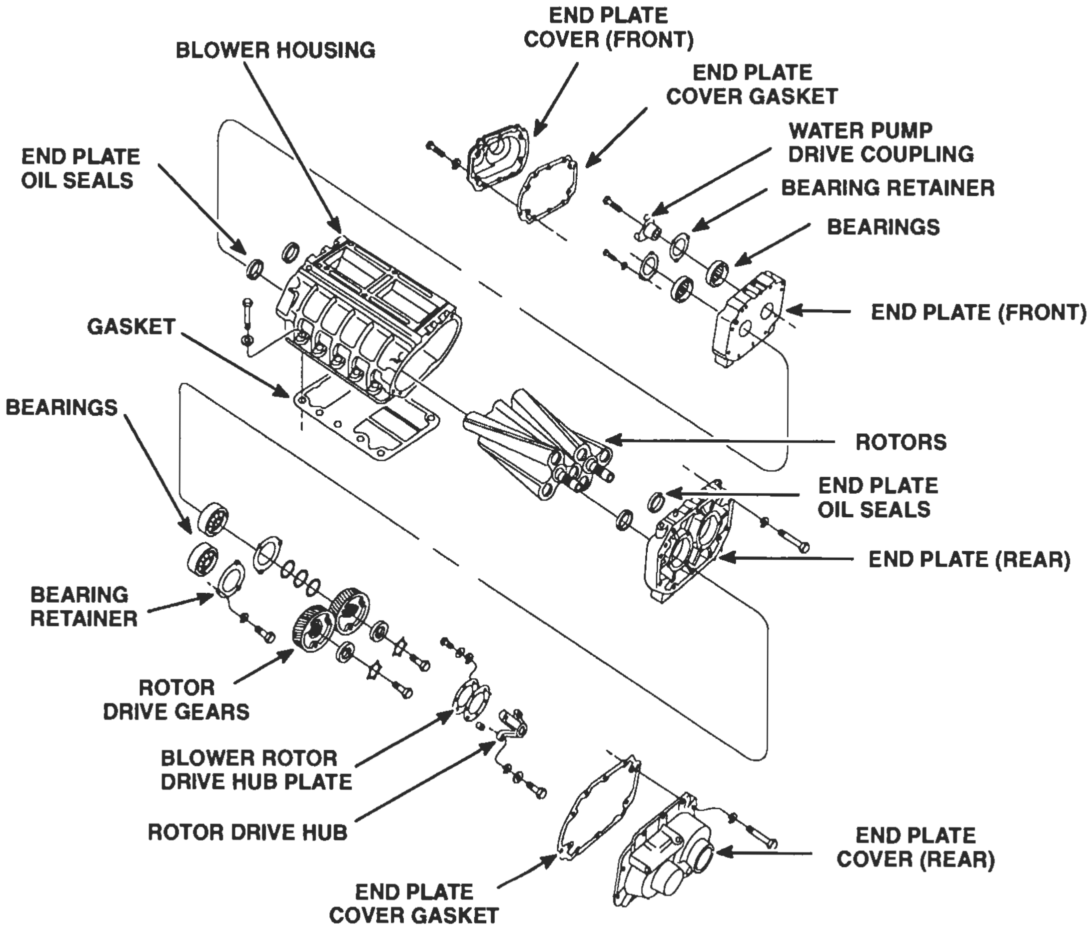

Figure 2. Former Reduction Blower Assembly (71E, 71N and 71T)

The blower rotors are timed by the two rotor (timing) gears and 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.

Normal gear wear causes a decrease in the rotor–to–rotor clearance between the leading edge of the upper rotor lobes and the trailing edge of the lower rotor lobes of the standard blower and the small diameter rotor blower. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While the rotor lobe clearance may be adjusted by the use of shims behind the gears, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds .004 inch, replace the gears.

SECTION 3.4 – BLOWER

LUBRICATION

Oil drains from the valve operating mechanism on the cylinder head into the camshaft pocket (A and C engines) or balance shaft pocket (B and D engines) in the cylinder block. Then, when it reaches a certain level, the oil flows from the pocket into cavities at the upper corners of the blower and through passages in the blower and end plates to lubricate the bearings, governor and water pump drives at the front end, and bearings and gears at the rear end of the blower. A slinger attached to the front end of the lower rotor shaft throws oil onto the front roller bearings and governor weights. A dam in the blower end plates maintains oil at a level adequate to submerge the lower portion of the slinger and the driven gear.

Surplus oil overflows the dams in the end plates and returns through two drilled holes in the cylinder block to the engine crankcase.

INSPECTION OF BLOWER

The blower may be inspected for any of the following conditions without being removed from the engine. However, the air silencer or air shutdown housing must be removed.

CAUTION:

When inspecting a blower on an engine with the engine running, keep fingers and clothing away from the moving parts of the blower and run the engine at low speeds only.

Dirt or chips drawn through the blower will make deep scratches in the rotors and housing and throw up burrs around such abrasions. If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine and dress the parts down to eliminate the interference, or replace the rotors if they are too badly scored.

Leaky oil seals are usually manifested by the presence of oil on the blower end plates and rotors or the inside surfaces of the housing. This condition may be checked by running the engine at low speed and directing a light into the rotor compartment at the end plates and the oil seals. A thin film of oil radiating away from the seals is indicative of an oil leak.

A worn blower drive, resulting in a rattling noise inside the blower, may be detected by grasping the top rotor firmly and attempting to rotate it. Rotors may move from 3/8 to 5.8 inch, measured at the lobe crown, with a springing action. When released, the rotors should move back at least 1/4 inch. If the rotors cannot be moved as directed above, or if the rotors move too freely, inspect the flexible blower drive coupling and replace it if necessary.

If the drive coupling is worn, the blower drive gear assembly may be removed from the cylinder block end plate after the blower has been removed from the engine and the drive gear hub bearing support to cylinder block end plate bolts are removed (Section 1.7.6).

Loose rotor shafts or damaged bearings will cause rubbing and scoring between the crowns of the rotor lobes and the mating rotor roots, between the rotors and the end plates, or between the rotors and the housing. Generally, a combination of these conditions exists. A loose shaft usually causes rubbing between the rotors and the end plates. Worn or damaged bearings will cause rubbing between the mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing. This condition will usually show up at the end where the bearings have failed. Excessive backlash between the blower timing gears usually results in the rotor lobes rubbing throughout their entire length.

To correct any of the above conditions, remove the blower from the engine and either repair or replace it.

Inspect the blower inlet screen periodically (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 the dirt deposits.

REMOVE BLOWER

In most cases, removal of the blower together with the governor drive, fresh water pump, fuel oil pump, and the blower drive shaft cover will be found most advantageous. To remove this assembly, (Figure 3.) proceed as follows:

1. Drain the cooling system.
2. Remove the limit or variable speed governor control housing assembly (Section 2.7.1 or Section 2.7.2). Refer to Section 2.8.1 or 2.8.2 if the engine is equipped with a hydraulic governor.
3. Disconnect the fuel lines at the fuel pump.
4. Loosen the water pump connections at the pump cover (inlet) and the cylinder block.

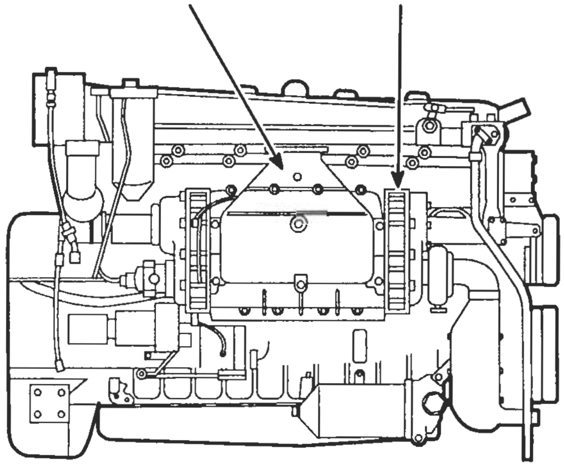

Figure 3. Typical Blower Mounting (71 Engine)

5. If the engine is equipped with a turbocharger, loosen the hose clamps and slide the hose and clamps back on the air inlet housing (Figure 4.)
6. If the engine is equipped with an automatic shutdown solenoid, tag and remove the wires from the solenoid. Then remove the solenoid.
7. If the engine is equipped with a manually operated shutdown, disconnect the control wire from the air shutdown valve shaft lever then remove the bolt securing the control wire clip to the air shutdown housing.
8. Remove the air cleaner (non–turbocharged engines) then remove the air inlet housing, gasket, striker plate and air inlet screen and gasket from the blower.
9. Remove the blower drive shaft (Section 1.7.6).
10. Loosen the blower drive shaft cover seal clamp at the blower drive gear hub support.
11. Remove the bolts and plain washers securing the blower to the cylinder block. Slide the blower slightly forward, withdraw the blower drive shaft cover from the seal, then lift the blower away from the cylinder block.

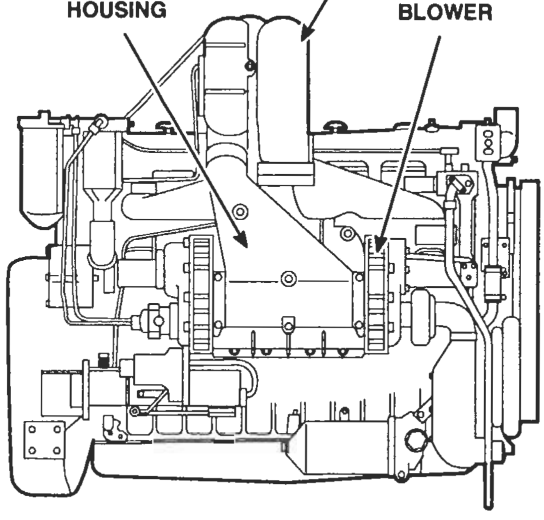

Figure 4. Typical Blower Mounting (71T Engine)

REMOVE ACCESSORIES FROM BLOWER

1. Remove the three bolts and seal washer assembly securing the fuel pump to the blower rear end plate cover. Then remove the fuel pump, gasket and drive coupling fork.
2. Loosen the seal clamp securing the blower drive shaft cover to the blower end plate cover. Then remove cover, seal and clamp from the end plate cover.
3. Remove the three bolts and seal washer assembly securing the fresh water pump to the blower front end plate cover. Then remove the water pump and gasket. If necessary, tap the pump with a plastic hammer to loosen it.
4. Remove the six bolts and seal washer assembly securing the governor weight housing or drive housing (hydraulic governor) to the blower front end plate cover. Then remove the weight housing or drive housing and gasket.

DISASSEMBLE BLOWER

Disassemble the blower as follows:

1. Remove the ten bolts and lock washers securing the end plate covers and to the blower front and rear end plates. Tap the ends of the end plate covers with a plastic hammer to loosen the covers from the gaskets and dowel pins in the end plates. Then remove the covers and gaskets from the end plates.
2. Place a clean folded cloth between the rotors to prevent the rotors from turning. Then remove the bolt securing the water pump drive coupling to the blower rotor shaft (Figure 5.)
3. Thread adaptor J 6471–4 (1/2–20 inch threads) or adaptor J 6471–10 (9/16–18 inch) into the water pump drive coupling. Then attach slide hammer and shaft J 6471–1 to the adaptor and pull the drive coupling from the blower rotor shaft.
4. Remove the bolts, lock washers and plain washers securing the blower rotor drive hub and drive hub plates to the blower rotor timing gear or drive gear. Remove the drive hub plates and spacers (and bearing retainer on former 71E, 71N and 71T blowers) from the gear.

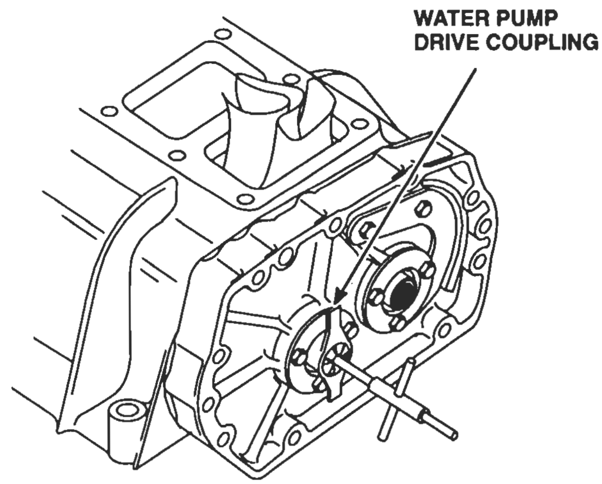

Figure 5. Removing Water Pump Drive Coupling Bolt from Blower Rotor Shafts

DISASSEMBLE BLOWER (CONT.)

If necessary, remove the three bolts, lock washer and plain washers securing the drive plates to the drive hub.

5. Remove the reduction drive gears (if used) and the blower rotor timing gears as follows:
   a. Remove bolt, lock washer and retainer securing the timing gear or the reduction drive gear (if used) to the right–hand helix rotor shaft. Then remove the bolt, lockwasher and fuel pump coupling disc securing the other timing gear or the reduction driven gear (if used), to the left–hand helix rotor shaft. If used, slide the right–hand helix reduction drive gear with bearing off the upper rotor shaft. Remove the reduction driven gear from the lower rotor.
   b. Back out the center screw of both pullers J 6270–31 and secure the pullers to the timing gears with 5/16–24 x 1–1/2 inch bolts.

NOTE: Both gears must be pulled from the rotor shafts at the same time.

   c. With shop towels between the blower rotors and housing to prevent them from turning, turn the puller screws uniformly clockwise and pull the gears from the rotor shafts (Figure 6.)
   d. Remove the shims from the rotor shafts or the inner face of the gears and note the number and thickness of the shims used with each gear.

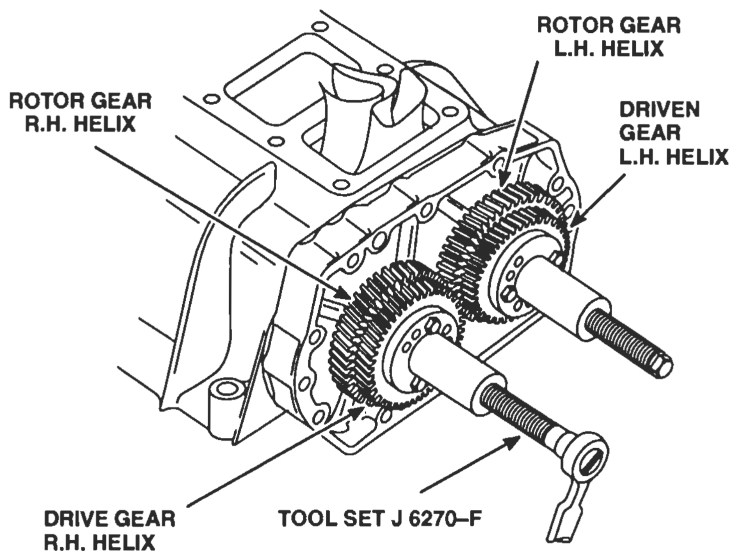

Figure 6. Removing Blower Rotor Gears from Blower Rotor Shafts

6. Remove the bolts and lock washers securing the rotor shaft bearing retainers to both the front and rear end plates. Remove the retainers.
7. Remove the blower rear end plate and bearing assembly from the blower housing and rotors with the two pullers J 6270–31 as follows:
   a. Remove the two head screws securing the rear end plate to the blower housing and loosen the two 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 hole 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 inch bolts.

NOTICE:

Be sure that the 1/4–20 inch 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.

DISASSEMBLE BLOWER (CONT.)

d. Turn the two pullers screws uniformly clockwise and withdraw the end plate and bearings from the blower housing and rotors (Figure 7.)

8. Remove the blower front end plate in the same manner as described in Step 7.
9. Withdraw the blower rotors from the housing.

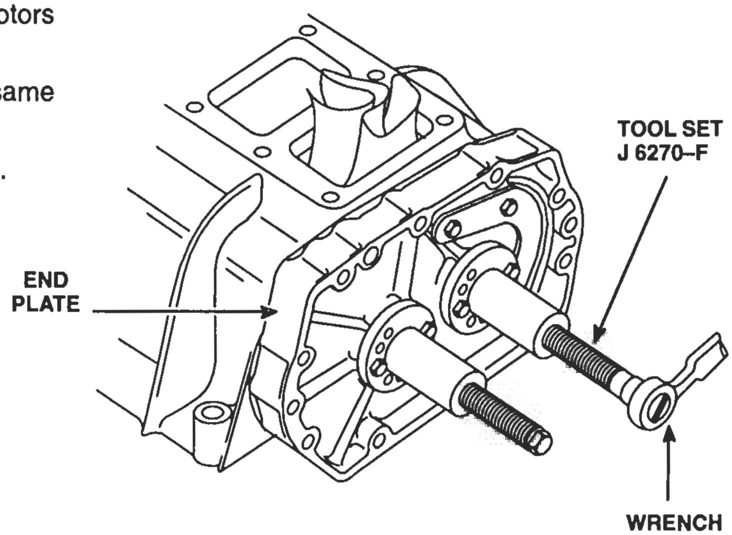

Figure 7. Removing Blower End Plate

10. Remove the bearings and the lip type oil seals from the blower end plates as follows:

a. When performing a major overhaul, discard the oil seals; otherwise inspect the oil seals. If the seals are scored, or hard, new seals must be installed. If necessary, remove the seals from the end plates at the same time the individual bearings are removed.

b. Support the outer face of the end plate on wood blocks on the bed of an arbor press.

c. 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 (Figure 8.) Then press the bearing and oil seal out of the end plate. Discard the oil seal.

d. Remove the remaining bearings and oil seals from the end plates in the same manner.

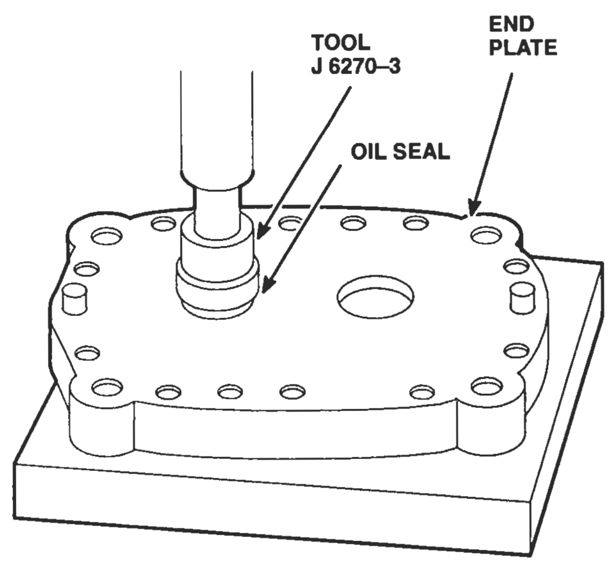

Figure 8. Removing Oil Seal and Bearing from End Plate

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DISASSEMBLE (CONT.)

11. Remove the bearings and ring type oil seals, carriers, and collars from the blower rotor shafts and end plates as follows:

    a. Clamp one lobe of the rotor in a bench vise equipped with soft jaws (Figure 9.) 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 J 4880.

NOTICE:

To avoid breakage or distortion, do not spread or twist the ring any more than necessary to remove it.

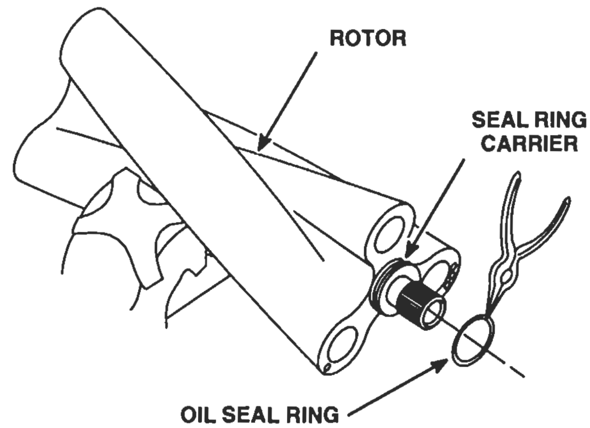


Figure 9. Removing Oil Seal Ring from Carrier

c. Place the seal ring carrier remover adaptor J 6270–2 over the carrier (Figure10). 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.

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 from the rotor shaft.

g. Remove the remaining oil seal ring carriers from the rotor shafts in the same manner.

h. 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. 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.

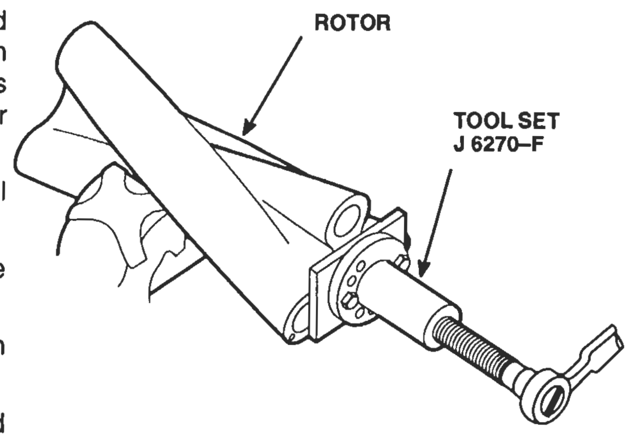


Figure 10. Removing Oil Seal Ring Carrier from Blower Rotor Shaft

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 lb/in^2 (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.

The double–row ball bearings are pre–loaded and have no end play. A new double–row bearing will seem to have considerable resistance to motion when revolved by hand.

Check the oil seal rings, carriers and collars for wear and scoring. If worn excessively, they must be replaced. The current oil seal rings are chrome flashed and the carriers are liquid nitrated. When replacement of an oil seal ring or carrier is necessary, both parts must be replaced together.

NOTE: Oversize oil seals and oil seal spacers are available in the blower kit to replace the standard oil seals where the blower rotor shafts are grooved.

Inspect the blower rotor lobes, especially the sealing ribs, for burrs and scoring. Rotors must be smooth for efficient 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 and scoring.

Inspect the inside surface of the blower housing for burrs and 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 and burrs. The end plates must set flat against the blower housing.

The finished inside face of each end plate must be smooth and flat. If the finished face is slightly scored or burred, it may be cleaned up with emery cloth.

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 and peening; also check the teeth for wear, chipping or damage. If the gears are worn to the point where the backlash between the gear teeth exceeds .004 inch, 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.

Inspect the serrations inside the rotor drive hub for wear and peening.

Inspect the blower drive coupling springs (pack) and the cam for wear.

Replace all worn or excessively damaged blower parts.

ASSEMBLE BLOWER

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing.

The lobes on the upper blower rotor and the teeth on its gear form a right–hand helix while the lobes and teeth of the lower rotor and gear form a left–hand helix. Therefore, a rotor with right–hand helix lobes must be used with a gear having right–hand helix teeth and vice versa (Figure 11.)

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.

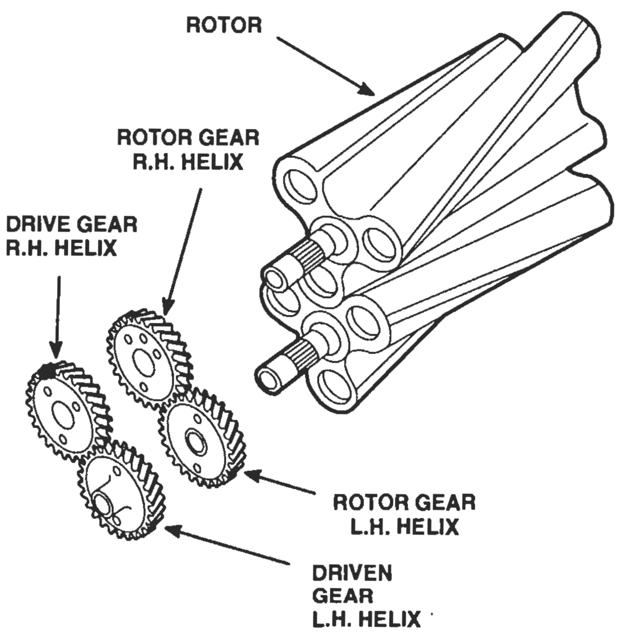


Figure 11. Upper and Lower Rotor and Gears (Former Reduction Blowers)

BLOWER ASSEMBLY (CONT.)

With this precaution in mind, proceed with blower assembly (Figure 12.) as directed in the text.

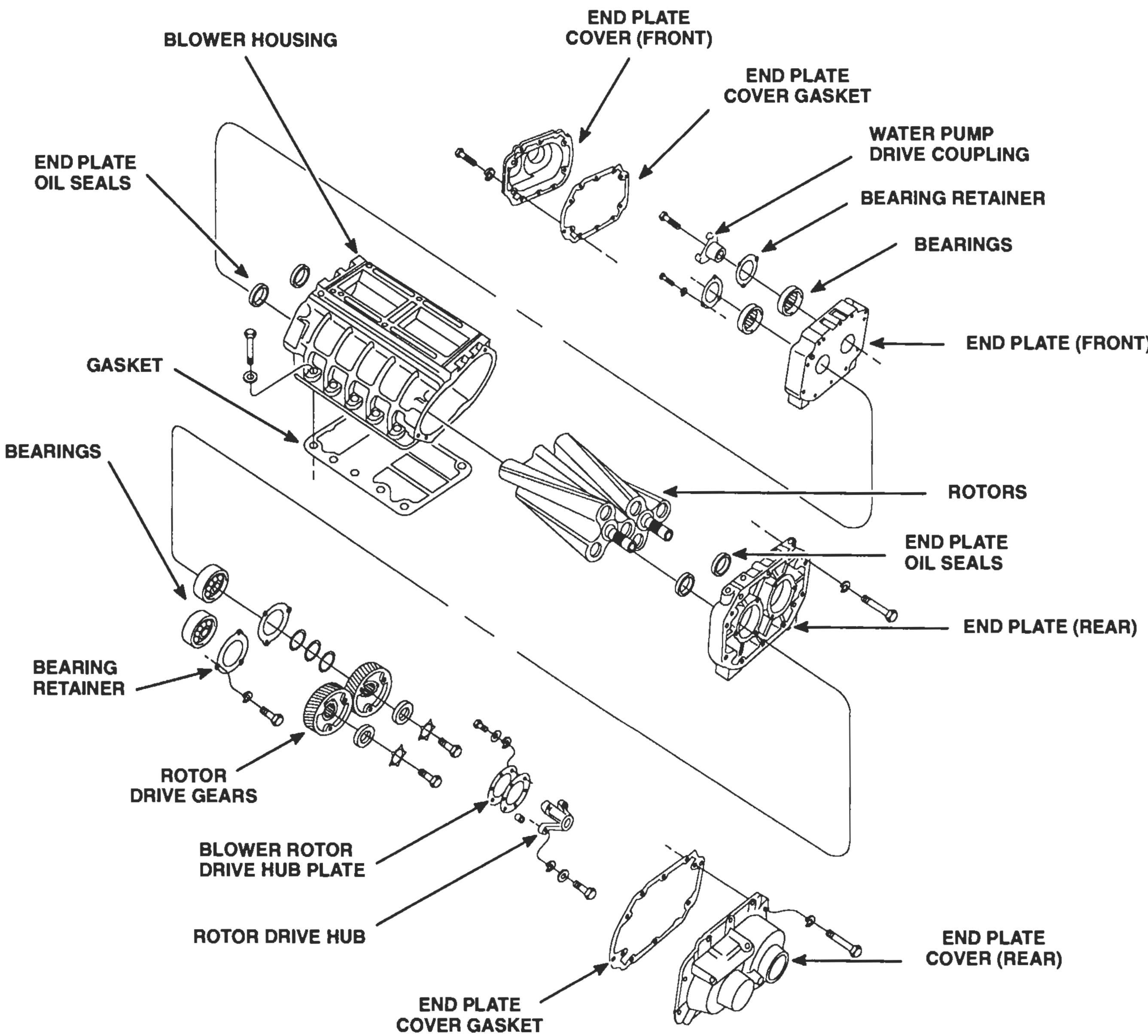


Figure 12. Standard and Small Diameter Rotor Six Cylinder 71 Blowers

BLOWER ASSEMBLY (CONT.)

Assemble the blower as follows.

1. Install the lip type oil seals as follows:

NOTE: When installing Teflon–lip seals, do not lubricate the seal, spacer, or blower rotor shaft prior to installation. Teflon–lip seals must be installed dry. This allows transfer of the Teflon to the spacer surface for proper sealing.

a. Support the blower end plate, finished surface facing up, on wood blocks on the bed of an arbor press.

NOTE: If oversize oil seals are being used in the blower end plates, use installer J 35781–1 to install the oversize oil seal spacer on the rotor shafts. The spacer must be pressed onto the rotor shaft from the end of the rotor until either shoulder of the tool or the spacer contacts the rotor.

b. Start the oil seal straight into the bore in the end plate with the sealing edge facing down (toward the bearing bore). If a double lip Teflon seal is used, make sure the part number on the seal case faces up (toward the rotor when installed).

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 (Figure 13.)

NOTE: A step under the shoulder of the installer will position the oil seal approximately .005 inch below the finished face of the end plate. This is within the .002 inch to .008 inch specified.

d. Install the remaining oil seals in the end plates in the same manner.

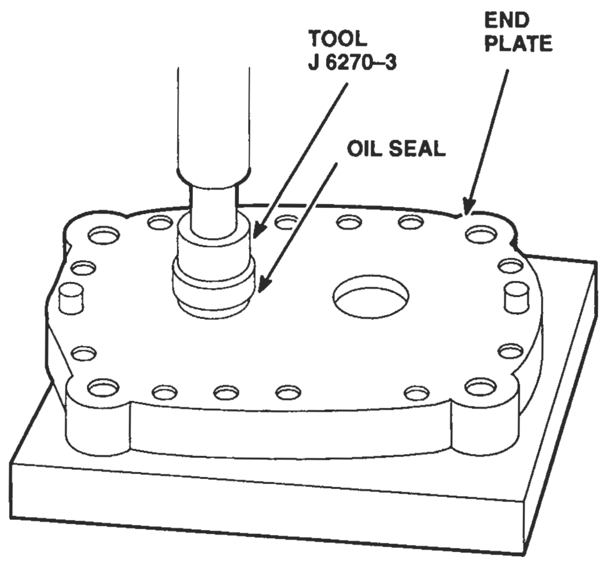


Figure 13. Installing Oil Seal in Blower End Plate

BLOWER ASSEMBLY (CONT.)

2. Install the ring type oil seal, carriers, and collars 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.

   b. Lubricate the inside diameter of the oil seal ring 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 6270–4 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.

   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 J 4880 in the same manner (Figure 14.)

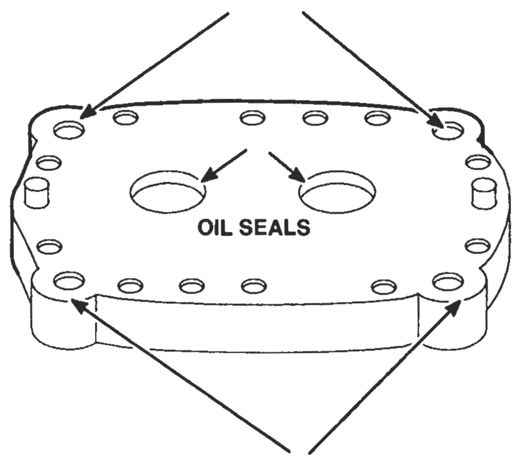


Figure 14. Blower End Plate and Lip Type Oil Seal Location

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 (Figure 15.)

   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 6270–4 on top of the seal ring collar and press the collar into the end plate until the shoulder on the installer contacts the end plate.

NOTE: A step under the shoulder of the installer will position the collar approximately .005 inch below the finished face of the end plate. This is within the .002 inch to .008 inch specified.

   i. Install the remaining oil seal ring collars in the end plates in the same manner.

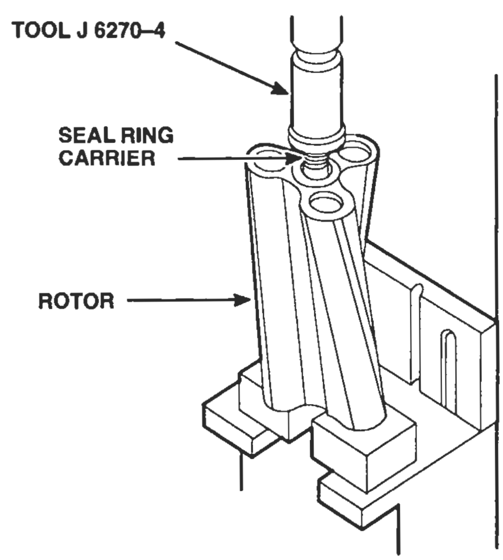


Figure 15. Installing Oil Seal Ring Carrier on Blower Rotor Shaft

ASSEMBLE ROTORS AND END PLATES (LIP TYPE OIL SEALS)

No gaskets are used between the end plates and the housing; therefore the mating surfaces must be perfectly flat and smooth.

For naturally aspirated engines apply a rubber base sealant as required to avoid leakage between the end plates and the blower housing.

For turbocharged engines apply a rubber base sealant between the entire joint face of the both ends of the blower housing–to–end plates interfaces, especially around the bolt holes and dowels.

NOTE: Be sure no sealant protrudes into the blower housing. Also, the sealant must not prevent the end plates from laying against the housing.

1. Install the blower front end plate. Make sure the mark TOP on the outer ribbed side is at the top of the blower housing, identified by the flange which supports the housing on the top edge of the cylinder block (Figure 16.) The front and rear end plates of the blower are interchangeable.

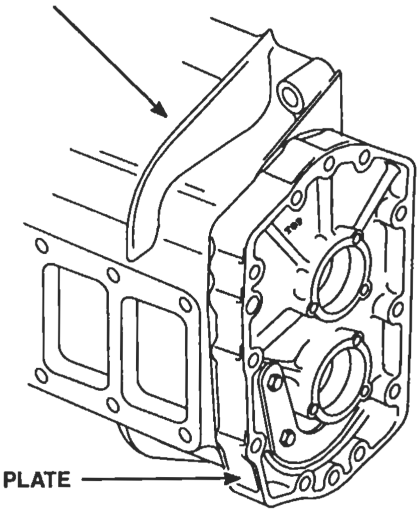


Figure 16. Position of Blower Front End Plate on Housing

One end plate should be assembled to the front end of the blower housing first and the other plate should be assembled to the rear of the blower housing after the rotors are in place. Attach an end plate to the front of the blower housing as follows:

a. Check the dowel pins. The dowel pins must project .380 inch from the flat inner face, and .270 inch from the outer face of the front end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.

b. Place the blower housing on a bench with the top of the housing up, and the front end of the housing facing the outside of the bench.

c. Position the end plate in front of the blower housing with the flat finished face of the end plate facing the housing and the end marked TOP facing the flanged side of the housing. Then start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing.

d. Insert the two 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. Assemble the blower rotors in the blower housing and front end plate as follows:

The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned.

ASSEMBLE ROTORS AND END PLATES (CONT.)

NOTE: The housing used in E and T blower assemblies are stamped for identification with the letter "E" or "T" near the top of the housing. The "N" engines are also stamped "E".

a. Place an oil seal pilot (seal protector) J 6270–5 on the short (non–splined) end of each rotor shaft. Then, place the rotors in mesh with the omitted serrations in the shafts in alignment.

NOTE: 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. Do not lubricate Teflon oil seals before installing blower rotors.

b. Insert the blower rotors with oil seal pilots straight into the blower housing with the right–hand helix rotor at the top flange side of the housing. Then push the rotor shafts and oil seal pilots on through the oil seal in the front end plate (Figure 17.)

c. Remove the oil seal pilots from the rotor shafts.

3. Attach the blower rear end plate to the blower housing as follows:

a. Reverse the blower housing on the bench (rear end of housing facing the outside of the bench).

b. Place an oil seal pilot J 6270–5 on the serrated end of each rotor shaft.

NOTE: 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. Do not lubricate Teflon oil seals before installing blower rotors.

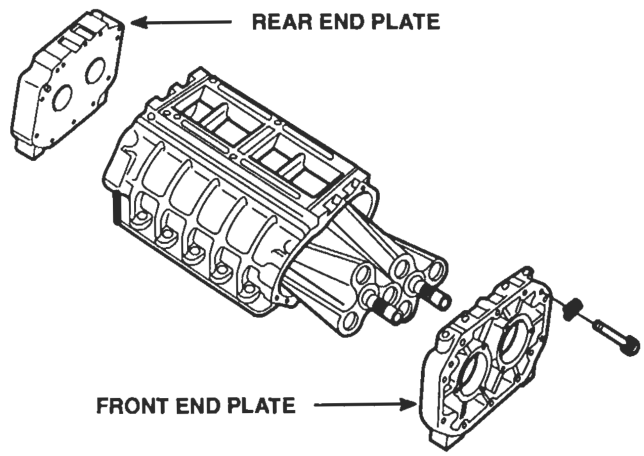


Figure 17. Assemble Blower Rotors into Housing and Front End Plate (Lip Type Oil Seals)

c. Check the dowel pins. The dowel pins must project .380 inch from the flat inner face, and .270 inch from the outer face of the rear end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.

d. Place the rear end plate in position in front of the oil seal pilots with the flat finished face of the end plate facing the blower housing and the mark TOP on the end plate at the top flange side of the housing.

ASSEMBLE ROTORS AND END PLATES (CONT.)

e. Place the rear end plate over the oil seal pilots and start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing (Figure 18.)

f. Insert the two 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.

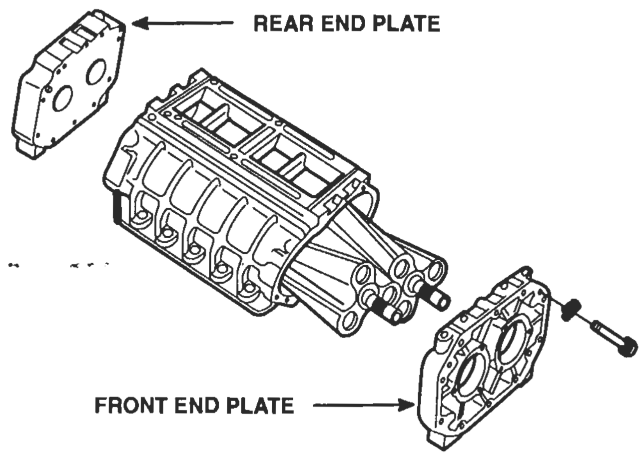


Figure 18. Install Blower Rear End Plate (Lip Type Oil Seals)

ASSEMBLE ROTORS AND END PLATES (RING TYPE OIL SEALS)

No gaskets are used between the end plates and the housing. Therefore, the mating surfaces must be perfectly flat and smooth.

For naturally aspirated engines apply a rubber base sealant as required to avoid leakage between the end plates and the blower housing.

For turbocharged engines apply a rubber base sealant between the entire joint face of both ends of the blower housing to end plates interfaces, especially around the bolt holes and dowels.

NOTICE

Be sure no sealant protrudes into the blower housing. Also the sealant must not prevent the end plates from laying against the housing.

1. The front and rear blower end plates are interchangeable. Install the blower rotors in the blower rear end plates as outlined below:

   a. Check the dowel pins. The dowel pins must project .380 in. from the flat inner face, and .270 in. from the outer face of the rear end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.

   b. Support the rear end plate on two wood blocks, approximately 4 in. high, with the inner face of the end plate facing up and the TOP side of the plate facing the service man's right.

ASSEMBLE ROTORS AND END PLATES (RING TYPE OIL SEALS) (CONT.)

c. 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.

d. 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 straight into the right–hand shaft opening in the end plate so that the gap portion of the seal ring is started into the collar. 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.

e. Perform steps “c” and “d” above on the left–hand helix rotor.

f. Position the rotors so the lobes are in mesh and the omitted serration in splines of both shafts face toward the top of the end plates. Then start the splined end of the shaft straight into the left–hand shaft opening in the end plate. Continue to lower the rotor in place as outlined in step “e”.

2. Determine the rotation of the blower being assembled then install the blower housing over the rotors as follows:

a. Position the blower housing above the rotors with its mounting flange facing toward the right–hand helix rotor. Lower the housing over the rotors until it contacts the dowel pins in the end plate.

b. Align the dowel pin holes in the blower housing with the dowel pins in the end plate. 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 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 front end plate on the rotors and housing as outlined below:

a. Check the dowel pins. The dowel pins must project .380 in. from the flat inner face, and .270 in. from the outer face of the front end plate to assure proper alignment of the end plate to the housing and the cover to the end plate.

b. Lubricate the oil seals in the carriers on the rotor shaft with engine oil.

c. Position the oil seal rings in the carrier so the ring protrudes from its grove the same amount on each side.

d. Position the front end plate over the top of the rotor shafts with the inner face of the end plate facing the rotors, and the mark “TOP” on the end plate at the flange side of the housing.

e. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing. 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.

f. 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.

ASSEMBLE ROTORS AND END PLATES (RING TYPE OIL SEALS) (CONT.)

1. With the blower housing, rotors and end plates still supported in a vertical position on the two wood blocks, install the roller bearings on the rotor shafts and in the front end plate as follows:
   a. Lubricate one of the roller bearings with engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.
   b. Place installer J 6270–4 on top of the bearing and tap the bearing on the shaft and into the front end plate (Figure 19.)
   c. Install the second roller bearing on the remaining rotor shaft in the same manner.
   d. Place the bearing retainers on top of the bearings and the end plate; then install the retainer bolts and lock washers. Tighten the bolts to 7–9 lb·ft (9–12 N·m) torque.
   e. Lubricate the oil seal ring in the carrier on the rear (splined) end of the right–hand helix rotor shaft with engine oil.
2. Start the end of the water pump drive coupling straight into the left–hand helix rotor shaft. Then place a clean folded cloth between the blower rotors to prevent them from turning. Install the drive coupling retaining bolt and draw the coupling and slinger tight against the end of the shaft, then tighten the bolt to 18 lb·ft (24 N·m) torque.
3. Install a new gasket to the blower front end plate cover.
4. Position the end plate cover over the end plate dowel pins, with the large hole in the cover toward the top of the end plate, then push the cover against the end plate.
5. Install the ten bolts and lock washers. Tighten the bolts to 13–17 lb·ft (18–23 N·m) torque.
6. Install the ball bearings on the rotor shafts and in the rear end plate as follows:

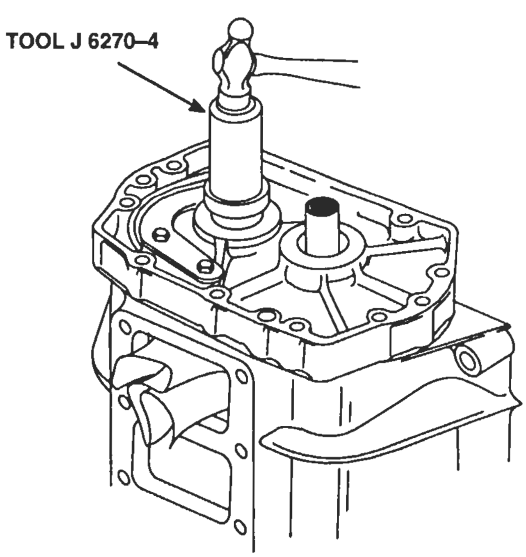


Figure 19. Installing Roller Bearings on Rotor Shaft and in Front End Plate

INSTALL BLOWER ROTOR SHAFT BEARINGS AND GEARS (CONT.)

a. Reverse the position of the blower housing on the two wood blocks.

b. On a blower with ring type oil seals, insert the two filister head screws through the rear end plate and thread them into the housing. Tighten the screws to 5–8 lb·ft 97–14 N·m) torque. Do not use lock washers on these screws.

c. Lubricate one of the ball bearings with engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

d. Place installer J 6270–7 on top of the bearing and tap the bearing straight on the shaft and into the rear end plate (Figure 20.)

e. Install the second ball bearing on the remaining rotor shaft in the same manner.

f. Place the bearing retainers on top of the bearings and the end plate, then install the retainer bolts and lock washers. Tighten the bolts to 7–9 lb·ft (9–12 N·m) torque.

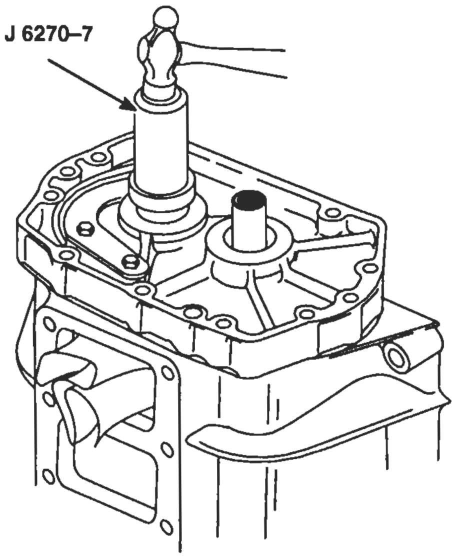


Figure 20. Installing Ball Bearing on Rotor Shaft and in Rear End Plate

7. Make a preliminary check of the rotor–to–end plate and rotor–to–housing clearances at this time with a feeler gage. Check minimum blower clearances.

8. Install the blower rotor timing gears on a standard blower or a smaller diameter rotor blower as follows:

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.

A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.

a. Place the blower housing and rotor assembly on the bench with the air inlet side of the housing facing 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 the top of the blower housing.

c. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

NOTE: When rebuilding a blower with new rotors or new gears, first install the gears on the rotor shafts without the shims, then check the clearances between the rotors to determine the location and thickness of shims to be used.

INSTALL BLOWER ROTOR SHAFT BEARINGS AND GEARS (CONT.)

d. Lubricate the serrations of the rotor shafts with 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, and the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.

g. Thread an installer screw J 6270–8 in the end of each rotor shaft until it bottoms. Place gear installer J 6270–7 over the installer screw and against the right–hand helix gear and gear installer J 6270–6 over the installer screw and against the left–hand helix gear. Then thread a nut on each installer screw (Figure 21.)

h. Place a clean folded cloth between the lobes of the rotors to prevent the rotors from turning. Then turn the nuts on the installer screws clockwise and draw the two gears into position at the same time, tight against the shims and bearing inner races.

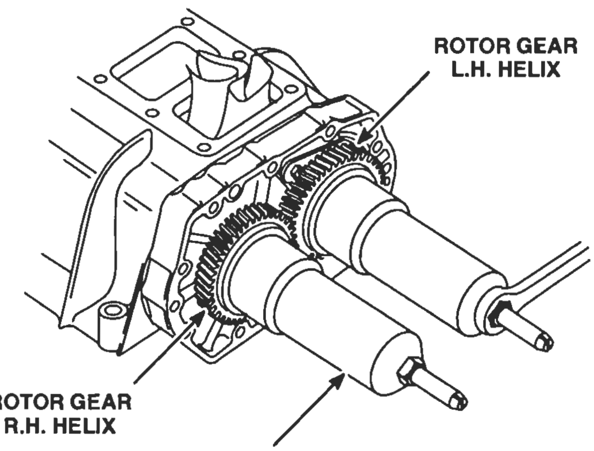


Figure 21. Installing Rotor Gears on Rotor Shafts for Preliminary Check of Clearances

i. Remove the rotor timing gear installers from the rotor shafts.

j. Place a lock washer and the gear retaining washer on one of the gear retaining bolts. Thread the bolt into the right–hand helix rotor shaft, and guide the lugs on the retaining washer in the slots in the gear hub. Bend one of the tangs on the lock washer over into the slot of the retaining washer. Tighten the gear retaining bolt to 55–65 lb·ft (75–88 N·m) torque.

k. Place a lock washer and the fuel pump drive coupling disc on the remaining gear retaining bolt. Thread the bolt into the left–hand helix rotor shaft and guide the lugs on the disc in the slots in the gear hub. Then bend one of the tangs on the lock washer over into the slot in the disc. Tighten the gear retaining bolt to 55–65 lb·ft (75–88 N·m) torque.

l. Bend one of the tangs of each lock washer over against the head of the gear retaining bolt. Remove the cloth from between the blower rotors.

9. Install the blower rotor timing gears on the former reduction blower as follows:

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.

INSTALL BLOWER ROTOR SHAFT BEARINGS AND GEARS (CONT.)

A center punch mark placed in the end of each rotor shaft at the omitted serrations will assist in aligning the gears on the shafts.

a. Place the blower housing and rotor assembly, air inlet side of housing facing up, on the bench with the rear end (serrated end of rotor shaft) of the blower facing the outside of the bench.

b. Rotate the rotors to bring the omitted serrations on the shaft in alignment and facing the top of the blower housing.

c. Install the same number and thickness of shims on the rotor shafts that were removed at the time of disassembly.

NOTE: When rebuilding a blower with new rotors or new gears, first install the gears on the rotor shafts without the shims, then check the clearances between the rotors to determine the location and thickness of shims to be used. Figure 22.

d. Lubricate the serrations on the rotor shafts with engine oil.

e. Start the left–hand helix gear on the shaft of the left–hand helix rotor with the omitted serrations in the gear and the shaft in alignment.

f. Thread an installer screw J 6270–8 in the end of the rotor shaft until it bottoms. Place the installer J 6270–7 over the screw and against the gear and thread a nut on the installer screw (Figure 21.)

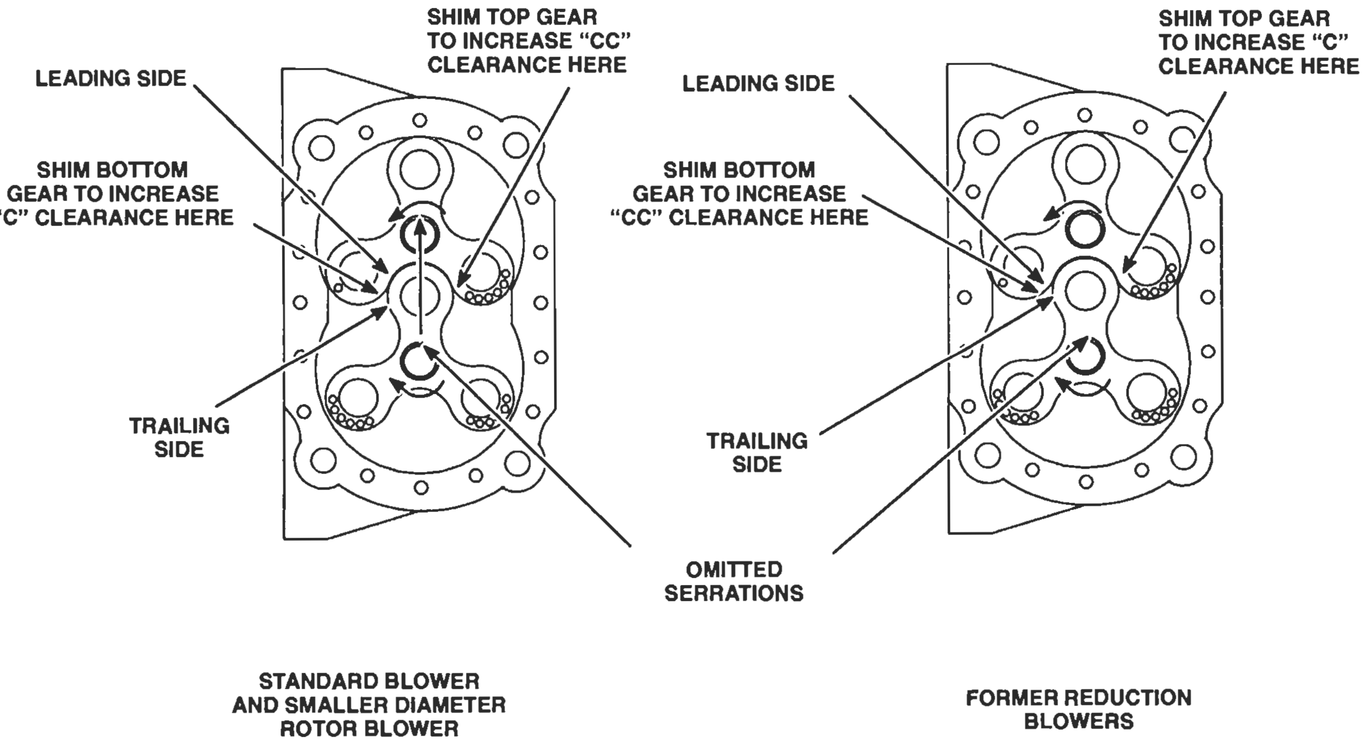


Figure 22. Location of Rotor Lobe Clearance Shims (C and D Engines Shown – A and B Engines Opposite) and End Rotor Clearance

INSTALL BLOWER ROTOR SHAFT BEARINGS AND GEARS (CONT.)

g. Place a clean folded cloth between the lobes of the rotors to prevent the rotors from turning. Then turn the nut on the installer screw clockwise and force the gear on the shaft until the outer face of the gear is flush or slightly below the end of the shaft.

h. Start the right–hand helix gear on the shaft of the right–hand helix rotor with the gear teeth in mesh and the omitted serrations in the gear and the shaft in alignment.

i. Thread an installer screw J 6270–8 in the end of the rotor shaft until it bottoms. Place the installer J 6270–6 over the screw and against the gear and thread a nut on the installer screw. Then turn the nuts on the installer screws uniformly clockwise and force the two gears into position at the same time, tight against the shims and bearings.

j. Remove the rotor timing gear installers from the rotor shafts.

k. Remove the cloth from between the blower rotors.

TIMING BLOWER ROTORS

After the blower rotors and timing gears are installed, the blower rotors must be timed.

When properly positioned in the housing, the blower rotors run with a slight clearance between the lobes. This clearance may be varied by moving one of the helical gears in or out on the shaft relative to the other gear.

If the 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 gear to obtain the proper clearance between the rotor lobes is known as blower timing.

Moving the gears "OUT" or "IN" on the rotor shafts is accomplished by adding or removing shims between the gears and the bearings.

The clearance between the rotor lobes should be checked with 1/2 inch wide feeler gages. When measuring clearances of more than .005 inch, laminated feeler gages that are made up of .002, .003 or .005 inch feeler stock are more practical and suitable than a single feeler gage. Clearances should be measured from both the inlet and outlet sides of the blower.

A specially designed feeler gage set J 1698–02 for the blower clearance operation is available. Time the rotors as follows:

1. 71 Blower — Timing the rotors to have .002 or .004 to .006 or .008 inch clearance between the TRAILING edge of the UPPER rotor and LEADING edge of the LOWER rotor ("CC" clearance) measured from both the inlet and outlet sides (Figure 23.) If possible, keep this clearance to the minimum dimension. Then check the clearance between the LEADING edge of the UPPER and the TRAILING edge of the LOWER rotors ("C" clearance) for the minimum clearance. Rotor–to–rotor measurements should be taken one inch from each end and at the center of the blower.

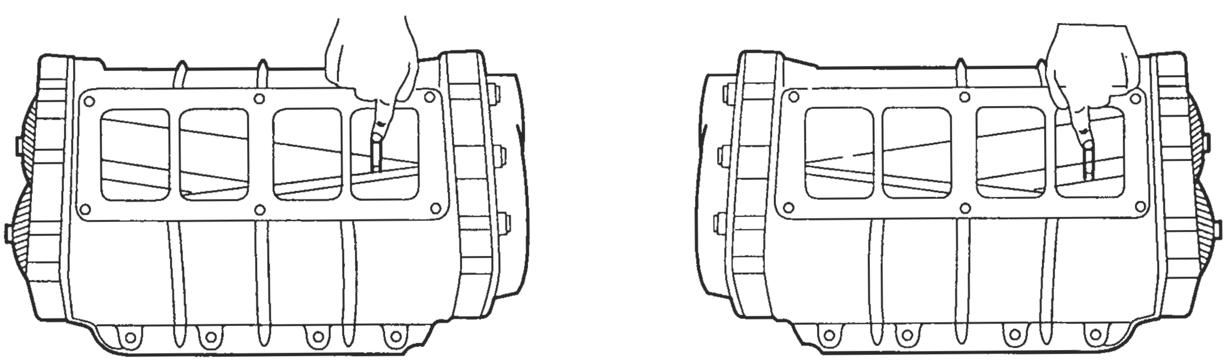
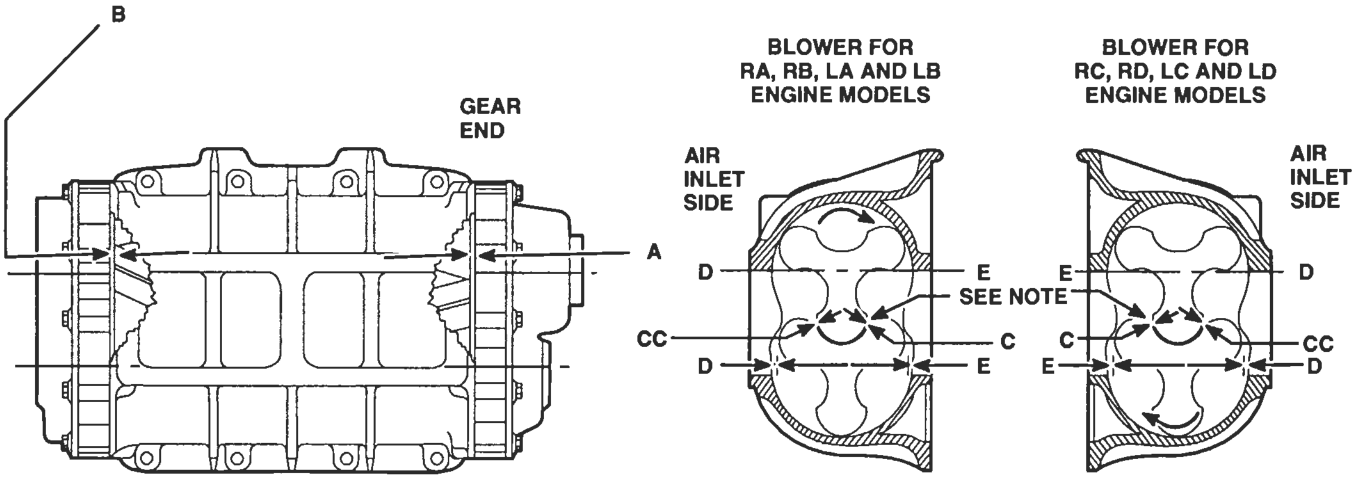


Figure 23. Measuring "CC" and "C" Clearances Between Blower Lobes and Clearances

TIMING ROTOR BLOWERS (CONT.)

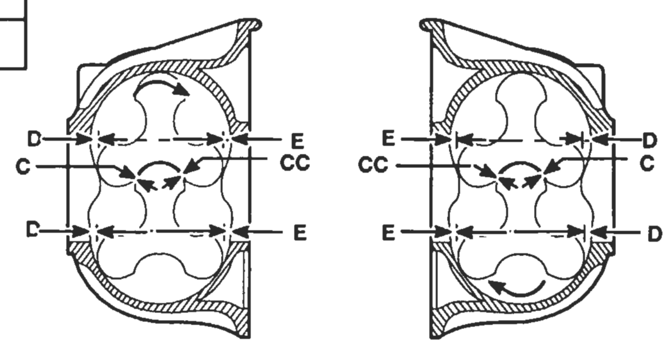
Former Reduction Blowers — Time the rotors to have .002 to .006 inch clearance between the TRAILING edge of the LOWER rotor and the LEADING edge of the UPPER rotor ("CC" clearance) measured from both the inlet and outlet sides (Figure 24.) If possible keep this clearance to the minimum (.002 inch). Then check the clearance between the LEADING edge of the LOWER and the TRAILING edge of the UPPER rotors ("C" clearance) for the minimum clearance. Rotor–to–rotor measurements should be taken one inch from each end and at the center of the blower.

2. 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. When more or less shims are required, both gears must be removed from the rotors. Placing a .003 inch shim in back of a rotor gear will revolve the rotor .001 inch.
3. Install the required thickness of shims back of the proper gear and next to the bearing inner race and reinstall both gears. Recheck the clearances between the rotor lobes.



		A	B	C	CC	D	E
4–71 DDEC	MIN.	.007	.009	.012	.002	.015	.004
	MAX.				.006		
6–71N & T DDEC	MIN.	.007	.014	.012	.002	.015	.004
	MAX.				.006		

NOTE: TIME ROTORS TO DIMENSION ON CHART FOR CLEARANCE BETWEEN TRAILING SIDE OF LOWER ROTORS AND LEADING SIDE OF UPPER ROTOR (CC) FROM BOTH OUTLET AND INLET SIDE OF BLOWER



ALL VIEWS FROM REAR OF ENGINE

Figure 24. Minimum Clearances for Former Reduction Blowers

TIMING ROTOR BLOWERS (CONT.)

4. Determine the minimum clearances at points "A" and "B". Insert the feeler gages between the end plates and the ends of the rotors. This operation must be performed at the ends of each lobe, making twelve measurements in all. Check the minimum clearances.
5. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side — twelve measurements in all. Check the minimum clearances.

After the blower rotors are timed, complete the assembly of the blower as outlined below.

1. On the former reduction blowers, install the rotor drive and driven gears on the rotor shafts as follows:
   a. Place the blower housing and rotor assembly, air inlet side of housing facing up, on the bench with the timing gear end of the blower facing the outside of the bench.
   b. Start the left–hand helix driven gear on the shaft of the left–hand helix rotor with the omitted serrations in the gear and the shaft in alignment. Then tap the gear on the shaft and against the timing gear with a plastic hammer, or install the gear with the gear installers J 6270–6, 7 and 8.
   c. If removed, install the drive gear bearing in the right–hand helix drive gear with the number on the race of the bearing facing the outside face of the gear.
   d. Lubricate the bearing in the drive gear with engine oil, then place the drive gear on the rotor shaft with the numbered side of the bearing facing out.
   e. Place the lock washer and the bearing retainer on the 7/16–20 x 1 1/4 inch drive gear retaining bolt. Thread the bolt into the right–hand helix rotor shaft and guide the lug on the rear face of the retainer in the slot in the end of the rotor shaft. Then bend one of the tangs on the lockwasher over into the slot in the retainer. Tighten the bolt to 55–65 lb·ft (75–88 N·m) torque.
   f. Place the lock washer and the fuel pump drive coupling disc on the 1/2–20 x 1 1/4 driven gear retaining bolt. Thread the bolt into the left–hand helix rotor shaft, and guide the lugs on the disc in the slots in the gear hub, then bend one of the tangs on the lock washer over into the slot in the disc. Tighten the bolt to 55–65 lb·ft (75–88 N·m) torque.
   g. Bend one of the tangs of each lock washer over against the head of each gear retaining bolt.
2. Attach the blower rotor drive hub and drive hub plates to the blower gears as follows:
   a. If removed, attach the rotor drive hub plates to the drive hub with three bolts, lock washers and plain washers. Tighten the bolts to 25–30 lb·ft (34–41 N·m) torque.
   b. Attach the rotor drive hub and drive plates to the right–hand helix rotor timing gear with three bolts, lock washers, plain washers and three spacers on the standard blower and smaller diameter rotor blower, or drive gear on the former reduction blowers, along with three spacers and bearing retainer between the plates and the face of the gear. Tighten the bolts to 25–30 lb·ft (34–41 N·m) torque.
   c. Check the runout of the splines in the rotor drive hub with an indicator. The spline runout must not exceed .020 inch total indicator reading.
3. Affix a new gasket to the blower rear end plate cover.

NOTE: The former blower end plate cover is not interchangeable with the current blower end plate cover.

4. Position the end plate cover over the end plate dowel pins, then push the cover against the end plate. Install the ten bolts and lock washers. Tighten the bolts to 13–17 lb·ft (18–23 N·m) torque.

ATTACH ACCESSORIES TO BLOWER

Attach the fuel pump, water pump, blower drive shaft cover and governor weight housing or drive housing (hydraulic governor) assembly to the blower as follows:

1. Attach the fuel pump to the blower (Section 2.2).
2. Attach the water pump to the blower (Section 5.1). To convert the former water pump drive coupling to the current coupling, refer to Section 3.0.
3. Attach the limiting speed, variable speed,or hydraulic governor weight housing or drive housing assembly to the blower (Sections 2.7.1, 2.7.2 or 2.8.3).
4. On the current blower, attach the blower drive shaft cover to the blower rear end plate cover with cover seal and seal clamp.
5. On a former blower, affix a new gasket to the bolting flange of the blower drive shaft cover and attach it to the blower rear end plate cover with six bolts and seal washer assemblies, finger tight only.

ATTACH BLOWER TO ENGINE

Attach the blower assembly to the engine as follows:

Before attaching the blower assembly to the engine, check the inside of the blower for any foreign material and revolve the rotors by hand to be sure they turn freely.

1. Install a new blower–to–block gasket to the cylinder block with 3M no. 77 spray–on adhesive, or equivalent, to prevent the gasket from shifting when placing the blower against the block.
2. Place a new drive shaft cover seal and seal clamp over the end of the drive shaft cover.
3. Place the water pump outlet packing flange, flat face toward pump body, and slide a new packing ring over the pump outlet. Then, place a new water pump cover seal and clamp on top of the oil cooler housing outlet opening.
4. Place the blower assembly into position against the cylinder block, being careful not to dislodge the blower gasket.
5. Install the eight blower–to–cylinder block bolts and the 1/8 inch thick, 3/4 inch diameter hardened steel washers, and tighten the bolts to 55–60 lb·ft (75–81 N·m) torque (cast iron block) or 35–40 lb·ft (47–54 N·m) torque (aluminum block).
6. Slide the blower drive shaft cover seal into position against the blower drive gear hub support and tighten the seal clamp.
7. On a former blower, tighten the bolts securing the blower drive shaft cover to the blower rear end plate cover.
8. Install the blower drive shaft by pushing the plain end, without squared hole, of the shaft through the blower drive coupling from the rear of the engine, then into the blower drive gear hub. If necessary, rotate the blower rotors slightly to align the splines of the drive shaft with those in the gear hub. Then, install the lock ring in the blower drive cam.
9. Install the flywheel housing small hole cover.
10. Connect the water pump outlet packing flange to the cylinder block. Also, tighten the seal clamp connecting the water pump cover to the oil cooler housing.
11. Place the blower air shutdown housing, together with the striker plate gasket, striker plate (if used) and screen and gasket assembly against the blower (with the screen side of gasket assembly toward the blower). Secure them in place with bolts and lock washers. Tighten the bolts to 16–20 lb·ft (22–27 N·m) torque.

ATTACH BLOWER TO ENGINE (CONT.)

12. If the engine is equipped with an automatic shutdown solenoid, install the solenoid and connect the wires to the solenoid.
13. If the engine is equipped with a manual shutdown assembly, connect the control wire to the air shutdown valve shaft lever and attach the control wire clip under the head of the air inlet housing attaching bolt.
14. Install the limited, variable or hydraulic governor control housing assembly (Section 2.7.1, Section 2.7.2 and 2.8.2).
15. Install the air cleaners (non–turbocharged engines).
16. Connect the fuel lines to the fuel pump.
17. If the engine is equipped with a turbocharger, slide the hose into position on the air inlet housing and turbocharger and secure in place with the hose clamps.
18. Fill the cooling system with clean, properly inhibited coolant/antifreeze solution and check the system for leaks.

TURBOCHARGER (AIRESEARCH)

The turbocharger (Figure 1.) is designed to increase the overall 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, a turbine housing and a 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.

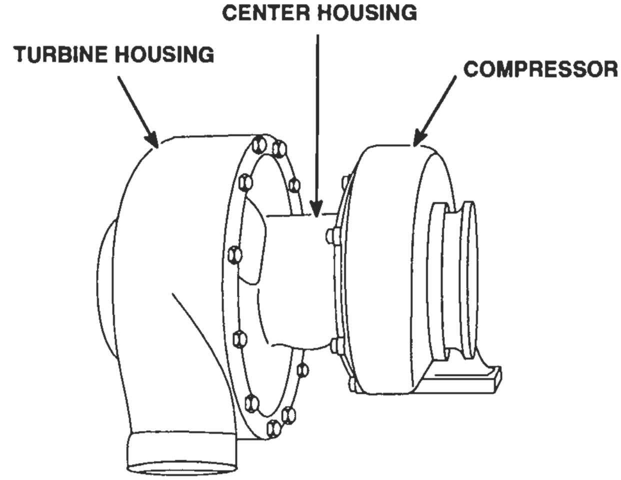


Figure 1. Turbocharger Assembly

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer thrust collar, thrust bearing, 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, thrust washer, thrust collar and thrust spacer thrust bearing, piston ring and thrust collar (Figure 2.)

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 other than TV61 and TV71 turbine housing is bolted to the turbine end of the center housing and the TV61 and TV71 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.

The compressor housing, which encloses the compressor wheel, provides an ambient air inlet and a compressed air discharge outlet. The compressor housing (other than the T04B) is secured to the compressor end of the center housing backplate assembly with a "V" band coupling. The T04B is bolted to the backplate assembly and the backplate assembly is bolted to the compressor end of the center housing.

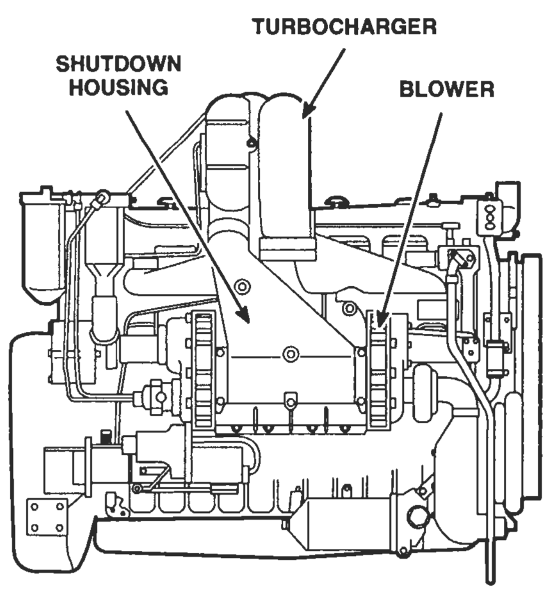


Figure 2. Turbocharger Mounting

SECTION 3.5 – TURBOCHARGER (AIRESEARCH)

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 (Figure 3.) The gases are discharged into the atmosphere after passing through the turbine housing.

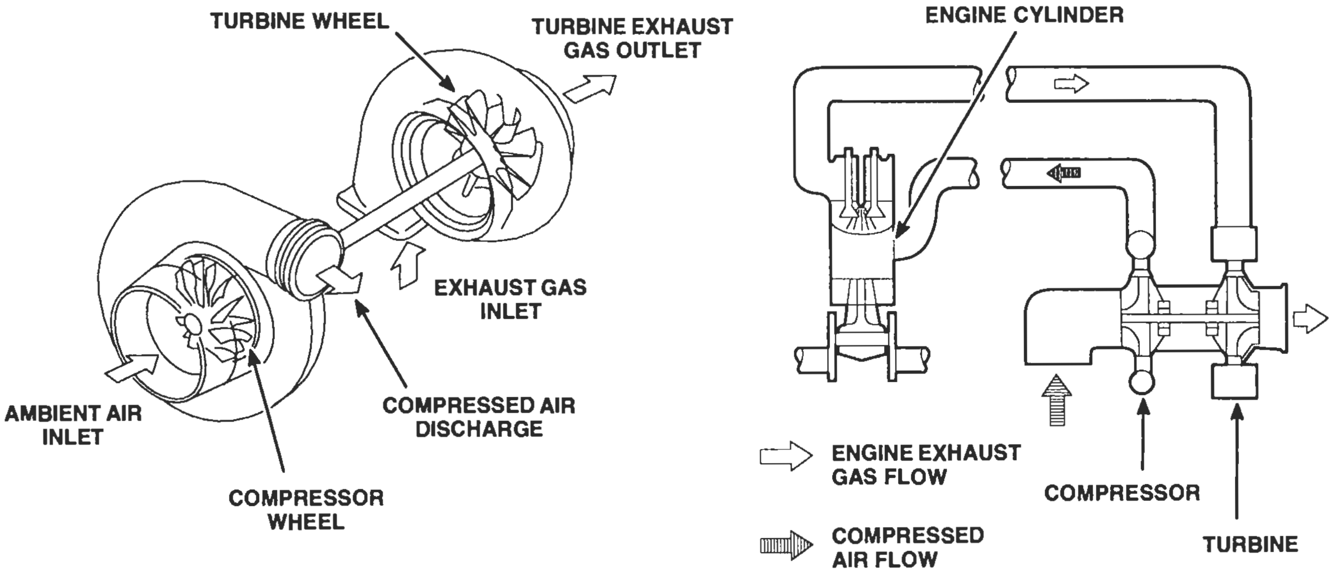


Figure 3. Turbocharger Air Flow Diagram

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.

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 (Section 3.5.3). Certain marine engines are equipped with an intercooler to reduce the temperature of the discharge air from the turbocharger before it enters the engine blower (Section 3.5.2).

LUBRICATION

Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings (thrust collar, thrust bearing–T04B), thrust ring, thrust bearing and backplate or thrust plate (Figure 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.

Before the initial engine start, when a new or overhauled turbocharger is installed, the turbocharger must be prelubricated (see Install Turbocharger).

NOTICE:
Failure to perform the prelubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

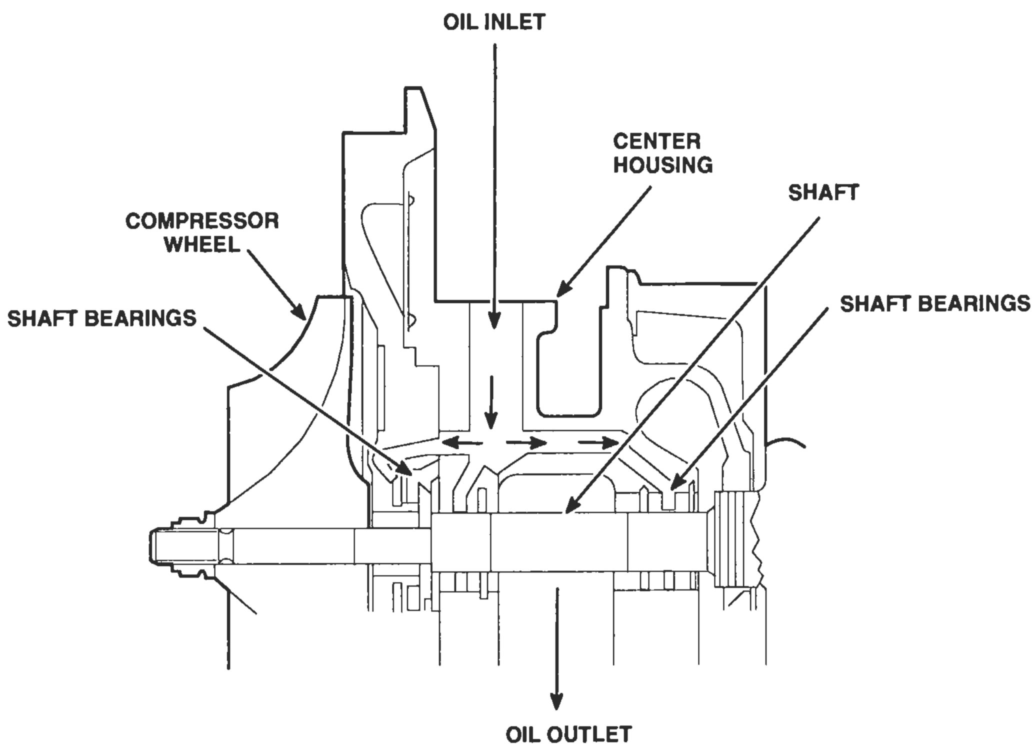


Figure 4. Turbocharger Oil Flow Diagram

SECTION 3.5 – TURBOCHARGER (AIRESEARCH)

PERIODIC INSPECTION

CAUTION:

A turbocharger compressor inlet shield J 26554–A, (Figure 5.) is available for use anytime the engine is operated with the air inlet piping removed. The shield helps to prevent foreign objects from entering the turbocharger and prevents a technician from touching the moving impeller. The use of this shield does not preclude any other safety practices contained in this manual.

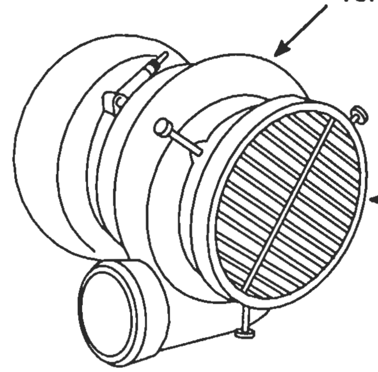


Figure 5. Inlet Shield (J 26554–A)

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 (Section 13.2). A periodic inspection of the turbocharger should be made along with an engine inspection. 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 (Figure 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 or dust build–up.

For proper operation, the turbocharger rotating assembly must turn free. Whenever the exhaust ducting is removed, spin the turbine wheel by hand. If it does not spin freely, troubleshooting is necessary. 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.

PERIODIC INSPECTION (CONT.)

CHART 1 TROUBLESHOOTING CHARTS

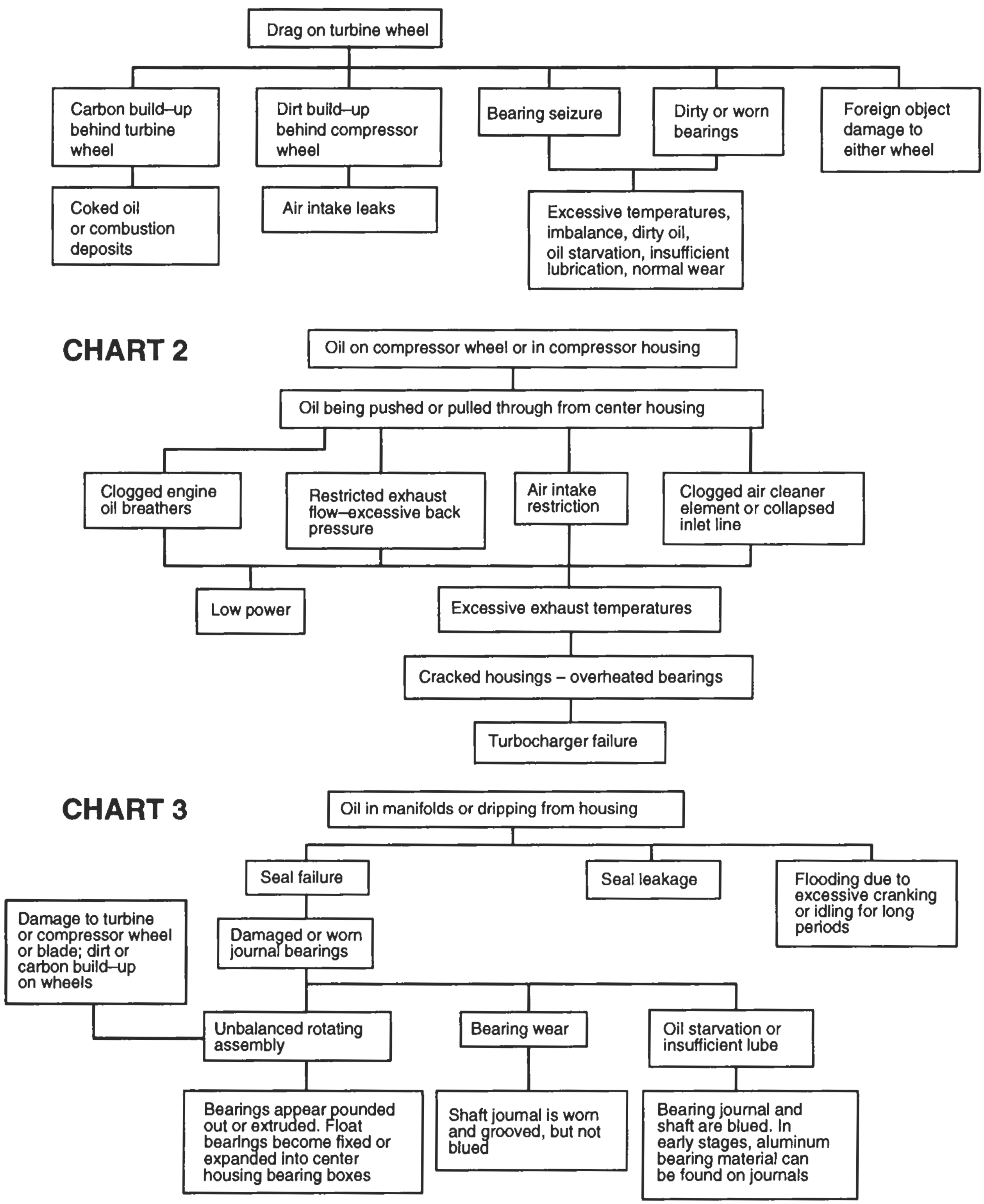


Figure 6. Troubleshooting Charts

PERIODIC INSPECTION (CONT.)

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. 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, see Chart 2, Figure. 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.

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 (Chart 3, Figure 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. This simple test will allow some positive testing on each engine in all cases.

Turbocharger compressor end shaft oil seal effectiveness can be determined by the following procedure:

1. Determine that air inlet restriction is within the Detroit Diesel maximum limit (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 compressor 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 the 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.

PERIODIC INSPECTION (CONT.)

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.
14. If oil leakage is not detected, reinstall the compressor housing, the air inlet duct or inlet shield (J 26554–A) and the outlet hose to the air inlet housing.

REMOVE TURBOCHARGER (T18A40, TV61, TV71 AND T04B)

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.
2. Disconnect the exhaust gas outlet piping attached to the turbine 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 lockwashers 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 TURBOCHARGER (T18A40 – TV61 – TV71)

Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembly and proceed as follows:

NOTE: 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. Loosen the "V" band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and "V" band.

NOTICE:

Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

DISASSEMBLE TURBOCHARGER (T18A40 – TV61 – TV71) (CONT.)

2. With the T18A40 (Figure 7. and Figure 8.) turbocharger, bend down the ends of the lockplates and remove the eight bolts securing the four lockplates and turbine housing clamps to the center housing and turbine housing. With the TV61 and TV71 turbocharger, loosen the "V" band coupling securing the turbine housing to the center housing. Remove the turbine housing from the center housing. Tap the housing with a soft hammer if force is needed for removal.

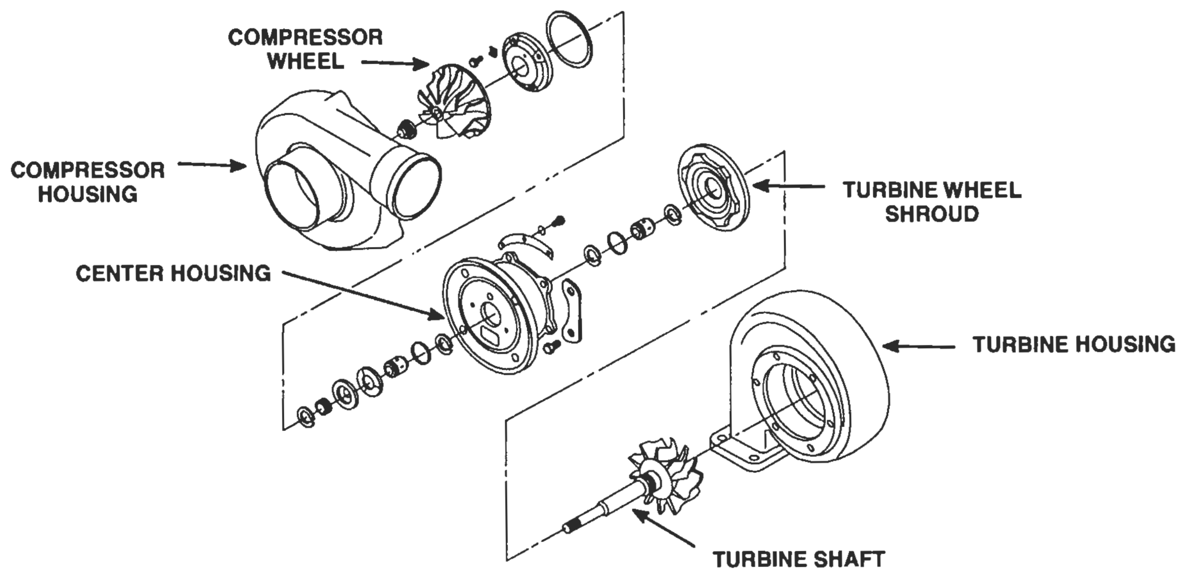


Figure 7. T18A40 Turbocharger Components

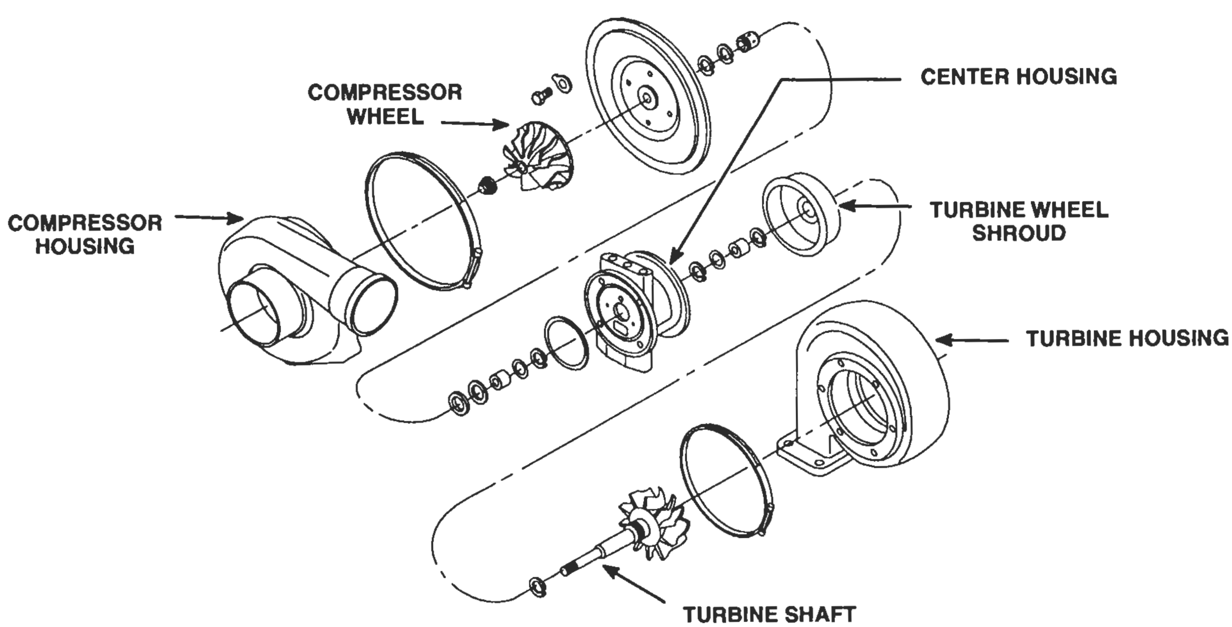


Figure 8. TV61 and TV71 Turbocharger Components

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DISASSEMBLE TURBOCHARGER (T18A40 – TV61 – TV71) (CONT.)

3. Position the turbine wheel of the center housing assembly in a suitable holding fixture (Figure 9.) Remove the the wheel nut from the shaft. 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.

NOTICE:

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.

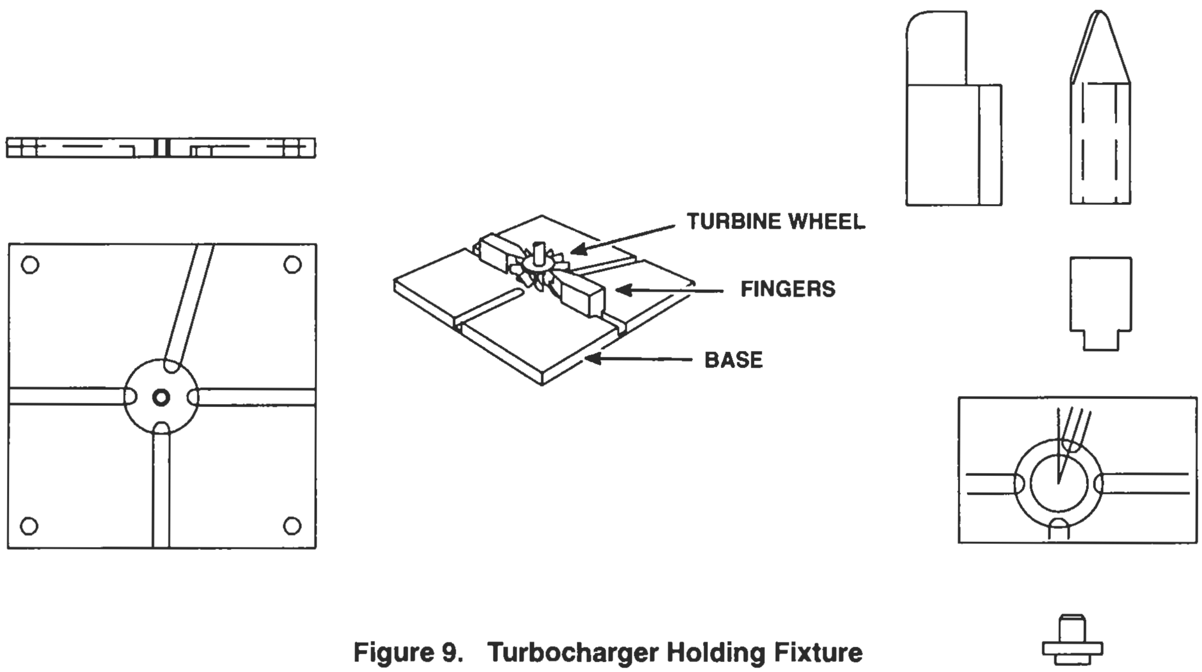

Figure 9. Turbocharger Holding Fixture

4. Press the compressor wheel from the wheel shaft assembly.
5. Withdraw the wheel shaft assembly from the center housing. The wheel shroud, which is not retained, will fall free when the wheel shaft is removed.
6. With the TV61 and TV71 turbocharger, remove and discard the turbine piston ring from the wheel shaft.
7. Bend down the lock tabs and remove the four bolts and lockplates securing the backplate assembly to the center housing and remove the backplate assembly. Tap the backplate lightly to remove it from the center housing recess.
8. Remove and discard the seal ring from the groove in the center housing.
9. Remove the thrust spacer and piston ring(s) from the backplate assembly. Discard the piston ring(s).
10. Remove the thrust collar, inboard thrust washer, bearing, bearing washer and snap ring from the center housing. Discard the thrust washer, bearing, washer and snap ring.
11. Remove the snap ring, bearing, bearing washers and snap ring from the opposite end of the center housing. Discard the snap rings, bearing and washers.

DISASSEMBLE TURBOCHARGER (T04B)

Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembling and proceed as follows:

NOTE: 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. Bend the lock tabs (Figure 10.) of the lock plates down and remove the bolts which hold the lockplates and clamps securing the compressor housing and turbine housing.

NOTICE:
Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels. Tap the housing with a soft hammer if force is needed for removal.

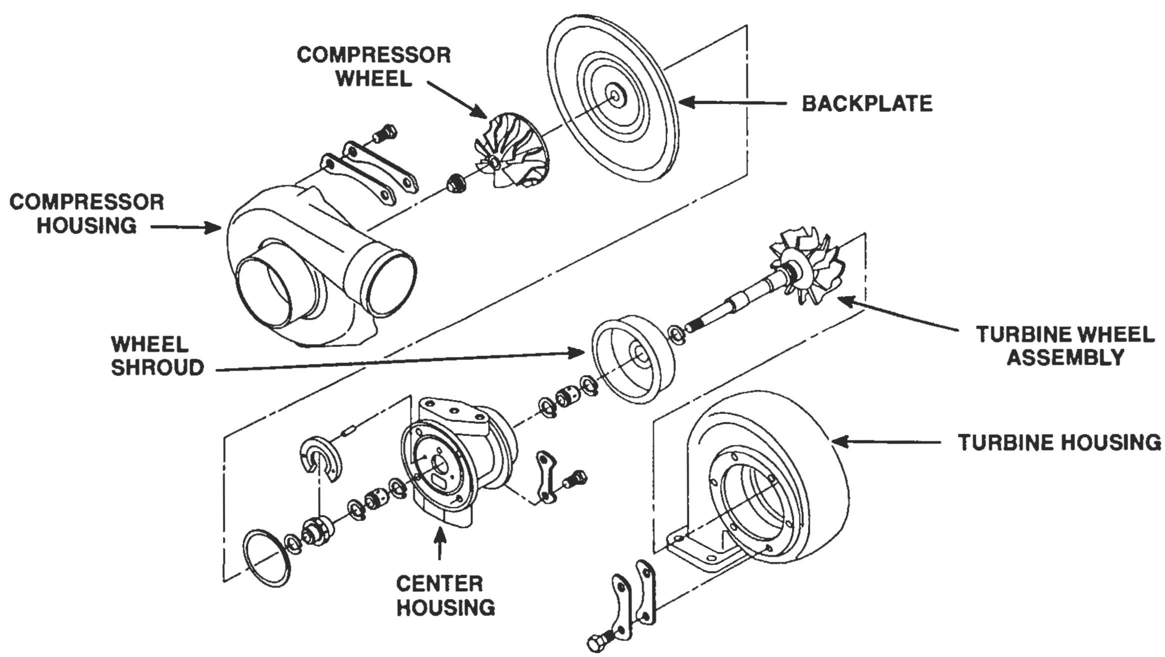

Figure 10. T04B Turbocharger Components

DISASSEMBLE TURBOCHARGER (TO4B) (CONT.)

2. Position the turbine wheel of the center housing assembly in a suitable holding fixture. Remove the wheel nut from the shaft. 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.

3. Lift the compressor wheel off of the turbine wheel shaft assembly.
4. Invert the center housing and turbine wheel assembly and remove the turbine wheel assembly (with piston ring) from the center housing. Remove the piston ring from the wheel assembly.
5. Bend the lock tabs down and remove the bolts and lockplates securing the backplate assembly to the center housing. Remove the back plate assembly. Tap the backplate lightly to remove it from the center housing recess.
6. Do not disassemble the backplate assembly. Also do not remove the pins from the center housing unless it is necessary to replace the pins.
7. Remove and discard the seal ring from the groove in the center housing.
8. Remove the thrust bearing and piston ring from the backplate assembly. Discard the piston ring.
9. Remove the thrust collar, bearing and snap ring from the center housing. Discard the bearing and snap ring.
10. Remove the snap ring, bearing and snap ring from the opposite end of the center housing. Discard the snap rings and bearings.

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. 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.

Clean the oil passage in the center housing 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 all of the parts for signs of damage, corrosion or deterioration. Check for nicked, crossed or stripped threads.

Visually check the turbine wheel for signs of rubbing or wear. Check shaft bearing journal dimensions and wear limits (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 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.

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 piston ring(s), thrust washers, bearing, bearing washers and snap rings be replaced at time of disassembly.

Inspect the exhaust outlet elbow seal ring for signs of wear or breakage.

ASSEMBLE TURBOCHARGER (T18A40 – TV61 – TV71)

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.

Proceed as follows:

1. Lubricate the new bearings with clean engine oil.
2. Install a new snap ring, bearing washer, bearing and snap ring in the turbine end of the center housing.
3. Install a new snap ring, bearing washer and bearing in the compressor end of the center housing. Install the current inboard thrust bearing (three oil grooves) with the smooth side against the center housing.
4. Install a new piston ring(s) on the thrust spacer and gently insert the spacer into the backplate assembly. With the T18A40 turbocharger, make sure the current small diameter thrust spacer (.672–.673 inch) is used with the current thrust collar (Figure 11.) The former spacer was .677–.678 inch in diameter. The current thrust spacer has two grooves. When replacing the former one groove spacer with the two groove spacer, be sure and include two piston rings. Do not force the piston rings into place.

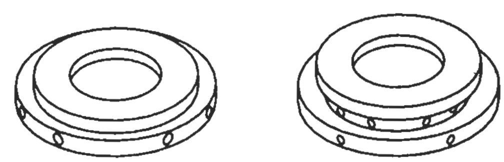

Figure 11. Former and Current Thrust Collar (T18A40)

5. Make sure the compressor bearing is in place, then position the new inboard thrust washer 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 snugly against the thrust washer. Lubricate the thrust collar and thrust washer with clean engine oil.
7. Install a new seal ring in the groove at the compressor end of the center housing.
8. Align the oil feed holes in the center housing and the backplate assembly and attach the backplate to the center housing with four bolts and new lockplates. Tighten the T18A40 bolts to 90–110 lb·in (10–12 N·m) torque or the TV61 and TV71 bolts to 80–100 lb·in (9–11 N·m) torque and bend the lockplate tangs up against the side of the bolt heads.

NOTE: 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.

9. On TV61 and TV71 turbochargers, install a new piston ring on the turbine wheel shaft assembly. Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.

ASSEMBLE TURBOCHARGER (T18A40 – TV61 – TV71) (CONT.)

10. Position the wheel shroud against the center housing and insert the wheel shaft assembly through the wheel shroud and into the center housing. 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. 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.
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 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 in length .007–.008 inch (T18A40) or .009–.010 inch (TV61 and TV71). Tighten the nut in such a manner as not to impose bending loads on the shafts. 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 TV61 and TV71 (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 (Figure 12.)
    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.
    c. Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be between .004 and .009 inch (T18A40) or .003 and .010 inch (TV61 and TV71). If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.

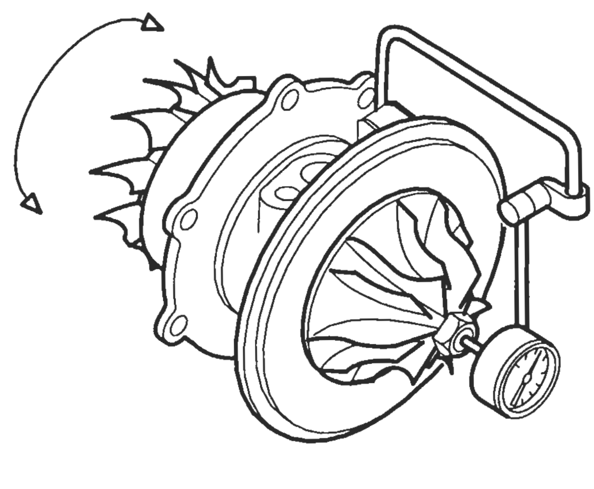

Figure 12. Checking Bearing Axial End Play

ASSEMBLE TURBOCHARGER (T18A40 – TV61 – TV71) (CONT.)

18. Position the turbine housing as marked at disassembly against the center housing and secure it in place.

    a. Secure the T18A40 turbine with four clamps, four new lockplates and eight bolts. Tighten the bolts to 100–130 lb·in (11–15 N·m) torque.

    b. Secure the TV61 and TV71 turbine housing with the "V" band coupling. Tighten the toggle nut as follows:

    - Lubricate the toggle bolt threads with a high temperature anti–seize compound, such as Jet Lube (Mil Spec A–907D), or equivalent.
    - Tighten the nut on the "V" band toggle bolt to approximately 160 lb·in (18 N·m) torque. Do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.
    - Loosen the "V" band coupling nut to approximately 50 lb·in (6 N·m) torque, then torque the nut to 152–168 lb·in (17–19 N·m) torque.

19. Position the compressor housings marked at disassembly against the backplate and secure it in place with the "V" band coupling. 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.

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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 (Figure 13.)

    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.

    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. Make sure the extension rod does not make contact with the sides of the center housing, otherwise it will be impossible to obtain an accurate reading.

    d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003 and .007 inch. If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.

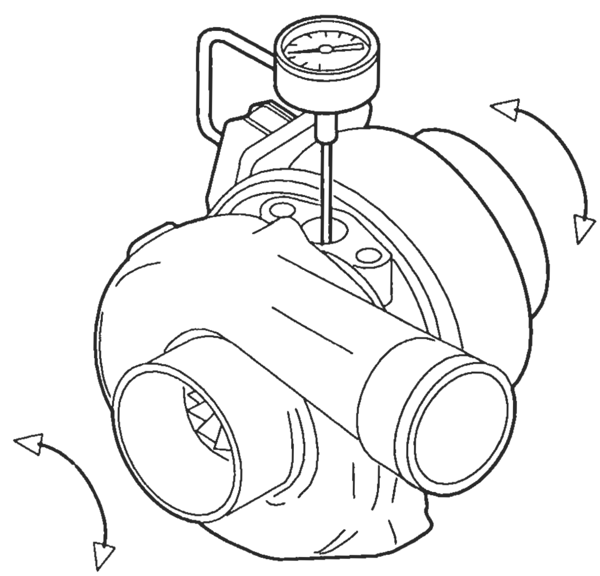

Figure 13. Checking Shaft Radial Movement

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.

ASSEMBLE TURBOCHARGER (T04B)

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.

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 using snap ring pliers J 28507.
3. Install a new snap ring, bearing and snap ring in the compressor end of the center housing, using snap ring pliers J 28507.
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. 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. 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.

NOTE: 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. 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 inches in length.

NOTE: Tighten the retaining nut in such a manner as not to impose a bending load on the shaft.

ASSEMBLE TURBOCHARGER (T04B) (CONT.)

15. Check the bearing axial end play:
    a. Clamp the center housing assembly in a bench vise equipped with soft jaws.
    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.
    c. Move the shaft axially back and forth by hand. The total indicator reading should be between .004 and .009 inches. 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.
    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.
    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. Make sure the extension rod does not make contact with the sides of the center housings, otherwise it will be impossible to obtain an accurate reading.
    d. Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The dial indicator displacement should be between .003 and .007 inches. 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.

OIL SEEPAGE (T04B)

On engine applications where crankcase vapors are routed to the breather system and into the air intake of the T04B turbocharger, oil seepage may be experienced between the turbocharger compressor housing and the backplate area. If seepage is observed in this area, apply a small uniform bead of high temperature RTV sealant on the outside diameter of the backplate (Figure 14.)

NOTICE:
Make certain that the sealant does not cause compressor housing misalignment, which can result in compressor wheel–to–housing contact and resultant damage.

Surfaces must be clean and dry. Application instructions for the sealant are normally available on the RTV tube or package.

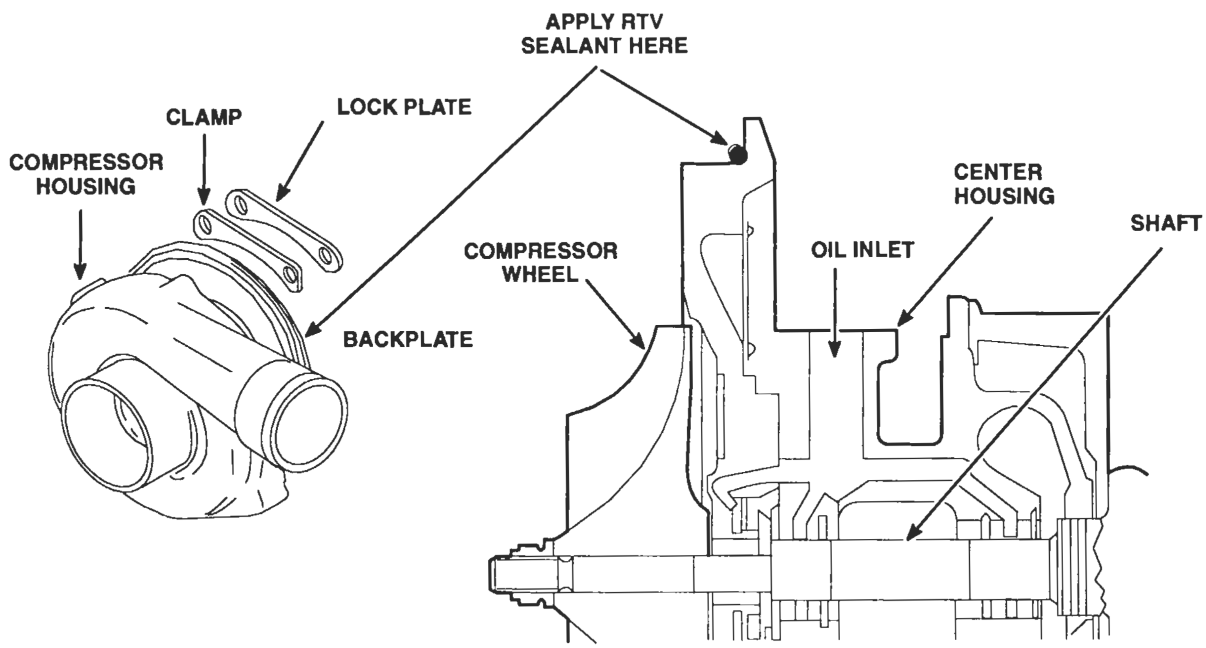

Figure 14. Application of RTV Sealant

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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. Install inlet shield J 26554–A in place.
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. 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 inner diameter. The turbine opening in a T04B turbocharger is 2.581 inches and the TV61 is 3.100 inches.

NOTICE:

When replacing turbo exhaust pipes, it is imperative that the exhaust manifold be loosened so that proper alignment between the turbo and exhaust manifold occurs. If this procedure is not followed, exhaust tube breakage will occur.

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. 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 tube hose over the compressor housing outlet opening and secure it in place with the hose clamps. Attach the turbocharger compressor inlet shield (J 26554–A) to the air inlet opening.
6. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then, remove the chain hoist and lifting sling from the turbocharger. Attach the exhaust gas outlet piping to the turbine housing.
7. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block. Attach the oil inlet line to the cylinder block.
8. 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.
   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 of the moving parts are getting lubrication is when the oil pressure gage registers pressure (5 lb/in.^{2} or 34.5 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. 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.

9. Check all ducts and gaskets for leaks. 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.

INSTALL TURBOCHARGER (CONT.)

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and repaired.

10. Shut down the engine. Remove the compressor inlet shield (J 26554–A). Attach the compressor air intake ducting. Check for leaks.

REMOVE TURBOCHARGER (T18 – T18A – TH08A)

1. Disconnect the exhaust manifold adaptor attached to the turbine housing.
2. Disconnect the exhaust gas outlet piping attached to the turbine 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 TURBOCHARGER (T18 – T18A – TH08A)

Disassemble the turbocharger (Figure 15.) assembly as follows:

1. Thoroughly clean the exterior of the turbocharger with a non–caustic cleaning solvent.

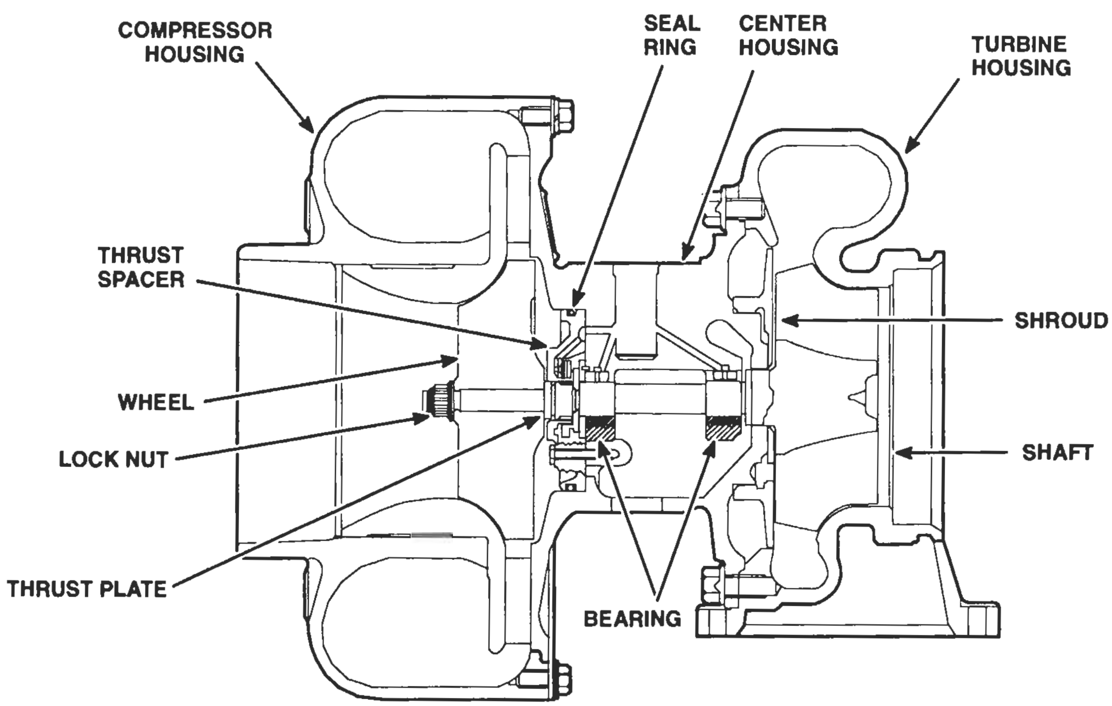


Figure 15. T18 Turbocharger Assembly

DISASSEMBLE TURBOCHARGER (T18 – T18A – TH08A) (CONT.)

2. Matchmark the compressor housing, center housing and the turbine housing with a punch or chisel (Figure 16.) so they may be installed in the same relative position.

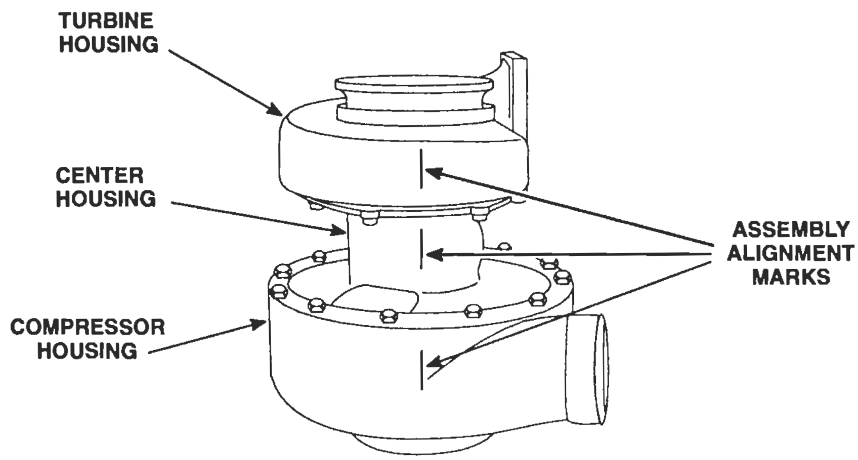


Figure 16. Turbocharger Housing Alignment Marks

3. Remove the twelve bolts, lock washers and clamps securing the T18 turbocharger compressor housing to the center housing. Then remove the compressor housing from the center housing. On the T18A or TH08A turbochargers, loosen the "V" band coupling securing the compressor housing to the backplate assembly and remove the compressor housing "V" band. If necessary, tap the 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 six bolts (T18) or eight bolts (T18A or TH08A) 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:
   a. The hexagon countersunk hole in the end of the turbine wheel must be scraped clean before installing it in the holding fixture. Clamp the turbine wheel holding fixture J 29086 in a bench vise. Then place the center housing and rotating assembly in the holding fixture, turbine wheel down (Figure 17.), with the hexagon countersunk hole in the turbine wheel over the protruding hexagon head in the holding fixture.

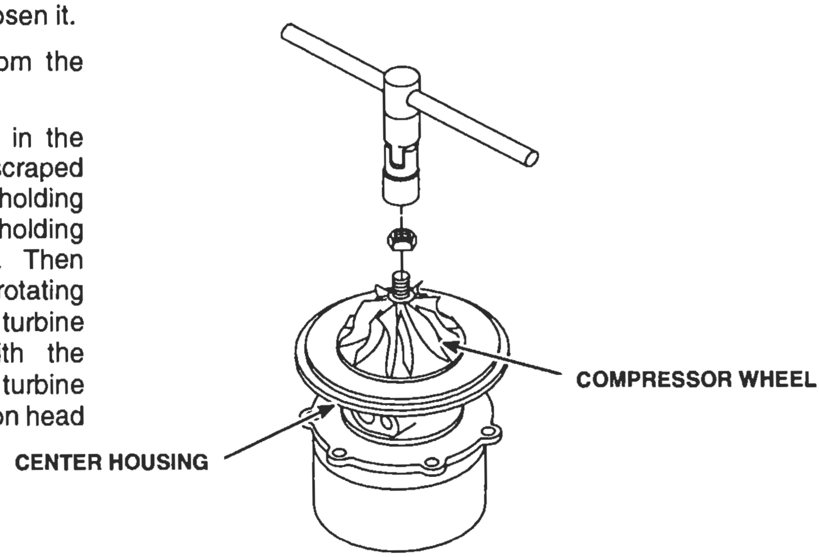


Figure 17. Removing Compressor Wheel Locknut

DISASSEMBLE TURBOCHARGER (T18 – T18A – TH08A) (CONT.)

b. To prevent the possibility of bending the shaft, remove the locknut from the shaft with a double universal socket and a tee handle. If required, use a suitable holding fixture (Figure 18.)

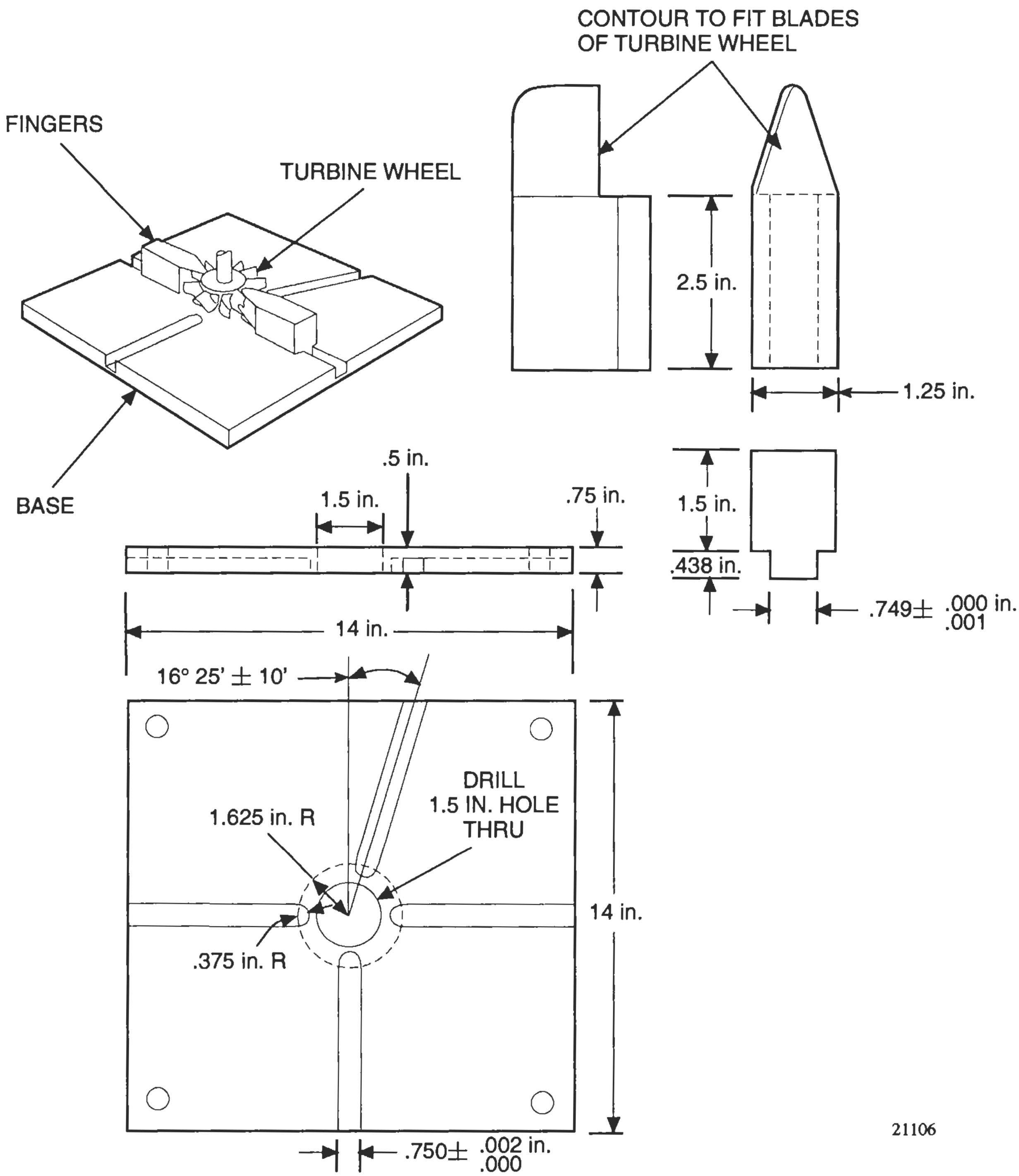


Figure 18. Turbocharger Holding Fixture

DISASSEMBLE TURBOCHARGER (T18 – T18A – TH08A) (CONT.)

c. Place the center housing and rotating assembly in an oven, furnace or hot oil bath that has been preheated to 350°–375°F (177°–190°C) for no longer than ten minutes. If a hot oil bath is used, immerse only the compressor wheel in the oil.

NOTICE:

Be careful not to damage the wheel blades when placing the assembly in the oven or furnace. Do not heat the compressor wheel above 375°F (190°C).

d. After heating the compressor wheel, remove the center housing and rotating assembly and support it on the bed of an arbor press with the compressor wheel end up (Figure 19.)

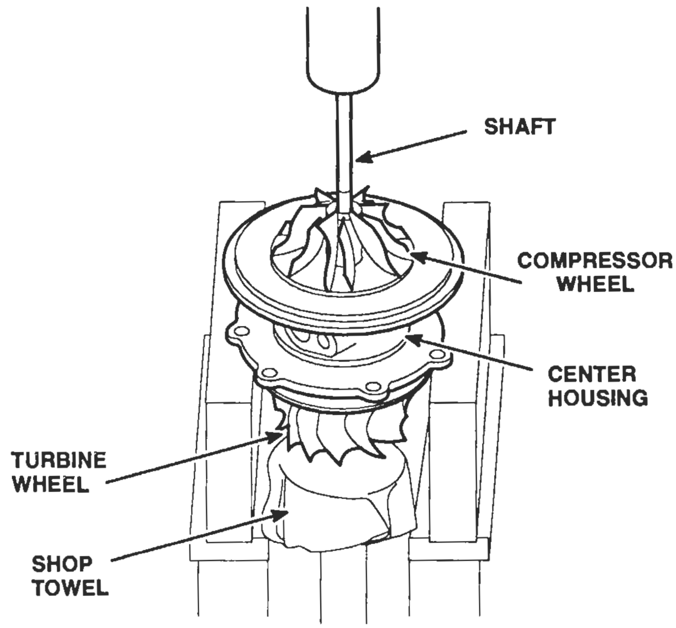


Figure 19. Removing Compressor Wheel Shaft

CAUTION:

To avoid being burned, use a pair of heat resisting or asbestos gloves when handling the center housing and rotating assembly.

e. 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.

f. 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. With the TH08A turbocharger, remove and discard the turbine piston ring from the wheel shaft.

DISASSEMBLE TURBOCHARGER (T18 – T18A – TH08A) (CONT.)

7. Place the center housing, compressor housing end up, on the bench (Figure 20.)
8. Bend the end of the center housing thrust (back) plate attaching bolt lockplates down, then remove the four bolts and lockplates securing the backplate or thrust plate to the center housing.

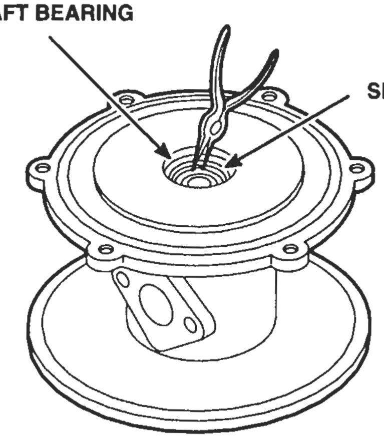


Figure 20. Center Housing and Thrust Plate Bolt Removal

9. Support the center housing on edge on the work bench (Figure 21.) Then, insert a 1/2 inch wood dowel approximately 8 inches long through the shaft bearings and against the backplate or thrust plate. Tap the thrust plate or backplate out of the center housing with a hammer.
10. Remove the thrust spacer and seal ring from the backplate or thrust plate, then remove the seal ring from the outside diameter of the backplate or thrust plate.
11. Remove the thrust ring and the backplate or thrust plate bearing from the center housing.
12. 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.

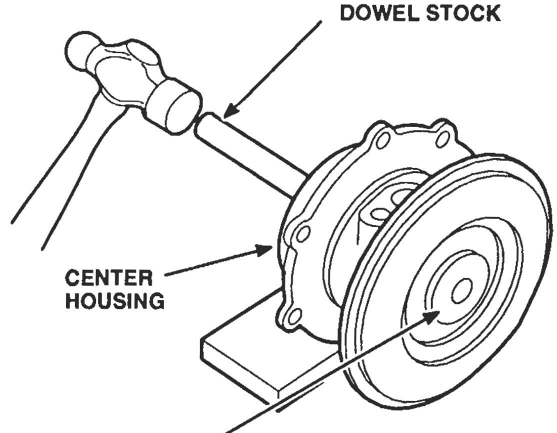


Figure 21. Center Housing Thrust Plate Removal

DISASSEMBLE TURBOCHARGER (T18 – T18A – TH08A) (CONT.)

13. 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 retaining ring from the center housing with a pair of snap ring pliers (Figure 22.)
    c. Lift the bearing straight up out of the housing.
    d. If necessary, remove the two spacers (on current turbochargers) and the two remaining snap rings inside the center housing.

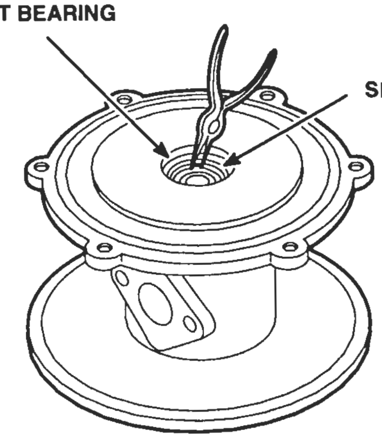


Figure 22. Shaft Bearing Retaining Ring Removal

14. If there is an oil reservoir plug in the center housing, remove it in the following manner and discard it, as the plug is no longer required (Figure 23.) The plug should also be removed for thorough cleaning of the center housing.
    a. Thread the inside diameter of the oil reservoir plug with a 1/2–13 tap approximately 1/2 inch deep.
    b. Attach a slide hammer and a 1/2–13 adaptor to the oil reservoir plug. Then, pull the plug from the center housing by striking the sliding hammer against the end of its shaft.
15. 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.

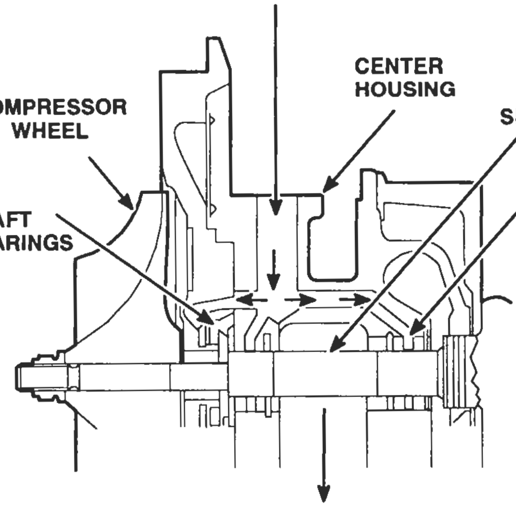


Figure 23. Location of Oil Passage in Center Housing

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. 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. Check shaft bearing journal dimensions and wear limits (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 Specifications – Section 3.0.

ASSEMBLE TURBOCHARGER

NOTE: If foreign particles fall into the turbocharger during the assembly procedure, remove the particles immediately, even though extensive disassembly is required.

Assemble the turbocharger as follows:

1. Install the shaft bearings in the center housing as follows:
   a. Place the center housing on the bench with the turbine end of the housing facing up.
   b. If removed, reinstall the inner shaft bearing retaining ring in the lower ring groove in the turbine wheel end bearing bore.
   c. On current turbochargers, reinstall the wear spacer.

ASSEMBLE TURBOCHARGER (CONT.)

d. Lubricate the outside diameter of a shaft bearing with engine oil, then place the bearing straight into the bearing bore in the center housing and push it down against the wear spacer (Figure 24.) On former turbochargers, push it down against the bearing inner retaining ring.

e. Install the outer shaft bearing retaining ring in the ring groove in the center housing bearing bore.

f. Turn the center housing over on the bench so the compressor end of the housing is facing up.

g. If removed, reinstall the shaft bearing retaining ring in the ring groove in the compressor end of the center housing bearing bore.

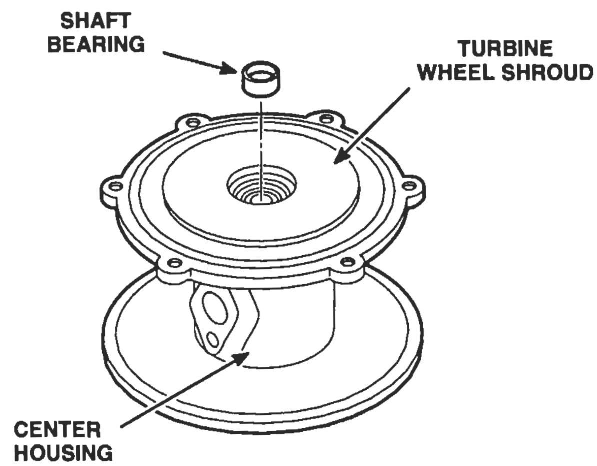


Figure 24. Center Housing Shaft Bearing Installation (Turbine End)

2. Clamp the shaft holding fixture J 29086 in a bench vise. Place the shaft assembly in the holding fixture with the hexagon countersunk hole in the turbine wheel over the protruding hexagon head in the holding fixture (Figure 25.) If required, use the appropriate holding fixture.
3. With the TH08A turbocharger, install a new piston ring on the turbine wheel shaft.

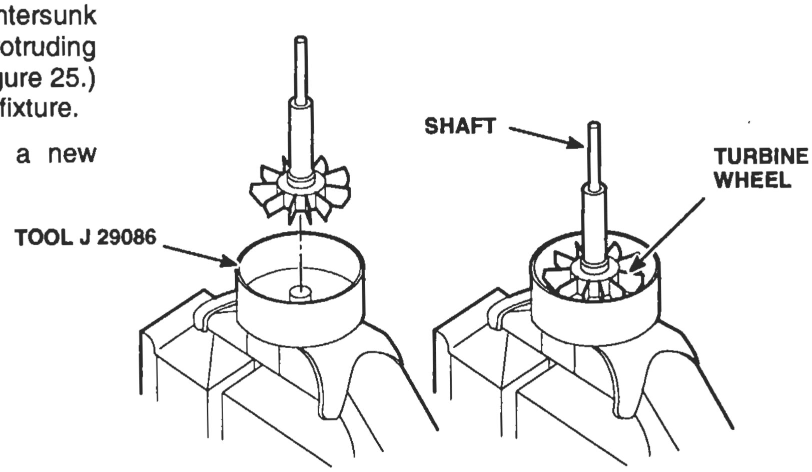


Figure 25. Shaft Assembly in Holding Fixture Assembly

ASSEMBLE TURBOCHARGER (CONT.)

4. Lubricate the shaft bearing journals with engine oil, then place the center housing over the shaft with the turbine end of the housing facing down. Carefully lower the center housing straight down over the shaft until it seats on the hub of the turbine wheel (Figure 26.)

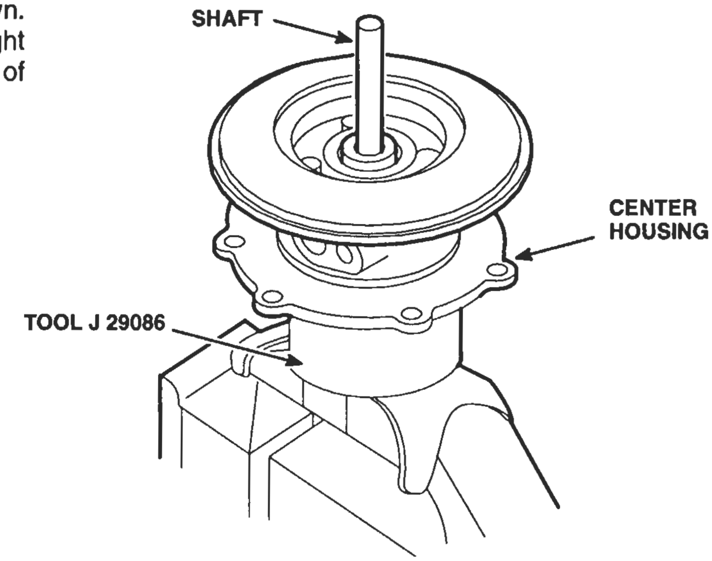


Figure 26. Center Housing on Shaft Installation

5. Lubricate the outside diameter of the second shaft bearing with engine oil, then place the bearing over the shaft and start it straight into the bearing bore (Figure 27.) Push the bearing down in the bearing bore against the wear spacer. On former turbochargers, push the bearing down against the retaining ring.

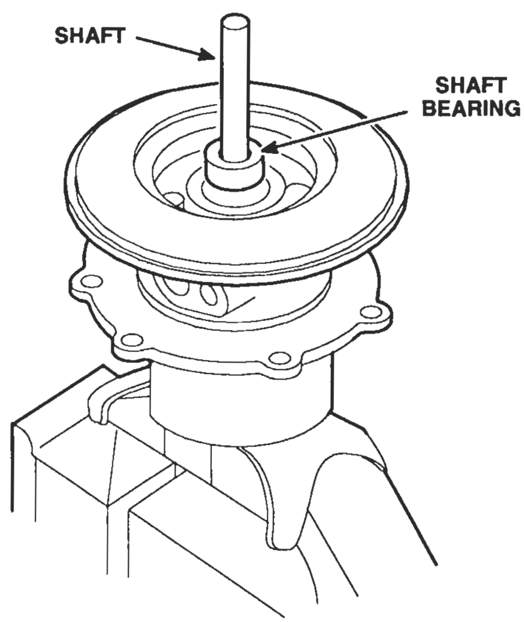


Figure 27. Shaft Bearing in Center Housing Installation (Compressor End)

ASSEMBLE TURBOCHARGER (CONT.)

6. Lubricate the backplate or thrust plate bearing with engine oil, then place it on the shaft with the three oil grooves in the face of the bearing facing up (Figure 28.) Align the hole and slot in the bearing with the dowel pins in the center housing, then place the bearing over the dowel pins and against the housing.

NOTE: Make sure the backplate or thrust plate bearing is seated flat against the face of the center housing.

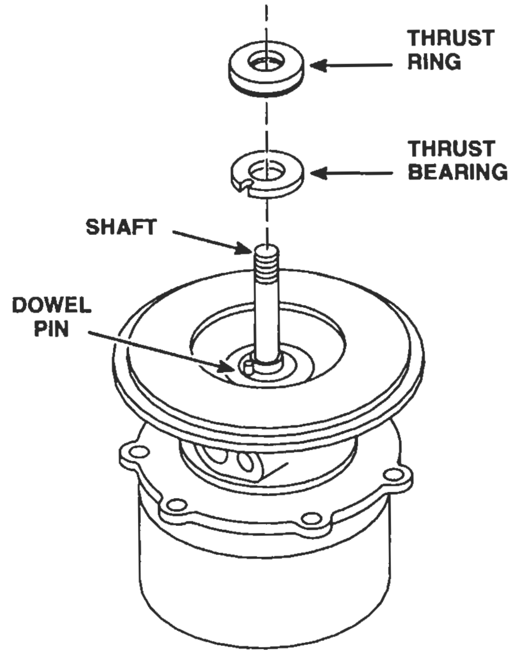


Figure 28. Thrust Bearing in Center Housing Installation

7. Place the thrust collar over the end of the shaft, recess side facing up (Figure 29.) and against the backplate or thrust plate bearing.
8. Install a new seal ring in the groove in the thrust spacer.

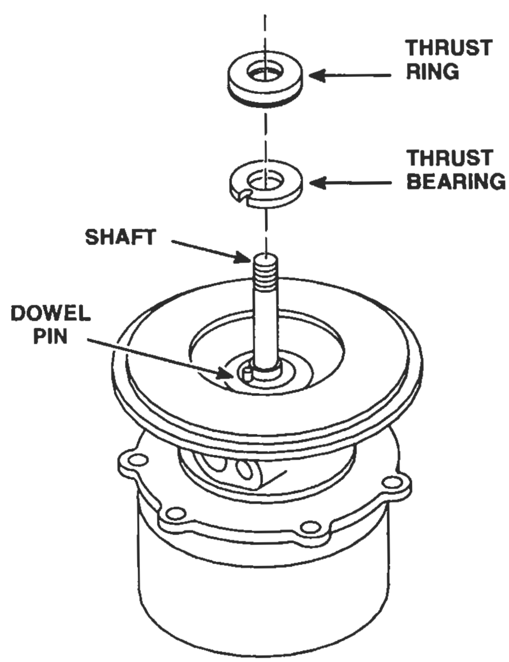


Figure 29. Thrust Ring in Center Housing Installation

ASSEMBLE TURBOCHARGER (CONT.)

9. Place the center housing backplate or thrust plate, less the thrust spacer and the rubber seal ring, over the shaft with the bolt holes and the oil hole in the under side of the backplate or thrust plate in alignment with the oil and bolt holes in the center housing (Figure 30.)

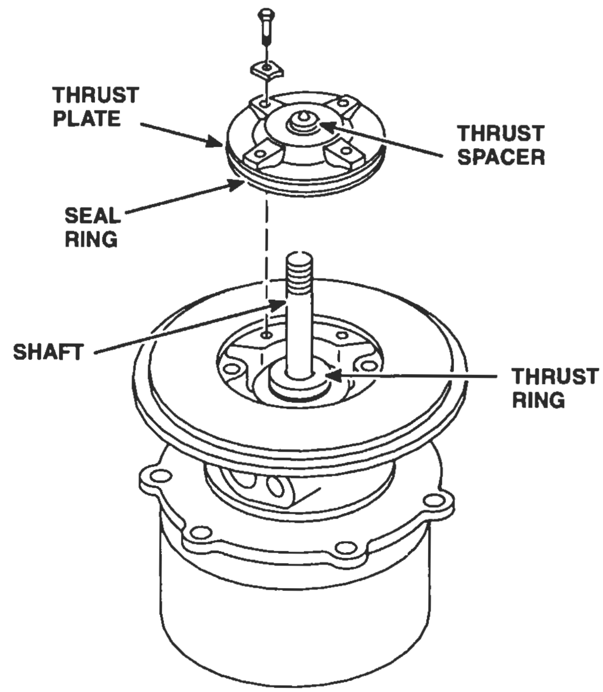


Figure 30. Installing Thrust Plate in Center Housing

10. Remove the backplate or thrust plate from the center housing. Then install the thrust spacer and seal ring assembly in the backplate or thrust plate (Figure 31.)
11. Lubricate a new backplate or thrust plate seal ring (rubber) with engine oil, then place the seal ring in the seal ring groove in the outside diameter of the backplate or thrust plate.

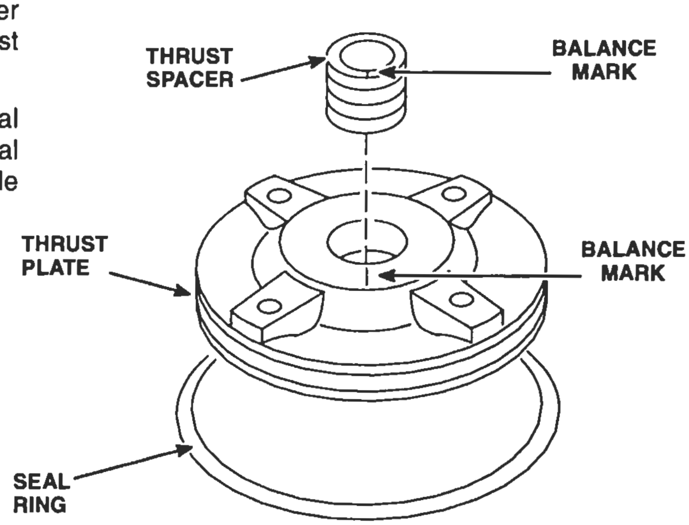


Figure 31. Installing Thrust Spacer in Center Housing Thrust Plate

ASSEMBLE TURBOCHARGER (CONT.)

12. Position the backplate or thrust plate with the thrust spacer and seal ring over the end of the shaft with the oil holes and bolt holes in the backplate or thrust plate and center housing in alignment. Then place the backplate or thrust plate on the shaft and lower it straight down against the center housing being careful not to let the thrust spacer move up out of the backplate or thrust plate.
13. To align the backplate or thrust plate, insert two of the backplate or thrust plate attaching bolts into the bolt holes in the backplate or thrust plate and thread them into the center housing.
14. Carefully push the backplate or thrust plate in the center housing until it contacts the thrust ring. Be sure the thrust spacer stays in the backplate or thrust plate.

NOTE: If the thrust spacer moves out of the backplate or thrust plate unseating the seal ring, repeat Steps 10 through 14 above.

15. Place a new lockplate on each backplate or thrust plate bolt and thread the bolts into the center housing. Tighten the 10–24 bolts to 30–40 lb·in (3–5 N·m) torque (T18 turbocharger) or to 90–110 lb·in (10–12 N·m) torque on the 5/16–18 bolts on the T18A or TH08A turbocharger (Figure 32.) Then bend one corner of each lockplate up against the flat side of each bolt head.

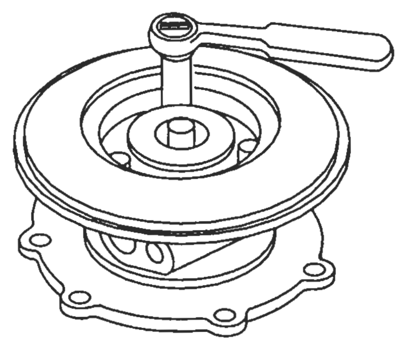


Figure 32. Tightening Thrust Plate Retaining Bolts

16. Install the compressor wheel on the shaft as follows:
    a. Place the compressor wheel in an oven, furnace or in hot oil bath that has been preheated to 350–375°F (177–190°C) for not longer than ten minutes.

CAUTION:

To avoid being burned, use a pair of heat resisting or asbestos gloves when handling the compressor wheel.

ASSEMBLE TURBOCHARGER (CONT.)

b. After heating the compressor wheel, remove the wheel and start it straight on the shaft (Figure 33.) Push the wheel down against the thrust spacer.

c. Place the compressor wheel on the shaft as soon as possible after removing it from the oven, furnace or hot oil.

d. While the compressor wheel is still hot, install the locknut and tighten it to 110–130 lb·in (12–14 N·m) torque.

NOTICE:
To prevent the possibility of bending the shaft, use a double universal socket with the torque wrench.

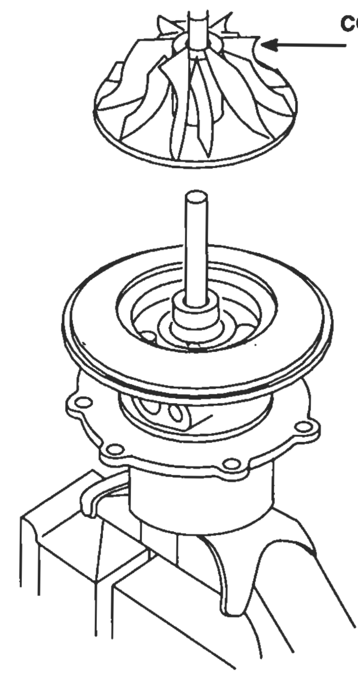


Figure 33. Installing Compressor Wheel on Shaft

e. After the compressor wheel has been allowed to cool to less than 150°F (66°C), remove the locknut from the shaft.

f. Inspect the flat surface of the locknut and the top face of the wheel hub for being smooth and clean.

g. Lubricate the threads and the flat surface of the wheel locknut lightly with engine oil, then install the locknut on the shaft and tighten it to 18–20 lb·in (2 N·m) torque. After tightening the locknut, turn it an additional 1/4 turn or 90° (T18 or T18A). Tighten the locknut through an angle of 120° on the TH08A turbocharger.

h. Place wrench J 21223–02 on the locknut and attach a sliding tee handle to the wrench (Figure 34.)

i. Place a magnetic base dial indicator on the center housing and position the stem of the indicator on the end of the shaft.

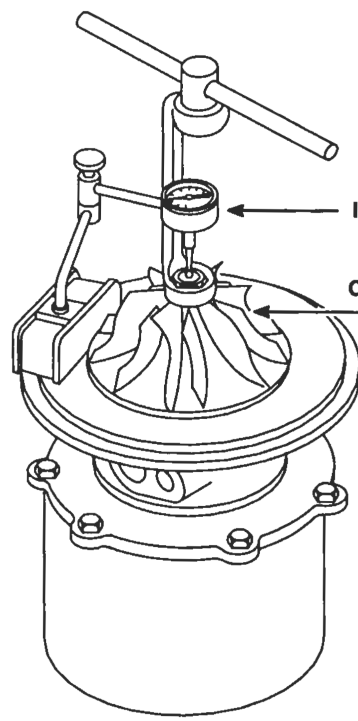


Figure 34. Tightening Compressor Wheel Locknut

ASSEMBLE TURBOCHARGER (CONT.)

j. Set the hand of the dial indicator at zero. Then tighten the locknut until the shaft length increases .006 to .007 inches (T18 or T18A). The current shaft requires 285 lb·in (32 N·m) torque to increase or stretch the shaft length .006 to .007 inch.

NOTICE:

Do not use a box wrench or any other type wrench to tighten the locknut as the excessive side strain may bend the shaft. Use a sliding tee handle with wrench J 21223–02 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.

17. 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 (Figure 35.)
    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.
    e. The end play is the difference between the two readings. The specified shaft end play is .004 to .009 inches.

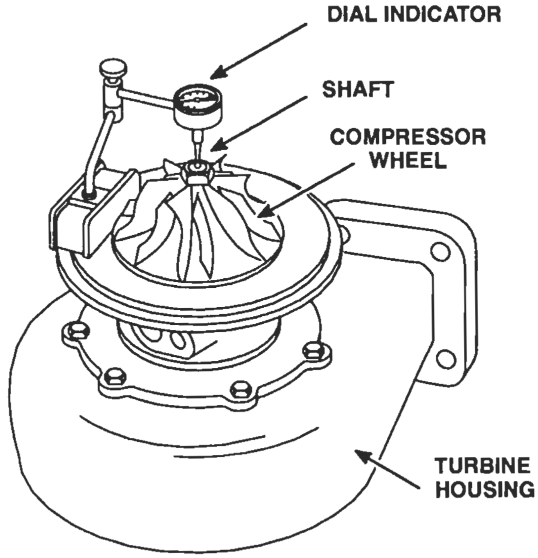


Figure 35. Checking Shaft End Play

18. 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 (Figure 36.) 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. For a true reading, the dial indicator stem must be on the same center line as the plunger of the dial indicator adaptor.

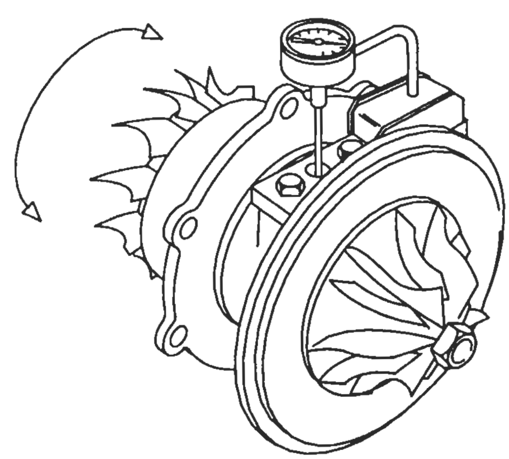


Figure 36. Checking Shaft Radial Movement

ASSEMBLE TURBOCHARGER (CONT.)

d. Raise the rotating assembly up by hand and note the indicator reading. Then push the rotating assembly down by hand and note the indicator reading. 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 inches. Repeat Steps d and e several times to be sure the readings are accurate. The shaft radial movement (bearing clearance) may be checked with the turbocharger assembly attached to the engine by mounting the dial indicator adaptor J 21224 and the dial indicator (Figure 37.)

19. Place the compressor housing over the compressor wheel and against the center housing, with the marks previously placed on the housings in alignment.

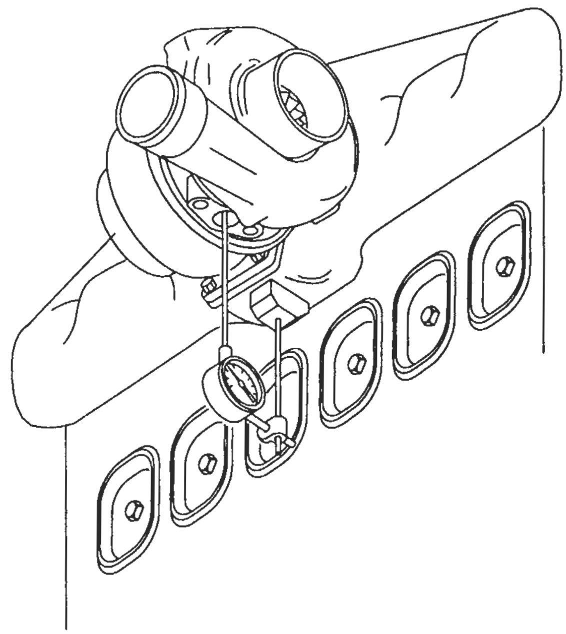


Figure 37. Indicator Mounting for Checking Shaft Radial Movement

20. Install the twelve bolts, lock washers and clamps that secure the T18 compressor housing to the center housing. Tighten the bolts to 100–110 lb·in (11–12 N·m) torque. On the T18A or TH08A turbochargers, 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.
21. Place the turbine housing over the turbine wheel and against the center housing, with the marks previously placed on the housings in alignment.
22. Lubricate the threads of the turbine housing retaining bolts with a high temperature anti–seize lubricant. Then install the three lockplates and six bolts securing the turbine housing to the center housing. Tighten the bolts to 100–110 lb·in (11–12 N·m) torque. Bend both ends of each lockplate up against the flat side of the bolt head.
23. With the turbocharger assembled, spin the rotating assembly by hand. The rotating assembly must turn freely without any indications of dragging or binding.
24. Cover all of the openings in the turbocharger to prevent any foreign material from entering.

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. Install inlet shield J 26554–A.
3. Place the turbocharger assembly into position on the mounting bracket.

NOTICE:

When replacing turbo exhaust pipes, it is imperative that the exhaust manifold be loosened so that proper alignment between the turbo and exhaust manifold occurs. If this procedure is not followed, exhaust tube breakage will occur.

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.
5. Slide the blower air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.
6. Attach the turbocharger compressor inlet shield (J 26554–A) to the air inlet opening.
7. Tighten the turbocharger to exhaust manifold adaptor bolts securely. Then remove the chain hoist and lifting sling from the turbocharger.
8. Attach the exhaust gas outlet piping to the turbine housing.
9. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.
10. Attach the oil inlet line to the cylinder block.
11. After installing a rebuilt or new turbocharger, it is very important that all of the 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.
    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 (5 lb/in.^{2} or 34.5 kPa at idle speed).

INSTALL TURBOCHARGER (CONT.)

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.

12. Check all ducts and gaskets for leaks.
13. 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.

NOTE: After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and repaired.

14. Shut down the engine. Remove the compressor inlet shield (J 26554–A). Attach the compressor air intake ducting. Check for leaks.

TURBOCHARGER INTERCOOLER

An intercooler (Figure 1.) is placed between the air discharge side of the turbocharger and the air inlet side of the engine blower. 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.

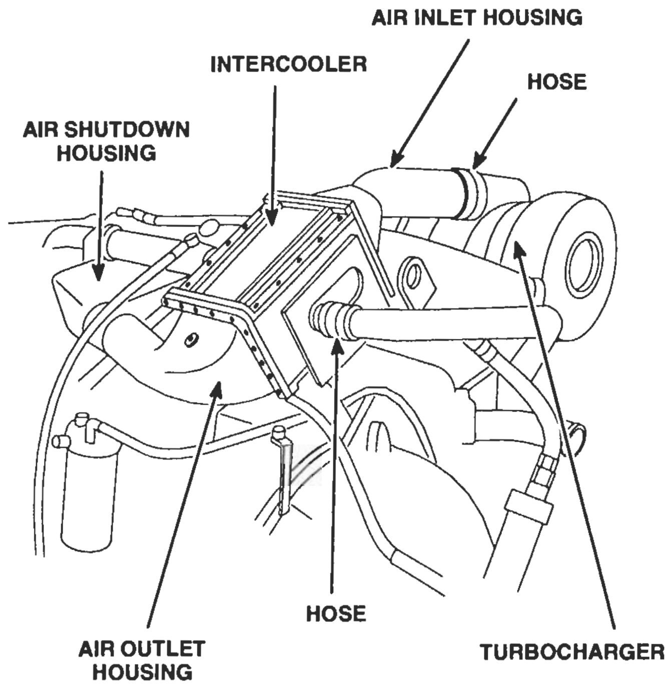


Figure 1. Turbocharger Intercooler

REMOVE INTERCOOLER

1. Drain the raw water system.
2. Disconnect the air and water inlet and outlet hose connections at the air shutdown housing, turbocharger and intercooler.
3. Remove the air inlet and outlet housings from the intercooler. Discard the gaskets.
4. Remove the intercooler from the support brackets.

NOTICE:

Be careful not to damage the intercooler core fins.

CLEAN INTERCOOLER

1. Only remove the end covers of the intercoolers.

NOTE: Prior to removing the end covers, match–mark each cover in its original position.

2. Reinstall two bolts at each end of the intercooler in order to hold the side covers in position while cleaning the core side of the cooler.
3. The coolant side of the cooler should be cleaned first. If the coolant side of the cooler does not require cleaning, disregard steps 1 and 2 and proceed to step 11 with cleaning the air side of the cooler.
4. After it is determined that the coolant side must be cleaned, block off both the inlet and outlet side of the core to prevent any of the blasting material from entering the air side of the cooler.
5. Glass bead both ends of the cooler and end covers in a suitable glass beading machine.
6. Rod out each tube in the core with a suitable size brass rod.
7. Remove any blasting material with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

8. Reassemble the end covers using new gaskets. At this time, only hand tighten the end cover bolts.
9. Place the complete assembly on a flat drill press table with slots in order to allow the excess end cover gasket material to set in and allow the end covers to be square with the top and bottom of the core.
10. Tighten the end cover bolts to the standard bolt torque and trim excess gasket material from the top and bottom of the cooler.
11. Place the complete cooler assembly into a degreasing (mineral spirits) tank in order to remove any soot and greasy oil accumulations from the air side of the cooler. Dry with compressed air.

NOTE: Depending on how dirty the air side is, this step may require repeating until the accumulations are removed.

12. Pressure test the coolant side of the cooler to see if any of the tubes leak. Block off the inlet and outlet connections with fabricated plugs and apply regulated air pressure at 20 lb/in.^{2} (138 kPa) at one of the drain openings in the end cover. Submerge the cooler in a tank of water and look for leaks.

INSTALL INTERCOOLER

1. Attach the intercooler to the support brackets with ten 5/16 –18 x 1 inch bolts and lock washers. Tighten the bolts.
2. Use new gaskets and attach the air inlet housing and air outlet housing to the intercooler with the sixteen 5/16–18 x 1 inch and twenty 5/16–18 x 1 1/4 inch bolts and lock washers. Tighten the bolts.
3. Connect the air and water inlet and outlet hoses at the shutdown housing, turbocharger and intercooler. Tighten the hose clamps.
4. Fill the raw water system. Start the engine and check for air or water leaks.

TURBOCHARGER AFTERCOOLER

The aftercooler is installed in the cylinder block air box at the blower opening (Figure 1.) The cylinder block is machined at the blower opening and the outer surface of the water jacket to receive the aftercooler. Cup plugs are used at the core holes of the water jacket in place of threaded pipe plugs. A separate opening in the water jacket is provided for the aftercooler water inlet connection.

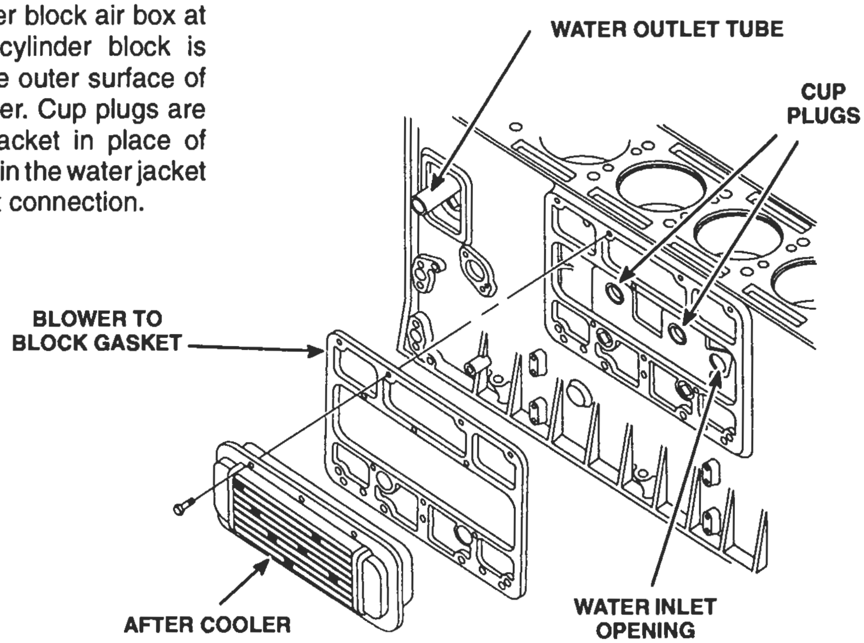


Figure 1. Aftercooler Mounting

The water outlet tubing is routed through the rear hand hole cover and then attaches to the cylinder head at the rear water manifold openings (Figure 2.)

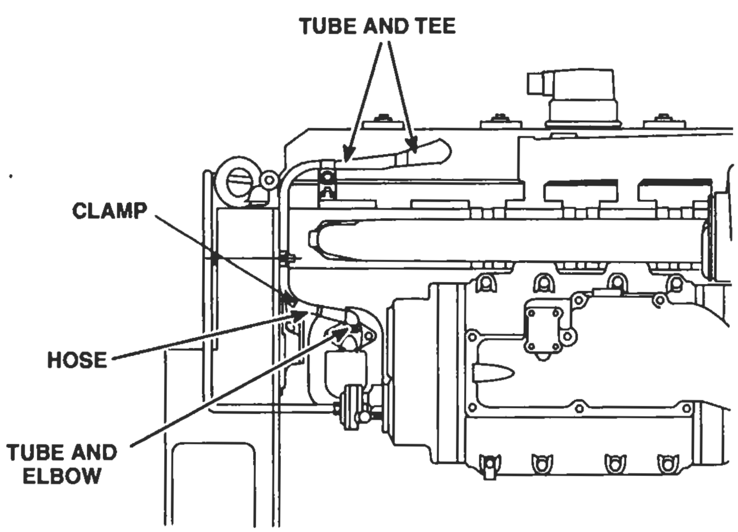


Figure 2. Aftercooler Components

TURBOCHARGER AFTERCOOLER (CONT.)

An air bleed line (Figure 3.) is installed between the aftercooler water inlet tube and the water manifold of all Inline 6–71 ALCC engines (model 1067–8600), effective with unit number 6A0445105. The bleed line prevents air from becoming trapped in the cooling system at initial fill, permits more rapid filling, and provides improved deaeration of the coolant during engine operation.

Because of the improved cooling system performance that results from the use of the new air bleed line, DDC recommends adding the line to all 6–71 ALCC engines built before the serial number above.

The current elbow on the aftercooler water inlet tube has a boss with a 1/4 inch NPTF drilled and tapped hole into which the new bleed line is installed. The elbow on the original assembly did not have this hole, but it may be reworked to add it (see shop notes).

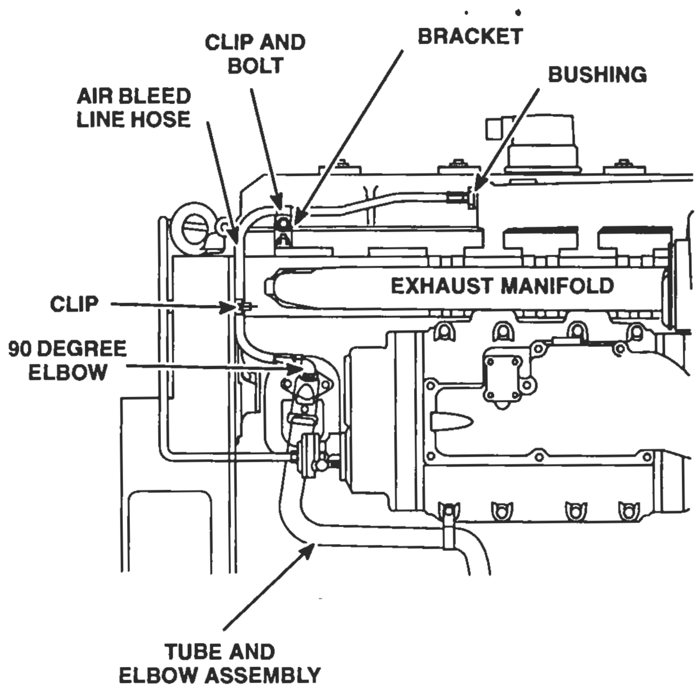


Figure 3. Air Bleed Line on 6–71 ALCC Engine

REMOVE AFTERCOOLER

1. Disconnect the turbocharger at the air inlet adaptor (Section 3.5).
2. Remove the air inlet adaptor from the blower.
3. Remove the blower from the cylinder block and any accessories attached to the blower (Section 3.4).
4. Disconnect the water outlet tube and elbow from the rear hand hole cover and unclamp it from the water return hose. Discard the 5/16 – 18 x 3/4 inch attaching bolts with nylon locking patch. Then remove the hand hole cover.
5. Remove the water outlet tube and adaptor at the aftercooler water outlet connection.
6. Remove and discard the 5/16 – 18 x 9/16 inch attaching bolts with nylon locking patch and remove the aftercooler from the cylinder block opening.

NOTICE:

Be careful not to damage the cooler fins when removing the aftercooler from the cylinder block.

7. Remove and discard the seal rings from the grooves in the water inlet and outlet connections 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 additives 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 lb/in.^{2} (276 kPa) air pressure to the water side of the cooler.

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:

NOTE: 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 corrected.

1. Steam 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. Do not apply more than 40 lb/in.^{2} (276 kPa).
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.
7. Using compressed air, blow dry the air and water sides of the core. Do not exceed 40 lb/in.^{2} (276 kPa) air pressure.
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 aftercooler water inlet and outlet connections. Coat the seal rings lightly with engine oil. Do not scratch or nick the sealing edge of the seal rings.
2. Install the aftercooler in the cylinder block opening. The water inlet connection of the cooler seats in the water inlet opening in the cylinder block. Install six new 5/16 – 18 x 9/16 inch attaching bolts with nylon locking patch. Tighten the bolts.
3. Install the water outlet tube and adaptor on the aftercooler outlet connection and through the rear hand hole cover opening.
4. Install the rear hand hole cover and gasket and tighten the cover bolt. Then with a new gasket (seal ring) connect the water outlet elbow and tube to the aftercooler outlet tube. Install two new 5/16 inch bolts with nylon lock patch that hold the elbow to the hand hole cover. Tighten the bolts.
5. Connect the elbow and tube to the water return hose. Tighten hose clamps.
6. Use a new blower to cylinder block gasket and install the blower and any accessories attached to the blower (Section 3.4).
7. Attach the air inlet adaptor to the blower with the 7/16 – 14 x 1 1/2 inch attaching bolts and lock washers. Tighten the bolts to 46–50 lb·ft (62–68 N·m) torque.
8. Install the turbocharger (Section 3.5).

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

INSTALLING WATER PUMP DRIVE AND ROTOR SHAFT KIT

The current design water pump intermediate drive coupling is designed to minimize wear thereby increasing service life.

To convert the former drive coupling to the current coupling, a "Water Pump Drive and Rotor Shaft Kit" must be used.

NOTE: Before the kit can be installed, refer to Section 3.4 and remove and disassemble the blower.

REMOVE ROTOR STUB SHAFT

To remove the rotor stub shaft, proceed as follows:

1. Use a sharp screwdriver or similar tool to punch a hole in the center of the core plug opposite the visible drilled hole in the rotor (Figure 1.) and pry out the plug.
2. Drive the groove pin down through the shaft with a punch until it reaches the position shown by the dotted line.

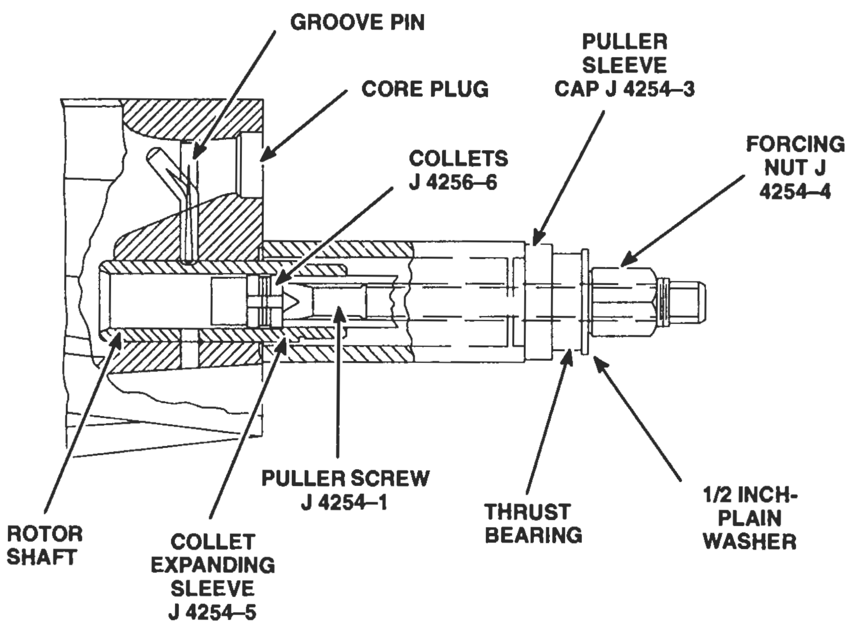


Figure 1. Rotor Stub Shaft Removal

REMOVE ROTOR STUB SHAFT (CONT.)

3. Bend the groove pin with the punch until it is almost "L" shaped as shown by the solid line. This operation is necessary because the length of the pin is greater than the corresponding width of the rotor cavity.
4. Drive the groove pin in until it drops into the rotor cavity.
5. Remove the plug from the inside of the rotor shaft by driving it out of the shaft and into the rotor body.
6. Clamp the rotor firmly in a vise with soft wood blocks between the rotor and the vise jaws.
7. Insert the puller screw (J 4254–1) with the collets (J 4254–6) in the retracted position into the rotor shaft until the collets are beyond the shoulder on the internal surface of the shaft.
8. Push the collets on to the larger diameter of the puller screw as shown. Remove the collet expanding sleeve (J 4254–5).
9. Coat the threads of the puller screw with an extreme pressure lubricant.
10. Pull the puller screw outward by hand until the collets seat against the internal shoulder of the rotor shaft and maintain tension on the puller screw.
11. While holding the puller screw in this position, place the following tool components in the order named over the puller screw: puller sleeve (J 4254–2), puller sleeve cap (J 4254–3), thrust bearing, 1/2 inch plain washer and forcing nut (J 4254–4).
12. Tighten the forcing nut until it is finger tight.
13. Thread the forcing nut on the puller screw to remove the shaft from the rotor.
14. Remove the rotor from the vise and shake the rotor shaft plug and groove pin from the rotor cavity.

INSTALL SERVICE ROTOR FRONT STUB SHAFT

1. Coat the new blower rotor front shaft with lubriplate or equivalent.
2. Use a suitable press arrangement and align the rotor shaft with its hole in the rotor and press the shaft into the rotor to the height of the spacer (J 4254–8).
3. Drill and ream a new .250 inch diameter, 2.500 inch deep pin hole in the rotor 120° from the existing pin hole.
4. Drive the new groove pin into the new hole. The end of the pin must be .0625 inch below the rotor surface.
5. Install a new core plug.
6. Stake the pin and the core plug after installation and remove all raised burrs.

After the modified lower blower rotor assembly has been used in the assembly of the blower up to the point where the water pump intermediate drive coupling is to be installed, install the new water pump intermediate drive coupling in accordance with the following procedure.

 May, 1994

ATTACH WATER PUMP INTERMEDIATE DRIVE COUPLING TO BLOWER ROTOR

1. Install the splined end of the water pump intermediate drive coupling into the lower blower rotor front stub shaft.
2. Insert the 5/16 inch bolt through the water pump coupling and thread it into the rotor shaft and plug assembly.
3. Tighten the bolt to 15–19 lb·ft (20–26 N·m) torque.

DRILLING PROCEDURE FOR AIR SHUTDOWN REPLACEMENT SHAFT

Whenever a replacement air shutdown valve shaft is installed on a Series 71 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 inch drill bit in the chuck of a drill press, then locate and align the bit through the existing hole in the shutdown cam. 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 inch from the end of the cam. Start the drill and bore a hole through the shaft (Figure 2.) Withdraw the drill bit, install the pin handle through the hole and remove the shaft from the drill press.

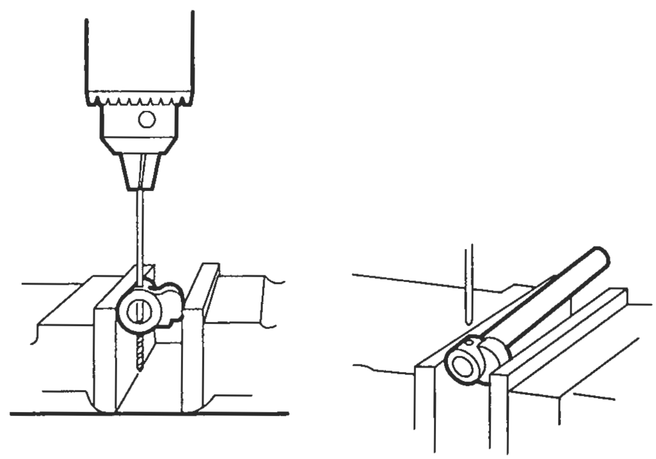


Figure 2. Aligning Drill Bit and Drilling Shaft

3. Insert the shaft into the shutdown housing bore and install the spacer on the end of the shaft. Place a .015 inch feeler gage between the housing and spacer and mark the shaft with a center punch inserted into the existing hole in the spacer (Figure 3.)
4. Remove the shaft from the housing. Locate and align the 1/8 inch 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.

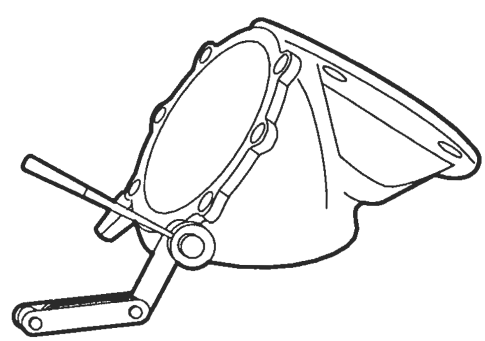


Figure 3. Center Punch Shaft thru Spacer Hole

DRILLING PROCEDURE FOR AIR SHUTDOWN REPLACEMENT SHAFT (CONT.)

6. Assemble the shaft, seal rings spring, flapper valve and spacer in the housing (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 (Figure 4.)

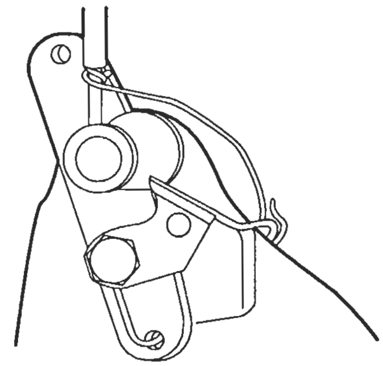


Figure 4. Cam Latch Wired to Prevent Movement

8. Place the housing on the drill press. With the valve held in the wide open run position, align the 1/8 inch drill bit with the marks center punched on the valve in Step 6. Then drill through the valve and shaft (Figure 5.) Install the retaining pins to hold the valve to the shaft.
9. Clean the air shutdown assembly thoroughly and check for proper operation before installing it on the engine.

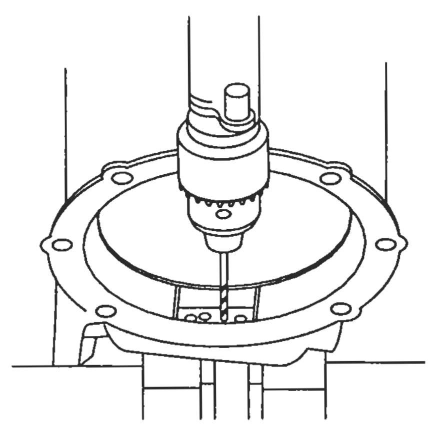


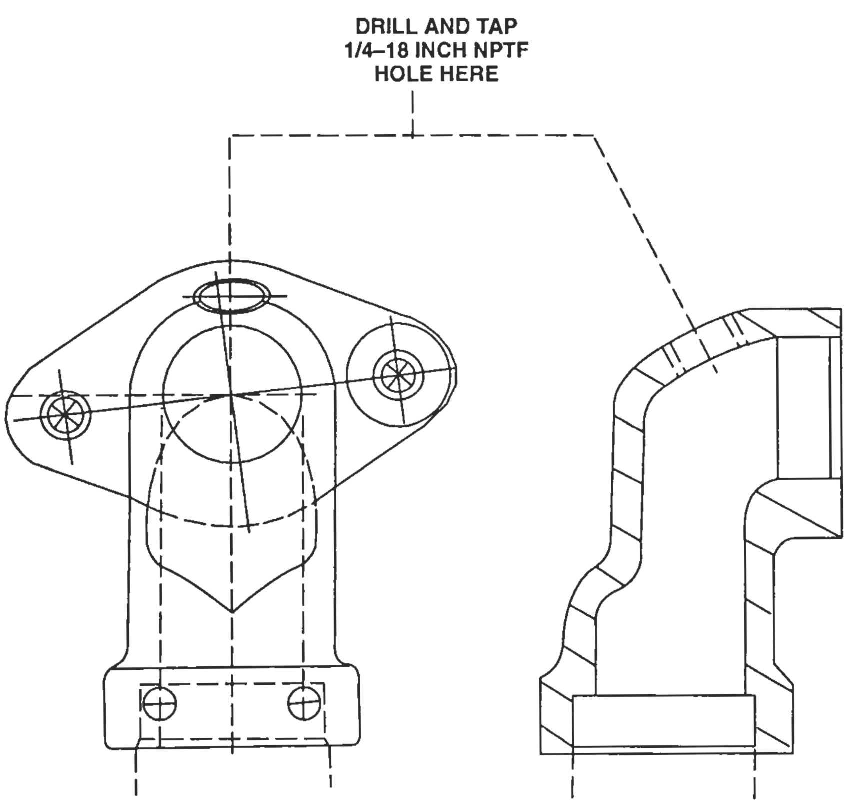
Figure 5. Drilling Valve–to–Shaft Holes

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, disassembly 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 and 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.

TROUBLESHOOTING INTERCOOLERS

CONDITION	PROBABLE CAUSE	SUGGESTED REMEDY
BLACK SMOKE (AIR SIDE)	AIR INLET RESTRICTION	Clean silencer (Section 3.2)
	INJECTORS – HIGH OUTPUT	(Section 2.0)
	DIRTY FINS INTERCOOLER	Clean intercooler fins
OVERHEATING (WATER SIDE)	THERMOSTATS	Check thermostat (Section 5.2.1)
	RAW WATER PUMP	Check impeller (Section 5.6)
	HEAT EXCHANGER	Clean element (Section 5.5)
	INTERCOOLER (WATER SIDE)	Clean intercooler (Section 3.5.2)
	INDUSTRIAL FILTER	Clean filter



Aftercooler Water Inlet Tube Elbow Rework Instructions

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 (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
BLOWER			
Backlash (timing gears)	.0005	.0025	.0040
Backlash (reduction gears)	.0020	.0060	.0080
Oil seal or seal collar (Below end plate surface)	.0020	.0080	
Dowel pin (projection beyond inside face of end plates)	.3800		
T18 AND T18A40 TURBOCHARGERS (AIRESEARCH)			
End Play — rotating shaft	.0040	.0090	
Radial movement — rotating shaft	.0030	.0070	
Inside diameter	.6268	.6272	
Outside diameter	.9780	.9785	
Journal diameter — turbine wheel shaft	.6247	.6250	.6242
Bearing bore I.D. — center housing	.9830	.9835	.9845
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

ENGINE PARTS (Standard Size, New)	MINIMUM (IN.)	MAXIMUM (IN.)	LIMITS (IN.)
TV61 AND TV71 TURBOCHARGER (AIRESEARCH)			
End play — rotating shaft	.0030	.0100	
Radial movement — rotating shaft	.0030	.0070	
Turbine wheel shaft journal bearings:			
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 (TV61)	.3121	.3124	.3134
Inside diameter (TV71)	.3736	.3739	.3749

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. (lb/in^2)
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 (IN.)	TORQUE (lb·ft)	TORQUE (N·m)
Blower Drive Hub–to–blower Rotor Gear Bolt	5/16–24	25–30	34–41
Blower Drive Plate–to–drive Hub Bolt	5/16–24	25–30	34–41
Blower Lower Front Bearing Retaining Bolt (Allen Head)	5/16–24	18	24
Air Inlet Housing–to–blower Housing Bolt	3/8–16	16–20	22–27
Blower Housing–to–cylinder Block Bolt (Alum. Block)	7/16–14	35–40	47–54
Blower Housing–to–cylinder Block Bolt (C.I. Block)	7/16–14	55–60	75–81
Blower Rotor Timing Gear Bolt	7/16–20	55–65	75–88
Blower Rotor Timing Gear Bolt	1/2–20	55–65	75–88
Fuel Pump Drive Disc Bolt	1/2 20	55–65	75–88

SERVICE TOOLS

TOOL NAME	TOOL NO.
BLOWER	
Blower clearance feeler set	J–1698–02
Blower rotor shaft remover and installer set	J–4254
Blower service tool set	J–6270–F
Slide hammer set	J–6471–02
Snap ring pliers (external type)	J–4880
Lip type oil seal (over size) and spacer installer	J–35787
TURBOCHARGER (AIRESEARCH)	
Compressor wheel nut wrench	J–21223–02
Compressor wheel remover	J–9496
Dial indicator adaptor	J–21224
Dial indicator set (magnetic base)	J–7872
Turbocharger inlet shield	J–26554–A
Turbocharger support fixture	J–29086
Turbocharger tool set	J–29149

LUBRICATION SYSTEM

CONTENTS

Lubrication System 4
Oil Pump 4.1
Lubricating Oil Pressure Regulator 4.1.1

Lubricating Oil Filters 4.2

Oil Cooler 4.4

Oil Level Dip Stick 4.6

Oil Pan 4.7

Ventilating System 4.8

Shop Notes – Troubleshooting – Specifications – Service Tools 4.0

LUBRICATION SYSTEM

Oil flows through a typical Inline 71 lubricating system (Figure 1.) including the various components such as the oil pump, oil cooler, bypass and full–flow filters, the pressure regulator valve and bypass valve.

The lubricating oil is circulated by a gear–type pressure pump mounted on the No.1 and No.2 main bearing caps and gear driven from the crankshaft.

All the oil leaving the pump is forced through the full–flow oil filter to the cooler and then into the oil gallery in the cylinder block from where it is distributed to the various engine bearings. The drain from the cylinder head and other engine parts leads back to the oil pan.

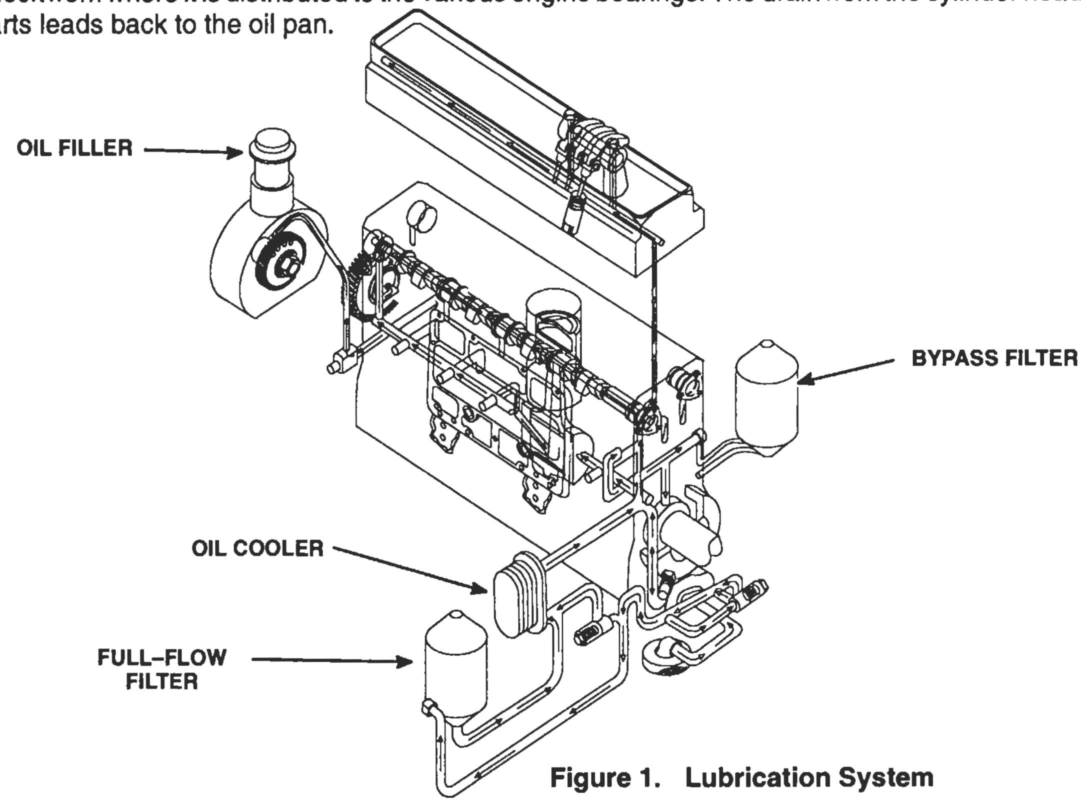


Figure 1. Lubrication System

A spring–loaded integral plunger–type relief valve, located in the oil pump body, bypasses excess oil from the discharge to the intake side of the pump when the pressure in the engine oil gallery exceeds approximately 105 lb/in.^{2} (724 kPa).

If the oil cooler should become clogged, the oil will flow from the pump through a spring–loaded bypass valve directly into the oil gallery.

Clean engine oil is assured at all times by the use of a full–flow oil filter incorporated in the engine lubrication system. With this type filter, which is installed in the lubricating system between the pump and the cooler, all of the oil is filtered before entering the engine.

A bypass filter is available as optional equipment. A portion of the oil is continually bypassed through the filter and the filtered oil is returned to the engine oil pan.

Stabilized oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located between the pump outlet and the inlet to the cylinder block. When the oil pressure at the valve exceeds 50 lb/in.^{2} (345 kPa), the regulator valve opens and remains open until the pressure is less than the opening pressure.

OIL DISTRIBUTION

Oil from the cooler is conducted by a vertical passage to a longitudinal main oil gallery on the blower side of the cylinder block. This gallery distributes the oil, under pressure, to the main bearings and to a horizontal, transverse passage at each end of the cylinder block. From each of these two horizontal passages, oil flows through two vertical bores (one at each end of the cylinder block) to the end bearings of the camshaft and balance shaft. In addition, oil is forced through an oil passage in the camshaft which lubricates the camshaft intermediate bearings. Oil for lubricating the connecting rod bearings, piston pins and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the bearings of the camshaft, balance shaft and idler gear.

The blower drive gear bearing is lubricated through an external pipe from the rear horizontal oil passage of the cylinder block.

A longitudinal oil gallery on the camshaft side of the cylinder head is supplied with oil from one of the vertical bores located at each end of the cylinder block. Oil from this gallery enters the drilled rocker arm shafts through the rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker arm bearings and push rod clevis bearings.

Excess oil from the rocker arms lubricates the ends of the valve push rods, injector push rods and the cam followers, and then drains to cam pockets in the top of cylinder block from which the cams are lubricated. When these pockets are filled, the oil overflows through two holes, one at each end of the blower housing (Figure 2.) and thus provides lubrication for the blower drive gears at the rear end and for the governor mechanism at the front end. A dam in the blower rear end plate cover maintains an oil level in which the teeth of the lower blower rotor timing gear run. A slinger at the forward end of the lower rotor throws oil from the dam onto the governor weight assembly. Surplus oil overflows the dam in the two end plate covers and passes through drilled holes in the cylinder block to the oil pan.

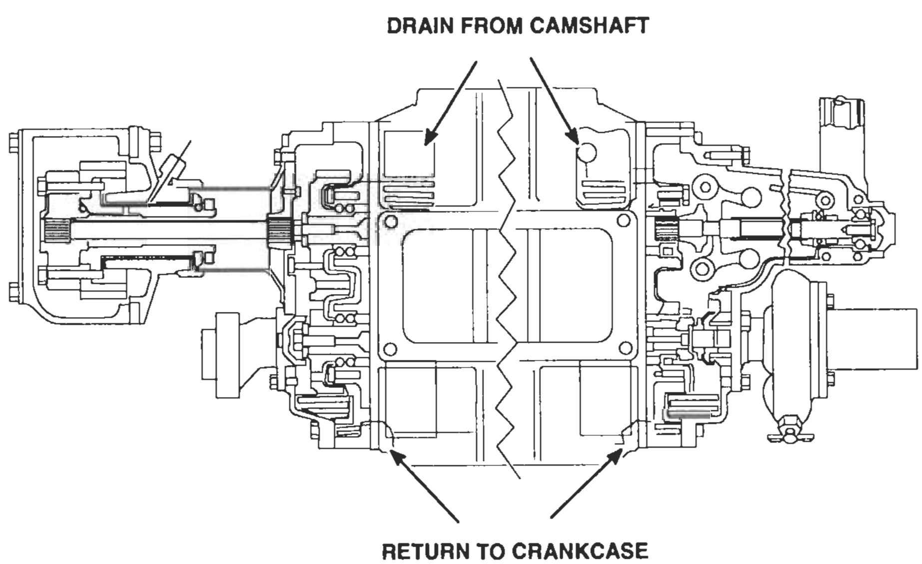


Figure 2. Blower Lubrication

LUBRICATION SYSTEM MAINTENANCE

Use the proper viscosity grade and type of heavy duty oil (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.

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 may 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 (Section 5), clean as required.

DETECTION OF LUBE OIL LEAKS

Detroit Diesel Corporation 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.

OIL PUMP

The gear–type oil pump is mounted on the first and second main bearing caps and is gear driven from the front end of the crankshaft.

The oil pump helical gears rotate inside a housing (Figure 1.) The drive gear is keyed to the drive shaft which is supported inside the housing on two bushings with a drive–driven gear keyed to the outer end of the shaft. The driven gear is supported on the driven gear shaft which is pressed into the pump body.

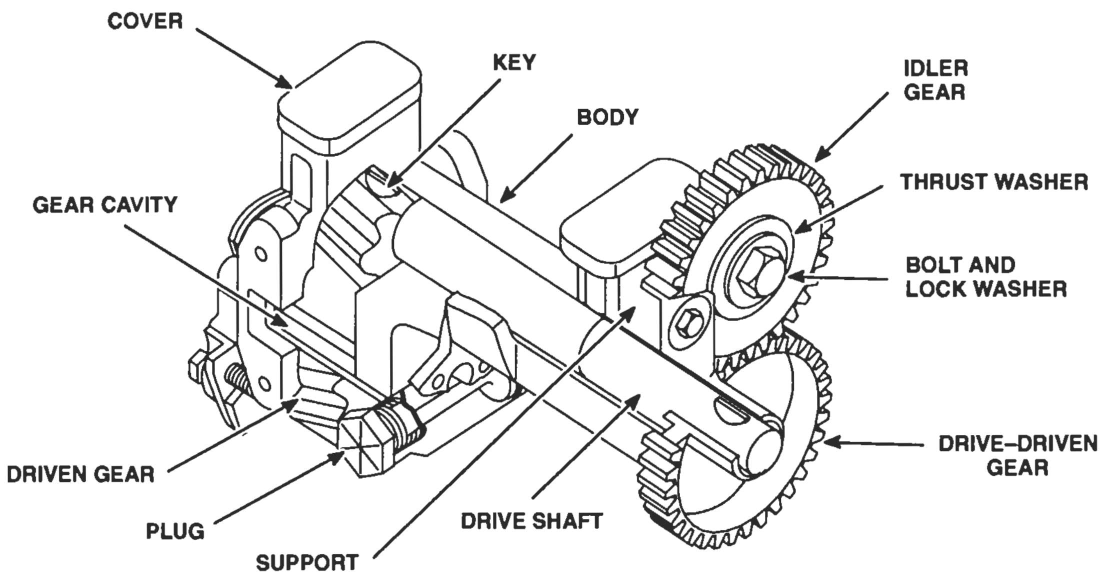


Figure 1. Oil Pump Assembly

An integral plunger, type relief valve bypasses excess oil to the inlet side of the pump when the pressure in the oil lines exceeds 105 lb/in.^{2} (724 kPa).

An inlet pipe attached to the inlet opening in the pump body leads to the inlet screen which is mounted with brackets to a main bearing cap.

The inlet screen is located below the oil in the pan and serves to strain out any foreign material which might damage the pump.

The oil pump inlet screen should be removed and cleaned periodically in addition to the cleaning it receives each time the engine is reconditioned.

When required–certain engines are equipped with a dual type pump which incorporates a scavenging pump. The scavenging pump consists of a spacer, two gears, and a pump body. Oil which normally flows to the front of the engine during inclined operation of the engine is transferred to the rear of the pan by the scavenging pump and is then picked up by the oil pump for distribution throughout the engine.

An idler gear is mounted on a support bracket which is attached to the pump body.

Pressure lubrication of the idler gear bushing is provided by means of a drilled passage in the pump body and a connecting passage in the idler gear support bracket.

SECTION 4.1 – OIL PUMP

REMOVE OIL PUMP

1. Remove the drain plug from the oil pan and drain the oil.
2. Remove the oil pan bolts and remove the oil pan.
3. Remove the bolts and lock washers securing the oil pump, regulator body and oil outlet tube and oil inlet tube support (including scavenging pump tube supports if used) from the main bearing caps, and cylinder block (Figure 2.)

NOTE: Remove and save the shims, if used, between the oil pump mounting feet and the bearing caps.

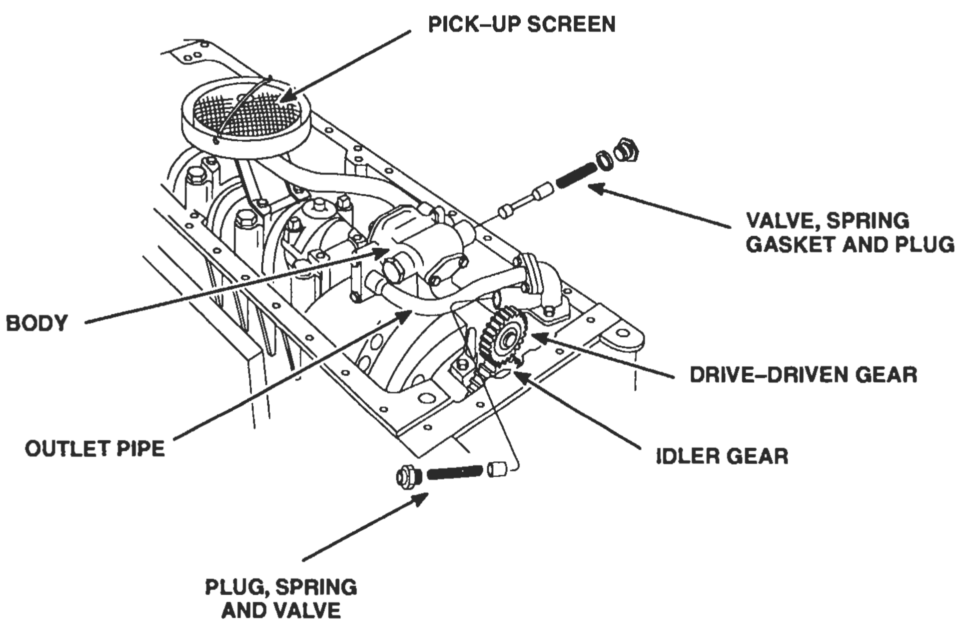


Figure 2. Oil Pump Mounting

DISASSEMBLE OIL PUMP

Observe carefully the position of all parts including the oil inlet and outlet pipes during disassembly to facilitate pump assembly.

1. Remove the scavenging pump inlet pipe together with the inlet screen, if so equipped, from the scavenging pump body.
2. Remove the scavenging pump outlet pipe, if so equipped.
3. Remove the oil pump inlet pipe with the screen cover and mounting brackets.
4. Remove the oil pressure regulator and the oil pump outlet pipe as an assembly from the pump body.
5. Remove the four bolts and lock washers securing the scavenging pump body or the cover to the oil pump body.
6. Remove the scavenging pump drive and driven gears from the oil pump drive and driven shafts, if so equipped.
7. Remove the Woodruff keys from the drive shaft and slide the spacer off the end of the shafts, if Step 6 is performed.
8. Remove the valve plugs and copper gaskets from each side of the pump body and jar the relief valve parts from the body (Figure 3.)

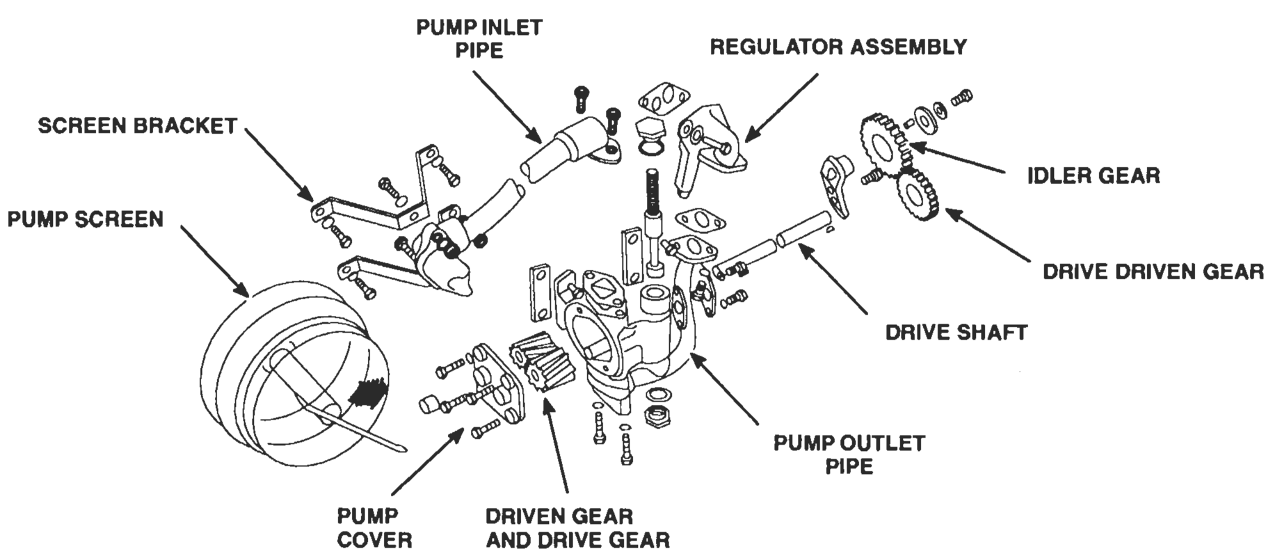


Figure 3. Oil Pump Components

DISASSEMBLE OIL PUMP (CONT.)

9. Remove the pump driven gear from the driven gear shaft.
10. Straighten the lip of the lock washer and unscrew the bolt thus freeing the idler gear.
11. Clamp the pump body, drive shaft and gear assembly in a bench vise. Pull the drive–driven gear from the outer end of the pump drive shaft (Figure 4.)
12. Remove the Woodruff key from the drive shaft and withdraw the shaft and driven gear from the pump body.
13. Unscrew the bolt and remove the idler gear support from the pump body.

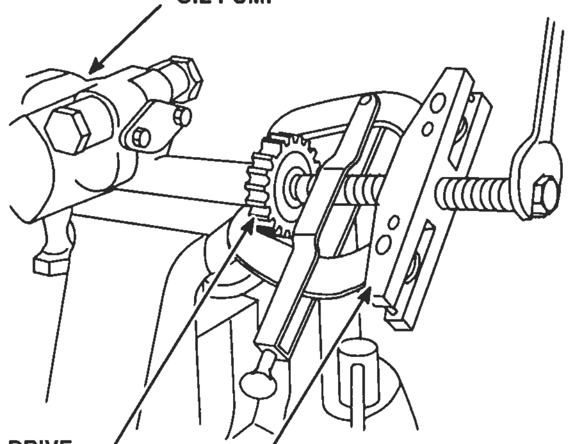


Figure 4. Removing Oil Pump Drive Gear from Shaft with Tool

14. If the drive gear is to be replaced, position the gear and shaft assembly on the bed of an arbor press with the long end of shaft extending down through the slot in bed plate and with the face of the gear resting on the plate (Figure 5.) Place a short 1/2 inch round steel rod on the end of the shaft, and press the shaft from the gear.

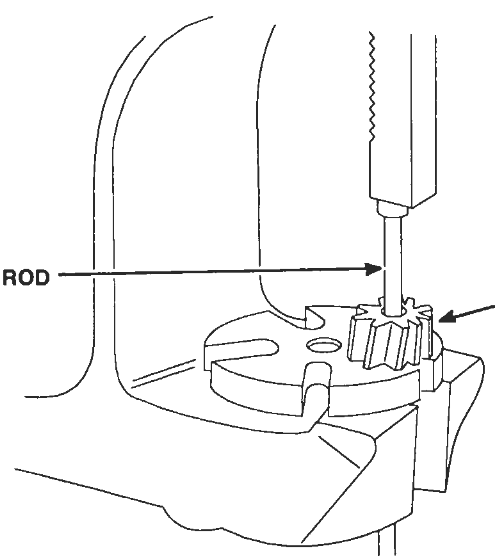


Figure 5. Removing Oil Pump Drive Gear from Shaft

INSPECT OIL PUMP PARTS

Wash all 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 lb/ft^2 (276 kPa) air pressure.

Examine the gear cavity in the pump body and the drive shaft bushings. If the driven gear bushings are worn, replace the bushings. Service replacement bushings in the driven gears must be reamed after assembly. Bushings used with the .499 inch diameter driven gear shaft must be reamed to .500 ± .0005 inches and bushings used with the .623 inch diameter shaft must be reamed to .625 ± .0005 inches.

Inspect the bushings in the pump body and cover or scavenging pump body. If the bushings are worn excessively, replace the pump and cover or scavenging pump body assemblies unless suitable boring equipment is available for finishing the new bushings. When installing new bushings, replace all of the bushings. The bushings must be located and positioned properly (Figure 6.) Also the gear bore and the bushing bore in both the pump body and cover or scavenging pump body must be concentric within .001 inch. The shaft–to–pump body–bushing clearance with new parts is .0008 to .0025 inch. The shaft–to–pump cover or scavenging pump body bushing clearance with new parts is .0010 to .0027 inch.

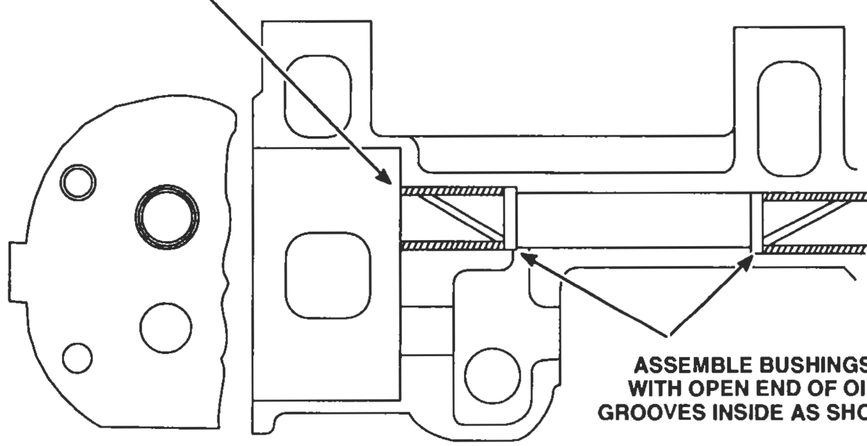


Figure 6. Location of Bushing in Oil Pump

In an efficient oil pump, the gears should have a free–running fit (not loose) in the pump housing. 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 pressure relief valve and its seat in the pump body. If necessary, install new parts.

ASSEMBLE OIL PUMP

Assemble the oil pump as follows:

1. If the drive gear was removed from the drive shaft, insert the Woodruff key in the keyway and apply a light coat of engine oil on the shaft. Start the shaft squarely into the bore of the gear and press the shaft into the gear.

The gear must be 6–15/16 inch on three and four cylinder engines, or 6 15/32 inch on six cylinder engines, from the keyway end of the drive shaft.

2. Press the dowel into the pump body, if removed.
3. Place the idler gear support in position against the forward end of the pump body and secure the support to the body. Tighten the bolt to 45–50 lb·ft (61–68 N·m) torque.
4. Install the drive gear and shaft assembly in the pump body and slide the driven gear onto the shaft.
5. If the engine is equipped with a scavenging pump, install the oil pump spacer over the end of the drive and driven gear shafts flush against the oil pump body.
6. Insert two Woodruff keys in the keyway and slide the drive gear (gear with keyway) against the spacer.
7. Slide the driven gear on the driven shaft against the spacer.
8. Secure the pump cover or scavenging pump body to the oil pump body with four bolts and lock washers.
9. Support the drive gear end of the drive shaft on the bed of an arbor press and insert the Woodruff key in the keyway of the shaft. Position the drive–driven gear on the end of the drive shaft with the extended hub side up away from the pump body. Insert a .004 inch to .006 inch feeler ribbon between the driven gear and the pump body and press the gear on the shaft until the clearance between the gear and the body is .004 inch to .006 inch.
10. If the locating pin was removed, install it in the idler gear support, then lubricate the bearing surface with engine oil and place the gear in position on the support with the flat side of gear facing the support.
11. Place the lock washer on the bolt and the special washer next to the lock washer and start the bolt into the idler gear support. Then rotate the special washer and lock washer so that the slot in each washer engages the locating pin.
12. Tighten the idler gear bolt to 21–26 lb·ft (28–35 N·m) torque so the bolt head is over the end of the locating pin. Then bend the lock washer against one flat of the bolt head.
13. Screw the relief valve plug, with copper gasket, into place in the side of the pump body opposite the inlet opening. Then place the valve and spring in the bore at the inlet side of the pump body and while compressing the spring, start the second relief valve plug, with gasket, into the body. Tighten the plugs to 25–35 lb·ft (34–47 N·m) torque.
14. If the cover and gasket were removed from the pump body, reinstall and secure them with the two bolts and lock washers.

The oil pump must turn freely after assembly. Any bind in the pump must be removed before it is installed on the engine.

REMOVE OIL PUMP DRIVING GEAR FROM CRANKSHAFT

With the oil pan and lubricating oil pump removed, the oil pump driving gear may be removed from the crankshaft as follows:

1. Support the front end of the engine and remove the crankshaft front cover (Section 1.3.5).
2. Remove the oil slinger.
3. If required, use puller J 8190 to pull the pump driving gear from the front end of the crankshaft as follows (Figure 7.):
   a. Screw the crankshaft pulley or cap retaining bolt into the end of the crankshaft.
   b. Place the jaws of the puller behind the gear and locate the point of the puller screw in the center of the retaining bolt.
   c. Turn the puller screw clockwise and draw the gear from the crankshaft.
4. Remove the Woodruff key from the crankshaft.

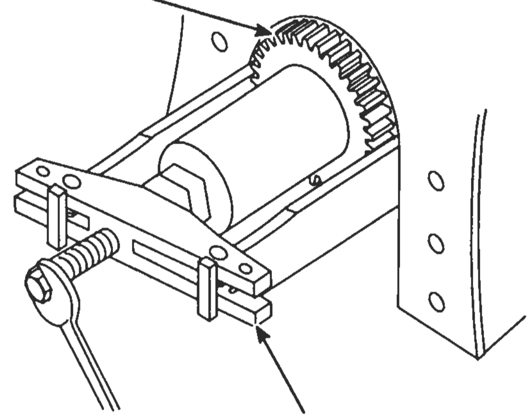


Figure 7. Removing Oil Pump Drive Gear from Crankshaft

INSTALL OIL PUMP DRIVING GEAR ON CRANKSHAFT

1. Install the Woodruff key in the crankshaft.
2. Position the gear so the chamfer on the gear hub is toward the main bearing cap and start the gear on the shaft and over the key.
3. Slide the gear on the crankshaft or use a sleeve if required (Figure 8.) and drive the gear tight against the shoulder on the crankshaft.
4. Install the oil slinger with the dished side away from the gear (Section 1.3.6).
5. Install the crankshaft front cover (Section 1.3.5).

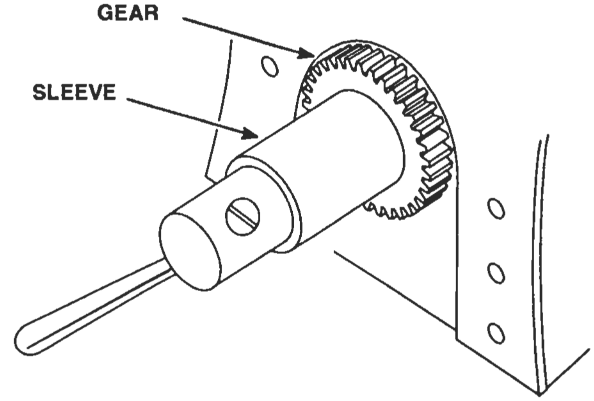


Figure 8. Installing Oil Pump Drive Gear on Crankshaft

INSTALL OIL PUMP

Install the oil pump on the main bearing caps as follows:

1. Hold the pump assembly against the main bearing caps so the idler gear meshes with the driving gear on the crankshaft.
2. Insert the four bolts with lock washers through the mounting feet of the pump and into the bearing caps. Align the pump so that the teeth of crankshaft gear and the idler gear are parallel, then tighten the bolts to 35–39 lb·ft (47–53 N·m) torque. Check clearance between the gear teeth with a feeler gage. Proper clearance between the crankshaft gear and idler gear is .005 inch minimum, .012 inch maximum (Figure 9.)

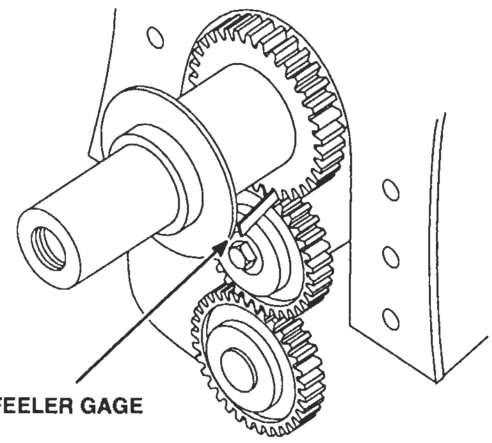


Figure 9. Measuring the Clearance Between the Oil Pump Drive Gear Teeth

NOTE: Always check the clearance between the crankshaft gear and the oil pump idler gear with the engine in the upright or running position.

If shims were used between the pump mounting feet and the bearing caps and new gears are not installed, the same shims (cleaned) or the same number of new (identical) shims should be installed and the number then adjusted to obtain the proper clearance between gear teeth. However, if new gears have been installed, a larger number of shims will be required under the mounting feet. In either event, the pump must be tightened on the bearing cap before the clearance between the gear teeth is measured.

NOTE: When adjusting for gear tooth clearance by installing or removing shims, the same number of shims must be changed under each foot so that the pump will always be level on the main bearing caps. The insertion or removal of one .005 inch shim will change the gear tooth clearance by .0035 inch.

3. Place a new gasket between the outlet pipe and the pressure regulator and bolt the two parts together loosely. Use a new gasket and secure the outlet pipe to the oil pump body with the bolts not over 7/8 inch long. Attach the pressure regulator to the cylinder block using a new gasket.

When attaching the pump outlet and the pressure regulator, none of the bolts should be tightened until all the bolts have been started. After all bolts are started, the outlet pipe bolts should be tightened alternately, then the pressure regulator bolts should be tightened, and finally the pipe–to–regulator bolts should be secured. Current die cast regulators use bolts and self locking nuts. This procedure prevents twisting the outlet pipe.

4. Attach the pump screen brackets to the main bearing caps with lock washers and bolts. Do not tighten the bolts.

INSTALL OIL PUMP (CONT.)

5. Affix a new gasket to the pump end of the inlet pipe, then attach the pipe to the oil pump.
6. Set the screen cover over the outer end of the oil inlet pipe and secure it to the pipe and brackets with bolts, washers, lock washers and nuts. Tighten the bracket bolts to the bearing caps.
7. Place the screen in the cover and lock it in place with retainer.
8. Affix a new gasket to the pump end of the scavenging pump inlet pipe, if so equipped, and secure with bolts and lock washers.

On three and four cylinder engines equipped with the scavenging pump, the scavenging pump screen is part of the oil inlet tube; however, on six cylinder engines a separate screen is used. Install the scavenging pump screen, if used.

9. Affix a new gasket to the scavenging pump outlet pipe, then secure the pipe to the pump body with lock washers and bolts. When installing an outlet flange (Figure 10.), be sure the opening in the flange is toward the front of the pump (toward the drive–driven gear).
10. Recheck all bolts for tightness to assure there will be no leaks in the oil pump and pipe mounting conditions.

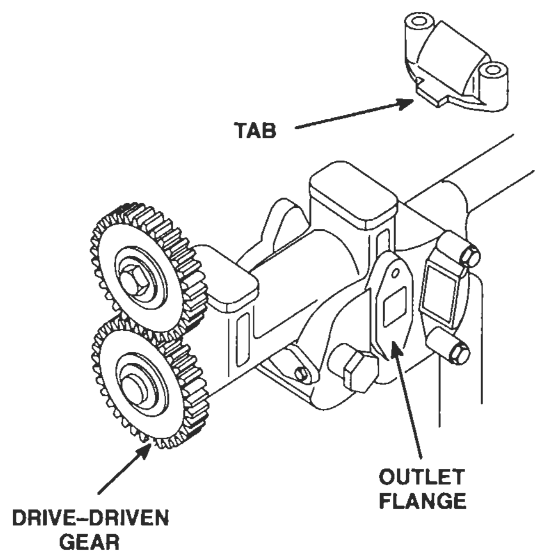


Figure 10. Oil Scavenging Outlet Flange Mounting

NOTE: On current engines a .20 inch longer connecting rod bolt is used which could interfere with the oil pump piping in the sump area. If there is interference, loosen the piping involved and tighten the bolts while holding the tubing away from the point of interference.

11. Place a new gasket on the oil pan and install the oil pan on the cylinder block. All the oil pan bolts should be started before any are tightened. Bolts should be tightened to 10–20 lb·ft (14–27 N·m) torque 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 crankcase to the proper level with the proper oil (Section 13.3).

LUBRICATING OIL PRESSURE REGULATOR

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator installed between the oil pump outlet pipe and the cylinder block.

The regulator assembly consists of a regulator body, a hollow piston–type valve, a spring and a plug to retain the valve and spring (Figure 1).

The valve is held on its seat by the spring, which is compressed by the plug threaded into the valve opening in the regulator body. The entire assembly is bolted to the lower flange of the cylinder block and sealed against oil leaks by a gasket between the two members. When the oil pressure at the valve exceeds 50 lb/in.^{2} (345 kPa), the valve is forced from its seat and oil from the engine oil gallery is by–passed to the oil pan.

Under normal conditions, the 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, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

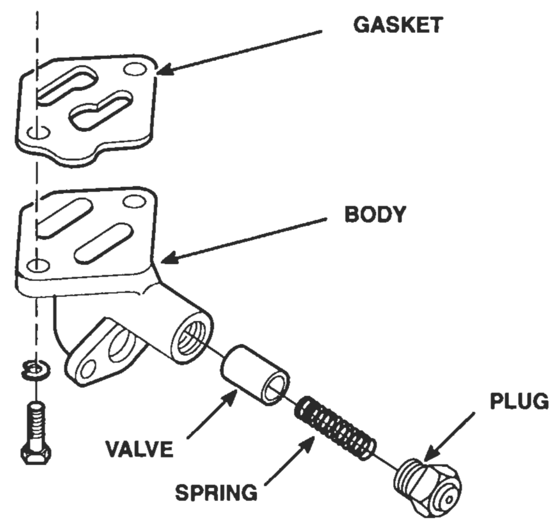


Figure 1. Lubricating Oil Pressure Regulator Details and Components

REMOVE OIL PRESSURE REGULATOR

1. Remove the two oil pump outlet pipe to regulator attaching bolts and lock washers.
2. Remove the two regulator body–to–cylinder block bolts and lock washers.
3. Tap the lower end of the regulator body lightly to loosen the body from the gasket and cylinder block. Remove the gasket.

DISASSEMBLE OIL PRESSURE REGULATOR

1. Clamp the flange of the regulator body in a bench vise with soft jaws and remove the plug from the body.
2. Remove the spring and valve from the regulator body.

SECTION 4.1.1 – LUBRICATING OIL PRESSURE REGULATOR

INSPECTION

Clean all of the regulator components in fuel oil and dry them with compressed air. Then inspect the parts for wear or damage.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

The regulator valve must move freely in the valve body. If the valve or regulator body is scored and cannot be cleaned up with crocus cloth, it must be replaced.

Replace a fractured or pitted spring.

ASSEMBLE OIL PRESSURE REGULATOR

Assemble the regulator as follows:

1. Apply clean engine oil to the outer surface of the valve and slide it into the regulator body, closed end first.
2. Insert the spring in the valve and, while compressing the spring, start the plug into the regulator body. Tighten the plug.

INSTALL OIL PRESSURE REGULATOR

1. Remove all traces of the old gasket from the regulator body, cylinder block and pump outlet pipe flange.
2. Affix a new gasket to the regulator body with the oil passage holes in the gasket in alignment with the oil passages in the body and secure the regulator to the cylinder block with two bolts.

NOTE: When attaching a new regulator be sure the new gasket is installed so that the tab on the gasket faces the oil pump and crankshaft drive gears (lower front cover side).

3. Place a new gasket between the regulator and the pump outlet pipe and connect these parts together with two bolts.

LUBRICATING OIL FILTERS

Inline 71 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 filter may be remotely mounted or mounted on the engine (Figure 1).

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 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, and then to the oil cooler.

A valve, which opens at approximately 18–21 lb/in.^{2} (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.

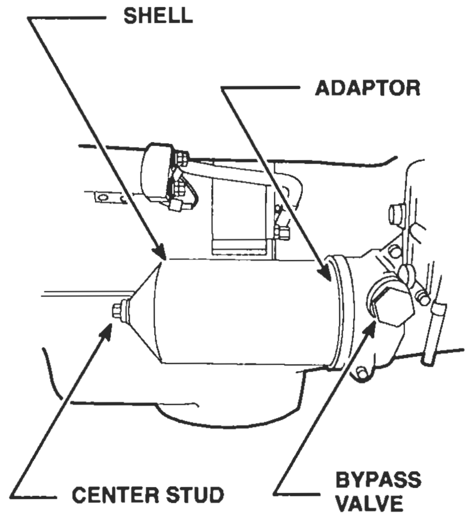


Figure 1. Full–Flow Oil Filter Mounting (Canister)

BYPASS OIL FILTER

When additional filtration is desired, a bypass type oil filter (Figure 2.) may also be installed on the engine. However, the size of the orifice on the discharge side of the filter must not exceed .062 inches 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.

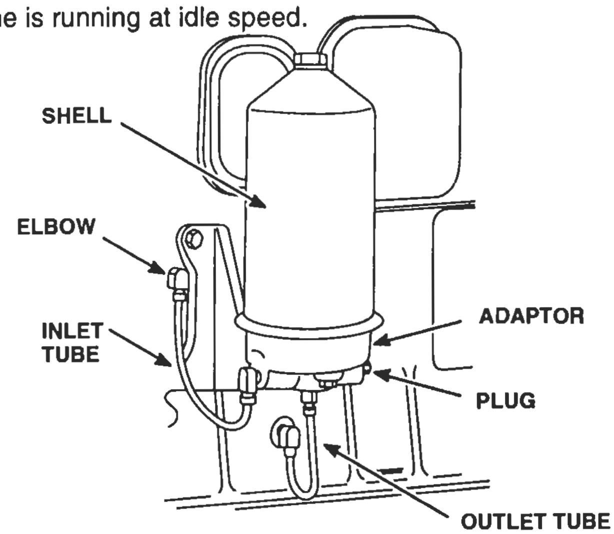


Figure 2. Bypass Oil Filter Mounting (Canister)

SECTION 4.2 – LUBRICATING OIL FILTERS

BYPASS OIL FILTER (CONT.)

On certain applications, the bypass filter assembly consists of two replaceable elements, each contained in a separate steel shell with both mounted on a single adaptor. The two filter elements operate in parallel since an oil passage in the filter adaptor connects with the annular space surrounding both elements.

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.

NOTE: 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 (CANISTER)

To replace the element in either the full–flow or bypass type oil filter assembly, refer to the appropriate illustration and proceed as follows:

1. Remove the drain plug (Figure 3.) from the filter shell or the filter adaptor or base and drain the oil.

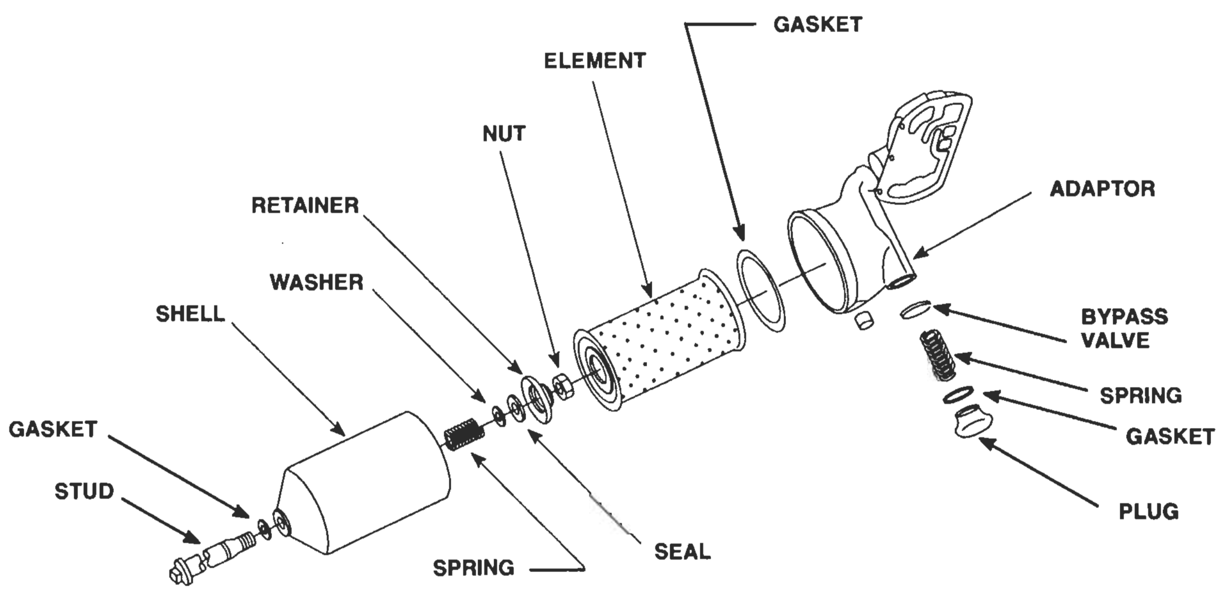


Figure 3. Full–Flow Type Oil Filter Components

REPLACE OIL FILTER ELEMENT (CANISTER) (CONT.)

2. Back out the center stud (Figure 4.) 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 or snap ring on the full–flow filter center stud.

NOTE: The center stud on the current full–flow oil filter has been improved by removing the snap ring groove and increasing the 5/8–18 thread length approximately 1/2 inch. To conform with this change, a 5/8–18 nut replaces the snap ring formerly used to retain the filter spring and seal.

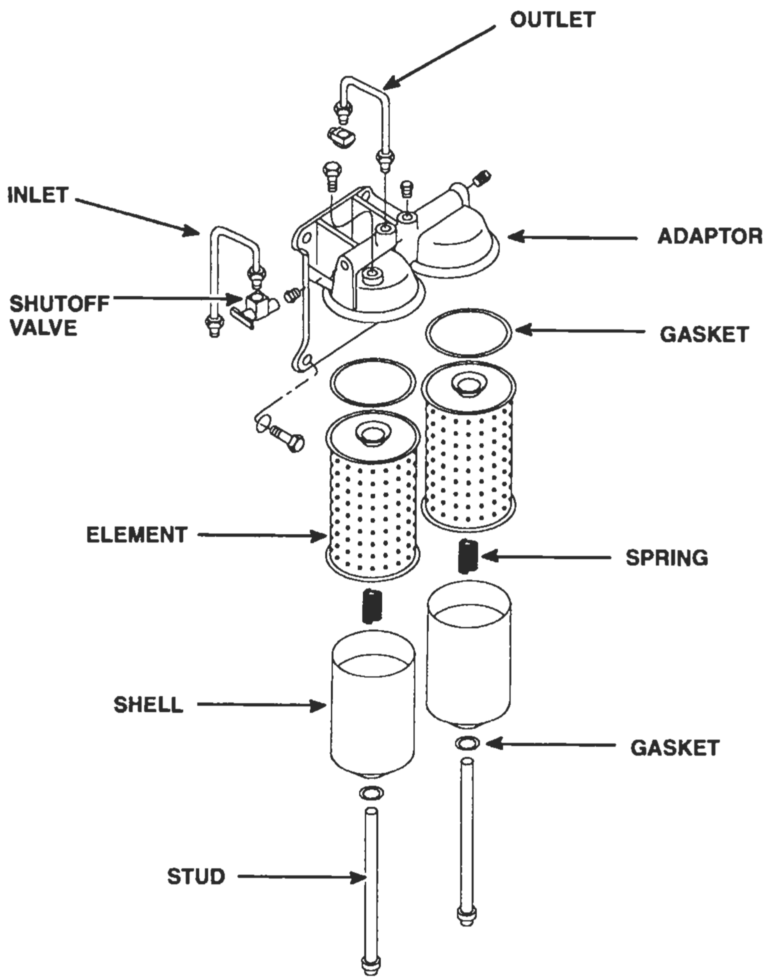


Figure 4. Bypass Type Oil Filter Components

REPLACE OIL FILTER ELEMENT (CANISTER) (CONT.)

5. Remove and discard the element retainer seal. Install a new seal.
6. Clean the filter shell and the adaptor or base. See Table 1 for lubricating oil filter specifications.
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.

NOTE: 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.
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 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.

LUBRICATING OIL FILTERS

Filter Type	DDC Part No.	AC Part No.	Micron Rating @ 98% Single Pass Efficiency
Full–Flow	25013192	PF–911L	12

TABLE 1

OIL COOLER

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.

The engine oil cooler is located in the bottom section of the expansion tank on six cylinder engines equipped with a heat exchanger or keel cooling system (Figure 1.) On three and four cylinder engines, the lubricating oil cooler is mounted on the side of the cylinder block near the water pump.

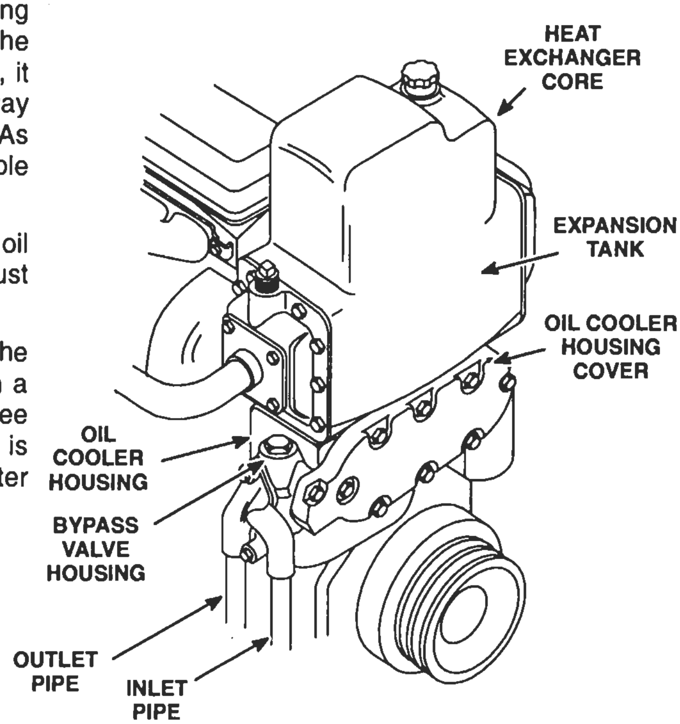


Figure 1. Lubricating Oil Cooler and Bypass Valve Details and Part Locations

On fan and radiator cooled engines, the lubricating oil cooler is usually located on the side of the engine just below the water pump (Figure 2.)

To assure engine lubrication if the oil cooler becomes clogged, a bypass valve located at the oil inlet to the cooler bypasses oil around the cooler directly to the oil gallery in the cylinder block.

The core through which the oil passes while being cooled is sealed to prevent coolant from getting into the oil. Whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight.

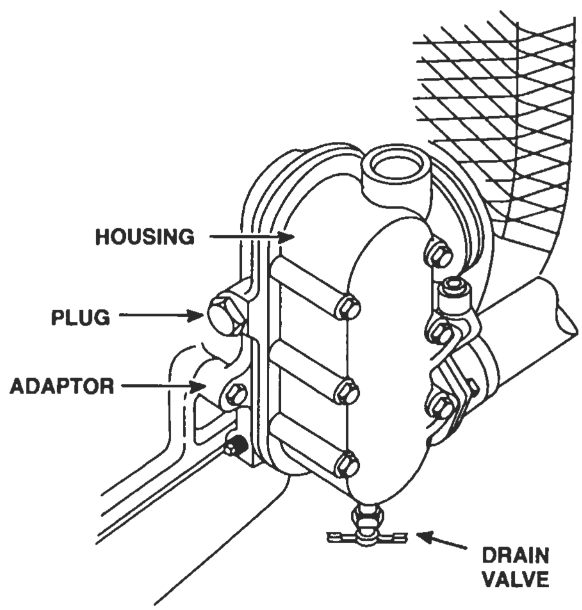


Figure 2. Lubricating Oil Cooler Mounting (Radiator Cooled Engines)

OIL COOLER (CONT.)

In order to standardize, a new aluminum oil cooler cover has replaced two cast iron covers.

The current oil cooler cover has two inlet holes (to filter) and two outlet holes (from filter). One of each of these holes must be plugged when the new cover is used (Figure 3.)

Different attaching bolts are required because of varying cover flange thicknesses. Only the current aluminum oil cooler will be serviced.

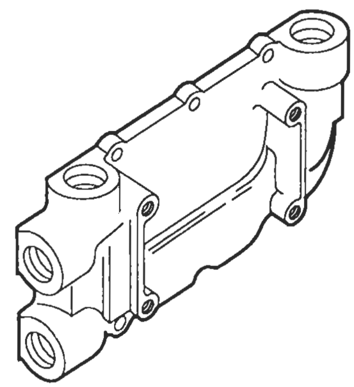


Figure 3. Oil Cooler Cover

REMOVE LUBRICATING OIL COOLER CORE (HEAT EXCHANGER COOLED ENGINE)

The oil cooler core may be removed from the housing for cleaning and inspection without removing the oil cooler housing from the engine as follows:

1. Drain the cooling system.
2. Remove two bolts which hold the bypass valve housing to the oil cooler housing cover.
3. Remove eight bolts and lock washers around the edge of the oil cooler housing cover.
4. Remove the cover and three gaskets – one between the cooler core and the housing, one between the core and the cover, and one between the cover and the bypass valve housing. When the cover is removed, the oil cooler core is free in the housing. Guard against the core falling from the housing when removing the cover.
5. Remove all traces of gasket material from the cylinder block and the oil cooler components.
6. If the openings are not marked "IN" and "OUT" on the oil cooler it is suggested that they be marked before reinstalling the oil cooler.

CLEAN OIL COOLER CORE

1. Clean Oil Side of Core – Circulate a solution of trichloroethylene through the core passages with a force pump to remove carbon and sludge.

CAUTION:

This operation should be done in the open or in a well ventilated room when trichloroethylene or other toxic chemicals are used for cleaning.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the core and flush thoroughly with clean hot water.

2. Clean Water Side of Core – After cleaning oil side of the core, immerse it in the following solution: add one–half pound of oxalic acid to each two and one–half gallons of solution composed of one–third muriatic acid and two–thirds water. The cleaning action is evidenced by bubbling and foaming. The process must be carefully watched and, when bubbling stops (this usually takes from 30 to 60 seconds), the core should be removed from the cleaning solution and thoroughly flushed with clean hot water. After cleaning, dip the core in light oil.

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, replacement of the oil cooler core is strongly recommended.

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 (Figure 4.)
2. Attach an air hose and apply 75–150 lb/in.^{2} (517–1 034 kPa) air pressure. Then, submerge the oil cooler core and plate assembly in a tank of heated water (180° F or 82° C). Any leaks will be indicated by air bubbles in the water.

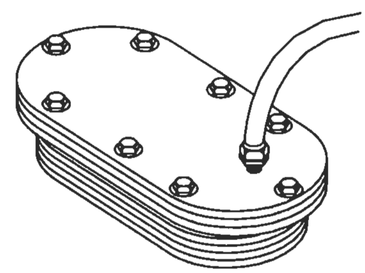


Figure 4. Oil Cooler Core Prepared for Pressure Test

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 (Section 5).

INSTALL LUBRICATING OIL COOLER CORE (HEAT EXCHANGER COOLED ENGINE)

The oil cooler core may be installed by reversing the sequence of operations given for removal as follows:

1. Affix new gaskets to the inner and outer faces of the core. Insert the core into the 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 cause foreign particles that may not have been removed to be loosened and circulated through the engine.

2. Affix a new cover–to–bypass valve housing gasket to the bypass valve housing.
3. Position the cover so that the two holes for the bolts in the cover align with the two holes in the bypass valve housing.
4. Install eight bolts and lock washers.
5. Install two bolts with lock washers through the cover and into the bypass valve housing.
6. Tighten the bolts.
7. Open the vent valve, fill the cooling system, and check for leaks. Close the vent valve.

REMOVE LUBRICATING OIL COOLER (RADIATOR COOLED ENGINE)

1. Drain the cooling system by opening the drain valve at the bottom of the oil cooler housing.
2. Remove the bolts and lock washers that attach the water inlet connector to the oil cooler housing.
3. Loosen the clamp on the water pump inlet seal.
4. Remove the bolts attaching the oil cooler housing to the adaptor, and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the oil cooler core.
5. Remove all traces of gasket material from the oil cooler components.
6. If the core openings are not marked "IN" and "OUT", mark the openings.
7. If the adaptor is to be removed, remove the bolts that hold the adaptor to the cylinder block and remove the adaptor and gaskets.
8. Clean the oil cooler core as outlined under Clean Oil Cooler Core.
9. Pressure check the oil cooler core as outlined under Pressure Check Oil Cooler Core.

INSTALL LUBRICATING OIL COOLER (RADIATOR COOLED ENGINE)

Install the lubricating oil cooler (Figure 5.) as follows:

1. If the oil cooler adaptor was removed from the cylinder block, remove the old gaskets from the bosses where the adaptor sets against the block. Affix the new adaptor to the cylinder block gaskets; then secure the adaptor to the cylinder block with bolts, lock washers and copper washer.

NOTE: The copper washer must be installed on the second bolt from the bottom of the oil cooler adaptor to prevent leakage of oil from the adaptor.

2. Affix the new gaskets to each side of the core and position the core inside the housing.

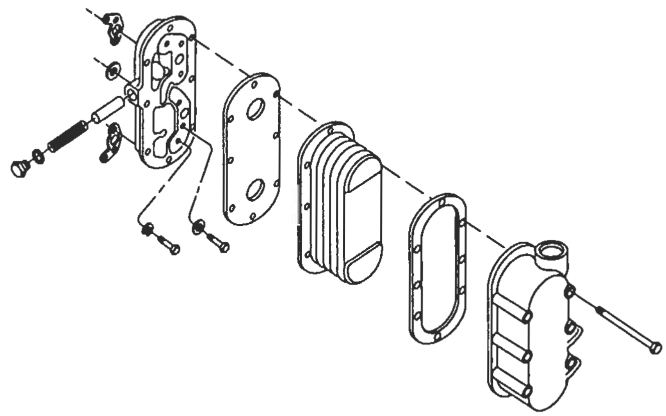


Figure 5. Lubricating Oil Cooler and Bypass Valve Components

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 cause foreign particles that may not have been removed to be loosened and circulated through the engine.

3. Set the housing with the cooler core against the adaptor and secure with bolts and lock washers, at the same time locating the seal and clamp. Tighten the clamp.
4. Affix a new gasket to the oil cooler water inlet connector and secure with bolts and lock washers.

LUBRICATING OIL COOLER BYPASS VALVE

To assure proper lubrication if the oil cooler core becomes clogged, a valve, located between the oil inlet and the core, bypasses the oil around the cooler directly to the oil gallery in the cylinder block.

On units where the oil cooler is mounted below the heat exchanger, the bypass valve is a self–contained unit consisting of a valve, spring, plug and gasket in a housing.

When the oil cooler is mounted at the side of the engine, the bypass valve, spring, plug and gasket are housed in the oil cooler adaptor.

The bypass valve should be removed, cleaned and reassembled whenever the cooler core is cleaned or replaced. However, if necessary, the bypass valve can be removed without removing the oil cooler.

REMOVE BYPASS VALVE

The bypass valve may be removed by removing the plug and lifting the gasket, valve and spring from the housing or adaptor.

REMOVE BYPASS VALVE HOUSING (OIL COOLER BELOW HEAT EXCHANGER)

1. Remove the bolts and lock washers which attach the oil inlet and outlet tube assembly to the bypass valve housing.
2. Hold the valve housing and remove the bolts and lock washers which secure the bypass valve housing to the oil cooler cover.

SECTION 4.4 – OIL COOLER

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 lb/in^2 (276 kPa) air pressure.

Inspect the valve parts for wear and replace the parts if necessary.

INSTALL BYPASS VALVE

1. Apply clean engine oil to the outside surface of the bypass valve and place the valve in the housing or adaptor, closed end first.
2. Slide the valve spring into the valve and screw the plug, with the gasket, into the housing or adaptor.

INSTALL BYPASS VALVE HOUSING (OIL COOLER BELOW HEAT EXCHANGER)

1. Coat new gaskets with grease and affix them to the bypass valve housing.
2. Place the bypass valve housing in position and install the bolts and lock washers through the oil cooler cover and into the valve housing.
3. Attach the oil inlet and outlet tube assembly to the valve housing with bolts and lock washers.

OIL LEVEL DIPSTICK

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 an adaptor attached, by means of a guide, to an opening in the cylinder block or the oil pan (Figure 1.)

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 20 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.

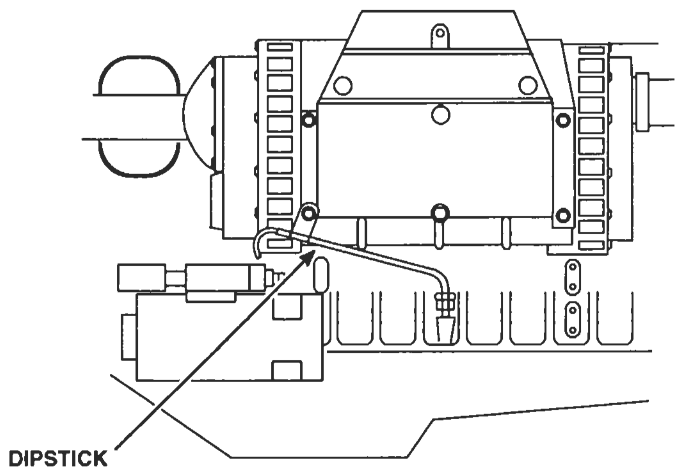


Figure 1. Typical Dipstick Mounting

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.

OIL PAN

A shallow type oil pan is used on engines where the longitudinal inclination ranges from 0°–10° (Figure 1.)

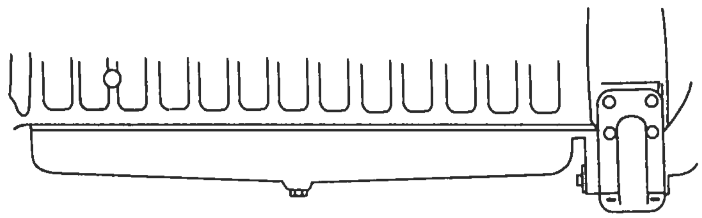


Figure 1. Typical Shallow Type Oil Pan

On installations where the inclination angle is greater than 10°, engines are equipped with a deep sump oil pan (Figure 2.)

A sectional oil pan gasket is used on six cylinder engines equipped with a cast iron oil pan. The gasket consists of two side sections and two end sections.

A one–piece gasket is used on six cylinder engines equipped with a stamped metal oil pan and on all three and four cylinder engines.

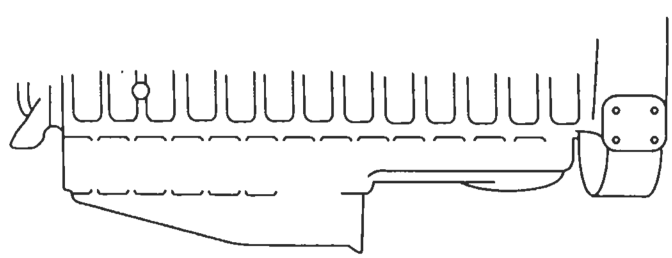


Figure 2. Typical Deep Sump Type Oil Pan

REMOVE AND INSTALL OIL PAN

1. Remove the drain plug and drain the oil.
2. Remove the bolt and washer assemblies. Then, remove the oil pan and gasket.
3. Clean all of the old gasket material from the cylinder block and the oil pan. Then clean the oil pan with fuel oil and dry it with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

4. Inspect a cast oil pan for porosity or cracks. Check a stamped oil pan for dents or breaks in the metal 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, use a new gasket 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. This could be detrimental to the 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.

NOTE: Oil pan bolts (stamped metal pans) are coated with a locking material. To reactivate the locking ability of the bolts, apply a drop or two of Loctite or equivalent to the threads of the bolts at assembly.

6. Install and tighten the drain plug to 25–35 lb·ft (34–47 N·m) (Section 4.0)
7. Fill the oil pan with new oil (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.
8. Stop the engine and, after approximately 20 minutes, check the oil level. Add oil, if necessary.

VENTILATING SYSTEM

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train and valve compartments by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the air box past the piston rings. This air sweeps up through the flywheel housing and is admitted to the valve compartment through cavities in the lifter brackets and vent castings (Figure 1.)

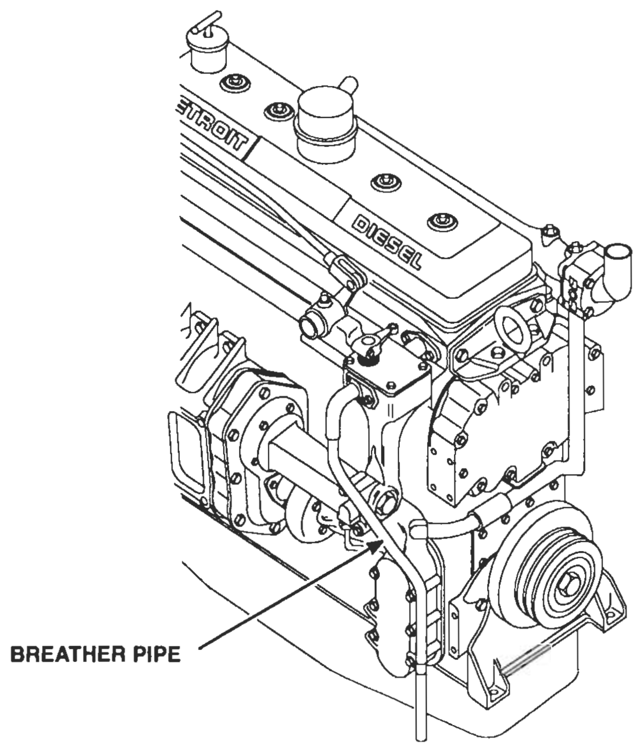


Figure 1. Breather Pipe Mounted on Governor

VENTILATING SYSTEM (CONT.)

Ventilating air in the valve compartment is drawn off the governor control housing through the breather pipe, through a breather attached to the valve rocker cover or through a breather attached to the side of the cylinder block (Figure 2.)

To index the breather assembly exhaust outlet on the aluminum die cast valve rocker covers, no disassembly is required. Insert a 1–1/8 inch diameter pipe or wood dowel into the breather outlet, apply pressure and rotate the outlet to the desired location.

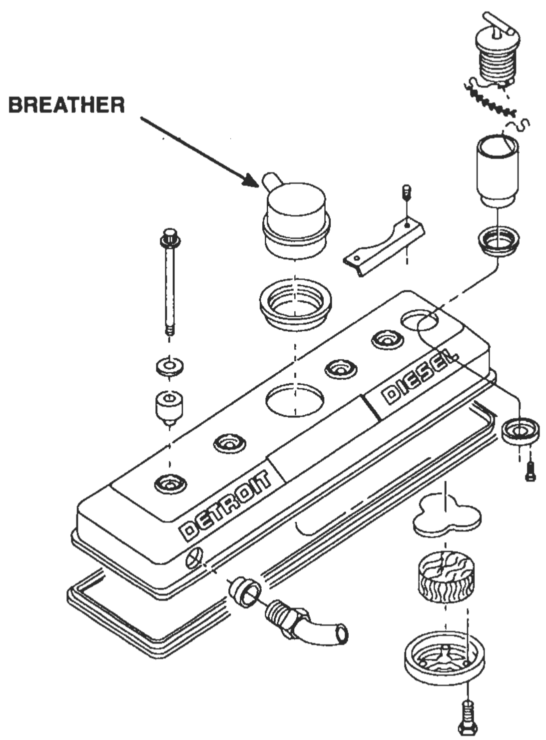


Figure 2. Breather Mounted on Valve Cover

SERVICE

Inspect and clean the breather tube or breather and baffle, if necessary, to eliminate the possibility of clogging. Remove the breather tube from the governor or the breather and baffle from the cylinder block. Wash with a suitable solvent and dry with compressed air.

CAUTION:

To prevent possible personal injury, wear adequate eye protection and do not exceed 40 lb/in^2 (276 kPa) air pressure.

The steel mesh pad should be removed and cleaned periodically (Section 15.1).

CLOSED CRANKCASE VAPOR COLLECTORS ON 6–71 MARINE ENGINES

A closed crankcase vapor collector system is available as an option on the Inline 6–71 TI maximum–rated marine engine. See Figure 3. for breather pipe routing for a typical Inline 6–71 closed crankcase collector system installation.

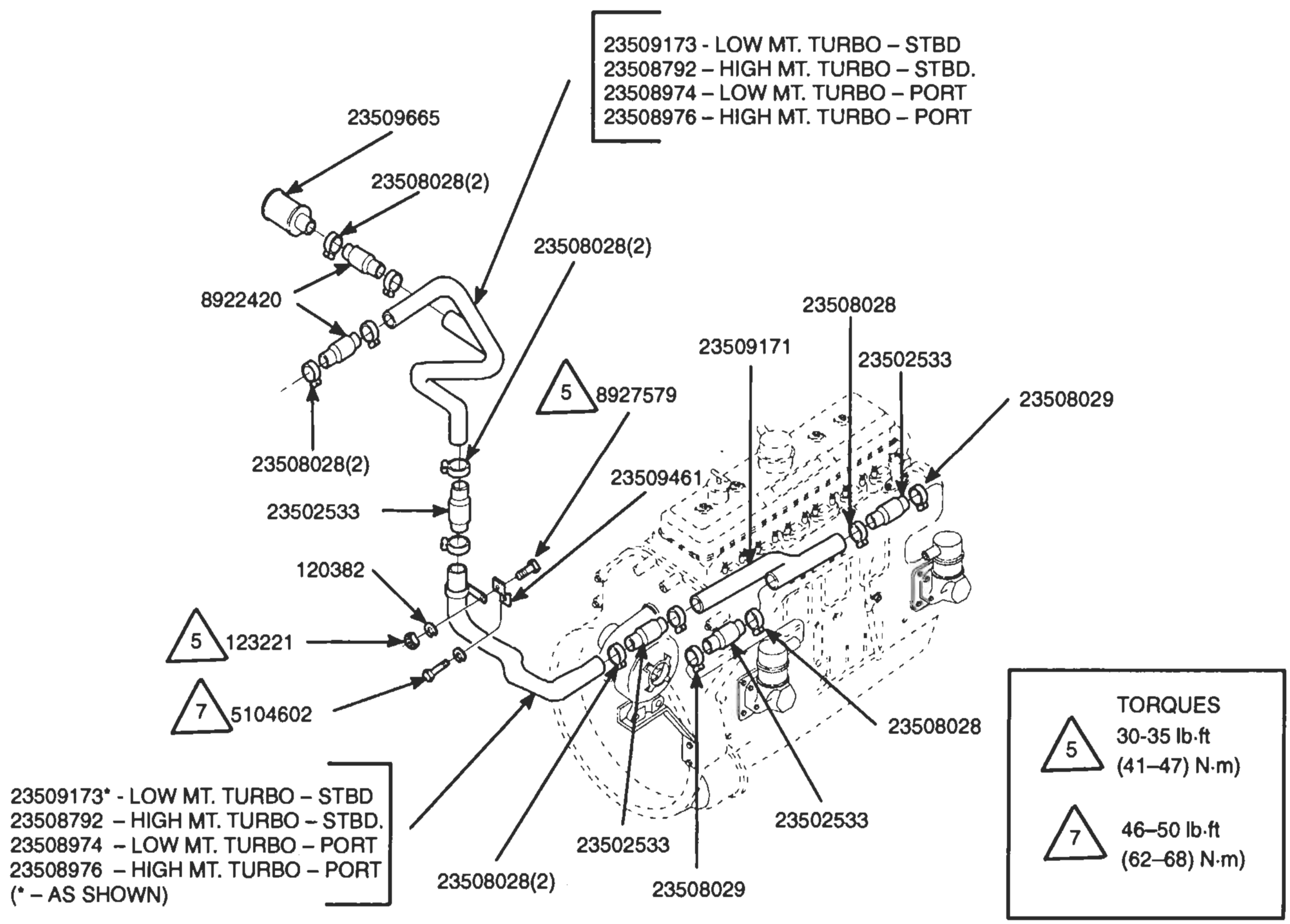


Figure 3. Breather Pipe Routing

CLOSED CRANKCASE VAPOR COLLECTORS ON 6–71 MARINE ENGINES (CONT.)

The closed breather system consists of a collector assembly mounted to the inlet side of the turbocharger, plus an oil drain tube, check valve, required breather piping, and mounting hardware. See Figure 4. for air separator drain routing.

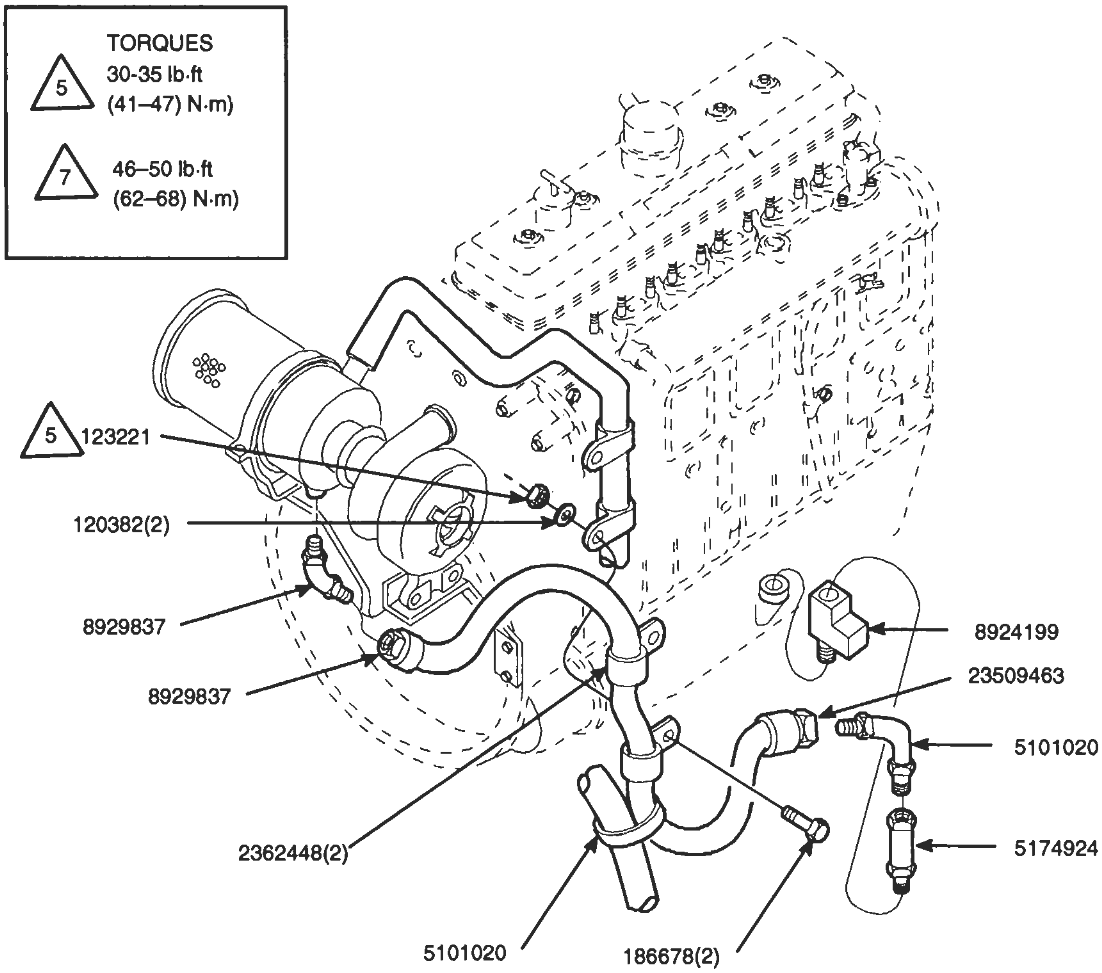


Figure 4. Air Separator Drain Routing

The system performs three functions:

9. It collects the crankcase vapors normally emitted to atmosphere by the breather system of the engine and separates the minute particles of oil from the vapors. Any oil collected in this manner drains back to the crankcase, while the remaining fumes are mixed with the turbocharger air flow. This system virtually eliminates crankcase fumes from the engine room.
10. It filters the outside air entering the turbocharger. The oil–coated cotton filter element removes dirt and salt particles from the incoming air.
11. It serves as an air silencer to reduce air induction noise.

CLOSED CRANKCASE VAPOR COLLECTORS ON 6–71 MARINE ENGINES (CONT.)

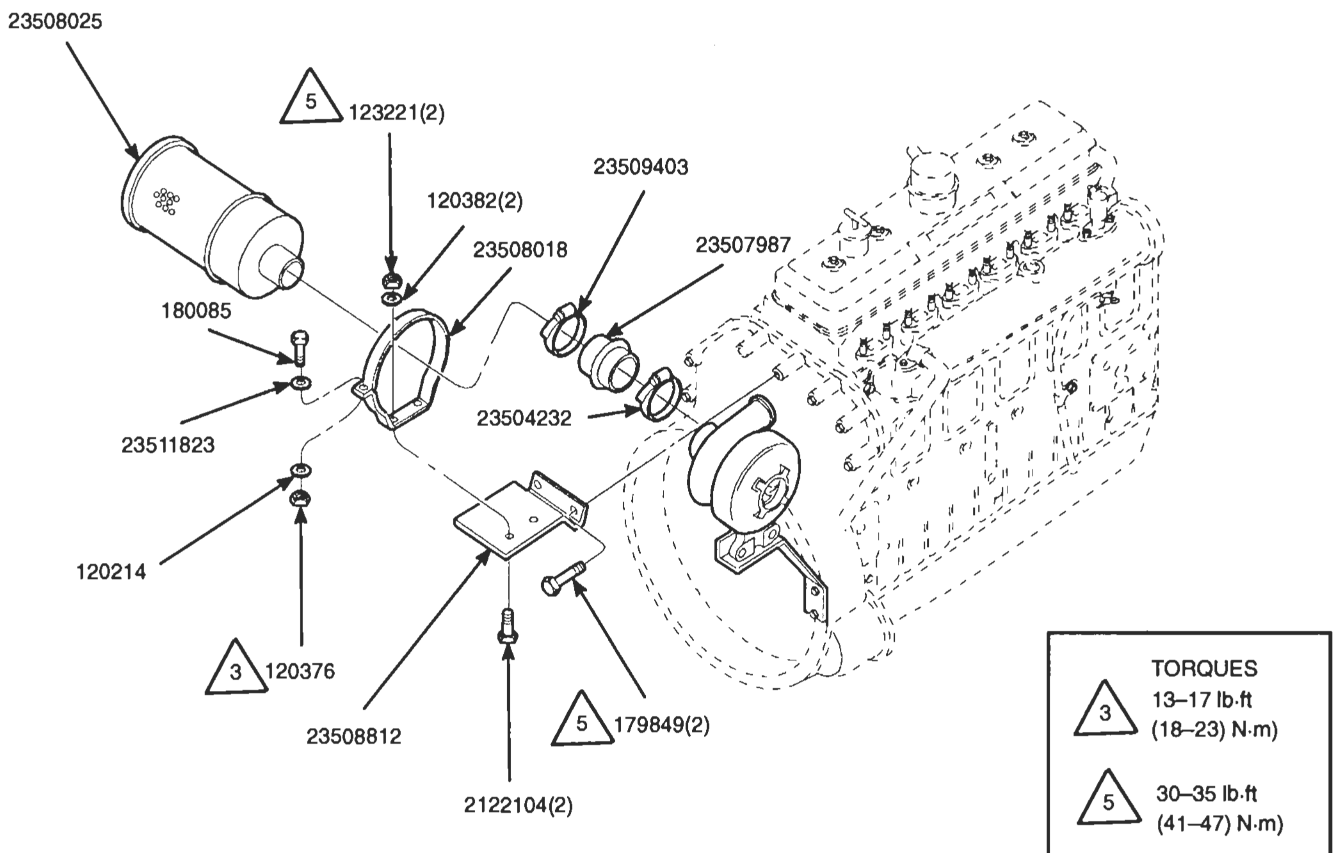


Figure 5. Air Separator Mounting High Mounted Turbo

See figures Figure 5. and Figure 6.for air separator mounting for low and high mount turbo for typical Inline 6–71 closed crankcase collector system installation.

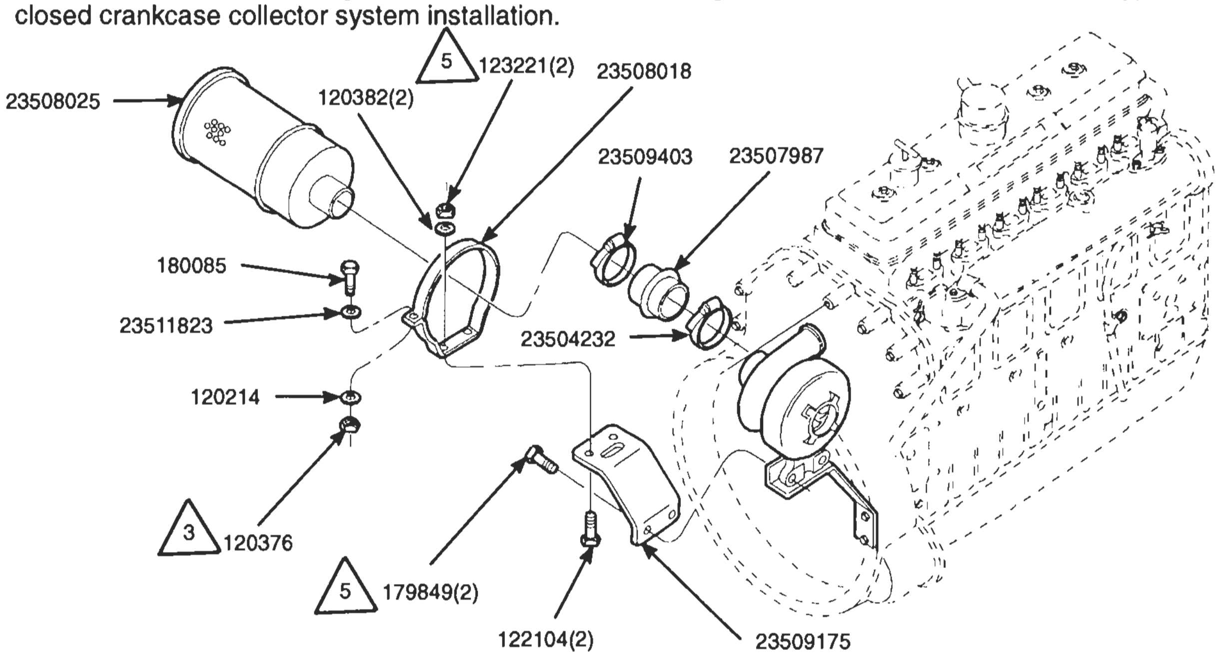


Figure 6. Air Separator Mounting Low Mounted Turbo

MAINTENANCE

To ensure efficient crankcase vapor collector system operation, service at these intervals:

Replace or clean the filter and the vacuum limiter when the air inlet restriction indicator turns **red**. This indicates the maximum allowable system restriction has been reached.

Replace the filter and the vacuum limiter every two years or 1500 hours of engine operation (whichever comes first), regardless of apparent condition.

Cleaning. If cleaned, filters **must** be cleaned and recoated with fluids specially designed for this purpose. Detroit Diesel recommends using Walker Engineering Service Kit DDF–9000. This product is available in the U.S.A. from:

Walker Engineering
7405 Havenhurst Place
Van Nuys, CA 91406
Phone: 818–782–2154
Fax: 818–909–7694

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

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. (lb·ft)
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	C.I. ENGINE TORQUE (lb·ft)	C.I. ENGINE TORQUE (N·m)	ALUM ENGINE TORQUE (lb·ft)	ALUM ENGINE TORQUE (N·m)
Oil pan bolts	5/16–18	10–20	14–27	10–20	14–27
Oil pump–to–bearing cap bolt	3/8–24			25–30	34–41
Oil pump drive idler gear nut	1/2–20	60–70	81–95	60–70	81–95
Oil pan drain plug (nylon) (washer)	18mm	25–35	34–47	15–25	20–34
Oil pump relief valve plug	7/8–18	25–35	34–47		
By–pass valve plug	1 1/4–16	95–105	129–143		

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb·ft)	TORQUE (N·m)
Oil filter center stud	50–60	68–81

SERVICE TOOLS

TOOL NAME	TOOL NO.
Oil pump drive gear installer	J–22285
Spring tester	J–9666
Strap wrench (spin–on filter)	J–29917
Universal puller (range 4l diam.)	J–24420–A
Universal puller (range 13l diam.)	J–8190

COOLING SYSTEM

CONTENTS

Cooling System 5
Water Pump 5.1

Water Manifold 5.2
Thermostat 5.2.1

Radiator 5.3
Coolant Pressure Control Cap 5.3.1

Engine Cooling Fan 5.4

Heat Exchanger 5.5

Raw Water Pump (Jabsco) 5.6

Coolant Filter and Conditioner 5.7

Shop Notes – Troubleshooting – Specifications – Service Tools 5.0

COOLING SYSTEM

To effectively dissipate the heat generated by the engine, one of three different types of cooling systems is used on a Series 71 engine: radiator and fan, heat exchanger and raw water pump or keel cooling.

A centrifugal type water pump attached to and driven by the blower, circulates the engine coolant in each system. A thermostat is utilized to maintain a normal engine operating temperature (Section 13.2).

RADIATOR AND COOLING FAN

The engine coolant is circulated through the radiator (Figure 1.) where the heat is absorbed in the air stream developed by either a blower or suction fan which is belt driven from the crankshaft. The water pump draws the coolant through the oil cooler and discharges it into the lower part of the cylinder block.

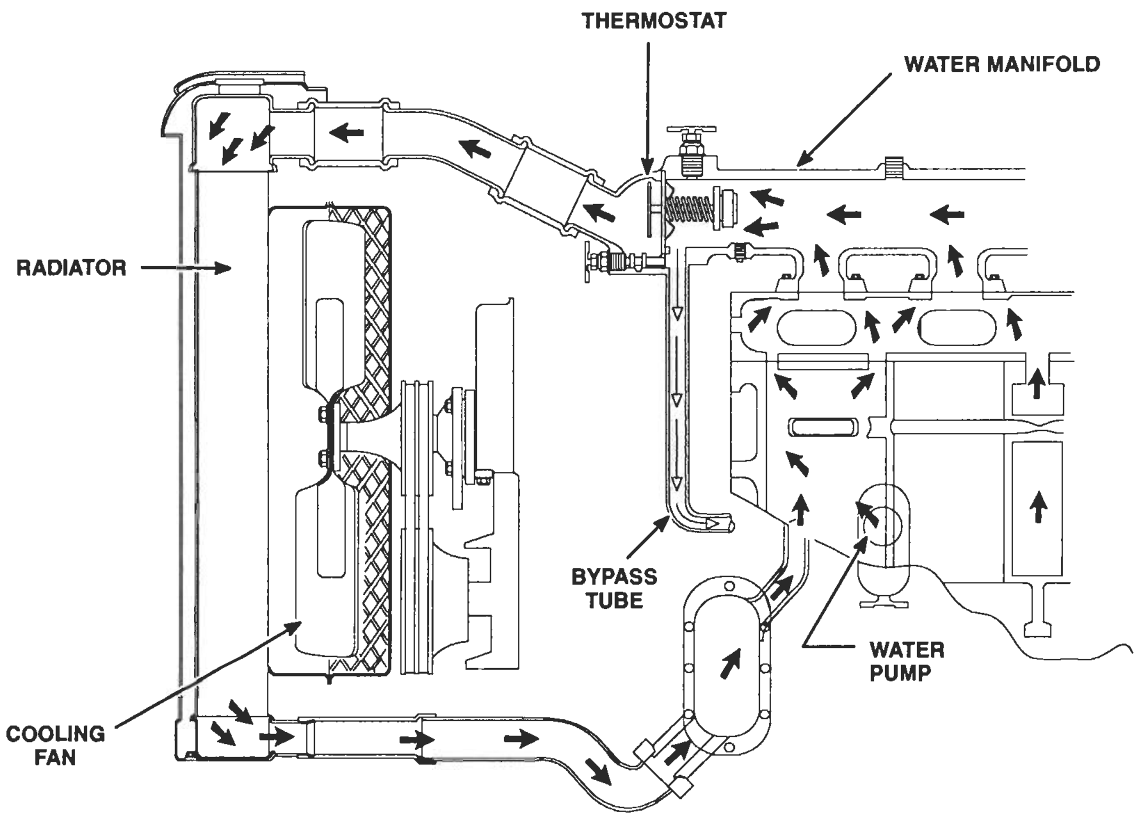


Figure 1. Typical Cooling System with Radiator and Fan

Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head through which the coolant rises to circulate around the valves and fuel injectors. Then, the coolant passes through a water manifold bolted to the cylinder head, past the thermostat and into the radiator.

Upon starting a cold engine or when the coolant is below operating temperature (thermostat closed) the coolant is bypassed from the water manifold directly to the pump, thus providing coolant circulation within the engine during the warm–up period.

HEAT EXCHANGER COOLING SYSTEM

In the heat exchanger cooling system, as applied to 3 and 4 cylinder units, the coolant is drawn by the circulating pump from the bottom of the expansion tank through the reverse gear oil cooler and engine oil cooler. On 6 cylinder single engine units, circulation is first through the engine oil cooler, then the reverse gear oil cooler, then through the engine. Openings in the water jacket around the cylinder bores connect with corresponding openings in the cylinder head through which the liquid rises to circulate around the valves and fuel injectors. Upon leaving the cylinder head, the coolant flows through the water manifold into the thermostat housing.

Upon leaving the thermostat housing, the coolant either flows down through the tubes of the heat exchanger element (core) and through the oil coolers from whence it returns to the water pump, or the coolant bypasses the heat exchanger and oil coolers and returns directly to the water pump, depending upon the coolant temperature.

KEEL COOLING SYSTEM

The keel cooling system is similar to the heat exchanger system, except heat transfer takes place in the keel cooler mounted on the hull, rather than in the heat exchanger mounted in the expansion tank.

In this system, the coolant is drawn by the circulating pump from the bottom of the expansion tank through the oil cooler, the cylinder block, cylinder head and into the water manifold. A portion of the coolant is bypassed from the aft end of the water manifold into the aft end of the jacket surrounding the exhaust manifold and then into the expansion tank.

When the thermostat is open, the major portion of the coolant in the water manifold passes through the thermostat housing and flows directly to the keel cooling coils. A cover plate installed in the expansion tank keeps the water from flowing into the tank. When the thermostat is closed, that portion of the coolant entering the thermostat housing is bypassed directly to the engine water pump inlet where it remixes with the coolant from the exhaust manifold jacket. The coolant is then circulated through the cylinder block and cylinder head. With the thermostat closed, a quick warm up is assured since the circulating coolant does not pass through the keel cooling coils.

ENGINE COOLING SYSTEM MAINTENANCE

A properly maintained and clean cooling system will reduce engine wear and increase the satisfactory engine operating time between engine overhauls. This is accomplished by the elimination of hot spots within the engine. Thus, when operating within the proper engine temperature range and when not exceeding the recommended horsepower output of the unit, all engine parts will be within their operating temperature ranges and at their proper operating clearances.

ENGINE COOLANT

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as exhaust valves, cylinder liners and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil–to–water oil cooler (Section 13.3).

COOLING SYSTEM CAPACITY

The capacity of the basic engine cooling system (cylinder block, head, thermostat housings and oil cooler housing) is shown in the following chart:

COOLING SYSTEM CAPACITY (Basic Engine)		
Engine	Gallons	Liters
3–71	2.5	9.5
4–71	3.5	13.2
6–71, T, TT, TI*	5.5	20.8

* Raw water intercooled

The complete amount of coolant in the cooling system, the additional capacity of the radiator, hoses and accessories such as a heater must be added to the capacity of the basic engine. The capacity of the radiator and related equipment should be obtained from the equipment supplier, or the capacity of a particular cooling system may be determined by filling the system with water, then draining and measuring the amount required.

DRAIN COOLING SYSTEM

Drain the coolant by opening the drain cocks in the water outlet elbow, oil cooler housing, the fresh water pump, the radiator and, on certain engines the water hole cover located on the blower side toward the rear of the cylinder block. Components of the cooling system that do not have a drain cock are drained through the oil cooler housing drain cock.

Remove the cooling system filler cap to permit the coolant to drain completely from the system.

To ensure that all of the coolant is drained completely from an engine, all cooling system drains should be opened. Should any coolant that may be trapped in the cylinder block or radiator freeze, it will expand and may cause damage. When freezing weather is expected, drain a unit not adequately protected by antifreeze. Leave all drain cocks open until refilling the cooling system.

FILL COOLING SYSTEM

Before starting the engine, close all of the drain cocks and fill the cooling system with water. The use of clean, soft water will eliminate the need for descaling solutions to clean the cooling system. A hard, mineral–laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals in the water and greatly reduce or eliminate the formation of scale.

Start the engine and, after normal operating temperature has been reached, allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within 2 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 of gases 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 from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate this leakage. Another method for observing trapped air in the cooling system is by inserting a transparent tube in the water outlet line.

FLUSH COOLING SYSTEM

If a coolant filter is used and properly maintained, the cooling system need not be flushed. Otherwise, the cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, preparing the cooling system for a new solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the unit.
2. Refill the cooling system with soft, clean water. If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.
3. Start the engine and operate it for 15 minutes to thoroughly circulate the water.
4. Drain the cooling system completely.
5. Refill the system with the solution required for the coming season.

COOLING SYSTEM CLEANERS

If the engine overheats and the fan belt tension and water level are satisfactory, it will be necessary to clean and flush the entire cooling system. Scale formation should be removed by using a quality descaling solvent. Immediately after using the solvent, neutralize the system with a neutralizer. It is important that the directions printed on the container of the descaling solvent be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and flush it with clean water. Then fill the system with the proper cooling solution.

NOTICE:

Whenever water is added to a hot engine, it must be done slowly to avoid rapid cooling which may cause distortion and possible cracking of engine castings.

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 with hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, thus loosening and forcing the scale deposits out.

Reverse flush the radiator as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.
2. Attach a hose at the top of the radiator to direct the water away from the engine.
3. Attach a hose to the bottom of the radiator and insert a 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.

NOTICE:

Apply air gradually. Do not exert more than 30 lb/in^2 (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.

Reverse flush the cylinder block and cylinder head water passages as follows:

7. Remove the thermostat and the water pump.
8. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.
9. Attach a hose to the water outlet at the top of the engine and insert the flushing gun in the hose.
10. Block the bottom opening and fill the coolant passages with water; then unblock the bottom opening and blow the water from the engine with full air pressure from the flushing gun.
11. Again fill the engine cooling system with water and blow clean with full air pressure. Repeat this procedure until the flushing water runs clean.

If the scale deposits in the radiator cannot be removed by chemical cleaners or reverse flushing, 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 thermostat and the radiator pressure cap should be checked and replaced if found 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. All external leaks should be corrected as soon as detected. The fan belt must be adjusted to the proper tension and the fan shroud must be tight against the radiator core to prevent circulation of air which may lower the cooling efficiency.

CONTAMINATED ENGINE

When the cooling system 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. In such a case oil will be forced into the cooling system while the engine is operating, and coolant will leak into the lubricating system when the engine is stopped.

Coolant contamination of the lubricating system is especially harmful to engines when the cooling system is filled with an ethylene glycol base 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 the internal coolant leak has been corrected before flushing the contaminated system(s).

Contaminants may be flushed from the engine systems as described in the following sections.

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following flushing procedure is recommended:

1. Prepare a mixture of Calgon, or its equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.
2. Remove the engine thermostat to permit the Calgon and water mixture to circulate through the engine and the radiator.
3. Fill the cooling system with the Calgon solution.
4. Run the engine for five minutes.
5. Drain the cooling system.
6. Repeat Steps 3 through 5.
7. Fill the cooling system with clean water.
8. Run the engine for five minutes.
9. Drain the cooling system completely.
10. Install the engine thermostat.
11. Close all of the drains and refill the engine with fresh coolant (Section 13.3).

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution or other soluble material, the following cleaning procedure, using DPM (Diproplyyene Glycol Methyl Ether) or its equivalent, is recommended.

CAUTION:

Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

If the engine is still in running condition, proceed as follows:

1. Drain all of the lubricating oil.
2. Remove and discard the oil filter element. Clean and dry the filter shell and install a new element.
3. Mix two parts of DPM, or its equivalent, with one part SAE 10W 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 r/min) for 30 minutes to one hour. Check the oil pressure frequently.
5. After the specified time, stop the engine and immediately drain the crankcase and the filter. Sufficient time must be allowed to drain all of the fluid.
6. Refill the crankcase with SAE 10W engine oil after the drain plug is replaced, and run the engine at the same fast idle speed for ten to fifteen minutes. Then, stop the engine and drain the oil thoroughly.

LUBRICATION SYSTEM (CONT.)

7. Remove and discard the filter element, clean the filter shell and install a new element.
8. Install the drain plug 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 r/min) for approximately 30 minutes. Then, stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.
10. If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.
11. 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.

WINTERFRONTS NOT RECOMMENDED

NOTICE

The use of winterfronts (cardboard, canvas, etc.) is not recommended with any Detroit Diesel Corporation engine installation. Their use can result in excessive engine coolant, oil and charge air temperatures. This can lead to turbocharger surge, poor fuel economy, loss of power, and reduced engine life. Winterfronts may also put abnormal stress on fan and fan drive components, creating the potential for premature malfunction and /or damage.

Blocking off the radiator is done to increase the cab heat level and improve driver/passenger comfort during severe cold weather operation. This practice is normally not necessary with a properly designed and operating cooling/heater system. Preventing air leakage and reducing exposed metal surfaces in the driver/passenger compartment, plus the use of properly installed shutters, can greatly improve the comfort level.

If winterfronts are used (NOT RECOMMENDED), they should never totally close off the grill frontal area. At least a 25% area of symmetrical shape in the center of the grill should remain open at all times. At no time should the air blockage device be applied directly to the radiator core. **The exception to this is an approved shutter system.**

WINTERFRONTS NOT RECOMMENDED (CONT.)

Qualifications tests should be run by the user to determine the minimum frontal opening area required. These are some of the factors that must be considered:

- Fluctuations in ambient air temperature and load
- Ice and snow intrusions
- Wind conditions
- Vehicle speed
- Cooling system degradation
- Fuel economy loss with air–to–air charge cooling

Under no conditions should engine specification limits be exceeded. Therefore, all warning and monitoring devices should be properly located and in good working condition.

All vehicle operators must be given notice to adjust and/or remove winter fronts as conditions warrant to ensure proper engine operation. This is especially important on air–to–air charge cooling systems. Elevated charge air cooling temperatures cause turbocharger surging and loss in fuel economy.

Operators must be advised to minimize winterfront usage. If used, the grill opening should be restricted only enough to maintain cab heat. **Do not restrict the opening so much that the elevated temperature turns on the fan.**

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 combinations 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. Close the pump drain cock and fill the engine cooling system. When filling the cooling system of certain models, it is necessary to open the vent valve at the top of the thermostat housing.

WATER PUMP

The centrifugal–type water pump (Figure 1.) circulates engine coolant through the cylinder block, cylinder head, heat exchanger or radiator, oil cooler and aftercooler (if used). The drive end of the pump shaft is supported by a sealed double–row combination radial and thrust ball bearing. The pump shaft serves as the inner race of the bearing.

The pump is mounted at the front end of the blower and is driven by the lower blower rotor shaft. The drive coupling, pressed on the end of the pump shaft, has an integral oil thrower that shrouds the flange end of the pump body and deflects the oil away from the bearing.

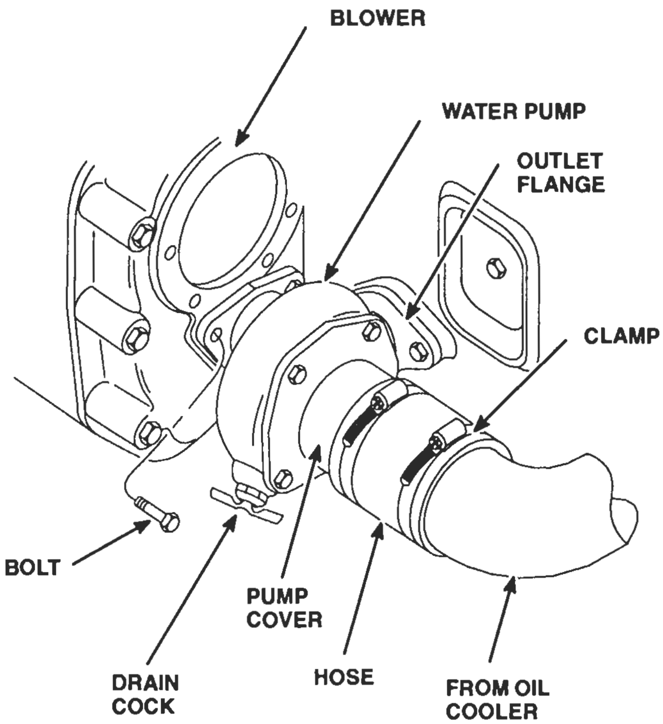


Figure 1. Water Pump Mounting

LUBRICATION

The sealed ball bearing in the bearing and shaft assembly is filled with lubricant at the time of manufacture, and no further lubrication is required.

REMOVE WATER PUMP

Remove the water pump as follows:

1. Open the drain cock in the pump body and drain the cooling system.
2. Loosen the hose clamps and slide the water pump inlet hose back against the pump cover.
3. Remove the two bolts and lock washers that attach the pump outlet flange to the cylinder block. Remove the flange and packing ring.
4. Remove the three bolt and seal assemblies that attach the pump to the blower assembly.
5. Withdraw the pump and remove the gasket.

DISASSEMBLE WATER PUMP

1. Remove the pump cover and gasket.

NOTE: Clean the corrosion from around the impeller and shaft before separating the shaft and bearing assembly from the impeller, seal and pump body.

2. Support the pump on its mounting flange in an arbor press (Figure 2.) Place a short steel rod on the end of the shaft and press the shaft and bearing assembly from the impeller, seal and pump body.

NOTICE:
Shaft bearing damage may occur on Inline 71 water pumps if an excessive thrust load is applied to the bearing assembly during pump disassembly for seal replacement. For this reason DDC recommends replacing the shaft and bearing assembly of the Inline 71 water pumps whenever the seal is replaced and/or at time of water pump overhaul.

3. Remove the impeller and seal assembly from the pump body.

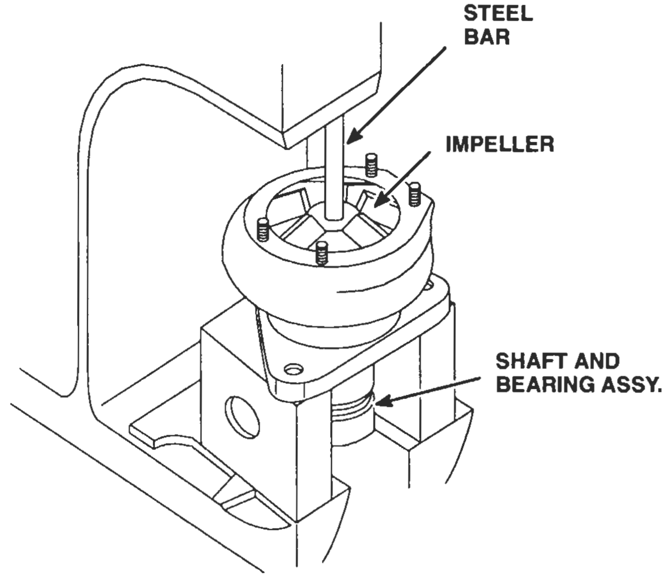


Figure 2. Pressing Pump Shaft from Impeller

4. Remove the pump drive coupling from the shaft with tool J 1930 (Figure 3.)

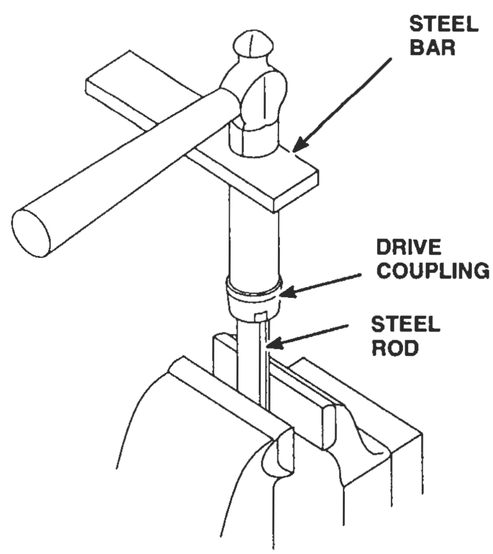


Figure 3. Removing Pump Drive Coupling from Shaft

INSPECTION

Clean all of the parts except the shaft and bearing assembly. The sealed type pump shaft bearing must not be immersed in a cleaning fluid since dirt may be washed in and the fluid cannot be entirely removed.

Replace the shaft and bearing assembly and the seal assembly.

ASSEMBLE WATER PUMP

Assemble fresh water pump components in this sequence:

1. Support the pump body on the bed of an arbor press, impeller end down. Insert the long (impeller) end of the shaft and bearing assembly into the body.
2. Press against the outer race of the bearing until the bearing is flush with the end of the pump body.

NOTICE:

The shaft and bearing assembly will be damaged if it is installed by applying pressure to the shaft or inner race.

NOTE: If the pump body requires modification to accommodate the current shaft bearing assembly with an integral secondary seal, machine the pump. Refer to drawing 18SP218 (included in the kit) for instructions.

3. To eliminate possible coolant leakage, apply a light coat of Loctite 290 sealant to the outside diameter of the new seal.
4. Invert the pump so that the impeller end faces up. With the pump body and bearing shaft properly supported, place the unitized seal over the shaft. Using Kent–Moore tool J 38858, press the seal into place.

NOTE: Tool J 38858 must be used to set the seal to its proper installed height.

5. Make sure the mating surfaces of the water seal and impeller are free of dirt, metal particles, and oil film.
6. Support the bearing end of the shaft on the bed of the arbor press. Using tool J 22437, press the impeller onto the shaft.

NOTICE:

The bearing shaft end must be supported during this operation. Do not press against the outer race of the bearing. This will damage the bearing.

The distance between the end of the shaft and the face of the impeller hub is .031 – .033 inches.

ASSEMBLE WATER PUMP (CONT.)

7. Invert the pump. With the impeller end of the shaft properly supported on the arbor press, press the drive coupling onto the shaft until it is flush with the end of the shaft. When installed, the drive coupling must hold 30 lb·ft (41 N·m) minimum torque (Figure 4.)
8. If a neoprene cover is installed on the pump body, make sure the tip of the cover is located below the weep hole in the pump body to allow coolant to drain.
9. Rotate the shaft by hand to make sure the rear faces of the impeller blades do not rub the pump body.
10. If previously removed, install the drain cock in the pump body.

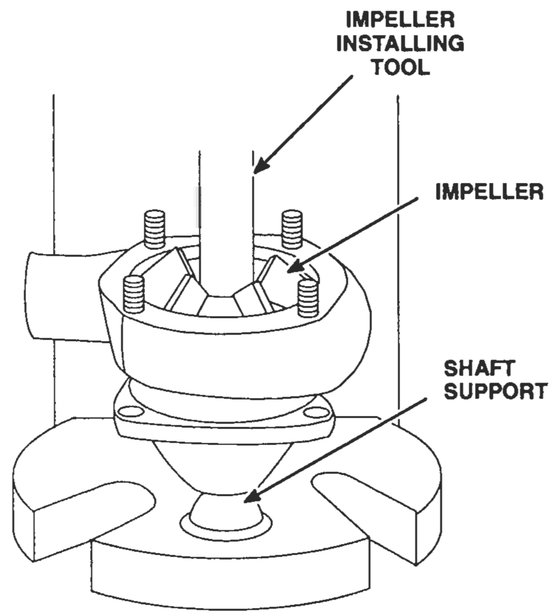


Figure 4. Installing Water Pump Impeller

INSTALL WATER PUMP

1. Make sure the intermediate shaft coupling is secure. If it was previously removed, insert the splined end of the coupling into the mating splines in the blower rotor shaft. Then draw the coupling in place with the 5/16–24 x 1–1/2 inch bolt. Tighten the bolt to 15–19 lb·ft (20–26 N·m) torque.
2. Place the pump outlet flange over the pump outlet with the flat side of the flange facing the pump body. Slip the packing ring over the pump outlet and next to the flange.
3. Use a new gasket at the bolting flange and place the pump against the blower end plate cover so that the lugs on the drive coupling mesh with the lugs on the intermediate shaft coupling. Secure the pump to the blower with the three bolts and seal washers.
4. Slide the pump outlet packing ring and packing flange against the cylinder block and secure the flange with two bolts and lock washers.
5. Slide the water pump inlet hose in place and secure it with the hose clamps.
6. Close the pump drain cock and fill the engine cooling system. When filling the cooling system of certain models, it is necessary to open the vent valve at the top of the thermostat housing.

 May, 1994

HIGH CAPACITY WATER PUMP

All Inline 6–71 automotive and certain industrial marine engines are equipped with a water pump of greater capacity to provide increased circulation of the coolant (Figure 5.) Six cylinder turbocharged engines require the high capacity pump to compensate for reduced pump speed; the ratio of blower speed (pump speed) to engine speed is 1.95:1 (former engines 1.55:1) for the turbocharged engines and 2.00:1 (former engines 1.69:1) for the non turbocharged engines. However, the standard pump provides sufficient circulation of the coolant for four cylinder turbocharged engines.

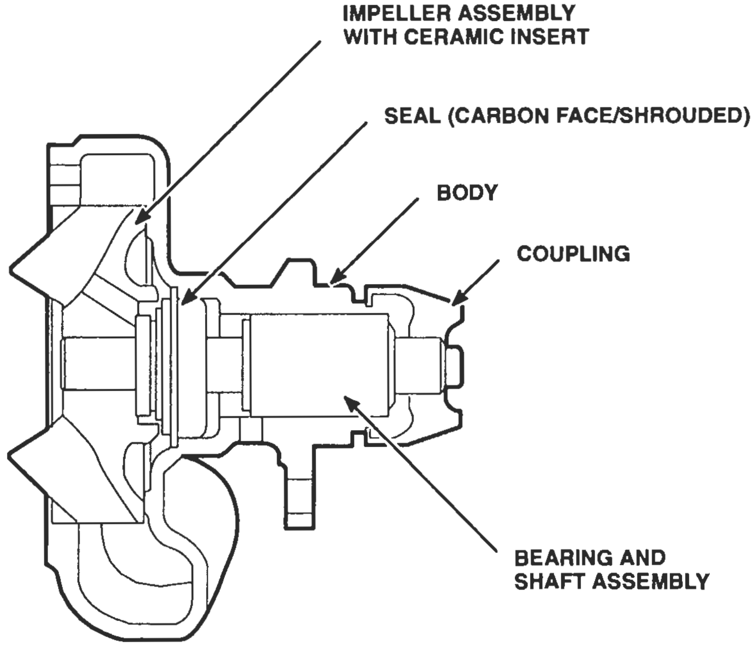


Figure 5. High Capacity Water Pump

SERVICE

The high capacity pump is serviced in the same manner as the standard pump.

Two 1/4 inch holes were added to the water pump impeller (Figure 6.) to vent the seal chamber and eliminate the possibility of foreign material build–up between the impeller and the seal, which could result in leakage. Where pump seal difficulties are encountered on pumps with former impellers, it is recommended that vent holes be added.

Remove any rough edges and burrs from the impeller after drilling the holes.

The old seal assembly is no longer available for service. If the impeller requires replacement, the current seal assembly and impeller must be used together. The shaft with the milled flat must also be replaced if a current impeller and seal are installed.

NOTE: The shaft and bearing assembly, unitized seal assembly, drive coupling and ceramic insert are the same for both the standard and high capacity water pumps.

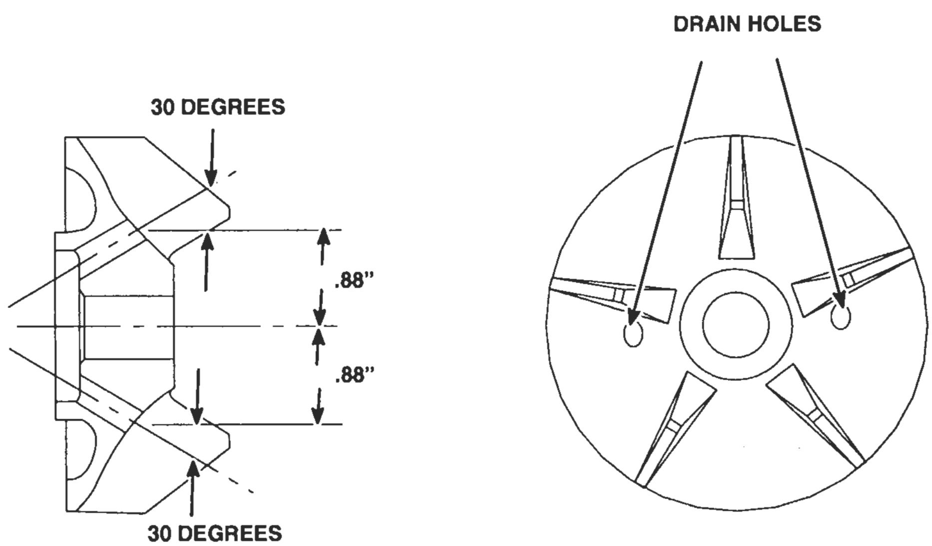


Figure 6. Reworking Diagram of Pump Impeller

SERVICE (CONT.)

The high capacity water pump used in the low profile six cylinder marine engine has two 1/4 inch tapped holes in the pump body. When the engine is to be installed so many degrees from horizontal, the lower tapped hole in the pump body must be plugged and the upper tapped hole must be open for installation of an air bleed line that connects to the water–cooled exhaust manifold. Former and current impellers are shown below (Figure 7.)

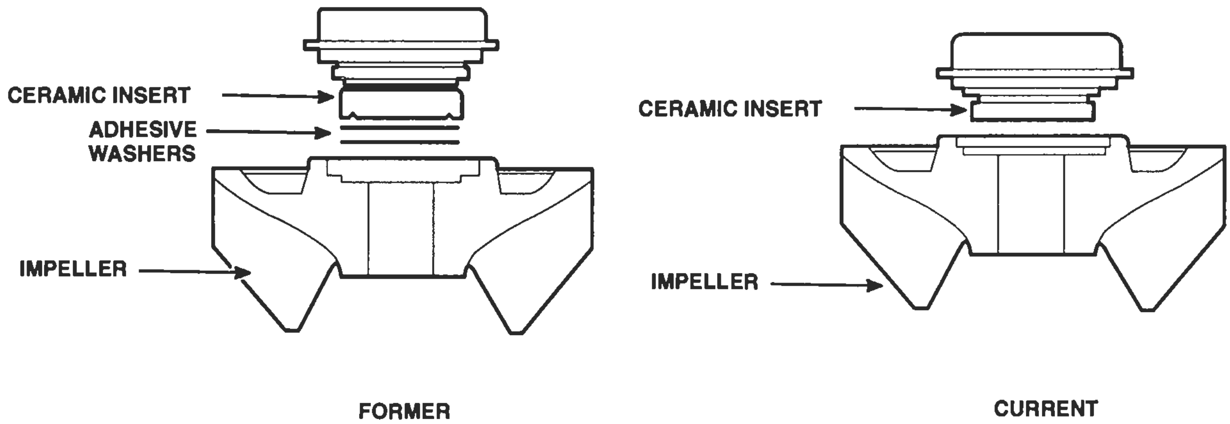


Figure 7. Former and Current Impellers

WATER MANIFOLD

Coolant leaving the cylinder head through an opening over each exhaust port, enters the water manifold which is attached to the cylinder head with two nuts and lock washers at each of the water openings (Figure 1.) A separate gasket is used at each attaching flange between the manifold and the cylinder head.

A gradually increasing area in the cast manifold from the rear end terminates in either a uniform circular section at the front where a hose and clamp connect the manifold to the thermostat housing, or a mounting flange to which the thermostat housing is attached by means of bolts and lock washers. On engines employing a water cooled exhaust manifold, a flexible tube at the aft end of the water manifold bypasses coolant to the exhaust manifold. The coolant leaves the exhaust manifold through an external tube and flows to the engine oil cooler.

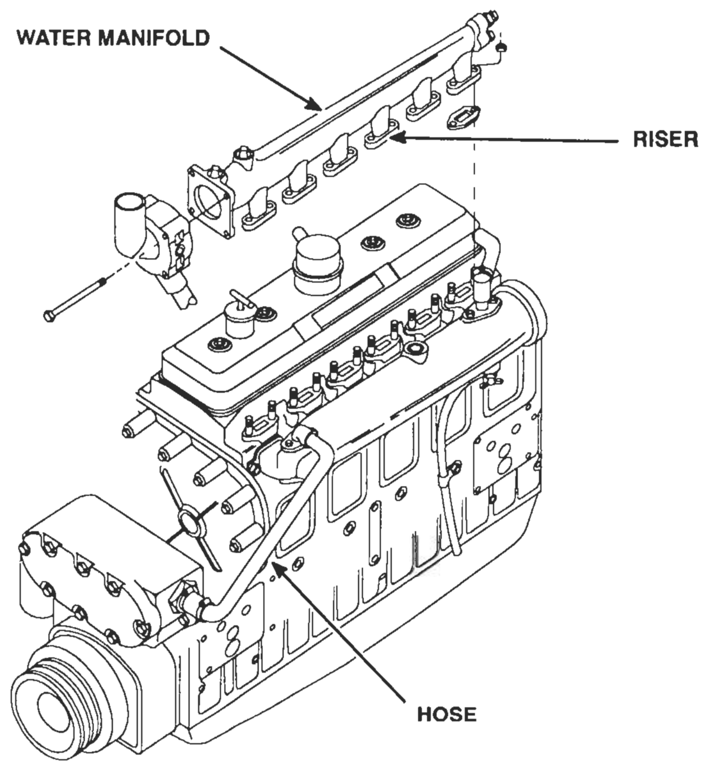


Figure 1. Typical Water Manifold Mounting (Industrial Engine)

SECTION 5.2 – WATER MANIFOLD

REMOVE WATER MANIFOLD

The water manifold may be removed as follows:

1. Drain the cooling system to the level necessary by opening the valve in the bottom of the water pump and the valve in the thermostat housing.
2. On heat exchanger engines, loosen the hose clamp. Slip the water manifold–to–thermostat housing hose over the neck of the thermostat housing.

On radiator engines, loosen the bolts which secure the outlet elbow and the thermostat housing to the water manifold.

3. Remove the cooling water temperature gage adaptor from the rear end of the water manifold.
4. Remove the water manifold stud nuts and lock washers and lift the manifold straight up off the studs. Remove the manifold to cylinder head gaskets.

INSTALL WATER MANIFOLD

Remove all old gaskets and install the manifold using new gaskets.

1. With new gaskets in place, lower the water manifold down over the studs and secure it to the cylinder head with two nuts and lock washer at each riser.
2. Install the temperature gage adaptor in the end of the manifold.
3. On heat exchanger engines, slide the hose onto the outlet end of the water manifold and secure the hose connection between the manifold and the thermostat housing with the hose clamp.

On radiator engines, attach the thermostat housing and outlet elbow to the water manifold with bolts and lock washers.

4. Fill the cooling system to the proper level.

NOTE: When filling cooling system on certain models, it is necessary to open the vent valve at the top of the thermostat housing.

THERMOSTAT

The temperature of the engine coolant is automatically controlled by a thermostat located in a housing connected to the outlet end of the water manifold. A blocking–type thermostat is used when a standard cooling system is employed; a semi–blocking type thermostat is used with a rapid warm–up cooling system.

CONSTRUCTION AND OPERATION

A thermostat is a type of automatic valve which controls the flow of coolant through a radiator or other heat exchanger. The thermostat senses changes in engine coolant temperature and regulates coolant flow to maintain efficient engine operating temperature (Figure 1.)

Thermostats used in Detroit Diesel engines consist of a brass cup filled with a heat–expansive wax–like material. The wax compound is retained within the cup by an elastomeric seal. The valve of the thermostat is attached to a piston which is held on the elastomer by a spring.

The basic principle (expansive wax) remains the same for all thermostats. The valve is in the closed position when the thermostat is cold (wax solid). When the wax–filled brass cup is heated by engine coolant, the wax–like material expands. As the coolant temperature in the engine reaches the calibrated "start to open" thermostat setting, the force of the expanding wax on the piston exceeds the closing force of the spring and the valve begins to open. As the coolant temperature continues to increase, the wax–like material continues to expand and the valve opens further until it reaches its maximum design travel.

As the temperature of the engine coolant drops, cooling of the wax causes it to contract. This reduces the pressure on the piston and allows the spring to draw the valve back toward its seat (closed thermostat).

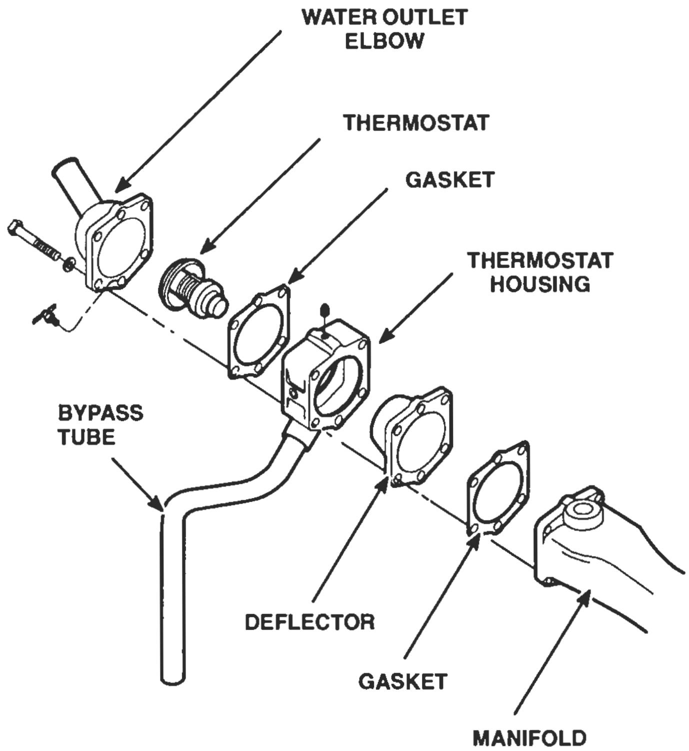


Figure 1. Typical Thermostat Housing Mounting

SECTION 5.2.1 – THERMOSTAT

REQUIREMENTS

In order to perform effectively, a thermostat must meet the following requirements:

1. Start to open at a specified temperature.
2. Be fully open at a specified number of degrees above the “start to open” temperature.
3. Permit the passage of a specified amount of coolant under a specified pressure when fully open.
4. Depending on cooling system requirements, allow little or no coolant to flow to the radiator core when in the closed position.

TYPES

Three basic types of thermostats are used in Detroit Diesel engines: full–blocking, non–blocking and partial blocking (Figure 2.)

The full–blocking type thermostat simultaneously controls the flow of coolant to the radiator and the bypass circuit. During the engine warm–up, all engine coolant flows through the bypass circuit. As the thermostat opens, increasing amounts of coolant flow to the radiator, and the bypass flow is correspondingly reduced. At approximately 17°–20°F (9.4°–11.1°C) above the opening temperature of the thermostat, the bypass opening is fully blocked and the total flow of coolant is directed into the radiator.

The non–blocking type thermostat controls the flow of coolant only to the radiator, while the continuously open bypass sends coolant directly back to the fresh water pump and engine block. Coolant flow to the radiator discharges through the thermostat valve when coolant temperature is above the opening temperature of the thermostat (see illustration). This type is full/open at 17°–20°F (9.4°–11.1°C) above the opening temperature of the thermostat.

The partial blocking type thermostat is a variation of the two previous thermostats. When the thermostat opens to permit coolant flow to the radiator, it partially blocks the bypass.

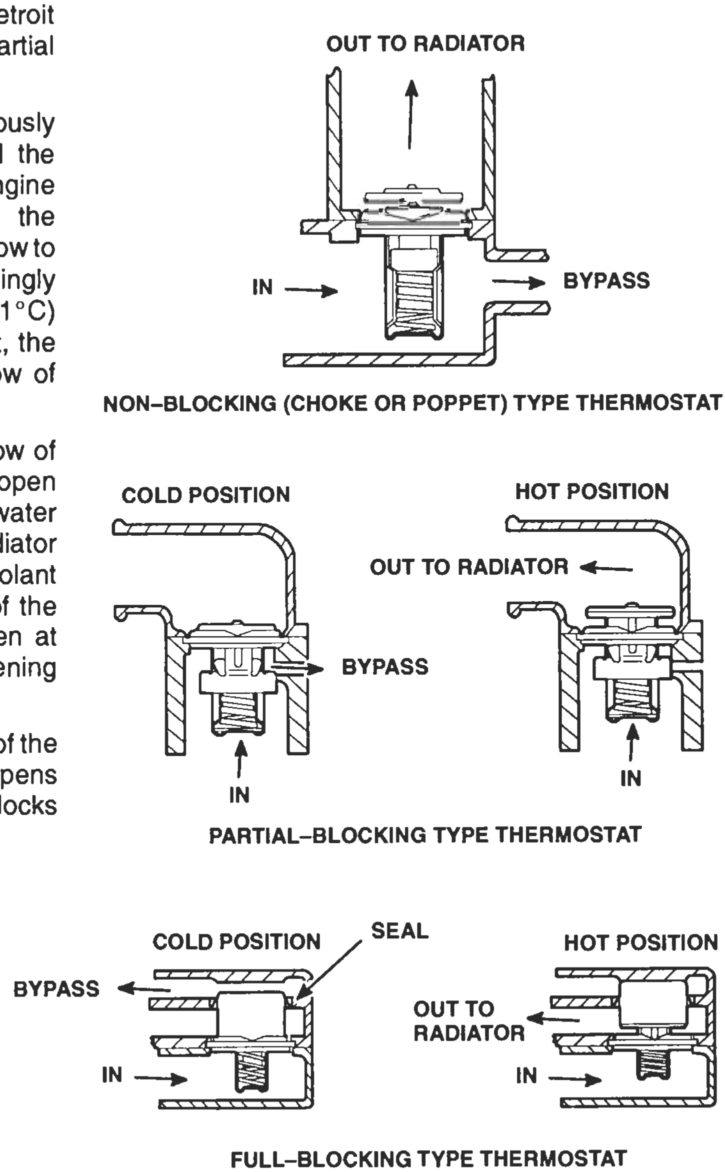


Figure 2. Thermostat Types

VENTED OR NON–VENTED

Thermostats may be vented or non–vented. Venting is accomplished with a small hole in the valve or a notch in the valve at its seat. Non–vented thermostats should be installed only in rapid warm–up type cooling systems. Vented thermostats are used primarily in conventional cooling systems.

THE RAPID WARM–UP COOLING SYSTEM

The amount of coolant leaking to the radiator when the thermostat is in the "closed" position has a direct bearing on the ability of the engine to warm up. For suitable engine warm–up, coolant leakage past the thermostat valve must be at a minimum.

The rapid warm–up cooling system may use any one of the three styles of thermostats, which must generally be non–vented. This characteristic may allow the elimination of radiator shutters.

THE BYPASS CIRCUIT

The bypass circuit provides a route for coolant circulation before the thermostat opens. Coolant from the top of the engine flows back to the water pump without passing through the radiator or other heat exchanger. This flow of bypass coolant permits the engine to warm up to operating temperature while preventing "hot spots" which might damage the engine during this period of operation.

OPERATION IN THE ENGINE

At coolant temperatures below approximately 160° to 170° F (71° to 77° C), the thermostat 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 or heat exchanger by means of a separate external deaeration line and then back to the water pump without going through the radiator or the heat exchanger cores. As the coolant temperature rises above 160° to 170° F (71° to 77° C) the thermostat valves start to open, restricting the bypass system, and permit a portion of the coolant to circulate through the radiator or the heat exchanger. When the coolant temperature reaches approximately 185° to 195° F (85° to 91° C) the thermostat valves are fully open, the bypass system is partially blocked off, and most of the coolant is directed through the radiator or the heat exchanger.

A properly operating thermostat is essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160° to 185°F (71° to 85° C) or 170° to 195° F (77° to 91° C), remove the thermostat and check it.

NOTE: 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 combines 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).

SECTION 5.2.1 – THERMOSTAT

REMOVE THERMOSTAT

1. Drain the cooling system to the necessary level by opening the drain valve.
2. On radiator units, remove the bolts which secure the outlet elbow and the thermostat housing (bypass tube) to the water manifold.

On heat exchanger units, loosen the clamp and slide (Figure 3.) the seal onto the water manifold or thermostat housing. Remove the four bolts and lock washers and separate the thermostat housing from the expansion tank.

3. Remove the thermostat and the deflector (if used) and clean the seat for the thermostat in the housing (heat exchanger or keel cooled units) or outlet elbow (radiator units).
4. Remove and discard the seals pressed in the water outlet elbow (blocking–type thermostats).

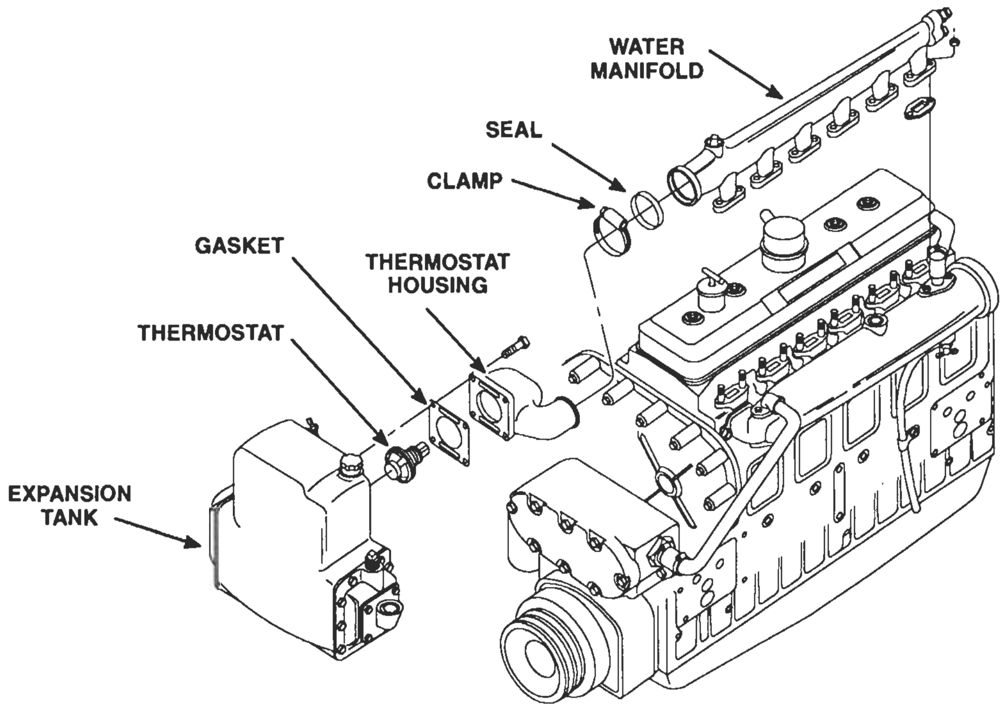


Figure 3. Thermostat Housing Mounting

INSPECTION

If the action of the thermostat has become impaired due to accumulated rust and corrosion from the engine coolant so that it remains closed or only partially open, thereby restricting the flow of coolant, overheating of the engine will result. A thermostat which is stuck in the wide open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold operation will result in build–up of carbon deposits on the pistons, rings and valves.

Check the operation of the thermostat (Section 5.0).

INSTALL THERMOSTAT

1. Affix a new gasket to each side of the thermostat housing.
2. Set the deflector and new gasket (if used) and the thermostat in the housing. On radiator units, attach the outlet elbow and the thermostat housing to the water manifold. On keel cooled units attach the water outlet housing to the thermostat housing.

NOTE: The openings in the side of the thermostat body must be fully open before the thermostat is installed. If the openings are partially closed in handling, they can be opened by grasping the body flange and turning the body.

On heat exchanger or keel cooled units, attach the thermostat housing to the expansion tank.

Using a new seal connect the thermostat housing to the water manifold.

NOTE: On keel cooled units, be sure to install the 2.874 inch diameter cover plate (if removed) in the expansion tank before attaching the thermostat housing to the expansion tank.

INSTALLATION TIPS

1. Before installing a thermostat, check the thermostat flange counterbore in the housing. Make sure it is clean and free from any obstruction that could prevent full seating of the flange.
2. In housings where seals are used, always install a new seal when replacing a full–blocking thermostat. Check seal position (Section 5.2.1). Using the right tool ensures that the seal is positioned the correct distance from the face of the cover and parallel to the thermostat flange counterbore.
3. When installing the thermostat, make sure it is properly seated in the housing counterbore.
4. Always use new gaskets when replacing a thermostat.
5. When installing a vented thermostat in a horizontal position, make sure the vent is at the top.
6. Always check for leaks after completing the installation.
7. Check for wear and proper alignment of thermostat housing cover bypass cast seal ring. Replace if thermostat will not properly block off the bypass cavity during full–open thermostat operation.

NOTE: This check is only necessary on full–blocking type thermostat housings.

SECTION 5.2.1 – THERMOSTAT

PREVENTIVE MAINTENANCE

Vehicle Engines – Check the calibration of the thermostat seals at 200,000 miles (maximum) or once per year, whichever comes first. Replace as required.

Off–Highway Industrial and Marine Engines – Check thermostat calibration and the condition of thermostat seals after 5,000 hours of operation or once per year, whichever comes first. Replace as required. Always replace thermostats and seals at time of engine overhaul, regardless of condition.

NOTICE:

Attempting to reuse defective thermostats and/or seals can result in inefficient engine operation and/or damage.

When comments of low operating temperatures are reported, check for the following *before* considering thermostat replacement.

1. Inaccurate temperature gauge.
2. Casting interference restricting thermostat valve movement.
3. Thermostat cocking or misalignment.
4. System contamination–sand or debris holding the thermostat open.
5. Malfunctioning rapid warm–up system.

Many cold complaints actually relate to lack of cab heat rather than engine temperature. When this is the case, look for such causes as a plugged heater core or restricted heater core hoses, improperly routed heater hoses, blocked heater ducts, inadequate heater coolant flow, etc.

RADIATOR

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 (Figure 1.)

To prolong the life of the radiator, use proper coolant (Section 13.3).

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 recirculation 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 (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.

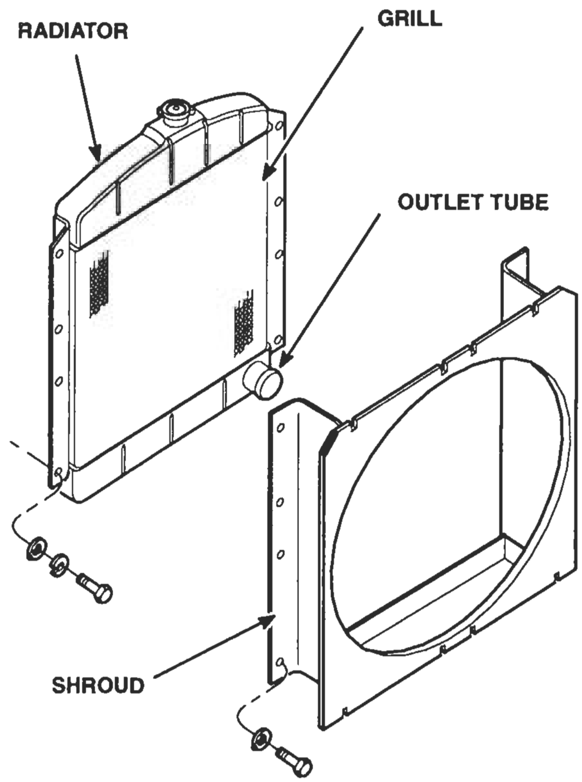


Figure 1. Radiator Components

NOTICE

The use of winterfronts (cardboard, canvas, etc.) is not recommended with any Detroit Diesel Corporation engine installation. Their use can result in excessive engine coolant, oil and charge air temperatures. This can lead to turbocharger surge, poor fuel economy, loss of power, and reduced engine life. Winterfronts may also put abnormal stress on fan and fan drive components, creating the potential for premature malfunction and /or damage.

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. Occasionally, however, oil may be present requiring the use of a solvent, such as mineral spirits, to loosen the dirt. The use of 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. 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 (Section 5).

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as salammoniac, 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 15 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 descaling 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 clean, soft water plus a corrosion inhibitor or an ethylene glycol base antifreeze (Section 13.3). After filling the cooling system, inspect the radiator and engine for water leaks.

NOTE: 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.

NOTE: When draining the cooling system on certain models, it is necessary to open the vent valve at the top of thermostat housing.

2. Remove the instrument panel and engine hood if the engine is so equipped.
3. Remove bolts, nuts, plain washers, and lock washers which attach the fan belt guards to the rear of the fan guard and remove the guards.
4. Withdraw screws, releasing the fan guard from the fan shroud.
5. Loosen the hose clamps at the radiator inlet pipe elbow or hose and remove the elbow or hose.
6. Loosen the hose clamps at the radiator outlet pipe extension tube or hose and remove the tube or hose.
7. 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.
8. Remove the bolts, nuts, plain washers, lock washer and bevel washer holding the radiator assembly to the base.

NOTICE:
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.

9. Lift the radiator assembly with a chain hoist and lifting hook, enough to clear the engine base; then move it away from the engine.

SECTION 5.3 – RADIATOR

INSPECTION

Clean all radiator parts thoroughly, removing dirt, scale and other deposits.

Examine the radiator for cracks or other damage. The radiator core fins should be straight and evenly spaced to permit the 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

Mount the assembly on the engine base by reversing the procedure given for removal.

Check the clearance between the tips of the fan blades and radiator shroud after the radiator is in place. There must be sufficient clearance between these parts 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 on–highway 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 take–off 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.

One such component is a Y–shaped device called an aspirator (Figure 2.) 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 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.

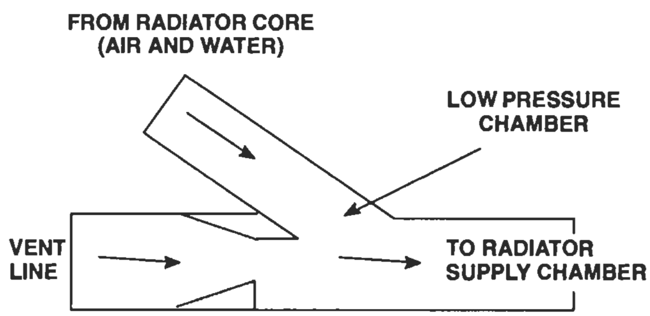


Figure 2. Aspirator for Cross–Flow Design Radiator

CROSS–FLOW DESIGN RADIATOR (CONT.)

The cross–flow system (Figure 3.) for the Inline 6–71 engine does not require a bypass restriction because there is sufficient pressure in the system to provide adequate engine deaeration and aspirator performance.

Properly installed hose connections are required for adequate cross–flow radiator efficiency.

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 for approximately 10 minutes at 1200–1400 r/min so that any entrapped air can be vented. Generally, additional coolant (approximately three to four 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 r/min. The radiator should be tested periodically for possible internal leaks.

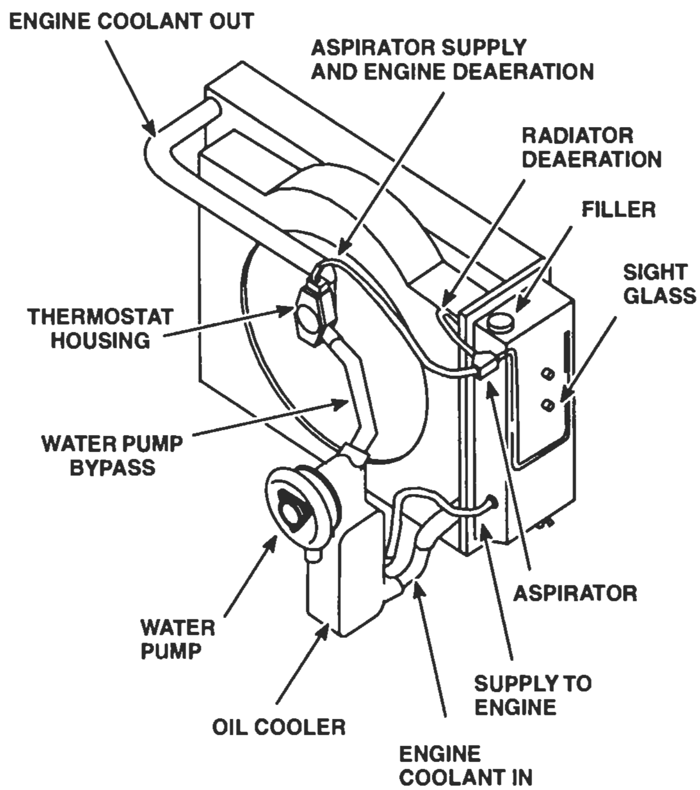


Figure 3. Cross–Flow Design Radiator

The procedure to determine if a leak is present is 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. Shut off the engine and drain four 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. Shut off 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

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap is designed to permit a pressure of 15 lb/in.^{2} (103 kPa) minimum in the system before the valve opens (Figure 1.) This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling.

CAUTION:

Use extreme care when removing the coolant pressure cap. Remove the cap slowly after the engine has cooled. The sudden release of pressure from a heated cooling system can result in the loss of coolant and possible personal injury (scalding) from the hot liquid.

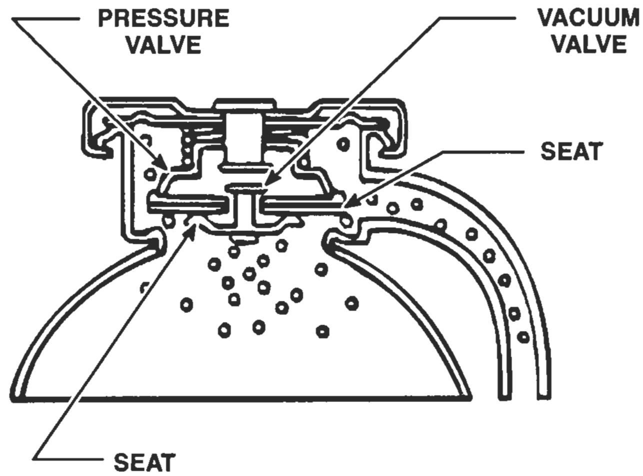


Figure 1. Pressure Control Cap (Pressure Valve Open)

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 (Figure 2.) 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. Service or replace the cap, as required.

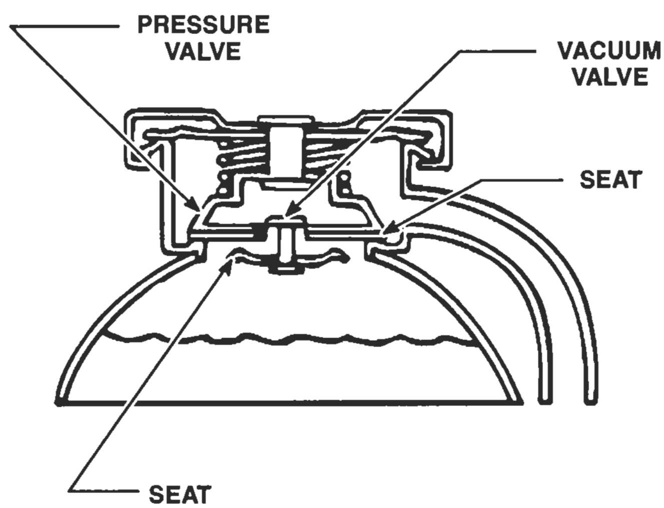


Figure 2. Pressure Control Cap (Vacuum Valve Open)

ENGINE COOLING FAN

The engine cooling fan is belt driven from the crankshaft pulley (Figure 1.)

The fan is bolted to a hub and pulley which is carried on two bearings. The bracket and shaft are mounted on the fan support which is in turn attached to the balance weight cover. The bracket is slotted to permit adjustment of the fan belt tension by moving the bracket and shaft on the attaching bolts. Formerly, the bracket and shaft were separate pieces and the rear end of the shaft was supported in the bracket and retained by a snap ring. On compact front end engines the pulley hub turns on tapered roller bearings.

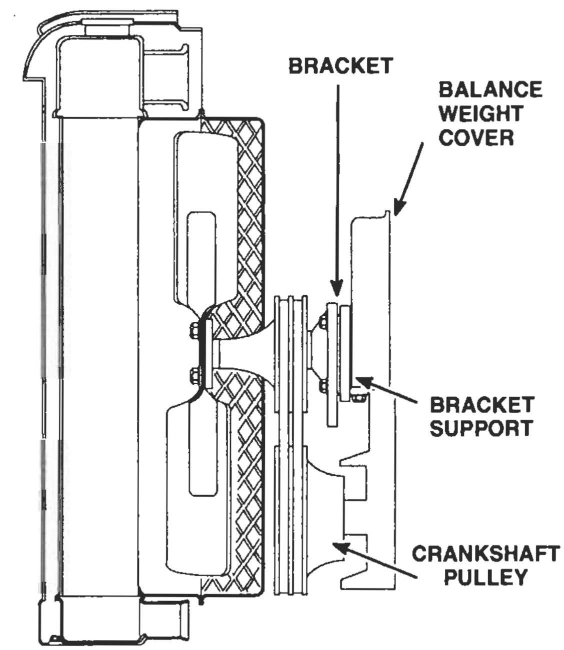


Figure 1. Typical Fan and Hub Assembly

LUBRICATION

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled (Section 15.1.)

FAN BELT ADJUSTMENT

Adjust the fan belt(s) periodically (Section 15.1.)

REMOVE AND INSTALL FAN

If enough clearance exists between the fan blades and the face of the radiator core, the fan and spacer may be removed by taking out the six mounting bolts, nuts and lock washers. If the fan cannot be removed in this manner, the fan, hub and bracket may be removed as an assembly. See the procedure for removing the fan, hub and bracket for details.

The fan may be installed by reversing the procedure used for removal.

SECTION 5.4 – ENGINE COOLING FAN

REMOVE FAN, HUB AND ADJUSTING BRACKET

The fan 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 belt and fan guards.
2. Remove the attaching bolts, lock washers and nuts, then remove the fan and spacer (if used).

NOTE: If insufficient clearance exists between the fan and radiator, remove the fan, hub and adjusting bracket as an assembly.

3. Remove the two adjusting bolts, lock washers and plain washers, then remove the drive belts.
4. Loosen the adjusting bracket pivot or adjusting bolts until the bracket is free. Remove the hub and bracket assembly from the engine.

DISASSEMBLE FAN, HUB AND BRACKET

1. Remove the fan attaching bolts and lock washers and detach the fan and the spacer (if used) (Figure 2.)
2. Remove the fan hub cap (if a spacer and cap assembly were not used).
3. Remove the hub bolt and washer.

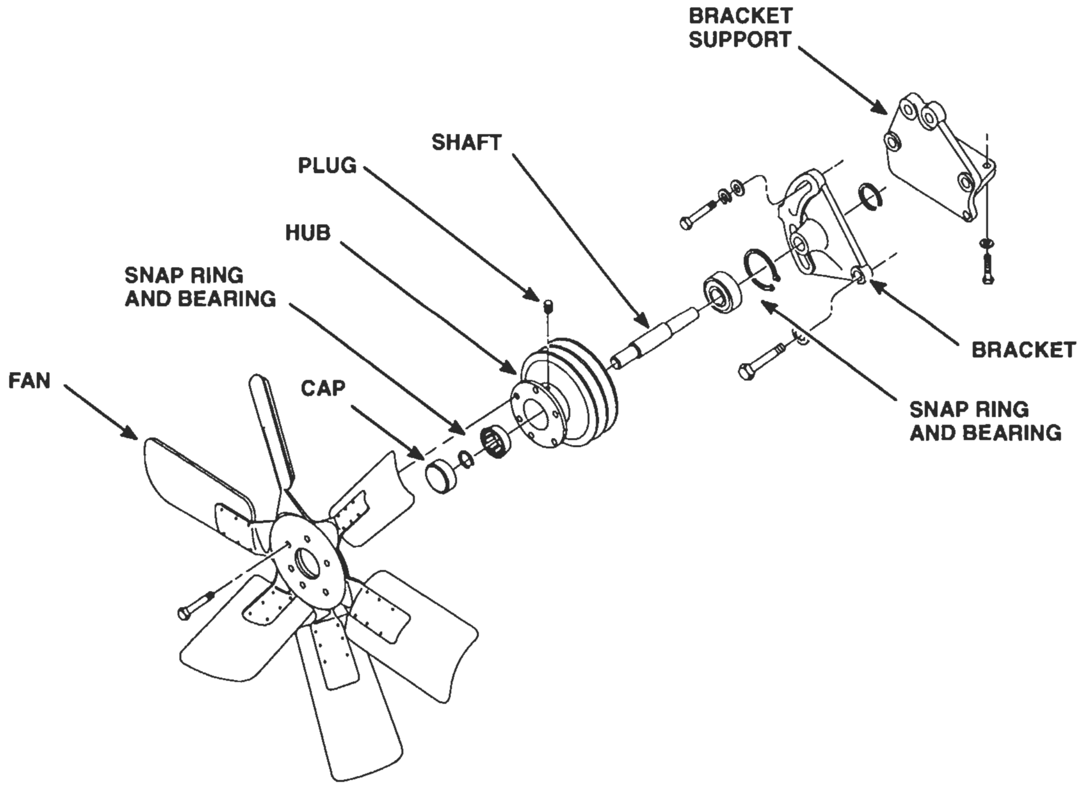


Figure 2. Fan Hub and Adjusting Bracket Components

DISASSEMBLE FAN, HUB AND BRACKET (CONT.)

4. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly (Figure 3.)
5. Remove the bearings and oil seal as follows:
   a. Remove the snap ring (if used) from the groove in the outer (front) of the hub.
   b. Remove the current ball bearing by tapping alternately around the outer edge of the bearing with a small brass rod and hammer.
   c. Remove the former roller bearing inner race from the outer (front) roller bearing.
   d. Remove the shims and bearing spacer (if used).
   e. Tap the outer race of the former roller 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.
   f. Reverse the pulley hub and remove the dust cap (if used). Then drive the oil seal from the hub. Discard the oil seal.
   g. Remove the inner (rear) roller in the same manner as outlined in Steps c and e.
   h. Remove the grease retainer (if used) from the pulley hub.

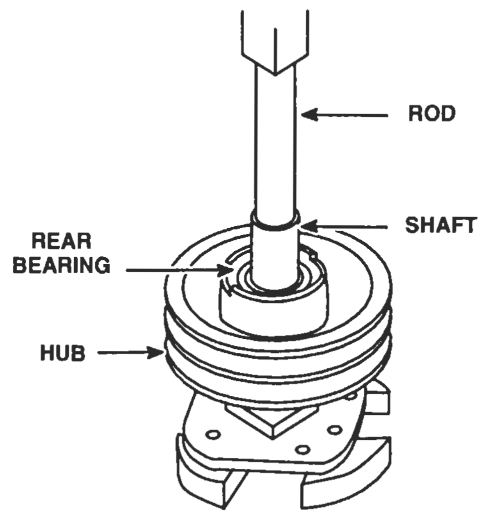


Figure 3. Fan Shaft and Front Roller Bearing Removal

INSPECTION

Clean the fan 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 lb/in^2 (276 kPa) air pressure.

Never wash shielded bearings. This may cause dirt to be washed in and the cleaning fluid could not be entirely removed from the bearing. Examine the bearings for any indication of corrosion or pitting. Hold the inner race or cone 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. Check for cracks in the adjusting and support bracket castings. Fan hubs equipped with roller bearings may be modified by adding a grease fitting (Section 5.0.)

SECTION 5.4 – ENGINE COOLING FAN

INSPECTION (CONT.)

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 than 1.7299 inches.

NOTE: 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 1.35 to 1.37 inches from the end of the shaft.

ASSEMBLE FAN, HUB AND BRACKET

1. Apply Texaco Premium RB grease, or an equivalent Lithium base multi–purpose grease to the rollers of both bearings before installing them in the pulley hub.
2. Install the inner (rear) roller bearing assembly (inner and outer race), with the protruding face of the inner race facing outward from the hub, (1.31 inches from end of shaft), by tapping alternately around the face of the bearing outer race with a small brass rod and hammer.

Assemble the fan hub and bracket (Figure 4.) as follows:

3. Install a new oil seal with the rubber side flush with the outer edge of the hub.

NOTE: Certain engines use a rubber lip type oil seal.

4. Install the dust cap over the oil seal (if used).
5. 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 (if used).
6. Pack the cavity 20–30% full with grease (Step 1) and install the grease retainer (if used).

NOTE: The grease retainer is not required when a grease fitting is installed in the pulley hub (Section 5.0.)

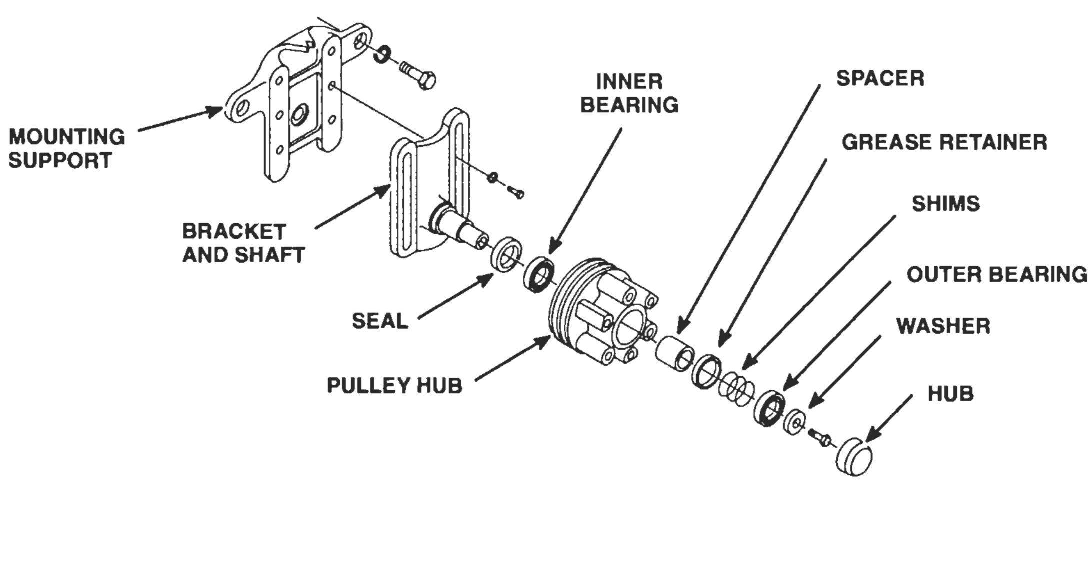


Figure 4. Shaft Type Fan Hub Assembly for Compact Front Engine

ASSEMBLE FAN, HUB AND BRACKET (CONT.)

7. Install snap ring (if used) in the groove of the pulley hub, to lock the outer (front) ball bearing onto the shaft.
8. Secure the hub with the washer and bolt. Tighten the 1/2–20 bolt to 83–93 lb·ft (113–126 N·m) torque while rotating the pulley.
9. 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 inches on former hub assembly. If necessary, remove the bolt, washer and outer bearing and adjust the number and thickness of shims to obtain the required end play. Shims are available in .015, .020 and .025 inch thickness. Then reassemble the fan hub and check the end play.
10. Fill a new fan hub cap 75% minimum full of grease and install it in the end of the fan hub (pulley).

NOTE: The cap must not protrude beyond the face of the hub.

11. Secure the fan blade and spacers to the pulley hub with six bolts, nuts and lock washers. Tighten the nuts to 15–19 lb·ft (20–26 N·m) torque.

INSTALL FAN, HUB AND BRACKET

1. Attach the fan hub and adjusting bracket assembly to the support bracket on the engine with bolts, lock washers and plain washers. Do not tighten the bolts.
2. Install the drive belts and adjust the belt tension (Section 15.1.) If used, install the adjusting bracket, bolt and plain washer.
3. Install the fan (and fan spacer and cap, if used) on the hub and secure it with bolts and lock washers.

THERMO–MODULATED FAN

A thermo–modulated suction fan assembly has been provided on some engines (Figure 5.)

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 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 multi–plate, fluid filled clutch housing.

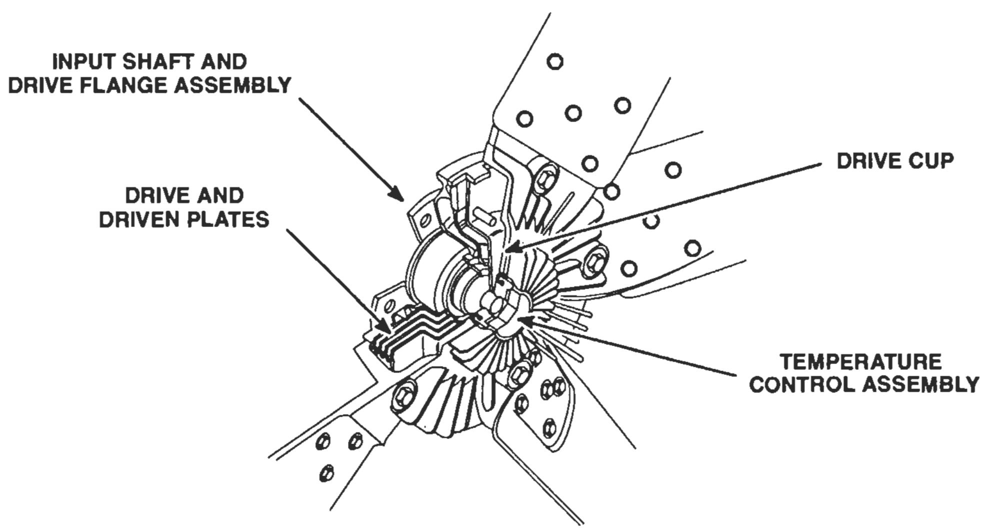


Figure 5. Thermo–Modulated Fan and Drive Assembly

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.

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 (Section 15.1.)

ADJUST FAN BELT

The adjustment of the fan belt is the same as 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 assembly consists of a series of vertical cells contained within a rectangular cage, with a header at one end and a circular water outlet at the opposite end (Figure 1.) The core is mounted inside of the expansion tank with the header (inlet end) bolted to the tank and the outlet end sealed inside of 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 core.

In this system of engine cooling, the hot coolant flows from the water manifold to the expansion tank and down through the vertical cells of the heat exchanger core. The raw water, flowing horizontally between the cells of the heat exchanger core, lowers the temperature of the engine coolant as it passes through the cells. The engine coolant is then circulated through the cylinder block and head by the water pump.

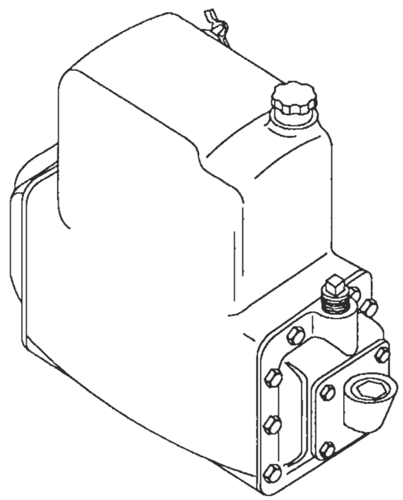


Figure 1. Heat Exchanger Assembly

Zinc electrodes, located in the heat exchanger inlet cover and the raw water pump inlet elbow, protect the heat exchanger core from electrolytic action.

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, attached near the top of the tank, provides a vent to the atmosphere.

When installing a new filler neck in the expansion tank be sure to drill a 3/16 inch 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 grade of corrosion inhibitor or antifreeze, should be used as the engine coolant. The coolant level should be maintained near the top of the expansion tank.

If the heat exchanger fails to cool the engine properly, the core assembly should be examined for foreign deposits.

SECTION 5.5 – HEAT EXCHANGER

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) pounds 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 30 to 60 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

Clean pitted electrodes with a wire brush. If replacement is required, remove the electrode from its holder. Thread a new electrode in the holder and install the assembly in the heat exchanger or raw water pump inlet elbow.

REMOVE HEAT EXCHANGER CORE

Remove the heat exchanger core for inspection or cleaning as follows:

1. Drain the engine coolant and the raw water system.
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.

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.

NOTE: To minimize electrolytic action of the raw water, brass pipe plugs are used in the raw water system components wherever pipe plugs are required. Replace any steel plugs that may be found on earlier units with brass plugs.

Refill the engine coolant 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. 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 camshaft or balance shaft gear.

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 in direction of flow.

The drive from the camshaft or balance shaft is to the pump drive shaft which is carried on a double row ball bearing located in the flange end of the pump housing (Figure 1.) Oil seals at each end of the ball bearing prevent lubricating oil from entering the impeller compartment.

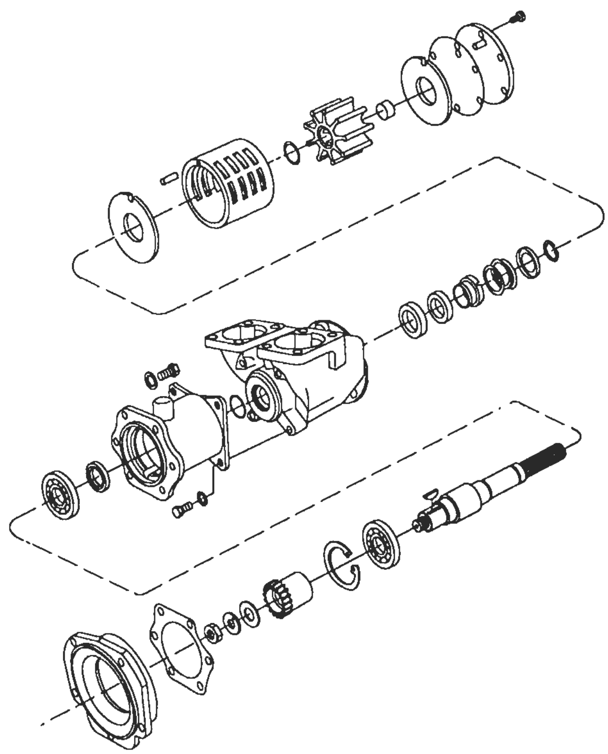


Figure 1. Raw Water Pump Assembly

RAW WATER PUMP (JABSCO) (CONT.)

An impeller, splined to the end of the drive shaft, is lubricated by the water pumped and should not be run dry for longer than normally required for the pump to prime itself (Figure 2.)

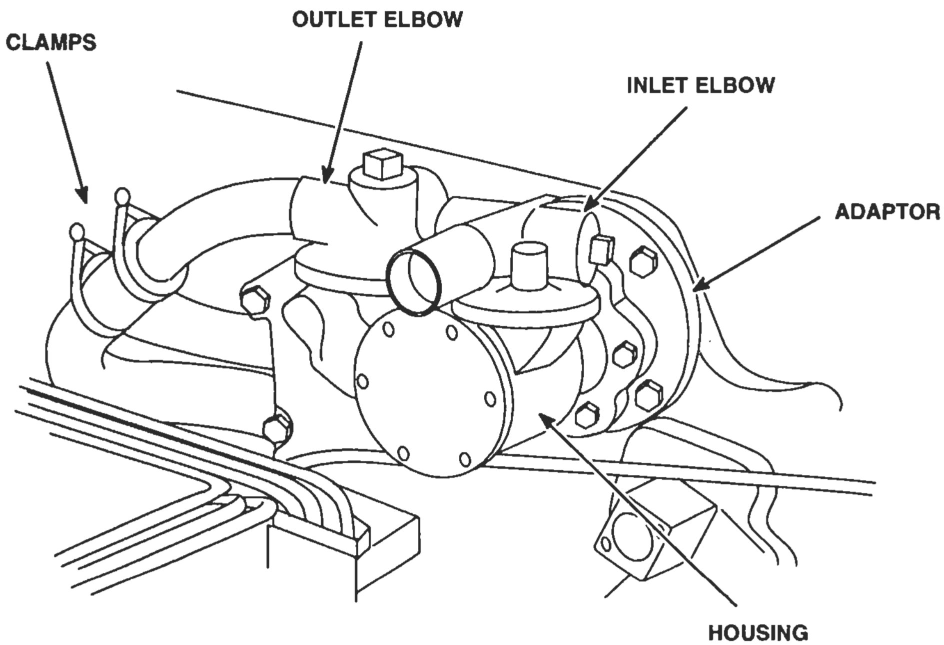


Figure 2. 100 gal/min Raw Water Pump (Part. No. 8923363)

RAW WATER PUMP (JABSCO) (CONT.)

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 (Figure 3.)

A rotary type seal assembly seals against leakage along the shaft.

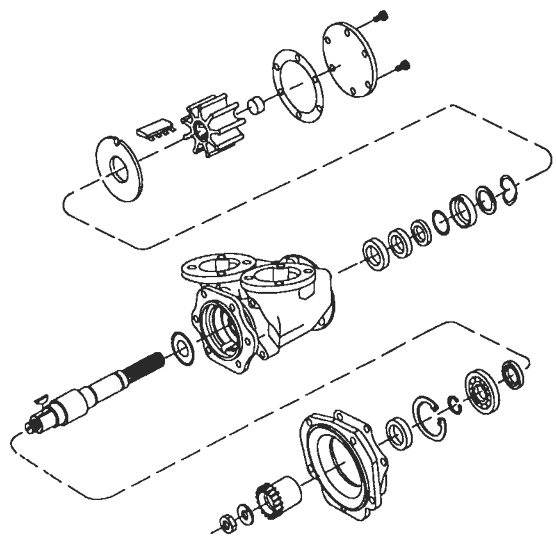


Figure 3. 125 gal/min Raw Water Pump (Part No. 8927296)

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, DDC recommends detaching the cover and removing the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

NOTICE:

After the barring operation, inspect the impeller for wear or damage and replace, if necessary. When reinstalling a serviceable impeller, make sure the vanes are deflected (bent) in the same direction in which the impeller was removed.

NOTICE:

Before barring a right–hand rotating marine engine equipped with a Jabsco raw water pump, fill the pump with water to prevent impeller or seal lip damage. Periodically inspect the impeller for wear or damage and replace, if necessary.

SECTION 5.6 – RAW WATER PUMP (JABSCO)

OPERATION

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.

LUBRICATION

The shielded–type double row ball bearing is filled with lubricant when assembled. No further lubrication is required.

REMOVE RAW WATER PUMP FROM ENGINE

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 inlet tube and slide the hose along the tube.
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.

NOTE: Cover the pump opening in the flywheel housing with a clean cloth to prevent entrance of foreign matter.

NOTICE:
Always prime the raw water pump before starting the engine. Since water acts as a lubricant for the impeller, failure to prime the pump (or at least wet the impeller vanes to induce a self–priming suction) can result in severe impeller damage when the engine is started. Insufficient raw water flow into the heat exchanger caused by a damaged impeller can lead to overheating and subsequent engine damage. To prime the pump: a) remove the pipe plug from the water inlet elbow; b) pour in at least a pint of water; c) replace the plug.

RAW WATER PUMP BODY DISASSEMBLY

1. Remove the end cover bolts or screws and the end cover. On 100 gal/min pump only, also remove the gasket and outer wear plate.
2. Grasp the hub of the impeller with pliers and remove it from the impeller bore. If the impeller O–ring remains on the shaft, remove it.
3. Remove the cam/liner from the pump body.
4. Remove the inner wear plate.
5. Remove the seal retaining ring and be sure not to scratch the shaft. Remove the carbon portion of the mechanical seal with the spring attached.
6. Remove the bolts that secure the adaptors to the pump inlet and outlet ports. With the pump body held securely to keep it from falling, remove the four 5/16 inch screws and lock washers that hold the pump body to the bearing housing.
7. Remove the pump body from the bearing housing and shaft sub–assembly. Remove any remaining gasket material from the port adaptors.
8. Remove the slinger O–ring from the shaft.
9. From the drive end of the pump body, press out any remaining portions of mechanical seal (boot and ceramic seat).
10. Clean and inspect all parts for wear. Worn wear plate(s) should be reversed if reusable, or replaced. If the cam/liner thickness is 3/8 inch or less at its thickest section, it should be replaced.

RAW WATER PUMP BODY ASSEMBLY

1. Install a new slinger O–ring on the shaft near the bearing housing.
2. Install the mechanical seal components. Do not allow the seal components to become soiled during assembly. Lubricate the ceramic seal seat boot with water only and press it into the seal bore of the pump body. Install the ceramic seal seat. The exposed ceramic surface should face toward impeller bore.
3. Slide the pump body over the shaft and take care not to dislodge the seal seat as the body is moved toward (and aligned with) the bearing housing. Attach the pump body to the bearing housing with four 5/16 inch screws and lockwashers. Tighten to 14–16 lb·ft (19–22 N·m) torque.
4. Install the carbon portion of the mechanical seal with the tensioning spring and spring washer over the shaft and locate it in the seal bore with the carbon face against the ceramic seal seat. Slide the real retaining ring over the shaft against the seal thrust ring and locate it in the retaining ring groove.
5. Install the inner wear plate in the pump body and align the notch in the wear plate with the pin in the body.
6. Lubricate the bore of the body with a film of water pump grease. Align the hole in top of the cam/liner with the pin in the pump body and push the cam/liner into the body. Cam/liner of a 100 gal/min pump should be recessed about 1/8 inch from the end cover surface to permit the installation of the wear plate.
7. Liberally coat the inside of the cam/liner with the water pump grease.

RAW WATER PUMP BODY ASSEMBLY (CONT.)

8. Insert the impeller O–ring in the groove in the impeller recess. With the O–ring end of impeller facing the pump housing, rotate the impeller in the direction of pump rotation to bend the vanes under the cam and push it into the bore until the impeller the insert flats align with the shafts. Then push the impeller all the way into the impeller bore. End of the impeller should be approximately even with the cam/liner. Install the rubber spline plug into the end of the impeller.
9. On 100 gal/min pump only, install the outer wear plate (align notch in wear plate with hole in top of cam/liner) and place the end cover gasket over the pin in the end cover.
10. Install the end cover, aligning the pin with the hole in the cam/liner. Install six 1/4 inch head screws (100 gal/min pump) or four 1/4 inch bolts (125 gal/min pump) in the end plate cover. Tighten to 72–78 lb·in (8.13–8.81 N·m) torque. **Do not over torque.**

BEARING HOUSING DISASSEMBLY

1. Follow disassembly steps 1 through 10 of the minor service instructions.
2. With the housing held securely to keep it from falling, remove the six 3/8 inch screws and lockwashers in the housing flange and remove the bearing housing and shaft sub–assembly from adaptor.
3. Prevent the shaft from rotating by holding it with a wrench on the shaft flats on the impeller end. Then remove the drive gear retaining nut, lock washers, and retaining flat washer.
4. Remove the drive gear from the shaft. A punch and small mallet may be used to gently tap the underside of the drive gear teeth to loosen the gear from shaft. Remove the woodruff key.
5. Remove the retaining ring securing the bearing in the bearing housing.
6. Press against the impeller end of the shaft to remove the shaft and the bearing sub–assembly from the bearing housing.
7. Support the inner race of the bearing and press the shaft out of the bearing. Repeat the procedure on the second bearing.
8. From the pump end of the bearing housing, push the oil seal out of the bearing housing.
9. Clean and inspect all parts for wear and replace as required. Clean any remaining gasket material from the face of the adaptor flange on the engine.

BEARING HOUSING ASSEMBLY

1. Lightly coat the outside diameter of a new oil seal with clean engine oil. From the drive end of the bearing housing, press the oil seal into the seal bore. Slip lip must point to the drive end of the housing.
2. With pressure applied to the inner race of the bearings, press the bearings onto the shaft.
3. With pressure applied to the outer race of the outer bearing, install the bearing and shaft sub–assembly into the bearing housing.
4. Install the bearing retaining ring in the bearing housing, insuring it is securely seated in the ring groove.
5. Insert the woodruff key into the groove end of the shaft. Install the drive gear onto the shaft by gently tapping it with a small plastic–face mallet.
6. Install flat washer, lock washer, and retaining nut onto shaft. Prevent the shaft from rotating by holding it with a wrench on the shaft flats at impeller end and tighten the nut to 24–30 lb·ft (33–41 N·m) torque.
7. Follow steps 1 through 10 of the minor assembly instructions to install the pump body and components.
8. Install s new adaptor flange gasket and secure the pump assembly to the adaptor with six 3/8 inch screws, flat washers, and lock washers. Tighten to 13–15 lb·ft (18–20 N·m) torque.
9. Use new gaskets and attach the raw water pump inlet and outlet adaptors.

INSTALL RAW WATER PUMP ON ENGINE

1. To install the raw water pump, follow the remove raw pump from engine procedure earlier in this section in reverse order.

NOTE: The end of the cover is marked to show the outlet port for RH rotation and and the outlet port for LH rotation. Follow these markings when installing the raw water pump to avoid any difficulty regarding the 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 the pump.

COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a spin–on type element.

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation and 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 (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.

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 (Section 15.1)

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 to approximately 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and reused. 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.

NOTE: A separate rust inhibitor should not be used in a cooling system protected by a coolant filter and conditioner.

SECTION 5.7 – COOLANT FILTER AND CONDITIONER

SERVICE

The coolant filter may be grounded at the option of the user.

Replace the element and service the filter and conditioner as follows:

1. Close the filter inlet and outlet shutoff valves. If shutoff 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. Remove and replace the element.

SPIN–ON TYPE ELEMENT

1. Remove and discard the element (Figure 1.)
2. Clean the gasket seal on the filter cover.
3. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.
4. 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.

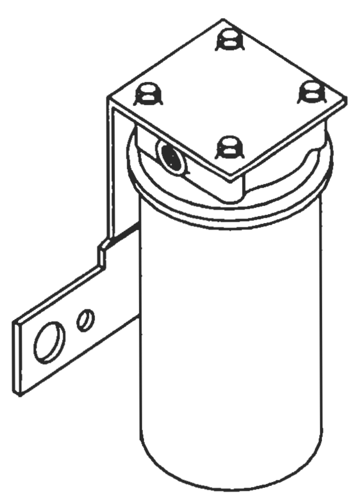


Figure 1. Coolant Filter and Conditioner (Spin–on Type)

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

FAN HUB GREASE FITTING

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. Disassemble the fan hub assembly (Section 5.4) and clean the parts thoroughly.
2. Drill and tap the fan hub (Figure 1.) to accept a 1/8 PTF x 11/16 inch threaded lubricator fitting. Clean the hub to remove any metal chips.
3. Reassemble the fan hub (Section 5.4.) 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.
5. Install a grease fitting in the fan hub and a relief valve in the fan hub cap.

Maintenance must be performed as necessary (Section 15.1.)

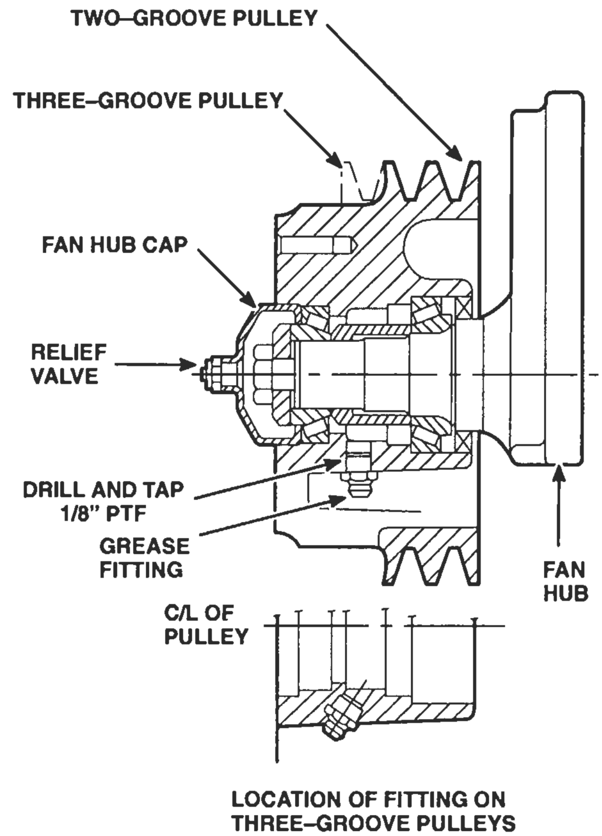


Figure 1. Fan Hub Grease Fitting and Relief Valve Location

DRAINING JABSCO RAW WATER PUMP

Although all engine units are provided with drain cocks 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 be completely drained. This may easily be accomplished by loosening the five 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 tightened.

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 (4.5°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.

WATER PUMP BODY MODIFICATION

The former water pump bodies can be reworked to accept a new shaft and bearing assembly. Use the following procedure.

1. Locate the center line of the pump bearing bore (Figure 2.)
2. Bore a hole 1.2 inch diameter minimum to 1.3 inch diameter maximum from the cover mounting face of the pump to a depth of 2.28 inch (± .010 inch). This will accommodate the secondary seal.

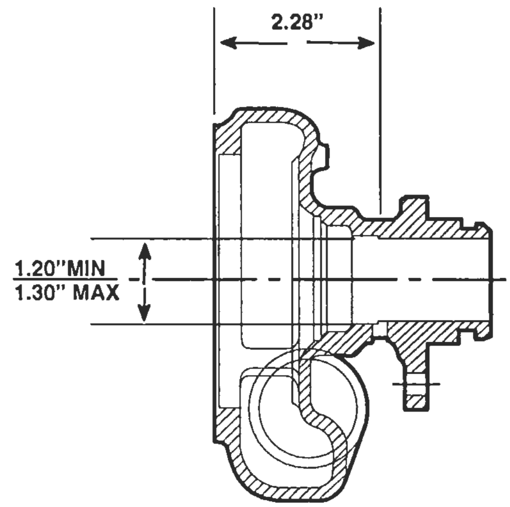


Figure 2. Pump Bearing Bore

FIND COOLANT LEAKS WITH FLUORESCENT DYE AND 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.

* Available from:

CHEMCENTRAL CORPORATION
7050 West 71st Street
Chicago, IL 60638

THERMOSTAT TESTING PROCEDURE

Place the vessel on a level surface and lower the bed plate into position, being careful to avoid contact with the heating element (Figure 3.)

NOTE: This procedure will take time to do properly.

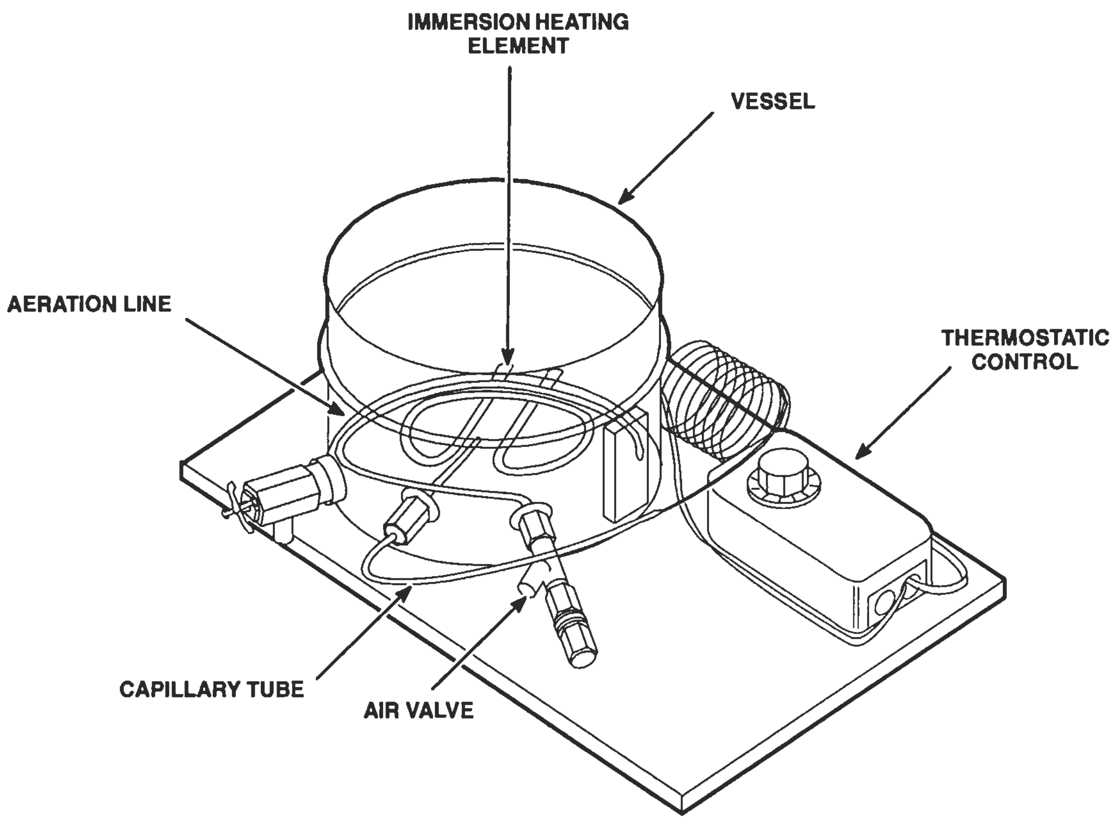


Figure 3. Thermostat Test Fixture

THERMOSTAT TESTING PROCEDURE (CONT.)

Fully submerge the thermostat in warm water and place a laboratory thermometer in one of the 7/16 inch 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 two–three minutes (Figure 4.)

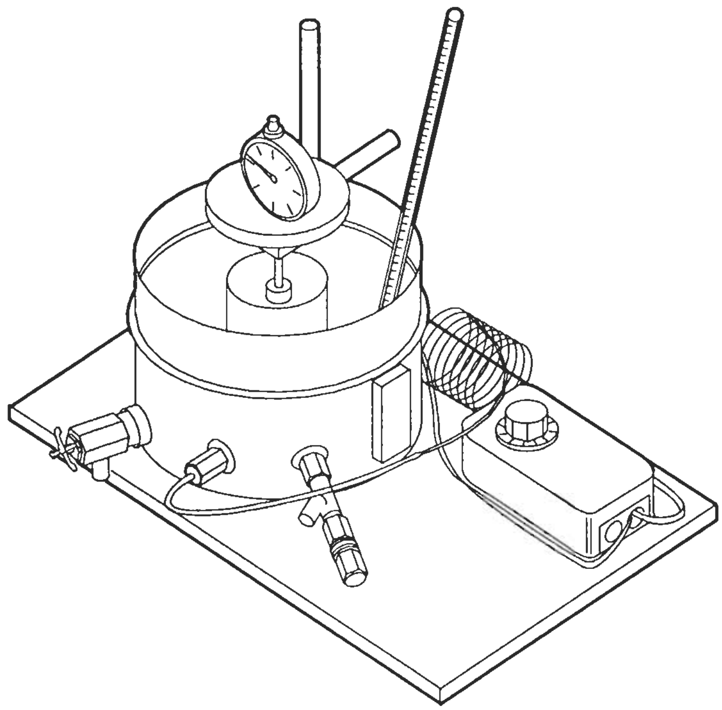


Figure 4. Testing a Thermostat in the Test Fixture

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.

For full–open temperature and travel, raise bath temperature a few degrees above the specified full–open temperature and hold at that temperature for two–three 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.

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.

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. (lb·ft)
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

 May, 1994

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	C.I. ENGINE TORQUE (lb·ft)	C.I. ENGINE TORQUE (N·m)	ALUM ENGINE TORQUE (lb·ft)	ALUM ENGINE TORQUE (N·m)
Water pump coupling bolt (current)	5/16–24	18 min.	24 min.	18 min.	24 min.
Water manifold nut	3/8–24	25–30	34–41	20–25	27–34
Water pump coupling bolt (former tapered shaft)	7/16–24	25–30	34–41	25–30	34–41
Raw water pump (Jabsco) drive gear retaining nut	5/8–18	25–30	34–41	25–30	34–41

STUD TORQUE SPECIFICATIONS

APPLICATION	TORQUE (lb·ft)	TORQUE (N·m)
Water manifold stud	10–25	14–34

SERVICE TOOLS

TOOL NAME	TOOL NO.
Drive handle	J 7079–2
Thermostat seal replacer	J–8550
Water pump and fuel pump wrench	J–4242
Water pump drive coupling remover	J–1930
Water pump impeller installer (.031–.033 inch)	J–22437
Water pump impeller installer (.052–.072 inch)	J–21917
Water pump impeller installer (.099–.101 inch)	J–9303

EXHAUST SYSTEM

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Exhaust System 6

Exhaust Manifold (Air–Cooled) 6.1

Exhaust Manifold (Water–Cooled) 6.1.1

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 air–cooled exhaust manifold (Figure 1.) is mounted on the cylinder head.

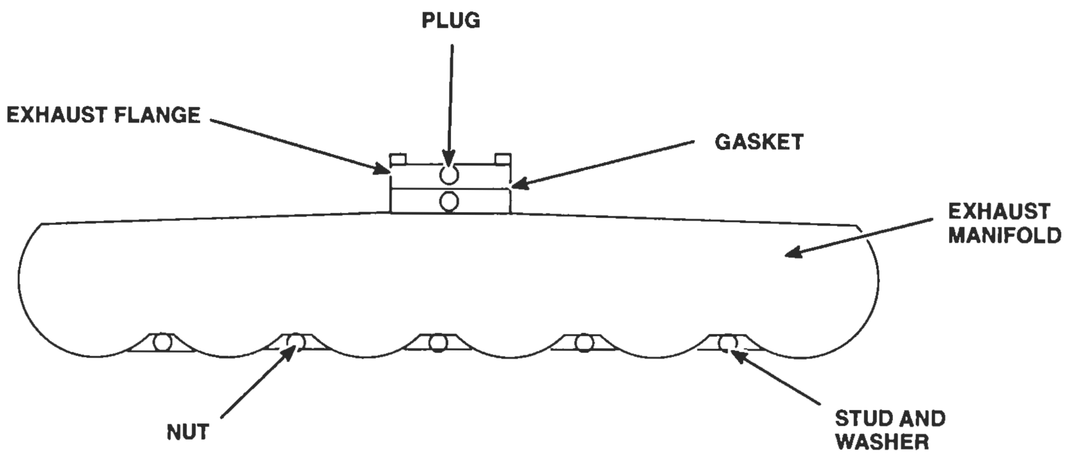

Figure 1. Air–Cooled Exhaust Manifold Mounting

REMOVE EXHAUST MANIFOLD

Remove the manifold as follows:

1. Disconnect the exhaust pipe or muffler from the exhaust manifold.
2. Remove the nuts and bevel washers that attach the exhaust manifold to the cylinder head. It is suggested that, as a safety measure, the nut be loosened but left on the center stud until all of the other nuts and washers have been removed.
3. Support the manifold and remove the nut and washer from the center stud.
4. Lift the manifold away from the cylinder head.
5. Remove the manifold gaskets.

SECTION 6.1 – EXHAUST MANIFOLD (AIR–COOLED)

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. Place a new gasket over the studs and up against the cylinder head. Metal–clad gaskets may look reusable, but once they have been used, they cannot be reused (Figure 2.)

NOTE: When installing the metal–clad exhaust manifold gasket, be sure the crimped side of the gasket faces the cylinder head.

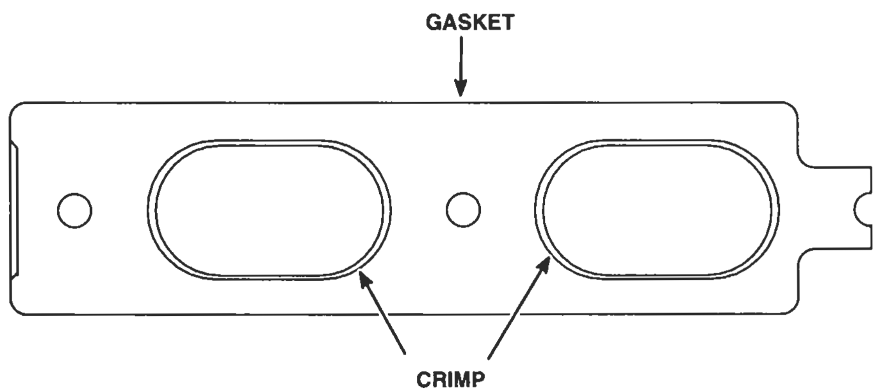

Figure 2. Metal Clad Exhaust Manifold Gasket

2. Position the exhaust manifold over the studs and up against the gasket.
3. Install the bevel washers on the studs.

NOTE: Install the bevel washers with the crowned sides toward the nuts.

4. Thread the nuts on the studs. Then, starting with the center nut and working alternately toward each end, tighten the manifold nuts to 30–35 lb·ft(41–47 N·m) torque (cast iron head).

NOTE: If the cylinder head was removed from the engine, do not tighten the manifold nuts until after the head is reinstalled. Otherwise, interference may be encountered between the manifold and cylinder block bosses which serve as a support for the manifold when the cylinder head is installed.

5. Connect the exhaust pipe or muffler to the manifold. Tighten the brass exhaust manifold outlet flange nuts to 20–25 lb·ft (27–34 N·m) torque.

NOTE: Do not allow exhaust piping to impose excessive loads on the turbocharger.

6. 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 exhaust manifold 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 water manifold into the rear end of the jacket surrounding the exhaust manifold and is discharged from the forward end through a tube into the lower section of the expansion tank. A drain cock with an attached hose is installed in the bottom of the manifold for draining the water jacket. A plug is provided in the bottom of the exhaust outlet elbow for draining moisture condensed from the exhaust gases.

REMOVE EXHAUST MANIFOLD

When an engine is being reconditioned, the exhaust manifold is removed along with the cylinder head. However, if only the manifold gaskets need replacing, the manifold can be removed from the cylinder head as follows:

1. Disconnect the exhaust pipe and elbow from the manifold.
2. Loosen the two hose clamps (Figure 1.) and remove the water inlet hose.
3. Loosen the hose clamp on the water outlet hose. Then remove the two nuts and washers and separate the water outlet tube from the exhaust manifold.
4. Remove the exhaust manifold drain hose.
5. Remove the exhaust manifold retaining nuts and washers. To facilitate removal of the number two stud nut (between the two forward manifold legs), unscrew the nut to the end of the stud, remove all of the other manifold nuts and washers, then pull the manifold away from the cylinder head and remove the number two nut and washer.
6. Remove the manifold and gasket.

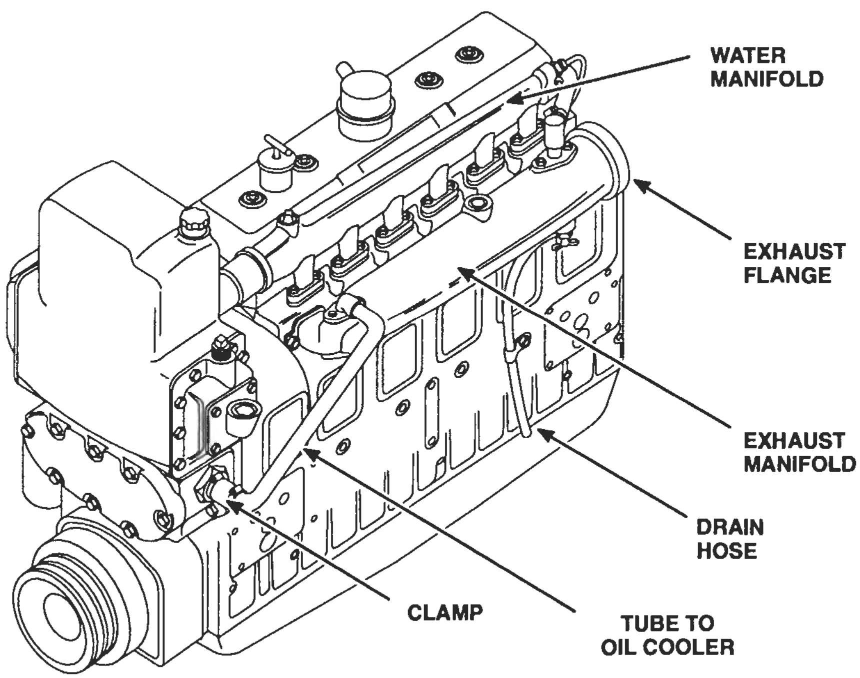

Figure 1. Water–Cooled Exhaust Manifold Mounting

SECTION 6.1.1 – EXHAUST MANIFOLD (WATER–COOLED)

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. Replace the studs if necessary. Studs are driven in to 25–40 lb·ft (34–54 N·m) torque.

INSTALL EXHAUST MANIFOLD

Install the exhaust manifold on the cylinder head as follows:

1. Place the manifold gasket over the studs and against the cylinder head.
2. Position the manifold on the studs so that about 1/2 inch of the stud threads extend beyond the mounting flanges of the manifold legs.
3. Place a bevel washer over the number two stud and thread the nut several turns on the stud.

NOTE: The bevel washers are installed so that the outer diameter will rest against the manifold and the crown of the washer will be next to the nut.

4. Slide the manifold up against the cylinder head and install the remaining washers and nuts. Then, starting with the center nut and working alternately toward each end, tighten the nuts to 30–35 lb·ft (41–47 N·m) torque (cast iron head).

NOTE: If the cylinder head was removed from the engine, do not tighten the manifold nuts until after the head is reinstalled. Otherwise, interference may be encountered between the manifold and cylinder block bosses which serve as a support for the manifold when the cylinder head is installed.

5. Connect the exhaust pipe and elbow to the manifold.

NOTICE:

To prevent possible turbocharger damage, do not allow exhaust piping to impose excessive loads on the turbocharger.

6. 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.
7. Install the exhaust manifold drain hose.
8. Install the water inlet hose and tighten the hose clamps.
9. Use a new gasket and install the water outlet tube. Secure the tube to the manifold with two nuts and washers. Install the water outlet tube hose and secure it to the oil cooler water inlet with a hose clamp.
10. Fill the cooling system and check for leaks.

ELECTRICAL SYSTEM

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Battery–Charging Alternator 7.1

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Cranking Motor 7.3

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BATTERY–CHARGING ALTERNATOR

The battery–charging alternator 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.

The battery–charging circuit consists of an alternator, a voltage regulator, a battery or batteries and the connecting wiring.

The alternator typically used is a hinge–mounted, alternating current (AC), self–rectifying unit (Figure 1.)

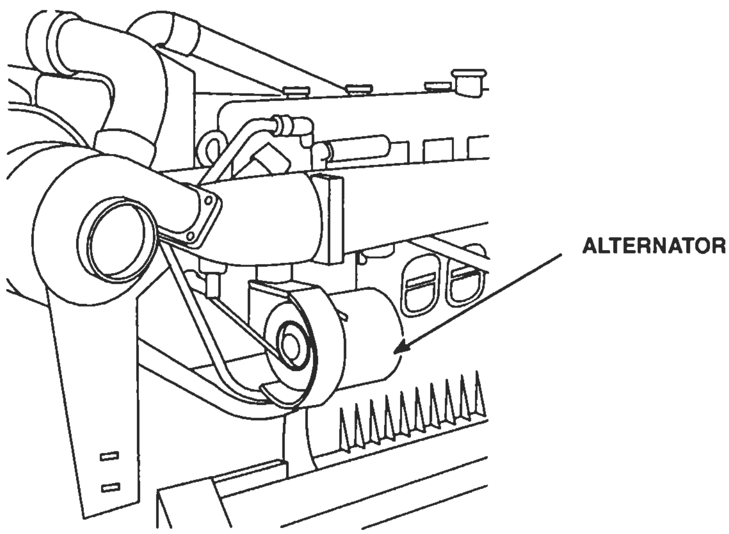

Figure 1. Inline Series 71 Alternator Mounting

On engines with the SI series Delco–Remy alternators, the voltage regulator is typically electronic and is located inside the alternator. Refer to the appropriate manufacturer's service instructions for complete regulator and alternator servicing information.

The alternator is generally belt driven using the accessory drive pulley. Refer to Section 1.7.7 for accessory drive information.

CAUTION:

With the exception of the DDEC system, never attempt to service any engine electrical systems until the batteries have been disconnected. For procedures covering service and diagnostics of the DDEC system, refer to Section 2.7 and the DDEC Troubleshooting Guide 6SE489. When working on the alternator, be careful not to come in contact with the exhaust manifold or turbocharger, as these components may be hot

SECTION 7.1 – BATTERY CHARGING ALTERNATOR

ALTERNATOR MAINTENANCE

Maintain proper drive belt tension as noted in Section 15.1. Replace frayed or worn belts. Belts should always be replaced as a matched set when dual belts are used.

NOTE: When installing or adjusting an alternator drive belt, be sure the bolt at the alternator pivot point in properly tightened, as well as the nut on the adjusting rod.

Alternator bearings are permanently lubricated. There are no external provisions for alternator bearing lubrication.

ALTERNATOR WIRING TEST

Any output of the alternator must reach the batteries and accessory loads with a minimum amount of voltage loss. Any loss shows the rate of charge to the batteries and could cause the batteries to be in some state of discharge. This voltage loss can appear to the technician as a faulty alternator or voltage regulator.

Before a suspected bad alternator or regulator is replaced or removed for service, the cables and connections between the alternator and the storage batteries should be checked for high resistance as follows:

CHARGING CIRCUIT VOLTAGE DROP TEST

Before the charging circuit voltage drop test is performed, the batteries should be load–tested to ensure they are suitable for service. Refer to the appropriate battery manufacturer's service instruction for load test information. Replace any batteries that fail a load test. All battery terminals should be cleaned and tightened. Then proceed as follows:

11. With the engine not running, connect a carbon pile to the altemator output terminal and the alternator housing as shown in Figure 2.

NOTICE:

Use care when connecting the carbon pile to the alternator output terminal, not to allow the pile clamp to touch ground. The output terminal is at battery voltage.

12. Connect a voltmeter across one of the batteries, red lead to positive and black lead to negative as shown in A in Figure 2.
13. With the engine not running, turn the knob of the carbon pile until the gage on the carbon pile reads the alternator rated output in amps.

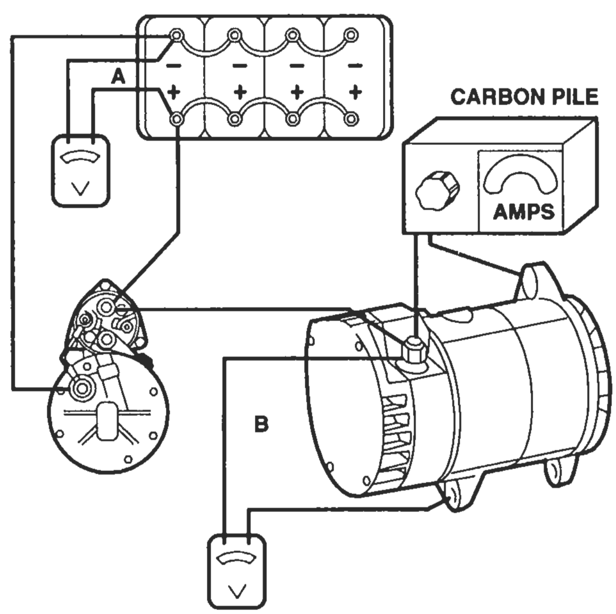

Figure 2. Charging Circuit Voltage Drop Test

CHARGING CIRCUIT VOLTAGE DROP TEST (CONT.)

NOTE: The alternator's rated output is typically stamped on the alternator housing or on a name tag located on the alternator housing.

14. Read and record the battery voltage. Turn the carbon pile off.
15. Move the the voltmeter to the alternator. Connect the red voltmeter lead to the alternator output terminal and the black voltmeter lead to the alternator housing as shown in B in Figure 2.

NOTE: Do not connect the voltmeter leads to the carbon pile leads.

16. Turn the carbon pile knob until the meter again reads alternator rated output in amps.
17. Read and record the voltage at the alternator. Turn the carbon pile off.
18. Subtract the voltage reading recorded at the alternator from the voltage reading obtained at the battery.

Voltage Reading at Batt.		Voltage Reading at Alt.		Total Voltage Drop
_________ v.	–	_________ v.	=	_________ v.

19. The result is a measure of the charging circuit voltage drop. Maximum allowable charging circuit voltage drop is .5 volts for a 12 volt system (1.0 volts for a 24 volt system).
20. If the voltage drop reading was below specification, the system is satisfactory. Go to the alternator output test. If the reading was more than allowed, it will be necessary to determine if the voltage drop is located in the positive or negative side of the charging circuit. Go to the next step.

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21. With the carbon pile still connected, connect a low scale voltmeter (digital preferred) as shown in Figure 3.
22. Connect the red lead of the voltmeter to a battery positive terminal. Connect the black voltmeter lead to the alternator output terminal as shown in Step 1, Figure 3. (you may need a jumper wire to extend the voltmeter leads).
23. Turn the carbon pile knob until the gage on the carbon pile reads the alternator rated output in amps.
24. Read and record the voltmeter reading. Turn the carbon pile off.
25. Connect the voltmeter leads to the negative side of the charging circuit as shown in Step 2, Figure 3.

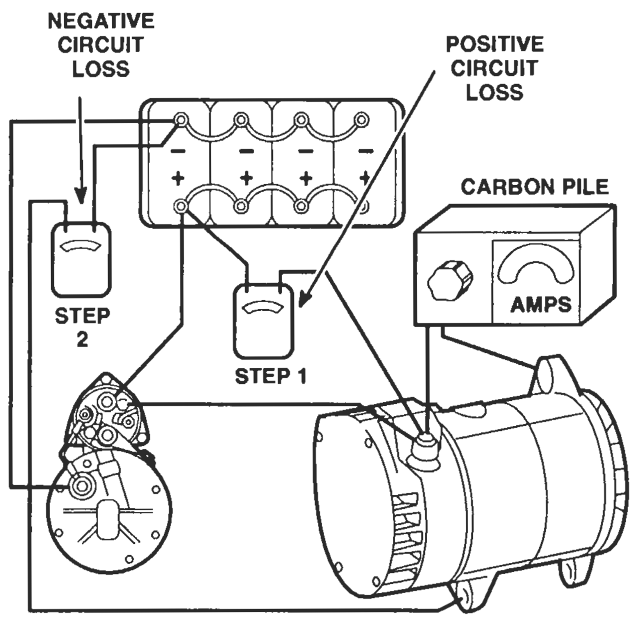


Figure 3. Charging Circuit Voltage Drop Test

SECTION 7.1 – BATTERY CHARGING ALTERNATOR

CHARGING CIRCUIT VOLTAGE DROP TEST (CONT.)

26. Connect the red voltmeter lead to the alternator housing and the black voltmeter lead to the battery negative terminal.
27. Turn the carbon pile knob until the gage on the carbon pile reads the alternator rated output in amps.
28. Read and record the voltmeter reading. Turn the carbon pile off.
29.

Positive Circuit Loss		Negative Circuit Loss		Total System Loss
_____ v.	–	_____ v.	=	_____ v.

12 volt system – 0.5 volts maximum
24 volt system – 1.0 volts maximum

30. The above procedure should show which circuit has the excessive voltage loss. Remove the carbon pile and voltmeter. Repair or replace the problem in the proper circuit.

ALTERNATOR OUTPUT TEST

If the wiring in the circuit is adequate, adjust the alternator drive belts to the specifications found in Section 15.1. Tighten both the alternator mounting bolts (adjusting rod and pivot point) and be sure all the charging circuit cables and connections are clean and tight. Then test the alternator output as follows:

1. The engine must be at shop temperature. Connect a charging–starting system analyzer, with a voltmeter, to the vehicle. Connect the volt meter leads to one of the batteries, observing proper polarity. If the analyzer has an inductive pickup, place it around the alternator output wire (Figure 4.)
2. If the charging–starting system analyzer does not have a carbon pile, connect a carbon pile across one of the batteries.

NOTE: On 24 volt vehicles, connect the carbon pile across one 12 volt battery. Connect the voltmeter across the normal 24 volt battery connection.

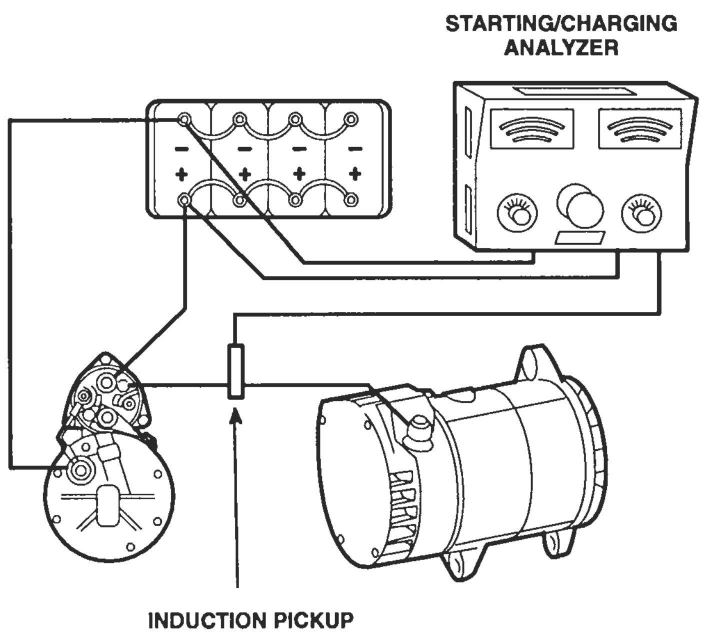


Figure 4. Alternator Output Test

CHARGING CIRCUIT VOLTAGE DROP TEST (CONT.)

3. With no electrical loads turned on, start the engine and accelerate to a fast idle. Observe the volt meter. When the voltage stabilizes (does not increase) for two minutes, read and record the voltage. Voltage should not exceed 15 volts (30 volts for a 24 volt system). If the voltage exceeds the maximum allowable by one volt, the voltage regulator is defective. Remove the alternator for repair.
4. If the voltage was acceptable, accelerate the engine to approximately 1,800 r/min and turn the carbon pile knob until the ammeter shows the output has reached the highest value. Record this reading _______ amps. Turn off the carbon pile. Allow the engine to idle down for at least 30 seconds. Turn off the engine.
5. The alternator rated output is stamped on the alternator case or on a name tag on the alternator housing. Compare the reading obtained in Step 4 above, to the alternator's rated output. If the current measured is not within 10% of the rated output, remove the alternator for repair.

ALTERNATOR REMOVAL

Refer to Figure 5. for alternator parts location.

CAUTION:

With the exception of the DDEC system, never attempt to service any engine electrical systems until the batteries have been disconnected. For procedures covering service and diagnostics of the DDEC system, refer to Section 2.7 and the DDEC Troubleshooting Guide 6SE489. When working on the alternator, be careful not to come in contact with the exhaust manifold or turbocharger, as these components may be hot.

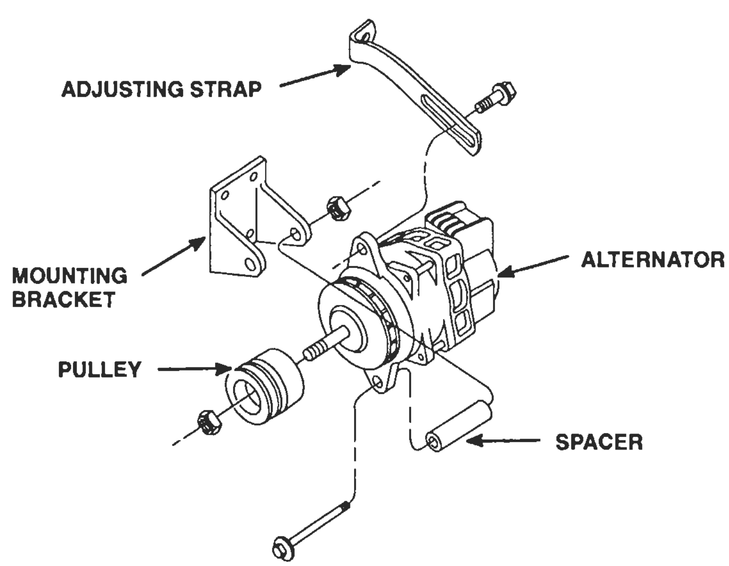


Figure 5. Typical Alternator and Related Parts Location

ALTERNATOR REMOVAL (CONT.)

1. Disconnect the cables at the batteries. If the alternator has more than the output cable lead, disconnect all other leads from the alternator and tag each one to ensure correct reinstallation. Remove the alternator output cable.
2. Loosen the alternator mounting bolts and adjusting rod nut to allow slack in the drive belts. Remove the drive belts.
3. While supporting the alternator, remove the adjusting rod bolt and hardened washer.
4. Loosen and remove the nut and washer at the rear alternator mounting flange. Remove the alternator–to–bracket bolt while supporting the alternator to prevent it from falling.
5. Remove the alternator carefully to prevent costly physical damage.
6. Remove and retain the alternator pulley locknut, alternator pulley and locknut, alternator pulley and fan from the unit if it is to be replaced.

ALTERNATOR SERVICE

Repair and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of the alternator. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco–Remy Division, repair service and part are available through AC Delco branches and repair stations.

ALTERNATOR INSTALLATION

1. Install the alternator mounting bracket, if removed. Torque the mounting bolts to 43–54 lb·ft (58–73 N·m). If removed, install the fan, drive pulley and locknut to the alternator. Tighten the pulley retaining nut to 70–80 lb·ft (95–108 N·m) torque.

NOTE: If the pulley was not removed, check the retaining nut for proper torque.

2. Position the alternator on the mounting bracket and align the holes in the alternator mounting flanges with the tube in the bracket.
3. Install the alternator–to–bracket bolt and locknut. Insert the adjusting rod bolt with washer installed, through the adjusting rod bracket and into the threaded hole in the alternator end frame. Tighten both bolts finger tight.

NOTE: There are two holes in the front alternator end frame mounting flanges. One is threaded and one is plain. The threaded hole is positioned up and is used to secure the alternator to the adjusting rod.

4. Install the drive belts in the grooves of the alternator and accessory drive pulleys.
5. Adjust the alternator belt tension as outlined in Section 15.1. Tighten the alternator–to–mounting bracket bolt and nut and the alternator–to–adjusting rod bracket bolt to 60–70 lb·ft (81–95 N·m) torque.
6. Attach the wires and cables to the alternator. Be sure that each one is correctly installed on the location it was removed from. Keep all connections clean and tight.
7. If new belts have been installed, start and operate the engine at approximately 1,200 r/min for ten to fifteen minutes and then allow the engine to idle for at least 30 seconds before stopping the engine. Recheck the alternator belt tension and adjust if necessary as outlined in Section 15.1.

STORAGE BATTERY

The lead–acid storage battery is an electro–chemical device for storing energy and converting chemical energy into electricity.

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 system demands exceed the output of the alternator.

In the selection on a replacement battery, it is always a good practice to select one of an “electrical size” at least equal to the battery originally engineered for the particular equipment by the manufacturer (Figure 1.)

		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)**
3–71 4–71	12V	950	1250
6–71	24V, 32V	475	625

*** Recommendation based on the use of Delco–Remy 42 MT (or equivalent) cranking motor.**

Figure 1. Battery Recommendations

BATTERY INSTALLATION

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.

Maintenance –Free Type Batteries

1. On batteries equipped with charge indicator "eyes", periodically check for adequate charge.
2. 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.

Filler Cap–Type Batteries

CAUTION:

Battery electrolyte is acid. Extreme caution should be exercised to prevent skin or eye contact with the electrolyte.

1. If the batteries are equipped with filler caps, check the level of the electrolyte regularly. Add distilled water, if necessary, but do not overfill. Overfilling can cause poor performance or early failure.
2. 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 battery cells.
3. Inspect the cables, clamps and hold–down bracket regularly. Clean and reapply a coat of grease when needed. Replace corroded or damaged parts.
4. Use the standard battery test as the regular service test to check the condition of the battery.
5. 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 the electrolyte can cause personal injury. Battery electrolyte is acid. Extreme care should be exercised to avoid skin or eye contact with the electrolyte. If you come in contact with the battery electrolyte:

1. Flush your skin with water.
2. Apply baking soda or lime to help neutralize the acid.
3. Flush your eyes with water for 10–15 minutes.
4. Get medical attention immediately.

CRANKING MOTOR

The cranking motor (Figure 1.) is bolted to the flywheel housing.

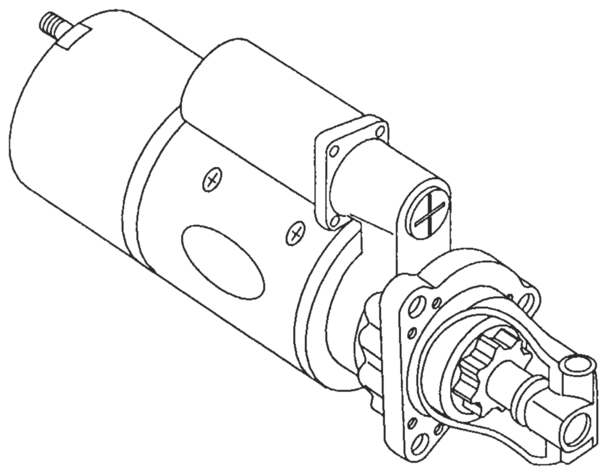


Figure 1. Cranking Motor Mounting

When the cranking circuit is closed, a 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 cranking motor. To accomplish this, the starting motor is equipped with an overrunning clutch within the drive pinion. The cranking motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

The 42 MT cranking motor typically used on the Series 71 engine has a nose housing that can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. High durability features include a newly designed drive, solenoid, brush rigging and one–piece brushes. Also, the commutator end cap can be removed to inspect the brushes, in most cases, without removing the cranking motor from the vehicle.

NOTE: Some engines may be equipped with air starters. Contact starter manufacturer for operating characteristics and rebuilding procedures.

CRANKING MOTOR (CONT.)

The cranking motor armature is supported by three sintered bronze bushings located one each in the nose and immediate housings, and one in the commutator end cap (Figure 2.)

Sintered bronze bearings used in these motors have a dull finish, as compared to the early–type machined, cast bronze bearings which had a shiny finish.

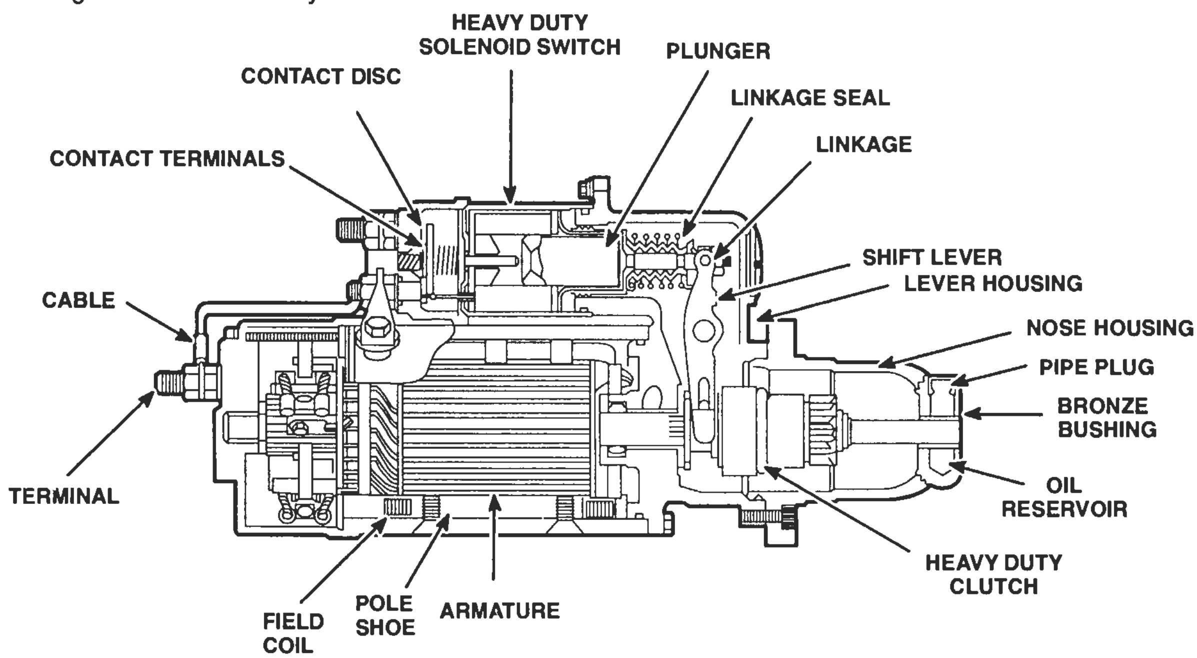


Figure 2. Typical Cranking Motor Cross–Section

There are many different cranking circuits (Figure 3.) used on various applications. The cranking circuit may contain a key start switch or push switch, or both, a relay, magnetic switches, solenoids, oil pressure switch, fuel pressure switch and other protective devices. Reference should be made to the vehicle manufacturer's wiring diagram for the complete cranking circuit.

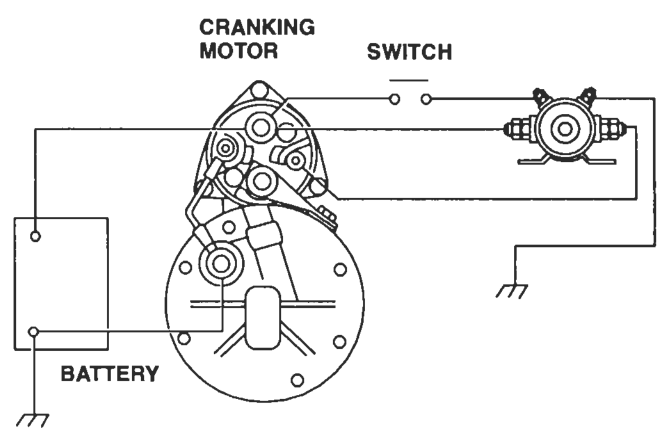


Figure 3. Basic Cranking Circuit

CRANKING MOTOR (CONT.)

A solenoid, mounted on the cranking motor housing, operates the overrunning clutch drive by linkage and a shift lever. When the start switch is closed, the contacts of the magnetic switch close and the solenoid windings are connected to the battery. The resulting plunger and shift lever movement causes the pinion to engage the engine flywheel ring gear and the solenoid main contacts close, and the cranking takes place. When the engine starts, pinion overrun protects the armature from excessive speed until the switch is opened, at which time the return spring causes the pinion to disengage. To prevent excessive overrun and damage to the drive and armature windings, the switch should be opened immediately when the engine starts. A cranking period should not exceed 30 seconds without stopping to allow the motor to cool for at least two minutes.

CRANKING MOTOR REPLACEMENT DETERMINATION

Failure of the cranking 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 cranking motor. To determine if the cranking motor is the problem, it will first be necessary to check the batteries by performing a load test. Refer to the appropriate battery manufacturer's instructions. If the batteries pass a load test, and a visual inspection of the cranking circuit does not reveal an obvious problem, use the following guidelines.

Circuits using a magnetic switch can fail to "hold in" during cold weather cranking and low voltage even though the switches and circuit test OK. This will sound as though the cranking motor is failing to stay engaged. It is caused by the low voltage of the system releasing the electrical connection of the magnetic switch.

If this condition exists, have an assistant clamp a heavy battery jumper cable between the two large studs of the magnetic switch while cranking.

CAUTION:

The magnetic switch studs are at battery voltage and the engine should crank when the jumper is connected.

Remove the jumper to stop cranking. If the engine cranks normally with this jumper in place, replace the magnetic switch.

If the batteries, switches, and wiring have been checked and the cranking motor still cranks slowly, check for available voltage at the cranking motor solenoid while cranking.

CRANKING MOTOR REPLACEMENT DETERMINATION (CONT.)

Place the red lead of a voltmeter to the solenoid "BAT" terminal, and the black voltmeter lead to the starter ground terminal (Figure 4.) Engage the starter switch and read the voltage on the meter. If the voltage is 9.0 volts or less **while cranking** (18.0 volts if it is a 24 volt system) at room temperature, check the interconnecting cables between batteries.

To check the interconnecting battery cables, quickly measure the terminal voltage of each battery while cranking. Touch voltmeter leads to the post or stud nut of each battery. If the difference between any two battery readings is more than 0.5 volt, or any cable or connection feels warm to the touch, check or replace the interconnecting cable.

After making all of the checks as described above, and the vehicle still does not crank properly, there is either an internal engine problem, or the cranking motor should be removed for repair.

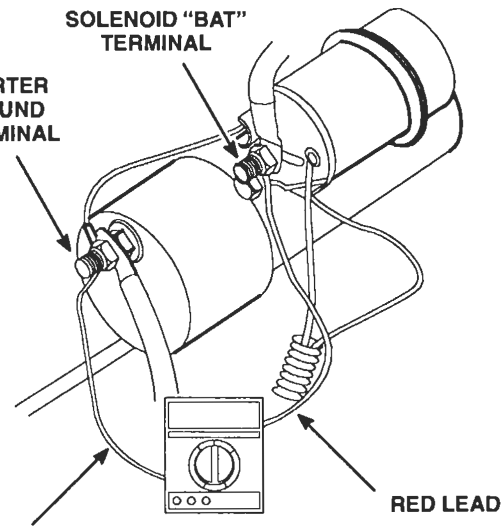


Figure 4. Cranking Motor Available Voltage Test

CRANKING MOTOR REMOVAL

CAUTION:

Never attempt to service engine electrical systems (except DDEC) until the batteries have been disconnected.

5. Remove the ground strap or negative cable(s) from the battery(s).
6. Disconnect the cranking motor cables and solenoid wiring.

NOTE: Tag each lead to ensure correct connections when cranking motor is reinstalled.

7. Support the motor and remove the three bolts which secure it to the flywheel housing. Pull the motor out to remove it from the flywheel housing.

NOSE HOUSING RELOCATION

The nose housing on the sprag clutch–type cranking motor on some starters can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. When repositioning of the solenoid is required on a service replacement cranking motor, proceed as follows:

The nose housing is attached to the lever housing by six bolts located around the outside of the housing. Relocate the nose housing as follows:

1. Remove the six socket head screws (one short and five long) and six neoprene plugs from the unused holes if a twelve–hole mounting flange is used.
2. Turn the nose housing to the required position.

NOTICE:
The solenoid should not be located below the centerline of the cranking motor or dust, oil, moisture and foreign material can collect and cause solenoid failure.

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 mounting flange is used.
4. Tighten the screws to 13–17 lb·ft (18–23 N·m) torque.

CRANKING MOTOR INSTALLATION

To install the cranking motor, reverse the procedure outlined for removal. Tighten the cranking motor attaching bolts to 138–154 lb·ft (187–209 N·m) torque.

Keep all of the electrical connections clean and tight. If equipped with a 42 MT, install wiring terminal leads to the cranking motor and the solenoid switch and tighten the smaller connections to 16–30 lb·in (1.8–3.4 N·m) torque and the larger connections to 20–25 lb·in (27–34 N·m) torque.

NOTE: If a cast iron flywheel housing is used, the cranking motor attaching bolts should be tightened to 181–226 lb·in (245–306 N·m) torque.

ENGINE PROTECTIVE SYSTEMS

A manually operated emergency engine shutdown device 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 shutdown device consists of a flap valve mounted in the air inlet housing and a suitable operating mechanism.

OPERATION

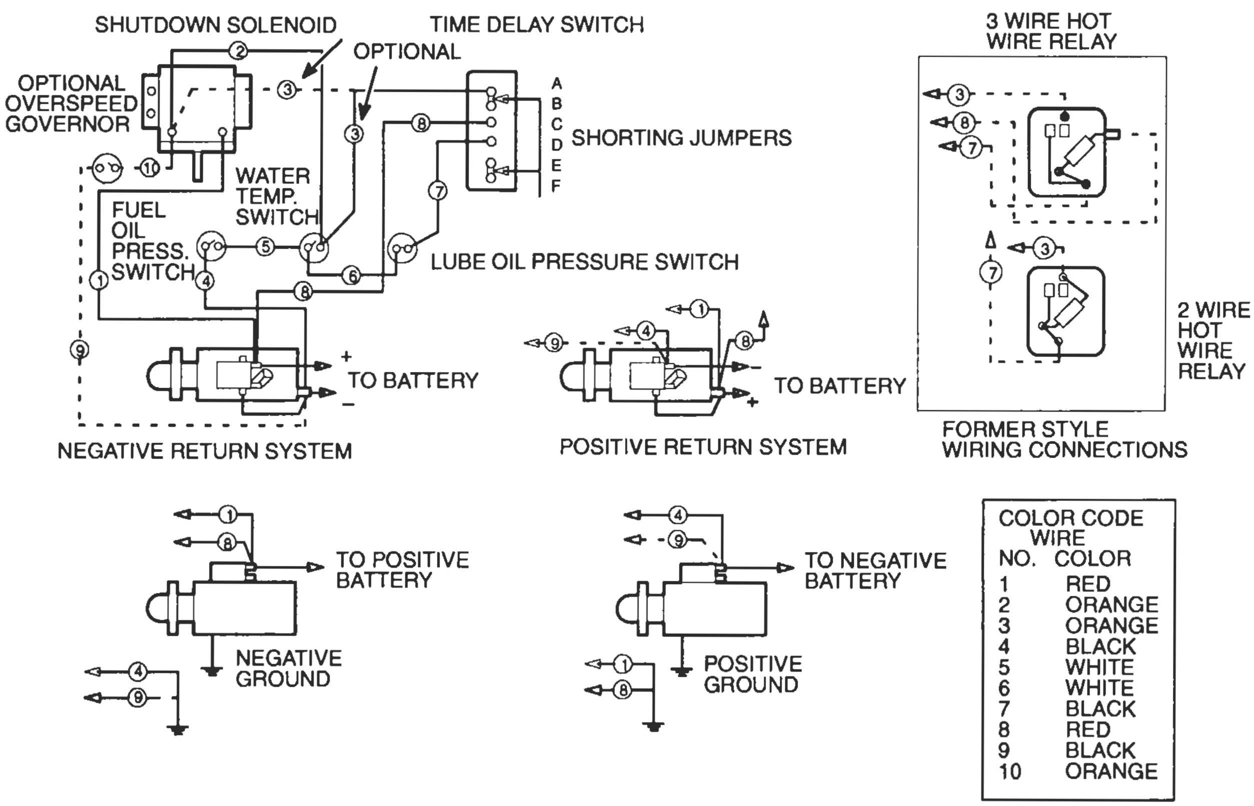
The manually operated shutdown device is operated by a knob located on the instrument panel and connected to a latch on the valve shaft by a Bowden wire or cable assembly. Pulling the shutdown knob all the way out will stop the engine. Push the knob all the way in and manually reset the air shutdown device in the shutdown housing 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 ELECTRICAL SHUTDOWN

The electrically operated automatic shutdown includes a fuel pressure switch, a lubricating oil pressure switch, a water temperature switch and a shutdown solenoid (Figure 1.)



WIRE NO.	COLOR
1	RED
2	ORANGE
3	ORANGE
4	BLACK
5	WHITE
6	WHITE
7	BLACK
8	RED
9	BLACK
10	ORANGE

Figure 1. Automatic Shutdown Wiring Diagram

AUTOMATIC ELECTRICAL SHUTDOWN (CONT.)

An overspeed governor switch may be employed separately or in conjunction with the above electrical shutdown system.

A hot wire relay or a solid state time delay switch may be introduced into the electrical shutdown system to prevent the fuel oil pressure switch from closing before the lubricating oil pressure switch opens, which would cause a shutdown of the engine.

When the engine is not running, the fuel oil pressure switch is open, the lubricating oil pressure switch is closed and the water temperature switch is open.

After starting the engine, the lubricating oil pressure switch contacts are open when the oil pressure is ten lb/in.^{2} (69 kPa) or higher (approximately 700 r/min), and the fuel oil pressure switch contacts are closed when the fuel oil pressure is 20 lb/in.^{2} (138 kPa) or greater (approximately 800 r/min). The electrical circuit of this system is so arranged that the closing of the fuel pressure switch energizes the entire system, and at anytime thereafter, the closing of either the lubricating oil pressure switch or water temperature switch will cause the shutdown to operate. When the engine starts, the fuel pressure increases so rapidly that the fuel pressure switch contacts close before the lubricating oil pressure reaches ten lb/in.^{2} (69 kPa). This condition would cause the engine to shut down, except for the introduction of a hot wire relay or a solid state time delay switch into the circuit. This relay or time delay switch delays the energizing of the shutdown solenoid by three to ten seconds, enabling the lubricating oil pressure to exceed ten lb/in.^{2} (69 kPa), thereby opening the lubricating oil pressure switch and preventing the energizing of the circuit. When the engine has reached normal operating speed, the fuel oil pressure switch is closed and the lubricating oil pressure switch is open.

When the lubricating oil pressure falls below ten ± two lb/in.^{2} (69 ± 14 kPa), the oil pressure switch closes and current flows to the hot wire relay or time delay switch which must be heated by the current to complete the circuit to the solenoid. The few seconds required to heat the hot wire relay or time delay switch provides sufficient delay to avoid engine shutdown when low oil pressure is caused by a passing condition such as an air bubble or by the temporary overlap in the operation of the lubricating oil pressure switch and fuel pressure during starting and stopping of the engine.

The high water temperature switch is connected in parallel with the lubricating oil pressure switch and normally remains open, closing only when the engine coolant temperature exceeds 200 ± 5°F (93 ± 3°C) thus energizing the shutdown solenoid.

The overspeed governor is driven by the blower drive shaft. If the engine speed exceeds the speed which has been established by the engine governor, the overspeed governor switch is actuated, causing the shutdown solenoid to close the shutdown valve.

When the engine is shut down, as described above, the fuel oil pressure switch opens, thus breaking the circuit and eliminating the possibility of damage due to continued exposure to current.

TIME DELAY SWITCH

The current solid state time delay switch is designed as a direct replacement for the former hot wire relay.

It is a solid state time device which effectively withstands shock and vibrations. The switch is polarity conscious. If a reverse polarity is applied the switch will not work.

The switch has two circuits: a time circuit and an electronic circuit which consists of a silicon control rectifier. The rectifier has sufficient capacity to handle standard loads such as the emergency shutdown solenoid. Abnormal load situations such as a collapsing magnetic field in a coil can damage the rectifier rendering it inoperative. To protect the rectifier a discharge diode is connected across the terminals B and C of the solid state time delay switch. Check the time delay switch periodically to be sure it is operating properly (Section 7.0.)

FUEL OIL PRESSURE SWITCH

From the above description, it can be seen that the fuel oil pressure switch is the controlling switch of the system, since this switch controls the flow of current to the other two switches. As previously stated, the fuel oil pressure switch is set to make contact when the fuel pressure reaches 20 lb/in.^{2} (138 kPa), and the phrase "20–MAKE" is stamped on the switch cover.

As the fuel pressure increases upon starting, a diaphragm in the switch body is expanded and forces the plunger upwards. 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 lb/in.^{2} (138 kPa), the breaker points close and the current flows to the terminals of the lubricating oil pressure switch and the water temperature 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 oil pressure decreases to 20 lb/in.^{2} (138 kPa), permits the lower breaker point arm to lower, thus breaking 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 points when the fuel pressure decreases sufficiently.

LUBRICATING OIL PRESSURE SWITCH

The lubricating oil pressure switch is similar to the fuel oil pressure switch, except that the fuel oil pressure switch is of the "make" type while the lubricating oil pressure switch is of the "break" type. In other words, the lubricating oil pressure switch is calibrated to break contact when the lubricating oil pressure increases to 10 lb/in.^{2} (69 kPa). The phrase "10–BREAK" is stamped on the switch cover.

As the lubricating oil pressure increases when the engine starts, the diaphragm in the switch body expands and forces the plunger upwards. 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 ten lb/in.^{2} (69 kPa), the points separate. However, as previously described, 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 pressure switch are open. If the lubricating oil pressure decreases to ten lb/in.^{2} (69 kPa) during operation, the breaker point will close and either the alarm bell or the shutdown solenoid will be energized.

WATER TEMPERATURE SWITCH

The terminals of the water temperature switch are connected into the shutdown system, and when the engine circulating water temperature reaches 205 ± 5°F (96 ± 3°C), the switch closes and energizes the shutdown or alarm system.

As the water temperature increases, a plunger rises and contacts a wheel which is attached to the switch actuating lever. A further increase in water temperature forces the contact end of the actuating lever upwards.

When the water temperature reaches 205 ± 5°F (96 ± 3°C), this lever forces the switch button upwards into the switch block thus closing the switch. Since this lever is spring loaded, the contact end of the lever moves away from the switch button as the water temperature decreases.

If the engine has been stopped by any of the above mentioned switches, the shutdown valve must be reset in the open position before the engine can be started.

SHUTDOWN SYSTEM FOR DIRECT MOUNTED TURBOCHARGED ENGINES

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 shutoff 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 shutoff valve can be installed upstream of the air inlet side of the turbocharger.

Care should be taken when installing the emergency air shutdown assembly 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 seven to five inch diameter reducing 90° rubber hose or a seven to five inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

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 is similar in many respects to the automatic shutdown system, but does not include the automatic shutdown feature incorporating the electrical solenoid or the flap valve in the air shutdown housing which is operated by the solenoid. A bell is substituted for the solenoid in the alarm system. The alarm may be substituted for the shutdown solenoid, or it may be added to the automatic shutdown system. In either case, the alarm notifies the operator of a dangerous condition in the engine (Figure 1.)

The voltage used for the alarm bell, however, must not exceed 12 volts.

Note that the cranking motor performs no essential function in the circuit.

An oil pressure switch, introduced into the engine oil gallery, is closed when the engine is not running, but opens after starting and remains open while the engine is running. This switch will close only in case of lowered oil pressure, thus causing the alarm to operate, or it will close if the engine is stopped by the operator. A water temperature switch, mounted in the water manifold, always remains open except in case of high water temperature when it closes and operates the alarm.

An automatic fuel oil switch closes after the engine is started and normal fuel oil pressure has been attained.

An optional overspeed switch is sometimes introduced into the system.

The water temperature switch and the oil pressure switch are similar to the same switches used in the automatic shutdown device.

Service of the alarm system is usually limited to replacement of the alarm bell.

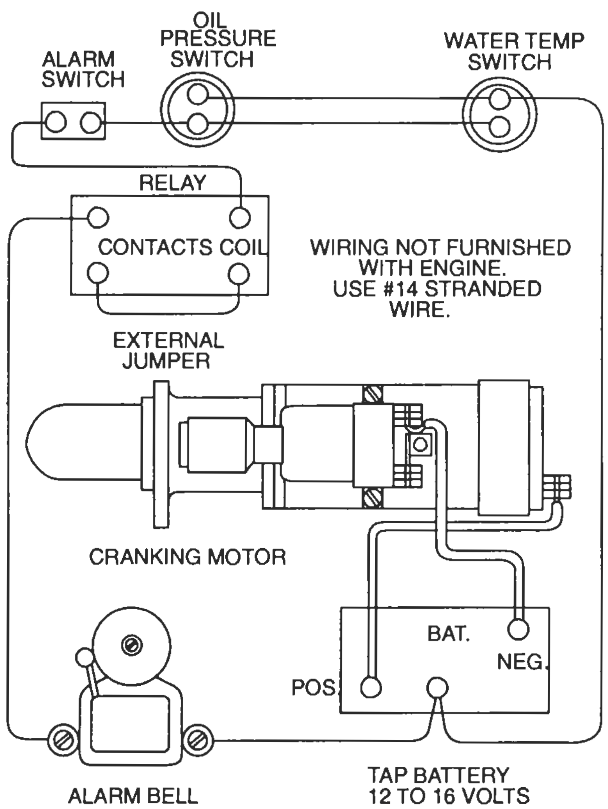


Figure 1. Alarm System Wiring Diagram

OVERSPEED GOVERNORS

Certain engines are equipped with an electric overspeed governor or a hydraulic overspeed governor to prevent excessive engine speeds.

The governors are adjustable in the full–load engine speed range of 1,200 to 2,300 r/min.

The electric overspeed governors are mounted on the flywheel housing and are driven by the engine blower drive shaft, the cam shaft or balance shaft. The governors are connected electrically to a solenoid which actuates the shutdown mechanism on the air inlet housing or actuates a warning device.

The hydraulic overspeed governor is mounted in an adaptor which is mounted on the rear of the flywheel housing and is normally driven from the blower drive shaft. The shutdown mechanism on the air inlet housing is activated by an oil bellows (Section 7.4.1).

ELECTRIC OVERSPEED GOVERNOR (SINGLE SWITCH)

Overspeed governors are calibrated by the manufacturer to open or close the switch contacts at the particular speed required. The switch contacts will reset automatically when the speed is reduced approximately 100 r/min below the trip speed.

SERVICE

All single switch electric overspeed governors contain sealed ball bearings which have sufficient grease for their useful life. The oil seal may be inspected and, if necessary, replaced as follows:

1. Remove the adjusting screw and the adjusting stud, then remove the governor cap.
2. Insert a sharp pointed instrument in the loop of the spring clip and pull the clip from the flexible shaft as far as possible. Then remove the shaft assembly.
3. Remove the retaining ring from the groove in the housing.
4. Remove the weight and shaft assembly.
5. Inspect the oil seal and, if necessary, replace the seal as follows:
   a. Place the governor body in an arbor press with the mounting flange facing down and use a 9/16 inch diameter rod to press the oil seal out of the body.
   b. Press the new oil seal in place, 3/64 inch from the bottom of the bearing cavity.
6. Reassemble the governor by reversing the procedure for disassembly and adjust the trip speed as outlined below.

SPEED ADJUSTMENT

Loosen the cap adjusting lock screw and turn the cap until the desired trip speed is reached. Clockwise rotation of the cap lowers the trip speed and counterclockwise rotation increases the trip speed. The total range of adjustment of the particular governor is indicated on the governor name plate. The governor should not be adjusted to trip below 100 r/min above the normal running speed of the engine. Make sure the governor cap locking screw is tightened after the adjustment has been completed.

NOTICE:

Under no circumstances should the governor switch be bypassed to prevent engine shutdown in the event of overspeed, otherwise serious damage to not only the engine but also to the governor may be incurred since the governor is not designed to operate above its tripping speed.

ELECTRIC OVERSPEED GOVERNOR (TWO SWITCH)

Syncro–Start overspeed governors contain two separate snap action switches with single pole double throw contacts which operate at two different speeds. The governors are 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. Contacts will return to normal when speed is decreased approximately 100 r/min below 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.

The current overspeed two switch governor with "Licon" switches (Figure 1.) is less sensitive to minor speed changes than the former "Micro" two switch governor.

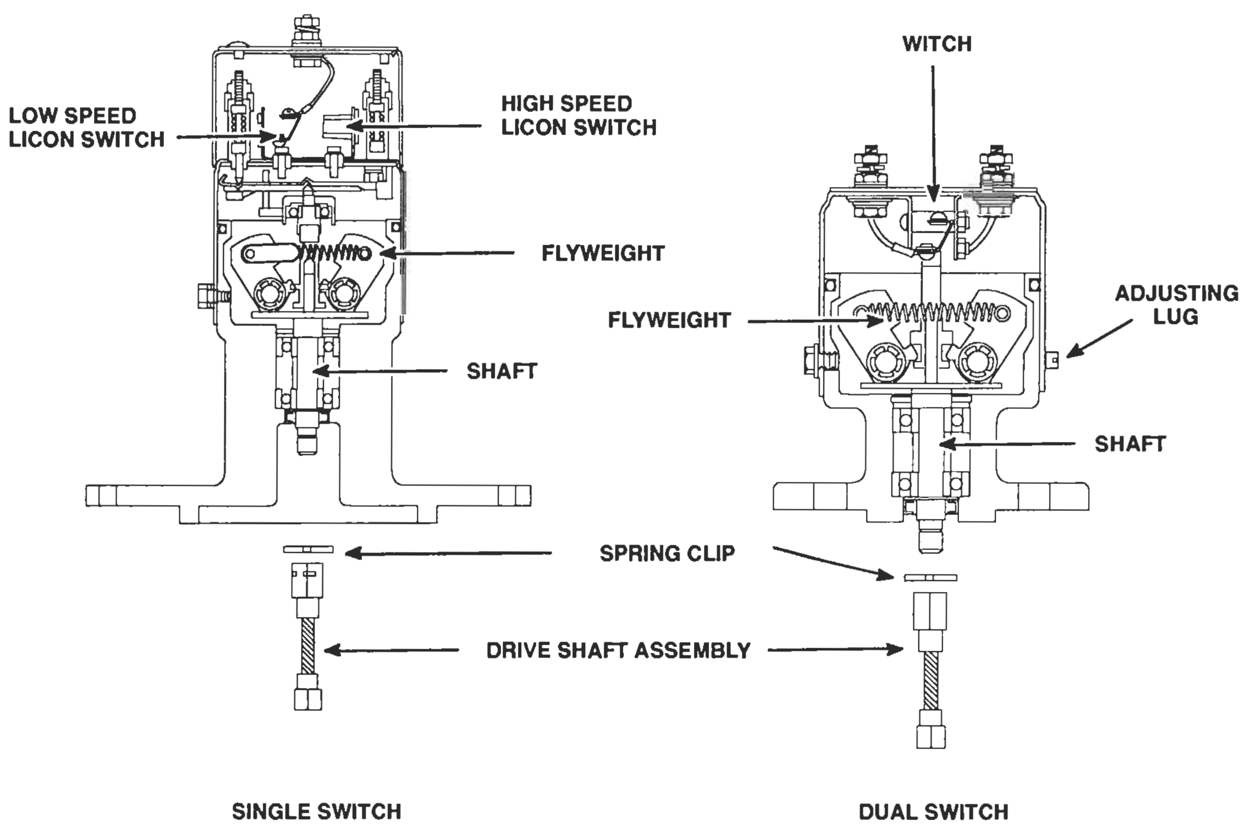


Figure 1. Electric Overspeed Governor (Licon Switch)

ELECTRIC OVERSPEED GOVERNOR (TWO–SWITCH) (CONT.)

A series GW–2N syncro–start overspeed governor is used on the railcar engine. It is the same as the other overspeed governors except that it has a six point connector and wire lead assembly attached to the governor cover, (Figure 2.) for a quick disconnect. The service and speed adjustments of the GW–2N is the same as the GW–2 and GY–2 series governors.

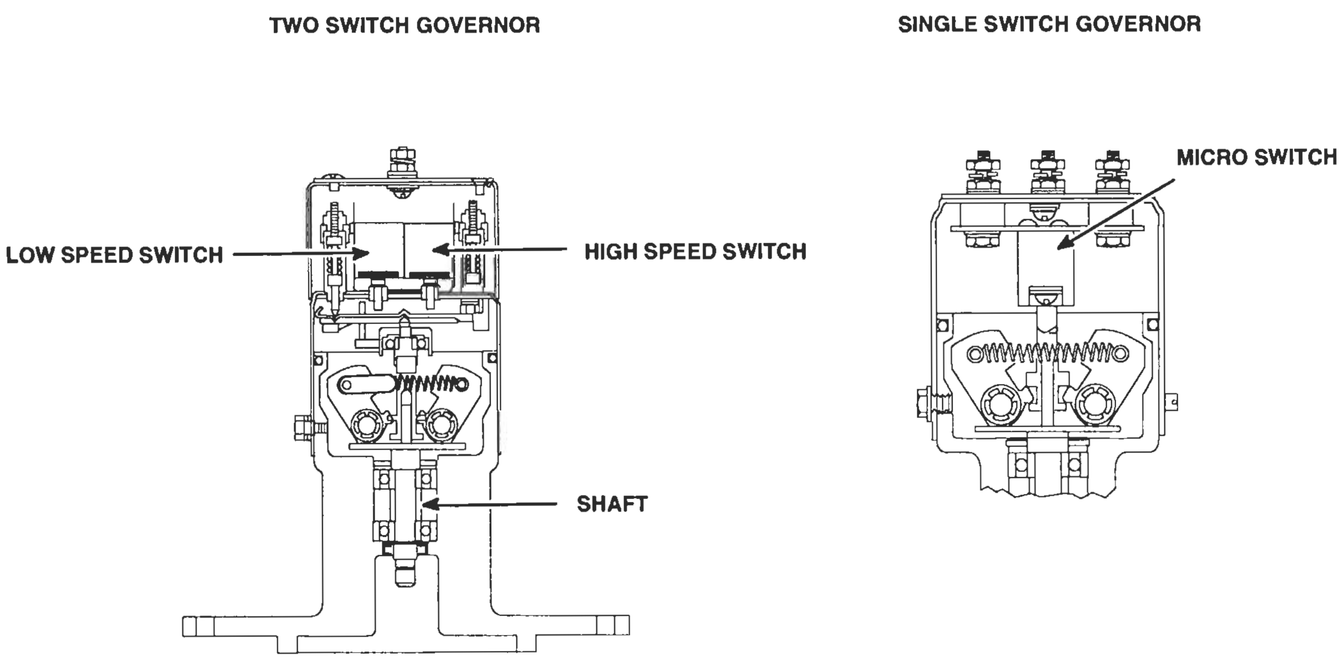


Figure 2. Electric Overspeed Governor (Micro Switch)

 May, 1994

SERVICE

1. The snap action switches may be replaced as follows:
   a. Mark the position of the dust cover.
   b. Remove the hold down screws.
   c. Observe the position of the switches. Usually they are positioned with 1/64 inch 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.
   d. Install the new switch and reassemble by reversing the above procedure.

NOTE: When replacing the dust cover on governors with manual reset, make certain that the switch wiring does not interfere with the reset mechanism.

   e. Adjust the speed as outlined under "Speed Adjustment".
2. Remove the governor cap as follows:
   a. Observe the marking on the cap and body.
   b. Remove the three holding screws.
   c. Remove the cap assembly being careful not to damage the seal ring.
   d. Replace any internal parts as required.
   e. Reassemble and return the cap to its original position. A light coat of grease will facilitate assembly of the seal ring to the body.

NOTE: The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1,000 r/min and the trip point of the high speed switch is above 2,100 r/min. 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.

   f. 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 inch open end wrench and loosen the adjusting stud nut with a 3/8 inch 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, 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 onto the square end of the governor shaft and the spring clip will snap in place.

NOTE: Check the position of the spring clip. If the clip has sprung out of position, use a small screwdriver to push it into place.

SECTION 7.4.3 – OVERSPEED GOVERNORS

SERVICE (CONT.)

5. Adjusting governor cap (with 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 inch 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 inch from the top of the dust cover.
   c. With partial tension on the cap holding screws, turn the governor cap to its maximum extended position.
   d. Operate the governor at 200 r/min 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 engine.
   f. Turn the cap another 1/16 inch and lock the holding screws securely.
   g. 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.

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 2,500 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 over–grease 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:
   a. Place the governor body in an arbor press with the mounting flange toward the bottom and use a 9/16 inch diameter rod to press out the oil seal.
   b. Press a new oil seal in place 3/64 inch from the bottom of the bearing cavity.
   c. 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. The dust cover screw marked “1” covers the low speed adjuster. The screw marked “2” covers the high speed adjuster. Proceed as follows:

1. Remove the appropriate dust cover screw.
2. Insert a 1/16 inch Allen wrench into the adjusting screw.
3. Turn the screw clockwise to increase the trip speed, or counterclockwise to decrease.

NOTE: 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 operating in the speed range required.

SYNCHRO–START MODEL GSG ELECTRIC OVERSPEED GOVERNOR

The Model GSG Synchro–Start overspeed governor is used on certain engine applications that operate in a speed range from 1,800 to 2,000 rpm at full load. This governor provides a simplified method of speed adjustment, thus facilitating engine overspeed setting.

OPERATION

In operation, the engine drives a set of weights that are held together by a pair of governor springs. When the speed of the engine approaches the overspeed setting, centrifugal force of the weights overcomes the tension of the governor springs and the weights move outward, allowing the shoulder on the weights to move the plunger. As the speed continues to increase, the weights move further apart, moving the plunger closer to the micro–switch. This movement of the plunger continues until the governor trip setting is reached and the micro–switch trips, completing or breaking the electrical circuit.

SERVICE

The governor should be lubricated every 100 hours with a few drops of engine oil in the oil cup.

ADJUSTMENT

The overspeed governor is adjusted by moving the micro–switch, which is attached to the cover of the governor, in relation to the plunger. This adjustment can be accomplished very readily by loosening the adjusting locking screw holding the governor cover. Rotating the cover clockwise when viewing the governor from the terminal end will lower the overspeed setting, while rotating the cover counterclockwise will increase the overspeed setting.

SHOP NOTES – TROUBLESHOOTING SPECIFICATIONS – SERVICE TOOLS

When a direct current battery–charging alternator regulator is remotely mounted rather than mounted on the engine, it should be mounted on a vertical surface which is as free from vibration as possible. It is preferable that the terminals be pointed downward, although this is not absolutely necessary.

It is recommended that shock absorbing mountings be used. On marine installations, where the vessel is subject to shock from docking, the regulator should be mounted in the vertical position.

By adhering to these recommendations, proper operation and long life of the regulator will be assured.

ELECTRICAL SWITCH OPERATION OR ALARM SYSTEM TESTING

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. Therefor, 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.

CAUTION:

Do not exceed 210°F (99°C) when performing this test.

2. Remove the radiator cap, if the engine is operating near sea level, and insert a steel jacketed thermometer.

WATER TEMPERATURE SWITCH (CONT.)

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.

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 lb/in.^{2} (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 (Figure 1.) since the bottom of the adjusting screw and the lower breaker point are also forced upwards.

When the fuel pressure reaches 20 lb/in.^{2} (138 kPa), the breaker points close and current flows to the terminals of the lubricating oil pressure switch and the water temperature 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 lb/in.^{2} (138 kPa), permits the lower breaker point arm to lower and break the electrical circuit.

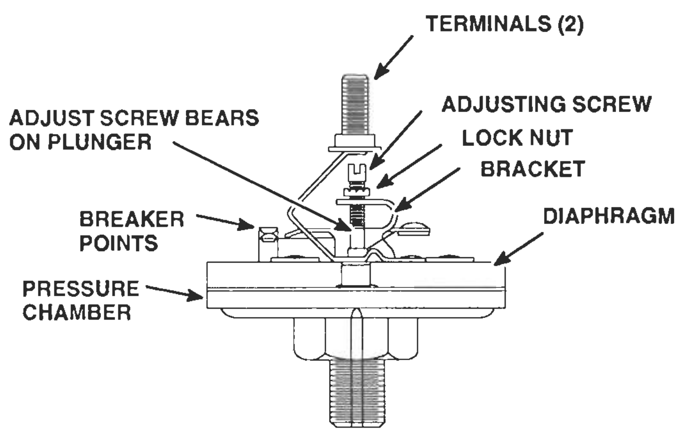


Figure 1. Fuel Oil Pressure Switch

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.

FUEL OIL PRESSURE SWITCH (CONT.)

4. Slow the engine down by moving the speed control lever towards the no–fuel position until the fuel pressure is approximately 15 lb/in.^{2} or (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 lubrication oil pressure increases to ten lb/in.^{2} (69 kPa). The phrase "10 BREAK" is stamped on the switch cover.

A 20 lb/in.^{2} (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 (Figure 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 ten lb/in.^{2} (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 ten lb/in.^{2} (69 kPa) during operation, the breaker point will close and either the alarm bell or shutdown solenoid will be energized.

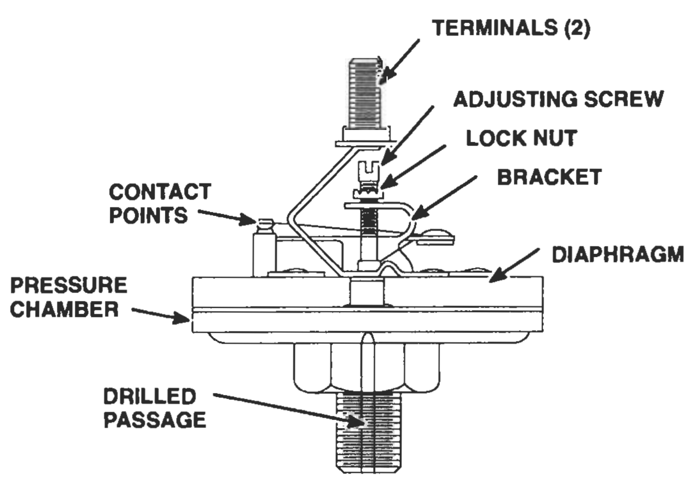


Figure 2. Fuel Oil Pressure Switch

1. Start and run the engine at idle speed.
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 to ten 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.

NOTE: 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 teat 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 (Figure 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 terminal “D” or the switch is closed, the lamp should light in eight to ten seconds. If not, the time delay switch must be replaced.

On certain rail car 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.

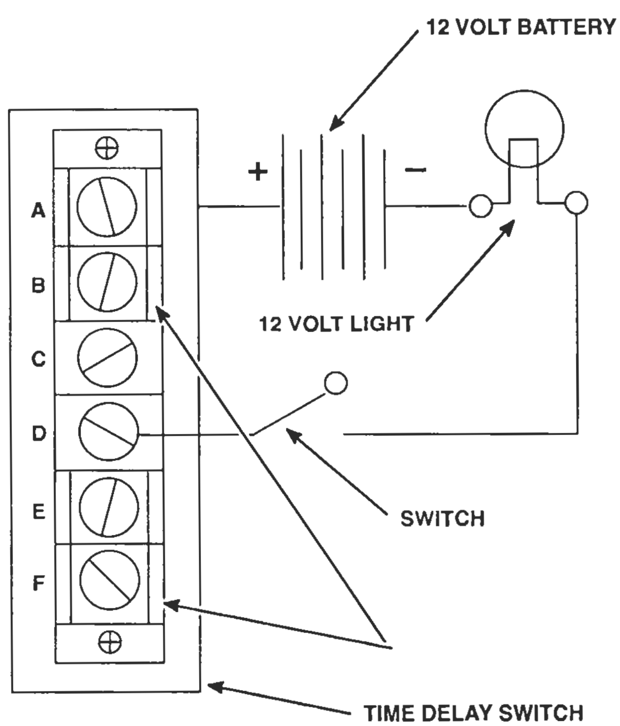


Figure 3. Time Delay Switch Testing Diagram

ALARM BELL FOR AUTOMATIC ELECTRICAL SHUTDOWN SYSTEM

On some engine installations, where the unit operates partly or wholly without an operator in attendance, it may be desirable to wire a 12 volt alarm bell into the automatic electrical shutdown system if it is of the "normally open circuit" type. The bell can be remotely mounted in an area where it can readily be heard should some unforeseen incident cause the engine to stop.

When wiring the alarm bell into the shutdown system so that the bell will ring continuously after the engine has stopped, until manually reset by the operating personnel, a drop relay (Figure 4.) is required.

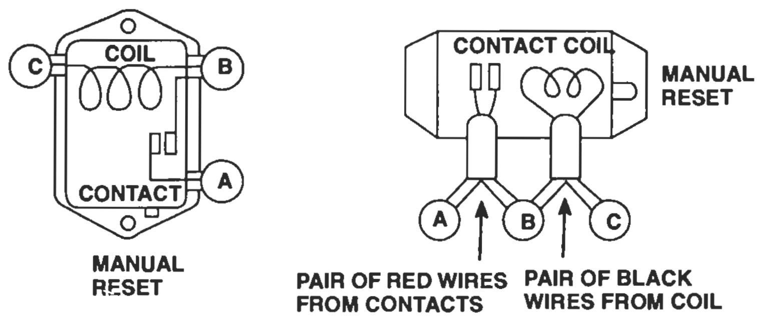


Figure 4. Two Types of Drop Relays for Use with Alarm Bell

The alarm bell may be wired into the shutdown system (Figure 5.). It is important that the drop relay be correctly wired into the system so that when the engine shutdown solenoid is energized the operating coil in the drop relay will close the set of points and place the bell across the battery. Once the points are closed, the bell will continue to ring until the points are manually reset by the operator or service personnel.

If the engine is equipped with a 12 volt electrical system, the bell may be wired directly across the battery, but should the electrical system be 24 or 32 volts, then a 12 volt tap–off from the batteries will be required.

A four ohm resistor is installed to protect the drop relay operating coil whenever a 24 or 32 volt electrical shutdown system is employed on the engine.

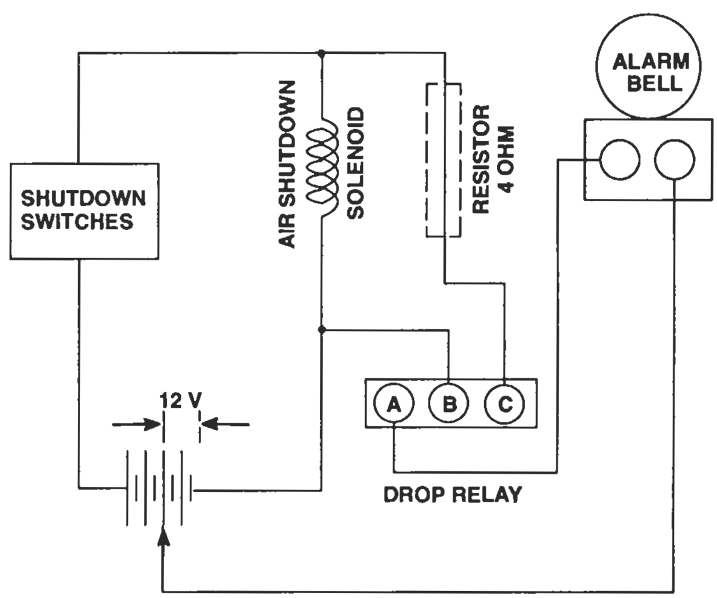


Figure 5. Single Engine Alarm Bell Installation

ALARM BELL FOR AUTOMATIC ELECTRICAL SHUTDOWN SYSTEM (CONT.)

Normally, a No. 14 wire will carry the bell current. Should the bell be mounted some distance from the engine, the bell wires should be suitably supported and well insulated to insure a permanent, trouble–free installation. An alarm bell can also be wired into the alarm system for twin and quad engines (Figure 6.)

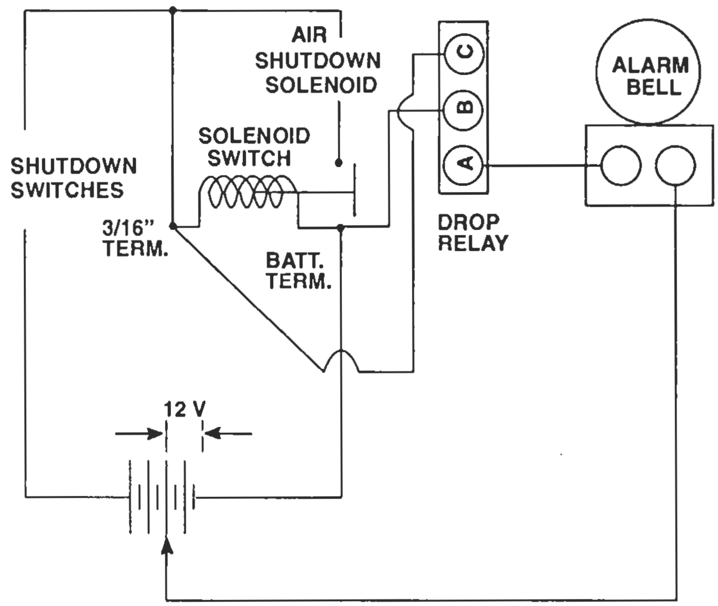


Figure 6. Twin and Quad Engine Alarm Bell Installation

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 (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 TOOL FOR TACOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed on an 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 the three tools in set J 23068 to establish the proper alignment (Figure 7.)

Because of the many different combinations of tachometer drive shafts, covers and adaptors available, 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.

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand revolution of the engine is made.

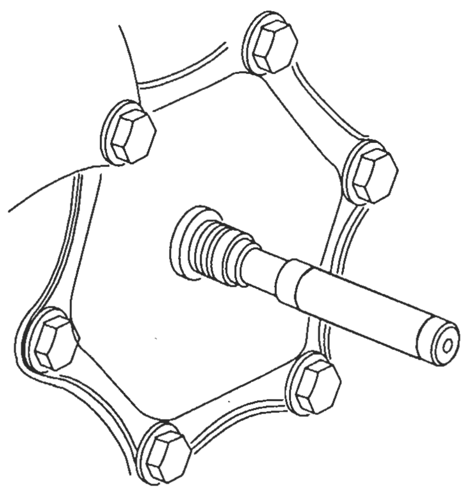


Figure 7. Checking Tachometer Drive Shaft Alignment

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. (lb/in.^{2})
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)
Alternator drive pulley nut		50–60	68–81
Cranking motor connector	1/2–13	20–25	27–34
Cranking motor connector	No. 10–32	*	*
Cranking motor switch mounting nut		§	§
Cranking motor attaching bolt (Alum. F/W)	5/8–11	95–105	129–143

* 16–30 lb/in.^{2} (2–3.5 N·m)

§ 36–48 lb/in.^{2} (4–5.5 N·m)

SERVICE TOOLS

TOOL NAME	TOOL NO.
Slide hammer	J–23907–1
Tachometer alignment tool set	J–23068
Tachometer drive shaft remove	J–5901–3

POWER TAKE–OFF – TORQMATIC CONVERTOR

For service and overhaul procedures for Allison products, contact the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

For service and overhaul procedures for Rockford products, contact the manufacturer:

Rockford Powertrain, Inc.
1200 Windsor Rd.
P.O. Box 2908
Rockford, IL 61132–2908

TRANSMISSIONS

For service and overhaul procedures for Detroit Diesel Twin Disc Marine Gear assemblies, contact an authorized Detroit Diesel distributor.

For service and overhaul procedures for Warner Gear products, contact the manufacturer:

Borg–Warner Automotive, Inc.
Transmission Systems
P.O. Box 2688
Muncie, IN 47302

For service and overhaul procedures for Allison products, contact the manufacturer:

Allison Transmission Division
General Motors Corporation
P.O. Box 894
Indianapolis, IN 46206

SPECIAL EQUIPMENT

CONTENTS

Air Compressor 12.4

Cold Weather Starting 12.6

Shop Notes – Troubleshooting – Specifications – Service Tools 12.0

AIR COMPRESSOR

The air compressor (Figure 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 the camshaft or balance shaft 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.

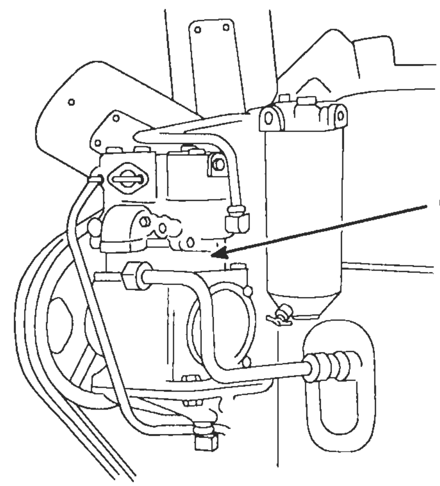


Figure 1. Air Compressor Mounting

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.

SECTION 12.4 – AIR COMPRESSOR

SERVICE NOTE

When installing a pulley or a drive hub on a flange mounted air compressor (Figure 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.

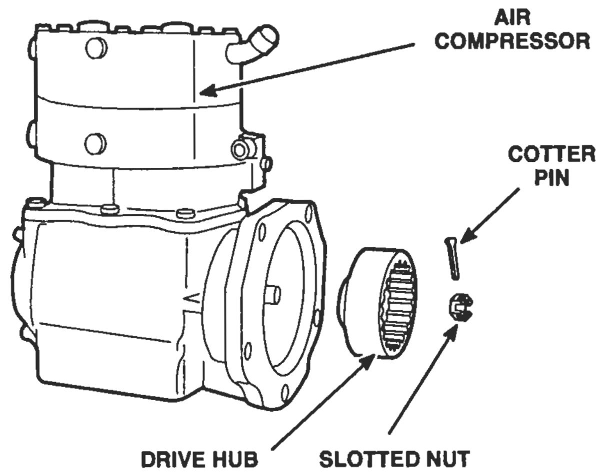


Figure 2. Typical Air Compressor with Drive Hub

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 (Figure 3.)

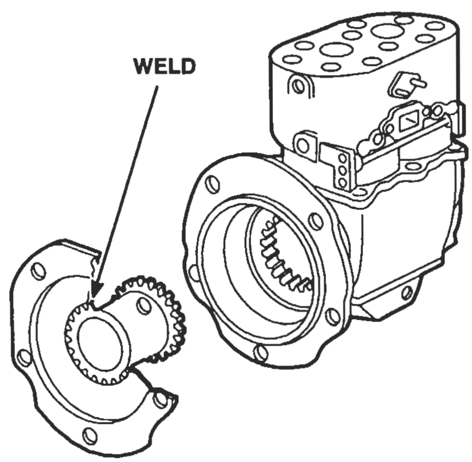


Figure 3. Fixture for Holding Drive while Installing or Removing Slotted Nut

COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls and coolant and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort required to crank the engine is much greater than when the engine is warm.

In a diesel engine, the normal means of igniting the fuel sprayed into the combustion chamber is by the heat of the air compressed in the cylinder. This temperature is high enough under ordinary operating conditions, but at extremely low outside temperatures may not be sufficiently high enough to ignite the fuel injected.

To assist in starting an engine under low temperature conditions, several cold weather starting devices are available.

NOTE: Starting aids are not intended to correct deficiencies such as low battery, heavy oil, etc. They are for use when other conditions are normal but the air temperature is too low for the heat of compression to ignite the fuel–air mixture.

PRESSURIZED CYLINDER STARTING AID OPERATION

Start the engine during cold weather, using the "Quick Start" starting aid system (Figure 1.) as follows:

1. Press the engine starter button.
2. Pull out the "Quick Start" knob for one or two seconds, then release it.
3. Repeat the procedure if the engine does not start on the first attempt.

NOTICE:

To prevent possible cranking motor damage, do not crank the engine more than 30 seconds at a time when using an electric cranking motor. Always allow one minute intervals between cranking attempts to allow the starting motor to cool.

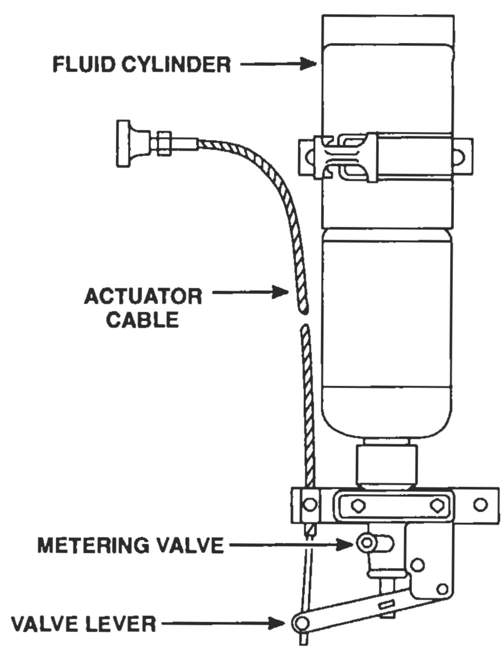


Figure 1. "Quick Start" Assembly

SECTION 12.6 – STARTING AIDS

SERVICE

Periodically perform the following service items to assure good performance:

1. Remove the fluid cylinder and lubricate the valve around the pusher pin under the gasket with a few drops of oil.
2. Lubricate the actuator cable.
3. Actuate the valve with the cable to distribute the oil on the cable and allow the oil to run down through the valve.
4. Remove any dirt from the orifice by removing the air inlet housing fitting, the orifice block and the screen. Then blow air through the orifice end only.
5. Assemble and tighten the air inlet housing fitting to the actuator valve and tube.
6. Check for leakage of fluid (fogging) on the outside of the engine air inlet housing by actuating the starting aid while the engine is stopped. If fogging occurs, disassemble and tighten the air inlet housing fitting to the housing.

CAUTION:

Do not actuate the starting aid more that once with the engine stopped. Overloading the engine air box with this fluid could result in a minor explosion.

7. Check the fluid cylinder for hand tightness.

FLUID STARTING AID

The fluid starting aid is designed to inject a highly volatile fluid into the air intake system to assist ignition of the fuel at low ambient temperatures. It consists essentially of a pump and nozzle for injecting the fluid into the air intake and a suitable container for the fluid (Figure 2.) The fluid is contained in suitable capsules to facilitate handling.

This starting aid consists of a cylindrical capsule container fitted with a screw cap. Inside the container is a sliding plunger–like piercing shaft. From the capsule container, a tube leads from the container to a hand–operated pump and another tube leads from the pump to an atomizing nozzle threaded into a tapped hole in the air inlet housing.

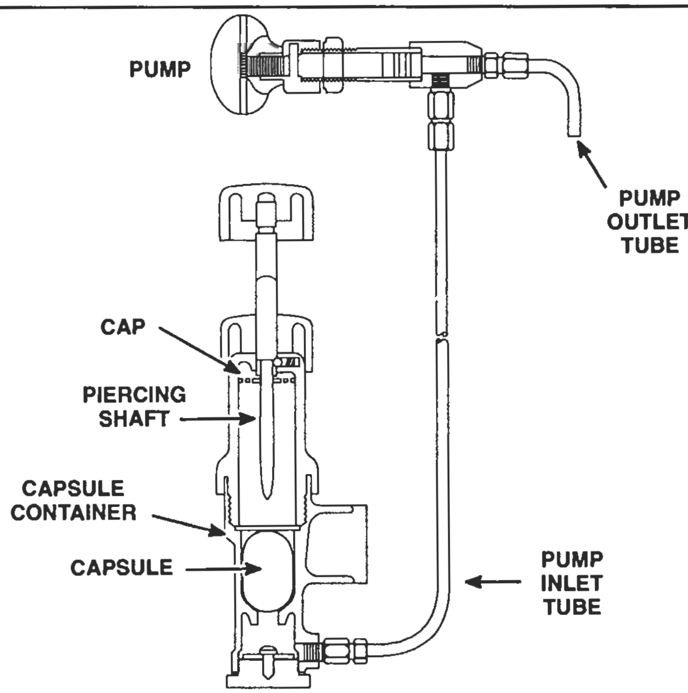


Figure 2. Fluid Starting Aid

INSTALLATION

The pump may be mounted on the instrument panel or in some other convenient location. The capsule container must be mounted in a vertical position away from such high heat areas as the exhaust manifold, muffler, etc. and should not be located under a hood or in a cab. The atomizing nozzle is screwed into a tapped hole in the air inlet housing. The tank–to–pump tube should be 3/16 inch O.D. copper tubing and the pump–to–nozzle tube 1/8 inch O.D.

OPERATION

1. Remove the cap from the capsule (Figure 2.) container. Insert a fluid capsule in the container.

CAUTION:

Mount the capsule in an upright position within the container. Use care when handling, since the the starting fluid is both toxic and inflammable.

2. Pull the piercing shaft all the way out and thread the cap tight on the container.
3. Push the piercing shaft down until it bottoms. This will break the capsule and fill the container with starting fluid vapor.
4. Move the engine throttle to the full–fuel position.
5. Engage the starter and simultaneously pull the pump plunger all the way out. Then push the plunger in slowly, forcing the starting fluid through the atomizing nozzle and into the air intake. Continue to push the pump plunger in until the engine starts. If the plunger is not all the way in when the engine starts, push it in very slowly until it locks in the in position.
6. Unscrew the cap and remove the used capsule.

NOTE: Do not leave the empty capsule in the container.

7. Reinstall the cap tightly on the container body.

NOTE: When not in use, the piercing shaft should be all the way down.

STARTING AID PUMP

The principal parts of the starting aid pump are the body, plunger and the spring–loaded ball type inlet and outlet check valves (Figure 2.) The pump body is threaded externally at one end for mounting purposes. One end of the plunger is threaded into the operating knob. Two seal rings of oil resistant material are located in grooves at the other end of the plunger. The inlet check valve, which opens on the suction stroke of the plunger and seats under pressure, is located in the side opening of the pump body. The outlet check valve, which seats under suction and opens under pressure, is installed in the end opening of the pump body. The check valves are identified by the number "1/2" stamped on the inlet valve and the number "30" on the outlet valve. An arrow indicating the direction of flow is also stamped on each check valve.

SECTION 12.6 – STARTING AIDS

REMOVE PUMP

Remove the starting aid pump from the mounting panel as follows:

1. Disconnect the starting fluid inlet and outlet tubes from the pump.
2. Unscrew the plunger nut from the pump body and withdraw the plunger assembly.
3. Loosen the pump body jam nut behind the mounting panel.
4. Remove the pump body from the rear of the panel.
5. Remove the jam nut from the pump body.

DISASSEMBLE PUMP

When the pump was removed from its mounting panel, the plunger assembly was removed from the pump body. If further disassembly is required, proceed as follows:

1. Unscrew the knob from the plunger assembly.
2. Slide the plunger nut from the plunger.
3. The plunger lock ball and spring may be removed by tapping the plunger nut to dislodge them. It is not necessary to remove the plug.
4. Remove the inlet and outlet check valves.

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 lb/in^2 (276 kPa) air pressure.

Examine the seal rings for wear or cracks. Replace the seal rings if necessary. The check valves cannot be disassembled. However, they may be cleaned by forcing fuel oil through them with any suitable pump. Inoperative valves must be replaced.

If excessive resistance was encountered during operation of the pump, the nozzle in the air inlet housing may be plugged. Remove and clean the nozzle.

ASSEMBLE PUMP

1. Install new seal rings on the plunger.
2. Install the lock spring in the plunger nut. Then place the steel ball on top of the spring.
3. Depress the lock ball and slide the plunger nut — hex end first — over the threaded end of the plunger.
4. Thread the knob on the plunger.
5. Install the outlet check valve (marked "30") in the end opening of the pump body. The arrow must point away from the pump body.
6. Install the inlet check valve (marked "1/2") in the side opening of the pump body. The arrow must point toward the pump body.

INSTALL PUMP

1. Thread the jam nut on the pump body.
2. Insert the thread end of the pump body through the mounting panel from the rear of the panel.
3. Lubricate the seal rings and carefully slide the plunger assembly into the pump body. Thread the plunger nut on the end of the pump body and tighten it.
4. Install the starting fluid inlet and outlet tubes.
5. If removed, install the nozzle in the air inlet housing.

ENGINE BLOCK HEATER

An immersion–type engine block heater may be installed to improve cold weather starting. To ensure the efficient operation of this accessory, always disconnect the electrical connections to the block heater *before* draining the coolant.

NOTICE:

Failure to disconnect electrical connections before draining coolant may result in damage to the block heater element if the heater is switched on without coolant in the system.

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
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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
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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

SERVICE TOOLS

TOOL NAME	TOOL NO.
Accumulator charging kit	J 6714–C
Air Compressor Hub Remover	J 36309
Air Compressor Hub Installer	J 36311
Oil seal installer set	J 7191
Piston, back–up ring, seal ring and washer installer	J 7192
Spring Compressor	J 7187

OPERATING INSTRUCTIONS

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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.

NOTE: When preparing to start a new or overhauled engine or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see Daily Operations in the Lubrication and Preventive Maintenance Chart, Section 15.1.

Cooling System

Install all of the drain cocks or plugs in the cooling system (drain cocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Loosen the water return line (if used) near the top of the turbocharger.

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.

Tighten the turbocharger water return line (if used).

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 prelubricator. Use the following procedure:

1. Remove the pipe plug from the engine main oil gallery and attach the prelubricator hose.
2. Remove the valve rocker cover(s) and, using a positive displacement pump set at 25–35 lb/in.^{2} (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 (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.

PREPARATION FOR STARTING ENGINE FIRST TIME (CONT.)

5. Disconnect the prelubricator 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 lubricator 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 cover 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 of the moving parts are getting lubrication is when the oil pressure gage registers pressure (ten lb/in.^{2} – 69 kPa at idle speed).

NOTICE:

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.

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.

PREPARATION FOR STARTING ENGINE FIRST TIME (CONT.)

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.

NOTE: 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.

NOTE: 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.

NOTE: The base of a generator set must be grounded.

A generator set should be connected and grounded in accordance with the applicable local electrical codes.

Clutch

Disengage the clutch, if the unit is so equipped.

PREPARATION FOR STARTING ENGINE FIRST TIME (CONT.)

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.

Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid. See Cold Weather Starting, Section 12.6.

CAUTION:

Starting fluid used in capsules is highly flammable, toxic and possesses anesthetic properties.

The instructions for the use of a cold weather fluid starting aid will vary depending 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 cranking 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 cranking motor is running.

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 Trouble Shooting 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 temperatures.

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.

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.

RUNNING (CONT.)

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.

NOTE: When prolonged engine idling is necessary, maintain at least 800 r/min.

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.

STOPPING (CONT.)

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 may have occurred during the previous run.

ENGINE OPERATING CONDITIONS

The engine operating charts are included as an aid for engine operation and troubleshooting. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Make sure that the readings represent true values, and that instruments are accurate, before attempting to make corrections to the engine.

3–71, 4–71 AND 6–71 ENGINES (2–VALVE HEAD)

	1200 r/min	1800 r/min	2100 r/min	2300 r/min
Lubrication Systems				
Lubricating oil pressure (lb/in.^{2}):				
Normal	30–60	43–65	45–65	45–65
Minimum for safe operation	18	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–225	200–225	200–225	200–225
Air System				
Air box pressure (inches mercury) – min. full load:				
At zero exhaust back pressure:				
3–71 and 4–71 engines	2.0	7.3	10.0	12.0
6–71 engine	2.4	8.1	11.0	13.0
At max. exhaust back pressure:				
3–71 & 4–71 engines	3.5	10.6	14.1	16.4
6–71 engine	3.9	11.4	15.1	17.4
Air inlet restriction (inches water) – max. full load:				
Dirty air cleaner (oil bath or dry)	12.4	25.0	25.0	25.0
Clean air cleaner (with pre–cleaner) (oil bath or dry)	8.7	13.4	15.9	17.5
Clean air cleaner (less pre–cleaner) (dry)	5.2	9.1	11.5	12.5
Crankcase pressure (inches water) – max.:				
3–71 engine	1.2	1.8	2.1	2.1
4–71 engine	1.8	2.5	2.8	2.8
6–71 engine	2.0	2.8	3.1	3.1
Exhaust back pressure (inches mercury) – max.:				
Full load	1.8	4.0	@5.0	5.0
Fuel System				
Fuel pressure at inlet manifold (lb/in.^{2}):				
Normal (.055 and .080 inch orifice)	30–65	45–70	45–70	45–70
Normal (.106 inch orifice)	30–65	45–70	45–70	45–70
Fuel spill (gal/min) – min. at no load:				
(.055 inch orifice)	0.5	0.6	0.6	0.6
(.080 and .106 inch orifice)	0.8	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:				
Clean system	6.0	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0	12.0

† 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.

@ Marine engines only: 5.5 inches mercury at 2100 r/min.

3–71, 4–71 AND 6–71 ENGINES (2–VALVE HEAD) – CONT'D.

	1200 r/min	1800 r/min	2100 r/min	2300 r/min
Cooling System				
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185	160–185
Raw water pump:				
Inlet restriction (inches mercury) – max.:				
3–71 and 4–71 engines	4.8	#5.0	#5.0	5.0
6–71 engine	2.4	#5.0	#5.0	5.0
Outlet pressure (lb/in.^{2}) – max.	4.8	#10.0	#10.0	10.0
Keel cooler pressure drop (lb/in.^{2}) – max. thru sys.:				
3–71 and 4–71 engines	2.4	#5.0	#5.0	5.0
6–71 engine	2.9	#6.0	#6.0	6.0
Compression				
Compression pressure (lb/ft^2 at sea level):				
Average – new engine at 600 r/min	440			
Minimum at 600 r/min	390			

Maximum when this is full–load speed of engine.

SECTION 13.2 – ENGINE OPERATING CONDITIONS

71N ENGINE

	1200 r/min	1800 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/in.^{2}):			
Normal	30–60	43–65	45–65
Minimum for safe operation	18	28	30
†Lubricating oil temperature (deg. F) – Normal	200–225	200–225	200–225
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N injector	0.1	2.8	4.6
C injector	0.4	2.4	4.1
7E injector	0.4	2.4	4.0
At max. full load exhaust back pressure:			
N injector	1.2	5.3	7.6
C injector	1.5	4.9	7.1
7E injector	1.5	4.9	7.0
Air inlet restriction (inches water) – max. full load:			
Dirty air cleaner (oil bath or dry)	12.4	25.0	25.0
Clean air cleaner (with pre–cleaner) (oil bath or dry)	8.7	13.4	15.9
Clean air cleaner (less pre–cleaner) (dry)	5.2	9.1	11.5
Crankcase pressure (inches water) – max.:			
4–71N engine	1.8	2.5	2.8
6–71N engine	2.0	2.8	3.1
Exhaust back pressure (inches mercury) – max.:			
Full load	1.5	3.3	4.0
Fuel System			
Fuel pressure at inlet manifold (lb/in.^{2}):			
Normal (.080 inch orifice)	30–65	45–70	45–70
Fuel spill (gal/min)–min. at no load (.080 orifice)	0.8	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
Engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (lb/in.^{2} at sea level):			
Average – new engine at 600 r/min 565			
Minimum at 600 r/min 515			

† 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.

4–71T ENGINE INDUSTRIAL

	1800 r/min	2000 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/in.^{2}):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N65 injector	14.0	19.2	22.0
N70 injector	17.0	22.2	25.0
N75 injector	18.0	23.2	26.0
At max. full load exhaust back pressure (clean ports):			
N65 injector	12.5	17.0	19.8
N70 injector	15.5	20.0	22.8
N75 injector	16.5	21.0	23.8
Air inlet restriction (inches water) – max. full load:			
Dirty air cleaner (dry)	14.5	20.0	20.0
Clean air cleaner (dry)	8.1	12.0	12.0
Crankcase pressure (inches water) – max.:	1.5	1.7	1.9
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/in.^{2} at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

4–71T ENGINE (WITH TV6141 TURBOCHARGER) (1.08 A/R* TURBINE HOUSING) INDUSTRIAL

	1800 r/min	2100 r/min	2300 r/min
Lubrication Systems			
Lubricating oil pressure (lb/in.^{2}):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N65 injector	20.0	28.5	35.0
N70 injector	21.0	30.0	37.0
N75 injector	22.8	31.9	38.3
At max. full load exhaust back pressure (clean ports):			
N65 injector	18.5	26.2	32.7
N70 injector	19.5	27.7	34.7
N75 injector	21.3	29.6	36.0
Air inlet restriction (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry)	14.5	20.0	20.0
Clean air cleaner (dry)	8.7	12.0	12.0
No–load speed:			
Dirty air cleaner (dry)	8.7	12.0	12.0
Clean air cleaner (dry)	5.2	7.2	7.2
Crankcase pressure (inches water) – max.:	0.5	0.9	1.2
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/in.^{2}) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – min. at no load (.080 orifice)	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 (lb/in.^{2} at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* Turbine housing designation (area over radius).

† The lubricating oil temperature range is based on the temperature 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.

4–71T ENGINE (WITH TO4B TURBOCHARGER) (1.14 A/R* TURBINE HOUSING) INDUSTRIAL

	1800 r/min	2000 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/in.^{2}):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N65, N70 and N75 injector	24.2	32.9	38.9
At max. full load exhaust back pressure (clean ports):			
N65, N70 and N75 injector	22.7	30.7	36.7
Air inlet restriction (inches water) – max. full load:			
Dirty air cleaner (dry)	14.5	20.0	20.0
Clean air cleaner (dry)	8.7	12.0	12.0
Crankcase pressure (inches water) – max.:	1.5	1.7	1.9
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/in.^{2}) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/in.^{2} at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* Turbine housing designation (area over radius).

† The lubricating oil temperature 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.

4–71T ENGINE (WITH TH08A TURBOCHARGER) (0.96 A/R* TURBINE HOUSING) GENERATOR SET

	1500 r/min	1800 r/min
Lubrication Systems		
Lubricating oil pressure (lb/in.^{2}):		
Normal	37–63	43–65
Minimum for safe operation	23	28
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235
Air System		
Air box pressure (inches mercury) – min. full load:		
At zero exhaust back pressure:		
N80 injector	13.9	20.0
N90 injector	15.9	22.0
N95 injector	17.9	24.0
At max. full load exhaust back pressure (clean ports):		
N80 injector	12.9	18.5
N90 injector	14.9	20.5
N95 injector	16.9	22.5
Air inlet restriction (inches water) – max. full load:		
Dirty air cleaner (dry)	10.5	14.5
Clean air cleaner (dry)	6.2	8.7
Crankcase pressure (inches water) – max.:	0.5	1.0
Exhaust back pressure (inches mercury) – max.:		
Full load	1.4	2.0
Fuel System		
Fuel pressure at inlet manifold (lb/in.^{2}) – Normal	45–70	50–70
Fuel spill (gal/min) – min. at no load (.080 orifice)	0.9	0.9
Pump suction at inlet (inches mercury) – max.:		
Clean system	6.0	6.0
Dirty system	12.0	12.0
Cooling System		
Coolant temperature (deg. F) – Normal	160–185	160–185
Compression		
Compression pressure (lb/in.^{2} at sea level):		
Average – new engine at 600 r/min 475		
Minimum at 600 r/min 425		

* 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.

4–71T ENGINE (WITH TO4B TURBOCHARGER) (1.14 A/R* TURBINE HOUSING) GENERATOR SET

	1500 r/min	1800 r/min	
Lubrication Systems			
Lubricating oil pressure (lb/in.^{2}):			
Normal	37–63	43–65	
Minimum for safe operation	23	28	
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N80 injector	21.1	30.3	
N90 injector	23.8	33.5	
N95 injector	27.5	38.0	
At max. full load exhaust back pressure (clean ports):			
N80 injector	20.1	28.8	
N90 injector	22.8	32.0	
N95 injector	26.5	36.5	
Air inlet restriction (inches water) – max. full load:			
Dirty air cleaner (dry)	10.5	14.5	
Clean air cleaner (dry)	6.2	8.7	
Crankcase pressure (inches water) – max.:	0.5	1.0	
Exhaust back pressure (inches mercury) – max.:			
Full load	1.4	2.0	
Fuel System			
Fuel pressure at inlet manifold (lb/in.^{2}) – Normal	45–70	50–70	
Fuel spill (gal/min) – min. at no load (.080 orifice)	0.9	0.9	
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	
Dirty system	12.0	12.0	
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	
Compression			
Compression pressure (lb/in.^{2} at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

6–71T ENGINE (WITH T18A40 TURBOCHARGER) (1.00 A/R* TURBINE HOUSING) VEHICLE

	1800 r/min	2000 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/in.^{2}):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N65 or C65 injector	23.2	28.5	31.5
N70 injector	24.0	29.3	32.3
N75 injector	24.7	30.0	33.0
At max. full load exhaust back pressure (clean ports):			
N65 or C65 injector	21.7	26.6	29.6
N70 injector	22.5	27.4	30.4
N75 injector	23.2	28.1	31.1
Air inlet restriction (inches water) – max. full load:			
Dirty air cleaner (dry)	20.0	20.0	20.0
Clean air cleaner (dry)	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:	1.3	1.8	2.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/in.^{2}) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – min. at no load (.080 orifice)	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
Engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (lb/in.^{2} at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

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6–71T ENGINE (WITH TV7101 TURBOCHARGER) (1.23 A/R* TURBINE HOUSING) VEHICLE

	1200 r/min	1800 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/in^2):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N65 injector	30.7	36.5	39.3
C70 injector	34.2	40.2	43.1
C75 injector	36.1	42.2	45.1
At max. full load exhaust back pressure (clean ports):			
N65 injector	29.2	34.5	37.0
C70 injector	32.7	38.2	40.8
C75 injector	34.6	40.2	42.8
Air inlet restriction (clean ports) (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry)	20.0	20.0	20.0
Clean air cleaner (dry)	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:	1.3	1.8	2.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.7	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/in^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/in^2 at sea level):			
Average – new engine at 600 r/min ... 475			
Minimum at 600 r/min ... 425			

* 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.

6–71TT ENGINE (WITH TV6141 TURBOCHARGER) (1.08 A/R* TURBINE HOUSING) VEHICLE

	1200 r/min	1800 r/min	1950 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft^2):			
Normal	32–70	50–70	50–70
Minimum for safe operation	25	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
7E75 injector	24.5	36.0	#37.8
At max. full load exhaust back pressure (clean ports):			
7E75 injector	23.9	34.5	#35.9
Air inlet restriction (clean ports) (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry type)	9.0	20.0	20.0
Clean air cleaner (dry type)	6.0	12.0	12.0
Crankcase pressure (inches water) – max.:	0.8	1.3	1.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.8	2.0	2.5
Fuel System			
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/ft^2 at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

230 BHP Values.

6–71TT ENGINE (WITH TV7101 TURBOCHARGER) (1.39 A/R* TURBINE HOUSING) VEHICLE

	1200 r/min	1800 r/min	1950 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft^2):			
Normal	32–70	50–70	50–70
Minimum for safe operation	25	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N75 injector	14.7	#29.4	#34.4
At max. full load exhaust back pressure (clean ports):			
N75 injector	14.0	#27.9	#32.6
Air inlet restriction (clean ports) (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry)	– –	#20.0	#20.0
Clean air cleaner (dry)	4.0	#12.0	#12.0
No–load speed:			
Dirty air cleaner (dry)	4.0	#8.7	#10.3
Clean air cleaner (dry)	2.0	#5.2	#6.0
Crankcase pressure (inches water) – max.:	0.8	1.3	1.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	2.0	2.5
Fuel System			
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – min. at no load (.080 orifice)	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 (lb/ft^2 at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

230 BHP Values.

6–71TA AND 6–71TTA ENGINE (WITH TV6141 TURBOCHARGER) (1.08 A/R* TURBINE HOUSING) – 1983 FEDERAL – VEHICLE

	1800 r/min	1950 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft²):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–230	200–230	200–230
Air System			
Air box pressure (inches mercury) – min. full load:			
At 15″ water – exhaust back pressure:			
6–71TA – 7C75 injector – 1.458 timing	37.4	42.0	– –
6–71TTA – 7E75 injector – 1.460 timing	@32.6	@35.4	@38.7
At max. full load exhaust back pressure (clean ports):			
6–71TA – 7C75 injector – 1.458 timing	35.9	40.1	– –
6–71TTA – 7E75 injector – 1.460 timing	@31.1	@33.5	@36.4
Air inlet restriction (inches water) – max. full–load:			
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.:	1.3	1.8	2.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/ft²) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/ft² at sea level):			
Average – new engine at 600 r/min 565			
Minimum at 600 r/min 515			

* Turbine housing designation (area over radius).

** TTA engines only.

† 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.

@ At 230 BHP.

6–71TA ENGINE (WITH TV6141 TURBOCHAGER) (1.39 A/R* TURBINE HOUSING) VEHICLE

	1800 r/min	2000 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft^2):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
7G65 injector	30.2	34.5	36.5
7G70 injector	32.3	36.5	38.5
7G75 injector	34.5	39.0	41.0
At max. full load exhaust back pressure (clean ports):			
7G65 injector	28.7	32.5	34.3
7G70 injector	30.8	34.5	36.3
7G75 injector	33.0	38.0	38.8
Air inlet restriction (clean ports) (inches water) – max.			
Full–load speed:			
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.:	1.3	1.8	2.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.7	3.0
Fuel System			
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/ft^2 at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

6–71TTA ENGINE (WITH TV6141 TURBOCHARGER) (1.39 A/R* TURBINE HOUSING) VEHICLE

	1200 r/min	1800 r/min	1950 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft^2):			
Normal	32–70	50–70	50–70
Minimum for safe operation	25	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
7G75 injector	18.6	#31.5	#33.3
At max. exhaust back pressure (clean ports):			
7G75 injector	18.0	#30.0	#31.4
Air inlet restriction (clean ports) (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry type)	9.0	20.0	20.0
Clean air cleaner (dry type)	6.0	12.0	12.0
Crankcase pressure (inches water) – max.:	0.8	1.3	1.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.8	2.0	2.5
Fuel System			
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – 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 (lb/ft^2 at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

\# 230 BHP Values.

6–71T ENGINE (WITH T18A40 TURBOCHARGER) (1.14 A/R* TURBINE HOUSING) INDUSTRIAL

	1800 r/min	2000 r/min	2100 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft^2):			
Normal	43–65	45–65	45–65
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N65 injector	17.7	23.0	26.0
N70 injector	18.5	23.8	26.8
N75 injector	19.2	24.5	27.5
N80 injector	25.0	30.2	33.0
N90 injector	31.5	36.7	39.5
N95 injector	34.0	39.0	41.5
At max. full load exhaust back pressure:			
N65 injector	16.2	21.2	24.2
N70 injector	17.0	22.0	25.0
N75 injector	17.7	22.7	25.7
N80 injector	23.5	28.4	31.2
N90 injector	30.0	34.9	37.7
N95 injector	32.5	37.2	39.7
Air inlet restriction (inches water) – max. full load:			
Dirty air cleaner (dry)	14.5	18.0	20.0
Clean air cleaner (dry)	8.7	10.8	12.0
Crankcase pressure (inches water) – max.:	1.3	1.8	2.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	2.5
Fuel System			
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – min. at no load (.080 orifice)	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 (lb/ft^2 at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

6–71TT ENGINE (WITH TV7101 TURBOCHARGER) (1.39 A/R* TURBINE HOUSING) INDUSTRIAL

	1200 r/min	1800 r/min	1950 r/min
Lubrication Systems			
Lubricating oil pressure (lb/ft²):			
Normal	32–70	50–70	50–70
Minimum for safe operation	25	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N75 injector	14.7	#29.4	#34.4
At max. full–load exhaust back pressure):			
N75 injector	14.0	#27.9	#32.6
Air inlet restriction (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry)	– –	#14.5	#17.0
Clean air cleaner (dry)	4.0	#8.7	#10.5
No–load speed:			
Dirty air cleaner (dry)	4.0	#8.7	#10.3
Clean air cleaner (dry)	2.0	#5.2	#6.0
Crankcase pressure (inches water) – max.:	0.8	1.3	1.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	2.0	2.4
Fuel System			
Fuel pressure at inlet manifold (lb/ft²) – Normal	50–70	50–70	50–70
Fuel spill (gal/min) – min. at no load (.080 orifice)	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 (lb/ft² at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

230 BHP Values.

6–71T ENGINE (WITH T18A40 TURBOCHARGER) (1.00 A/R* TURBINE HOUSING) GENERATOR SET

	1500 r/min	1800 r/min	
Lubrication Systems			
Lubricating oil pressure (lb/ft²):			
Normal	37–63	43–65	
Minimum for safe operation	23	28	
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	
Air System			
Air box pressure (inches mercury) – min. full load:			
At zero exhaust back pressure:			
N75 injector	18.0	24.7	
N80 injector	18.9	25.0	
N90 injector	24.4	31.5	
M95 injector	25.0	34.0	
At max. full load exhaust back pressure:			
N75 injector	17.0	23.2	
N80 injector	17.9	23.5	
N90 injector	18.4	30.0	
M95 injector	24.0	32.5	
Air inlet restriction (inches water) – max.			
Full–load speed:			
Dirty air cleaner (dry)	10.5	14.5	
Clean air cleaner (dry)	6.2	8.7	
No–load speed:			
Dirty air cleaner (dry)	6.2	8.7	
Clean air cleaner (dry)	3.5	5.2	
Crankcase pressure (inches water) – max.:	0.7	1.3	
Exhaust back pressure (inches mercury) – max.:			
Full load	1.4	2.0	
Fuel System			
Fuel pressure at inlet manifold (lb/ft²) – Normal	45–70	50–70	
Fuel spill (gal/min) – min. at no load (.080 orifice)	0.9	0.9	
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	
Dirty system	12.0	12.0	
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	
Compression			
Compression pressure (lb/ft² at sea level):			
Average – new engine at 600 r/min 475			
Minimum at 600 r/min 425			

* 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.

6–71TI ENGINE (WITH T18A40 TURBOCHARGER) (1.32 A/R* TURBINE HOUSING) INTERCOOLED MARINE ENGINE

	1800 r/min	2000 r/min	2100 r/min	2300 r/min
Lubrication Systems				
Lubricating oil pressure (lb/ft^2):				
Normal	43–65	45–65	45–65	45–65
Minimum for safe operation	28	30	30	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235	200–235
Air System				
Air box pressure (inches mercury) – min. full load:				
At zero exhaust back pressure:				
N90 injector	20.4	25.9	28.6	34.0
At max. full load exhaust back pressure (clean ports):				
N90 injector	18.9	24.1	26.8	32.2
Air inlet restriction (inches water) – max.				
Full–load speed:				
Dirty air cleaner (dry)	14.5	18.0	20.0	20.0
Clean air cleaner (dry)	8.7	10.8	12.0	12.0
No–load speed:				
Dirty air cleaner (dry)	8.7	10.8	12.0	12.0
Clean air cleaner (dry)	5.2	6.6	7.3	7.3
Crankcase pressure (inches water) – max.	1.3	1.8	2.0	2.4
Exhaust back pressure (inches mercury) – max.:				
Full load	2.0	2.5	2.5	2.5
Fuel System				
Fuel pressure at inlet manifold (lb/ft^2) – Normal	50–70	50–70	50–70	50–70
Fuel spill (gal/min) – min. at no load (.055 orifice)	0.9	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:				
Clean system	6.0	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0	12.0
Cooling System				
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185	160–185
Compression				
Compression pressure (lb/ft^2 at sea level):				
Average – new engine at 600 r/min	475			
Minimum at 600 r/min	425			

* 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.

6–71TI 480 HP

Configuration	
Turbocharger	TW7302 (1.19 A/R)
Charge Air Cooling System	Raw Water Intercooled
Blower Type	BYPASS
Blower Drive Ratio	2.00:1
Low Idle Speed–r/min	500
Maximum No Load Speed–r/min	2700
Engine Crankcase Vent System	Closed
Maximum Pressure–in H_2O(kPA)	–6.0–3.0 (–1.49–0.75)
Marine Gear	
Type	DD–507–2
Reduction Ratios	1.51:1
Lube Oil Capacity approx.–qts (litre)	7.4 (7.0)
(Marine Gear must use straight viscosity oil)	
Gear Weight–lb–(kg)	350 (159)
Fuel System	
Fuel Injector/Timing	7245/1.515
Fuel Consumption–lb/hr (kg/hr)	182.1 (82.6)
Fuel Spill Rate–gal/hr (L/hr)	77.4 (293.0)
Total Fuel Flow–gal/hr(L/hr)	103.4 (391.6)
Maximum Allowable Fuel Pump Suction	
Clean System–in. Hg (kPa)	6 (20)
Dirty System–in. Hg (kPa)	12 (41)
Fuel Filter Micron Size	
Primary–Micron	30
Secondary Micron	12
Recommended Suply Line I.D.	
in. (mm)	0.5 (12.7)
Lubrication System	
Oil Pressure	
Rated Speed–lbf/in.^{2}(kPa)	42–55 (290–379)
Low Idle–lbf/in.^{2}(kPa)	5 (34)
In Pan Oil Temperature – °F (°C)	200–250 (93–113)
Oil Flow – gal/min (L/min)	40 (151)
Oil Pan Capacity at Installation Angle	Zero to 9°
High Limit – qt (L)	29 (27)
Low Limit – qt (L)	25 (24)
Total Engine Oil Capacity With Filters – qt (L)	32 (30)
Maximum Installation Angle	9°

6–71TI 480 HP (CONT.)

Cooling System

Engine Heat Rejection Btu/min (kW)	17000 (299)
Inter Cooler Heat Reject Btu/min (kW)	4250 (74.7)
Engine Rated Heat Btu/min (kW)	849 (14.7)
Max. Frexh Water Flow–gal/min (L/min)	150 (568)
Raw Frexh Water Flow–gal/min (L/min)	108 (409)
Maximum Water Pump Inlet restriction	
Fresh Water–in. Hg (kPa)	3.0 (10.2)
Raw Water–in. Hg (kPa)	5.0 (17.0)
Fresh Water Capacity–qt(L)	48 (45)
Maximum Coolant Pressure (Exclusive of Pressure Cap)–lbf/in.^{2} (kPa)	37 (255)
Maximum Raw water pump Pressure lbf.in.^{2} (kPa)	14 (96.5)
Maximum Top Tank Temperature – °F (°C)	210 (99)
Suggested Raw Water Pipe Size–in (mm)	3.0 (76)
Suggested Sea Strainer Size	
Simplex–in. (mm)	3.0 (76)
Duplex–in. (mm)	4.0 (102)

Air System

Maximum Allowable Temperature Rise (Outside Air to Engine Inlet)–°F (°C)	30 (16.7)
Air Intake Restriction Maximum Limit	
Dirty Air Clleaner – in. H_2O (kPa)	15 (3.7)
Clean Air Cleaner – in. H_2O (kPa)	10 (2.5)
Engine Air Flow –ft^3/min (m^3/Min)	1150 (32.6)
Engine Air Box/Manifold Pressure – in. Hg (kPa)	63.0 (212.8)
Recommended Intake Pipe Dia.–in.9 (mm)	6.0 (152)
Suggested min. engine room vent area– (Max. engine room depression 0.2in. H_2O)–in^2 (cm^2)	110 (712)

Exhaust System

Exhaust Flow:–ft^3/min (m^3/min)	2590 (73.3)
Exhaust Temperature –°F (°C)	750 (399)
Maximum Allowable Back Pressure – in. Hg (kPa)	2.5 (8.5)
Recommended Exhaust Pipe Outer Diameter:	
Single – in. (mm)	6.0 (152)

All values are at rated speed and power and with standard engine hardware, unless otherwise noted.

6–71TI 450 HP

Configuration	
Turbocharger	TW7302 (1.19 A/R)
Charge Air Cooling System	Raw Water Intercooled
Blower Type	BYPASS
Blower Drive Ratio	2.00:1
Low Idle Speed–r/min	500
Maximum No Load Speed–r/min	2700
Engine Crankcase Vent System	Collector
Maximum Pressure–in H_2O(kPA)	3.0 (0.75)
Marine Gear	
Type	DD–507–1
Reduction Ratios	1.51:1
Lube Oil Capacity approx.–qts (litre)	7.4 (7.0)
(Marine Gear must use straight viscosity oil)	
Gear Weight–lb–(kg)	350 (159)
Fuel System	
Fuel Injector/Timing	7255/1.500
Fuel Consumption–lb/hr (kg/hr)	171.3 (77.7)
Fuel Spill Rate–gal/hr (L/hr)	77.4 (293.0)
Total Fuel Flow–gal/hr(L/hr)	101.9 (385.7)
Maximum Allowable Fuel Pump Suction	
Clean System–in. Hg (kPa)	6 (20)
Dirty System–in. Hg (kPa)	12 (41)
Fuel Filter Micron Size	
Primary–Micron	30
Secondary Micron	12
Recommended Suply Line I.D.	
in. (mm)	0.5 (12.7)
Lubrication System	
Oil Pressure	
Rated Speed–lbf/in.^{2}(kPa)	42–55 (290–379)
Low Idle–lbf/in.^{2}(kPa)	5 (34)
In Pan Oil Temperature – °F (°C)	200–250 (93–113)
Oil Flow – gal/min (L/min)	40 (151)
Oil Pan Capacity at Installation Angle	Zero to 9°
High Limit – qt (L)	29 (27)
Low Limit – qt (L)	25 (24)
Total Engine Oil Capacity With Filters – qt (L)	32 (30)
Maximum Installation Angle	9°

6–71TI 450 HP (CONT.)

Cooling System

Engine Heat Rejection Btu/min (kW)	15000 (263.8)
Inter Cooler Heat Reject Btu/min (kW)	3750 (65.9)
Engine Rated Heat Btu/min (kW)	790 (13.8)
Max. Frexh Water Flow–gal/min (L/min)	150 (568)
Raw Frexh Water Flow–gal/min (L/min)	108 (409)
Maximum Water Pump Inlet restriction	
Fresh Water–in. Hg (kPa)	3.0 (10.2)
Raw Water–in. Hg (kPa)	5.0 (17.0)
Fresh Water Capacity–qt(L)	48 (45)
Maximum Coolant Pressure (Exclusive of Pressure Cap)–lbf/in.^{2} (kPa)	37 (255)
Maximum Raw water pump Pressure lbf.in.^{2} (kPa)	14 (96.5)
Maximum Top Tank Temperature – °F (°C)	210 (99)
Suggested Raw Water Pipe Size–in (mm)	2.5(63.5)
Suggested Sea Strainer Size	
Simplex–in. (mm)	3.0 (76)
Duplex–in. (mm)	4.0 (102)

Air System

Maximum Allowable Temperature Rise (Outside Air to Engine Inlet)–°F (°C)	30 (16.7)
Air Intake Restriction Maximum Limit	
Dirty Air Clleaner – in. H_2O (kPa)	15 (3.7)
Clean Air Cleaner – in. H_2O (kPa)	10 (2.5)
Engine Air Flow –ft^3/min (m^3/Min)	1070 (30.3)
Engine Air Box/Manifold Pressure – in. Hg (kPa)	67.5(194.2)
Recommended Intake Pipe Dia.–in.9 (mm)	6.0 (152)
Suggested min. engine room vent area– (Max. engine room depression 0.2in. H_2O)–in^2 (cm^2)	103 (663)

Exhaust System

Exhaust Flow:–ft^3/min (m^3/min)	2390 (67.7)
Exhaust Temperature –°F (°C)	750 (399)
Maximum Allowable Back Pressure – in. Hg (kPa)	2.5 (8.5)
Recommended Exhaust Pipe Outer Diameter:	
Single – in. (mm)	6.0 (152)

All values are at rated speed and power and with standard engine hardware, unless otherwise noted.

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 technician 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 (6°C) higher than the water inlet temperature. Though a 10°F (6°C) rise across an engine is recommended, it has been found that a 15°F (8°C) temperature rise maximum can be permitted.

A thermostat is used in the engine to control the coolant flow. Therefore, be sure it is 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 the thermostat.

The Basic Engine Run–In Schedule is shown in the following tables. The horsepower shown is at SAE conditions: dry air density .0705 lb/ft^3 (1.129 Kg/m^3, air temperature of 85°F (29.4°C) and 500 ft. elevation.

BASIC ENGINE RUN–IN SCHEDULE

Speed (r/min)	Time (minutes)	Horsepower		
		3–71	4–71, 71N	6–71, 71N
1200	10	21	28	42
1800	30	67	90	135
*1800	30	82	110	164
*2100	30	85	118	180
*2300	30	92	128	196

* Run at only one of the speeds shown, whichever is at or nearest to the governed speed and reset governor after final run, if necessary.

FINAL ENGINE RUN–IN SCHEDULE (TRUNK–TYPE PISTONS)

Speed (r/min)	Time (minutes)	Horsepower	
		4–71T	6–71T
1200	10 (minimum)	0	0
2300	60	0	0
2100	30	57	86
2100	30	114	172
2100	30	+	+

+ Within ± 5% of rated bhp.

ENGINE RUN–IN INSTRUCTIONS (CONT.)

FINAL ENGINE RUN–IN SCHEDULE (CROSS–HEAD PISTONS)

Speed (r/min)	Time (minutes)	Horsepower	
		4–71T	6–71T
1200	10 (minimum)	28	42
2100	30	116	174
2100	30	130	195
2100	30	+	+

+ Within ± 5% of rated bhp.

DYNAMOMETER TEST AND RUN–IN PROCEDURES

The Basic Engine

The great number of engine applications makes 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 generator or 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 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 x R/MIN)/5250 Kw = (T x R/MIN)/9429

Where:

BHP = brake horsepower kW = power in kW

T = torque in lb–ft T = torque in N·m

R/MIN = revolutions per minute R/MIN = revolutions per minute

5250 = dynamometer constant 9429 = dynamometer constant

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).

DYNAMOMETER TEST AND RUN–IN PROCEDURES (CONT.)

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.

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 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 or kilopascales 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 lb/in.^{2} or kPa, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water = lb/in.^{2} x 27.7

Inches of mercury = lb/in.^{2} x 2.04

Inches or water = kPa x 4.02

Inches of mercury = kPa x 0.30

NOTE: 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 lubricating oil system, DDC recommends plugging the filter bypass before start–up and during basic engine run–in. This allows all the lubricating oil to flow through the filter(s), trapping contaminants.

Run–In Procedure

The procedure outlined below will follow the order of the sample Engine Test Report.

SERIES 71 ENGINE TEST REPORT

Date:______________________ Unit Number: ______________________

Repair Order Number: ______________________ Model Number: ______________________

PROM ID: ______________________ Max. N\L R/MIN: ______________________

Rated F/L R/MIN: ______________________ Idle R/MIN: ______________________

A. PRESTART					
1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJECTORS	5. ADJUST GOVERNOR	6. ADJUST INJECTOR RACKS
B. BASIC ENGINE RUN–IN START ________ STOP ________					
TIME AT SPEED	R/MIN	BHP	WATER TEMP.	LUBE OIL PRESSURE	
C. BASIC RUN–IN INSPECTION					
1. OIL AT ROCKERS	2. LUBE OIL LEAKS	3. FUEL OIL LEAKS	4. WATER LEAKS	5. LOOSE BOLTS	
D. INSPECTION AFTER BASIC RUN–IN					
1. TIGHTEN ROCKER BOLTS	2. ADJUST VALVES	3. TIME INJECTORS	4. ADJUST GOVERNOR GAP	5. ADJUST INJECTOR RACKS	
E. FINAL RUN–IN START ________ STOP ________					
R/MIN MAX. SPEED	LOAD 100%	BHP	AIR BOX PRESSURE F/L	EXHAUST BACK PRES-SURE F/L	CRANKCASE PRESSURE F/L
BLOWER IN-TAKE RES. F/L	FUEL OIL PRESSURE INLET F/L	WATER TEMP. F/L	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE F/L	LUBE OIL PRESSURE IDLE
F. INSPECTION AFTER RUN					
AIR BOX, PIS-TONS, LIN-ERS, RINGS	BLOWER	GENERATOR CHARGING PLATE	WASH OIL PAN, CHECK GASKET	CLEAN OIL PUMP SCREEN	TIGHTEN OIL PUMP BOLTS
REMARKS:					

OK__________ Reject____________ Dynamometer Operator____________ Date ____________

DYNAMOMETER TEST AND RUN–IN PROCEDURES (CONT.)

To plug the bypass, proceed as follows:

If the valve is secured by a retainer and screw, remove the spring and install a spacer of the appropriate length under the retainer (Figure 1.) The spacer must be long enough to contact the valve and keep it from moving during the dynamometer test. When the test is completed, remove the spacer and reinstall the spring. Then change the filter(s).

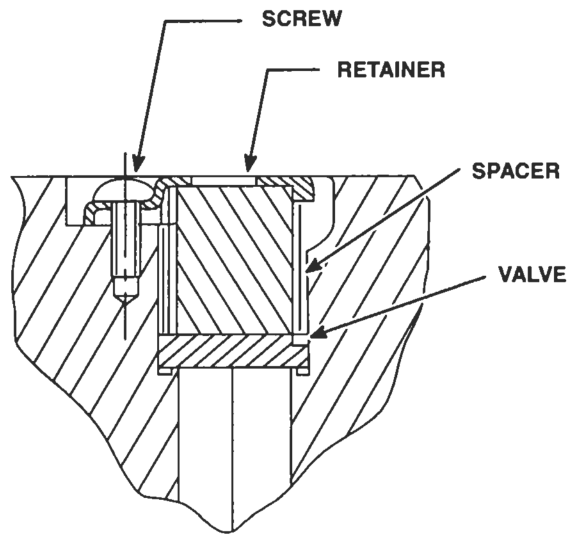


Figure 1. Bypass Valve with Spacer Installed

If the valve is secured by a plug, 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 (Figure 2.) When the dynamometer test is completed, replace the modified plug with a standard plug and change the filter(s).

CAUTION:

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 lubricating oil temperature up to at least 60°F (15.6°C) before starting the engine prior to testing. If the lubricating oil is too cold when the engine is started, the resistance to flow of the heavier oil may cause filter gasket leakage or bearing surface damage from inadequate oil film.

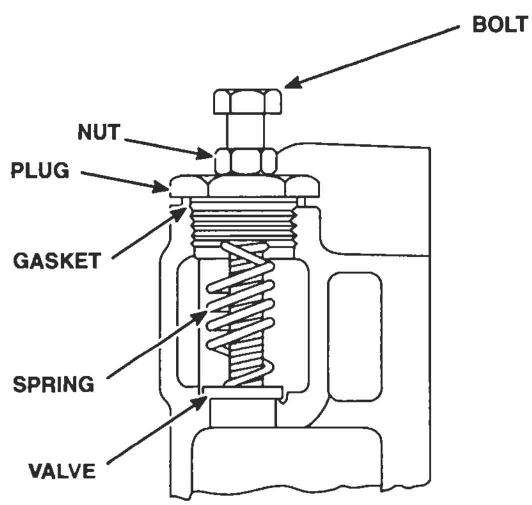


Figure 2. Bypass Valve with Modified Valve Plug Installed

SECTION 13.2.1 – ENGINE RUN–IN INSTRUCTIONS

PRE–STARTING (SECTION A)

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).

NOTE: Prior to starting a turbocharged engine, remove the oil supply line at the turbocharger and add clean engine oil to the oil inlet to ensure prelubrication of the turbocharger. Reconnect the oil line and idle the engine for at least one minute after starting and before increasing the speed.

BASIC ENGINE RUN–IN (SECTION B)

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 technician 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 five lb/in.^{2} (seven N·m) on the torque gage (or ten–fifteen 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 (r/min), 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.

Any four or six cylinder engine to be run at speeds in excess of 1800 r/min must be equipped with a vibration damper.

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 ten 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.

BASIC RUN–IN INSPECTION (SECTION C)

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.

INSPECTION AFTER BASIC RUN–IN (SECTION D)

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.

FINAL RUN–IN (SECTION E)

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 ten 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 lb/in.^{2} after being taken at engine speeds indicated in the operating 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 lb/in.^{2} or 0–103 kPa) 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 two inches 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 inch 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.

FINAL RUN–IN (SECTION E) (CONT.)

The restriction at this point should be checked at a specific 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 the turbocharger (See Section 13.2, Chart).

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 six to twelve inches 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.

INSPECTION AFTER FINAL RUN–IN (SECTION F)

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 rust–proofing 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.

IN–LINE 71 AUTOMOTIVE ENGINE CHARGE COOLING SYSTEMS

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 a new "charge cooling" system on Detroit Diesel engines. In addition to current JWAC (jacket water aftercooled) engines released in 1979, ALCC (advanced liquid 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 in–line 71 JWAC models, the coolant circulation is from the cylinder block through the aftercooler and to the cylinder head (Figure 3.)

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 in–line 71 cooling system are identical to the standard non–aftercooled engines.

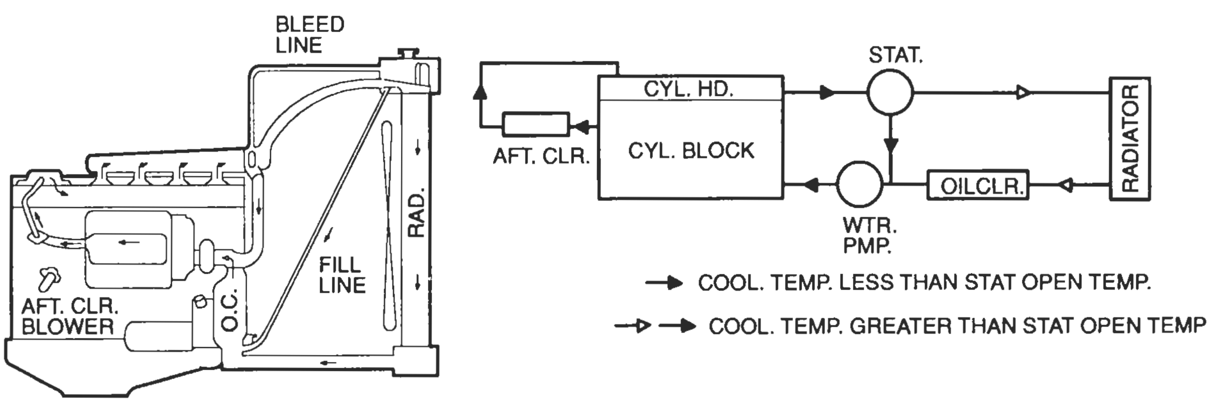


Figure 3. 6–71 TA JWAC Coolant Flow Path

IN–LINE 71 AUTOMOTIVE ENGINE CHARGE COOLING SYSTEMS (CONT.)

ADVANCED LIQUID CHARGE COOLING (ALCC)

The ALCC cooling system is designed to provide cool charge air to inline 71TA 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.

6L–71TA ALCC OPERATION

The 6L–71TA ALCC cooling system (Figure 4.) consists of the water pump that flows coolant through the engine cylinder block and cylinder head to the water manifold and the partial blocking thermostat S1 170°F (77°C). Under a cold engine condition all the coolant is directed past the temperature sensing element of the choke type thermostat S2 180°F (82°C) through the oil cooler into the engine water pump. This flow pattern will continue until engine coolant out temperature of 170°F (77°C) is reached. At this temperature, the S1 thermostat will begin to open, flowing coolant through the radiator to the aftercooler and into the inlet of the water pump where it mixes with the 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 bypass flow through the oil cooler is reduced. At no time does the bypass flow fall below 70% of its original value.

At high load and under high ambient temperature conditions when engine coolant–out temperature exceeds the opening temperature of the S2 thermostat 185°F (84.7°C), this thermostat will open, allowing part of the coolant from the radiator discharge to flow into the oil cooler, bypassing the aftercooler. The addition of this flow path lowers the radiator discharge pressure, resulting in a higher radiator flow that enhances engine cooling.

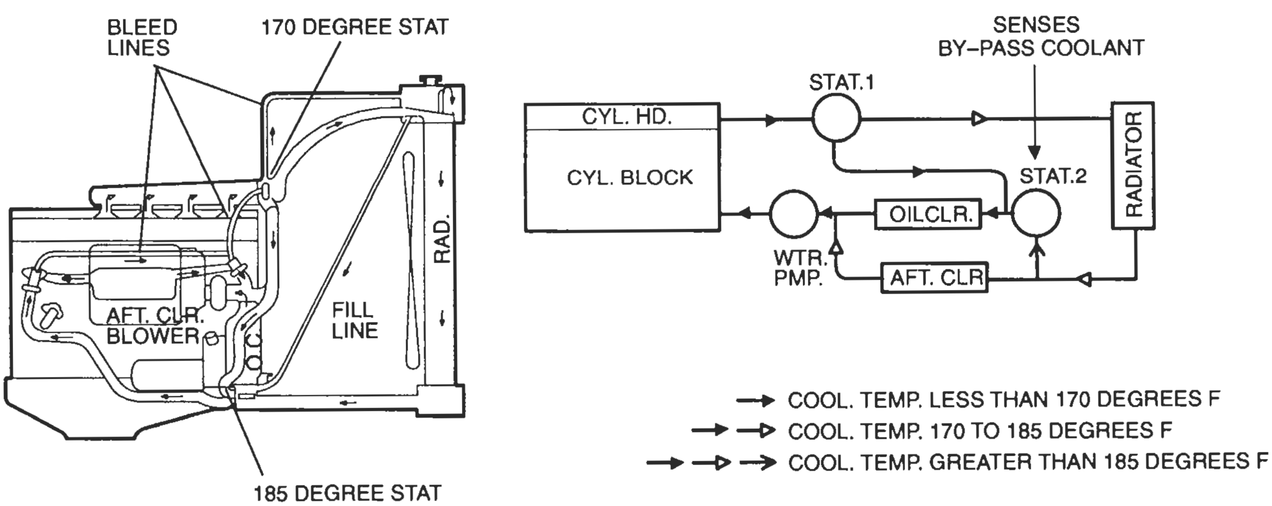


Figure 4. Typical Inline 6–71 TA ALCC Coolant Flow Path

IN–LINE 71 AUTOMOTIVE ENGINE CHARGE COOLING SYSTEMS (CONT.)

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 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 70°F (21.1°C) for in–line 71TA 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 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.

NOTE: Radiators with these tubes cannot be conventionally cleaned 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.

COOLING SYSTEM REQUIREMENTS FOR TESTING JWAC AND ALCC 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 on an engine dynamometer must meet the following requirements:

1. To properly fill the inline 71 ALCC engine, the 1 inch fill line must be connected at the water inlet connection or at the boss in the front face of the oil cooler housing just above the water inlet.
2. To properly vent the inline 71 ALCC engine, a 1/4 inch tube or No.4 flexible hose vent/deaeration line must be connected between the top of the 170°F (77°C) S1 thermostat housing and the heat exchanger or radiator surge tank.

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.

The inline 71 ALCC engine operates with conventional coolant flows, and either an open or closed cooling system may be used for engine dynamometer test. A power evaluation of a 6L–71TA engine in a vehicle/machine is run identical to the JWAC engine.

LUBRICANTS, FUEL AND COOLANTS

FUEL OILS FOR SERIES 71 ENGINES

Quality and Selection

The quality of fuel oil used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. The Series 71 engine was designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (Grades 1D and 2D) have provided satisfactory performance. The ASTD D 975 specification, however, does not in itself adequately define the fuel characteristics necessary to assure 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 (0.05)	0.5 (0.05)
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

Note 1: The cloud point should be 10 ° F (6 ° C) below the lowest expected fuel temperature to prevent clogging of fuel filters by 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.

SECTION 13.3 – LUBRICANTS, FUEL AND COOLANTS

The fuels used must be clean, completely distilled, stable, and non–corrosive. A reputable fuel oil supplier is the only one who can assure that the fuel you receive meets the property limits shown in the fuel oil selection chart. For more information regarding the significance of these properties and selection of the pro per fuel, refer to DDC publication 7SE270, “Lubrication Oils, Fuel Oils, and Filter Recommendations,” available from your DDC dealer or distributor.

FUEL OILS FOR SERIES 71 ENGINES (CONT.)

Fuel Sulfur Content

The sulfur content of the fuel should be as low as possible to avoid premature wear of piston rings and liner, excessive deposit formation, and minimize sulfur dioxide exhausted into the atmosphere. Limited amounts can be tolerated, but the amount of sulfur in the fuel and engine operating conditions can influence corrosion and deposit formation tendencies. The use of fuel containing greater than 0.5% sulfur will require more frequent oil changes.

Cold Weather Operation

In cold weather, diesel fuel will form wax crystals that can restrict flow and clog filters. Fuel oil suppliers approach this problem several ways. Some provide a specially refined product while others may use flow improving additives or winter blends. Winter blended fuel will likely contain kerosene or 1–D fuel which provide good cloud point temperatures but will result in a lighter fuel with a lower heat content. The use of such fuels is acceptable but may result in reduced engine power and/or fuel mileage.

Fuel Cleanliness

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, or water–emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier. If fuel is stored on site, the following is recommended:

1. Do not use a fuel storage tank or lines made from galvanized steel. The fuel oil will react chemically with the galvanized coating to form powdery flakes that will quickly clog fuel filters and cause damage to the fuel pump and injectors.
2. Keep the storage tank filler cap covered to prevent contamination by rain water.
3. Keep the tank clean, especially around the filler cap and tap areas.
4. Position the tank so that it tilts slightly toward the bottom drain. This will make it easier to drain accumulated water and sediment.
5. Minimize condensation by keeping the tank reasonably filled at all times.
6. After filling the fuel storage tank, wait a few hours before filling equipment tanks. This will allow contaminants to settle.

Using Drained Lubricating Oil in Diesel Fuel

Detroit Diesel DOES NOT recommend blending engine drain oil into diesel fuel. Such practice will adversely effect exhaust emissions, and will likely result in damage to the fuel injection system and the formation of excessive combustion deposits. The disposal of waste oil is a serious environmental concern, best addressed by the engine oil supplier, who should accept responsibility for proper disposal of this material as part of the business of providing lubricant. Detroit Diesel will not be responsible for any detrimental effects that it determines result from this practice.

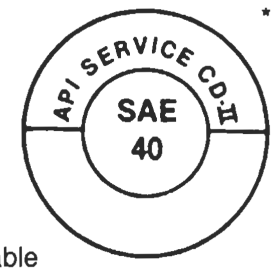
SECTION 13.3 – LUBRICANTS, FUEL AND COOLANTS

LUBRICATING OILS FOR SERIES 71 ENGINES

The selection of the proper lubricating oil is important for achieving the long and trouble–free service Detroit Diesel Series 71 engines are designed to provide. Only oils displaying the American Petroleum Institute (API) Symbol shown below are recommended. This symbol assures that the lubricant meets the minimum performance levels necessary for proper engine performance and durability.

SERIES 71 LUBRICANT RECOMMENDATION

API Symbol:



SAE Viscosity Grade: 40
API Classification: CF2
Sulfated Ash: less than 1.0%

*CF–2 when available

Lubricant Recommendation

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

API Performance category CF–2 represents an enhanced level of lubricant performance over the CD–II category which it replaces. Lubricants meeting this new performance level may not be readily available for some time. During this interim period, oils labeled as API CD–II may be used.

As 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 these requirements:

1. For continuous high temperature operation over 200°F (94°C) coolant out, the use of an SAE grade 50 lubricant in all two–stroke cycle engines is required.
2. At ambient temperatures below freezing 32°F (0°C) sufficient starter cranking speed may not be achieved to start the engine with SAE 40 grade oils. Where starting aids are not available or at very cold temperatures 0 to –25°F (–18 to –32°C) even if starting aids are available, then use of multigrade SAE 15W–40 or monograde SAE 30 lubricants will improve startability. These lubricants must possess a High Temperature – High Shear Rate Viscosity (measured by ASTM D 4741 or equivalent) of 3.70 cP minimum. **These oils must be replaced with monograde SAE 40 lubricants as soon as ambient conditions permit.**

Exception: Do not use multigrade or SAE 30 or 15W–40 grade lubricants in two–stroke cycle marine engines.

3. When the use of high sulfur fuel (greater then 0.5% mass) is unavoidable, the use of lubricants with higher alkalinity is recommended. Be aware that such lubricants may have a sulfated ash content above 1.0% mass. The use of high sulfur fuel also requires modification to oil drain intervals.
4. The use of multigrade and/or greater than 1% sulfated ash oils are exceptions for special circumstances. The use of such lubricants under normal circumstances may not provide satisfactory service.

OIL CHANGE INTERVAL

The length of time an engine may operate before changing oil depends on the lubricant and fuel used, engine oil consumption, and operating cycle. The following table lists the maximum interval the engine may operate before changing oil. Oil analysis may be used to determine whether this interval should be shorter, but should not be used to lengthen the interval.

SERIES 71 MAXIMUM OIL DRAIN INTERVALS

Service Application	Lube Oil/Filter Change Interval
Highway Truck & Motor Coach	15,000 Miles (24,000 km)
City Transit Coaches	6,000 Miles (9,600 km) or 3 months*
Pick–up & Delivery, Stop & Go, Short Trip	12,000 Miles (19,000 km)
Industrial, Agricultural & Marine	150 Hours
Stationary Units Continuous	300 Hours or 3 Months*
Stationary Units Standby	150 Hours or 1 Year*

*Whichever comes first

The use of fuels with sulfur content above 0.5% will require a shorter of drain interval, and/or the use of a higher TBN oil. Refer to DDC Publication 7SE270, “Lubricating Oils, Fuel Oils, and Filter Recommendation,” for details.

STATEMENT OF POLICY ON SUPPLEMENTAL FUEL AND LUBRICANT ADDITIVES

The Series 71 engine will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets. The regular and continued use of supplementary additives in fuels and lubricants is not recommended.

Supplementary additives include all products marketed as fuel conditioner, smoke suppressants, masking agents, deodorants, tune–up compounds, top oils, break–in oils, graphitizers, and friction–reducing compounds.

NOTE: The manufacturer’s warranty applicable to Series 71 engines provides, in part, that the provisions of such warranty shall not apply to any engine unit that has been subject to misuse, negligence, or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer’s fuel or lubricating recommendations may not be within the coverage of the warranty.

FILTER SELECTION AND CHANGE INTERVALS FOR SERIES 71

The oil and fuel filters recommended for use on the Series 71 engine are as follows:

ENGINE OIL FILTERS

Filter Type	DDC Part No.	AC Part No.	Micron Rating @ 98% Single Pass Efficiency
Full Flow	25013192	PF–911L	12

FUEL OIL FILTERS

Filter Type	DDC Part No.	AC Part No.	Micron Rating @ 98% Single Pass Efficiency
Spin–On			
Primary			
3 & 4–71	25014371	TP936	25
6–71	25014274	TP915D	25
Secondary			
3 & 4–71	25010959	TP928	8
6–71	25014342	TP916D	8
4 & 6–71 DDEC	25013535	TP959L	5
Cartridge			
Primary			
3 & 4–71	5574961	T553	30
6–71	5575032	T552	30
Secondary			
3 & 4–71	5573261	TP509	12
6–71	5574508	TP540X	12

The change interval for oil and fuel filters is 15,000 miles (24,000 km) for highway trucks and 150 hours for industrial and agricultural applications.

USED LUBRICATING OIL ANALYSIS GUIDELINES

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown. Characteristics relating to lubricating oil dilution should trigger corrective action to identify and find the the source(s) of leaks, if these values are realized (Figure 1). Contact your DDC distributor or dealer regarding oil analysis services.

WARNING LIMITS		
	ASTM DESIGNATION	SERIES 71
Pentane Insolubles Mass %	D–893	1.00
Carbon (Soot) Content Mass %, Max.	E–1131	.08
Viscosity at 100°F., SUS % Max. Increase % Max. Decrease	D–445 & D–2161	40 15
Total Base Number (TBN) Min.	D–664	1.00
Total Base Number (TBN) Min.	D–2896	2.00
Water Content (Dilution), Vol. %, Max.	D–85	.30
Flash Point, °F, Max. Reduction	D–92	40.0
Fuel Dilution, Vol. %, Max.	*	2.50
Glycol Dilution, PPM, Max.	D–2982	1000
Iron Content, PPM, Max.	**	150
Sodium Content, PPM, MAx. Allowed Over Lube Oil Baseline	**	50
Boron Content, PPM, Max. Allowed Over Lube Oil Baseline	**	20
Copper Content, PPM, Max.	**	25
Lead, PPM, Max.	**	25
Tin, PPM, Max.	**	40
Silicon, PPM, Max.	**	40
Chrome, PPM	**	20

Figure 1. Used Lube Oil Analysis Guidelines

***No ASTM procedure designation.**

**** Elemental analyses are conducted using either emission or atomic absorption spectroscopy. Neither method has an ASTM designation.**

MISCELLANEOUS FUEL AND LUBRICANT INFORMATION

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled *EMA Lubricating Oils Data Book for* **Heavy–Duty Automotive and Industrial Engines**. The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION
401 NORTH MICHIGAN AVE.
CHICAGO, ILLINOIS 60611–4267

ENGINE COOLANT

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, some of 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. Therefore, coolant must be carefully selected and properly maintained.

The following terms are used throughout this section and must be understood.

- **Coolant**
  The fluid mixture circulation in the engine cooling system.
- **IPG**
  Full strength (non–diluted) inhibited Propylene Gycol meeting applicable heavy–duty formulation specifications.
- **Precharged IEG**
  Also referred to as a :fully formulated IEG." Contains the proper amount of SCA. Additional SCA must not be used with a precharged IEG at initial fill.
- **Precharged IPG**
  Also referred to as a "fully formulated IPG." Not approved for use in Seriese 71 engines.
- **Initial fill**
  Any time the cooling system is empty, then filled with new coolant.
- **Dropout**
  Sludge or deposit formation in or on cooling system components.

Coolants for Detroit Diesel Engines

Using a coolant with the appropriate concentrations of SCA (Supplemental Coolant Additives) is one of the most important aspects of quality engine maintenance. To achieve the chemical balance needed to protect a cooling system, certain coolant basics must be understood.

This section provides the directions and information required to ensure cooling system protection for Detroit Diesel engines. These recommendations are general rules and reflect the current technology. Specific concerns not covered should be addressed to your local Detroit Diesel representative.

The coolant used in Detroit Diesel engines must meet the following basic requirements:

COOLANT FOR DETROIT DIESEL ENGINES (CONT.)

- Provide an adequate heat transfer medium.
- Protect against cavitation damage.
- Provide a corrosion/erosion–resistant environment.
- Prevent formation of scale or sludge deposits.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze protection.

A properly maintained coolant can be used for two years, 200,000 miles, or 4000 hours, whichever comes first. At this time the cooling system must be drained, thoroughly cleaned and filled with new coolant.

To achieve these requirements, coolants are mixtures of good quality water, SCA and often an IEG or IPG for freeze protection. The rest of this bulletin will describe the requirements and usage of the water, SCA, IEG, and IPG.

Water

Water is the best practical medium for heat transfer. However, water alone can cause corrosion and inherently contains minerals that can produce scale deposits on internal cooling system surfaces. Chlorides, sulfates, magnesium, and calcium dissolved in the water can cause scale deposits, sludge deposits and/or corrosion.

Distilled or deionized water is preferred to minimize the adverse effects of minerals in water. The maximum allowable limits for minerals in water are specified in TABLE 1–1. The procedure for evaluating the quality of water is shown in FIGURE 1–1.

	Maximum Allowable	
	Parts per Million	Grains per Gallon
Chlorides	40	2.5
Sulfates	100	5.8
Total dissolved solids	340	20
Total Hardness: Magnesium & Calcium	170	20

TABLE 1–1 Satisfactory Water Limits

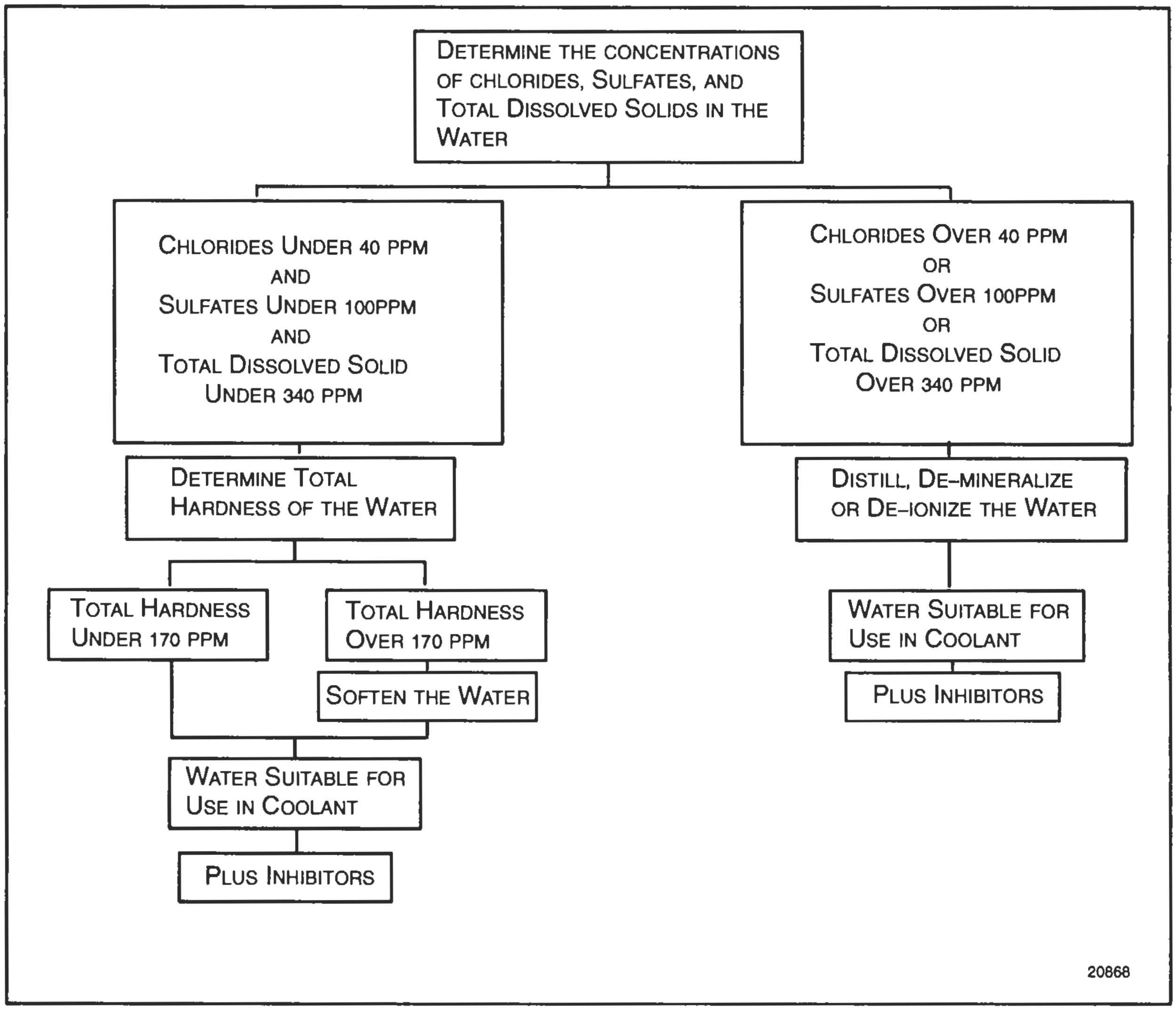


FIGURE 1–1 Water Evaluation Procedure

Antifreeze, Inhibited Ethylene Glycol (IEG)

Ethylene glycol is used for freeze protection of the coolant. IEG, commonly referred to as "antifreeze", also contains chemicals that provide a limited protection against corrosion. The use of an IEG product with a low silicate formulation that meets either the GM 6038–M formulation (GM1899–M performance) or ASTM D 4985 requirements is recommended.

Antifreeze, Inhibited Propylene Glycol IPG

An IPG/water mixture provides freeze protection.

Propylene glycol must meet the performance requirements of ASTM D 4985 and the physical/chemical requirements of ASTM D5216. The maintenance procedures for propylene glycol are the same as for IEG. All references to IEG will also apply to IPG for the above approved series engines.

For best overall performance, a 50% concentration of IEG (1/2 IEG, 1/2 water) is recommended. An IEG concentration over 67% (2/3 IEG, 1/3 water) is not recommended because of poor heat transfer, reduced freeze protection, and possible silicate dropout. An IEG concentration below 33% (1/3 IEG, 2/3 water) offers little freeze or corrosion protection and is not recommended (FIGURE 1–2, FIGURE 1–3, and FIGURE 1–4).

IEG coolants require the addition of SCA to provide cooling system corrosion and deposit protection. The SCA added should match the chemistry of the additive package included in the coolant. If this precaution is not observed, coolant monitoring can become difficult, making overinhibiting more likely. IEG formulations available in the market may contain from zero to the full amount of the required SCA. A basic IEG with no SCA must have additional SCA added at the time of initial fill. A Fully Formulated or Precharged IEG such as Detroit Diesel Powercool already contains the required SCA (TABLE 1–2). Overconcentration will result if SCA's are added to a fully formulated IEG coolant at the time of initial fill. This can result in solids dropout and the formation of deposits.

POWERCOOL	
DDC PART NO.	**SIZE**
23512138	1 GALLON
23512139	55 GALLONS
23512140	BULK

TABLE 1–2 Powercool Fully Formulated/Precharged IEG

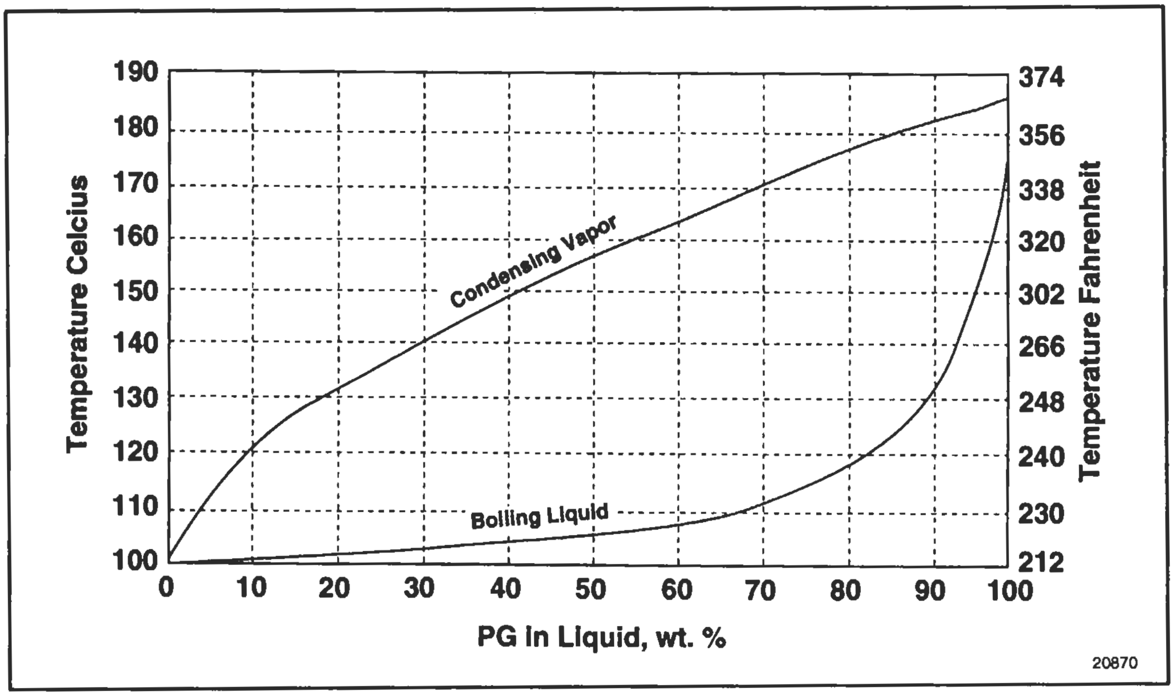


FIGURE 1–2 IPG Boiling Point

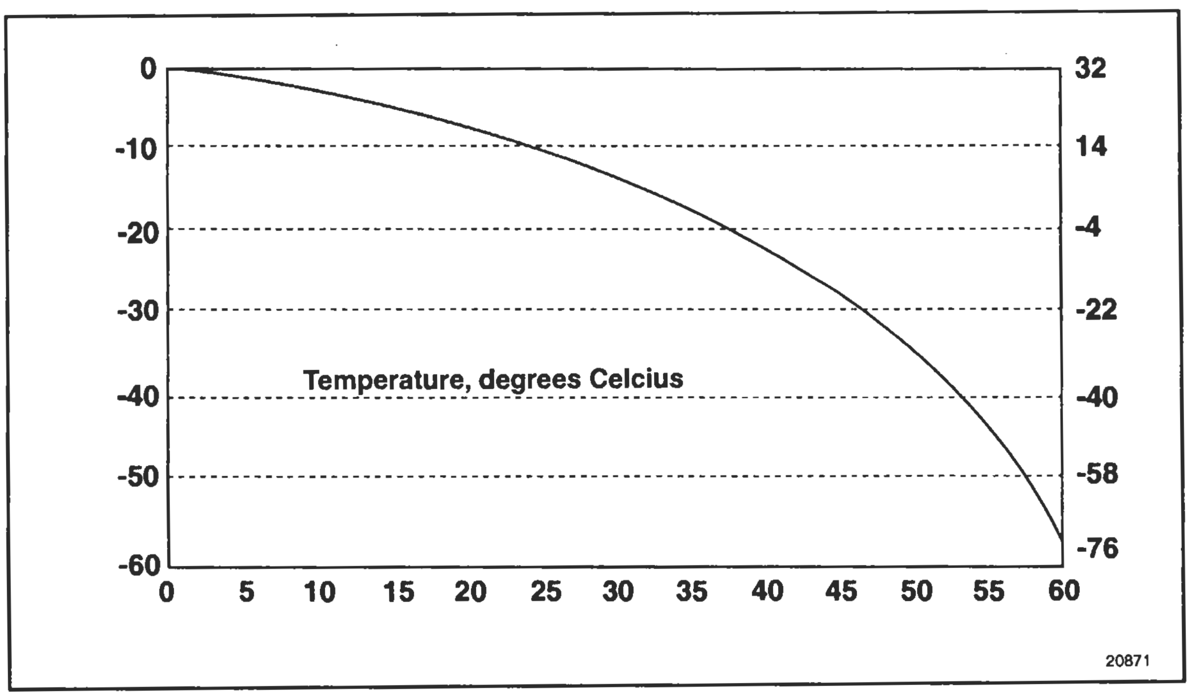


FIGURE 1–3 IPG Freezing Point

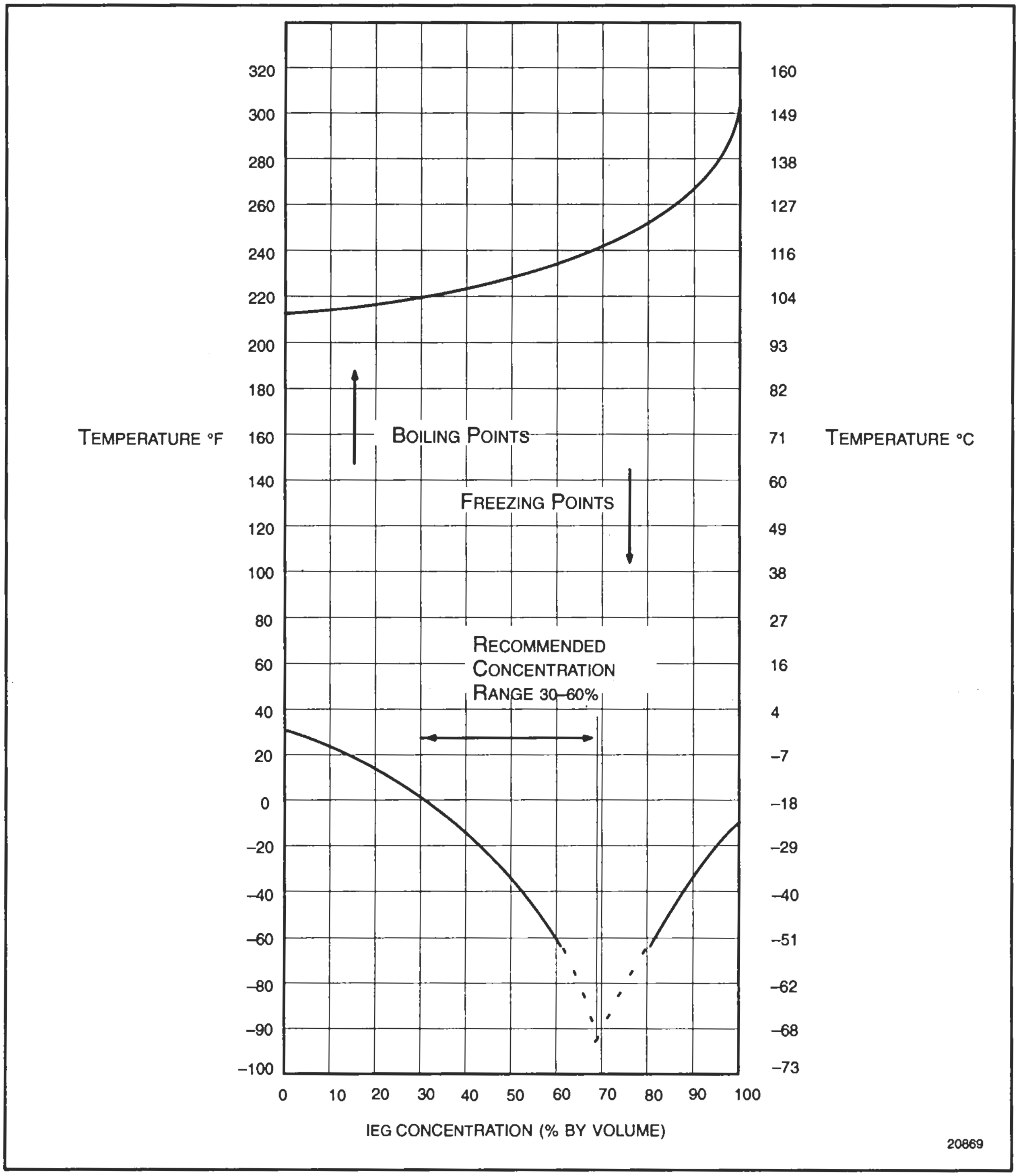


FIGURE 1–4 Coolant Freezing and Boiling Temperature vs. Inhibited Ethylene Glycol (IEG) Concentration (Sea Level)

Coolants Not Recommended

Methyl alcohol–based antifreeze should not be used in Detroit Diesel engines because of its effect on the non–metallic components of the cooling system and its low boiling point. Similarly, methoxy propanol–based antifreeze should not be used in Detroit Diesel engines because it is not compatible with fluoroelastomer seals found in the cooling system. Glycol–based coolants formulated for heating/ventilation/air conditioning (HVAC) should not be used in Detroit Diesel engines. These coolants generally contain high levels of phosphates, which can deposit on hot internal engine surfaces and reduce heat transfer.

Supplemental Coolant Additive (SCA)

SCA's provide protection for the cooling system components. The coolant must have the proper concentration of SCA's. Detroit Diesel Maintenance products are recommended for use in all Detroit Diesel engines.

NOTICE:

Excessive amounts of chemicals in the engine coolant can cause a gel–type or crystalline deposit that reduces heat transfer and coolant flow. The deposit, called dropout takes the color of the coolant when wet, but appears as a white powder when dry. It can pick up solid particles in the coolant and become gritty, causing excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non–acid (alkali) type heavy–duty cleaner, Detroit Diesel Maintenance Product cleaner DD–2001 (sodium nitrite/sodium tetraborate). If the gel is allowed to dry, it is necessary to disassemble the engine and clean with a caustic solution or mechanically clean individual components.

The proper application of SCA will provide:

- A pH control to prevent corrosion.
- Water–softening to deter formation of mineral deposits.
- Cavitation protection to reduce the effects of cavitation.

The proper dosage for initial cooling system fill are shown in TABLE 1–3, TABLE 1–4, TABLE 1–5 and TABLE 1–6. The proper maintenance dosages are shown in TABLE 1–7.

COOLANT	COOLANT ELEMENT	LIQUID
Precharged IEG & Water	NONE	NONE
IEG & Water	Select Element from Table 13–11.	3% by Volume, or 1 Pint per 4 Gallons
Water only	Select Element from Table 13–12.	6% by Volume, or 1 Quart per 4 Gallons

TABLE 1–3 Initial Fill SCA Dosage

COOLANT ELEMENT	LIQUID
Select Element from Table 13–14.	0.6% by Volume or 1 Pint per 20 Gallons

TABLE 1–4 Maintenance SCA Dosage

INITIAL FILL			
COOLING SYSTEM CAPACITY, GALLONS	QTY.	DDC PART NUMBER	NALCO PART NUMBER
1–4	1	23507545	DDF–3000–4
5–8	1	23508425	DDF–3000–8
9–12	1	23508426	DDF–3000–12
13–16	1	23507189	DDF–60, 16
24–32	1	23508427	DDF–3000.32
47–52	1	23508428	DDF–3000.53
50–75	2	23508427	DDF–3000.32
75–100	2	23508428	DDF–3000.53
100–125	2	23508428	DDF–3000.53
125–150	2	23508428	DDF–3000.53
8–20	1	23503140	NF–2088†

† Need release use only per specific operator's guide instructions.

TABLE 1–5 Coolant Inhibitor Element Size Requirements–Intial Fill Dosage for IEG or IPG plus Water Coolant Mixtures

Cooling System Capacity Gallons	SCA ElementQuantity	Detroit Diesel SCA Element Part Number	Nalco Element Part Number	Additional SCA Liquid Required
3	1	23507545	DDF–3000.4	None
4	2	23507545	DDF–3000.4	None
5	1	23508425	DDF–3000.8	None
7	1	23508426	DDF–3000.12	None
10	1	23507189	DDF–60.12	None
15	2	23508426	DDF–3000.12	None
20	1	23508427	DDF–3000.32	None
25	1 1	23508427 23507545	DDF–3000.32 DDF–3000.4	None
30	1 1	23508427 23508426	DDF–3000.32 DDF–3000.12	None
35	1 1	23508427 23507189	DDF–3000.32 DDF–3000.4	None
40	2	23508427	DDF–3000.32	None
50	2	23508427	DDF–3000.32	None
60	1 1	23508428 23508427	DDF–3000.53 DDF–3000.32	None
70	2	23508428	DDF–3000.53	None
85	2	23508428	DDF–3000.53	1 Gallon†
100	2	23508428	DDF–3000.53	2 Gallons†
125	2	23508428	DDF–3000.53	3 1/4 Gallons†
150	2	23508428	DDF–3000.53	5 Gallons†

† Use Nalcool 2000 or 3000 liquid SCA, or equivalent. Refer to TABLE 1–10.

TABLE 1–6 Coolant Inhibitor Element Size Requirements–Intial Dosage for Water–Only System

	MAINTENANCE		
COOLING SYSTEM CAPACITY, GALLONS	QTY.	DDC PART NUMBER	NALCO PART NUMBER
1–4	1	23507545	DDF–3000
5–8	1	23507545	DDF–3000
9–12	1	23507545	DDF–3000
13–16	1	23507545	DDF–3000
24–32	1	23508425	DDF–3000.8
47–52	1	23508426	DDF–3000.12
50–75	2	23508426	DDF–3000.12
75–100	2	23507189	DDF–3000.60
100–125	2	23507189	DDF–3000.60
125–150	2	23508427	DDF–3000.32

TABLE 1–7 Coolant Inhibitor Element Size Requirements–Maintainence Dosage for IEG, IPG, Precharged, and Water–Only Coolant Mixture

The concentration of SCA will gradually deplete during normal engine operation. Check the SCA concentration at the regular intervals shown in TABLE 1–8. Additional SCA must be added to the coolant when it becomes depleted below a specified level (TABLE 1–6). Maintenance dosage of SCA must only be added if nitrite concentration is less than 800 PPM. If nitrite concentration is greater than 800 PPM, do not add additional SCA.

Service Application	Inhibitor Test Interval
On–highway Trucks and Motor Coaches	15,000 miles (24,000 kilometers)
City Transit Coaches, Pick–up and Delivery, Short Trip, and Emergency Vehicles	6,000 miles (9,600 km) or three months, whichever comes first.
Industrial, Marine, Generator Set, and all other Applications.	200 Hours or yearly, whichever comes first.

TABLE 1–8 Required Coolant Inhibitor Test Intervals

	Minimum PPM	Maximum PPM
Boron (B)	1,000	1,500
Nitrite (NO_2)	800	2,400
Nitrates (NO_3)	1,000	2,000
Silicon (Si)	50	250
Phosphorus (P)	0	500
pH	8.5	10.5

TABLE 1–9 SCA Limits with GM6038–M or ASTM–D 4985 (50/50 Coolant/Water Mixture)

Soluble Oils

Soluble oil additives are not approved for use in Detroit Diesel engine cooling systems. A small amount of oil adversely affects heat transfer. A 1.25% concentration of soluble oil increases the fire deck temperature 6%. A 2.50% concentration increases the fire deck temperature 15%.

Chromate

Chromate additives are not approved for use in Detroit Diesel engine cooling systems. Chromate additives can form chromium hydroxide, commonly called green slime. This, in turn, can result in engine damage due to poor heat transfer. Cooling systems operated with chromate–inhibited coolant must be chemically cleaned with Nalco 2015 cool ing system cleaner/conditioner (or equivalent sulfamic acid/sodium carbonate cleaner) and flushed.

Some coolant filter elements with magnesium internal support plates have caused engine damage. The coolant dissolves the magnesium and deposits it on the hot zones of the engine where heat transfer is most critical. The use of elements with these plates is not approved.

Detroit Diesel Cooling System Maintainance Products

Detroit Diesel Maintenance Products SCA are water–soluble chemical compounds. These products are available in coolant filter elements, liquid packages, and a fully formulated IEG.

Coolant Filter Elements

Replaceable coolant filter elements (spin–on canisters) are available in various sizes suitable for cooling systems of varying capacity. Selection of the proper element size is vital when precharging the coolant system at initial fill and at maintenance intervals. **A fully formulated IEG or IPG must NOT have SCA added at initial fill.**

The need for maintenance elements is determined by the results of the SCA concentration test performed at each cooling system service interval.

SCA Test Procedures

Nitrite concentration is an indication of the SCA concentration in the coolant. Nitrite test kits and test strips are commercially available. The coolant must be tested for required inhibitor levels at the intervals shown in TABLE 1–8. SCA levels must be within the ranges shown in TABLE 1–9.

Liquid SCA

Detroit Diesel Cooling System Maintenance Procedures SCA and Cleaners are available in liquid form TABLE 1–10.

PRODUCT	SIZE	DDC PART NO.
NALCOOL ® 2000 Liquid SCA	Pint (12 per case) Half Gallon (6 per case) 5 Gallon 55 Gallon	23507858 23507859 23507860 23507861
NALCOOL ® 3000 † Liquid SCA	PInt (12 per case) Half Gallon (6 per case) 5 Gallon 55 Gallon	23507854 23507855 23507856 23507857
NALPREP ® 2001 ON–LINE CLEANER	Half Gallon (6 per case) 5 Gallon 55 Gallon	23507862 23507863 23507864
NALCOOL ® 2015 Twin Pac Dry Chemical Cleaner/Conditioner	2 per case	23507867

† Nalcool 3000 is more compatible with hard water than Nalcool 2000. Use Nalprep 2001 for light deposits. Use Nalprep 2015 for heavy deposits or scale. Nalcool) and Nalprep) are licensed trademarks of the Penray Companies.

TABLE 1–10 Liquid SCA and Additional Coolant Treatment Products

Test Kit Procedures

Use Detroit Diesel Powertrac ® 2–Way Coolant Test Strips (part number 23515917) to measure nitrite and glycol concentrations. Cavitation/corrosion protection is indicated on the strip by the level of nitrite concentration.

NOTICE:

Failure to properly maintain coolant with SCA can result in damage to the cooling system and its related components. Conversely, overconcentration of SCA inhibitor can result in poor heat transfer, leading to engine damage. Always maintain concentrations at recommended levels.

TEST KIT PROCEDURES (CONT.)

Freeze/boilover protection is determined by glycol concentration. Use the test strips as follows:

1. Dip the strip into coolant for one second. Remove and shake briskly to eliminate excess fluid.
2. Immediately compare end pad (% glycol) to the color chart.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad.

For best results make the tests while the coolant is between 50°–140 °F (10.0 ° – 60° C). Wait at least 60, but not longer than 75 seconds before reading the nitrite level. Promptly replace and tighten container cap after each use. Discard unused strips if they have turned light pink or tan.

A factory coolant analysis program is also available through authorized Detroit Diesel service outlets under part number 23508774.

ENGINE TUNE–UP

CONTENTS

Engine Tune–Up Procedures 14

Exhaust Valve Clearance Adjustment 14.1

Fuel Injector Timing 14.2

Limiting Speed Mechanical Governor and Injector Rack Control Adjustment 14.3
Limiting Speed Mechanical Governor (Dual Range) Injector Rack Control Adjustment 14.3.2
Limiting Speed Mechanical Governor Adjustment (Variable Low–Speed) 14.3.3
Limiting Speed Mechanical Governor Adjustment (Fast Idle Cylinder) 14.3.4
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Variable Speed Mechanical Governor and Injector Rack Control Adjustment 14.4

Constant Speed Mechanical Governor and Injector Rack Control Adjustment 14.6

Hydraulic SG Governor and Injector Rack Control Adjustment 14.7

Hydraulic Woodward PSG Governor and Injector Rack Control Adjustment 14.8

Supplementary Governing Device Adjustment 14.14

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. Tune–up should be considered at 100,000 miles (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. Constant–speed mechanical.
4. 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 the 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.

The tune–up procedures apply to the individual engines of multiple engine units as well as to the single engine units. However, the throttle linkage of multiple engine units must be adjusted after the individual engines have been tuned up.

Use a new valve rocker cover gasket after the tune–up is completed and reinstall the valve rocker cover.

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 and starting aid screw.
9. Adjust the throttle booster spring (variable speed governor only).
10. Adjust the supplementary governing device, if used.

The steps necessary to adjust an engine with a fuel modulating governor are in Section 14.5.

TUNE–UP SEQUENCE FOR HYDRAULIC GOVERNOR

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the fuel rod.
4. Position the injector rack control levers.
5. Adjust the load limit screw.
6. Compensation adjustment (PSG governors only).
7. Adjust the speed droop.
8. Adjust the maximum no–load speed.

TUNE–UP SEQUENCE FOR DDEC ELECTRONIC CONTROL

1. Adjust the exhaust valve clearances.
2. Time the fuel injectors.

EMISSION REGULATIONS FOR ON–HIGHWAY VEHICLE ENGINES

On–highway vehicle engines built by Detroit Diesel Corporation 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.

1970 AND 1971 CERTIFIED AUTOMOTIVE ENGINES

Engines	3, 4, 6–71 (4 Valve)	3, 4, 6–71 (4 Valve)	3, 4, 6–71 (4 Valve)
Injectors	71N5 N55 N60	N65	N70
*Max. Full–load Speed	2100	2100	2300
Camshaft Timing	Std.	Adv.	Adv.
**Injector Timing	1.460"	1.484"	1.460"
Throttle Delay	No	No	No

* No load engine speed will vary with injector size and governor type.

** The adjustable height of the fuel injector follower in relation to the injector body.

1972 CERTIFIED AUTOMOTIVE ENGINES

Engines	3, 4, 6–71 (4 Valve)	3, 4, 6–71 (4 Valve)	3, 4, 6–71 (4 Valve)	6–71T	*6–71T
Injectors	71N5 N55 N60	N65	N70	N65	N70 N75
**Max. Full–load Speed	2300	2300	2300	2100	2100
Camshaft Timing	Std.	Adv.	Adv.	Adv.	Adv.
†Injector Timing	1.460"	1.484"	1.460"	1.484"	1.460"
Throttle Delay	No	No	No	.016" Orifice	.016" Orifice

* 6–71 Fire Truck Application exempt from certification.

**No load engine speed will vary with injector size and governor type.

† The adjustable height of the fuel injector follower in relation to the injector body.

1973 CERTIFIED AUTOMOTIVE ENGINES

Engines	3–71N 4–71N 6–71N (4 Valve) ▼	3–71N 4–71N 6–71N (4Valve) ▼	3–71N 4–71N 6–71N (4 Valve) ▼	6–71T	6–71T	*6–71T	*6–71T
Injectors	71C5	C55 C60	C65 C70	C65	N70 N75	C65	N70 N75
**Max. Full–load Speed	2300	2300	2300	2100	2100	2300	2300
Camshaft Timing	Std.	Std..	Adv.	Std.	Std.	Std.	Std.
Injector Timing	1.484"	1.460"	1.484"	1.460"	1.484"	1.460"	1.484"
Throttle Delay	No	No	No	•.016" Orifice	•.016" Orifice	•.016" Orifice	•.016" Orifice

▼ Includes certain Parlor and Suburban Coach Engines.

* Exempt Engine Rating for Fire Truck Application only (Code No. 351).

Use Minimum idle speed of 500 r/min on all engines except coach engines where a minimum of 400 r/min is allowed.

**No–load engine speed will vary with injector size and governor type.

† The adjustable height of the fuel injector follower in relation to the injector body.

• .78" diameter fill hole.

1974 CERTIFIED AUTOMOTIVE ENGINES

Engines	6–71N ■	6–71N ■	6–71N ■	6–71N ■	6–71N ■	6–71T	6–71T	6–71T
Injectors	71C5	C55	C60	C65	C70	C65	N70	N75
*Max. Full–load Speed	2300	2300	2300	2300	2300	2100	2100	2100
Cam-shaft Timing	Std.	Std.	Std.	Adv.	Adv.	Std.	Std.	Std.
Injector Timing	1.484"	1.460"	1.460"	1.484"	1.484"	1.460"	1.484"	1.484"
Throttle Delay	No	No	No	No	No	**.016" Orifice	**.016" Orifice	**.016" Orifice
Yield Link	No	No	No	No	No	Yes	Yes	Yes

**.078" Diameter fill hole.

* No–load engine speed will vary with injector size and governor type.

■ Includes certain Parlor and Suburban Coach Engines.

Use minimum idle speed of 500 r/min on all engines, except coach engines where a minimum of 400 r/min is allowed.

1975 CERTIFIED AUTOMOTIVE ENGINES

Engines	*6–71N	*6–71N	*6–71N	*6–71N	*6–71N	6–71T	6–71T	6–71T
Injectors	71C5	C55	C60	C65	C70	C65	N70	N75
†Max. Full–load Speed	2300	2300	2300	2300	2300	2100	2100	2100
Cam-shaft Timing	Std.	Std.	Std.	Adv.	Adv.	Std.	Std.	Std.
Injector Timing	1.484"	1.460"	1.460"	1.484"	1.484"	1.460"	1.484"	1.484"
Throttle Delay	No	No	No	No	No	#.016" Orifice	#.016" Orifice	#.016" Orifice
Yield Link	No	No	No	No	No	Yes	Yes	Yes

FEDERAL AND CALIFORNIA				
Engine	6–71N	6–71N	6–71N	6–71N
Injectors	71B5	B55	B60	B65
Maximum Full–load Engine Speed	2300	2300	2300	2300
Camshaft Timing	Std.	Std.	Std.	Adv.
Injector Timing	1.500"	1.500"	1.500"	1.484"
Throttle Delay	No	No	No	#Yes
Yield Link	No	No	No	Yes

† Not to exceed fuel injector size and maximum operating speed that has been established for the specific application of the engine.

* Includes certain highway coach engines.

.078" diameter fill hole.

Use minimum idle speed of 500 r/min on all engines, except coach engines where a minimum of 400 r/min is allowed.

1976 CERTIFIED AUTOMOTIVE ENGINES

Engine	FEDERAL		CALIFORNIA
	6L–71N (c)	6L–71T	6L–71N
(a) Injectors	71C5 C55 C60 C65 C70	C65 N70 N75	71B5 B55 B60 B65
(b) Maximum Full–load Speed	2300	2100	2300
Camshaft Timing	Std. (71C5) Std. (C55) Std. (C60) Adv. (C65) Adv. (C70)	Std.	Std. (Adv.–B65)
Injector Timing	1.484" (71C5) 1.484" (C65) 1.484" (C70) 1.460" (C55) 1.460" (C60)	1.460" (C65) 1.484" (N70) 1.484" (N75)	1.500" 1.484" (B65)
Throttle Delay Yield Link	Not Req'd.	(g) Req'd.	Not Req'd. (Req'd. –B65) (g)
Turbocharger A/R		T18A40 1.00 4MF–782 4.70	

(a) Not to exceed injector size and maximum operating speed that has been established. No–load speed will vary with injector size and governor type.

(b) Use a minimum idle·speed of 400 r/min on all coach engines with throttle delay and a minimum idle speed of 500 r/min on all other engines.

(c) Includes certain highway coach engines.

(g) Small fill hole (.078" Dia.), .016" discharge orifice.

1977 CERTIFIED AUTOMOTIVE ENGINES

Engine	FEDERAL			CALIFORNIA	
	6L–71N (c)	6L–71T T	6L–71T T	6L–71T TT	6L–71N
(a) Injectors	71C5 C55 C60 C65 C70	C65 N70 N75	C65 N70 N75	N75	71B5 B55 B60
(a) Approved Minimum Constant Horsepower				220	
(a) Maximum rated Speed	2300	2100	2100	2100	2300
(a) Minimum Rated Speed	2300 (71C5) 1950 (C55) 1900 (C60) 1950 (C65) 2100 (C70)	2100	1900	1900	2300 (71B5) 2100 (B55) 2100 (B60)
Gear Train Timing	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484” (71C5) 1.460” (C55) 1.460” (C60) 1.484” (C65) 1.484” (C70)	1.460” (C65) 1.484” (N70) 1.484” (N75)			1.500”
Throttle Delay (Yield Link) Setting	None	(f) Req'd. .570”			None
Liner Port Height	1.05”	1.05”	1.05”	1.05”	1.05”
Compression Ratio	18.7:1	17.7:1	17.7:1	17.7:1	18.7:1
Blower Drive Ratio	2:1	1.95:1	1.95:1	1.95:1	2:1
Governor Type	Limiting Speed				
Thermostat	170–180° F (77–82° C) Nominal Operating Temperature				
Turbocharger A/R		T18A40 1.00 4MF–782 4.70	TV7101 1.39	TV7101 1.39	

Use minimum idle speed of 500 r/min on all engines, except coach engines where a minimum of 400 r/min is allowed.

(a) Not to exceed injector size and maximum operating speed that has been established. No–load speed will vary with injector size and governor type.

(c) Includes certain highway coach engines.

(g) Small fill hole (.078” Dia.), .016” discharge orifice.

1978 CERTIFIED AUTOMOTIVE ENGINES

Engines	(c) 6L–71N	FEDERAL 6L–71T				CALIFORNIA
		T	OTM	TT	T	
Injectors (a)	71C5 C55 C60 C65 C70	C65 N70 N75	C65 N70 N75	N75	C65 N70 N75	71B5 B55 B60
Approved Constant Horsepower for TT & TA Engines				220–230		
Maximum Full–Load Speed (b)	2300	2100	2100	2100	2100	2300
Minimum Full–Load Speed	71C5–1800 C55–1800 C60–1800 C65–1900 C70–1900	1900	1900	1900	1900	1800
Camshaft Lobe Position		Std.	Std.	Std.	Std.	Std.
Injector Timing			C65–1.460" N70 & N75 – 1.484"			1.500"
Throttle Delay Yield Link	Not Req'd.	(f) Req'd.	(f) Req'd.	(f) Req'd.	(f) Req'd.	Not Req'd.
Turbocharger A/R		*T18A40 1.00 *4MF–782 4.70 Sq. In.	TV7101 1.39	TV7101 1.39	*T18A40 1.50 *4MF–782 8.54 Sq. In.	

(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 r/min on all coach engines with a throttle delay and a minimum idle speed of 500 r/min on all other engines.

(c) Includes certain highway coach engines.

(f) Small fill hole (.078" dia.), .016" discharge orifice.

* These turbocharger options to be cancelled effective 9/1/78.

Use a minimum idle speed of 500 r/min on all engines, except coach engines where a minimum of 400 r/min is allowed.

1979 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL			CALIFORNIA
Engine	6L–71N***	6L–71T	6L–71TT	6L–71NC
Injectors	7E65, 7E60 7E55, 7E50	N65 7C70 7C75	7E75	71B5 B55 B60
Max. Full–Load Speed	2300	2100	2100	2300
Min. Full–Load Speed	1800 7E65–1900	1900	1800	1800
Min. Idle Speed	500	500	500	500
Gear Train Timing	Std.%	Std.	Std.	Std.
Injector Timing	1.484" 7E55–1.496"	N65–1490" 7C70–1.470" 7C75–1.460"	1.466"	71B5–1.500" 1.508"
Throttle Delay Setting	DNA	.570%%	.594%%	DNA
Liner Port Height	1.05	.95	.95	1.05
Liner Port Number	5113953	5102795	5102795	5113953
Turbocharger A/R	DNA	TV–7101 1.23 A/R	TV–6141 1.08 A/R	DNA
Turbocharger Part Number	DNA	5107617	5107616	DNA
Blower Drive Ratio	2:1	1.65:1	1.51:1	2:1
Blower Part Number	5138554–LH 5138553–RH 5142017–Hor.	5107609 5108031–RH	5107608	5138554–LH 5138553–RH 5142017–Hor.
Compression Ratio	18.7:1	17:1	17:1	18.7:1
Exhaust Valve Material	Inconel X Type 751	Nimonic 90 Aluminized	Nimonic 90 Aluminized	Inconel X Type 751
Exhaust Valve Part Number	5114288	5111336	5111336	5114288
Certification Number	14B7–268	14B7–263	14B7–263	14B7–269

Timing Gages

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–28479 For .395"
J–9509–2 For .404"
J–23190 For .454"
J–29062 For .504"
J–25559 For .570"
J–26927 For .586" & .686"
J–29064 For .660"
J–29063 For .594"
J–26645 For .160"
J26646 For .290"

Pin Gage

J–25558 For .069" & .072"

% 7E65–Built in advanced camshaft timing.

%% Small fill hole (.078" dia.), .016" diameter discharge orifice.

*** Includes certain highway coach engines.

DNA Does not apply.

 May, 1994

1980 AND 1981 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL			CALIFORNIA	
Engine	(c) 6L–71N	6L–71T	6L–71TT	6L–71TA C	6L–71TTA C
Injectors (a)	7SE50 7SE55 7SE60 7SE65	N65 7C70 7C75	7E75	7G75	7G75
Max. Full–Load Speed	2300	2100	2100	2100	2100
Min. Full–Load Speed	1800 7E65–1900	1800	1800	1800	1800
Min. Idle Speed	500	500	500	700	700
Gear Train Timing	(d) Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484" 7E55–1.496"	N65–1490" 7C70–1.470" 7C75–1.460"	1.466"	1.470"	1.470"
Throttle Delay Setting	DNA	(f) .570	(f) .594	(f) .586	(f) .586
Turbocharger A/R	DNA	TV7101 1.23 A/R	TV6141 1.08 A/R	TV–6141 1.39	TV–6141 1.39

<u>Timing Gages</u>

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 <u>Starting AID Gages</u>

J–24889 For .345"
J–28779 For .365"
J–24882 For .385"
J–28479 For .395"
J–9509–2 For .404"
J–23190 For .454"
J–29062 For .504"
J–25559 For .570"
J–26927 For .586" & .686"
J–29064 For .660"
J–29063 For .594"
J–26645 For .160"
J26646 For .290"

<u>Pin Gage</u>

J–25558 For .069" & .072"

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for each specific application usage of injector size and full–load speed combination. No–load speed will vary with injector size and governor.

(c) Includes certain highway coach engines.

(d) 7E65 Injector has built–in advance camshaft timing.

(f) Small fill hole (.078" dia.), .016" diameter discharge orifice.

1980 AND 1981 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	Peak Torque (lb/in.^{2})
6L71N	7E50 7E55 7E60 7E65	185 @ 2100 200 @ 2100 215 @ 2100 230 @ 2100	565 @ 1200 590 @ 1200 611 @ 1200 611 @ 1600
6L71T	N65 7C70 7C75	245 @ 2100 260 @ 2100 275 @ 2100	736 @ 1200 781 @ 1200 801 @ 1400
6L–71TT	7E75	210 @ 2100 260 @ 2100 275 @ 2100	853 @ 1200 853 @ 1200 853 @ 1200
6L–71TAC (California)	7G75	270 @ 2100	783 @ 1200
6L–71TTAC (California)	7G75	230 @ 1950 240 @ 2100 *270 @ 2100	783 @ 1200 783 @ 1200 *783 @ 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)			

* 1980 Engines only.

1982 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL			CALIFORNIA	
Engine	***6L–71N	6L–71T	6L–71TT	6L–71TA	6L–71TTA
Injectors (a)	7SE50, 7B5 7SE55, B55 7SE60, B60 7SE65	N65 7C70 7C75	7E75	7G65 7G70 7G75	7G75
Max. Full–Load Speed	2300	2100	2100	2100	2100
Min. Full–Load Speed	1800 7E65–1900	1800	1800	1800	1800
Min. Idle Speed	500	500	500	700	700
Gear Train Timing	%Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484" 7E55–1.496" X	N65–1490" 7C70–1.470" 7C75–1.460"	1.466"	1.470"	1.470"
Throttle Delay Setting	DNA	.570%%	.594%%	.586	.586
Liner Port Height	1.05	.95	.95	.95	.95
Liner Part Number	5113953	5102795	5102795	5102795	5102795
Turbocharger A/R	DNA	TV7101 1.23 A/R	TV6141 1.08 A/R	TV–6141 1.39 A/R	TV–6141 1.39 A/R
Turbocharger Part Number	DNA	5107617	5107616	8921391	8921391
Blower Drive Ratio	2:1	1.65:1	1.51:1	1.65:1	1.65:1
Blower Part Number	513855–LH 5138553–RH 5142017–Hor.	5107609 5108031–RH 5142017–Hor.	5107608	8921306 8921307–Hor.	8921306 8921307–Hor.
Compression Ratio	18.7:1	17:1	17:1	17:1	17:1
Exhaust Valve Part Number	5114288	5111336	5111336	5111336	5111336
Certification Label Number	14B7–329	14B7–330	14B7–330		

*** Includes certain highway coach engines.

% 7E65 Injector has built–in advance timing.

X B60, B55–1, 508 71B5–1.500

%% Small fill hole (.078" dia.), .016" diameter discharge orifice.

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 164 of the California Vehicle Code.

1982 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	Peak Torque (lb·ft)
6L–71N	7E50 7E55 7E60 7E65	185 @ 2100 200 @ 2100 215 @ 2100 230 @ 2100	565 @ 1200 590 @ 1200 611 @ 1200 611 @ 1600
6L–71T	N65 7C70 7C75	245 @ 2100 260 @ 2100 275 @ 2100	736 @ 1200 781 @ 1200 801 @ 1400
6L–71TT	7E75	210 @ 1800 230 @ 1950 240 @ 2100	853 @ 1200 853 @ 1200 853 @ 1200
6L–71TAC/TTAC (California)	7G75	230 @ 1950 240 @ 2100 270 @ 2100	783 @ 1200 783 @ 2100 783 @ 2100
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)			

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 164 of the California Vehicle Code.

1983 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL					CALIFORNIA
Engine	(c) 6L–71N	6L–71T	6L–71TT	6L–71TA	6L–71TTA	6L–71TAC/TTAC
Injectors (a)	7SE50 7SE55 7SE60 7SE65	N65 7C70 7C75	7E75	7C75	7E75	7G75
Max. Full–Load Speed (a)	2300	2100	2100	1950	2100	2100
Min. Full–Load Speed	1800 7E65–1900	1800	1800	1800	1800	1800
Min. Idle Speed	500	500	500	500	500	700
Gear Train Timing	(d) Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484" 7E55–1.496"	N65–1490" 7C70–1.470" 7C75–1.460"	1.466"	1.458"	1.460"	1.470"
Throttle Delay Setting	DNA	.570 (f)	.594 (f)	.550 (f)	.570 (f)	.586 (f)
Modulator Setting	DNA	.365	.385	.404	.404	DNA
Liner Port Height	1.05	.95	.95	.95	.95	.95
Liner Part Number	5113953	5102795	5102795	5102795	5102795	5102795
Turbocharger A/R	DNA	TV7101 1.23 A/R	TV6141 1.08 A/R	TV6141 1.08 A/R	TV6141 1.08 A/R	TV6141 1.39 A/R
Turbocharger Part Number	DNA	5107617	5107616	5107616	5107616	8921391
Blower Drive Ratio	2:1	1.65:1	1.51:1	1.51:1	1.51:1	1.65:1
Blower Part Number	513855–LH 5138553–RH 5142017–Hor.	5107609 5108031–RH 5142017–Hor.	5107608	8924966	8924966	8921306 8921307–Hor.
Compression Ratio	18.7:1	17:1	17:1	18.7:1	18.7:1	17:1
Exhaust Valve Part Number	5114288	5111336	5111336	5111336	5111336	5111336

DNA – Does not apply

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for each specific application usage of injector size and full–load speed combination. No load speed will vary with injector size and governor.

(c) Includes certain highway coach engines.

(d) 7E65 injector has built–in advance camshaft timing.

(f) Small fill hole (.078" dia.), .016" diameter discharge orifice.

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 164 of the California Vehicle Code.

1983 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	Peak Torque (lb·ft)
6L–71N	7E50 7E55 7E60 7E65	185 @ 2100 200 @ 2100 215 @ 2100 230 @ 2100	565 @ 1200 590 @ 1200 611 @ 1200 611 @ 1600
6L–71T	N65 7C70 7C75	245 @ 2100 260 @ 2100 275 @ 2100	736 @ 1200 781 @ 1200 801 @ 1400
6L–71TT	7E75	180 @ 1800 230 @ 1800 230 @ 1950 240 @ 2100	853 @ 1200 853 @ 1200 853 @ 1200 853 @ 1200
6L–71TA	7C75	260 @ 1800 270 @ 1950	810 @ 1200 810 @ 1200
6L–71TTA	7E75	180 @ 1800 230 @ 1800 230 @ 1950 240 @ 2100	840 @ 1200 840 @ 1200 840 @ 1200 840 @ 1200
6L–71TAC/TTAC (California)	7G75	230 @ 1800 230 @ 1950 240 @ 2100 270 @ 2100	783 @ 1200 783 @ 1200 783 @ 2100 783 @ 2100
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)			

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 164 of the California Vehicle Code.

1984 CERTIFIED AUTOMOTIVE ENGINES

	FEDERAL					CALIFORNIA
Engine	(c) 6L–71N	6L–71T	6L–71TT	6L–71TA	6L–71TTA	6L–71TAC/ TTAC
Injectors (a)	7SE50 7SE55 7SE60 7SE65	N65 7C70 7C75	7E75	7C75	7E75	7G75
Max. Full–Load Speed (a)	2300	2100	2100	1950	2100	2100
Min. Full–Load Speed	1800 7E65–1900	1800	1800	1800	1800	1800
Min. Idle Speed	500	500	500	500	500	700
Gear Train Timing	(d) Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.484" 7E55–1.496"	N65–1490" 7C70–1.470" 7C75–1.460"	1.466"	1.458"	1.460"	1.480"
Throttle Delay Setting	DNA	(f) .570	(f) .594	(f) .550	(f) .570	(f) .570
Modulator Setting	DNA	DNA	DNA	.385	.385	.404
Turbocharger A/R	DNA	TV7101 1.23 A/R	TV6141 1.08 A/R	TV–6141 1.08	TV–6141 1.08	TV–6141 1.39

DNA – Does not apply

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for each specific application usage of injector size and full–load speed combination. No load speed will vary with injector size and governor.

(c) Includes certain highway coach engines.

(d) 7E65 Injector has built–in advance camshaft timing.

(f) Small fill hole (.078" dia.), .016" diameter discharge orifice.

1984 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	Peak Torque (lb·ft)
6L–71N	7E50 7E55 7E60 7E65	185 @ 2100 200 @ 2100 215 @ 2100 230 @ 2100	565 @ 1200 590 @ 1200 611 @ 1200 611 @ 1600
6L–71T	N65 7C70 7C75	245 @ 2100 260 @ 2100 275 @ 2100	736 @ 1200 781 @ 1200 801 @ 1400
6L–71TT	7E75	230 @ 1800 230 @ 1950 240 @ 2100	853 @ 1200 853 @ 1200 853 @ 1200
6L–71TA	7C75	260 @ 1800 270 @ 1950	810 @ 1200 810 @ 1200
6L–71TTA	7E75	180 @ 1800 230 @ 1800 230 @ 1950 240 @ 2100	837 @ 1130 840 @1200 840 @ 1200 840 @ 1200
6L–71TAC/TTAC (California)	7G75	230 @ 1800 230 @ 1950 240 @ 2100 270 @ 2100	788 @ 1200 788 @ 1200 788 @ 1200 788 @ 1200
All engine horsepower ratings are based on SAE J 1348 conditions 85° F (29.4° C) – Air inlet temperature 29.00 in. hg. (98.19 kPa) – Barometer (dry)			

1985 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	r/min	Peak Torque (lb·ft)	r/min	Max. Full–Load Speed	Min. Full–Load Speed	Min. Idle Speed	Injector Timing	Throttle Delay Setting	Fuel Mod. Setting	Turbo	A/R
6L–71N	7E50 7E55 7E60 7E65	185 200 215 230	2100 2100 2100 2100	571 590 611 611	1000 1200 1200 1600	2300 2300 2300 2300	1800 1800 1800 1900	500 500 500 500	1.484 1.496 1.484 1.484	DNA DNA DNA DNA	DNA DNA DNA DNA	DNA DNA DNA DNA	DNA DNA DNA DNA
6L–71TA	7N65 7E75 7C70 7E75 7375	250 260 265 270 **290	2100 1800 2100 1900 2100	703 792 737 792 810	1200 1400 1400 1400 1200	2100 2100 2100 1950 2100	1800 1800 1800 1800 2100	500 500 500 500 500	1.500 1.490 1.490 1.490 1.490	DNA DNA DNA DNA DNA	.454 .454 .454 .454 .454	S4H–005 S4H–005 S4H–005 S4H–005 S4H–005	0.99 0.99 0.99 0.99 0.99
6L–71TTA (JWAC)	7E75	180	1800	780	1200	2100	1800	500	1.490	DNA	.454	S4H–005	0.99
6L–71TTA	7E75 7E75 7E75	230 240 240	1800 1950 2100	792 792 792	1400 1400 1400	2100 2100 2100	1800 1800 1800	500 500 500	1.490 1.490 1.490	DNA DNA DNA	.454 .454 .454	S4H–005 S4H–005 S4H–005	0.99 0.99 0.99
6L–71TAC (CAL)	7G70 7G75	265 285	2100 2100	792 847	1200 1200	2100 2100	1800 1800	700 700	1.480 1.480	DNA DNA	.480 .480	S4H–005 S4H–005	0.99 0.99
6l–71TTAC (CAL)	7G75 7G75 7G75	230 230 240	1800 1950 2100	847 847 847	1200 1200 1200	2100 2100 2100	1800 1800 1800	700 700 700	1.480 1.480 1.480	DNA DNA DNA	.480 .480 .480	S4H–005 S4H–005 S4H–005	0.99 0.99 0.99
6L–71TA (ALCC)	7N65 7E75 7C70 7E75 7E75	255 265 270 275 **300	2100 1800 2100 1900 2100	703 800 743 800 833	1200 1400 1400 1400 1400	2100 1950 2100 1950 2100	1800 1800 1800 1800 2100	500 500 500 500 500	1.500 1.480 1.480 1.480 1.480	DNA DNA DNA DNA DNA	.454 .454 .454 .454 .454	S4H–005 S4H–005 S4H–005 S4H–005 S4H–005	0.99 0.99 0.99 0.99 0.99
6l–71TTA (ALCC)	7E75 7E75 7E75 7E75	180 230 240 240	1800 1800 1900 2100	778 800 800 800	1200 1400 1400 1400	2100 2100 2100 2100	1800 1800 1800 1800	500 500 500 500	1.480 1.480 1.480 1.480	DNA DNA DNA DNA	.454 .454 .454 .454	S4H–005 S4H–005 S4H–005 S4H–005	0.99 0.99 0.99 0.99
6L–71TAC ALCC/CAL	7G70 7G70	270 290	2100 2100	805 862	1200 1200	2100 2100	1800 1800	700 700	1.470 1.470	DNA DNA	.480 .480	S4H–005 S4H–005	0.99 0.99
6L–71TTAC (ALCC/ CAL)	7G75 7G75 7G75	230 230 240	1800 1950 2100	862 862 862	1200 1200 1200	2100 2100 2100	1800 1800 1800	700 700 700	1.470 1.470 1.470	DNA DNA DNA	.480 .480 .480	S4H–005 S4H–005 S4H–005	0.99 0.99 0.99
6L–71TA Hor. Coach	7N65	255	2100	703	1200	2100	1800	500	1.500	.570	DNA	S4H–005	0.99
6L–71TAC Hor. Coach	7G70	265	2100	792	1200	2100	2100	700	1.480	.636	DNA	S4H–005	0.99

TA – Turbocharged/Jacket Water Aftercooled.

TTA – Constant Horsepower/Turbocharged/JAcket Water Aftercooled.

All engine horsepower ratings are based on SAE J 1349 conditions.

Specifications subject to change without notice.

** 6L–71 Federal ratings of 290 and above require 17:1 compression ratio pistons.

JWAC – Jacket Water Aftercooled.

ALCC – Advanced Liquid Charge Cooling.

DNA – Does not apply.

Effective January 1, 1982, California allowed the use of Federal certified engines in Public Transport Busses and in Authorized Emergency Vehicles as defined in section 165 of the California Vehicle Code.

1986 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	r/min	Peak Torque (lb·ft)	r/min	Max. Full–Load Speed	Min. Full–Load Speed	Min. Idle Speed	Injec-tor Timing	Throttle Delay Setting	Fuel Mod. Setting	Turbo	A/R
6L–71N	7E60	215	2100	611	1200	2300	1800	500	1.484	DNA	DNA	DNA	DNA
	7E65	230	2100	611	1600	2300	1900	500	1.484	DNA	DNA	DNA	DNA
6L–71TA (FED/ JWAC)	7A77	300	2100	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99A/R
	7A77	270	1800	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99A/R
	7C70	270	2100	742	1200	2100	2100	500	1.496	.550	.385	S4H–005	.99A/R
	7N65	250	2100	729	1200	2100	2100	500	1.508	.550	.385	S4H–005	.99A/R
6L–71TTA (FED/ JWAC)	7A77	240	2100	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99A/R
	7A77	240	1800	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99A/R
	7A77	230	1950	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99A/R
6L–71TA (FED/ ALCC)	7A77	300	2100	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99A/R
	7A77	270	1800	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99A/R
	7C70	270	2100	748	1200	2100	2100	500	1.490	DNA	.385	S4H–005	.99A/R
	7N65	255	2100	730	1200	2100	2100	500	1.500	DNA	.385	S4H–005	.99A/R
6L–71TTA (FED/ ALCC)	7A77	240	2100	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99A/R
	7A77	240	1800	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99A/R
	7A77	230	1950	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99A/R
6L–71TTA (CAL/ ALCC)	7G75	285	2100	860	1000	2100	1800	700	1.470	DNA	.454	S4H–005	.99A/R
	7G70	265	2100	810	1000	2100	2100	700	1.470	DNA	.454	S4H–005	.99A/R
6L–71TTA (CAL/ ALCC)	7G75	240	2100	860	1000	2100	1800	700	1.470	DNA	.454	S4H–005	.99A/R
	7G75	240	1800	860	1000	2100	1800	700	1.470	DNA	.454	S4H–005	.99A/R
	7G75	230	1950	860	1000	2100	1800	700	1.470	DNA	.454	S4H–005	.99A/R
6L–71TA (FED/ JWAC) (FIRE TRUCK)	7A77	320	2300	845	1200	2300	2300	500	1.490	DNA	.430–.454	S4H–005	.99A/R
	7E75	290	2100	810	1200	2300	2100	500	1.490	DNA	.430–.454	S4H–005	.99A/R
6L–71TA (CAL/ JWAC)	7G75*	270	2100	788	1200	2100	2100	700	1.480	.586	DNA	TV–6141	1.39A/R
	7G70*	250	2100	729	1200	2100	2100	700	1.480	.586	DNA	TV–6141	1.39A/R
	7G70	265	2100	792	1200	2100	2100	700	1.480	.570	.480	S4H005	.99A/R
	7G75	285	2100	847	1200	2100	2100	700	1.480	.570	.480	S4H–005	.99A/R

TA – Turbocharged/Jacket Water Aftercooled.

TTA – Constant Horsepower/Turbocharged/JAcket Water Aftercooled.

All engine horsepower ratings are based on SAE J 1349 conditions.

Specifications subject to change without notice.

** 6L–71 Federal ratings of 290 and above require 17:1 compression ratio pistons

JWAC – Jacket Water Aftercooled.

ALCC – Advanced Liquid Charge Cooling.

DNA – Does not apply.

6–71TA, TTA Fed. & Calif. Engines Only:

* Horizontal Engine (Only California Ratings Avail.)

with 1.51 Blower Drive Ratio, 18.7:1 Comp. Ratio,

FT – Fire Truck (Only Fed. JWAC Available for these ratings.

All Federal cams are 5122202–3J28/3x167.187 lift.

All California cams are 8921260–3J40/17x162.117 lift.

All gear train timing is standard.

1987 CERTIFIED AUTOMOTIVE ENGINES

Engine	Injector	Rated BHP	r/min	Peak Torque (lb·ft)	r/min	Max. Full–Load Speed	Min. Full–Load Speed	Min. Idle Speed	Injec-tor Timing	Throttle Delay Setting	Fuel Mod. Setting	Turbo	A/R
6L–71N	7E60	230	2100	611	1600	2300	1800	550	1.484	DNA	DNA	DNA	DNA
	7E65	239	2300	611	1600	2300	1800	550	1.484	DNA	DNA	DNA	DNA
6L–71TA (JWAC)	7N65	250	2100	729	1200	2100	1800	500	1.508	DNA	.385	S4H–005	.99
	7A77	270	1800	835	1200	1800	1800	500	1.496	DNA	.395	S4H–005	.99
	7C70	270	2100	742	1200	2100	1800	500	1.496	DNA	.385	S4H–005	.99
	7E75	**290	2100	810	1200	2300	2100	500	1.490	DNA	.454	S4H–005	.99
	7A77	300	2100	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99
6L–71TTA (JWAC)	7A77	230	1950	835	1200	1950	1800	500	1.496	DNA	.395	S4H–005	.99
	7A77	240	1800	835	1200	1800	1800	500	1.496	DNA	.395	S4H–005	.99
	7A77	240	2100	835	1200	2100	1800	500	1.496	DNA	.395	S4H–005	.99
6L–71TAC (CAL/ JWAC)	7G0$$	250	2100	729	1200	2100	2100	700	1.480	.586	DNA	TV–6141	.99
	7G70■	265	2100	792	1200	2100	1800	500	1.480	.570	.480	S4H–005	.99
	7G75$$	270	2100	788	1200	2100	2100	700	1.480	.586	DNA	TV–6141	.99
	7G75■	285	2100	847	1200	2100	1800	500	1.480	.570	.480	S4H–005	.99
6L–71TA (ALCC)	7C70	270	2100	748	1200	2100	1210	500	1.490	DNA	.385	S4H–005	.99
	7N65	255	1210	730	1200	2100	2100	500	1.500	DNA	.385	S4H–005	.99
	7A77	270	1800	840	1200	1800	1800	500	1.490	DNA	.385	S4H–005	.99
	7A77	300	2100	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99
6L–71TTA (ALCC)	7A77	230	1950	840	1200	1950	1800	500	1.490	DNA	.385	S4H–005	.99
	7A77	240	1800	840	1200	1800	1800	500	1.490	DNA	.385	S4H–005	.99
	7A77	240	2100	840	1200	2100	1800	500	1.490	DNA	.385	S4H–005	.99
6L–71TAC (CAL/ ALCC)	7G70	265	2100	810	1000	2100	1800	500	1.470	DNA	.454	S4H–005	.99
	7G75	285	2100	860	1000	2100	1800	500	1.470	DNA	.454	S4H–005	.99
6–71TAC (ALCC/ CAL)	7G75	240	1800	860	1000	1800	1800	500	1.470	DNA	.454	S4H–005	.99
	7G75	230	1950	860	1000	1950	1800	500	1.470	DNA	.454	S4H–005	.99
	7G75	240	2100	860	1000	2100	1800	500	1.470	DNA	.454	S4H–005	.99

TA – Turbocharged/Jacket Water Aftercooled.

TTA – Constant Horsepower/Turbocharged/JAcket Water Aftercooled.

All engine horsepower ratings are based on SAE J 1349 conditions.

Specifications subject to change without notice.

** 17:1 compression ratio pistons, 1.65:1 Blower Drive Ratio

JWAC – Jacket Water Aftercooled.

ALCC – Advanced Liquid Charge Cooling.

DNA – Does not apply.

$$ 1.5:1 Blower Drive Ratio

■ 1.65:1 Blower Drive Ratio

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. 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 (TWO VALVE HEAD ON COLD ENGINE)

1. Remove the loose dirt from the valve rocker cover and remove the cover. Discard the gasket. 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, manually or with the cranking motor, until the injector follower is fully depressed on the cylinder to be adjusted. 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.

4. Loosen the exhaust valve rocker arm push rod locknut. Place a .012 inch feeler gage (J 9708–01) between the end of the exhaust valve stem and the rocker arm (Figure 1.) Adjust the push rod to obtain a smooth "pull" on the feeler gage.
5. Remove the feeler gage. Hold the push rod with a 5/16 inch wrench and tighten the locknut with a 1/2 inch wrench.
6. Recheck the clearance. At this time, if the adjustment is correct, the .011 inch feeler gage will pass freely between the valve stem and the rocker arm, but the .013 inch feeler gage will not pass through. Readjust the push rod, if necessary.
7. Check and adjust the remaining exhaust valves in the same manner as outlined above.

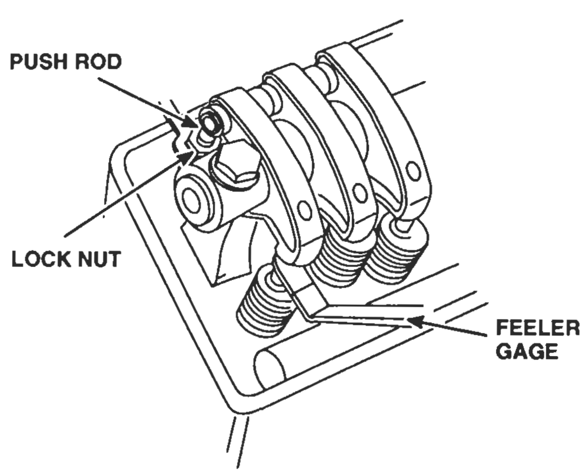


Figure 1. Adjusting Valve Clearance on Two Valve Head

SECTION 14.1 – EXHAUST VALVE CLEARANCE ADJUSTMENT

VALVE CLEARANCE ADJUSTMENT (TWO VALVE HEAD ON 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 final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full–load, may become insufficient.

NOTE: 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 (Section 13.2), set the exhaust valve clearance with feeler gage J 9708–01. At this time, if the valve clearance is correct, the .008 inch feeler gage will pass freely between the end of the exhaust valve stem and the rocker arm and the .010 inch 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 .012 inch feeler gage (± .004 inch) will pass between the end of the exhaust valve stem and the rocker arm, the valve clearance is satisfactory. If necessary, adjust the push rod.

ENGINES WITH FOUR VALVE CYLINDER HEADS

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.

VALVE CLEARANCE ADJUSTMENT (FOUR VALVE HEAD ON COLD ENGINE)

1. Remove the loose dirt from the valve rocker cover and remove the cover. Discard the gasket. 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, manually or with the cranking motor, until the injector follower is fully depressed on the cylinder to be adjusted. 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.

VALVE CLEARANCE ADJUSTMENT (FOUR VALVE HEAD ON COLD ENGINE) (CONT.)

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 inch feeler gage (J 9708–01) between the end of the exhaust valve stem and the valve bridge adjusting screw (spring–loaded bridge only – Figure 2.)

   Or, insert feeler gage between the valve bridge and the valve rocker arm pallet (unloaded bridge only – Figure 3.) Adjust the push rod to obtain a smooth "pull" on the feeler gage.

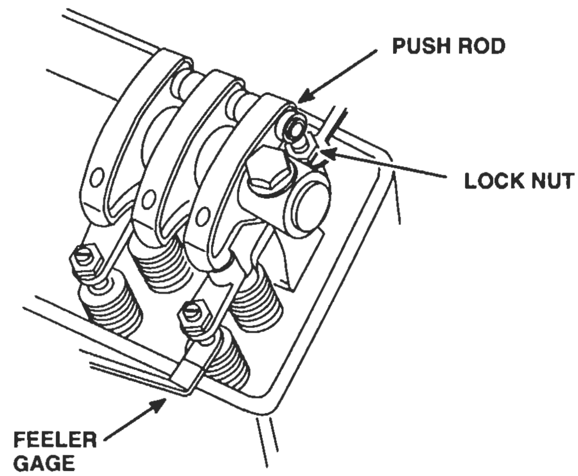


Figure 2. Adjusting Valve Clearance (Spring–Loaded Valve Bridge)

6. Remove the feeler gage. Hold the push rod with a 5/16 inch wrench and tighten the locknut with a 1/2 inch wrench.
7. Recheck the clearance. At this time, if the adjustment is correct, the .015 inch gage will pass freely between the valve stem and the adjusting screw (spring–loaded bridge) or between the valve bridge and the rocker arm pallet (unloaded bridge), but the .017 inch gage will not pass through. Readjust the push rod, if necessary.
8. Check and adjust the remaining exhaust valves in the same manner as above.

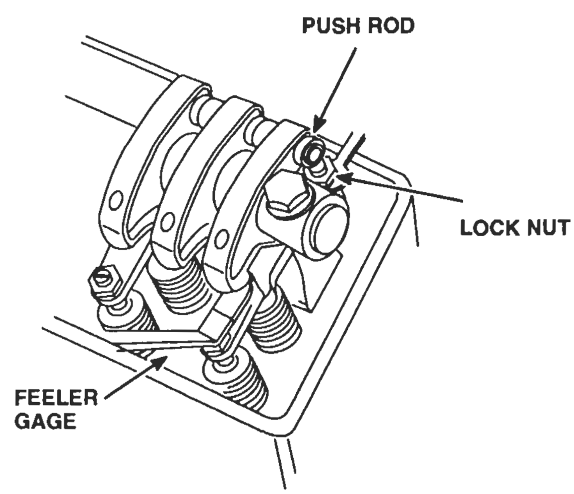


Figure 3. Adjusting Valve Clearance (Unloaded Valve Bridge)

SECTION 14.1 – EXHAUST VALVE CLEARANCE ADJUSTMENT

VALVE CLEARANCE ADJUSTMENT (FOUR VALVE HEAD ON 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 final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance when running at full–load may become insufficient.

NOTE: Since these adjustments are 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 (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 inch feeler gage will pass freely between the valve stem and the valve bridge adjusting screw (spring–loaded bridge) or between the valve bridge and the valve rocker arm pallet (unloaded bridge), but the .015 inch 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 inch feeler gage (± .004 inch) will pass between the end of the exhaust valve stem and the valve bridge adjusting screw (spring–loaded bridge) or between the valve bridge and the valve rocker arm pullet (unloaded bridge), 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 the General Specifications at the front of the manual for the engine firing order.

TIMING 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 no–fuel position.
2. Rotate the crankshaft, manually or with the cranking motor, 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 in the hole provided in the top of the injector body with the flat of the gage toward the injector follower (Figure 1.) Refer to Table 1 for the correct timing gage (for vehicle engines, see Section 14).
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, use a new gasket and reinstall the valve rocker cover.

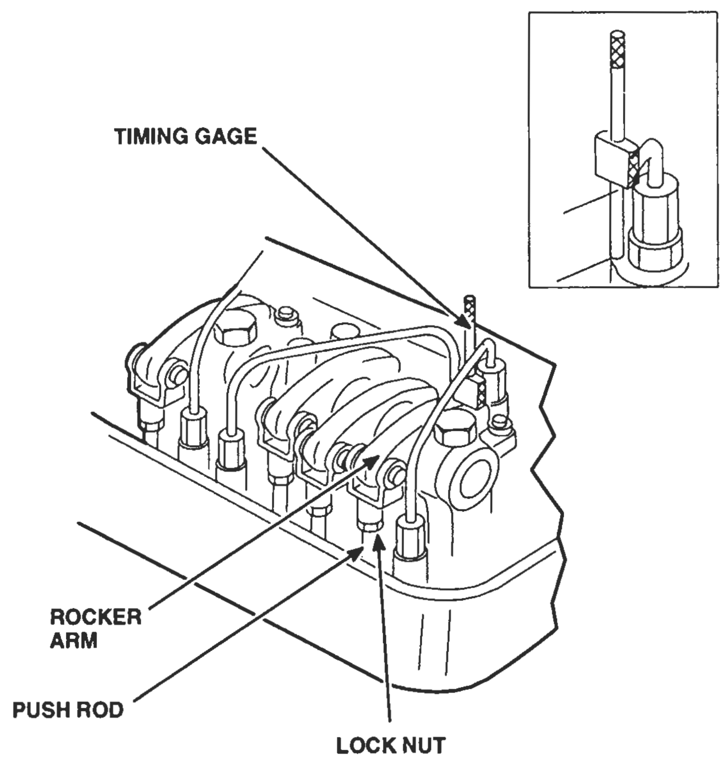


Figure 1. Timing Fuel Injector

TIMING FUEL INJECTOR (CONT.)

INJECTOR	TIMING DIMENSION	TIMING GAGE	CAMSHAFT TIMING
GENERATOR SET APPLICATIONS			
All	1.460"	J 1853	Standard
# ALL OTHER APPLICATIONS			
71N5	*1.460"	J 1853	* Standard
N55	*1.460"	J 1853	* Standard
N60	* 1.460"	J 1853	* Standard
N60 (turbo)	1.460"	J 1214	Standard
N65 (white tag)	1.460"	J 1853	Standard
N65 (turbo brown tag)	1.484"	J 1214	Standard
N65 (non–turbo brown tag)	†1.484"	J 1214	†Advanced
HN65	1.460"	J 1853	Standard
N70 (turbo)	1.460"	J 1853	Standard
N75 (turbo)	1.460"	J 1853	Standard
N80 (turbo)	1.484"	J 1242	Standard
N80 (non–turbo)	†1.484"	J 1242	†Advanced
N90	1.460"	J 1853	Standard
DDEC E.U.I.	1.460"		Standard

TABLE 1 – INJECTOR TIMING (Needle Valve)

For automotive applications, refer to Section 14.

* Use 1.484" timing gage (J1242) when engine has advanced camshaft timing. Correct to standard camshaft timing and 1.460" injector timing as first opportunity to be consistent with correct production build.

† Use 1.460" timing gage (J 1853) when engine has standard camshaft timing. Correct to advanced camshaft timing and 1.484" injector timing at first opportunity.

Advanced camshaft timing is indicated by "ADV–GT ADV–CAM" stamped on the lower right hand side of the engine option plate.

LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the limiting speed mechanical governor and position the injector rack control levers.

NOTE: 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 (Section 14.14).

Back out the external starting aid screw.

NOTE: On "TT" engines back out the Belleville spring retainer nut until there is approximately .060″ clearance between the washers and the retainer nut (Figure 1.)

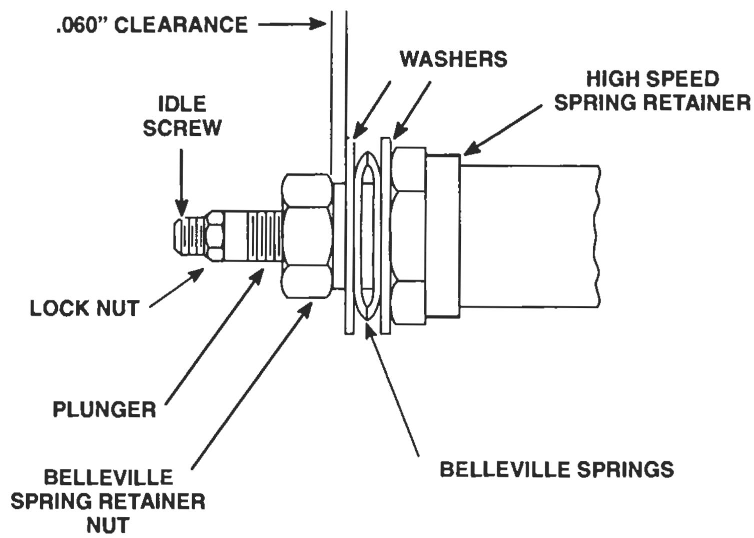


Figure 1. Belleville Washer Location

ADJUST GOVERNOR GAP (SINGLE–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 governor high–speed spring retainer cover.
2. Back out the buffer screw or fast idle cylinder until it extends approximately 5/8 inch from the locknut.
3. Start the engine and loosen the idle speed adjusting screw locknut. Then adjust the idle screw to obtain the desired engine idle speed. Hold the screw and tighten the locknut to hold the adjustment. EPA certified minimum idle speeds are 500 r/min for trucks and highway coaches and 400 r/min for city coaches.
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.

ADJUST GOVERNOR GAP (SINGLE–WEIGHT GOVERNOR) (CONT.)

6. Check the gap between the low–speed spring cap and the high–speed spring plunger with gage J 5407 (.170 inch) (Figure 2.) 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 governor and injector control tube lever.
11. Use a new gasket and install the governor cover and lever assembly.

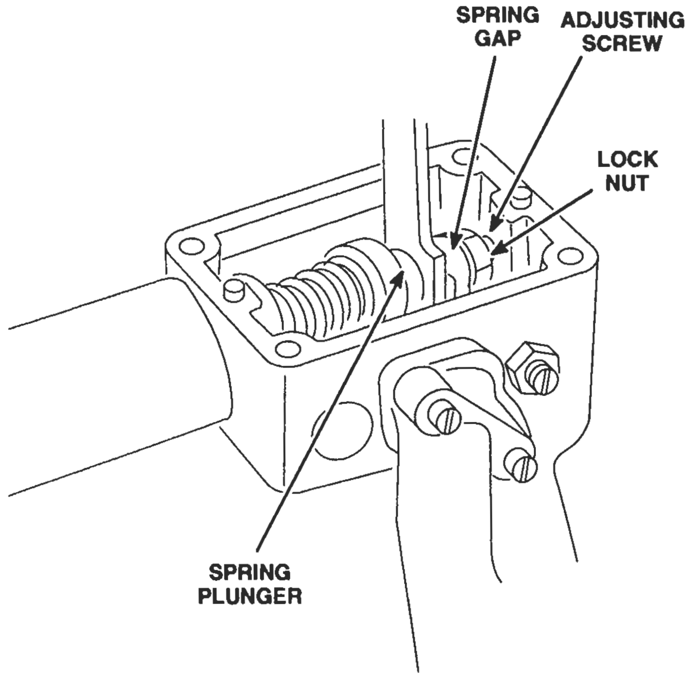


Figure 2. Adjusting Gap (Single–Weight Governor) Using Tool J 5407

ADJUST GOVERNOR GAP (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 governor high–speed spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8 inch from the locknut.
3. Start the engine and loosen the idle speed adjusting screw locknut and adjust the idle screw to obtain the desired engine idle speed. Hold the screw and tighten the locknut to hold the adjustment. EPA certified minimum idle speeds are 500 r/min for trucks and highway coaches and 400 r/min for city coaches.

NOTE: Current limiting–speed governors used in turbocharged engines include a starting aid screw threaded into a boss on the governor housing.

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gaskets.

ADJUST GOVERNOR GAP (DOUBLE–WEIGHT GOVERNOR) (CONT.)

5. Remove the fuel rod from the differential lever and the injector control tube lever (Figure 3.)
6. Start and run the engine between 1,100 and 1,300 r/min by manual operation of the differential lever. Do not overspeed the engine.

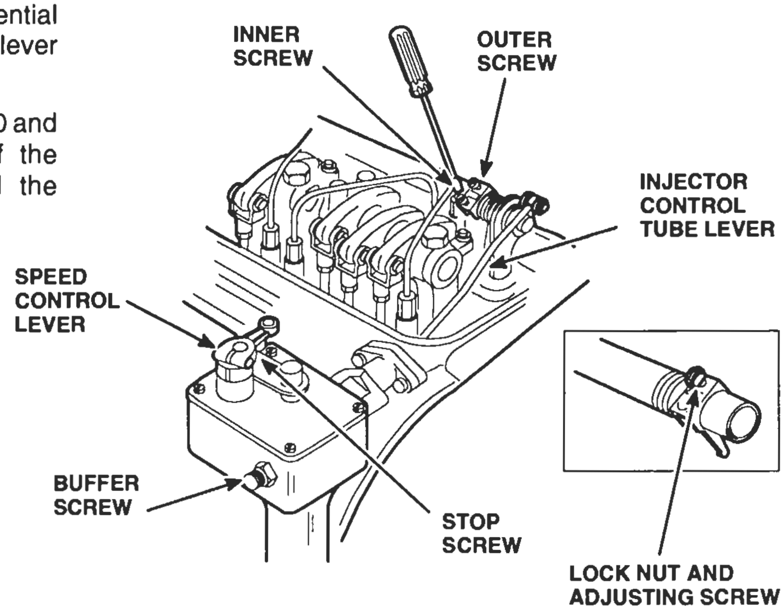


Figure 3. Positioning No. 1 Injector Rack Control Lever

7. Check the gap between the low–speed spring cap and the high–speed spring plunger with a feeler gage (Figure 4.) The gap should be .002–.004 inch. If the gap setting is incorrect, reset the gap adjusting screw.
8. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.
9. Recheck the gap with the engine operating between 1,100 and 1,300 r/min. Readjust if necessary.
10. Stop the engine and install the fuel rod between the differential lever and the control tube lever.
11. Use a new gasket and install the governor cover and lever assembly.

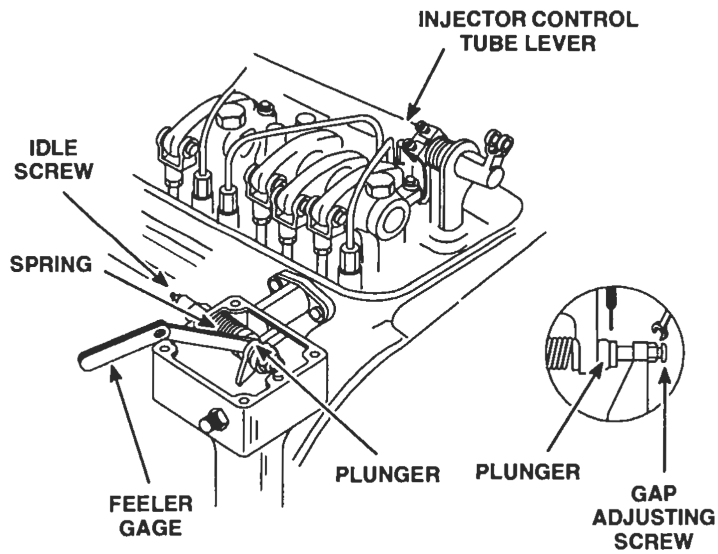


Figure 4. Adjusting Gap (Double–Weight Governor) using Tool J 3172

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.

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 racks in the full–fuel position.

NOTE: When positioning the injector racks on an early engine equipped with a fuel modulator, be sure no interference is encountered from the fuel modulator. Loosen the fuel modulator lever ("U" bolt) and move the modulator lever along the injector control tube to avoid contact with the modulator cam.

Adjust the No. 1 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 inch 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.

NOTE: 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 that 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, not allowing the speed control lever to reach the end of its travel.
b. Binding of the fuel rod.
c. Failure to back out the idle screw.

3. Back out the buffer screw approximately 5/8 inch, if it has not already been done.
4. Loosen all of the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts. Be sure all of the control levers are free on the injector control tube.

NOTE: On engines equipped with a yield link–type fuel rod, attach a small "C" clamp at the shoulder of the rod to prevent the yield spring from compressing while adjusting the injector rack control levers.

5. Move the speed control lever to the maximum speed position. Hold the lever in that position with light finger pressure and proceed as follows:
6. **No Screw Assembly** — Turn the inner adjusting screw on the No. 1 injector rack control lever down until a slight movement of the control tube is observed or a step–up in effort is noted. This will place the No. 1 injector rack in 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 screw.
7. **One Screw and Locknut Assembly** — Tighten the adjusting screw of the No. 1 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.

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).

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

The previous 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 (Figure 5.)

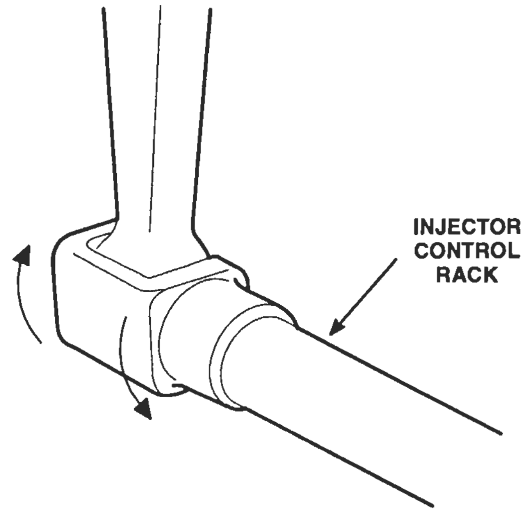


Figure 5. Checking Rotating Movement of Injector Control Rack

9. 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 or finger tip is released, the control rack should "spring" back upward (Figure 6.)

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.

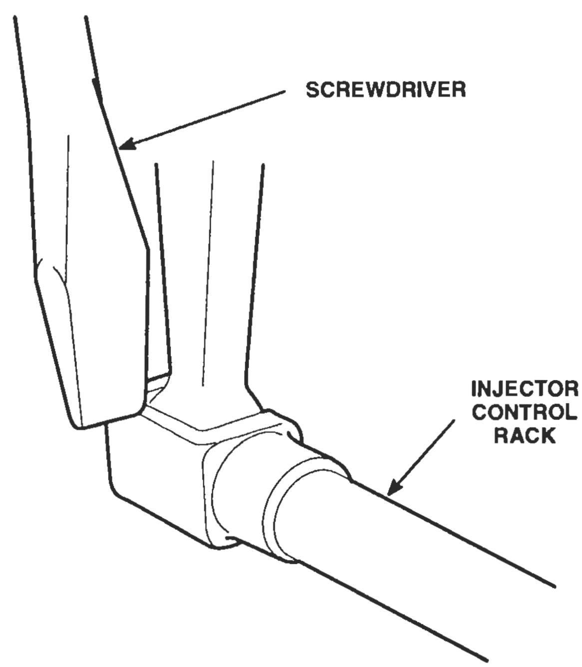


Figure 6. Checking Injector Control Rack "Spring"

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

The setting is too tight if, when moving the speed control lever from the idle speed position 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.

10. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever. 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:

Two Screw Assembly:

a. Turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into the full–fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws.

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. Recheck the No. 1 injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the No. 2 injector. If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever and tighten the outer adjusting screw.

One Screw and Locknut Assembly:

a. Tighten the adjusting screw of the No. 2 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. 1 as outlined in Step 6. If No. 1 does not "spring" back upward, turn the No. 2 adjusting screw counterclockwise slightly until the No. 1 injector rack returns to its full–fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1 and No. 2 injectors. Turn clockwise or counterclockwise the No. 2 injector rack adjusting screw until both No. 1 and No. 2 injector racks are in the full–fuel position when the locknut is securely tightened.

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

11. Position the remaining injector rack control levers as outlined in Step 7.
12. Connect the fuel rod to the injector control tube lever.
13. Turn the idle speed adjusting screw until it projects 3/16 inch from the locknut to permit starting the engine.

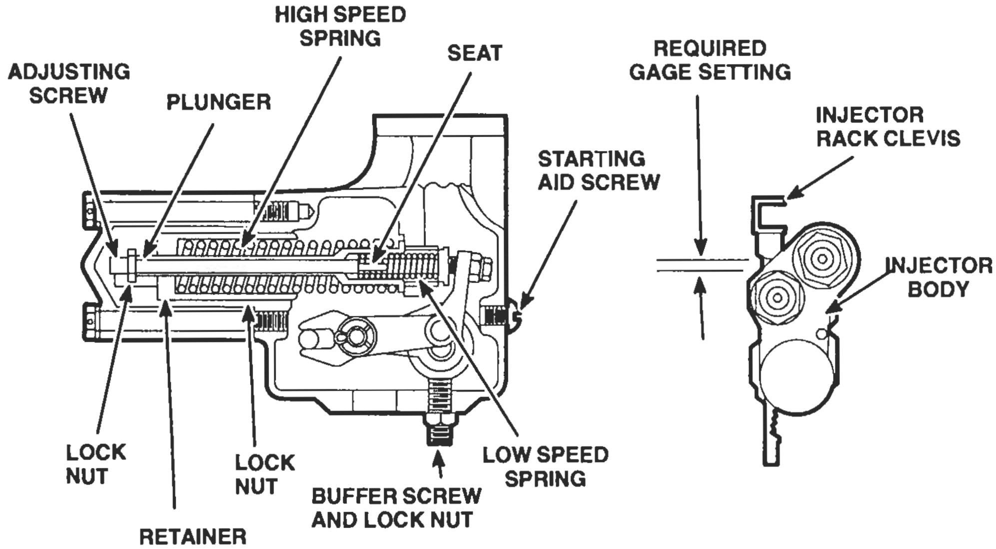
NOTE: Remove the "C" clamp from the fuel rod on units equipped with a yield link.

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

14. 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 (Figure 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.



INJECTOR	GAGE SETTING	TOOL NUMBER
N60	.345"	J 24889
N65	.385"	J 24882
N70	.385"	J 24882
N75	.385"	J 24882
N80	.385"	J 24882
N90	.454"	J 23190
C65	.385"	J 24882
C70	.385"	J 24882
7C70	.385"	J 24882
7C75	.385"	J 24882
7E50	.345"	J 24889
7E55	.345"	J 24889
7E60	.345"	J 24889
7E65	.385"	J 24882
7E75	.385"	J 24882
71B5	.345"	J 24889
B55	.345"	J 24889
B60	.345"	J 24889
7G65	.385"	J 24882
7G70	.385"	J 24882
7G75	.385"	J 24882

Figure 7. Adjusting Starting Aid Screwdriver Current Turbocharged Engines)

    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. Move the speed control lever from the idle speed, & position to the maximum speed position. 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 operating shaft lever 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.

15. Use a new gasket and reinstall the valve rocker cover.

 May, 1994

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:

Be sure the buffer screw projects 5/8 inch from the locknut to prevent interference while adjusting the maximum no–load speed.

1. Loosen the spring retainer locknut (Figure 8.) and back off the high–speed spring retainer approximately five turns.
2. With the engine running at operating temperature and no load, 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.

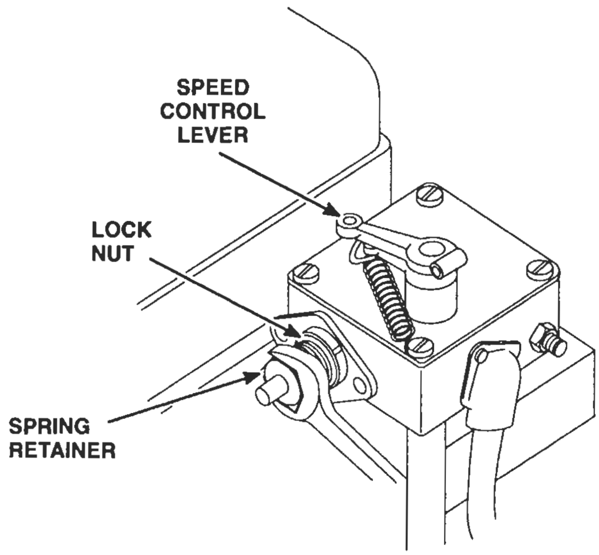


Figure 8. Adjusting Maximum No–Load Speed

ADJUST IDLE SPEED

With the maximum no–load speed properly adjusted, adjust the idle speed as follows:

1. Remove the spring housing to uncover the idle speed adjusting screw.
2. With the engine running at normal operating temperature and with the buffer screw (Figure 9.) backed out to avoid contact with the differential lever, turn the idle speed adjusting screw until the engine is operating at approximately 15 r/min below the recommended idle speed. EPA certified minimum idle speeds are 500 r/min for trucks and highway coaches and 400 r/min for city coaches.
3. Hold the idle screw and tighten the locknut.
4. Install the high–speed spring retainer cover and tighten the two bolts.
5. For "TT" engines, refer to Section 14.3.5 for the adjustment of the Belleville spring.

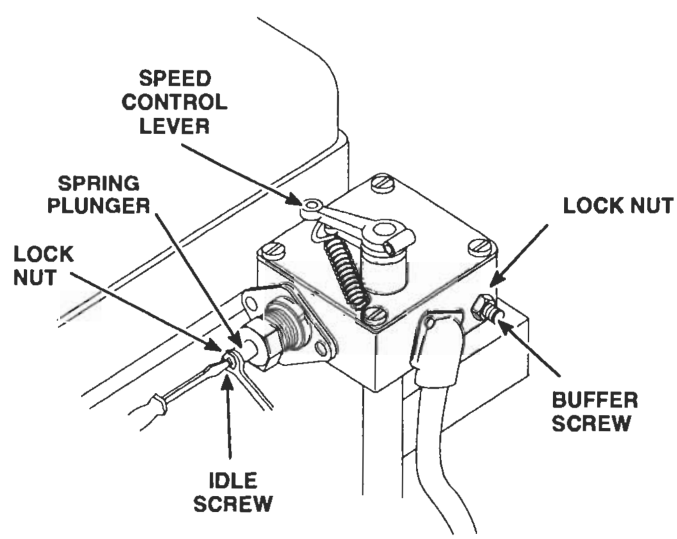


Figure 9. Adjusting Engine Idle Speed

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. Do not increase the engine idle speed more than 15 r/min with the buffer screw.
2. Recheck the maximum no–load speed. If it has increased more than 25 r/min, back off the buffer screw until the increase is less than 25 r/min.
3. Hold the buffer screw and tighten the locknut.

LIMITING–SPEED MECHANICAL GOVERNOR (DUAL RANGE) INJECTOR RACK CONTROL ADJUSTMENT

Adjust the limiting–speed mechanical governor (dual range) and injector rack control levers after adjusting the exhaust valves and timing the fuel injectors. Loosen the lever and disconnect the air cylinder link (if used), before proceeding with the governor adjustment.

ADJUST GOVERNOR GAP – (DOUBLE–WEIGHT GOVERNOR)

1. With the engine stopped and at normal operating temperature, remove the two attaching bolts and withdraw the governor high–speed spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8 inch from the locknut.
3. Start the engine, loosen the idle speed adjusting screw locknut and adjust the idle screw to obtain the desired idle speed. Hold the screw and tighten the locknut to retain the adjustment. The recommended idle speed is 450 r/min, but may vary with special engine applications.
4. Stop the engine. Clean and remove the valve rocker cover, the governor cover and lever assembly. Discard the gaskets.
5. Remove the fuel rod from the differential lever and the injector control tube lever.
6. Start and run the engine between 1,100 and 1,300 r/min by manual operation of the differential lever. Do not overspeed the engine.

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7. Check the gap between the low–speed spring cap and the high–speed spring plunger with a feeler gage (Figure 1.) The gap should be .002–.004 inch. If the gap setting is incorrect, reset the gap adjusting screw.
8. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.
9. Recheck the gap with the engine operating between 1,100 and 1,300 r/min. Readjust, if necessary.
10. Stop the engine and install the fuel rod between the differential lever and the control tube lever.
11. Use a new gasket and install the governor cover and lever assembly.

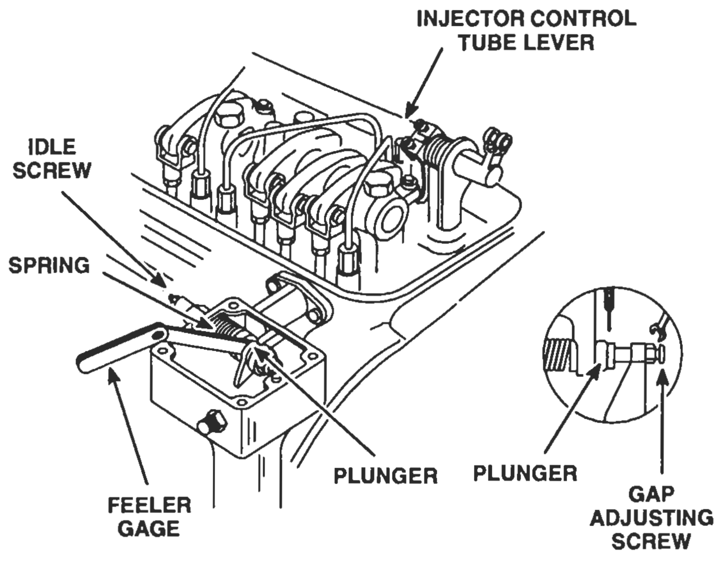


Figure 1. Adjusting Governor Gap using Tool J 3172

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.

Properly positioned injector rack control levers 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 racks in the full–fuel position.

Adjust the No. 1 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. Loosen the idle speed adjusting screw locknut and back out the idle speed adjusting screw until 1/2 inch of the threads project from the locknut when the nut is against the high–speed plunger.
3. Back out the buffer screw approximately 5/8 inch, if it has not already been done.
4. Loosen all of the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts. Be sure all the injector rack control levers are free on the injector control tube. On engines equipped with a yield link–type fuel rod, attach a small "C" clamp at the shoulder of the rod to prevent the yield spring from compressing while adjusting the injector rack control levers.
5. Move the governor speed control lever to the maximum speed position (Figure 2.) Hold the lever in that position with light finger pressure and proceed as follows:

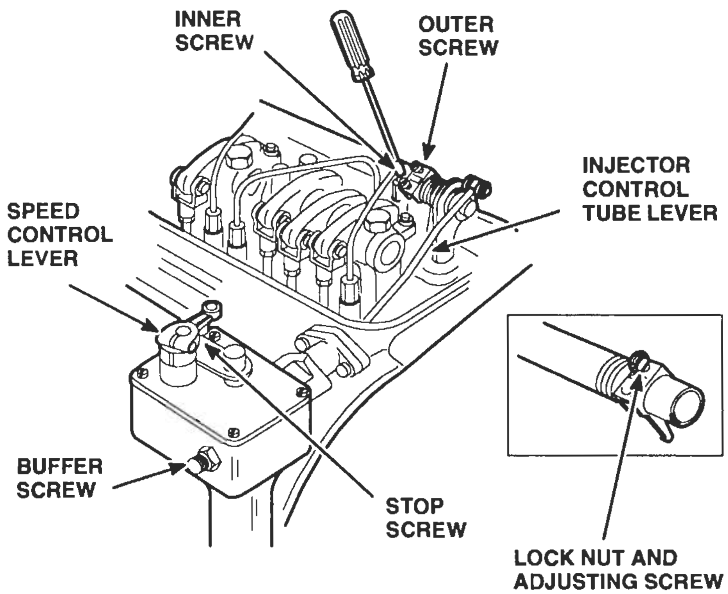


Figure 2. Positioning No. 1 Injector Rack Control Lever

Two Screw Assembly — Turn the inner adjusting screw on the No. 1 injector rack control lever down until a slight movement of the control tube is observed or a step up in effort is noted. This will place the No. 1 injector rack in 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.

One Screw and Locknut Assembly — Tighten the adjusting screw of the No. 1 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.

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).

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

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.

6. To be sure the control lever is properly adjusted, 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 "rotating" movement of the injector control rack when the speed control lever is in the maximum speed position (Figure 3.)

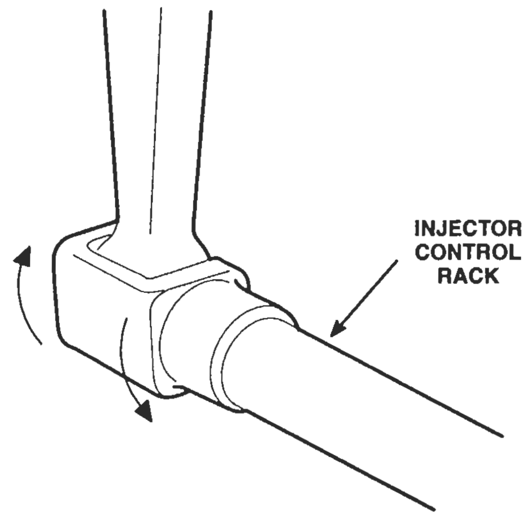


Figure 3. Checking Rotating Movement of Injector Control Rack

7. Hold the speed control lever in 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 (Figure 4.)

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.

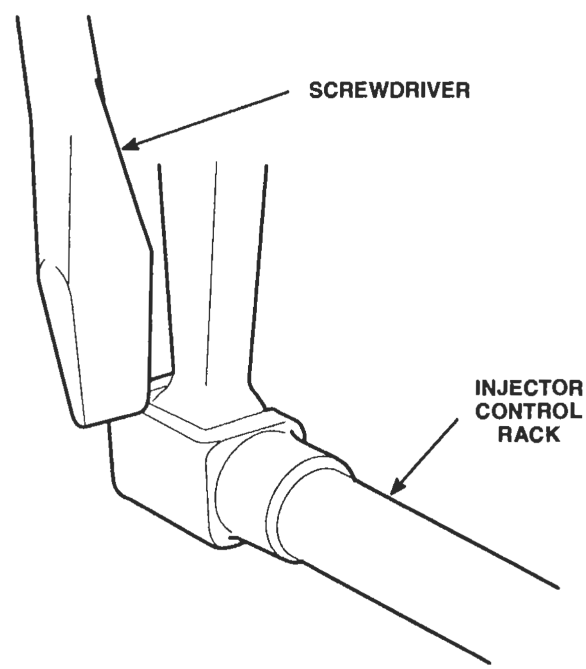


Figure 4. Checking Injector Control Rack "Spring"

SECTION 14.3.2 – MECHANICAL GOVERNOR INJECTOR RACK ADJUSTMENT

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

The setting is to tight if, when moving the speed control lever from the idle 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. To adjust the remaining injector rack control levers, remove the clevis pin from the fuel rod and the injector control tube lever. 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:

Two Screw Assembly:

a. Turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into the full–fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screw.

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. Recheck the No. 1 injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while adjusting the No. 2 injector rack. If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever and tighten the outer adjusting screw.

One Screw and Locknut Assembly:

a. Tighten the adjusting screw of the No. 2 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. 1 as outlined in Step 6. If No. 1 does not "spring" back upward, turn the No. 2 adjusting screw counterclockwise slightly until the No. 1 injector rack returns to its full–fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1 and No. 2 injectors. Turn clockwise or counterclockwise the No. 2 injector rack adjusting screw until both No. 1 and No. 2 injector racks are in the full–fuel position when the locknut is securely tightened.

POSITION INJECTOR RACK CONTROL (CONT.)

When the settings are correct, the racks of both injectors must be snug on the ball end of their respective rack control levers.

9. Position the remaining injector rack control levers as outlined in Step 7.
10. Connect the fuel rod to the injector control tube lever.
11. Turn the idle speed adjusting screw until it projects 3/16" from the locknut to permit starting the engine. Tighten the locknut. Remove the "C" clamp from the fuel rod on unites having a yield link.
12. On current turbocharged engines, adjust the external starting aid screw (Fig. 5). 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. 5). Select the proper gage and measure the setting at any convenient cylinder. When the starting 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:
        - Position the stop lever in the run position.
        - Move the speed control lever from the idle speed position to the maximum speed position.
        - 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 operating shaft lever 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.

13. Use a new gasket and replace the valve rocker 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 unit name plate, the maximum no–load speed may be set as follows:

Use the following procedure to adjust governors on engines with dual range limiting–speed mechanical governors.

ADJUST MAXIMUM NO–LOAD ENGINE SPEED (CONT.)

After positioning the injector rack control levers, set the maximum engine speeds. Be sure the buffer screw projects 5/8 inch 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 inch shims and ten .010 inch shims (Figure 5.) and the low maximum speed screw extending from the spring housing approximately 1 1/4 inch, proceed as follows:

NOTE: Do not apply air pressure to governor until performing Step 1f.

1. Set the high maximum no–load speed.
   a. Start the engine and 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.

NOTE: Do not permit the seal ring on the piston to slide past the air inlet port.

   d. Note the distance the piston is within 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.

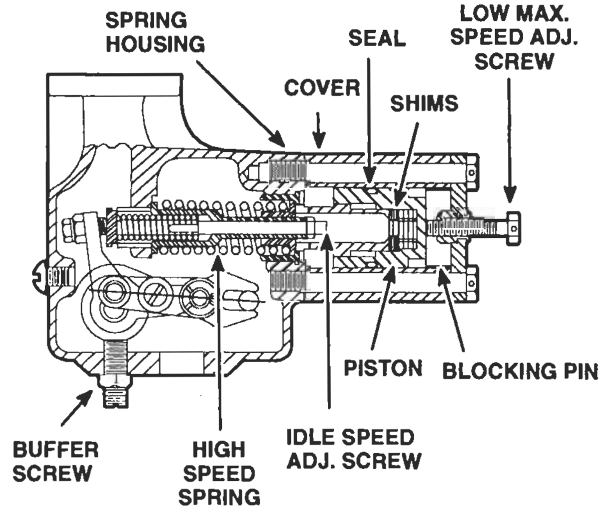


Figure 5. Dual Range Governor

   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 engine speed control lever in the maximum speed position and apply air pressure to the governor and note the engine speed.
   g. Remove the air 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 inch shim removed or added will decrease or increase the engine speed approximately ten r/min.
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 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 high 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, the idle speed may be adjusted as follows:

1. Remove the spring housing to uncover the idle speed adjusting screw.
2. With the engine 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 is operating at approximately 15 r/min below the recommended idle speed.

The recommended idle speed is 450 r/min but may vary with engine applications.

3. Hold the idle screw and tighten the locknut.
4. Install the high speed spring retainer and retain with the two bolts.

ADJUST BUFFER SCREW

With the idle speed set, the buffer screw may be adjusted as follows:

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 the engine roll. Do not increase the engine idle speed more than 15 r/min with the buffer screw.
2. Hold the buffer screw and tighten the locknut.
3. Recheck the maximum no–load speed. If it has increased more than 25 r/min, back off the buffer screw until the increase is less than 25 r/min.

LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT (VARIABLE LOW–SPEED)

The variable low–speed, limiting–speed mechanical governor is used on 6–71 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 current governor is a single–weight type and provides an idle speed range of 500 to 1800 r/min.

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 is turned to the speed required within the above range to operate the auxiliary equipment.

For the air operated governor, 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.

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 (SINGLE–WEIGHT TYPE)

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine, remove the two bolts and withdraw the governor spring retainer cover. Discard the gasket.
2. Back out the buffer screw until it extends approximately 5/8 inch from the locknut.
3. For cable operated governor make a preliminary idle speed (normal highway idle speed) adjustment as follows (Figure 1.):
   a. Back out the variable low–speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer.
   b. Start the engine. Then hold the locknut and loosen the low–speed adjusting shaft retainer.
   c. Adjust the retainer and shaft assembly to obtain the desired idle speed (500 r/min 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. Back out the buffer screw, after the idle speed is established to the previous setting (5/8 inch).
   d. Install the spring housing, using a new gasket. Tighten the attaching bolts.

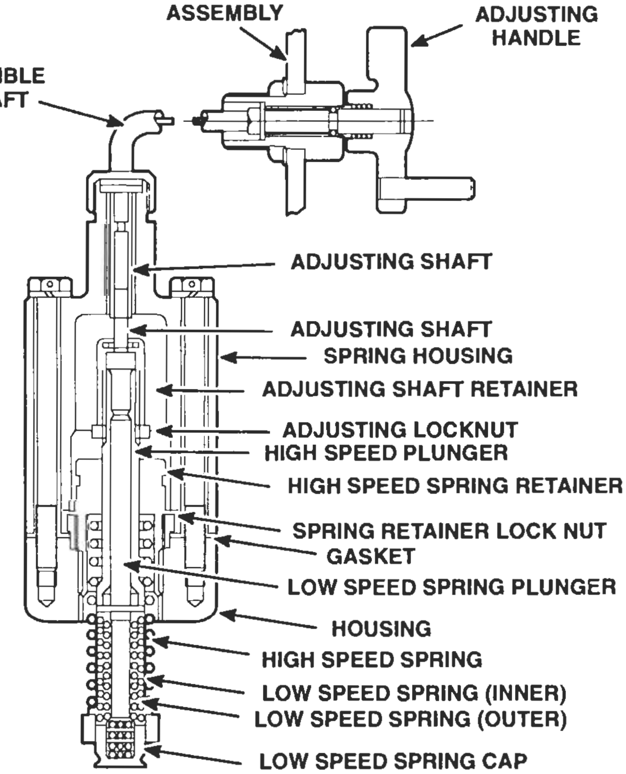


Figure 1. Cable Operated Governor Spring Housing and Components

ADJUST GOVERNOR GAP (SINGLE–WEIGHT TYPE) (CONT.)

4. For air operated governor make a preliminary idle speed (normal highway idle speed) adjustment as follows (Figure 2.):

Adjust the maximum idle speed.

a. Loosen the idle speed and high idle speed jam (lock) nuts.

b. Turn the idle speed adjusting screw clockwise into the air cylinders, until the piston contacts the air cap. Do not force the idle speed adjusting screw. The air cylinder should be two or three threads from its position of maximum engagement with the high speed spring plunger, to prevent the piston from contacting the high speed plunger before it contacts the air cap.

c. 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.

d. Lock the air cylinder to the high speed plunger with the jam nut in the position which provides the desired maximum idle speed.

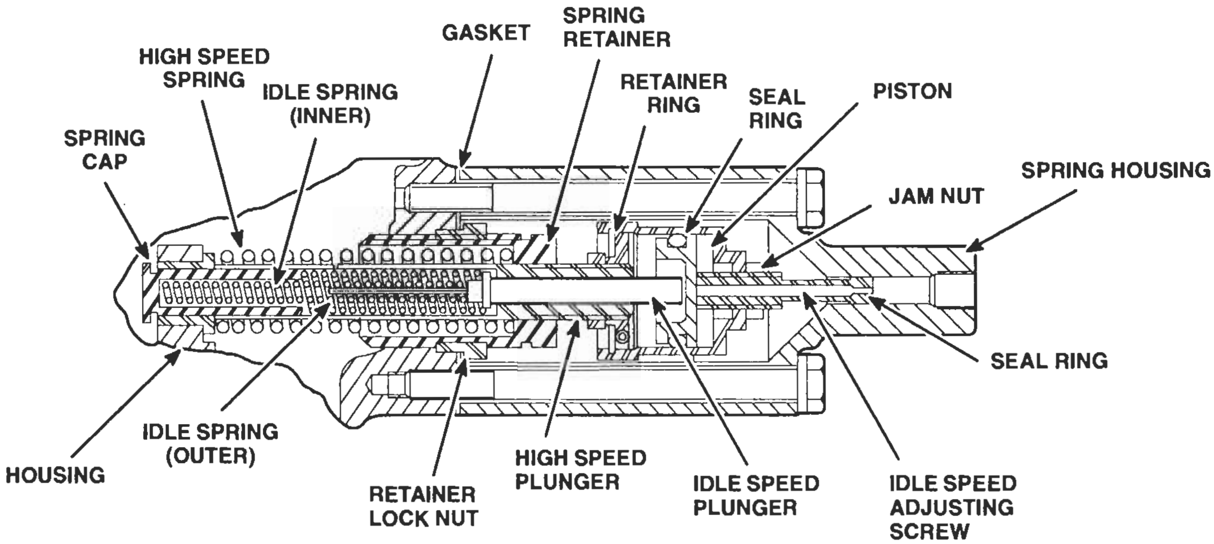


Figure 2. Air Operated Governor Spring Housing and Components

Adjust the minimum idle speed adjustment.

NOTE: 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 and clockwise to raise the idle speed.

c. Lock the idle speed adjusting screw with the jam nut, in the position which provides the desired minimum idle speed.

d. Stop the engine and lubricate the bore of the spring housing with engine lubrication oil.

e. Install the spring housing, using a new gasket. Tighten the attaching bolts.

5. Stop the engine and remove the governor cover and lever assembly.
6. Clean and remove the valve rocker cover. Discard the gasket.
7. Remove the fuel rod from the differential lever and the injector control tube lever.

ADJUST GOVERNOR GAP (SINGLE–WEIGHT TYPE) (CONT.)

8. Check the gap (.170 inch) between the low–speed spring cap and the high–speed spring plunger with gage J 5407 (Figure 3.) A .170 inch 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.
9. If required, loosen the locknut and turn the gap adjusting screw until a slight drag is felt on the gage.
10. Hold the adjusting screw and tighten the locknut.
11. Recheck the gap and readjust, if necessary.
12. Install the fuel rod between the governor and the injector control tube lever.
13. 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.

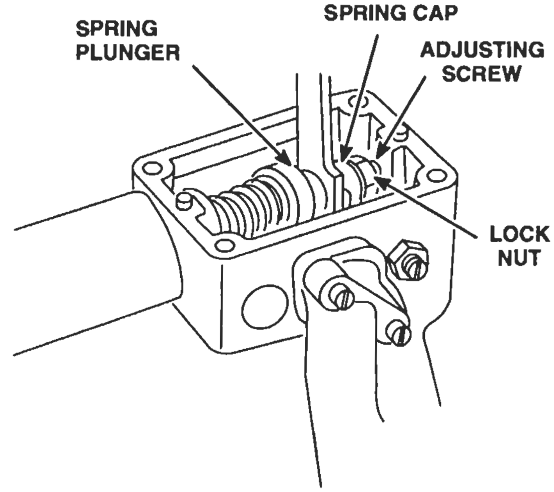


Figure 3. Adjusting Governor Gap (Single–Weight Governor)

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.

ADJUST GOVERNOR GAP (DOUBLE–WEIGHT TYPE) CABLE–OPERATED GOVERNORS ONLY

With the engine at operating temperature, adjust the governor gap as follows:

1. Stop the engine, remove the two bolts and withdraw the governor spring retainer cover.
2. Back out the buffer screw until it extends approximately 5/8 inch from the locknut.
3. Make a preliminary idle speed (normal highway idle speed) adjustment as follows:
   a. Back out the variable low–speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer.
   b. Start the engine. Then, hold the locknut and loosen the low–speed adjusting shaft retainer.
   c. Adjust the retainer and shaft assembly to obtain the desired idle speed (450 r/min minimum). 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 inch). Then hold the retainer and tighten the locknut to retain the adjustment.
   d. Install the spring housing, using a new gasket. Tighten the attaching bolts.

ADJUST GOVERNOR GAP (DOUBLE–WEIGHT TYPE) CABLE OPERATED (CONT.)

4. Stop the engine. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gasket.
5. Start and run the engine between 1,100 and 1,300 r/min 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 (Figure 4.) The gap should be .002–.004 inch. If the gap setting is incorrect, reset the gap adjusting screw.
7. On governors without the starting aid screw, hold the gap adjusting screw and tighten the locknut.
8. Recheck the gap with the engine operating between 1,100 and 1,300 r/min. Readjust, if necessary.
9. Reinstall the governor cover and lever assembly.

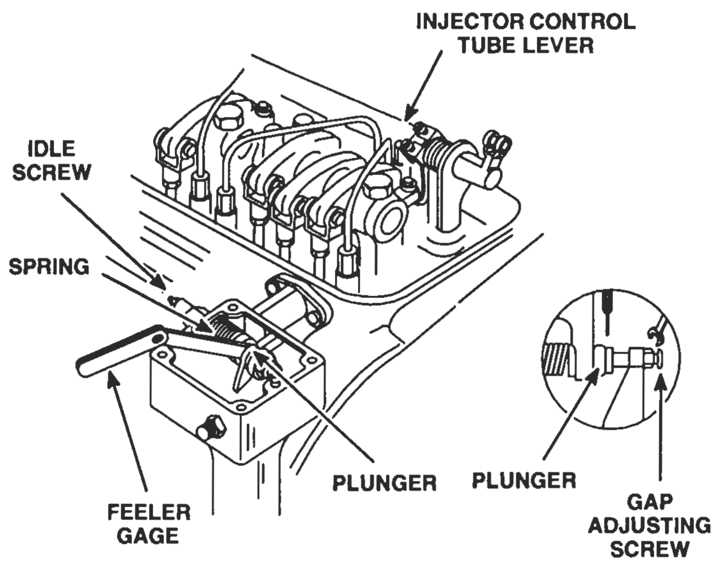


Figure 4. Adjusting Governor Gap (Double–Weight Governor)

POSITION INJECTOR RACK CONTROL LEVERS

Position the injector rack control levers as outlined in Section 14.3.

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

Adjust the normal highway idle speed as follows:

With the engine running at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, hold the locknut and loosen the variable low–speed adjusting shaft retainer. Adjust the retainer and shaft assembly to obtain a minimum of 500 r/min idle speed (current single–weight governor) or 450 r/min (former double–weight governor). 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 inch).

SECTION 14.3.3 – LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT

ADJUST BUFFER SCREW

Adjust the buffer screw as outlined in Section 14.3.

After the governor tune–up is completed, install the variable low–speed adjuster coupling and spring housing. Center the coupling before securing the spring housing to the governor. Install the flexible shaft and manual control assembly.

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 (Figure 1.) An engine shutdown air cylinder, if used, is also mounted on the governor cover.

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.

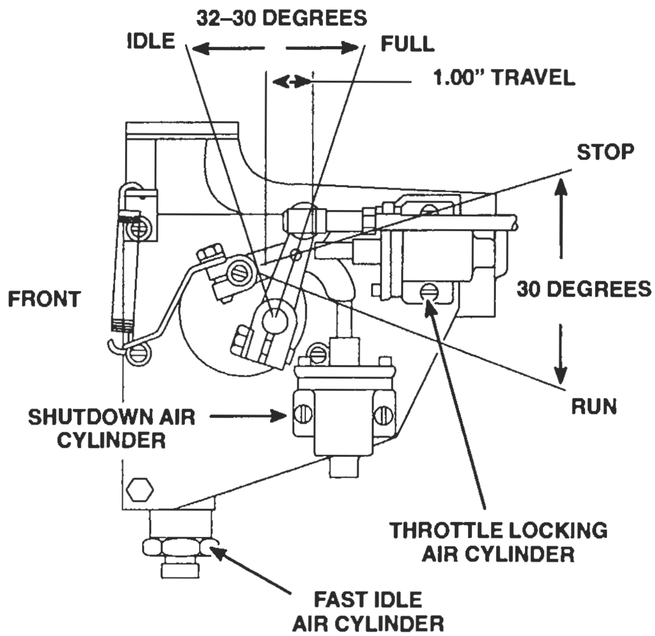


Figure 1. Governor with Fast Idle Cylinder

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 (Figure 2.) is added to the force of the governor low–speed spring, thus increasing the engine idle speed.

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.

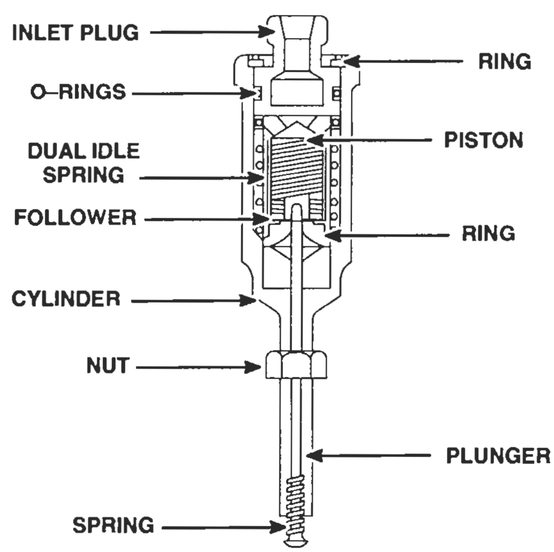


Figure 2. Fast Idle Air Cylinder

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 r/min. Tighten the fast idle jam nut.
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 250–550 r/min, depending upon the dual idle spring used. The throttle locking air cylinder is adjusted when it is activated, but will not limit the throttle movement when not activated. (Figure 3.).

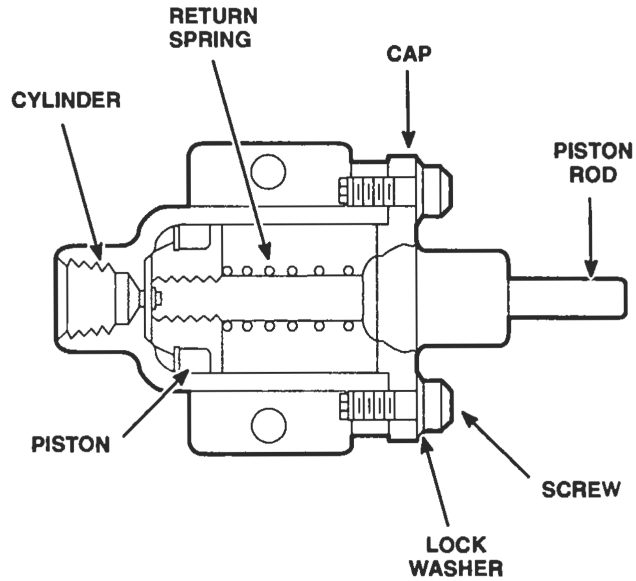


Figure 3. Throttle Locking Air Cylinder

GOVERNOR SETTINGS FOR "TT" ENGINES

The operating characteristics of a 6–71 "TT" or "TT" engine are its' ability to maintain reasonably constant horsepower over a wide speed range and its 6% torque rise per one hundred r/min. These characteristics are achieved by the action of two Belleville springs (washers) in a limiting speed governor.

The horsepower Table for the 6–71"TT" engine indicates 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 (Figure 1.) 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 r/min.

If the maximum speed of a 6–71"TT" engine equipped with single weight, limiting speed governor is reduced to 1,950 r/min no load, 1,800 r/min full load, the high–speed spring retainer may not provide sufficient thread engagement in the governor housing to make the adjustment. Consequently, the threads in the housing may be damaged when the locknut is tightened after the no–load speed is reached. To avoid this condition when adjusting engines to 1,950 r/min no load, 1,800 r/min full load, the high–speed spring with one green and one white stripe must be replaced with a spring with two pink stripes. Engines shipped from DDC with an 1800 r/min full–load speed specified on the sales order will not experience this condition.

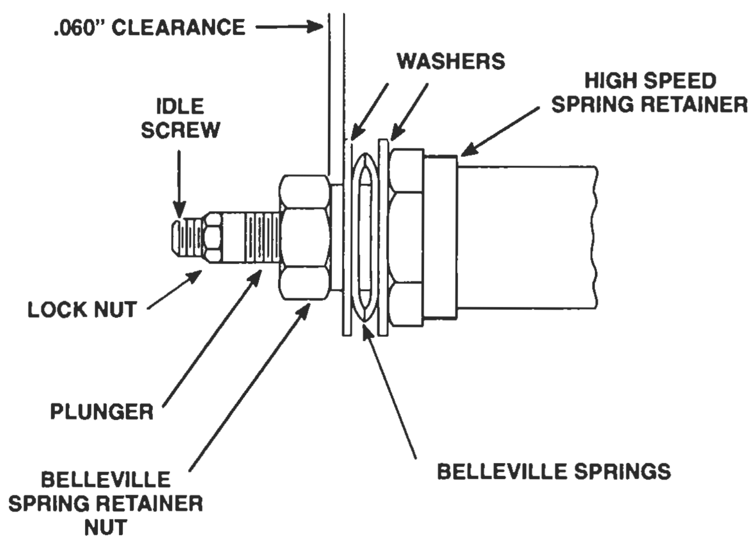


Figure 1. Belleville Washer Location

Tune–up the 6–71"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. 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.

SECTION 14.3.5 – GOVERNOR SETTINGS FOR "TT" ENGINES

GOVERNOR SETTINGS FOR "TT" ENGINES (CONT.)

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 (Single Weight Governor)
2. Power Reduction Factor

For satisfactory results, both methods require an engine in good condition and properly tuned. Do not attempt Belleville spring adjustment until an engine tune–up has been correctly completed.

METHOD 2 – POWER REDUCTION FACTOR

Do not attempt an idle drop setting, a power reduction setting, or a Belleville spring (washer) adjustment until an engine tune–up has been properly performed. Refer to sections 14 and 14.3.5 of the Service Manual for engine tune–up procedures.

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. 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 prior to operating the engine on the dynamometer.
2. Set the no–load speed as required (see Tables).
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 r/min below rated engine speed with the Belleville springs loose. 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 for the proper engine type, desired rated horsepower and rated engine speed from the Tables.
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 r/min 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 r/min above rated engine speed and repeat the power reduction factor method.

METHOD 2 – POWER REDUCTION FACTORS (CONT.)

8. Check the idle speed and, if necessary, reset to the specified idle speed.
9. Adjust the buffer screw and starting aid screw.

HORSEPOWER RATINGS 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 upgrade 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 change the engine rating 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.

ENGINE TYPE	MAXIMUM RATED B.H.P.	RATED "TT" HORSE-POWER	RATED ENGINE SPEED	NO–LOAD SPEED	POWER REDUCTION FACTOR
6-71TT–N–75	272 @ 2100	230	1900	2050	.91
Injectors Federal Certified	2275 r/min	230	1950	2100	.89
Throttle Delay Setting .570	Maximum	230	2100	2250	.86
	No–Load	220	1900	2050	.85
		220	1950	2100	.86
		220	2100	2250	.83

TABLE 1 – 71 POWER REDUCTION FACTORS — 1978 MODEL YEAR

SECTION 14.3.5 – GOVERNOR SETTINGS FOR "TT" ENGINES

HORSEPOWER RATING AND COOLING SYSTEM CAPACITY (CONT.)

MAXIMUM RATED BHP*	RATED TT HORSEPOWER	POWER REDUCTION FACTOR
258 @ 1700 r/min Full–Load	180	.70
	190	.73
	200	.77
	210	.81
	220	.85
	230	.89
	240	.93

TABLE 2 – 71 POWER REDUCTION FACTORS — 1979–1983 MODEL YEARS

ENGINE TYPE and MAX. RATED BHP		RATED TT HP	RATED ENGINE R/MIN	NO–LOAD ENGINE R/MIN	POWER REDUCTION FACTOR
6L–71TT 240 @ 2100 r/min	Injector	240	2100	2250	.86
	7E75	230	1800	1950	.89
	Timing	230	1950	2100	.85
	1.466	230	2100	2250	.82
	Throttle Delay	210	1800	1950	.82
	.594	170	1800	1950	.70
	Modulator Setting				
	DNA				
6L–71TTA 240 @ 2100 r/min	Injector	240	2100	2250	.85
	7E75	230	1800	1950	.89
	Timing	230	1950	2100	.85
	1.460	230	2100	2250	.81
	Throttle Delay	210	1800	1950	.81
	.570	180	1800	1950	.70
	Modulator Setting	170	1800	1950	.69
	.385				
6L–71TTAC 270 @ 2100	Injector	240	2100	2275	.88
	7G75	230	1800	1975	.92
	Timing	230	1950	2125	.88
	1.480	230	2100	2275	.84
	Throttle Delay	210	1800	1975	.84
	.570	180	1800	1975	.72
	Modulator Setting				
	.404				

TABLE 3 – 71 POWER REDUCTION FACTORS — 1984 MODEL YEAR

HORSEPOWER RATING AND COOLING SYSTEM CAPACITY (CONT.)

ENGINE TYPE and MAX. RATED BHP		RATED TT HP	RATED ENGINE R/MIN	NO–LOAD ENGINE R/MIN	POWER REDUCTION FACTOR
6L–71TTA JWAC 275 @ 1950 r/min	Injector 7E75 Timing 1.490 Throttle Delay DNA Modulator Setting .454	240 240 230 180	1900 2100 1800 1800	2050 2250 1950 1950	.92 .86 .92 .72
6L–71TTAC JWAC 285 @ 2100 r/min	Injector 7G75 Timing 1.480 Throttle Delay DNA Modulator Setting .480	240 230 230	2100 1800 1950	2225 1925 2075	.86 .90 .86
6L–71TTA ALCC 279 @ 1950 r/min	Injector 7E75 Timing 1.480 Throttle Delay DNA Modulator Setting .454	240 240 230 180	1900 2100 1800 1800	2050 2250 1950 1950	.91 .84 .91 .71
6L–71TTAC ALCC 290 @ 2100 r/min	Injector 7G75 Timing 1.470 Throttle Delay DNA Modulator Setting .480	240 230 230	2100 1800 1950	2275 1975 2125	.85 .88 .84

TABLE 4 – 71 POWER REDUCTION FACTORS — 1985 MODEL YEAR

SECTION 14.3.5 – GOVERNOR SETTINGS FOR "TT" ENGINES

HORSEPOWER RATING AND COOLING SYSTEM CAPACITY (CONT.)

ENGINE TYPE and MAX. RATED BHP		RATED TT HP	RATED ENGINE R/MIN	NO–LOAD ENGINE R/MIN	POWER REDUCTION FACTOR
6L–71TTA JWAC 245 @ 2100 r/min	Injector 7A77 Timing 1.496 Throttle Delay DNA Modulator Setting .395	240 230 240	2100 1950 1800	2225 2075 1925	.86 .86 .90
6L–71TTAC JWAC 240 @ 2100 r/min	Injector 7G75 Timing 1.480 Throttle Delay DNA Modulator Setting .454	240 230 230	2100 1950 1800	2225 2075 1925	.86 .86 .90
6L–71TTA ALCC 240 @ 2100 r/min	Injector 7A77 Timing 1.490 Throttle Delay DNA Modulator Setting .385	240 230 240	2100 1950 1800	2225 2075 1925	.81 .81 .91
6L–71TTAC ALCC 240 @ 2100 r/min	Injector 7G75 Timing 1.470 Throttle Delay DNA Modulator Setting .454	240 230 240	2100 1950 1800	2225 2075 1925	.86 .86 .94

TABLE 5 – 71 POWER REDUCTION FACTORS — 1986, 1987 MODEL YEARS

FLEXISPEC ENGINE GOVERNOR ADJUSTMENTS FOR "TT" ENGINES

When it is desirable to adjust a 6–71"TT" engine to obtain non "TT" maximum rated horsepower, proceed as follows:

1. Adjust the engine governor to obtain a no–load speed 175 r/min above the desired rated speed. Do not exceed a full–load speed of 2100 r/min or a no–load speed of 2275 r/min. Refer to Section 14.3 for the no–load engine speed adjustment.
2. Position the Belleville spring retainer to provide approximately .060 inch clearance between the Belleville washers and the retainer when the engine is not running.

The exception to the above procedure would be a 6–71"TT" engine using a double weight–limiting speed governor. The double weight "TT" governor's high speed spring may become "solid" not allowing the no–load speed to be adjusted properly. Therefore, in addition to backing off of the Belleville springs (washers), the governor's high–speed spring must be replaced. This replacement is to make sure that the no–load speed may be adjusted 175 r/min above the desired rated speed. High–speed spring part number 5153629 (two aluminum stripes) is the suggested replacement for the 6–71"TT" engine double weight–limiting speed governor.

VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and the injector rack control levers.

NOTE: 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 (Section 14.14).

ADJUST GOVERNOR GAP

1. With the engine running, set the idle screw at 550 r/min.
2. With the engine stopped and at normal operating temperature, disconnect any linkage attached to the governor levers.
3. Back out the buffer screw until it extends approximately 5/8 inch from the locknut.
4. Clean and remove the governor cover and valve rocker cover. Discard the gasket.
5. Place the speed control lever in the maximum speed position (Figure 1.)
6. Insert a .006 inch feeler gage between the spring plunger and the plunger guide. If required, loosen the locknut and turn the adjusting screw in or out until a slight drag is noted on the feeler gage.
7. Hold the adjusting screw and tighten the locknut. Check the gap again and, if necessary, readjust.
8. Secure the governor cover to the governor housing with three regular screws, one special screw and lock washers.
9. Hook the torsion retracting spring on the special cover screw and the stop lever. The former retracting spring is hooked between the stop lever and the retracting spring clip mounted on the end of the variable speed spring housing.

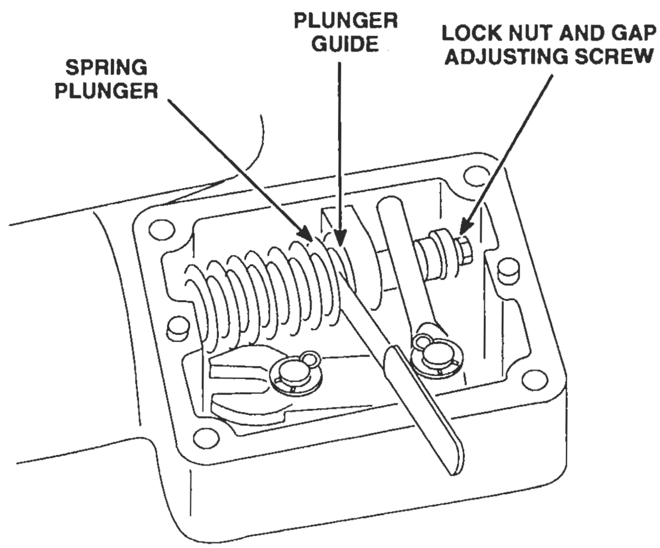


Figure 1. Adjusting Governor Cap

SECTION 14.4 – VARIABLE SPEED MECHANICAL GOVERNOR ADJUSTMENT

POSITION INJECTOR RACK CONTROL LEVERS

The position of the injector control rack 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.

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 on the seat in the governor control housing.
4. Injector fuel control racks in the full–fuel position.

NOTE: The cross link equalizer spring must be removed from multiple engine units before performing the individual engine tune–up. See "Throttle Adjustment for Load Equalization on Twin or Quad Units With Variable Speed Mechanical Governors" for procedure on removing cross link equalizer spring.

Adjust the No. 1 injector rack control lever first, to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the stop lever.
2. Loosen all the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts (Figure 2.) Be sure all 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. Hold it in that position with light finger pressure and proceed as follows:

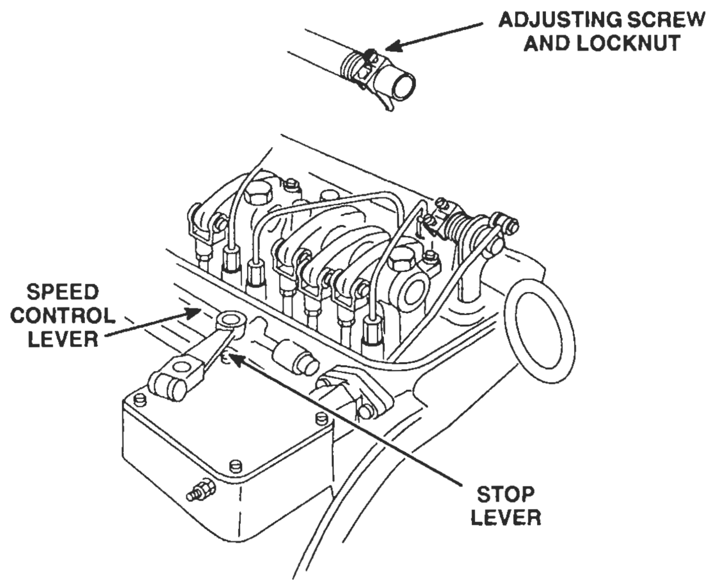


Figure 2. Positioning No. 1 Injector Rack Control Lever

Two Screw Assembly — Turn the inner adjusting screw of the No. 1 injector rack control lever down until a slight movement of the control tube is observed or a step–up in effort is noted. This will place the No. 1 injector rack in 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.

One Screw and Locknut Assembly — Tighten the adjusting screw of the No. 1 injector rack control lever until the injector rack clevis is observed to roll up or and 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.

NOTICE:

Over–tightening 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).

 May, 1994

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

The previous 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 the control lever is properly adjusted, 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 "rotating" movement of the injector control rack when the speed control lever is in the maximum speed position (Figure 3.).

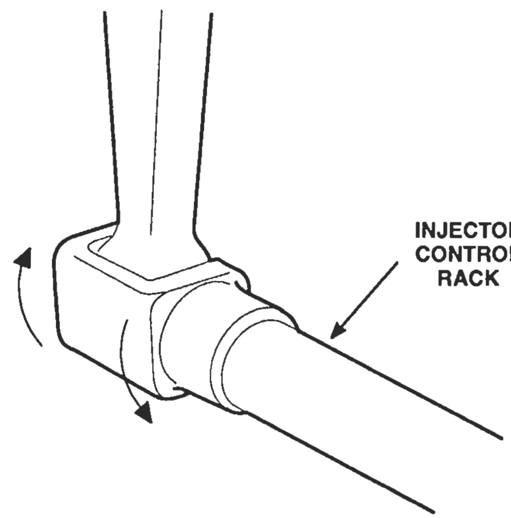


Figure 3. Checking Rotating Movement of Injector Control Rack

6. 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 (Figure 4.)

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 stop lever from the stop to the run position, the injector rack becomes tight before the stop 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 stop 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.

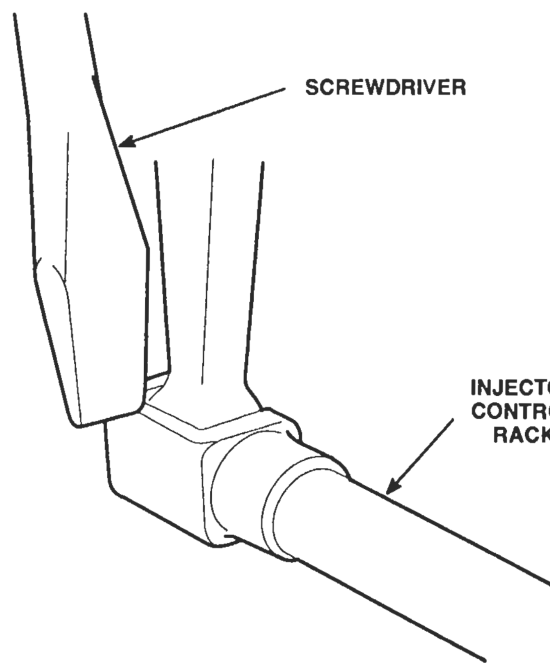


Figure 4. Checking Injector Control Rack "Spring"

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

7. Manually hold the No. 1 injector rack in the full–fuel position and proceed as follows:

Two Screw Assembly:

a. Turn down the inner adjusting screw of the No. 2 injector until the injector rack has moved into full–fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws until tight.

NOTICE:

Over–tightening 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. Recheck the No. 1 injector rack to be sure that it has remained snug on the ball end of the injector rack control lever while positioning the No. 2 injector rack. If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw of the No. 2 injector control lever and tighten the outer adjusting screw.

One Screw and Locknut Assembly:

a. Tighten the adjusting screw of the No. 2 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:

Over–tightening 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. 1 injector rack as outlined in Step 5. If No. 1 injector rack does not “spring” back upward, turn the No. 2 adjusting screw counterclockwise slightly until the No. 1 injector rack returns to its full–fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1 and No. 2 injectors. Turn clockwise or counterclockwise the No. 2 injector rack adjusting screw until both No. 1 and No. 2 injector racks are in the full–fuel position when the locknut is securely tightened.

8. Position the remaining injector rack control levers as outlined in Step 7.
9. Use a new gasket and reinstall the valve rocker cover.

ADJUST MAXIMUM NO–LOAD SPEED

The maximum no–load speed on engines equipped with variable speed governors must not be less than 125 r/min or more than 150 r/min above the recommended full–load speed.

With a hand tachometer, determine the maximum no–load speed of the engine. Then make the following adjustments, if required:

1. Disconnect the booster spring.
2. Remove the two bolts and withdraw the variable speed spring housing and the variable speed spring plunger from inside the spring housing.
3. Refer to Table 1 and determine the stop or shim required for the desired full–load speed for engines with two valve cylinder heads. A split stop can only be used with a solid stop (Figure 5.)

Refer to Table 2 and determine the stops or shims required for the desired full–load speeds for engines with four valve cylinder heads.

4. Install the variable speed spring housing and recheck the maximum no–load speed.
5. If required, add shims to obtain the necessary operating speed.

NOTE: If the maximum no–load speed is raised or lowered more than 50 r/min by the installation or removal of the governor shims, the governor gap should be rechecked.

If readjustment of the governor gap is required, the position of the injector racks must be rechecked.

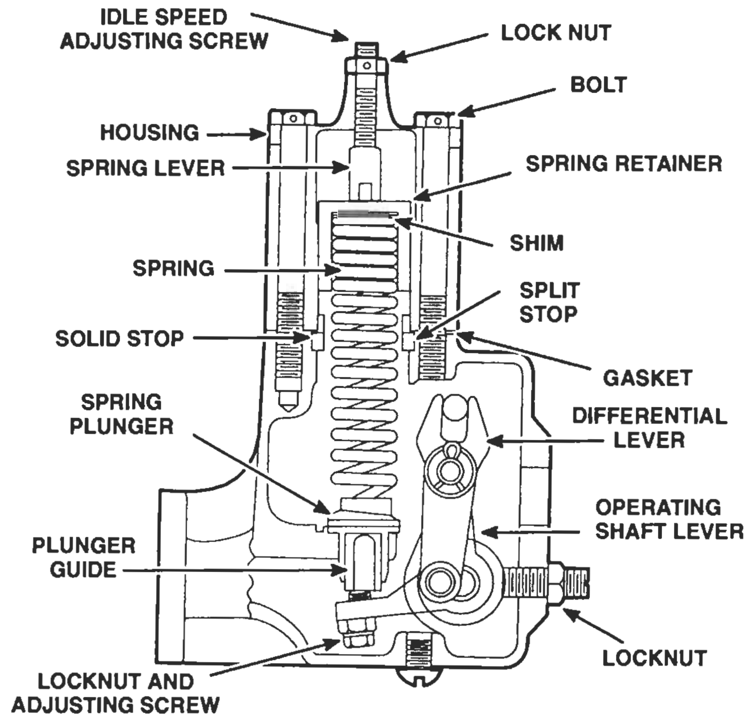


Figure 5. Location of Stops and Shims

FULL LOAD SPEED	STOPS	SHIMS
1200 to 1425 r/min	2	Up to .325"
1426 to 1825 r/min	1	Up to .325"
1826 to 2100 r/min	0	Amount Required to get to necessary speed.

TABLE 1 – TWO VALVE CYLINDER HEADS

FULL LOAD SPEED	STOPS	SHIMS
1450 to 1650 r/min	2	Amount Required to get to necessary speed.
1651 to 2150 r/min	1	
2151 to 2300 r/min	0	

TABLE 1 – FOUR VALVE CYLINDER HEADS

SECTION 14.4 – VARIABLE SPEED MECHANICAL GOVERNOR ADJUSTMENT

ADJUST IDLE SPEED

With the maximum no–load speed properly adjusted, the idle speed may be adjusted 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 r/min below the recommended idle speed.

The recommended idle speed is 500–600 r/min but may vary with the engine application.

4. Hold the idle speed adjusting screw and tighten the locknut.

ADJUST BUFFER SCREW

With the idle speed set at approximately 15 r/min below the recommended idle speed, the buffer screw may be set as follows:

1. Turn the buffer screw in until the engine is operating at the recommended idle speed. Do not raise the engine speed more than 15 r/min with the buffer screw.
2. Hold the buffer screw and tighten the locknut.

ADJUST BOOSTER SPRING

With the engine idle speed set, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.
2. 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. Move the spring retaining 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 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 where it will not return to idle. Then, reduce the spring tension until the lever does return to idle and tighten the locknuts on the eyebolt. This setting will result in the minimum force required to operate the speed control lever.

CONSTANT–SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and injector rack control levers.

1. Stop the engine and disconnect any linkage attached to the speed control lever.
2. Remove the governor cover and lever assembly.
3. Remove the fuel rod from the differential lever and the injector control tube lever.
4. Check the governor gap by inserting a .006 inch feeler gage between the operating speed spring plunger and the governor boss (Figure 1.)
5. Loosen the locknut and adjust the gap adjusting screw until the gap is .006 inch.
6. Hold the gap adjusting screw to prevent changing the setting, and tighten the locknut.
7. Recheck the gap and readjust it, if necessary.
8. Install the governor cover.

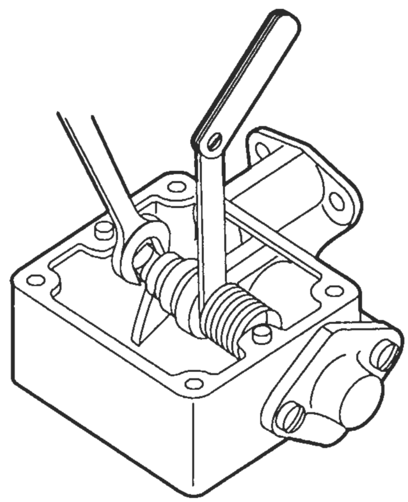


Figure 1. Adjusting Governor Gap

a. Secure the cover to the governor housing with three regular screws, one special screw and lock washers.

b. Hook the torsion retracting spring to the special cover screw and the control lever. On former engines the governor cover is secured with four regular cover screws and lock washers. The former retracting spring is hooked between the control lever and the retracting spring clip mounted on the end of the spring housing.

SECTION 14.6 – CONSTANT–SPEED MECHANICAL GOVERNOR ADJUSTMENT

POSITION INJECTOR CONTROL RACKS

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

Adjust No. 1 injector rack control lever first to establish a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the control lever.
2. Loosen all the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts (Figure 2.) Be sure all the control levers are free on the injector control tube.
3. Move the control lever to the maximum speed position.

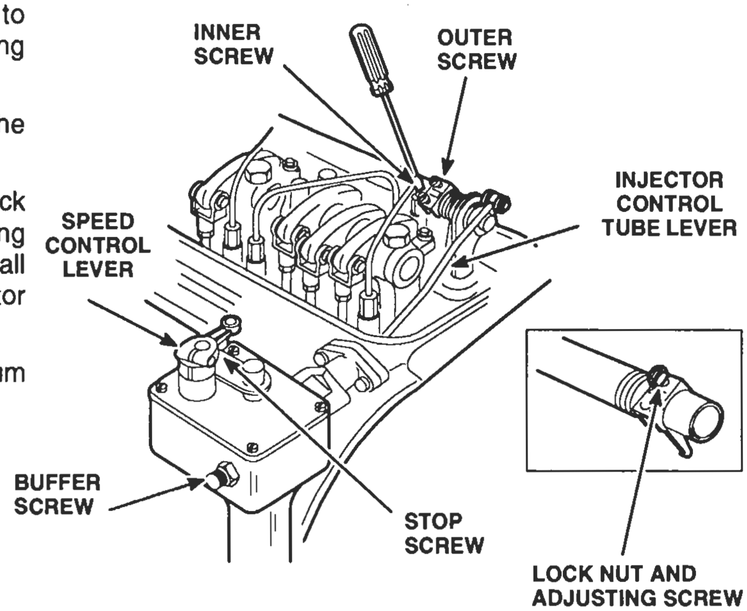


Figure 2. Positioning No. 1 Injector Rack Control Lever

Two Screw Assembly — Turn the inner adjusting screw down until a step up in effort is noted. 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 until they are tight.

One Screw and Locknut Assembly — Tighten the adjusting screw of the No. 1 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. 1 injector rack in the full–fuel position.

NOTICE:
Over–tightening 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).

POSITION INJECTOR CONTROL RACKS (CONT.)

4. To be sure the control lever is properly adjusted, 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 "rotating" movement of the injector control rack when the speed control lever is in the maximum speed position (Figure 3.)

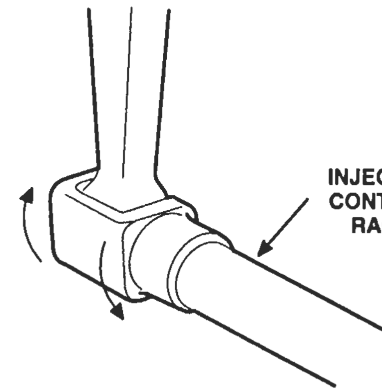


Figure 3. Checking Rotating Movement of Injector Control Rack

5. Hold the speed control lever in maximum speed position and, using a screwdriver, press downward on the injector control rack. The rack should tilt downward (Figure 4.) and when the pressure of the screwdriver is released, the control rack should "spring" back upward.
6. If no movement is observed, back off the inner adjusting screw (Two Screw Assembly) approximately 1/8 of a tum and tighten the outer adjusting screw. Loosen the locknut (One Screw and Locknut Assembly) and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

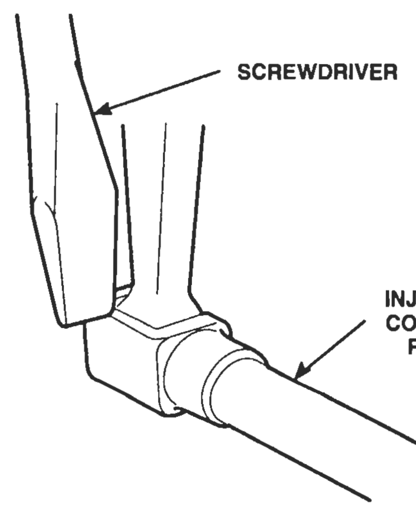


Figure 4. Checking Injector Control Rack "Spring"

If the movement exceeds that specified, back off the outer adjusting screw (Two Screw Assembly) approximately 1/8 of a turn and tighten the inner adjusting screw. Loosen the locknut (One Screw and Locknut Assembly) and turn the adjusting screw clockwise a slight amount and retighten the locknut.

When the setting is correct, the injector rack will be snug on the pin of the rack control lever and still maintain the movement specified in Step 5.

NOTE: Performing Steps 3, 4 and 5 will result in placing the governor linkage and control tube assembly in the same positions that they will attain while the engine is running at full load. These positions are:

POSITION INJECTOR CONTROL RACKS (CONT.)

a. The governor speed control lever is at the maximum speed position.

b. The governor gap is closed.

c. The governor spring plunger is on its seat in the governor control housing.

d. The injector fuel control racks are in the maximum speed position.

7. Remove the clevis pin between the fuel rod and the injector control tube lever.
8. Manually hold the No. 1 injector in the maximum speed position.

Two Screw Assembly — Turn down the inner adjusting screw of the No. 2 injector until the injector rack of the No. 2 injector has moved into the maximum speed position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws until they are tight.

One Screw and Locknut Assembly — Tighten the adjusting screw of the No. 2 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:

Over–tightening 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).

9. Recheck the No. 1 injector fuel rack to be sure that it has remained snug on the pin of the rack control lever while adjusting No. 2 injector. If the rack of the No. 1 injector has become loose (Two Screw Assembly), back off slightly on the inner adjusting screw on the No. 2 injector rack control lever. Tighten the outer adjusting screw. Loosen the locknut (One Screw and Locknut Assembly) and turn the adjusting screw counterclockwise a slight amount and retighten the locknut.

When the settings are correct, the racks of both injectors must be snug on the pin of their respective rack control levers.

10. Position the remaining control rack levers as outlined in Steps 7 and 8.
11. Insert the clevis pin between the fuel rod and the injector control tube lever.

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 unit name plate, the maximum no–load speed may be set as follows:

1. Start and warm up the engine.
2. With engine disconnected from the load, start the engine and observe the engine speed. Be sure the speed control lever is in the run position.

NOTE: There must be no load on the engine during the maximum no–load speed adjustment.

3. Observe the engine speed and set it, if necessary, to the recommended speed with shims placed between the operating speed spring and spring plunger.

Since the engine performance and efficiency will be governed, to a large extent, by the accuracy with which the tune–up adjustments are made, the technician should always perform these operations carefully.

HYDRAULIC SG GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the hydraulic governor and injector rack control levers.

Adjust the fuel rod as follows:

To be sure of a full travel between no–fuel and full–fuel adjust the fuel rod as follows:

1. Remove the governor cover and the valve rocker cover. Loosen all the inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts. Make sure all control levers are free on the injector control tube.
2. Loosen the fuel rod locknut and remove the fuel rod knob (Figure 1.)
3. Turn the locknut until 3/16 inch of the fuel rod extends beyond the nut. Then, reinstall the fuel rod knob and tighten the locknut.

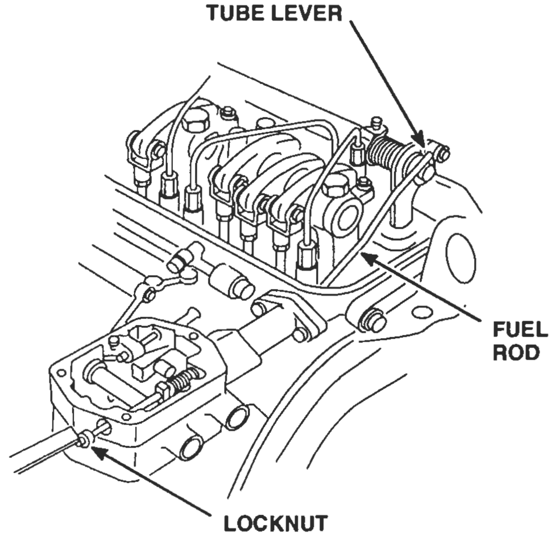


Figure 1. Adjusting Fuel Rod

POSITION INJECTOR RACK CONTROL LEVERS

After the fuel rod is properly adjusted, adjust the injector rack control levers in the no–fuel position as follows:

1. **Two Screw Assembly** — Turn the outer adjusting screw in until a slight movement of the injector control tube lever is observed (Figure 2.) Tighten the inner adjusting screw.

One Screw and Locknut Assembly — Turn the adjusting screw in until a slight movement of the injector control tube lever is observed (Fig. 2). Then, turn the adjusting screw 1/8 of a turn more and lock securely with the adjusting screw locknut.

2. Pull the fuel rod out and check for 1/32 to 1/16 inch movement.

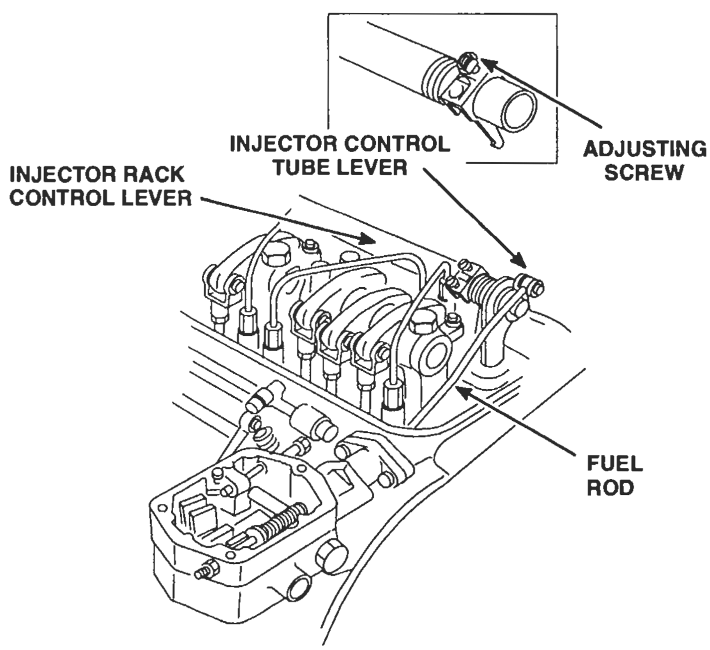


Figure 2. Positioning No. 1 Injector Rack Control Lever

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

If the movement exceeds the distance specified with the Two Screw Assembly, back off the inner adjusting screw approximately 1/8 of a turn and tighten the outer adjusting screw. 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.

If the movement is less than the specified distance with the Two Screw Assembly, back off the outer adjusting screw approximately 1/8 of a turn and tighten the inner adjusting screw. 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.

3. Disconnect the fuel rod from the injector rack control tube lever.
4. Manually hold the No. 1 injector rack control lever in the full–fuel position and proceed as follows:

Two Screw Assembly:

a. Turn the inner adjusting screw into the No. 2 injector rack control lever until the injector rack has moved into the full–fuel position and the inner adjusting screw is bottomed on the injector control tube. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws until they are tight.

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. 1 injector fuel rack to make sure that it has remained snug on the ball end of the injector rack control lever while adjusting the No. 2 injector rack. If the rack of the No. 1 injector has become loose, back off slightly on the inner adjusting screw on the No. 2 injector rack control lever. Tighten the outer adjusting screw.

One Screw and Locknut Assembly:

a. Tighten the adjusting screw of the No. 2 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. 1 injector rack as outlined in Step 6. If No. 1 injector rack does not "spring" back upward, turn the No. 2 adjusting screw counterclockwise slightly until the No. 1 injector rack returns to its full–fuel position and secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 1 and No. 2 injectors. Turn clockwise or counterclockwise the No. 2 injector rack adjusting screw until both No. 1 and No. 2 injector racks are in the full–fuel position when the locknut is securely tightened.

POSITION INJECTOR RACK CONTROL LEVERS (CONT.)

When the settings are correct, the rack of both injectors must be snug on the pin of their respective rack control levers.

5. Position the remaining rack control levers as outlined in Step 4.

When the settings are correct, the racks of all injectors must be snug on the pins of the rack control levers when the control tube lever is held in the full–fue/ position.

6. Reconnect the fuel rod to the injector rack control tube lever.

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 adjusting screw locknut and adjust the screw to obtain a distance of approximately 2 inches from the outside face of the boss on the governor subcap to the end of the screw.
2. Place the fuel rod and terminal lever in the full–fuel position (Figure 3.)
3. Turn the load limit screw until a .020 inch space exists between the fuel rod collar and the terminal lever, then hold the screw and tighten the locknut.

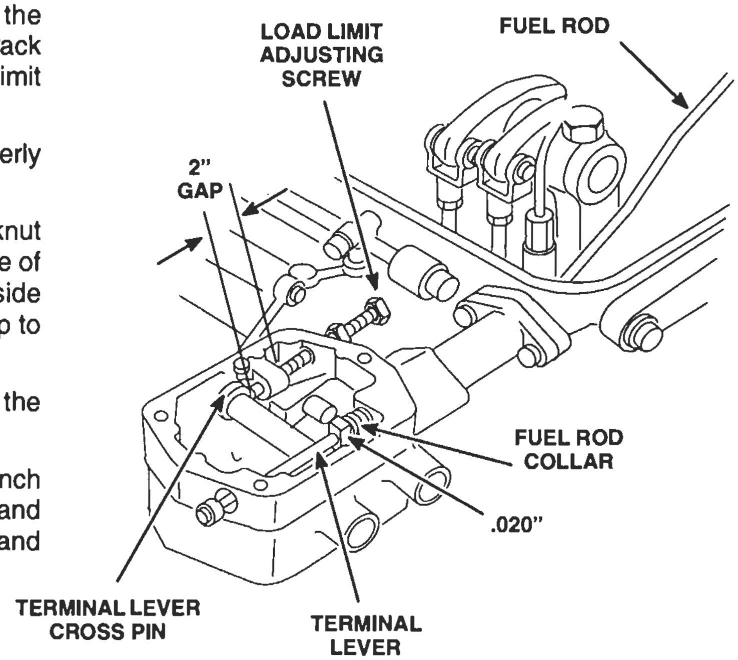


Figure 3. Adjusting Load Limit

ADJUST SPEED DROOP

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 is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs, the speed droop should be readjusted.

Use an accurate tachometer to determine the engine speed.

When a full rated load on the unit is established and the fuel rod, injector control rack levers, and load limit have been adjusted, the speed droop may be adjusted as follows:

1. Start the engine and operate at approximately one–half the rated no–load speed until the lubricating oil has had an opportunity to warm up.

NOTE: When the engine lubricating oil is cold, the governor regulation may be erratic. The regulation should become increasingly stable as the temperature of the lubricating oil increases.

ADJUST SPEED DROOP (CONT.)

2. Stop the engine and remove the governor cover.
3. Loosen the locknut and back off the maximum speed adjusting screw approximately 5/8 inch (Figure 4.)
4. Loosen the speed droop adjusting screw. Move the bracket so the screw is midway between the ends of the slot in the bracket. Tighten the screw.
5. Be sure the bracket remains on the shoulder of the terminal lever.
6. With the throttle in the run position, adjust the engine speed until the engine is operating at 5% above the recommended full load speed.
7. Apply the full rated load on the engine and readjust the engine speed to the correct full–load speed.
8. Remove the rated load and note the engine speed after the speed has stabilized under no load. If the speed droop is correct, the engine speed will be approximately 5% higher than the full–load speed.

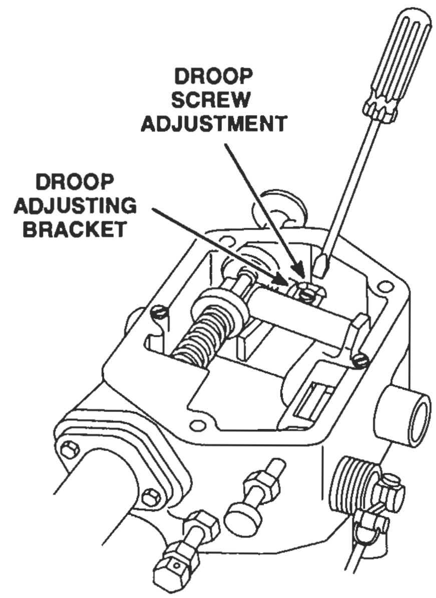


Figure 4. Adjusting Speed Droop

If the speed droop is too high, stop the engine, loosen the bolt again and move the speed droop adjusting bracket in (toward the engine). Tighten the screw. To increase the speed droop, move the droop adjusting bracket out (away from the engine).

If the speed droop in the governors of power generator engines are not the same, the electrical load will not be equally divided when the generators are operated in parallel.

ADJUSTING SPEED DROOP (CONT.)

The speed droop bracket in the governor of each engine must be adjusted to obtain the desired variation between the engine no–load and full–load speeds shown in Table 1.

The recommended speed droop at full load for power generator units operating in parallel is 50 r/min (2 1/2 cycles) at 1,000 and 1,200 r/min. For units operating at 1,500 and 1,800 r/min the speed droop should by 75 r/min (2 1/2 cycles). The speed droop may be varied to suit the particular application.

FULL LOAD	NO–LOAD
50 cycles 1,000 r/min	52.2 cycles 1,050 r/min
60 cycles 1,200 r/min	62.5 cycles 1,250 r/min
50 cycles 1,500 r/min	52.5 cycles 1,575 r/min
60 cycles 1,800 r/min	62.5 cycles 1,875 r/min

TABLE 1

ADJUST MAXIMUM NO–LOAD SPEED

After the speed droop is properly adjusted, set the maximum no–load speed as follows:

1. Loosen the maximum speed adjusting screw locknut and back the adjusting screw out three turns.
2. With the engine operating at no load, adjust the engine speed until the engine is operating approximately 8% higher than the rated full–load speed.
3. Turn the maximum speed adjusting screw in lightly until contact is felt with the linkage in the governor (Figure 5.)
4. Hold the adjusting screw and tighten the locknut.
5. Install the governor cover.

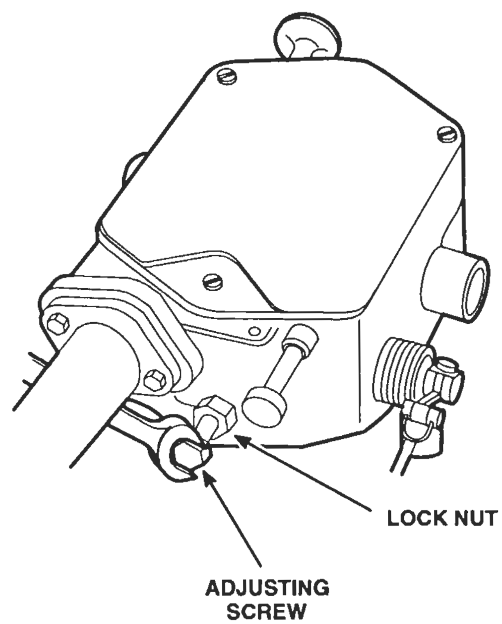


Figure 5. Adjusting Maximum No–Load Speed

GOVERNORS WITH SYNCHRONIZING MOTOR

Some hydraulic governors are equipped with a reversible synchronizing motor which is mounted on the governor cover (Figure 6.) This motor makes a close adjustment of the engine speed possible by remote control and is especially valuable for synchronizing two generators from a central control panel.

The motor is connected to the source of electrical supply through a two–way switch located on the control panel. When this switch is held in the desired position, the motor shaft turns the governor speed adjusting shaft by means of a reduction gear and slip coupling. The position of the switch determines the direction of rotation of the speed adjusting shaft. When the desired engine speed is indicated on a tachometer or frequency meter mounted on the control panel, the switch is placed in the off position.

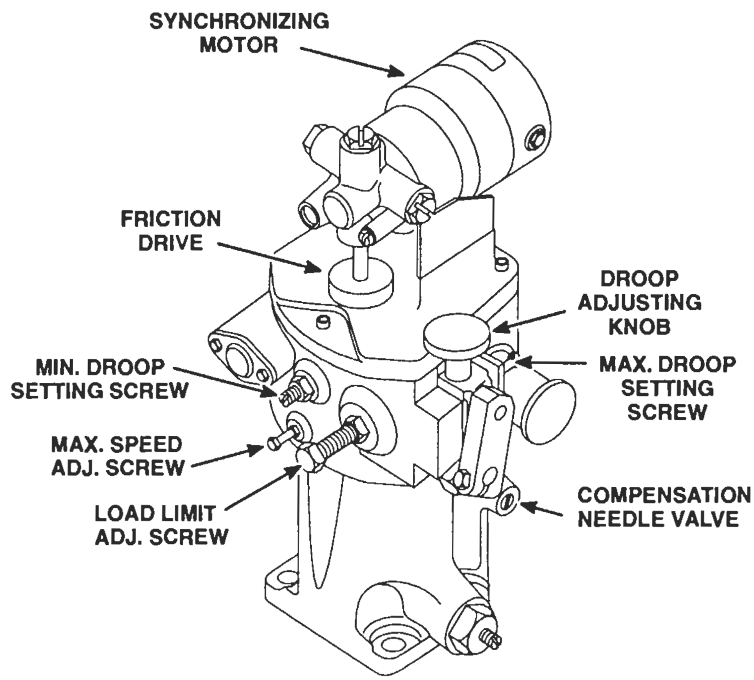


Figure 6. Typical Synchronizing Motor Mounting

NOTE: If the switch is held in the Lower Speed position too long, the synchronizing motor will continue to lower the engine speed and the engine will ultimately stop. If the switch is held in the Raise Speed position too long the synchronizing motor will turn the speed adjusting shaft until it strikes the maximum speed adjusting screw. The clutch or slip coupling will slip and the motor will continue to run at a slightly reduced speed without affecting the governor after the shaft strikes the adjusting screw.

The adjustments on a governor equipped with a synchronizing motor are the same as on a governor without the motor. If the governor does not have an external droop setting screw the governor cover and motor assembly must be removed when the engine speed droop is set. Reinstall the governor cover and motor to check the speed droop.

HYDRAULIC WOODWARD PSG GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

Adjust engines with hydraulic governor assemblies after adjusting the exhaust valves and timing the fuel injectors as follows:

To adjust the fuel rod:

1. Remove the governor cover and the rocker cover. Loosen all inner and outer injector rack (Figure 1.) control lever adjusting screws or the adjusting screws and locknuts. Be sure all control levers are free on the injector control tube.
2. Loosen the fuel rod locknut and remove the fuel rod knob.
3. Turn the locknut to a position so that 3/16″ of the fuel rod extends beyond the nut. Install the fuel rod knob and tighten the locknut.

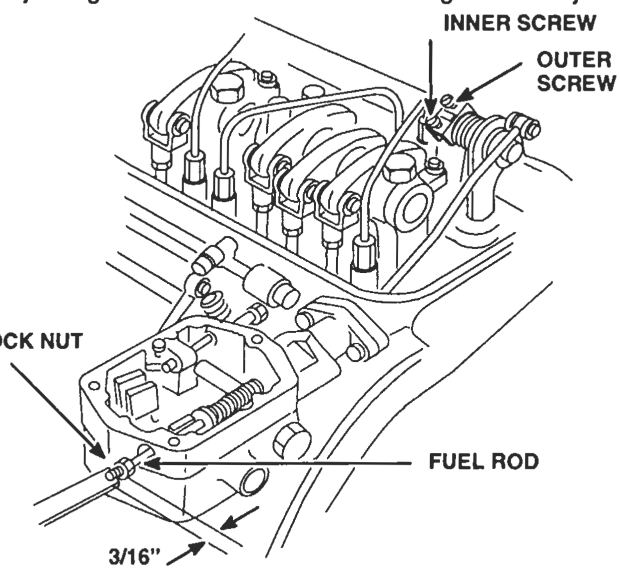


Figure 1. Adjusting Fuel Rod

POSITION INJECTOR RACK CONTROL LEVERS

With the fuel rod properly adjusted, the rack control levers may be adjusted as follows:

1. **Two Screw Assembly** — Adjust the No. 1 injector rack control lever by turning the outer adjusting screw in until a slight movement of the injector control tube lever is observed. Tighten the inner adjusting screw

One Screw and Locknut Assembly — Adjust the No. 1 injector rack control lever 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 (Figure 2.) Tighten the screw approximately 1/8 of a turn more and lock securely with the adjusting screw locknut.

This will place the No. 1 injector rack in the full–fuel position.

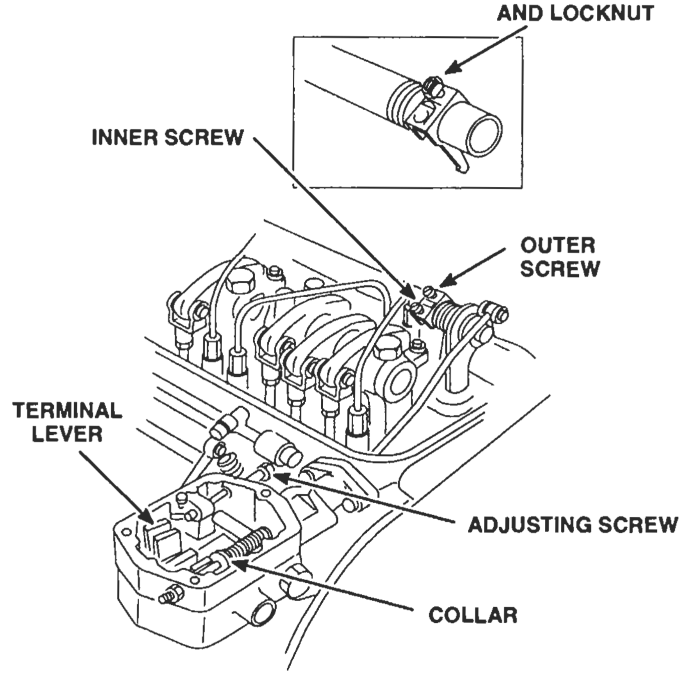


Figure 2. Positioning No. 1 Injector Rack Control Lever

POSITION INJECTOR RACK CONTROL LEVERS

2. Pull out on the fuel rod and check for 1/32 to 1/16 inch movement.
   a. Two screw assembly—If movement exceeds that specified, back off inner adjusting screw approximately 1/8 of a turn and tighten outer adjusting screw.

If movement is less than that specified, back off outer adjusting screw approximately 1/8 of a turn and tighten inner adjusting screw.

   b. Disconnect fuel rod from injector control tube lever.
   c. Holding the clevis at the end of the injector control tube, position the number 1 injector in the FULL FUEL position and screw down the inner adjusting screw of number 2 injector until the injector control lever for that injector contacts the injector body. This may be felt at the clevis end by a slight movement as contact is made.
   d. Tighten outer adjusting screw until it bottoms lightly on the injector control tube. then alternately tighten both the inner and outer adjusting screws until tight.
   e. Make sure the rack remains snug on the pin of the rack control lever at No. 1 injector.

If the rack of No. 1 injector has become loose, back off slightly on the inner adjusting screw at No. 2 injector rack control lever. Tighten outer adjusting screw.

When the settings are correct, the rack of both injectors must be snug on the pin of their respective rack control.

   f. Position the remaining rack control levers as outlined in Steps c, d and e.

When the settings are correct, the rack of all injectors must be snug on the pins of the rack control levers when the control tube lever is held in the full–fuel position.

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. Place fuel rod and terminal lever in the full–fuel position (Figure 3.)
2. Loosen the locknut and turn the adjusting screw until a .020 inch space exists between the fuel rod collar and the terminal lever. Hold the screw and tighten the locknut.

If the movement exceeds that specified with the Two Screw Assembly, back off the inner adjusting screw approximately 1/8 of a turn and tighten the outer adjusting screw. To correct the condition with the One Screw and Locknut Assembly, loosen the locknut and turn the adjusting screw clockwise a slight amount and retighten the locknut.

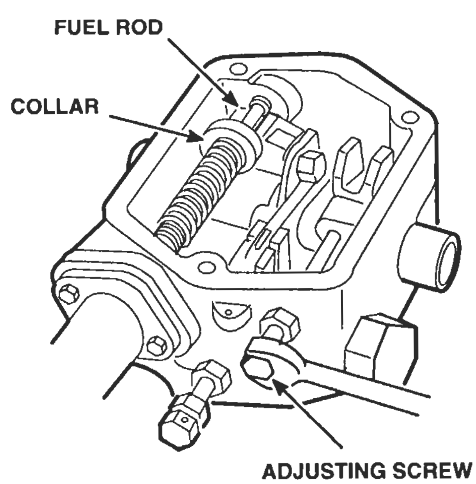


Figure 3. Setting Maximum Fuel Adjusting Screw (Load Limit)

ADJUST LOAD LIMIT (CONT.)

If movement is less than specified with the Two Screw Assembly, back off the outer adjusting screw approximately 1/8 of a turn and tighten the inner adjusting screw. 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.

3. Disconnect the fuel rod from the injector control tube lever.
4. Hold onto the clevis at the end of the injector control tube and position the No. 1 injector in the full–fuel position.

Two Screw Assembly — Screw down the inner adjusting screw of the No. 2 injector until the injector control lever for that injector contacts the injector body. This may be felt at the clevis end by a slight movement as contact is made. Tighten the outer adjusting screw until it bottoms lightly on the injector control tube. Then, alternately tighten both the inner and outer adjusting screws until tight.

One Screw and Locknut Assembly — Tighten the adjusting screw of the No. 2 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).

5. Make sure the rack remains snug on the pin of the rack control lever at the No. 1 injector.

Two Screw Assembly — If the rack of No. 1 injector has become loose, back off slightly on the inner adjusting screw at the No. 2 injector rack control lever. Tighten the outer adjusting screw.

One Screw and Locknut Assembly — If the rack of the No. 1 injector has become loose, loosen the locknut and turn the adjusting screw on the No. 2 injector rack control lever clockwise a slight amount and retighten the locknut.

When the settings are correct, the rack of both injectors must be snug on the pin of their respective rack control levers.

6. Position the remaining rack control levers as outlined in Steps 4 and 5.

When the settings are correct, the racks of all injectors must be snug on the pins of the rack control levers when the control tube lever is held in the full–fuel position.

COMPENSATION ADJUSTMENT

After the temperature of the engine and the oil supplied to the governor reach their normal operating values, adjust the governor compensation, without load on the engine, as follows:

1. Open the compensating needle valve two or three turns with a screwdriver and allow the engine to "hunt" or "surge" for about one–half minute to bleed trapped air from the governor oil passages.
2. Gradually close the needle valve until "hunting" just stops. Do not go beyond this position. Check the amount of needle valve opening by closing the valve completely, noting the amount required to close. Open the valve to the previously determined opening at which "hunting" stopped. Test the action by manually disturbing the engine speed. The engine should return promptly to original steady speed with only a small overshoot. The correct needle valve setting will be between 1/8 and 1/2 turn open.

It is desirable to have as little compensation as possible. Closing the needle valve farther than necessary will make the governor slow to return to normal speed after a load change.

ADJUST SPEED DROOP

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 droop is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs, the speed droop should be readjusted.

The best method of determining the engine speed is by the use of an accurate hand tachometer.

If a full rated load on the unit can be established and the fuel rod, injector rack control levers and load limit have been adjusted, the speed droop may be adjusted as follows:

1. Start the engine and run it at approximately one–half the rated no–load speed until the lubricating oil temperature stabilizes.

NOTE: When the engine lubricating oil is cold, the governor regulation may be erratic. The regulation should become increasingly stable as the temperature of the lubricating oil increases.

2. With the engine stopped, remove the governor cover.
3. Loosen the locknut and back off the maximum speed adjusting screw approximately 3/8 inch.
4. Loosen the droop (Figure 4.) adjusting bolt. Move the bracket so that the bolt is midway between the ends of the slot in the bracket. Tighten the bolt. Be sure the bracket remains on the shoulder of the terminal lever.
5. With the throttle in 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 adjust 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.

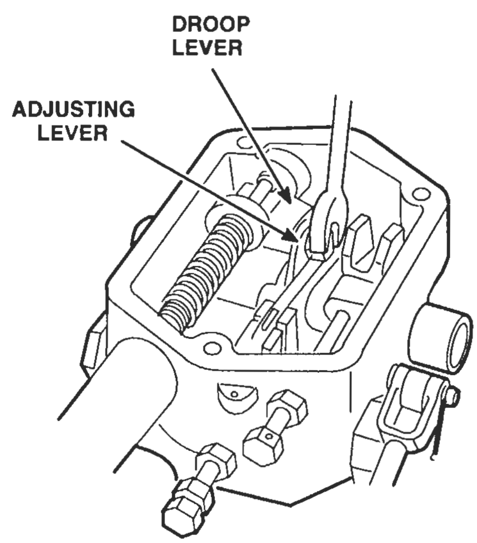


Figure 4. Adjusting Speed Drop

If the speed droop is too high, stop the engine and again loosen the bolt and move the droop adjusting bracket in toward the engine. Tighten the bolt. To increase the speed droop, move the droop adjusting bracket out, away from the engine.

The speed droop in governors which control engines driving generators in parallel should be identical, otherwise, the electrical load will not be equally divided.

ADJUST SPEED DROP (CONT.)

Adjust the speed droop bracket in each engine governor to obtain the desired variation between the engine no–load and full–load speeds shown in Table 1.

FULL LOAD	NO–LOAD
50 cycles 1,000 r/min	52.2 cycles 1,050 r/min
60 cycles 1,200 r/min	62.5 cycles 1,250 r/min
50 cycles 1,500 r/min	52.5 cycles 1,575 r/min
60 cycles 1,800 r/min	62.5 cycles 1,875 r/min

The recommended speed droop of generator sets operating in parallel is 50 r/min (2 1/2 cycles) for units operating at 1,000 and 1,200 r/min and 75 r/min (2 1/2 cycles) for units operating at 1,500 and 1,800 r/min full load. This speed droop recommendation may be varied to suit the individual application.

A single engine unit equipped with an isochronous type hydraulic governor may operate at a constant frequency by setting the governor droop to zero. However, when operating generator sets in parallel, the governor of each unit must be set with an equal amount of droop for stable operation and proper division of the load.

If required, the zero droop setting may be carried out by performing Steps 1 through 7 as outlined, except adjust for zero droop instead of 3% to 5% stated.

ADJUST MAXIMUM NO–LOAD SPEED

With the speed droop properly adjusted, set the maximum no–load speed as follows:

1. Loosen the locknut and back out the maximum speed adjusting screw three turns.
2. With the engine operating at no load adjust the engine speed until the engine is operating at approximately 10% higher than the rated full–load speed.
3. Turn the maximum speed adjusting screw in lightly until contact is felt with the linkage in the governor (Figure 5.)
4. Hold the screw and tighten the locknut. Install the governor cover.

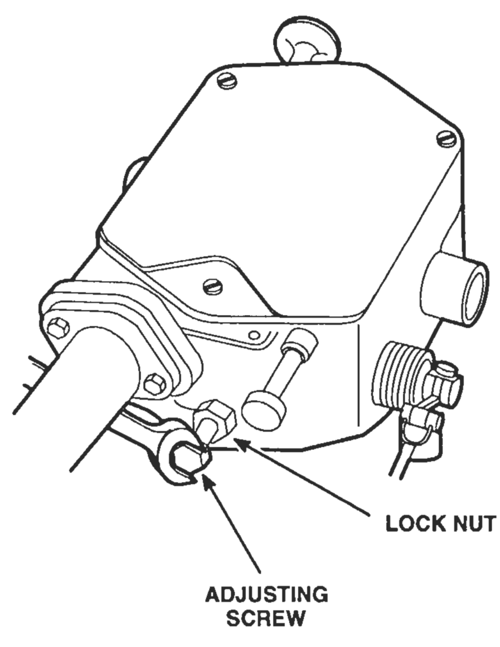


Figure 5. Setting Maximum Speed Adjusting Screw

GOVERNORS WITH SYNCHRONIZING MOTOR

On some hydraulic governors, a reversible electric synchronizing motor is mounted on the governor cover. This motor permits close adjustment of engine speed by remote control. This feature is especially valuable when synchronizing two generators from a central control panel (Figure 6.)

When the two–way control switch for the unit on the central control panel is closed by the operator, the motor shaft turns the governor speed adjusting shaft by a reduction gear and slip coupling. 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 panel, the operator returns the switch to the off position.

Should the switch be held in the "Lower Speed" position too long, the synchronizing motor will continue to lower the unit speed until it ultimately shuts down the engine. Should the switch be held too long in the "Raise Speed" position, the motor will turn the governor shaft until the shaft strikes the maximum speed adjusting screw, after which the clutch will slip and the motor will continue to run at a slightly reduced speed without further effect.

The adjustments on the governor equipped with a synchronizing motor are the same as on units without a synchronizing motor. The synchronizing motor is used in place of the vernier throttle control knob to raise and lower the engine speed.

The governor cover and motor assembly must be removed when setting the engine droop. The desired engine speeds may be obtained by manually turning the worm drive while the cover is removed.

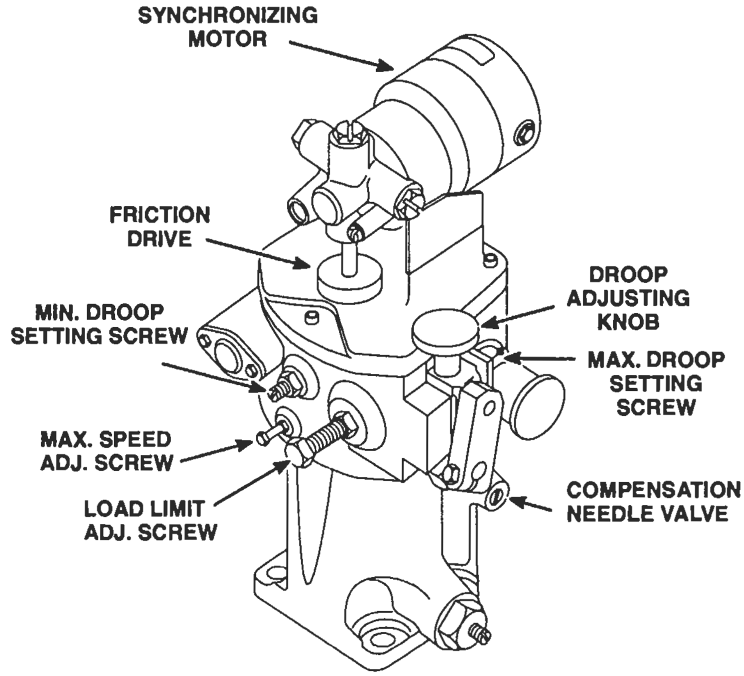


Figure 6. Typical Synchronizing Motor Mounting

GOVERNORS WITH EXTERNAL DROOP CONTROL

Some PSG governors have an external adjustable droop control to enable droop adjustment without the removal of the governor cover. Units having a governor with this feature, may be paralleled with another unit that is operating at constant frequency (zero droop). The incoming unit should 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, the load should be shifted to the incoming unit and its governor droop bracket moved to zero droop. The outgoing unit can then be adjusted to maximum droop, removed from the line and stopped. The incoming unit will not be carrying the load and operating at constant frequency (zero droop).

Adjustment of governor droop by the external adjustable droop control should be performed as follows:

1. Start the engine, and run it at approximately one–half the rated full–load speed until the lubricating oil temperature stabilizes. Then, remove the load from the engine.
2. Back off the 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. Then, back out the minimum and maximum droop setting screws.
3. Loosen the droop adjusting knob and move the slider all the way in toward the engine, and then tighten the knob (Figure 7.)
4. Loosen the locknut on the maximum speed adjusting screw and turn the screw out until 5/8″ of the threads are exposed.
5. 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 by means of the synchronizing motor.
6. 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 drop adjusting knob and set the slider to a reduced droop position.

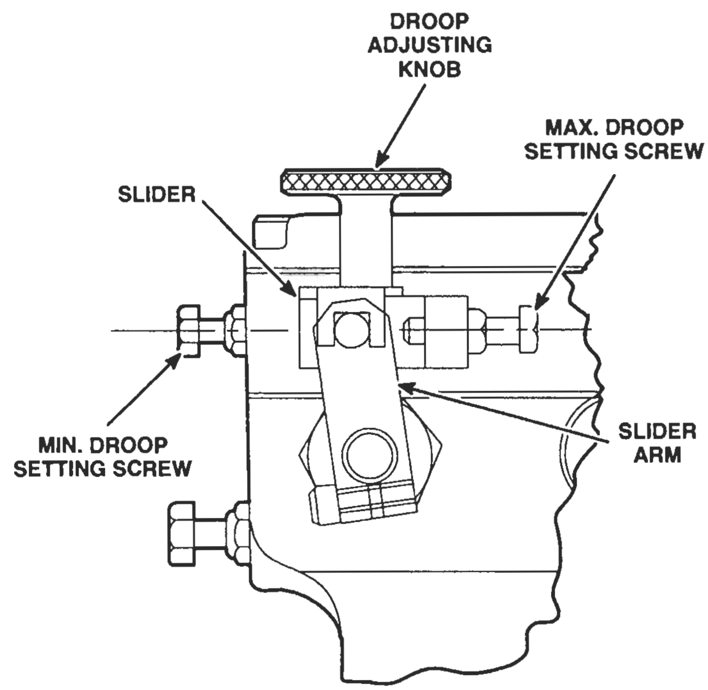


Figure 7. External Droop Control on PSG Isochronous Governor

GOVERNORS WITH EXTERNAL DROOP CONTROL (CONT.)

7. 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.
8. Loosen the droop adjusting knob and slide the droop bracket in a direction to increase the droop. Perform Steps 5 and 6 to check the droop until the desired maximum droop is attained.
9. 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.
10. Recheck the minimum and maximum droop setting as outlined in Steps 5 and 6 and adjust the adjustment screws, if necessary, until the correct settings are attained.
11. Adjust the maximum no–load speed.

SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

Engines with mechanical governors may be equipped with a load limit device to reduce the maximum horsepower.

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 of a three cylinder engine, between the No. 2 and No. 3 cylinders of a four cylinder engine or between the No. 3 and No. 4 cylinders of a six cylinder engine.

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.

Detroit Diesel's naturally aspirated engines are designed to operate in most areas of the United States without any changes or modifications. However, as the engine is operated at higher elevations, the operator will begin to notice a loss of engine power and a noticeably darker exhaust smoke. This is due to the thinner air at the higher elevations not having enough oxygen to burn the fuel completely in the combustion chamber.

This is generally not a problem if operation at the higher altitudes is only temporary and can be offset somewhat by reducing vehicle loads to compensate for the loss of engine power at the higher elevations. This may also result in cleaner exhaust smoke if the power demands on the engine are reduced. The exhaust smoke will also be cleaner if drivers avoid lugging the engine by using lower gears to keep engine speed up.

If the engine is intended to be used continuously at higher elevations and the exhaust smoke is objectionable (excessively dark), you may wish to install a load limiter to restrict injector output or switch to a smaller injector for your Series 71 engine. Detroit Diesel has certified with the U.S. EPA injector sizes ranging from 50 to 65 in.^{3} output, depending on whether the engine is used in coach or truck applications. A listing of injectors which are available for these engines and their tune–up specifications is shown in Table 1.

ENGINE	INJECTOR	INJECTOR TIMING	GEAR TRAIN TIMING	FULL LOAD SPEED RANGE*
6L–71N	7E65	1.484	Std. Gear – Adv. Cam	2100 – 1900
	7E60	1.484	Std.	2100 – 1800
	7E55	1.496	Std.	2100 – 1800
	7E50	1.484	Std.	2100 – 1800

* 2300 r/min full–load speed is permitted for certain emergency vehicles.

To reduce engine fuel input in order to reduce exhaust smoke density at high altitudes, remove injectors and replace with next smallest injector shown on chart. Adjust cam and gear timing as required.

TABLE 1 – ALTITUDE ADJUSTMENT DATA

SECTION 14.14 – GOVERNING DEVICE ADJUSTMENT

ADJUSTMENT

After the engine tune–up is completed, make sure the load limit device is properly installed. Make sure the counterbores in the adjusting screw plate 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 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, adjust the load limit screw locknut so the bottom of the locknut is 1 3/4 inch from the bottom of the load limit screw (Figure 1.) for the initial setting.
4. Thread the load limit screw into the adjusting screw plate until the locknut 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.

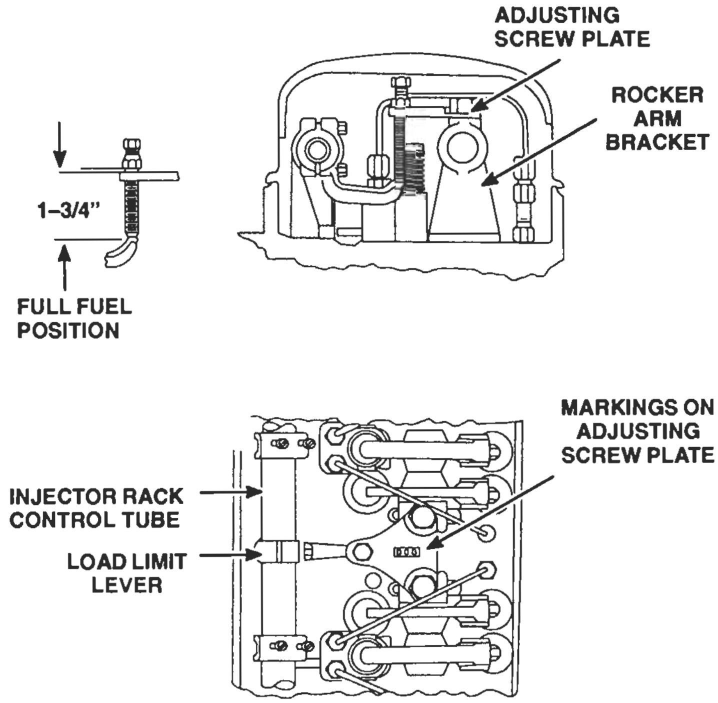


Figure 1. Engine Load Limit Device

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. See Table 2 for high altitude settings. Each full turn screw equals .042 inch, or .007 inch for each flat on the hexagon head. 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.

INJECTOR	LOCK NUT SETTING ABOVE PLATE	
	INCHES	NUMBER OF TURNS
7E65	.19	4 1/4
7E60	.12	3
7E55	.16	4
7E50	.20	5

TABLE 2 – LOAD LIMIT DEVICE SETTINGS TO REDUCE FUEL INPUT AT HIGH ALTITUDE

ADJUSTMENT (CONT.)

As experience is gained with the load limiter, you may wish to readjust the limiter to either improve performance or to further reduce smoke.

NOTE: Remember that the load limiter is a device which limits both the fuel output of the injectors and the power output of the engine. Therefore, after the device is installed, the vehicle driver should be cautioned that the power output of his engine has been restricted.

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

10. The power control (torque limiting) device (Figure 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.
11. This device 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.

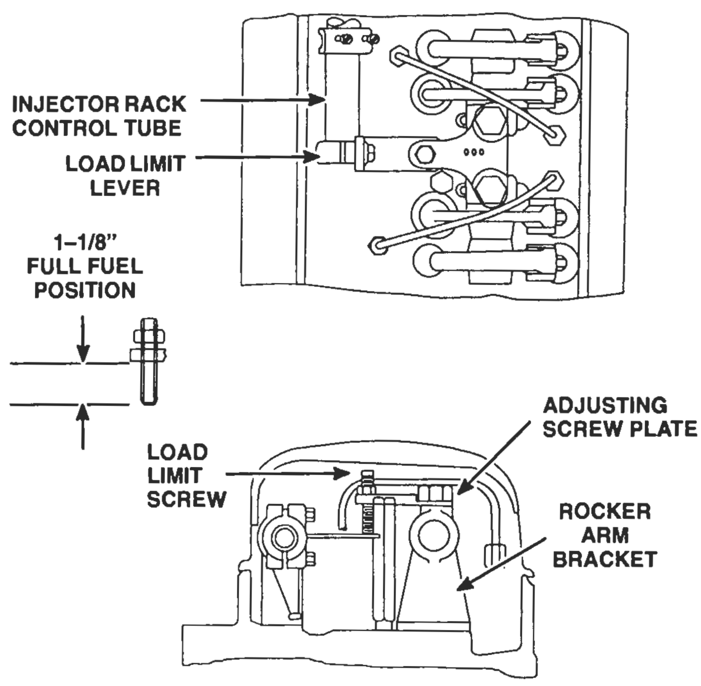


Figure 2. Power Control Device

NOTE: The rocker arm shaft bracket bolts that retain the adjusting screw plate 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 a three cylinder engine, between the No. 2 and No. 3 cylinders on a four cylinder engine and between the No. 3 and No. 4 cylinders on a six cylinder engine.

SECTION 14.14 – GOVERNING DEVICE ADJUSTMENT

ADJUSTMENT

After the engine tune–up is completed, adjust the power control device 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 the spring until it projects parallel to the cylinder head 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 the 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.

NOTE: Wipe the oil from the spring and the bottom of the adjusting screw so the point of contact can be seen readily.

4. Start the engine. Then with the engine running at full governed speed, check the horsepower. If necessary, readjust the screw to obtain the specified horsepower. Turn the screw down to decrease the horsepower; turn the screw up to increase the horsepower. When the desired wheel horsepower is obtained, hold the screw from turning and tighten the locknut.

NOTE: If a dynamometer is not available, backup the lock nut the distance stamped on the plate. Then turn the screw and locknut down together until the locknut bottoms on the plate. Hold the screw from turning and tighten the locknut.

THROTTLE DELAY MECHANISM

The throttle delay mechanism is used 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 cylinder head. 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 yield lever and spring assembly replaces the standard lever and pin assembly on the front end of the injector control tube.

OPERATION

Oil is supplied to a reservoir above the throttle delay cylinder through an orifice plug in the drilled oil passage in the rocker arm shaft bracket (Figure 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 lever and spring assembly replaces the standard lever on the front end of the injector control tube.

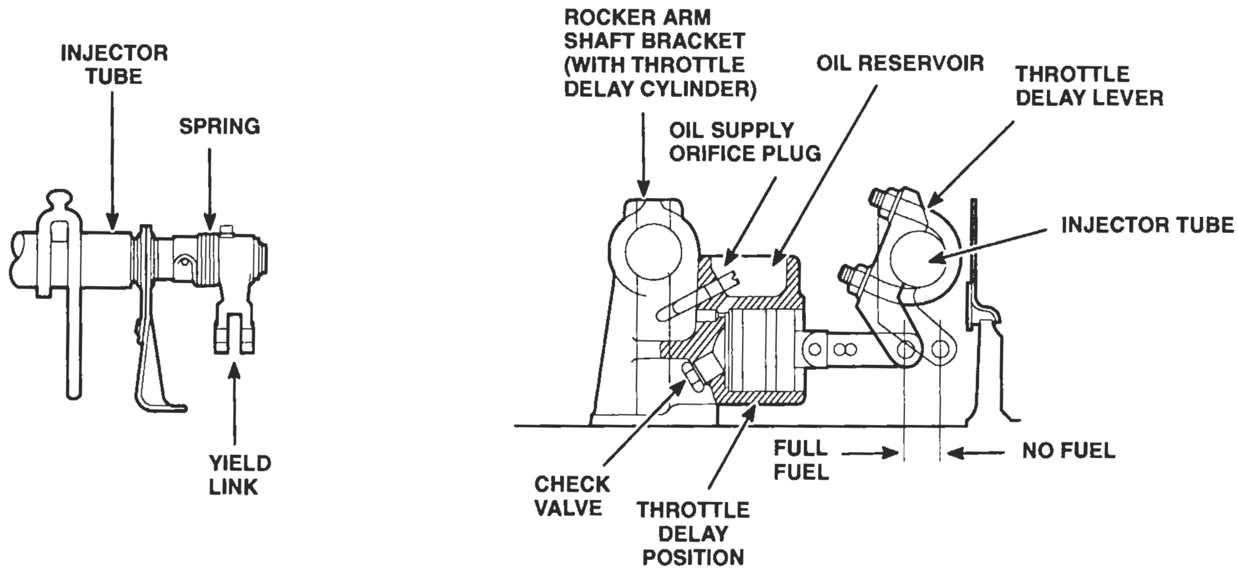


Figure 3. Throttle Delay Cylinder and Yield Link

INSPECTION

The current throttle delay bracket has a closer tolerance on the piston and cylinder bore. The current check valve has a nylon check 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.

SECTION 14.14 – GOVERNING DEVICE ADJUSTMENT

SERVICE NOTE

The current throttle delay cylinder rocker arm bracket has a 5/64 inch diameter fill hole. The former throttle delay cylinder with a 1/4 inch diameter fill hole can be modified as follows:

1. Ream the fill hole to .2646–.2666 inch diameter with a 17/64 inch 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 as outlined under Adjustment (Former Throttle Delay).

Effective with unit serial number 6A0448935, inline 6–71 horizontal engines use a new throttle delay/rocker shaft bracket. The new bracket is similar to the former, except that it has a larger cylinder oil fill hole (1/8 inch vs. 5/64 inch) and an additional 1/8 inch diameter oil bleed hole (Figure 4.)

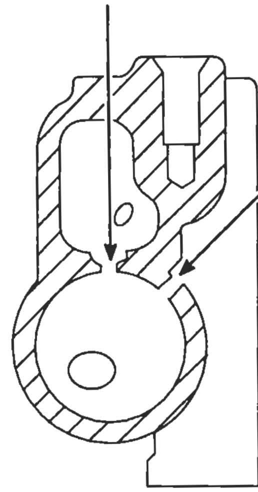


Figure 4. Cutaway View of Throttle Delay Cylinder Rocker Arm Shaft Bracket for Horizontal Engines

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.
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.

ADJUSTMENT (CURRENT THROTTLE DELAY) (CONT.)

3. Insert the appropriate throttle delay timing gage (see charts in Section 14) on the rack between the injector body and the shoulder on the injector rack clevis (Figure 5.)
4. Hold the governor throttle lever in the maximum speed position. This should cause the injector rack to move toward the full–fuel position.

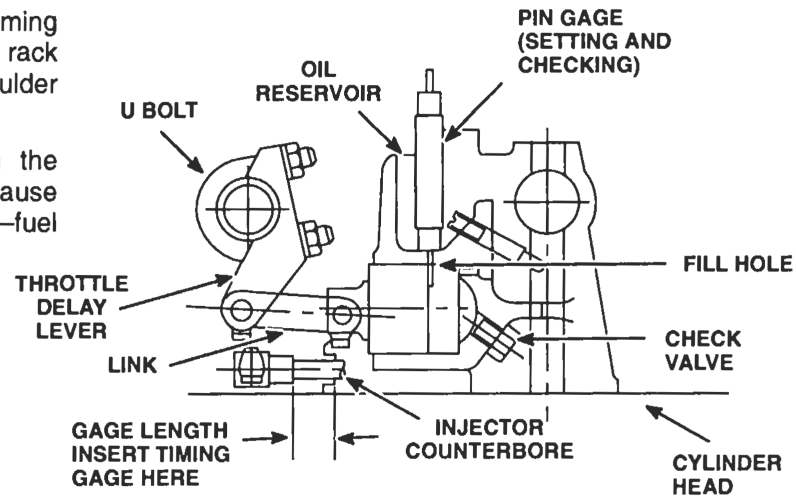


Figure 5. Adjusting Throttle Delay Cylinder (Current)

5. Insert pin gage J 25558 with the "go" (green .069 inch) end in the cylinder fill hole. If the throttle delay housing has multiple holes, use the hole shown in Figure 6.
6. Rotate the throttle delay lever until further movement is limited by the piston contacting the pin gage.
7. Tighten the U–bolt nut 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 inch) 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 inch) end in the fill hole. If the "no go" end of the gage enters the fill hole past the piston without resistance, increase 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.

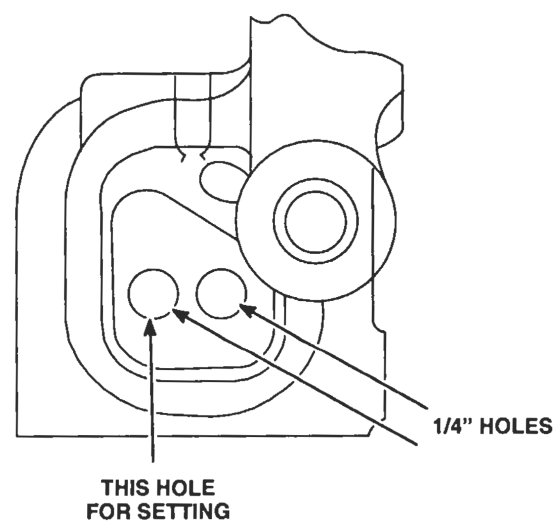


Figure 6. Throttle Delay with Multiple Fill Holes

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.

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. Insert gage J 23190 (.454 inch setting) between (Figure 7.) 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.
5. Refer to Engine Tune–Up in Section 15.1 for maintenance.

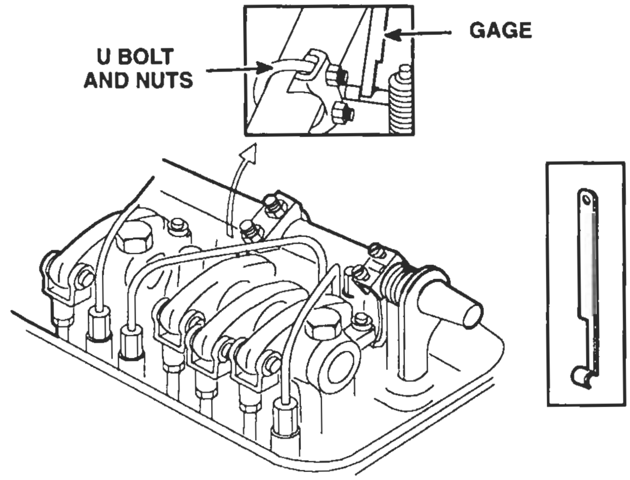


Figure 7. Adjusting Throttle Delay Cylinder

FUEL MODULATOR

Fuel modulators are now available for use on industrial and Federal–certified 6–71T and 6–71TT highway vehicle engines.

The fuel modulator (Figure 8.) is mounted on the cylinder head between the No. 5 and No. 6 cylinders and consists of a cast housing containing a cylinder, piston, cam and spring. 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. On early industrial turbocharged engines, the fuel modulator is connected to the engine air box and is sensitive to the air box pressure.

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 turbocharger speed is high enough to provide sufficient air for combustion.

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.

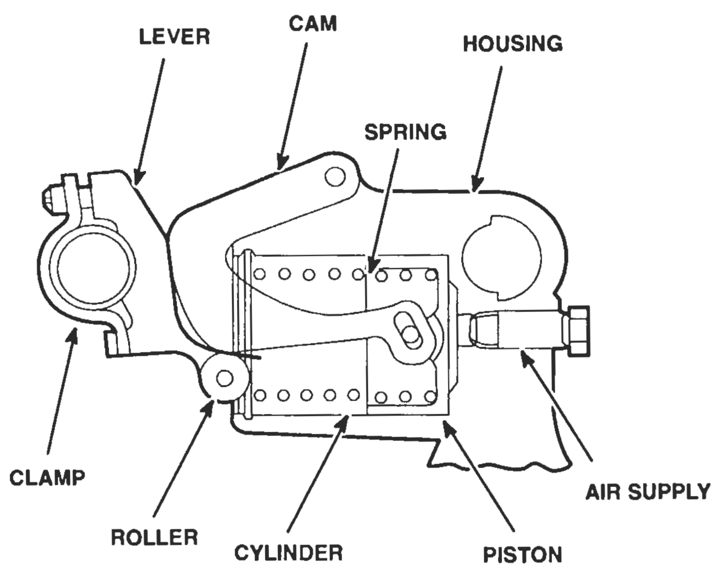


Figure 8. Fuel Modulator Assemble 6–71T and 6–71TT Highway Vehicle Engines

 May, 1994

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:

1. Ensures that the engine emission–related adjustments comply with EPA requirements.
2. Ensures a regulated fuel/air ratio to prevent over–fueling and smoke.
3. Ensures smooth, free operation of the fuel modulator and linkage.
4. Ensures proper adjustment of the modulator to DDC factory specifications, thereby eliminating any previously made incorrect adjustment.

Fuel modulator setting dimensions for specific engine models are shown in Tune–up Section 14.14 or the engine service manual.

INSPECT FUEL MODULATOR

1. With the engine stopped, insert the correct rack gage between the injector body rack recess and the shoulder on the injector rack (Figure 9.) 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.

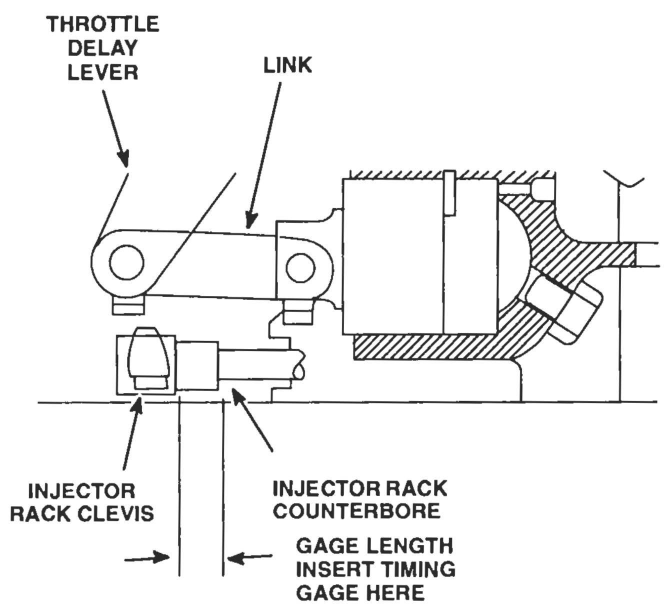


Figure 9. Rack Gage Positions

INSPECT FUEL MODULATOR (CONT.)

Fuel modulator specifications and setting tools for 1979 thru 1983 1/2 – certified engines are shown in Table 1. For fuel modulator settings of certified engines built after 1983, see Section 14 (Engine Tune–up).

Fuel modulator setting tools (injector rack gages) are as follows:

TOOL NO.	SETTING
J 24889	.345
J 28779	.365
J 24882	.385
J 9509–C	.404
J 35735	.430
J 23190	.454
J 34080	.480
J 34609	.550
J 25559	.570
J 26927	.586 & .686
J 29063	.594

TABLE 1 – TOOL SETTINGS

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 inch feeler gage between the modulator roller and cam (Figure 10.) The rack gage must fall over. The rack gage should stand at a 45 degree angle by itself when the .005 inch feeler gage is removed.

NOTE: Rack gages are marked with the tool number and specific dimensions. Dimensional tolerances are ± .002 inch.

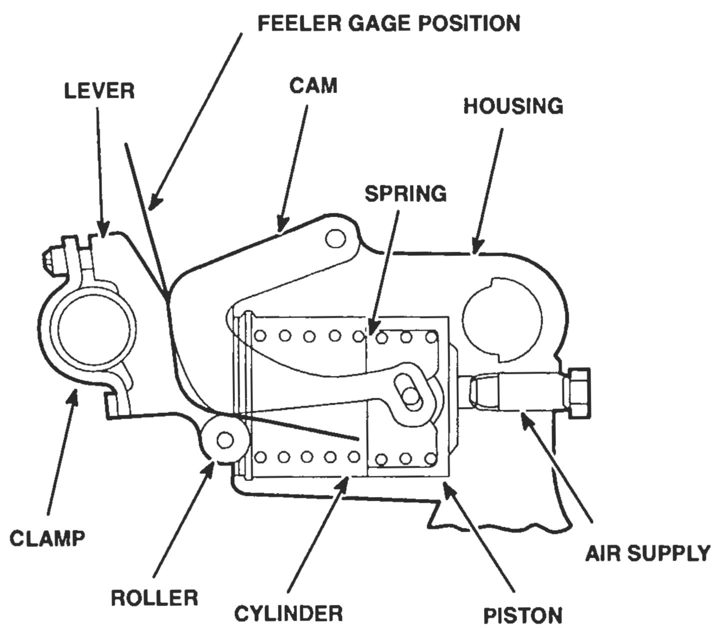


Figure 10. Fuel Modulator Assembly (Feeler Gage in Position)

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. Perform steps 1 and 2 under "inspect fuel modulator".
2. The rack gage must stand up while being held in place by the rack.
3. With the 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 inch feeler gage between the cam and the roller. Make sure the cam is centered, and tighten the clamp screw until the gage falls. Replace the .017 inch thick feeler gage with a .004 inch 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 inch feeler gage between the modulator roller and cam. If the rack gage falls, the setting is correct.
5. Remove the gage.

CERTIFICATION	SETTING	TOOL	RATING	INJECTOR
1979 THRU 1983 FEDERAL ENGINES	6–71T .365*	J28779	245 @ 2100 260 @ 2100	N65 7C70
	6–71TA .385*	J24882	275 @ 2100 260 @ 1800 270 @ 1950	7C75 7C75 (TA ENGINE) 7C75 (TA ENGINE)
1979 THRU 1983 1/2 FEDERAL ENGINES	6–71TT & TTA .385*	J24882	180 @ 1800 230 @ 1800 230 @ 1950 240 @ 2100	7E75 7E75 7E75 7E75

ADJUST FUEL MODULATOR (EARLY TURBO INDUSTRIAL ENGINES)

After completing adjustment of the injector rack control levers, adjust the fuel modulator as follows:

1. Relocate the fuel modulator lever and roller assembly to its original position opposite the cam so the cam is centrally located on the roller (Figure 11.) Tighten the U–bolt nuts until the lever and roller assembly is snug on the control tube. This will not only permit adjustment of the lever, but will retain the adjustment until the roller and lever assembly can be securely tightened.
2. Hold the fuel modulating piston and cam in the high speed position by applying not less than 20 lb/in.^{2} (138 kPa) air pressure to the piston or by prying the cam out with a screwdriver.
3. Hold the injector rack in the full–fuel position.
4. While holding the cam and the injector rack, move the fuel modulating lever and roller assembly until the roller contacts the cam. Carefully, tighten the nuts on the U–bolt alternately to avoid changing the position of the roller against the cam.

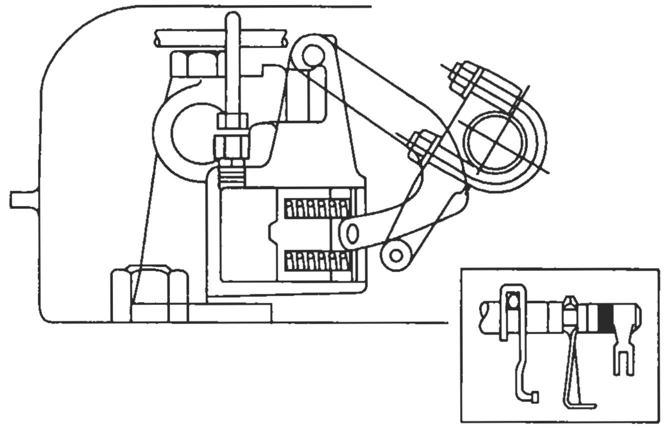


Figure 11. Fuel Modulator Assembly – Early Turbocharged Industrial Engines

CHECK FUEL MODULATOR SETTING

1. Pry the fuel modulating cam out with a screwdriver.
2. Move the injector control tube to the full–fuel position.
3. Release the pressure on the screwdriver slightly and allow the cam to move in slightly. If properly set, the roller of the fuel modulating lever and roller assembly will rotate as soon as the cam moves. Repeat this check several times to ensure the proper setting was not disturbed while tightening the U–bolt clamping nuts.

FUEL SHUTOFF AIR CYLINDER ASSEMBLY

An air cylinder (Figure 12.) is mounted at the rear of the cylinder head on some engines to move the injector fuel control racks to the no–fuel position to stop the engine. The air cylinder permits the use of a governor with a single control lever, eliminating the need of an off–on lever and the necessary operating linkage.

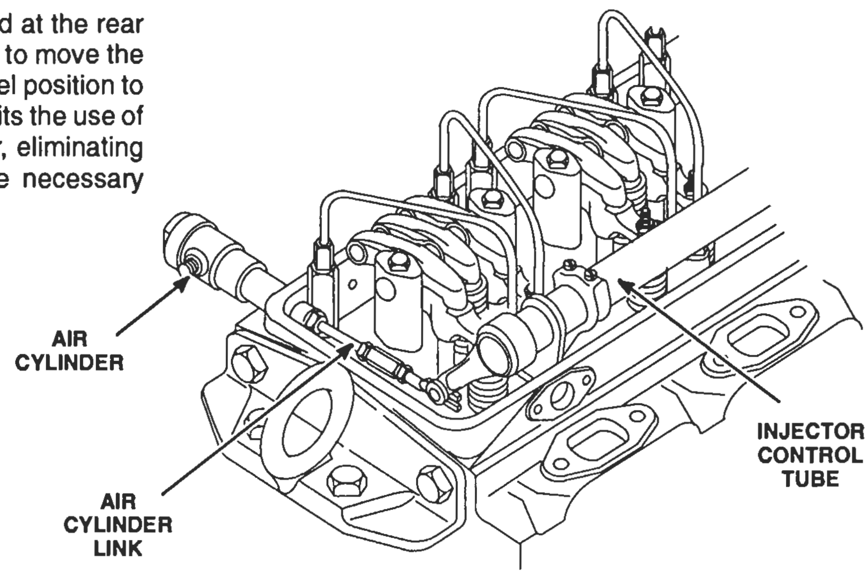


Figure 12. Air Cylinder Used with Limiting–Speed Governor

The use of the air cylinder on an engine with a limiting–speed governor (Figure 13.) requires a yielding fuel control rod.

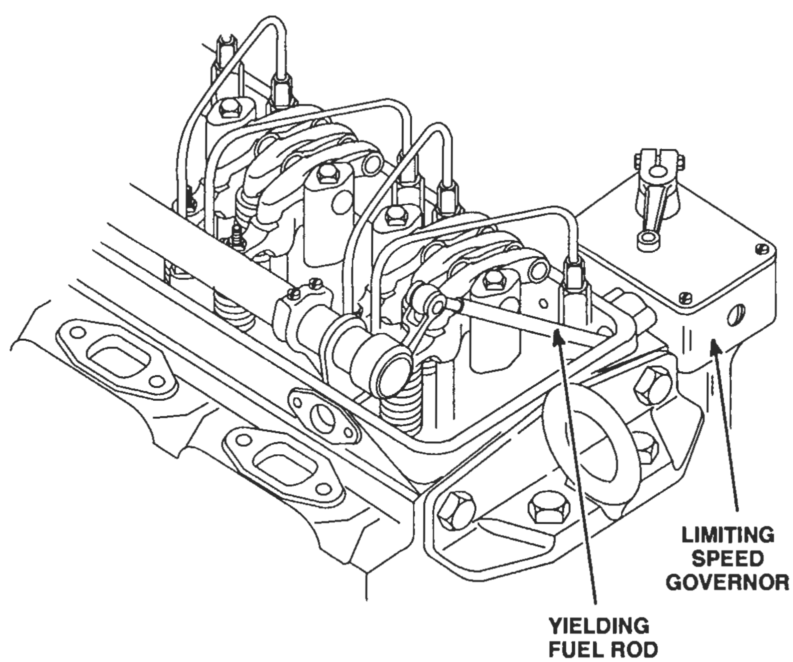


Figure 13. Yielding Fuel Rod used with Limiting–Speed Governor

FUEL SHUTTOFF AIR CYLINDER ASSEMBLY (CONT.)

An engine equipped with an air cylinder does not require the yielding rod because (Figure 14.) the torsion spring within the governor will perform the same purpose.

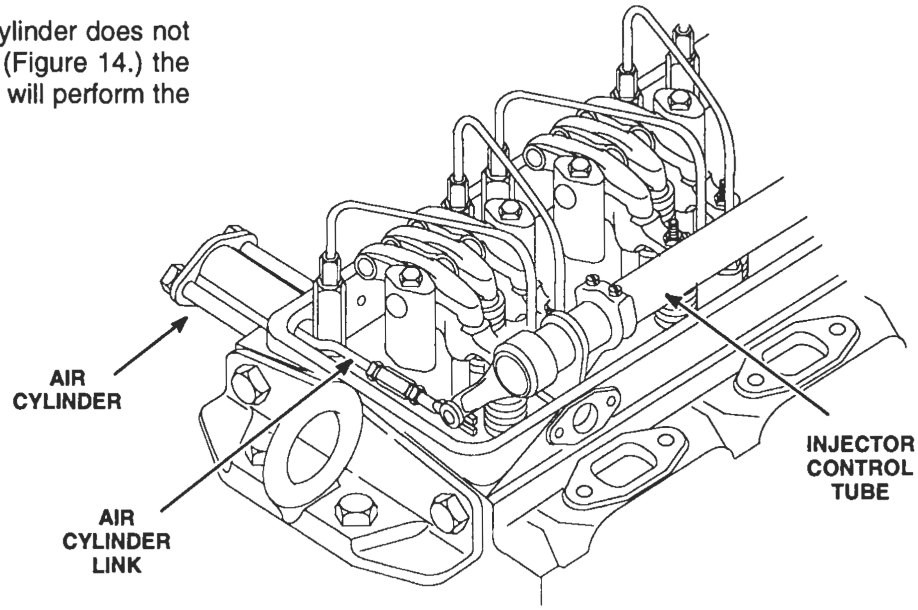


Figure 14. Air Cylinder used with Fuel Modulating Governor

OPERATION

The fuel shutoff cylinder is actuated by air pressure. The air enters the cylinder and forces the piston forward, thus overcoming the tension of the air cylinder spring; the yielding fuel rod is used to move the injector fuel control racks to the no–fuel position, shutting the engine down. When the air pressure is released, the spring within the air cylinder moves the piston to the end of its travel away from the engine allowing the yielding rod to expand, moving the injector racks into the full–fuel position required for engine starting.

ADJUST AIR CYLINDER LINKAGE

Adjust the linkage between the fuel shutoff cylinder and the injector control tube lever as follows:

1. Place the governor speed control lever in the maximum speed position. Movement of the control lever will move the injector racks to the full–fuel position.
2. Loosen the locknuts on the air cylinder link and lengthen the rod by turning the turnbuckle until the end of the slot contacts the pin in the end of the control tube lever. Then shorten the rod one complete turn of the turnbuckle and tighten the locknuts. Adjusting the rod in this manner will permit the governor to move the injector control racks into the full–fuel position without coming to the end of the slot in the air cylinder link.

ADJUSTMENT OF MECHANICAL GOVERNOR SHUTDOWN SOLENOID

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 (Figure 15. and Figure 16.) 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 inch travel which is more than adequate to move the injector control racks from the full–fuel to the complete no–fuel position and shutdown 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 inch minimum. The locknut can be either on top 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.

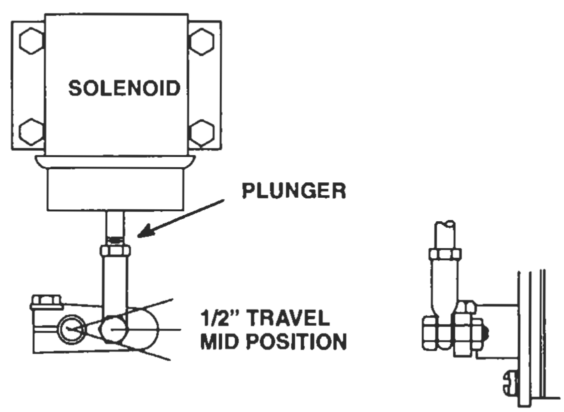


Figure 15. Typical Variable Speed Governor Lever Position

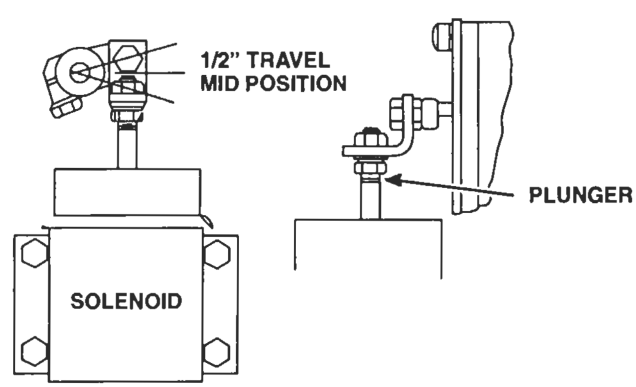


Figure 16. Typical Limiting Speed Governor Lever Position

PREVENTIVE MAINTENANCE – TROUBLESHOOTING – STORAGE

CONTENTS

Lubrication and Preventive Maintenance 15.1

Troubleshooting 15.2

Storage 15.3

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 chart 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.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

ITEM DAILY	
1–Lubricating Oil	①
2–Fuel Tank	①
3–Fuel Lines and Flexible Hoses	①
4–Cooling System	①
5–Turbocharger	①
ITEM 3,000 MILE (4,800 KM) INTERVAL	
6–Battery	①
7–Tachometer Drive	①
ITEM 4,000–6,000 MILE (6,400–9,500 KM) INTERVAL	
8–Air Cleaner (oil bath)	①
9–Drive Belts	①
10–Air Compressor	①
11–Throttle Control	①
ITEM 15,000 MILE (24,000 KM) INTERVAL	
(2)–Fuel Tank	①
(8)–Air Cleaner (oil bath)	①
12–Lubricating Oil Filter	Ⓡ

MAINTENANCE

SERVICE RECOMMENDATIONS

(VEHICLE ENGINES)

ITEM	MONTHS	6	12	18	24	30	36	42	48	54	60
6 MONTHS or 10,000 Mile Intervals	MILES/KM (1000)	10	20	30	40	50	60	70	80	90	100
13–Fuel Filter		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
14–Coolant Filter & Water Pump*		Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ	Ⓡ
15–Starting Motor		①	①	①	①	①	①	①	①	①	①
(2)–Fuel Tank			①		①		①		①		①
(4)–Cooling System (hoses)			①		①		①		①		①
(10)–Air Compressor			①		①		①		①		①
16–Air System			①		①		①		①		①
17–Exhaust System			①		①		①		①		①
18–Air Box Drain Tube				①			①			①	
19–Emergency Shutdown			①		①		①		①		①
20–Engine (steam clean)			①		①		①		①		①

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

ITEM (CONT.) MONTHS	6	12	18	24	30	36	42	48	54	60
6 MONTHS or 10,000 Mile Intervals MILES/KM (1000)	10	20	30	40	50	60	70	80	90	100
21–Radiator		①		①		①		①		①
22–Shutter Operation		①		①		①		①		①
23–Oil Pressure		①		①		①		①		①
24–Governor					①					①
25–Fuel Injector & Valve Clearance					①					①
26–Throttle Delay					①					①
27–Generator or Alternator*										
28–Engine & Transmission Mounts						①				
29–Crankcase Pressure						①				
30–Air Box Check Valves										①
(8)–Air Cleaners (dry)										Ⓡ
(1)–Lubricating Oil*										
31–Fan Hub*										
(3)–Fuel Lines and Flexible Hoses	①									
(4)–Cooling System	①									
(8)–Air Cleaners	①									
32–Thermostats & Seals	①									
33–Blower Screen	①									
34–Crankcase Breather	①									
35 Fan (thermo–modulated)	①									
36–Engine Tune–Up	As Required									

CODES: ① Inspect, Service, Correct or Replace as Necessary **Ⓡ Replace**
***See Item in Text**

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

INDUSTRIAL OFF HIGHWAY AND MARINE TIME INTERVALS

ITEM	Hours	Daily	8	50	100	150	200	300	500	700	1000	2000
	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	
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 and Water Pump*									x			
15–Cranking Motor*												
16–Air System										x		
17–Exhaust System										x		
18–Air Box Drain Tube											x	
19–Emergency Shutdown										x		
21–Radiator										x		

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

INDUSTRIAL OFF HIGHWAY AND MARINE TIME INTERVALS (CONT.)											
ITEM Hours	Daily	8	50	100	150	200	300	500	700	1000	2000
MILES		240	1,500	3,000	4,500	6,000	9,000	15,000	20,000	30,000	60,000
22–Shutter Operation									x		
23–Oil Pressure									x		
24–Overspeed Governor								x			
26–Throttle Delay*											
27–Generator or Alternator				x		x		x			x
28–Engine & Transmission Mounts											x
29–Crankcase Pressure											x
30–Air Box Check Valves*											
31–Fan Hub*											
32 Thermostats and Seals*											
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					
42–Torqmatic Convertor	x		x					x		x	
43–Reduction Gear (Single Engine)		x	x					x		x	
44–Reduction Gear (Mult.–Ind.)	x									x	
45–Reduction Gear (Mult.–Marine)	x					x					
46–Hydrostarter System*											
47–Transmission (Railcar)	x									x	
48–Oil Filter (Railcar)										x	

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

Item 1 – Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately 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 (Section 13.3).

NOTE: 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 external oil lines.

Change the lubricating oil at the intervals shown in the charts.

ENGINE OIL CHANGE INTERVALS		
SERVICE APPLICATION	MAXIMUM ALLOWABLE OIL DRAIN INTERVALS	
	DIESEL FUEL SULFUR CONTENT LESS THAN 0.5% BY WT. MAX.	
	LUBE OIL CHANGE INTERVAL	FILTER CHANGE INTERVAL
HWY. TRUCK & MOTOR COACH	15,000 MILES 24,000 km	15,000 MILES 24,000 km
CITY TRANSIT COACHES	6,000 miles 9,600 km or 3 Months*	6,000 miles 9,600 km or 3 Months*
PICK–UP & DELIVERY, STOP & GO, SHORT TRIP	12,000 MILES 19,000 km	12,000 MILES 19,000 km
INDUSTRIAL, AGRICULTURAL & MARINE	150 HOURS	150 HOURS
STATIONARY UNITS CONTINUOUS	300 HOURS or 3 Months*	300 HOURS or 3 Months*
STATIONARY UNITS STANDBY	150 HOURS or 1 Year*	150 HOURS or 1 Year*

*Whichever comes first.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

ENGINE OIL CHANGE INTERVALS (Use oil analysis to determine optimum drain interval)		
SERVICE APPLICATION	SUGGESTED MAXIMUM OIL DRAIN INTERVALS	
	DIESEL FUEL SULFUR CONTENT ABOVE 0.5% BY WT. MAX.	
	TBN (D 2896) ABOVE 10	FILTER CHANGE INTERVAL
HWY. TRUCK & MOTOR COACH	10,000 MILES 16,000 km	10,000 MILES 26,000 km
CITY TRANSIT COACHES	4,000 miles 6,400 km or 3 Months Max.*	4,000 miles 9,400 km or 3 Months Max.*
PICK–UP & DELIVERY, STOP & GO, SHORT TRIP	8,000 MILES 12,500 km	8,000 MILES 12,500 km
INDUSTRIAL, AGRICULTURAL & MARINE	150 HOURS or 1 Year Max.*	150 HOURS or 1 Year Max.*
STATIONARY UNITS CONTINUOUS	150 HOURS or 3 Months Max.*	150 HOURS or 3 Months Max.*
STATIONARY UNITS STANDBY	100 HOURS or 1 Year Max.*	100 HOURS or 1 Year Max.*

*Whichever comes first.

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.

Item 2 – Fuel Tank

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.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

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 mircobe growth. The mircobes 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 commerciality available biocides. There are two basic types on the market.

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.

Diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax or equivalent, treats the fuel 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 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.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

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 njury and/or property damage may result from fire due to the leakage of flammable 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 and 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 lubricating 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.

NOTE: The new hose assemblies do not require automatic replacement after five years service or at major overhaul.

Item 4 – Cooling System

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.

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 intercooler 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.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

Item 5 – Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks or restrictions to oil flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause.

Item 6 – Battery

Check the specific gravity of the electrolyte in each cell of the battery 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 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 Air Cleaner

Remove the dirty oil and sludge from the oil bath type air cleaner cups and center tubes every eight 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.

Dry Type Air Cleaner

Inspect elements every 15,000 miles or 24,000 km (highway vehicles), 150 hours (non–vehicle engines), or more often if the engine is operated in severe dust conditions. Replace element if necessary.

Check gaskets for deterioration and replace, if necessary.

If housing is equipped with an aspirator, check for damage or clogging. Clean, repair, or replace, as required.

Replace air cleaner elements after one year of service or when the maximum allowable air inlet restriction is reached, whichever comes first.

Cleaning and/or reusing dry paper type air cleaner element is not recommended unless the cleaning method used removes clogging without damage to the element. Inspection and cleaning of elements must be done in accordance with the air cleaner manufacturer's recommendations, if any.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

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 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 eight 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 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.

ENGINE	FAN DRIVE		GENERATOR DRIVE		
	2 OR 3 BELTS	SINGLE BELT	TWO 3/8" or 1/2" BELTS	ONE 1/2" BELT	ONE WIDE BELT
3, 4–71	50–60	80–100	40–50	50–70	40–50
6–71	60–80	80–100	40–50	50–70	40–50
ALL	For 3 point or triangular drives use a tension of 90–120.				

Belt tension is 50–70 for a single premium high capacity belt (.785" wide) used to drive a 12 ft^3/min air compressor.

BELT TENSION CHART (lbs/belt)

Item 10 – Air Compressor

Remove and wash all of the polyurethane sponge strainer parts every 5000 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 limiting speed governor control shaft. Remove the plug in the end of the shaft and install a temporary grease fitting. Then, remove the governor cover to obtain a visual indication when greasing is complete. 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. After greasing the shaft remove the fitting and install the plug and governor cover using a new cover gasket.

Lubricate the clutch control levers and all other control mechanisms, as required, with engine oil.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

Item 12 – Lubricating Oil Filter

Install new oil filter elements and gaskets at a maximum of 15,000 miles (vehicle engines) or 150 hours (non–vehicle engines) or each time the engine oil is changed, whichever occurs first. Any deviation, such as changing filters every other oil change, should be based on a laboratory analysis of the drained oil and the used filter elements to determine if such practice is practical for proper protection of the engine.

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.

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 six months or 6,000 miles (vehicle engines) and 300 hours or 9,000 miles (non–vehicle engines) or when plugging is indicated.

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 six inches of mercury (20.3 kPa). At normal operating speeds (1600–2100 r/min), the fuel pressure is 45 to 70 lb/in.^{2} (310 to 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 45 lb/in.^{2} (310 kPa).

Item 14 – Coolant Filter and Water Pump

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every six 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 Engine Coolant 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 six 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 – Cranking Motor

VEHICLE ENGINES – Cranking motors which are provided with lubrication fittings (grease cups, hinge cap oilers oil tubes sealed with pipe plugs) should be lubricated every six months or 10,000 miles. Add eight to ten 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 cranking motors do not require lubrication except during overhaul.

NON–VEHICLE ENGINES – The electrical cranking 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 cranking 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 cranking motor is overhauled.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

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 – 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.

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 20 – Engine (Steam Clean)

Steam clean the engine and engine compartment.

NOTE: Do not apply steam or solvent directly on the battery–charging generator /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 gasoline. It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

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.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

Overspeed Governor

Lubricate the overspeed governor, if it is equipped with a hinge–type cap oiler or oil cup, with five or six 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 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

Inspect and adjust, if necessary.

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.

Item 27 – Generator or Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

VEHICLE ENGINES – If the battery–charging generator or alternator is equipped with hinge cap oilers, add a few drops of medium grade engine oil to each oiler during the unit or vehicle lubrication period. Alternators having a built–in supply of grease or sealed bearings require no additional lubrication except during engine or unit overhaul.

NON–VEHICLE ENGINES – Lubricate the battery–charging generator (alternator) bearings or bushings with five or six drops of engine oil at the hinge cap oiler every 200 hours or 6,000 miles.

Some generators have a built–in supply of grease, while others use sealed bearings. In these latter two cases, additional lubrication is not necessary.

On generators, inspect the commutator and brushes every 500 hours or 15,000 miles. Clean the commutator every 2,000 hours or 60,000 miles, if necessary, with No. 00 sandpaper or a brush seating stone. After cleaning, reseat the brushes and blow out the dust.

On alternators, the slip rings and brushes can be inspected through the end frame assembly. If the slip rings are dirty, they should be cleaned with 400 grain or finer polishing cloth. Never use emery cloth to clean the slip rings.

Hold the polishing cloth against the slip rings with the alternator in operation and blow away all dust after the cleaning operation. If the slip rings are rough or out of round, replace them.

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 (Section 15.2).

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

Item 30 – Air Box Check Valves

Every 100,000 miles or approximately 3,000 hours remove the 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) and 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 – 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 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 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 minutes.
3. Remove the inspection plug. If fluid begins to flow from the inspection hole, the drive has sufficient fluid. Replace the inspection plug.

MAINTENANCE SCHEDULE EXPLANATION (CONT.)

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 two inches 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 inch 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 and inspect the heat exchanger core. If a considerable amount of scale or deposits are present, contact a Detroit Diesel Corporation Service Outlet.

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.

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 cover. Discard the gaskets.
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 (Figure 1.) 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 (Section 14.2).
   b. Check the compression pressure.
   c. Install a new injector.
   d. If the cylinder still misfires, remove the cam follower (Section 1.2.1) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushings.

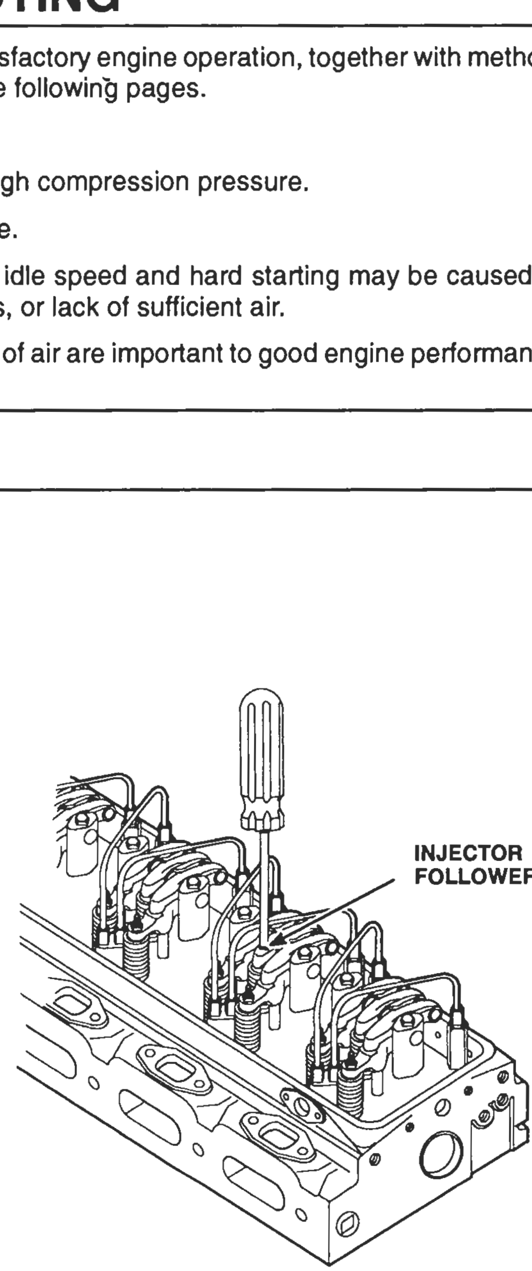


Figure 1. Locating a Misfiring Cylinder

CHECKING COMPRESSION PRESSURE

Compression pressure is affected by altitude (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 from Diagnosis Kit J 9531–01 (Figure 2.)
4. Use one of the fuel pipes as 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 600 r/min. 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 lb/in.^{2} (172 kPa) at 600 r/min.

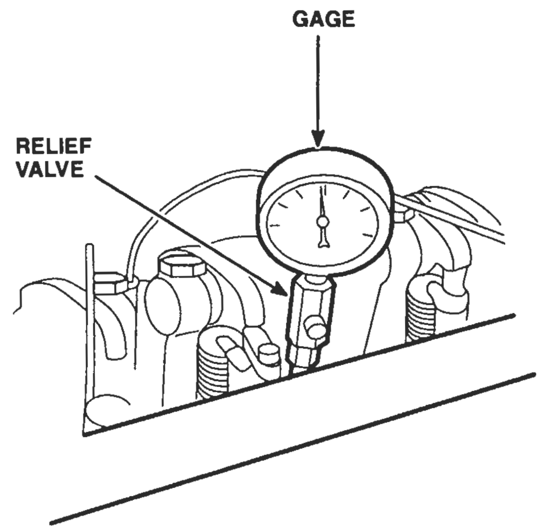


Figure 2. Checking Compression Pressure

Minimum Compression Pressure at 600 r/min				Altitude Above Seal Level		*Air Density
Engine						
71N		71T				
lb/in.^{2}	kPa	lb/in.^{2}	kPa	feet	meters	
515	3551	400	2758	500	152	.0715
480	3310	370	2551	2,500	762	.0663
440	3034	340	2344	5,000	1,524	.0613
410	2827	315	2172	7,500	2,285	.0567
380	2620	295	2034	10,000	3,048	.0525

TABLE 1 – AIR DENSITY INFORMATION

* Air density at 500 ft. altitude based on 85° F (29.4° C) and 29.38 in. Hg (99.49 kPa) wet barometer.

CHECKING COMPRESSION PRESSURE (CONT.)

Low compression pressure may result from any one of several causes:

1. 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 (Figure 3.) A broken or stuck ring will not have a "spring–like" action.
2. Compression pressure may be leaking past the cylinder head gasket, the valve seats, the injector tube or a hole in the piston.

Using a new gasket, reinstall the valve rocker cover.

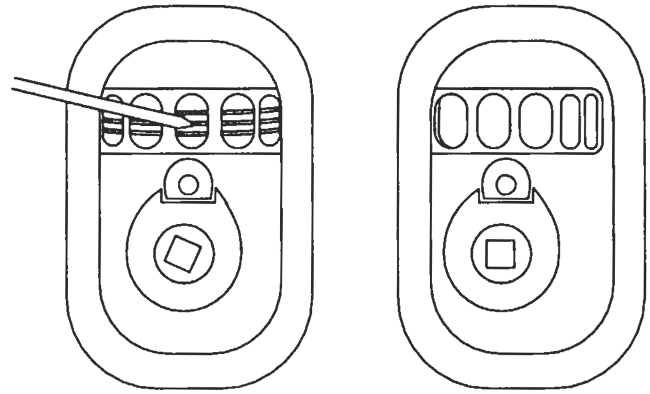


Figure 3. Inspect Piston Rings

ENGINE OUT OF FUEL

The problem in restarting an 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.

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 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 the 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.

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.

SECTION 15.2 – TROUBLESHOOTING

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 Section 2.0 under Troubleshooting.

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 head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the Engine Operating Conditions in 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.

Check the exhaust back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold (except on turbocharged engines) by removing the 1/8 inch pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32 inch hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8 inch pipe plug.

On turbocharged engines, check the exhaust back pressure in the exhaust piping six to twelve inches from the turbine outlet. 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 in 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. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected 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 inlet ducting located two inches above the air inlet housing (non–turbocharged engines) or the compressor inlet (turbocharged engines). When practicability prevents the insertion of a fitting at this point (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 speeds and compare the results with the Engine Operating Conditions in Section 13.2.

PROPER USE OF MANOMETER

The U–tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface and the scale (Figure 4.) A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

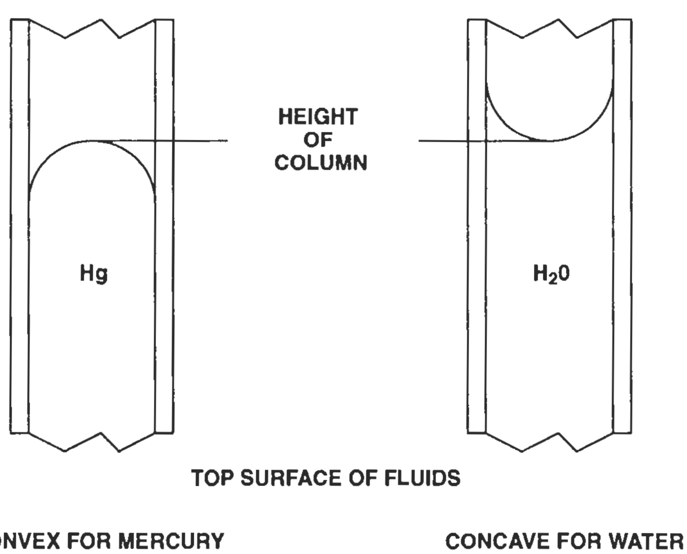


Figure 4. Comparison of Column Height for Mercury and Water Manometers

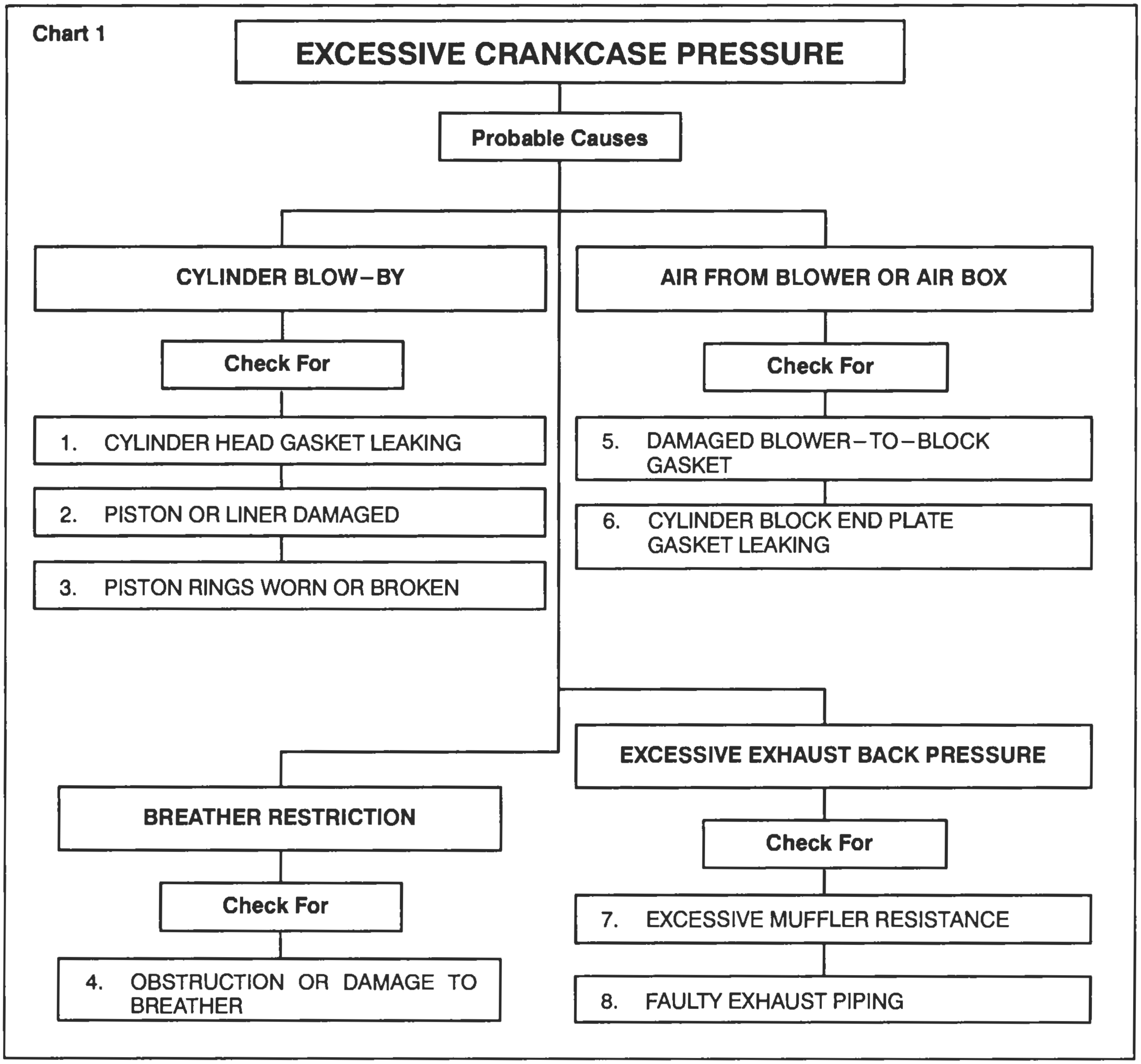
PROPER USE OF MANOMETER (CONT.)

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.

Convert the manometer reading (Figure 5.) into other units of measurement.

PRESSURE CONVERSION CHART		
1 inch water	=	.0735 inches mercury
1 inch water	=	.0361 lb/in.^{2}
1 inch mercury	=	13.6000 inches water
1 inch mercury	=	.4910 lb/in.^{2}
1 lb/in.^{2}	=	27.7000 inches water
1 lb/in.^{2}	=	2.0360 inches mercury
1 lb/in.^{2}	=	6.895 kPa
1 kPa	=	.145 lb/in.^{2}

Figure 5. Pressure Conversion Chart



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 gas 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

BLUE SMOKE

Check For

4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)

WHITE SMOKE

Check For

5. MISFIRING CYLINDERS

 May, 1994

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 incomplete 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.

Restrict air inlet to the engine cylinders is caused by clogged 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 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.

Check for improperly timed injectors and improperly positioned injector rack control levers. Time fuel injectors and perform appropriate góvernor tune–up.

Replace faulty injectors if this condition still exists after timing the injectors and performing the engine tune–up.

Avoid lugging the engine because 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 for internal lubricating oil leaks and refer to the High Lubricating Oil Consumption Charts.
5. Check for faulty injectors and replace as necessary.

White smoke of misfire at idle may occur when any one or more injectors idle output is considerably high or lower than the remaining 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 too little fuel or no fuel at idle. The cylinder that is not firing at idle may be detected by shorting out the injector with a screwdriver, or performing a cylinder cut–out using a reader for DDEC.

Depress the injector follower to prevent injector operation. If there is a change noted in the engine, (noise, r/min, etc.), the injector can be considered operational. If there is no change, 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 as necessary.

The use of low cetane fuel will cause this condition. Refer to Fuel Specifications in Section 13.3.

Chart 3

HARD STARTING

Probable Causes

ENGINE WILL NOT ROTATE

Check For

1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE CRANKING 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

LOW COMPRESSION

Check For

9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING

INOPERATIVE STARTING AID AT LOW AMBIENT TEMP

Check For

14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 3

HARD STARTING

1. Refer to Items 2, 3 and 5 and perform the operations listed.
2. Replace the cranking motor switch.
3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is present. Disassemble the engine and repair the damage.
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 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 brushes for wear. Replace the brushes if badly work 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 box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.
11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gasses 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 (Section 3.4).
14. Check the blower bypass valve piston (if 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

DETONATION

Check For

13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 4

ABNORMAL ENGINE OPERATION

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. Then, check engine fuel spill back and if the return is less than specified, consult the No Fuel or Insufficient Fuel Chart.
2. 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. Check the compression pressures within the cylinders and consult the Hard Starting Chart if compression pressures are low.
3. 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. 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.

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.

4. 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.
5. 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 (see the Hard Starting Chart).
6. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures. 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.
7. 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. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.
8. 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. 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. Refer to Item 1 of this chart.

Clean the air box and drain tubes. 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.

CAUTION:

The blower rotors are exposed and rotating during the test. Contact with the rotors must be avoided as personal injury could result.

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

FLOW OBSTRUCTION

Check For

5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURES LESS THAN 10°F. (6°C.) ABOVE POUR POINT OF FUEL

LACK OF POWER

Check For

7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING

FAULTY INSTALLATION

Check For

10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 5

NO FUEL OR INSUFFICIENT FUEL

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 all loose connections.
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 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 point upward. Reposition the valve, if necessary. If the valve is inoperative, replace 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

NOTE: Lubricating oil consumption must be verified after each repair is made.

1. Repair oil leaks by replacing necessary gaskets, seals or tightening connections. Steam cleaning the engine and operating at no–load r/min, (engine at operating temperature) will often reveal excessive oil leaks.
2. Consult the original equipment manufacturer for proper repair of the automatic oil filler system.
3. Check the air compressor for oil pullover and/or remove and replace the compressor.
4. Check dipstick and tube for proper oil pan levels to correct overfilled crankcase.
5. Check crankcase pressure. Clean breathers and recheck crankcase pressure.
6. Overhaul blower, turbocharger or re–kit engine (refer to Items 9, 10, 14 and 15). Also, refer to the Excessive Crankcase Pressure Chart.
7. 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.
8. Refer to the Abnormal Engine Operation Chart.
9. Remove the piping from the air inlet housing and components. 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.

10. 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.
11. 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.

12. Replace worn exhaust valve guides.
13. Take compression test – refer to Item 14.

Chart 6 (Cont.)

14. Run engine at idle speed with the air box cover 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.

15. 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.
16. Refer to Items 9, 10, 14 and 15.
17. Refer to Item 15.
18. Check the crankshaft thrust washers for wear. Replace wore and defective parts.
19. Decrease the installation angle.
20. Fill the crankcase to the proper level only.

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Chart 7

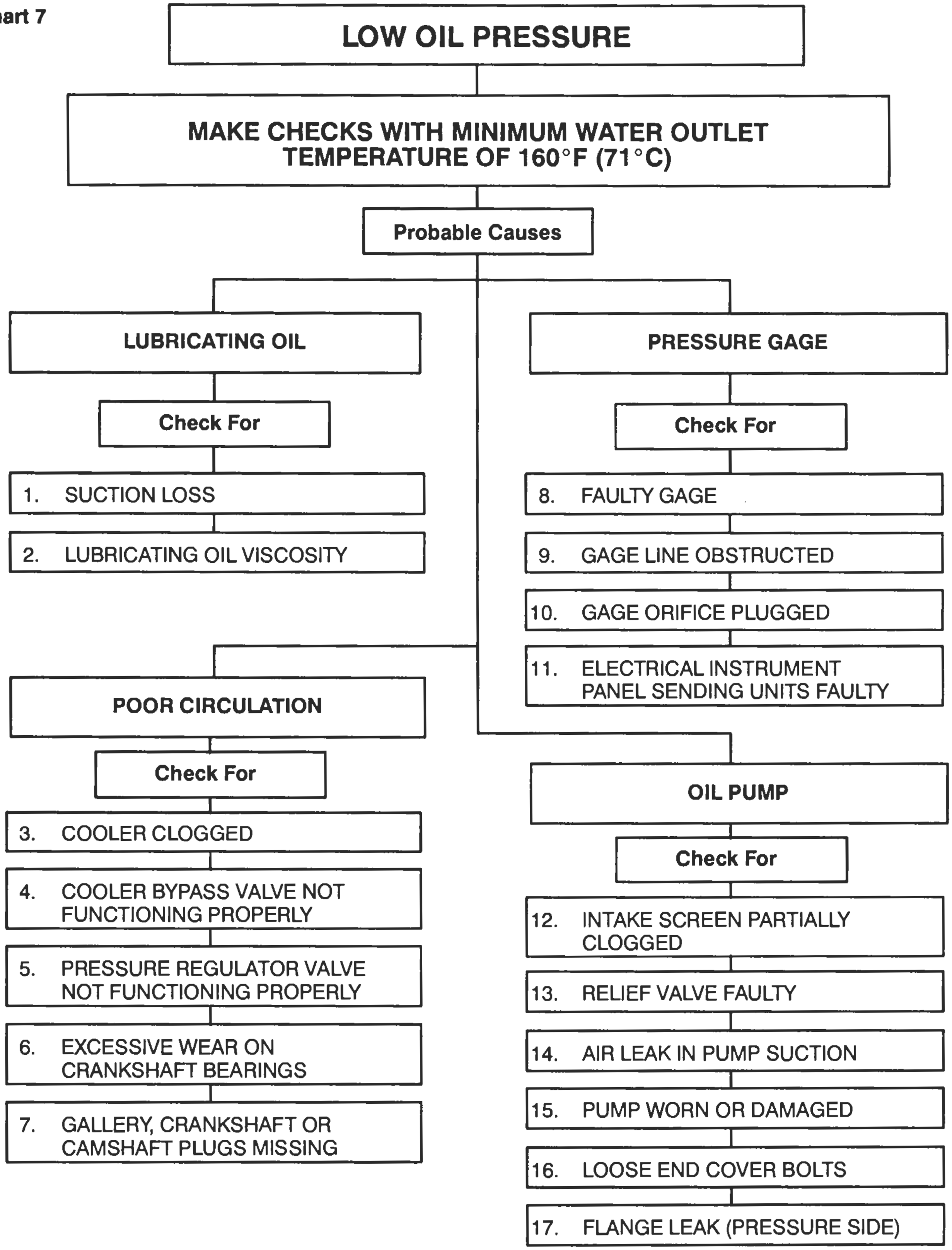
LOW OIL PRESSURE
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F (71°C)
Probable Causes
LUBRICATING OIL
Check For
1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY
PRESSURE GAGE
Check For
8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY
POOR CIRCULATION
Check For
3. COOLER CLOGGED
4. COOLER BYPASS 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. LOOSE END COVER BOLTS
17. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

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 leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to Fuel Leak Detection in 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 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

Chart 8

ABNORMAL ENGINE COOLANT OPERATING TEMPERATURE

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 improperly sized radiator or 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 gasses in the cooling system. The cylinder head must be removed and inspected for crack and the head gaskets replaced if combustion gasses 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 is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal.

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 gradeability, for example).

2. **Check customer engine and vehicle order specifications and vehicle road speeds, if necessary.**

   a. Determine if the engine no–load speed (r/min) and horsepower meet customer order specifications. The O.E.M. truck dealer or Detroit Diesel Corporation 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 r/min) than the no–load speed set at Detroit Diesel Corporation due to engine accessories (air compressor, power steering pump, etc.) installed by the O.E.M. There is a ± 25 r/min manufacturing tolerance for no–load speed setting. It would be normal, therefore, for an engine order specification of 2050 r/min no–load speed to check out at 2025 to 2075 r/min in the vehicle.

   c. The rated full–load engine speed will not change because of a slight change of no–load speed (r/min) 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:

$$GS = \frac{\text{Full Load engine r/min} \times 60}{\text{Axle ratio} \times \text{tire revolutions/mile}}$$

EXAMPLE:

$$GS = \frac{1900 \text{ r/min} \times 60 = 55 \text{ mph}}{4.11 \times 504}$$

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 r/min 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.

VEHICLE LOW POWER/PERFORMANCE AT LOW MILEAGE (CONT.)

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) – (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 r/min. 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 (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.

VEHICLE LOW POWER/PERFORMANCE AT LOW MILEAGE (CONT.)

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.
13. Check for excessive air leakage between the piston and cylinder which may be caused by excessive piston clearance due to wear.
14. **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.
15. **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 14.0 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 inch. Rack gages are marked with the specific dimension and have an allowable tolerance of ± .002 inch.

Item 48 – Oil Filter (Railcar)

Install new oil filter elements and gaskets every time the transmission oil is changed. Check for oil leaks after starting the engine.

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 1,200 r/min and no load.

NOTE: 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, vapor–proof 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.

NOTE: 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 r/min 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.

NOTE: The performance of this step is not necessary on torque converter units.

EXTENDED STORAGE (MORE THAN 30 DAYS) (CONT.)

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 1,000 r/min 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 ten minutes at a minimum of 1,000 r/min. 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. 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.

EXTENDED STORAGE (MORE THAN 30 DAYS) (CONT.)

17. Drain the engine cooling system.
18. Drain the preservative oil from the engine crankcase. Reinstall and tighten the drain plug.
19. 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.
20. Insert heavy paper strips between the pulleys and belts to prevent sticking.
21. Seal all engine openings, including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.
22. 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.
23. 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–of–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 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 1,000 rpm to scavenge the oil from the converter.

NOTE: 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. 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.

15. After all of the preparations have been completed, start the engine.

NOTE: Before subjecting the engine to a load or high speed, it is advisable to check the engine tune–up.