6SE50 MARCH 2004

SERIES 50®

Service Manual

Detroit Diesel® Series 50 Diesel and Natural Gas-Fueled Engines

DETROIT DIESEL CORPORATION

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

CALIFORNIA
Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

ENGINE EXHAUST

Consider the following before servicing engines:

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

ABSTRACT

This manual provides instruction for servicing on-highway, construction and industrial, generator set, and marine applications of the Detroit Diesel Series 50 Diesel and Natural Gas-Fueled Engines.

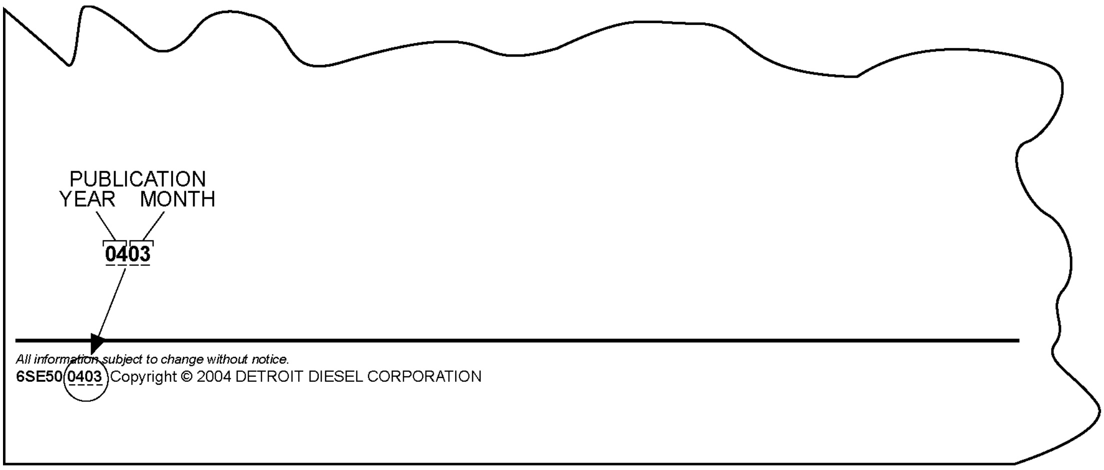
Specifically a basic overview of each major component and system along with recommendations for removal, cleaning, inspection, criteria for replacement, repair and installation and mechanical troubleshooting are contained in this manual.

DDEC III/IV troubleshooting concerns are contained in the *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

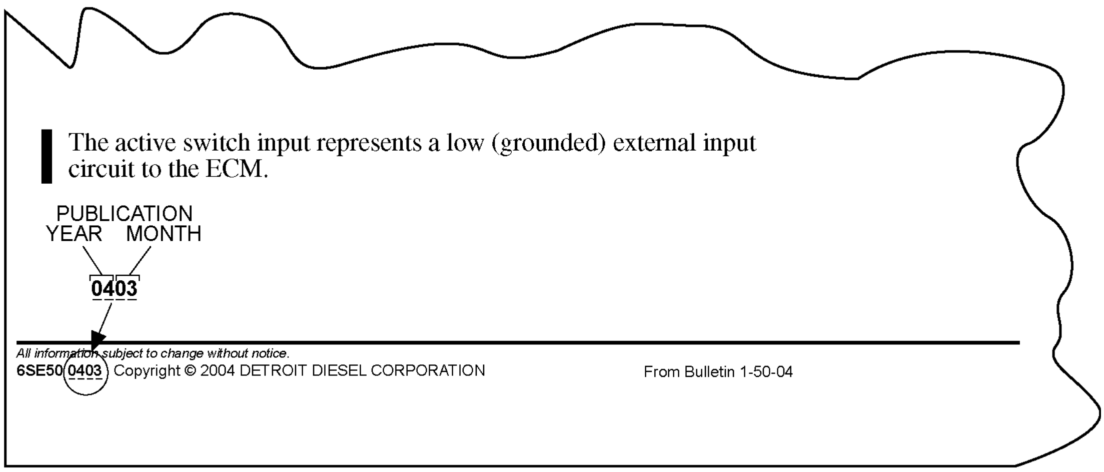
REVISION NOTIFICATION

Modifications to this manual are announced in the form of Service Information Bulletins. The bulletins include attachment pages and are posted on the World Wide Web (www.detroitdiesel.com/svc/sibindex.htm).

Revisions to this manual will be sent marked with a revision bar (see Example 2). Sections containing revisions will have a third line in the page footer (compare Examples 1 and 2).



Example 1 - Unchanged Pages



Example 2 - Changed Pages

TABLE OF CONTENTS

GENERAL INFORMATION

SCOPE AND USE OF THIS MANUAL

This manual contains complete instructions on operation, adjustment (tune-up), preventive maintenance, and repair (including complete overhaul) for the basic Series 50 Inline Diesel Engines. This manual was written primarily for persons servicing and overhauling the engine. In addition, this manual contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all Series 50 Engines, and 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 engine subassembly. Each section begins with a table of contents. Pages and illustrations are numbered consecutively within each section.

Information can be located by using the table of contents at the front of the manual or the table of contents at the beginning of each section. Information on specific sub-assemblies or accessories within the major section is listed immediately following the section title.

SERVICE PARTS AVAILABILITY

Service parts are available throughout the world. A complete list of all Detroit Diesel Corporation (DDC) distributors and dealers is available in the *Detroit Diesel Corporation World Wide Parts and Service Directory* , 6SE280. This publication can be ordered from any authorized DDC distributor. The dealer must have the engine identification and model number (located on the engine block directly beneath the intake manifold) to fill a parts order.

CLEARANCE OF NEW PARTS AND WEAR LIMITS

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 must be qualified by the judgement of personnel responsible for installing new parts. For additional information, refer to the section entitled "Inspection" within this section. Refer to Section ADDITIONAL INFORMATION, "Specifications, New Clearances, and Wear Limits" under "Specifications", for a listing of clearances of new parts and wear limits on used parts.

THE FOUR-CYCLE PRINCIPLE

The diesel engine is an internal combustion engine, in which the energy of burning fuel is converted into work in the cylinder of the engine. In the diesel engine, air alone is compressed in the cylinder, raising its temperature significantly. After the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression. The four piston strokes of the cycle occur in the following order: intake, compression, power and exhaust. See Figure 1.

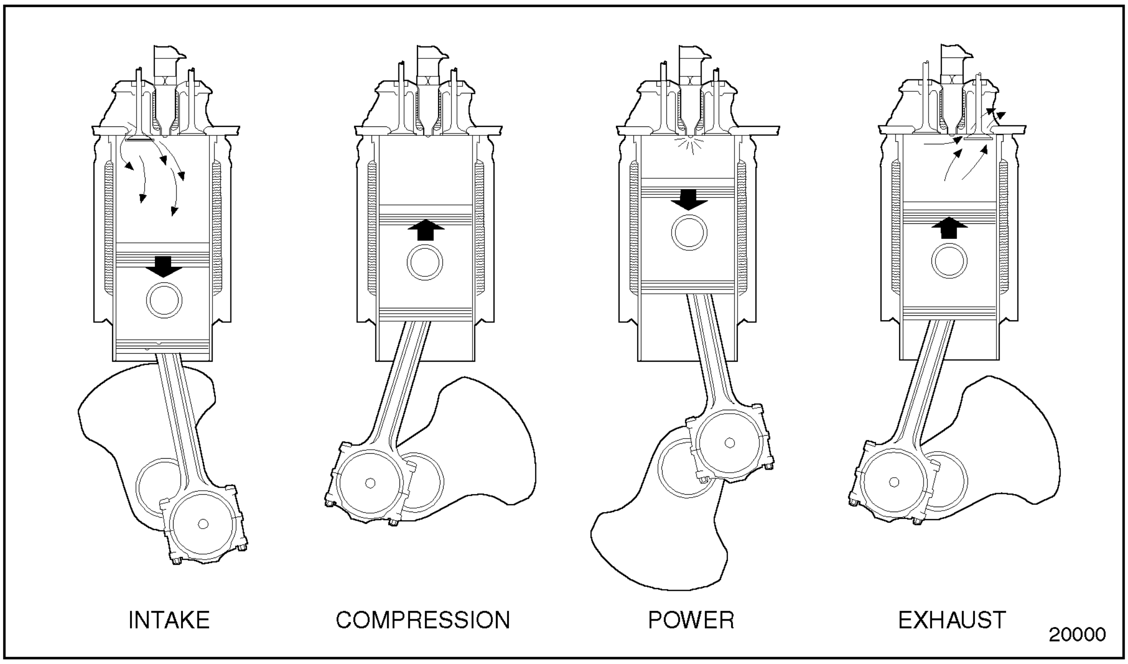


Figure 1 The Four Stroke Cycle

Intake Stroke

During the intake stroke, the piston travels downward, the intake valves are open, and the exhaust valves are closed. The downstroke of the piston facilitates air from the intake manifold to enter the cylinder through the open intake valves. The turbocharger, by increasing the air pressure in the engine intake manifold, assures a full charge of air is available for the cylinder.

The intake charge consists of air only with no fuel mixture.

Compression Stroke

At the end of the intake stroke, the intake valves close and the piston starts upward on the compression stroke. The exhaust valves remain closed.

At the end of the compression stroke, the air in the combustion chamber has been compressed by the piston to occupy a space about one-fifteenth as great in volume as it occupied at the beginning of the stroke. Thus, the compression ratio is 15:1.

Compressing the air into a small space causes the temperature of that air to rise. Near the end of the compression stroke, the pressure of the air above the piston is approximately 3445 to 4134 kPa (500 to 600 lb/in.^{2}) and the temperature of that air is approximately 538°C (1000°F). During the last part of the compression stroke and the early part of the power stroke, a small metered charge of fuel is injected into the combustion chamber.

Almost immediately after the fuel charge is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn, beginning the power stroke.

Power Stroke

During the power stroke, the piston travels downward and all intake and exhaust valves are closed.

As the fuel is added and burns, the gases get hotter, the pressure increases, pushing the piston downward and adding to crankshaft rotation.

Exhaust Stroke

During the exhaust stroke, the intake valves are closed; the exhaust valves are open, and the piston is on its upstroke.

The burned gases are forced out of the combustion chamber through the open exhaust valve port by the upward travel of the piston.

From the preceding description, it is apparent that the proper operation of the engine depends upon the two separate functions: first, compression for ignition, and second, that fuel be measured and injected into the compressed air in the cylinder in the proper quantity and at the proper time.

GENERAL DESCRIPTION

The Series 50® Diesel Engine described in this manual is a four-stroke cycle, high speed, diesel engine.

It uses an inline cast iron block and has a cast iron cylinder head that contains a single overhead camshaft. The camshaft actuates all the valves (two intake, two exhaust per cylinder), and operates the fuel injectors. The vertically aligned gear train, located at the front end of the engine in a gear case, contains drive gears for the lubricating oil pump, crankshaft, camshaft, air compressor drive, fuel pump drive, water pump and alternator accessory drives.

Each current engine is equipped with dual full flow oil filters, a bypass oil filter, an oil cooler, two fuel oil filters, a turbocharger and an electronic engine control system.

Full pressure lubrication is supplied to all main, connecting and camshaft bearings, and to other moving parts. A gear-type pump draws oil from the oil pan through a screen and delivers it to the oil filters. From the filter, a small portion of the oil is delivered directly to the turbocharger by an external oil line. The remainder of the oil flows to the oil cooler, or bypasses the cooler, and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the cylinder head where it feeds the camshaft bearings and rocker assemblies; part of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft. The remainder of the oil feeds the balance support where it lubricates the balance shaft bearings and is regulated. Drilled passages in the connecting rod feed oil to the piston pin and the inner surface of the piston crown.

Coolant is circulated through the engine by a centrifugal-type water pump. The cooling system, including the radiator, is a closed system. Heat is removed from the coolant by the radiator. Control of the engine temperature is accomplished by thermostats that regulate the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the primary fuel filter by a gear-type fuel pump. From there, the fuel is forced through the secondary fuel filter and into the fuel inlet in the cylinder head and to the injectors. Excess fuel is returned, through a restricted fitting, to the supply tank through the outlet connecting line. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air is supplied by the turbocharger to the intake manifold and into the engine cylinders after passing through an air-to-air charge air cooler mounted ahead of the cooling system radiator. The charge air cooler cools the pressurized intake air charge coming from the turbocharger before it enters the intake manifold.

Engine starting may be provided by an electric or air starting motor energized by a storage battery or air pressure storage system. A battery charging alternator, with a suitable voltage regulator, serves to keep the battery charged.

The Series 50 Diesel Engine was designed to be electronically controlled. The Detroit Diesel Electronic Control (DDEC) system has evolved with the product.

DDEC II

DDEC II controls the timing and amount of fuel injected into each cylinder. The system monitors several engine sensors that send electrical signals to the main ECM. See Figure 2. Unlike DDEC I, the DDEC II ECM uses this information to actuate the Electronic Unit Injector (EUI) solenoids. The ECM also has the ability to limit or shut down the engine completely (depending on option selection) in the case of damaging engine conditions, such as low oil pressure, low coolant level, or high oil temperature.

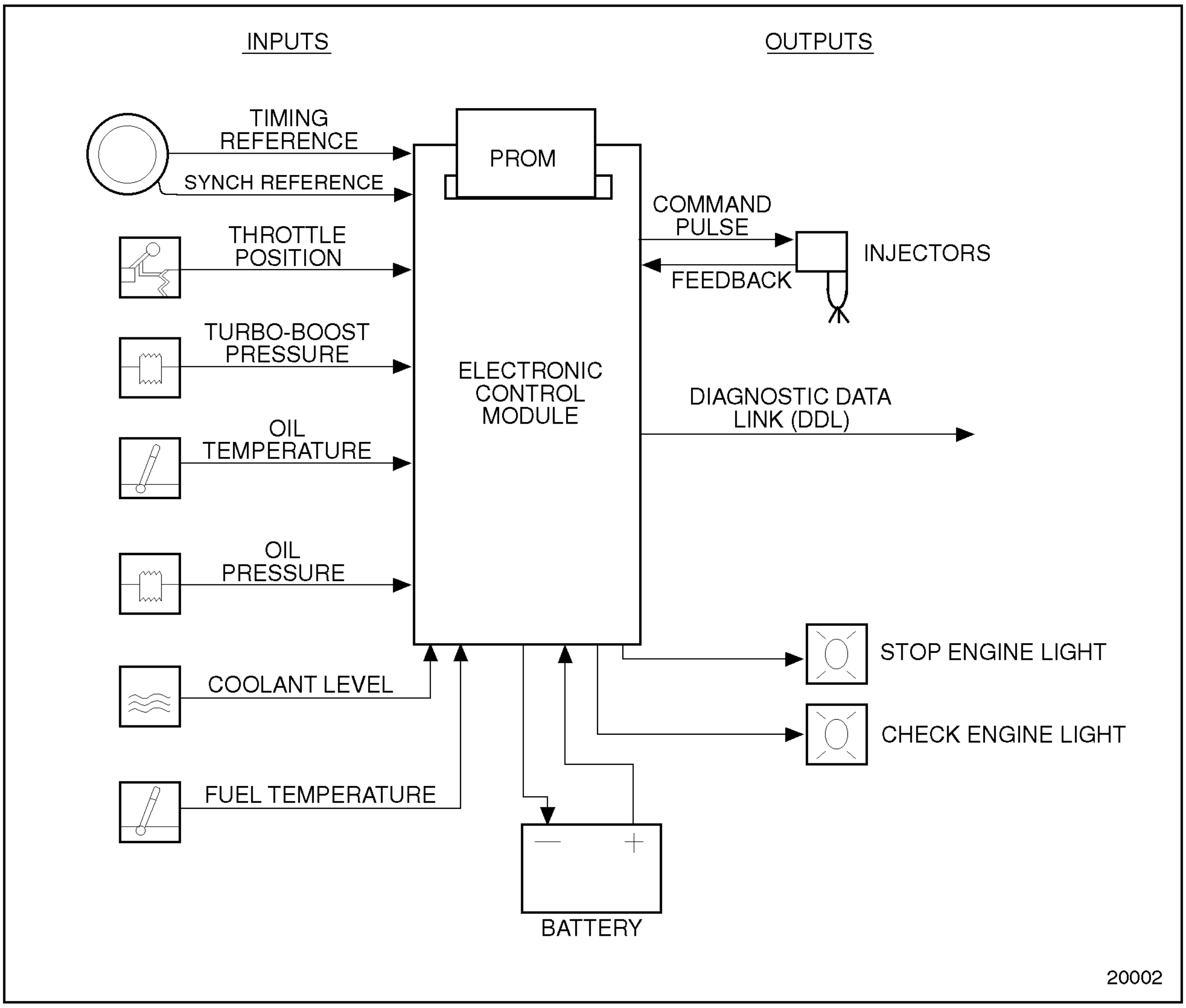


Figure 2 Schematic Diagram of DDEC II

DDEC III

The DDEC III ECM receives electronic inputs from sensors on the engine and vehicle, and uses the information to control engine operation. It computes fuel timing and fuel quantity based upon predetermined calibration tables in its memory.

Fuel is delivered to the cylinders by the EUI solenoids, which are cam-driven to provide the mechanical input for pressurization of the fuel. The ECM controls solenoid operated valves in the EUIs to provide precise fuel delivery. See Figure 3.

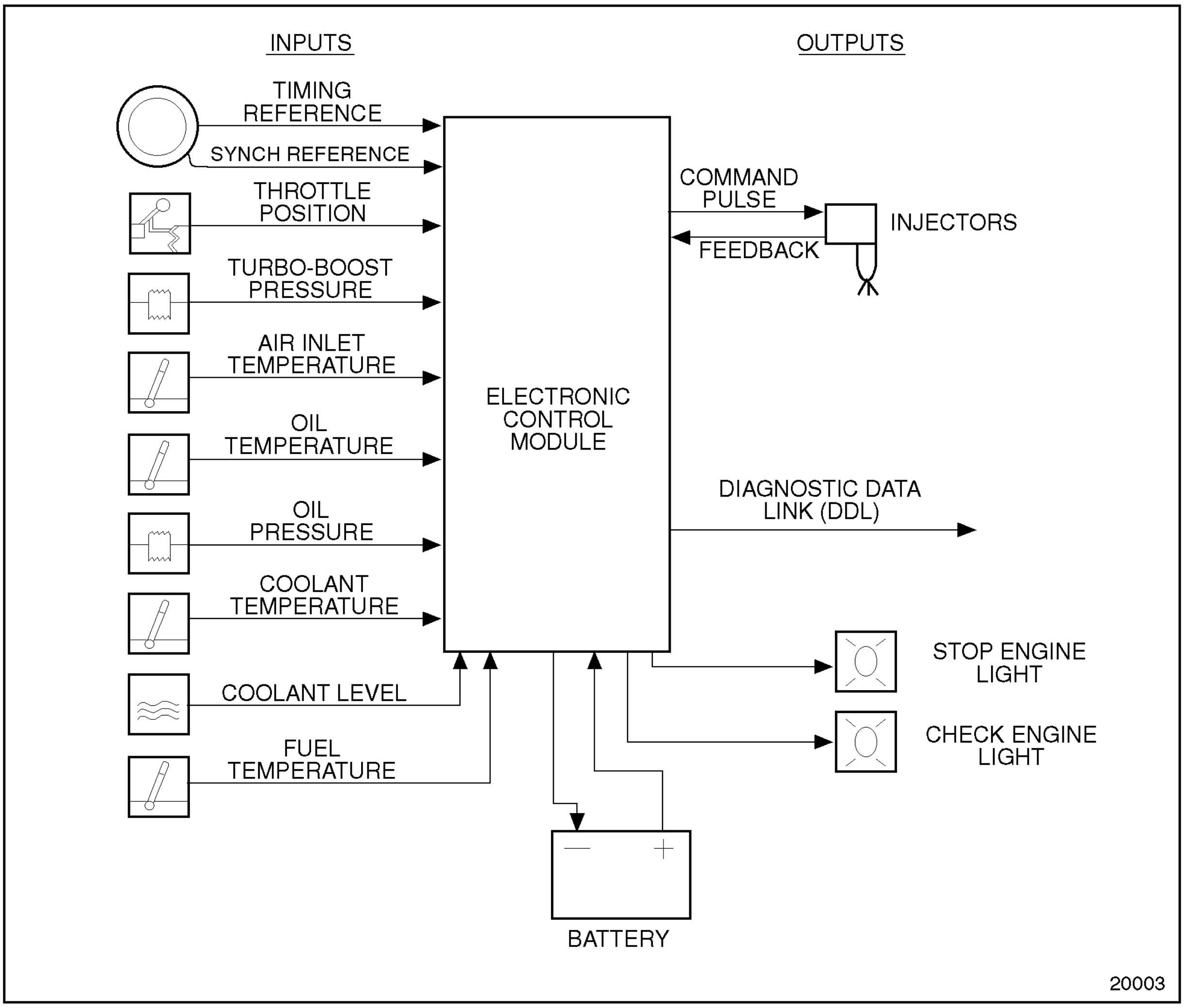


Figure 3 Schematic Diagram of DDEC III

Portable equipment facilitates access to diagnostic capabilities of DDEC. The Diagnostic Data Reader (DDR) requests and receives engine data and diagnostic codes. This equipment provides many unique capabilities including cylinder cutout, parameter vs. engine speed (or time), printer output, and data snapshot. The DDR also provides limited programming capability.

DDEC III (Series 50G)

The DDEC III ECM receives electronic inputs from sensors on the engine and vehicle, and uses the information to control engine operation.

Natural gas is delivered to the cylinders by the G.F.I compuvalve on a high pressure fuel system. Fuel is controlled by DDEC on the low pressure system. See Figure 4.

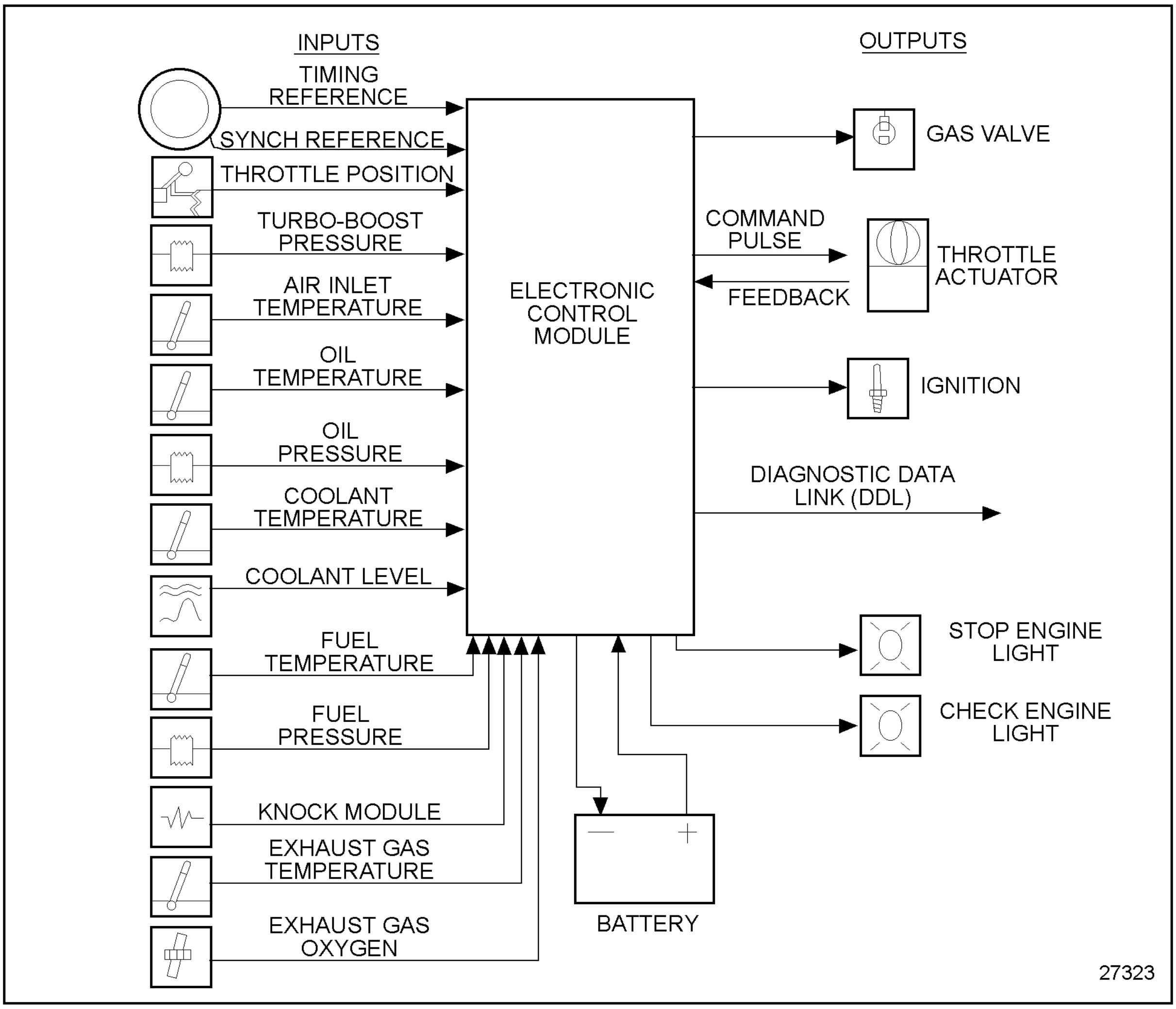


Figure 4 Schematic Diagram of DDEC III (Series 50G)

Portable equipment facilitates access to diagnostic capabilities of DDEC. The Diagnostic Data Reader (DDR) requests and receives engine data and diagnostic codes. This equipment provides many unique capabilities including cylinder cutout, parameter vs. engine speed (or time), printer output, and data snapshot. The DDR also provides limited programming capability.

GENERAL SPECIFICATIONS

The general specifications for the Series 50 Engine are listed in Table 1. See Figure 5 for the cylinder designation and firing order.

General Specifications	Engine Family
Total Displacement (L)	8.5
Total Displacement (in.^{3})	518
Type	Four-cycle
Number of Cylinders	4
Bore (in.)	5.12
Bore (mm)	130
Stroke (in.)	6.30
Stroke (mm)	160
Compression Ratio	15.0:1
Number of Main Bearings	5

Table 1 General Specifications for the Series 50 Engine

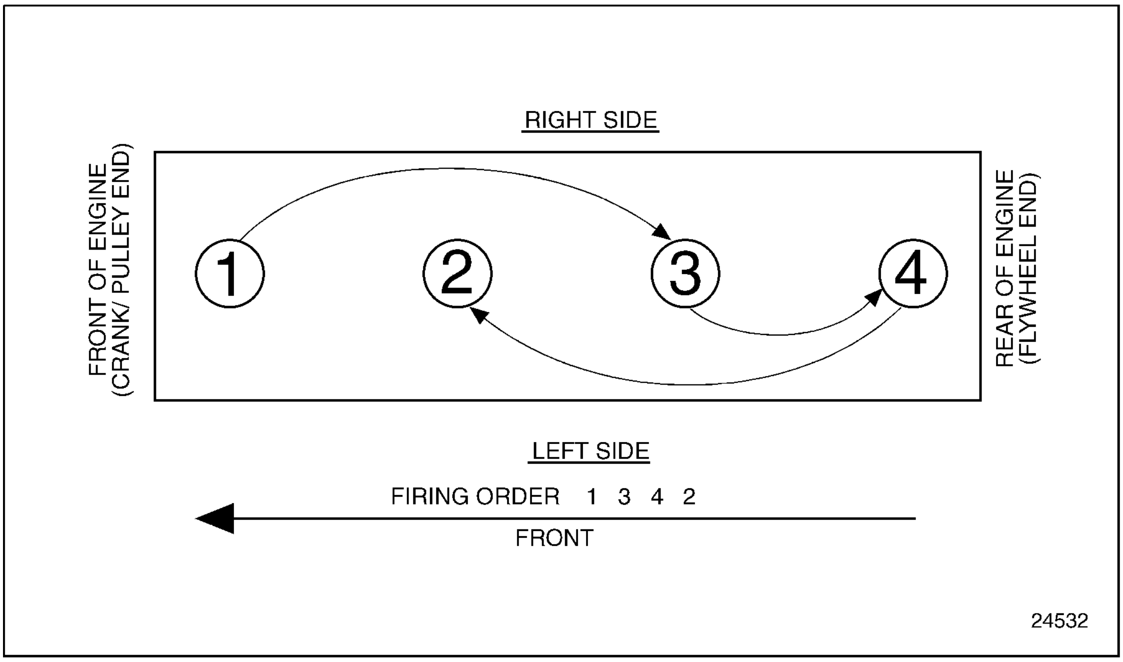


Figure 5 Cylinder Designation and Firing Order

GENERAL SPECIFICATIONS FOR THE SERIES 50G ENGINE

The general specifications for the Series 50G Engine are listed in Table 2. See Figure 6 for cylinder designation and firing order.

General Description	Specification
Total Displacement (L)	8.5
Total Displacement (in.^{3})	518
Type	Four-cycle
Number of Cylinders	4
Bore (in.)	5.12
Bore (mm)	130
Stroke (in.)	6.30
Stroke (mm)	160
Compression Ratio	10:1
Number of Main Bearings	5

Table 2 General Specifications for the Series 50G Engine

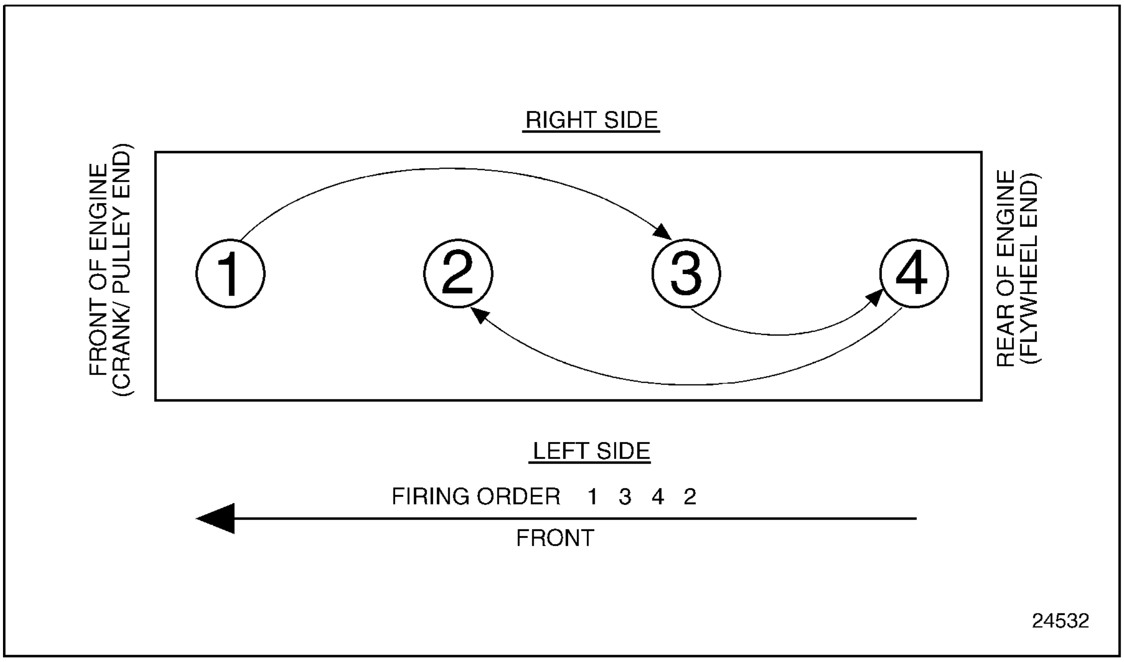


Figure 6 Cylinder Designation and Firing Order for the Series 50G Engine

ENGINE MODEL, SERIAL NUMBER AND OPTION LABEL

The engine serial and model numbers are stamped on the cylinder block. See Figure 7. A guide to the meaning of the model number digits is listed in Table 3.

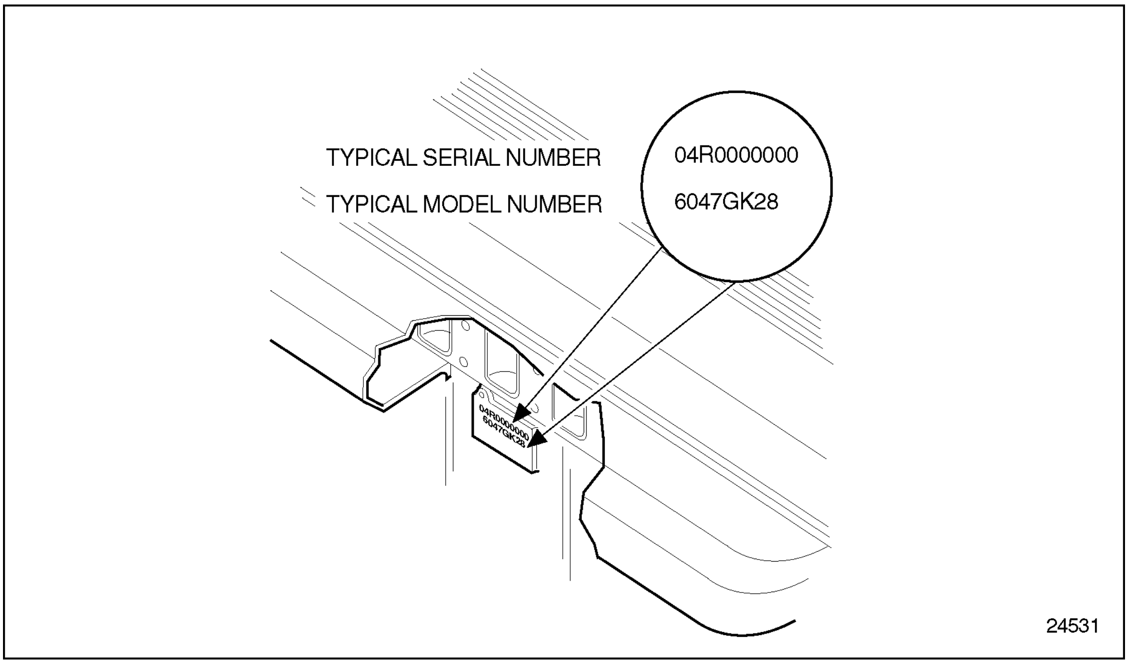


Figure 7 Location of Engine Serial and Model Number on Block

Digit	Value	Meaning
1	6	Series 50 Engine
2 & 3	04	Four Cylinders
4	7	Automotive Application
5	G	8.5 L Displacement
6	U	DDEC II Engine Control
6	K	DDEC III Engine Control
7 & 8	28	" T" Drive
7 & 8	26	" V" Drive

Table 3 Model Number Description for Series 50

ENGINE MODEL, SERIAL NUMBER AND OPTION LABEL (SERIES 50G)

The engine serial and model numbers are stamped on the cylinder block. See Figure 8. The model number description for the Series 50G is listed in Table 4.

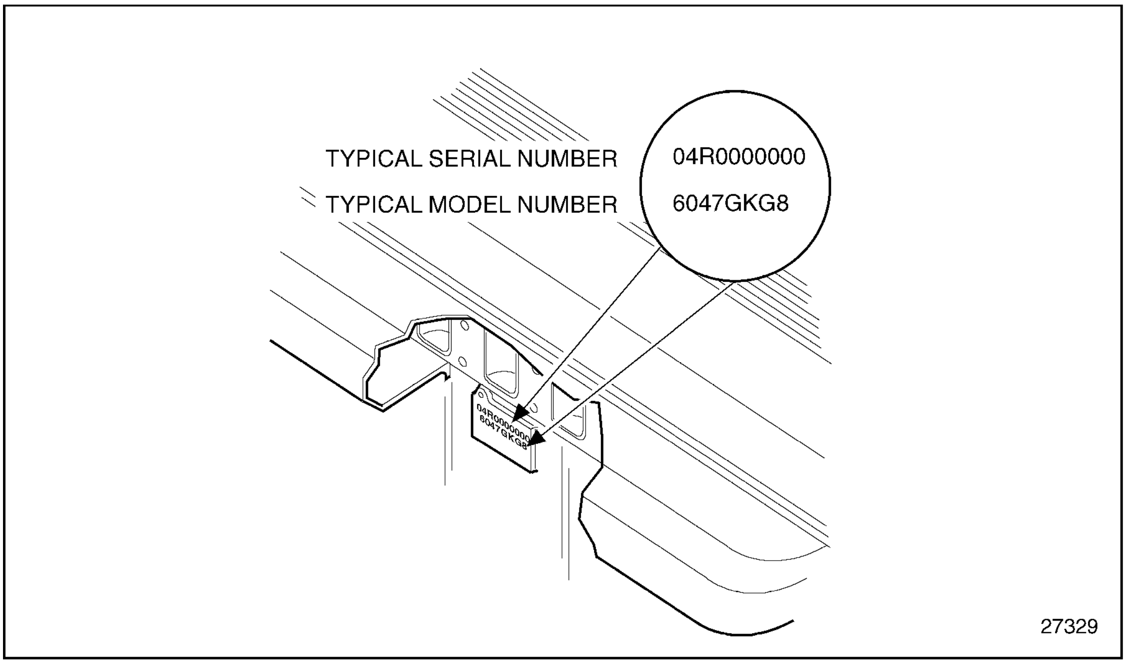


Figure 8 Location of Engine Serial and Model Number on Block (Series 50G)

Digit	Value	Meaning
1	6	Series 50 Engine
2 & 3	04	Four Cylinders
4	7	Automotive Application
5	G	8.5 L Displacement
6	K	DDEC III Engine Control
7	G	Alternate Fuel Engine
8	8	Customer Designation

Table 4 Model Number Description for Series 50G

Option labels attached to the valve rocker cover contain the engine serial and model numbers and list any optional equipment used on the engine. See Figure 9.

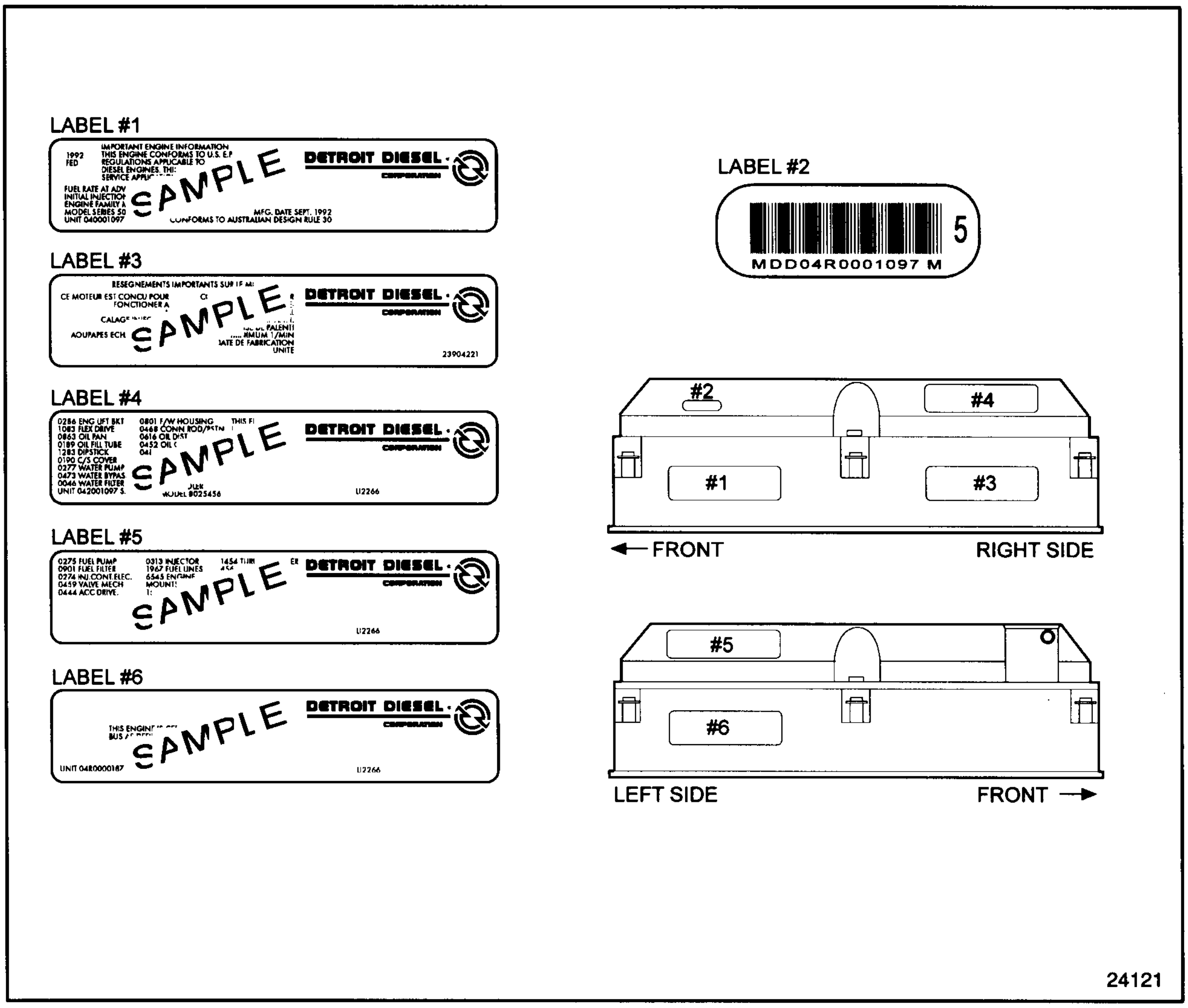


Figure 9 Rocker Cover with Option Label

With any order for parts, the engine model number with serial number should 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 or parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

REPLACING AND REPAIRING

In many cases, a service person is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Exchange assemblies such as injectors, fuel pumps, water pumps and turbochargers are desirable service items.

Various factors such as the type of operation of the engine, hours in service and the 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

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

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles. Bleed the air from the air starter system before disconnecting the air supply hose.

Before any major disassembly, the engine must be drained of lubricating oil, coolant and fuel.

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.

NOTICE:
The Series 50 Engine is equipped with various sensors and other electronic components which may be damaged if subjected to the high temperatures in a solvent tank. Do *not* immerse any electrical components in a solvent tank. Care should be taken to ensure that all electronic components are removed from the various engine assemblies before they are immersed in a solvent tank. Refer to Section 2.10for a description of these components.

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 the same as the following cylinder block cleaning procedure. Any special cleaning procedures will be mentioned when required.

Remove cylinder liners with the cylinder liner removal tool, J 35791, before putting the block in cleaning or descaling baths, to avoid trapping cleaning agents in block liner seating bores.

After stripping and before removing the cylinder block from the overhaul stand for cleaning and inspection, install the two metric eye bolts, J 35595, into head bolt holes at each end of the cylinder block.

Remove all oil and water gallery and weep hole plugs to allow the cleaning solution to enter the inside of the oil and water passages.

1. Using two metric eye bolts, J 35595 installed in the head bolt holes at opposite ends of the block, and with a suitable lifting device and spreader bar, immerse and agitate the block in a hot bath of a commercial, heavy-duty alkaline solution.
2. Wash the block in hot water or steam clean it to remove the alkaline solution.
3. If the water jackets are heavily scaled, proceed as follows:
   - [a] Agitate the block in a bath of inhibited phosphoric acid.
   - [b] Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
   - [c] Lift the block, drain it and re-immerse it in the same acid solution for 10 more minutes. Repeat until all scale is removed from the water jacket area.
   - [d] Rinse the block in clear, hot water to remove the acid solution.
   - [e] Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   - [f] Wash the block in clean water or steam clean it.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

4. Dry the cylinder block with compressed air.
5. Blow out all of the bolt holes and passages with compressed air.

NOTE:
The above cleaning procedure may be used on all ordinary cast iron and steel parts for the engine. Aluminum parts, such as flywheel housing, air intake manifold, oil filter adaptor and the camshaft gear access cover should NOT be cleaned in this manner. Mention will be made of special procedures when necessary.

6. Be certain that all water passages and oil galleries have been thoroughly cleaned. After the cylinder block has been thoroughly cleaned and dried, install weep hole plugs and precoated pipe plugs. Install new cup plugs using a coating of good grade non-hardening sealant such as Loctite 620 or equivalent.

Steam Cleaning

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

Solvent Tank Cleaning

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

Fill the tank with a commercial heavy-duty solvent that is heated to 52°C (125°F). 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.

NOTE:
Aluminum or plastic parts such as the flywheel housing, fuel pump drive, air intake manifold, oil filter adaptor, camshaft gear access cover, oil pan or rocker covers, should not be cleaned in this manner.

Chlorinated solvents such as 1,1,1 trichloroethane have been identified by the EPA (Environmental Protection Agency) as possessing ozone-depleting properties. Detroit Diesel believes that a prudent environmental approach to the use of 1,1,1 trichloroethane should be taken. Therefore, Detroit Diesel recommends replacing 1,1,1 trichloroethane with Tech Solv 340 branded solvent wherever the former solvent was used.

Tech Solv 340 is a petroleum-based solvent which contains no chlorinated or fluorinated compounds, has a controlled evaporation rate, leaves no residue, is odorless, has a high flash point, and provides outstanding cleaning. To enhance its cleaning and drying properties, it may be heated to 525°C (977°F). Spills can be cleaned up with commercially available oil absorbents, and conventional waste treatment methods for petroleum-base products can be used when disposing of this product.

Tech Solv 340 is manufactured by and available from the following supplier:

Chemical Technologies, Inc.*

1610 Clara Street

Jackson, MI 94203

Telephone: 800-688-8262

FAX: 517-782-2448

** We believe this source and their Tech Solv 340 solvent to be reliable. There may be other manufacturers of solvents that replace 1,1,1 trichloroethylene. Detroit Diesel does not endorse, indicate any preference for, or assume any responsibility for the solvents from these firms or for any such products that may be available from other sources.*

Rinsing Bath

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

Drying

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

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

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.

Gasket Eliminator Removal

The gasket eliminator used on numerous mating surface joints in the Series 50 engine results in a very thin film that must be removed from both surfaces prior to reassembly. As many of the surfaces are aluminum and/or dimensionally critical, conventional scraping methods, or the use of emery cloth for removing gasket eliminator is not recommended.

Four-inch, 3M Scotch-Brite Surface Conditioning Discs, used with an electric or air powered hand drill (with a speed of 15,000-18,000 r/min), have proven successful in removing the gasket eliminator without damaging the mating surfaces of engine parts. See Figure 10.

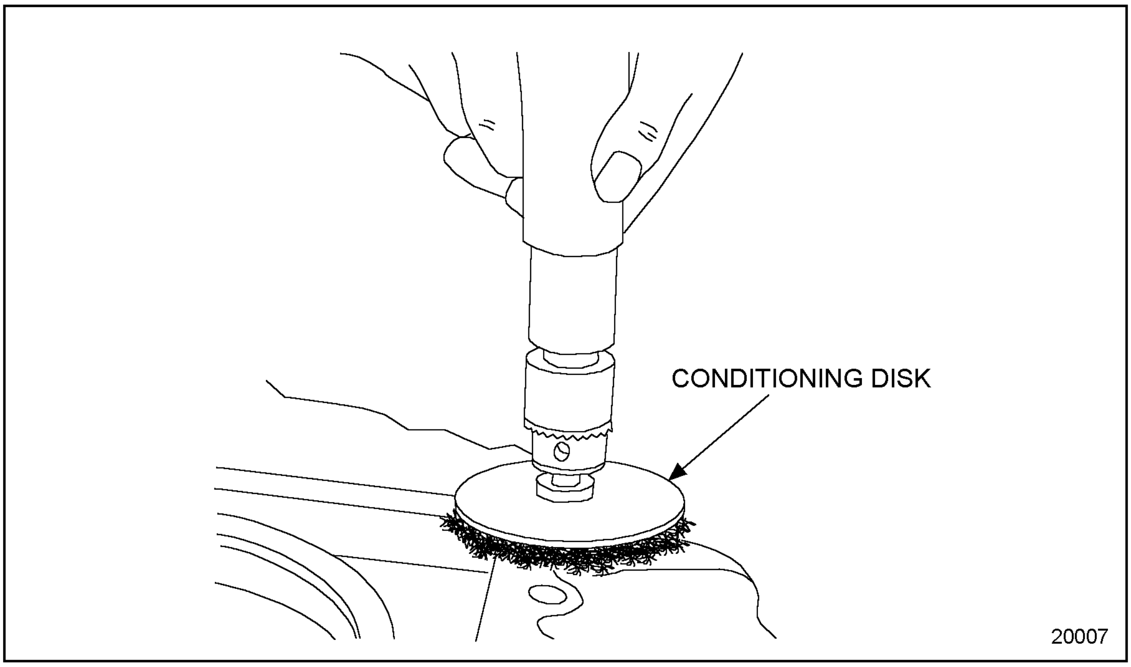


Figure 10 Gasket Eliminator Removal

A coarse pad, J 36571-3 part of tool set J 36571, (3M #07450, brown color), is suitable for steel surfaces. A medium pad, J 36571-2 part of tool set J 36571 (3M #07451, maroon color), is recommended for aluminum surfaces.

The pads are easily interchangeable using disc holder, J 36571-1 part of tool set J 36571 (3M #07492). See Figure 11.

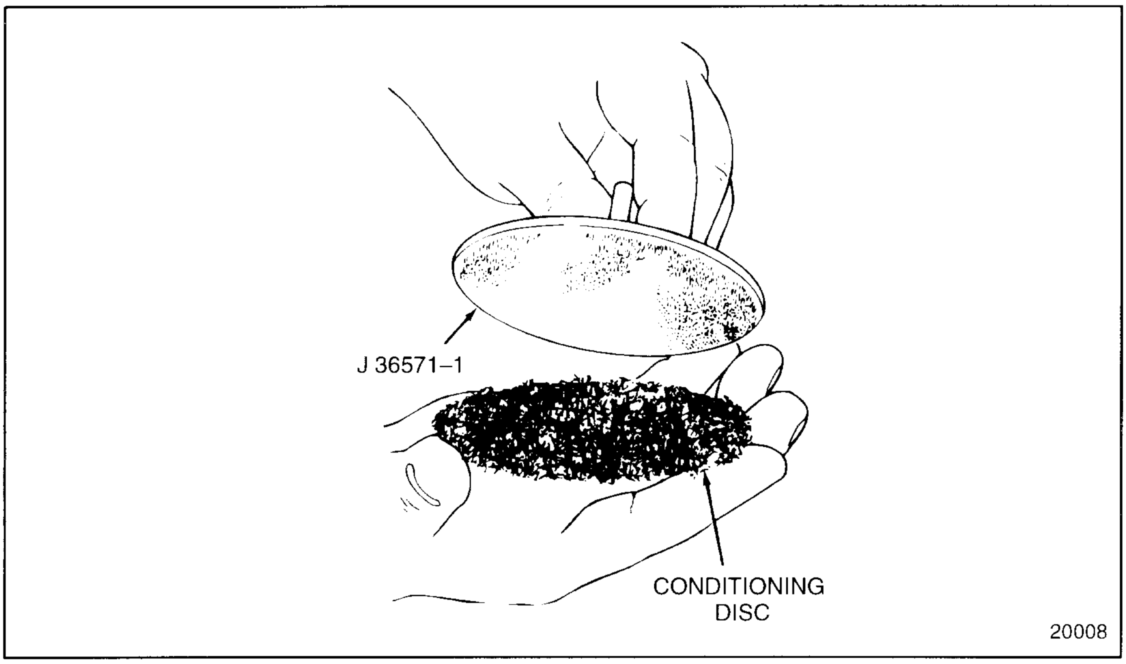


Figure 11 Scotch-Brite Surface Conditioning Disc Installation, J 36571

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, that 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 allowed 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 or oversizes as well as standard sizes. Also, service kits for reconditioning certain parts and service sets that 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 detrimental conditions.

SAFETY PRECAUTIONS

The following safety measures are essential when working on the Series 50 engine.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

Stands

Safety stands are required in conjunction with hydraulic jacks or hoists. **Do not** rely on either the jack or the hoist to carry the load. When lifting an engine, be sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

Glasses

Select appropriate safety glasses for the job. It is especially important to wear safety glasses when using tools such as hammers, chisels, pullers or punches.

Welding

Wear welding goggles and gloves when welding or using an acetylene torch. Ensure that a metal shield separates the acetylene and oxygen that must be chained to a cart.

CAUTION:

To avoid injury from arc welding, gas welding, or cutting, wear required safety equipment such as an arc welder's face plate or gas welder's goggles, welding gloves, protective apron, long sleeve shirt, head protection, and safety shoes. Always perform welding or cutting operations in a well-ventilated area. The gas in oxygen/acetylene cylinders used in gas welding and cutting is under high pressure. If a cylinder should fall due to careless handling, the gage end could strike an obstruction and fracture, resulting in a gas leak leading to fire or an explosion. If a cylinder should fall resulting in the gage end breaking off, the sudden release of cylinder pressure will turn the cylinder into a dangerous projectile. Observe the following precautions when using oxygen/acetylene gas cylinders:

- **Always wear required safety shoes.**
- **Do not handle tanks in a careless manner or with greasy gloves or slippery hands.**
- **Use a chain, bracket, or other restraining device at all times to prevent gas cylinders from falling.**
- **Do not place gas cylinders on their sides, but stand them upright when in use.**
- **Do not drop, drag, roll, or strike a cylinder forcefully.**
- **Always close valves completely when finished welding or cutting.**

Work Place

Organize your work area and keep it clean. Eliminate the possibility of a fall by:

- Wiping up oil spills
- Keeping tools and parts off the floor

After servicing or adjusting the engine:

- Reinstall all safety devices, guards or shields
- Ensure that all tools and servicing equipment are removed from the engine

Clothing

Safe work clothing fits and is in good repair. Work shoes are sturdy and rough-soled. Bare feet, sandals or sneakers are **not**acceptable foot wear when adjusting and/or servicing an engine.

CAUTION:

To avoid injury when working near or on an operating engine, remove loose items of clothing, jewelry, tie back or contain long hair that could be caught in any moving part causing injury.

Power Tools

Never use defective portable power tools.

CAUTION:

To avoid injury from electrical shock, follow OEM furnished operating instructions prior to usage.

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. Use only approved air blow guns that do not exceed 276 kPa (40 lb/in.^{2}). Be sure to wear safety glasses or goggles. Use proper shielding to protect everyone in the work area.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

Fuel Lines

Remove fuel lines as an assembly. **Do not**remove fuel lines individually. Avoid getting fuel injection lines mixed up.

Fluids and Pressure

Be extremely careful when dealing with fluids under pressure. Fluids under pressure can have enough force to penetrate the skin. These fluids can infect a minor cut or opening in the skin. If injured by escaping fluid, see a doctor at once. Serious infection or reaction can result without immediate medical treatment.

CAUTION:

To avoid injury from penetrating fluids, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing.

Fuel

Keep the hose and nozzle or the funnel and container in contact with the metal of the fuel tank when refueling.

CAUTION:

To avoid injury from penetrating fluids, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing.

CAUTION:

To avoid injury from fire, do not overfill the fuel tank.

This will avoid the possibility of an electric spark igniting the fuel.

CAUTION:

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

Batteries

Electrical storage batteries emit highly flammable hydrogen gas when charging and continue to do so for some time after receiving a steady charge.

CAUTION:

To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

Always disconnect the battery cable before working on the electrical system.

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles. Bleed the air from the air starter system before disconnecting the air supply hose.

Disconnect the batteries or disable an air starter when working on the engine to prevent accidental starting.

Fire

Keep a charged fire extinguisher within reach. Be sure you have the correct type of extinguisher for the situation.

Cleaning Agent

Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Be sure the work area is adequately ventilated. Use protective gloves, goggles or face shield, and apron.

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

Working on a Running Engine

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, or battery explosion.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

CAUTION:

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

CAUTION:

To avoid injury when working near or on an operating engine equipped with an hydraulic clutch fan:

- **Never work in close proximity to the fan.**
- **Never try to keep the fan from rotating by holding the fan.**
- **Never tie down the fan with straps, chains, or other restraints.**
- **Never shut off the oil supply to the fan clutch.**

CAUTION:

To avoid injury when working near or on an operating engine equipped with an hydraulic clutch fan, remove loose items of clothing, jewelry; tie back or contain long hair that could be caught in any moving part causing injury. An hydraulic fan may start without warning.

CAUTION:

To avoid injury from electrical shock, do not touch battery terminals, alternator terminals, or wiring cables while the engine is operating.

CAUTION:

To avoid injury when working near or on an operating engine equipped with electric fans, remove loose items of clothing, jewelry; tie back or contain long hair that could be caught in any moving part causing injury. Electric fans may start without warning.

CAUTION:

To avoid injury when working near or on an operating engine, remove loose items of clothing, jewelry, tie back or contain long hair that could be caught in any moving part causing injury.

Start Attempts

Avoid excessive injection of ether into the series 50 engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

CAUTION:

To avoid injury from flames, explosion, and toxicants when using ether, the following precautions must be taken:

- ☐ **Do not smoke when servicing ether system.**
- ☐ **Work in well-ventilated area.**
- ☐ **Do not work near open flames, pilot flames (gas or oil heaters), or sparks.**
- ☐ **Do not weld or carry an open flame near the ether system if you smell ether or otherwise suspect a leak.**
- ☐ **Always wear goggles when testing.**
- ☐ **If fluid enters the eyes or if fumes irritate the eyes, wash eyes with large quantities of clean water for 15 minutes. A physician, preferably an eye specialist, should be contacted.**
- ☐ **Contents of cylinder are under pressure. Store cylinders in a cool dry area. Do not incinerate, puncture or attempt to remove cores from cylinders.**

Turbocharger Compressor Inlet Shield

A turbocharger compressor inlet shield, J 26554-A is available and must be used anytime the engine is operated with the air inlet piping removed. See Figure 12. The shield helps to prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the turbocharger impeller. The use of this shield does NOT preclude any other safety practices contained in this manual. See Figure 13 for Series 50G.

CAUTION:

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

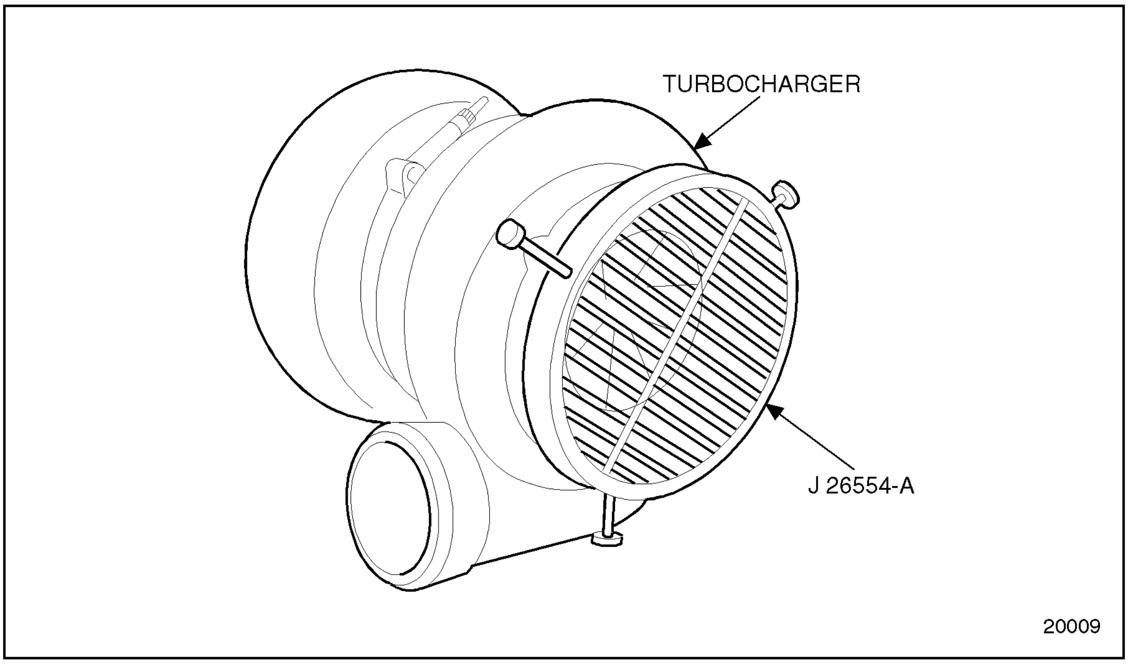


Figure 12 Turbocharger Compressor Inlet Shield, J 26554-A

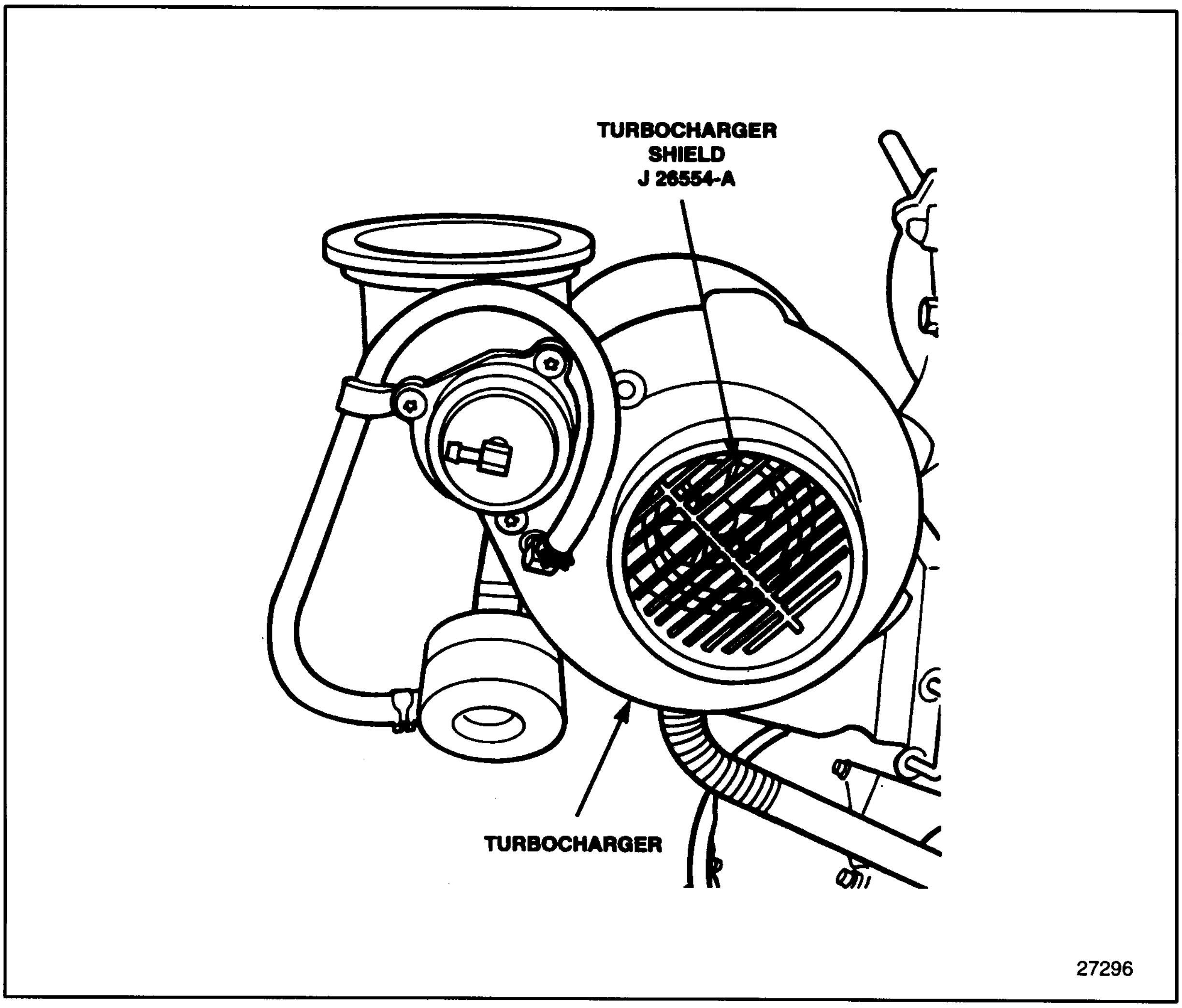


Figure 13 Turbocharger Compressor Inlet Shield, Series 50G

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 316°C (600°F), such as during a cylinder failure or engine fire. At temperatures above 316°C (600°F) 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 injury from chemical burns, wear a face shield and neoprene or PVC gloves when handling fluoroelastomer O-rings or seals that have been degraded by excessive heat. Discard gloves after handling degraded fluoroelastomer parts.

ENGINE VIEWS AND ELECTRONIC CONTROL MODULE MOUNTING

With the introduction of the improved mounting of the Series 50 electronic control module (ECM) to horizontal position, it was necessary to modify the 50 DN alternator mounting. This modification provides for longer bracket support bolted directly to the engine block from the alternator which reduces vibration. Also, this new position will provide for easier servicing and reduces the potential for moisture to enter the wiring harness connections. This change went into effect in December 1995.

The former alternator support bracket is not required with the current block and the bracket support are not interchangeable with the improved mounting. This change does not affect the rear-mounted ECM.

The current cylinder block assembly (23519301) is interchangeable with the former cylinder block assembly (23511361) with the only change being the addition of three bosses and a mounting pad. A service kit (23519302) was released to allow the current block to be used in place of former blocks for service. The current block service kit now contains stud and spacer (23519297) to allow for the mounting of the ECM in the vertical position. Service kit (23519302) will supersede former service kit (23517607).

For Series 50 engine views, see Figure 14.

For Series 50G engine views, see Figure 15.

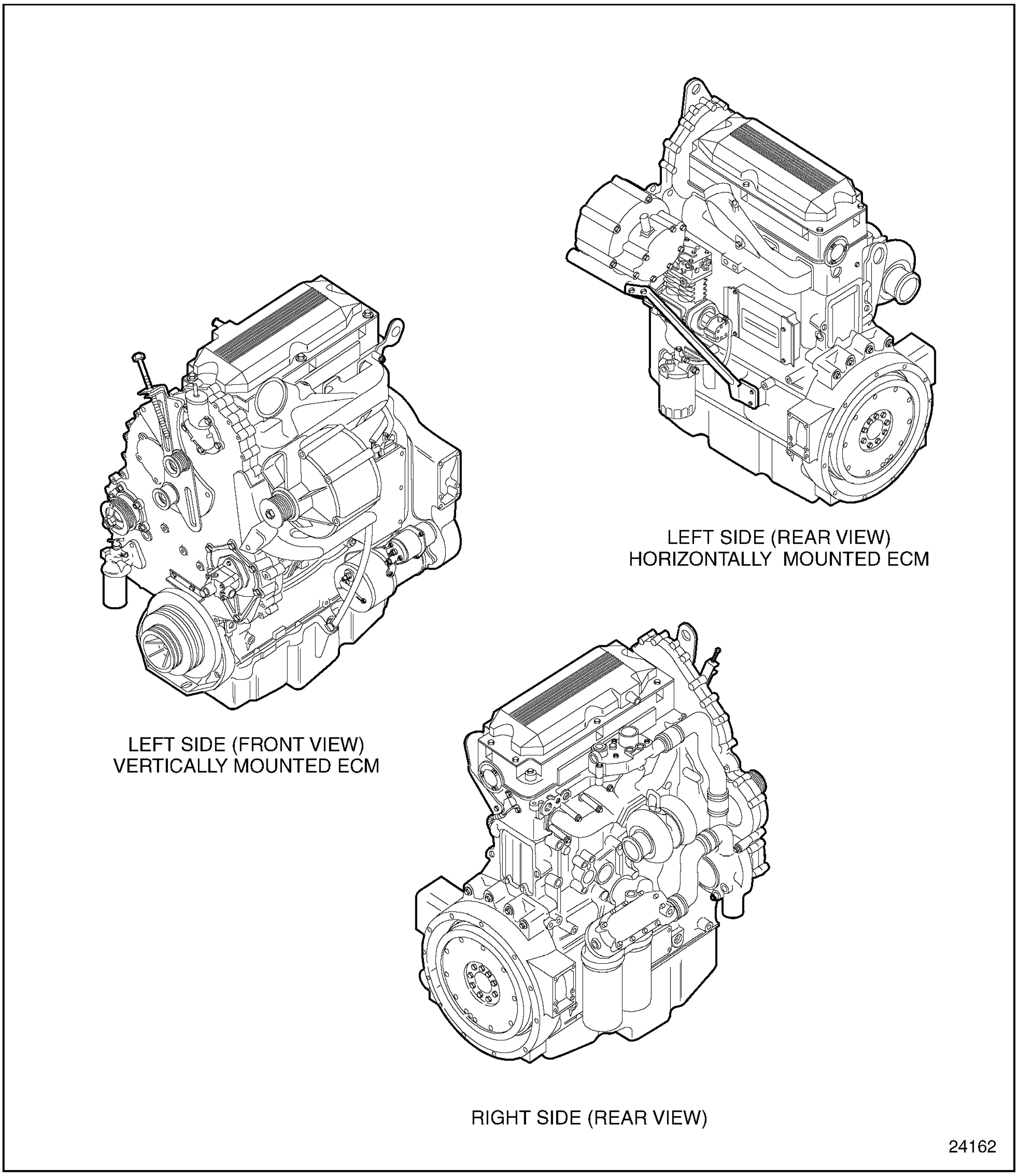


Figure 14 Engine Views Series 50

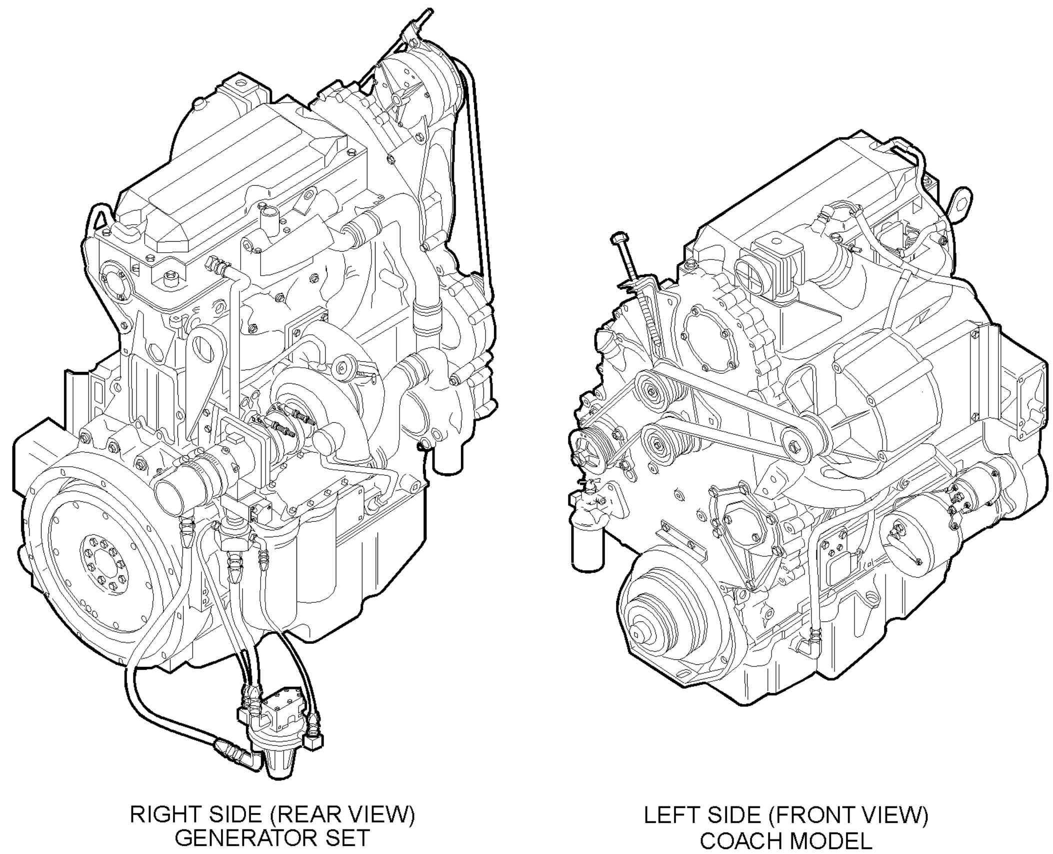


Figure 15 Engine Views Series 50G

ENGLISH TO METRIC CONVERSION

Listed in Table 5 are the English to metric conversions.

Description	By	Unit of Measurement
Multiply Length	**By**	**To get equivalent number of:**
Inch (in.)	25.4	Millimeters (mm)
Foot (ft)	0.3048	Meters (m)
Yard (yd)	0.9144	Meters (m)
Mile (mile)	1.609	Kilometers (km)
Multiply Area	**By**	**To get equivalent number of:**
Inch^2(in.^{2})	6452	Millimeters^2(mm^2)
Inch^2(in.^{2})	6.45	Centimeters^2(cm^2)

Description	By	Unit of Measurement
Foot^2(ft^2)	0.0929	0.0929
Yard^2(yd^2)	0.8361	Meters^2(m^2)
Multiply Volume	**By**	**To get equivalent number of:**
Inch^3(in.^{3})	16387	Millimeters^3(mm^3)
Inch^3(in.^{3})	16.387	Centimeters^3(cm^3)
Inch^3(in.^{3})	0.0164	Liters (L)
Quart (qt)	0.9464	Liters (L)
Gallon (gal)	3.785	Liters (L)
Yard^3(yd^3)	0.7646	Meters^3(m^3)
Multiply Mass	**By**	**To get equivalent number of:**
Pound (lb)	0.4536	Kilograms (kg)
Ton (ton)	907.18	Kilograms (kg)
Ton (ton)	0.907	Tonne (t)
Multiply Force	**By**	**To get equivalent number of:**
Kilogram (kg)	9.807	Newtons (N)
Ounce (oz)	0.2780	Newtons (N)
Pound (lb)	4.448	Newtons (N)
Multiply Temperature	**By**	**To get equivalent number of:**
Degree Fahrenheit (°F)	(°F-32) ÷ 1.8	Degree Celsius (° C)
Multiply Acceleration	**By**	**To get equivalent number of:**
Foot/second^2(ft/sec^2)	0.3048	Meter/second^2(m/s^2)
Inch/second^2(in./sec^2)	0.0254	Meter/second^2(m/s^2)
Multiply Torque	**By**	**To get equivalent number of:**
Pound-inch (lb·in.)	0.11298	Newton-meters (N·m)
Pound-foot (lb·ft)	1.3558	Newton-meters (N·m)
Multiply Power	**By**	**To get equivalent number of:**
Horsepower (hp)	0.746	Kilowatts (kW)
Multiply Pressure or Stress	**By**	**To get equivalent number of:**
Inches of water (in. H_2O)	0.2491	Kilopascals (kPa)
Pounds/square in. (lb/in.^{2})	6.895	Kilopascals (kPa)
Multiply Energy or Work	**By**	**To get equivalent number of:**
British Thermal Unit (Btu)	1055	Joules (J)
Foot-pound (ft·lb)	1.3558	Joules (J)
kilowatt-hour (kW·hr)	3,600,000. or 3.6 x 10^6	Joules (J = one W/s)
Multiply Light	**By**	**To get equivalent number of:**
Foot candle (fc)	1.0764	Lumens/meter^2(lm/m^2)

Description	By	Unit of Measurement
Multiply Fuel Performance	**By**	**To get equivalent number of:**
Miles/gal (mile/gal)	0.4251	Kilometers/liter (km/L)
Gallons/mile (gal/mile)	2.3527	Liter/kilometer (L/km)
Multiply Velocity	**By**	**To get equivalent number of:**
Miles/hour (mile/hr)	1.6093	Kilometers/hour (km/hr)

Table 5 English to Metric Conversion

DECIMAL AND METRIC EQUIVALENTS

Listed in Table 6 are the decimal to metric equivalents.

Fractions of an inch	Decimal (in.)	Metric (mm)	Fractions of an inch	Decimal (in.)	Metric (mm)
1/64	.015625	0.39688	33/64	.515625	13.09687
1/32	.03125	0.79375	17/32	.53125	13.49375
3/64	.046875	1.19062	35/64	.546875	13.89062
1/16	.0625	1.58750	9/16	.5625	14.28750
5/64	.078125	1.98437	37/64	.578125	14.68437
3/32	.09375	2.38125	19/32	.59375	15.08125
7/64	.109375	2.77812	39/64	.609375	15.47812
1/8	.125	3.175	5/8	.625	15.87500
9/64	.140625	3.57187	41/64	.640625	16.27187
5/32	.15625	3.96875	21/32	.65625	16.66875
11/64	.171875	4.36562	43/64	.671875	17.06562
3/16	.1875	4.76250	11/16	.6875	17.46250
13/64	.203125	5.15937	45/64	.703125	17.85937
7/32	.21875	5.55625	23/32	.71875	18.25625
15/64	.234375	5.95312	47/64	.734375	18.65312
1/4	.250	6.35000	3/4	.750	19.05000
17/64	.265625	6.74687	49/64	.765625	19.44687
9/32	.28125	7.14375	25/32	.78125	19.84375
19/64	.296875	7.54062	51/64	.796875	20.24062
5/16	.3125	7.93750	13/16	.8125	20.63750
21/64	.328125	8.33437	53/64	.828125	21.03437
11/32	.34375	8.73125	27/32	.84375	21.43125
23/64	.359375	9.12812	55/64	.859375	21.82812
3/8	.375	9.52500	7/8	.875	22.22500
25/64	.390625	9.92187	57/64	.890625	22.62187
13/32	.40625	10.31875	29/32	.90625	23.01875
27/64	.421875	10.71562	59/64	.921875	23.41562
7/16	.4375	11.11250	15/16	.9375	23.81250
29/64	.453125	11.50937	61/64	.953125	24.20937
15/32	.46875	11.90625	31/32	.96875	24.60625
31/64	.484375	12.30312	63/64	.984375	25.00312
1/2	.500	12.70000	1	1.00	25.40000

Table 6 Conversion Chart- Customary and Metric Units

SPECIFICATIONS

This section contains fastener torque specifications and pipe plug torque specifications.

Torque Specifications - Fasteners

The proper bolt and nut torque is dependent on its size. Standard (customary) nut and bolt torque specifications are listed in Table 7. The proper torque specifications for metric nuts and bolts are listed in Table 8.

Nut and Bolt Size, mm	280M or Better Torque, N·m	280M or Better Torque, lb·ft
#10-24	5-7	4-5
1/4 in.-20	9-12	7-9
1/4 in.-28	11-14	8-10
5/16 in.-18	18-23	13-17
5/16 in.-24	20-26	15-19
3/8 in.-16	41-47	30-35
3/8 in.-24	47-53	35-39
7/16 in.-14	62-68	46-50
7/16 in.-20	77-83	57-61
1/2 in.-13	96-102	71-75
1/2 in.-20	112-126	83-93
9/16 in.-12	122-136	90-100
9/16 in.-18	145-159	107-117
5/8 in.-11	186-199	137-147
5/8 in.-18	228-241	168-178
3/4 in.-10	325-339	240-250
3/4 in.-16	393-407	290-300
7/8 in.-9	556-569	410-420
7/8 in.-14	644-657	475-485
1 in.-8	789-799	580-590
1 in.-14	928-942	685-695

Table 7 Standard (Customary) Fastener Torque Specifications

Nut and Bolt Size, mm	Property Class 10.0 Torque, N·m	Property Class 10.0 Torque, lb·ft
M6 X 1.0	13-16	10-12
M8 X 1.25	30-38	22-28
M10 X 1.5	58-73	43-54
M12 X 1.75	101-126	75-93
M14 X 2.0	160-200	118-148
M16 X 2.0	245-306	181-226
M20 X 2.5	478-598	353-441

Table 8 Class 10.9 Torque Specifications for Metric Fasteners

Torque Specification - Pipe Plugs

Standard pipe plug torque specifications supporting the Series 50 engine are listed in Table 9.

Pipe Plug Size, NPTF *	Torque Specifications, N·m	Torque Specifications, lb·ft
1/8 in.	14-18	10-13
1/4 in.	19-24	14-18
3/8 in.	24-31	18-23
1/2 in.	31-39	23-29
3/4 in.	45-56	33-41
1 in.	101-126	75-93
1-1/4 in.	129-161	95-119
1-1/2 in.	149-187	110-138

* Use sealant such as Pipe Plug Sealant with Teflon, J 26558-92 part of PT-7276 (Loctite 592) or equivalent on all uncoated pipe plugs.

Table 9 Standard Pipe Plug Torque Specifications

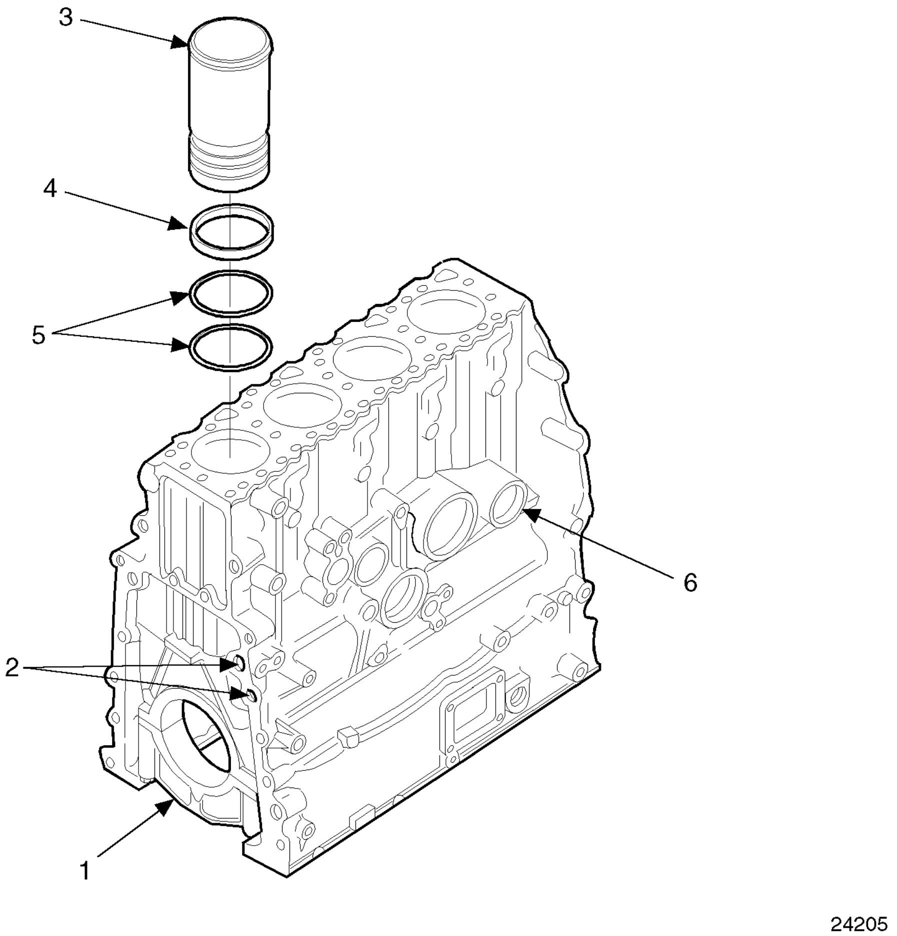
1 ENGINE

Section | Page

1.1 CYLINDER BLOCK AND CYLINDER LINER

The cylinder block is the basic engine structure, establishing and maintaining the alignment of all engine working parts. In the Series 50 Engines, the cylinder liners are not an integral part of the block casting, but are in the form of replaceable, wet type cylinder liners. See Figure 1-1.

Flanges at the liner upper ends seat in counterbores in the block deck, and project slightly above the deck to compress the head gasket for a good compression seal. Below the water jacket the lower end of the cylinder liner has two D-shaped seal rings and a lipped crevice seal to prevent leakage between the water jacket and crankcase.



1. Rear Main Bearing Cap
2. Oil Galleries
3. Cylinder Liner
4. Crevice Seal
5. D-ring Seals
6. Integral Coolant Inlet

Figure 1-1 Engine Cylinder Block and Liner

An integral coolant inlet manifold is cored into the right side of the block. It distributes the water pump output along the length of the block. Oil galleries are machined into the cooler side of the block. See Figure 1-1.

The integral oil galleries direct the oil pump output through the external oil cooler and filters, to the main oil gallery and to drilled passages in the crankcase webs which supply oil under pressure to each main bearing. In the crankcase, three integral webs plus front and rear bulkheads support the crankshaft in five main bearings. See Figure 1-2.

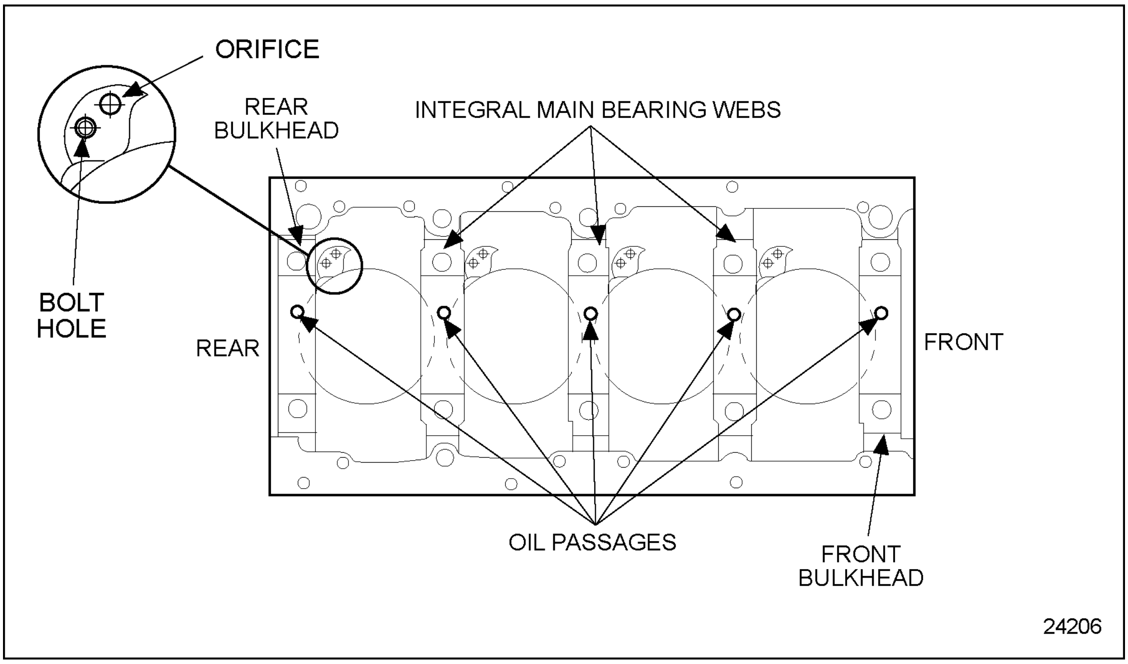


Figure 1-2 Engine Cylinder Crankcase

An improved cylinder block has replaced the former block on all Series 50 engines. This change took effect with unit serial number 4R6959, built November 22, 1994. The former cylinder block was used on engines built prior to this serial number.

The Series 50 cylinder block was further improved by the addition of a drilled lubrication orifice and bolt hole at the base of each cylinder bore. See Figure 1-2. The orifices are drilled into the main oil gallery and are required for installation of bolt-on oil spray nozzles used with forged steel pistons on premium engines. When blocks are used for non-premium engines with cast-iron pistons, the lubrication orifices are closed with bolt-on steel plates. First usage of the drilled block was on October 2002 with engine model 6047MK1E.

The improved block has a slightly modified sidewall configuration that eliminates interference between the block and adaptorless compressor. To compensate for the elimination of the adaptor, air compressor mounting bracket bolt holes have been moved forward 130.3 mm (5.13 in.) on the block. See Figure 1-3. Since these holes have a different spacing than the former holes, an improved compressor mounting bracket is required. A new air compressor coolant supply port has also been added forward of the former supply port. The former port is plugged when the adaptorless compressor is installed.

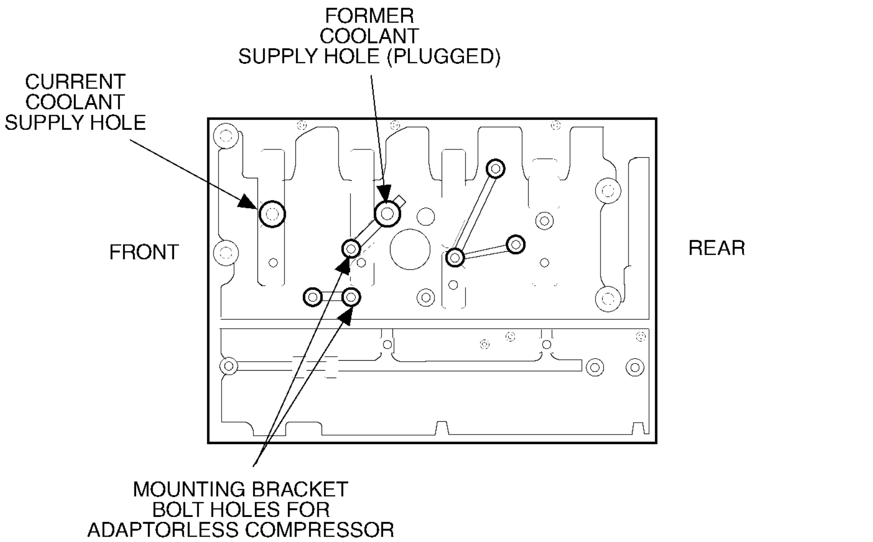


Figure 1-3 Improved Cylinder Block Showing Modifications

When replacing a former block with an improved block, an adaptorless air compressor, improved compressor mounting bracket, and improved compressor coolant supply hose *must* be installed. Refer to Section 10.1.4 of this manual for information on installing the adaptorless air compressor.

1.1.1 Repair or Replacement of the Cylinder Block

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-4.

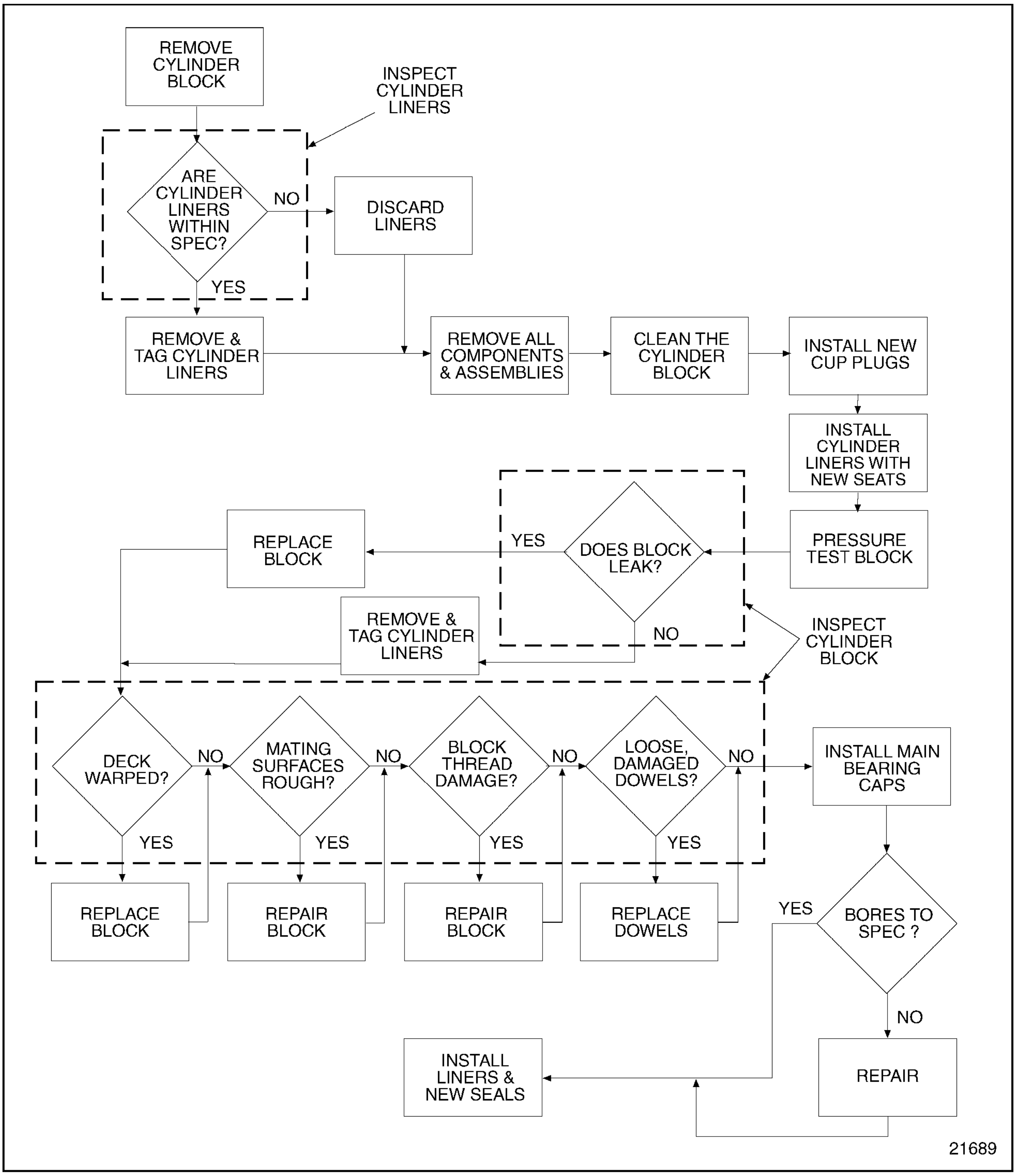


Figure 1-4 Flowchart for Repair or Replacement of Cylinder Block

1.1.2 Removal of Engine from the Vehicle and Disassembly

Before mounting an engine on an overhaul stand, it must be disconnected from the transmission. Details of removing an engine will vary from one vehicle to another. However, the following steps will be necessary, regardless of vehicle type:

1. Disconnect the battery cable(s) from the battery(s).
2. Drain the cooling system completely by removing the drain plug in the oil cooler and opening the draincocks in the cylinder block, thermostat housing and water pump housing. Refer to Section 13.5.4.
3. Drain the lubricating oil. Refer to Section 13.5.1.
4. Disconnect the inlet fuel line from the primary fuel filter and the outlet line from the upper fitting at the rear of the cylinder head.
5. Remove the air cleaner ducting as necessary for engine removal.
6. Remove the charge air cooler ducting from the turbocharger and intake manifold. Refer to Section 6.7.2.
7. Disconnect the exhaust piping from the turbocharger.
8. Disconnect the 30-pin DDEC vehicle electrical connector and the six-pin DDEC II power connector or DDEC III five-pin power connector.
9. Disconnect and remove the cranking motor or air starter, alternator and other electrical equipment, as necessary.
10. Remove the air compressor and any air lines, as necessary.
11. Disconnect and remove the coolant hoses.
12. Remove the charge air cooler, radiator, fan guard and other cooling system related parts as necessary to remove the engine.
13. Connect a suitable lifting device to the engine using all three lifting brackets (two at the rear and one at the front).
14. Separate the engine from the transmission.
15. Remove the engine mounting bolts.

CAUTION:

To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided lifter brackets must be used.

16. Lift the engine from its mounts using a suitable lifting device. See Figure 1-5.

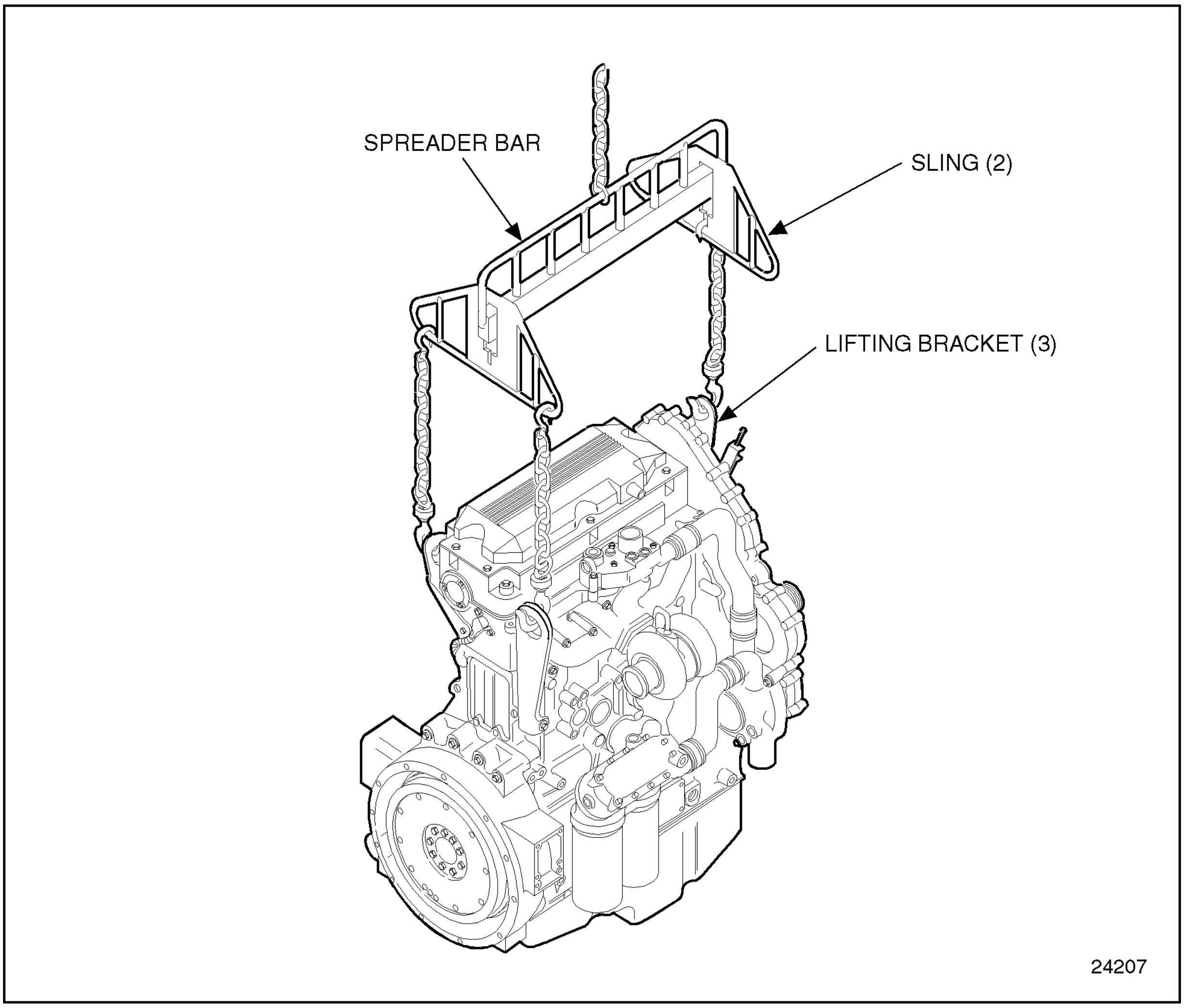


Figure 1-5 Lifting Engine

CAUTION:

To avoid injury from a falling engine, ensure the engine is securely attached to the engine overhaul stand before releasing the lifting sling.

17. Use engine overhaul stand, J 29109, with stand adaptor plate, J 39652, for support when stripping a Series 50 Engines cylinder block. See Figure 1-6.

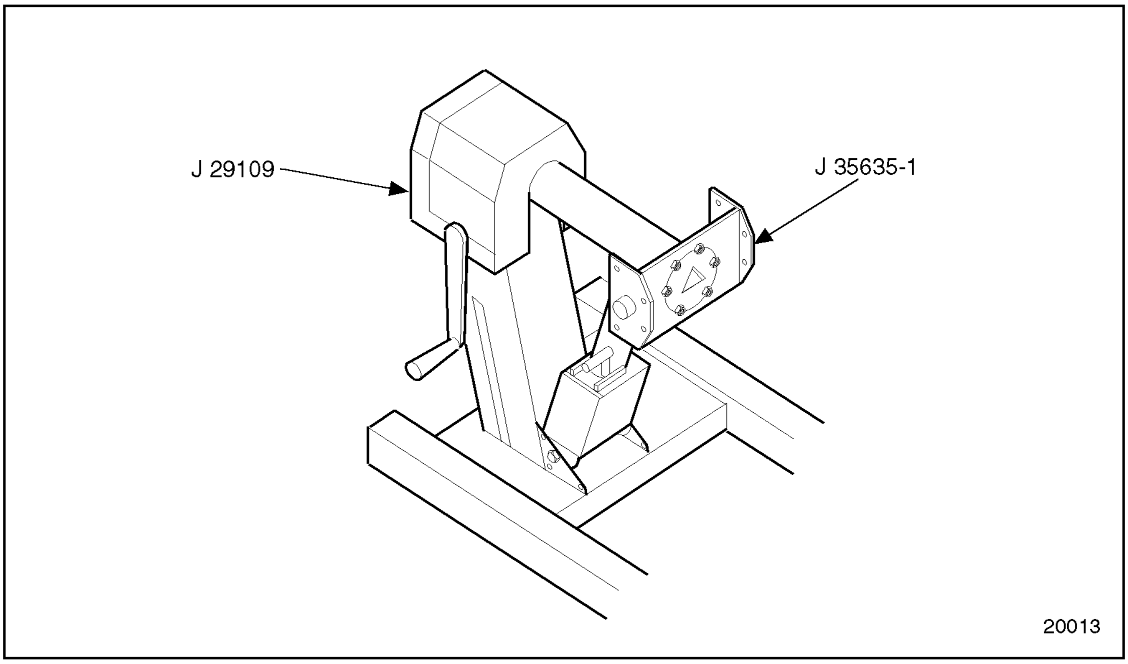


Figure 1-6 Engine Overhaul Stand and Adaptor

18. Bolt cylinder block adaptor, J 35635-2 part of J 35635–A, to the cylinder block and mate it with the stand adaptor, J 39652. See Figure 1-7.

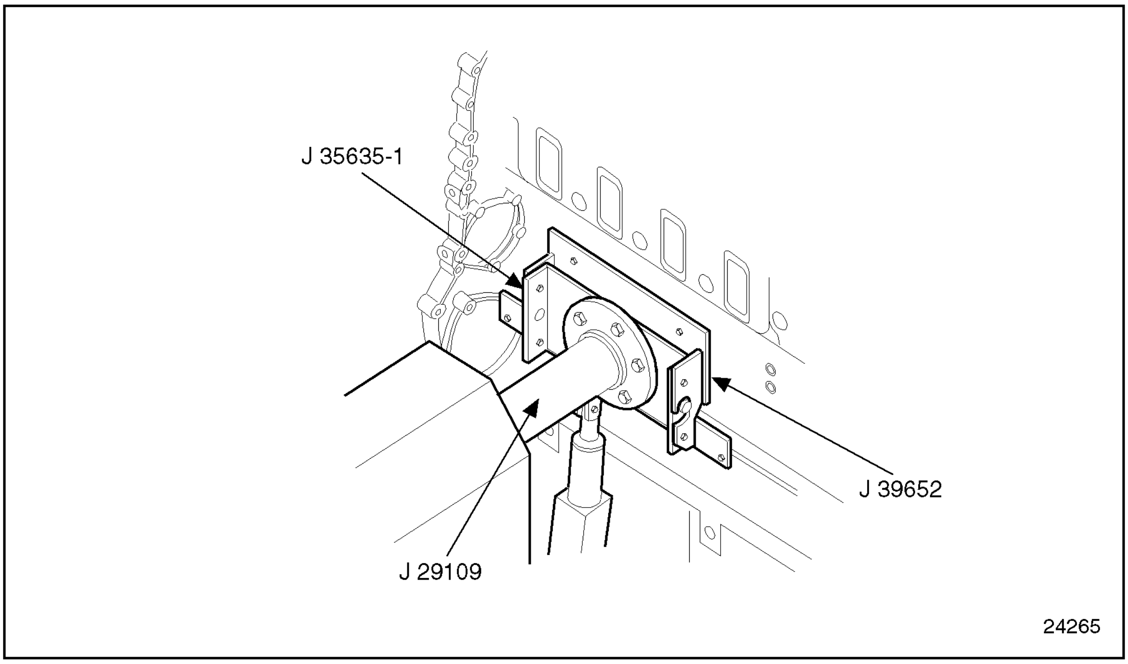


Figure 1-7 Cylinder Block Adaptor

19. The engine is left-side mounted in an upright position. Rotate it in either direction and lock it into position.
20. Remove the ECM from the cold plate.
    [a] For DDEC II engines, remove the inlet and outlet fuel lines connected to the Electronic Control Module (ECM) cold plate, the ECM mounting bolts, and the ECM.

NOTE:
DDC has discontinued the use of the ECM cold plate on all Series 50 Engines. In place of the ECM cold plate, a No. 6 x 37.92 in. (963 mm) long hose assembly (23504785) is now routed from the fuel pump discharge fitting to the inlet of the secondary fuel filter.

    [b] The current DDEC III engines do not have a cold plate.

21. Disconnect the harness connector (gray) from the timing reference sensor (TRS) at the lower left corner of the gear case. Remove the TRS from the gear case. Refer to Section 2.21.2.
22. Disconnect the harness (black) connector from the synchronous reference sensor (SRS) at the left rear wall of the gear case. Remove the SRS from the gear case. Refer to Section 2.20.2.
23. Remove any electrical components, connectors or wiring looms from the engine.

24. With the engine mounted on the overhaul stand, remove all of any remaining subassemblies and parts from the cylinder block.
    - [a] To remove the valve rocker cover, refer to Section 1.6.2.
    - [b] To remove the engine lifter brackets, refer to Section 1.5.2.
    - [c] To remove the crankshaft pulley, refer to Section 1.13.2.
    - [d] To remove the crankshaft vibration damper, refer to Section 1.12.2.
    - [e] To remove the accessory drive, refer to Section 1.29.2.
    - [f] To remove the gear case cover, refer to Section 1.10.2.
    - [g] To remove the camshaft drive gear, refer to Section 1.24.2.
    - [h] To remove the bull gear and camshaft idler gear assembly, refer to Section 1.26.2.
    - [i] To remove the adjustable idler gear assembly, refer to Section 1.25.2.
    - [j] To remove the crankshaft timing gear and timing wheel, refer to Section 1.27.2.
    - [k] To remove the gear case, refer to Section 1.11.2.
    - [l] To remove camshaft, refer to Section 1.22.2.
    - [m] To remove the cylinder head, refer to Section 1.2.2.
    - [n] To remove the flywheel, refer to Section 1.14.2.
    - [o] To remove the flywheel housing, refer to Section 1.16.2.
    - [p] To remove the oil pan, refer to Section 3.9.2.
    - [q] To remove the piston and connecting rod assembly, refer to Section 1.18.2.
    - [r] To remove the cylinder liner, refer to Section 1.20.2.

NOTICE:
Before removing main bearing caps, be sure each is stamped or punch-marked in numerical order, beginning with No. 1 at the front, to ensure installation in their original position. Mark all caps on the oil cooler side (right side) of the engine to prevent reversal at assembly. Failure to mark numerical order may result in the caps being put back in incorrect order.

    - [s] To remove the crankshaft, refer to Section 1.7.2.
    - [t] To remove the crankshaft main bearings, refer to Section 1.9.2.

1.1.3 Cleaning the Cylinder Block

Before removing cylinder liners for block cleaning, the liner bores should be gaged to determine whether liner replacement is necessary. Refer to Section 1.20.2.1.

Remove cylinder liners with the cylinder liner removal tool, J 35791, before putting the block in cleaning or describing baths, to avoid trapping cleaning agents in block liner seating bores. See Figure 1-8.

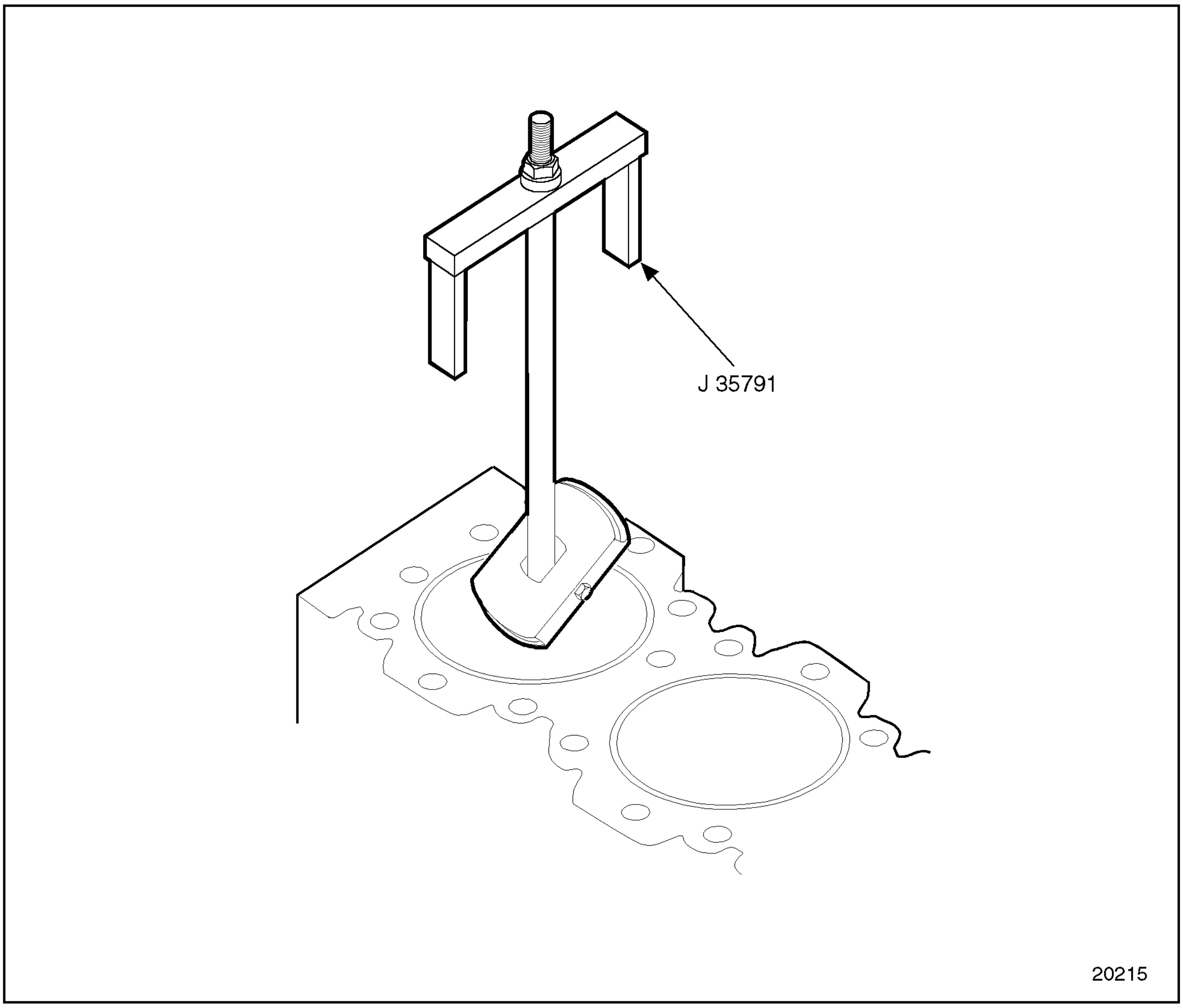


Figure 1-8 Cylinder Liner Removal Tool

After disassembling and before removing the cylinder block from the overhaul stand for cleaning and inspection, install the two metric eye bolts J 35595 to the cylinder block.

Clean the cylinder block as follows:

1. Remove all oil and water gallery and weep hole plugs to allow the cleaning solution to enter the inside of the oil and water passages.
2. Using two metric eye bolts, J 35595, installed in the head bolt holes at opposite ends of the block, and with a suitable lifting device and spreader bar, immerse and agitate the block in a hot bath of a commercial, heavy-duty alkaline solution.
3. Wash the block in hot water or steam clean it to remove the alkaline solution.

4. 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 re-immerse it in the same acid solution for 10 more minutes. Repeat until all scale is removed from the water jacket area.
   - [d] Rinse the block in clear, hot water to remove the acid solution.
   - [e] Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   - [f] Wash the block in clean water or steam clean it.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

5. Dry the cylinder block with compressed air. Blow out all of the bolt holes and passages with compressed air.

NOTE:
The above cleaning procedure may be used on all ordinary cast iron and steel parts for the engine. Aluminum parts, such as flywheel housing, air intake manifold, oil filter adaptor and the camshaft gear access cover should NOT be cleaned in this manner. Mention will be made of special procedures when necessary.

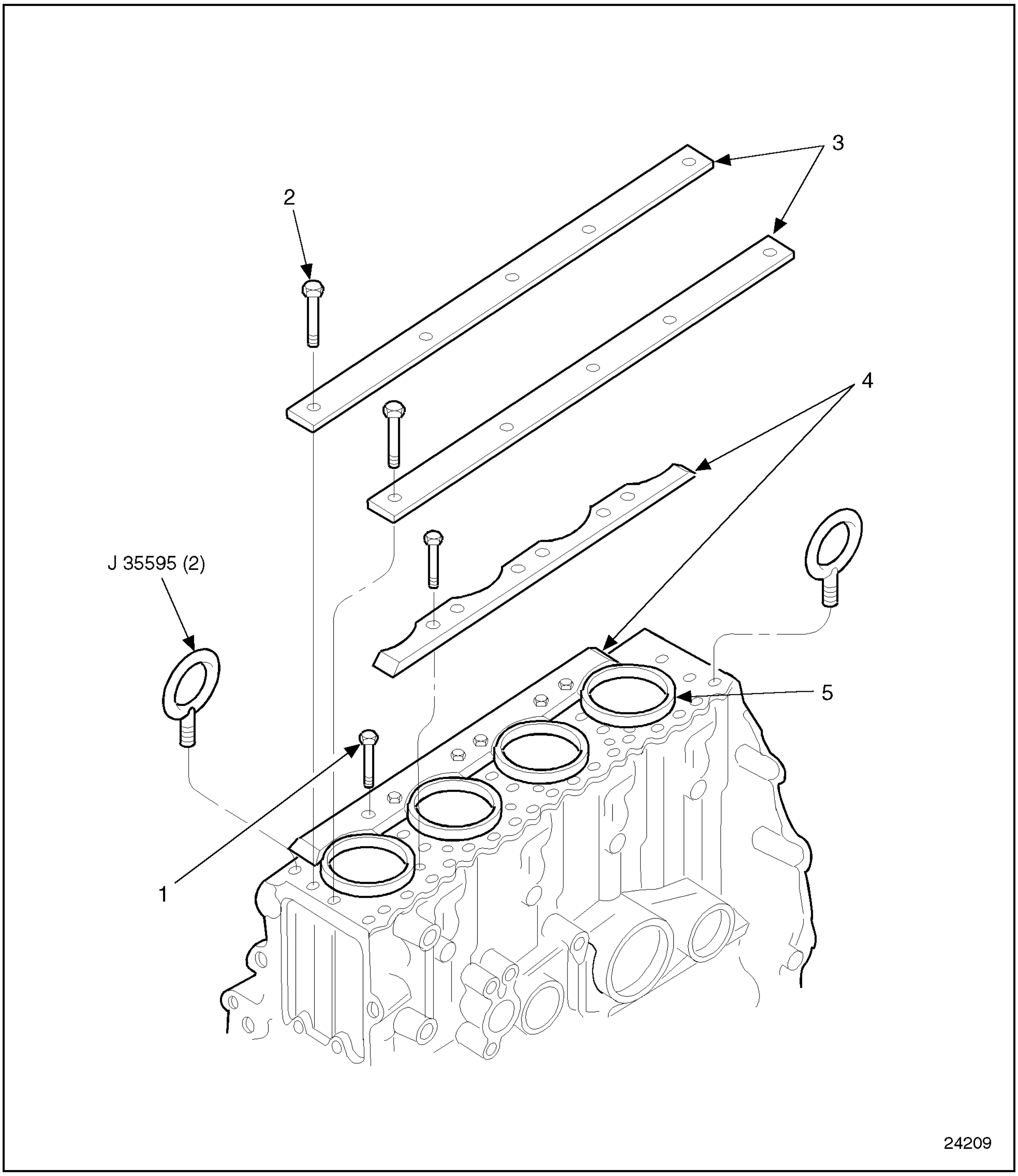
6. Be certain that all water passages and oil galleries have been thoroughly cleaned and dried. Install weep hole plugs and precoated pipe plugs. Install new cup plugs using a coating of good grade non-hardening sealant such as Loctite 620 or equivalent.
7. Pressure test the cylinder block. Two methods of cylinder block pressure testing may be used depending on the test facilities available:
   - [a] Immersion method; refer to Section 1.1.3.1.
   - [b] Leak-marker method; refer to Section 1.1.3.2.

1.1.3.1 Cylinder Block Immersion Method Pressure Testing

Use cylinder block pressure test kit, for immersion method pressure testing as follows:

1. Install cylinder liners with new seal rings and crevice seals. Refer to Section 1.20.3. Seat the liners firmly in the block counterbores with cylinder liner installation tool, J 35597–A.

2. Install two metric eye bolts, J 35595, in the head bolt holes at opposite ends of the block. See Figure 1-9.



1. Bolts (12)
2. Bolts (10)
3. Outside Test Strips (2)
4. Test Strips (2)
5. Test Rings (5)

Figure 1-9 Cylinder Block Test Deck Plate Installation

3. Install the cylinder block test strips and rings. See Figure 1-9.

4. Install the bolts through the strips and into the cylinder block. Torque the bolts on the ring strips to 231-237 N·m (170-175 lb·ft). Torque the bolts on the outside strips to 14 N·m (10 lb·ft).
5. Install the water inlet cover plate, J 36223-7A part of J 36223–D. See Figure 1-10. Use the bolt supplied with the tool to secure it to the cylinder block.

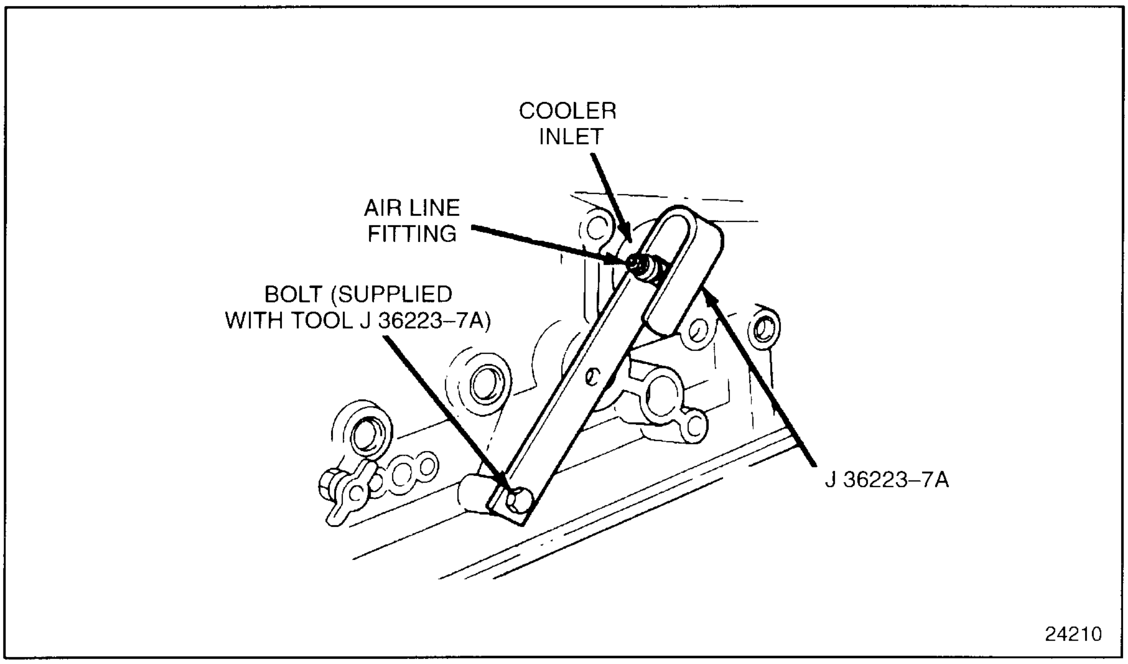


Figure 1-10 Water Inlet Cover Plate Installation

NOTE:
At the base of each liner, the space between upper and lower liner seals is vented to the block surface, on the left side. Any coolant leakage past the upper seal is drained to the outside rather than into the crankcase, and is easily detected by a visual inspection.

6. With a suitable lifting device and spreadable bars, immerse the cylinder block for twenty minutes in a tank of water heated to 82-93°C (180-200°F).
7. Attach an air line to the water inlet cover plate and apply 138 kPa (20 lb/in.^{2}) air pressure to the water jacket. Observe the water in the tank for bubbles that will indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

8. Remove the block from the water tank. Remove the plates and gaskets and blow out all of the passages in the block with compressed air.
9. Remount the cylinder block to the engine overhaul stand, J 29109.

1.1.3.2 Cylinder Block Leak-Marker Pressure Testing

When a large water tank is not available, or when it is desired to check the block for cracks without removing the engine from the vehicle cylinder block leak-marker pressure testing may be used.

1. Install cylinder liners with new seal rings and crevice seals. Refer to Section 1.20.3. Seat the liners firmly in the block counterbores with cylinder liner installation tool, J 35597–A.
2. Install two metric eye bolts, J 35595, in the head bolt holes at opposite ends of the block. See Figure 1-9.
3. Fill the water jacket with a mixture of water and 3.8 liters (1 U.S. gallon) of permanent-type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.
4. Install the cylinder block test strips and rings. See Figure 1-9.
5. Install the bolts through the strips and into the cylinder block. Torque the bolts on the ring strips to 231-237 N·m (170-175 lb·ft). Torque the bolts on the outside strips to 14 N·m (10 lb·ft).
6. Install the water inlet cover plate, J 36223-7A part of J 36223–D. See Figure 1-10. Use the bolt supplied with the tool to secure it to the cylinder block.

NOTE:
At the base of each liner, the space between upper and lower liner seals is vented to the block surface, on the left side. Any coolant leakage past the upper seal is drained to the outside rather than into the crankcase, and is easily detected by a visual inspection.

7. With a suitable lifting device and spreadable bars, immerse the cylinder block for twenty minutes in a tank of water heated to 82-93°C (180-200°F).
8. Apply 138 kPa (20 lb/in.^{2}) 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.
9. At the end of this test period, examine the outside diameter area of the liner flanges, 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.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

10. After the pressure test is completed, remove the test deck plate and gasket and the water inlet cover plate. Drain the water jacket. Then blow out all of the passages in the cylinder block with compressed air.
11. Remount the cylinder block to the engine overhaul stand, J 29109.

1.1.4 Cylinder Block Inspection Procedures

Perform the following preliminary step prior to performing cylinder block inspections:

1. Remove the cylinder liners and regage to determine whether liner replacement is necessary. Refer to Section 1.20.2.

1.1.4.1 Inspection of the Cylinder Block

Perform the following for cylinder block inspection:

1. Measure the bore of each cylinder with cylinder bore gage, J 5347-B, which has a dial indicator calibrated in 0.0001 in. increments. See Figure 1-11.

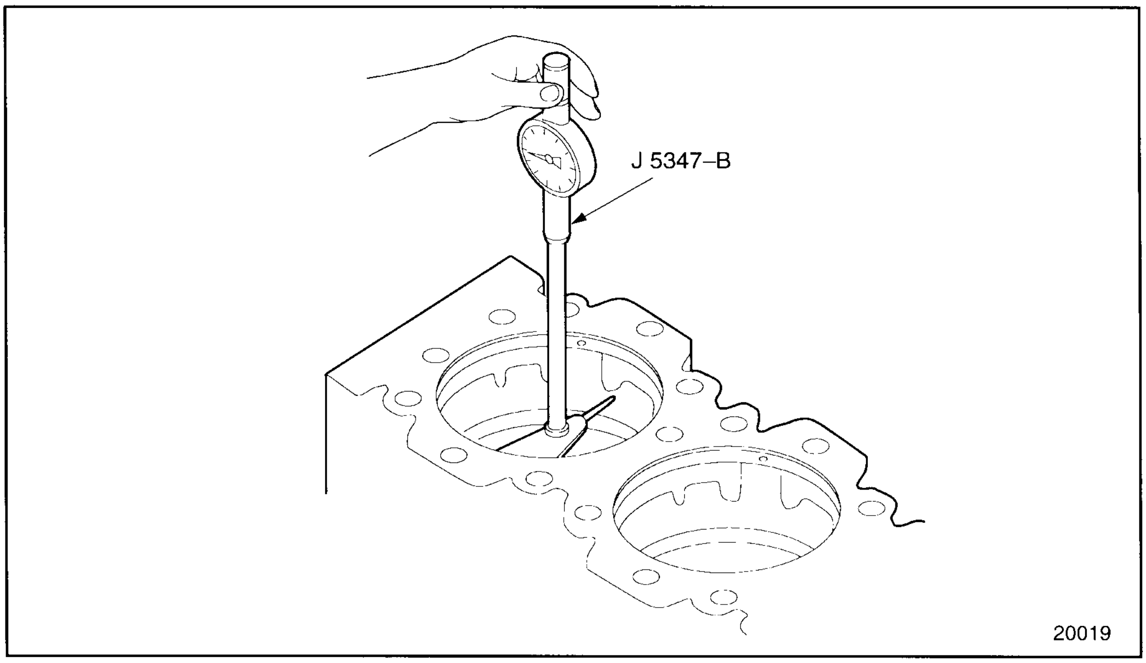


Figure 1-11 Gaging Cylinder Bores

2. Measure cylinder block bore, at the positions on axis 90° apart. See Figure 1-11. If the diameter does not exceed the dimensions listed in Table 1-1, the block may be reused.

NOTE:
The above measurements are average gage readings at each position. Also, the out-of-round must not exceed 0.0254 mm (0.001 in.). See Figure 1-12.

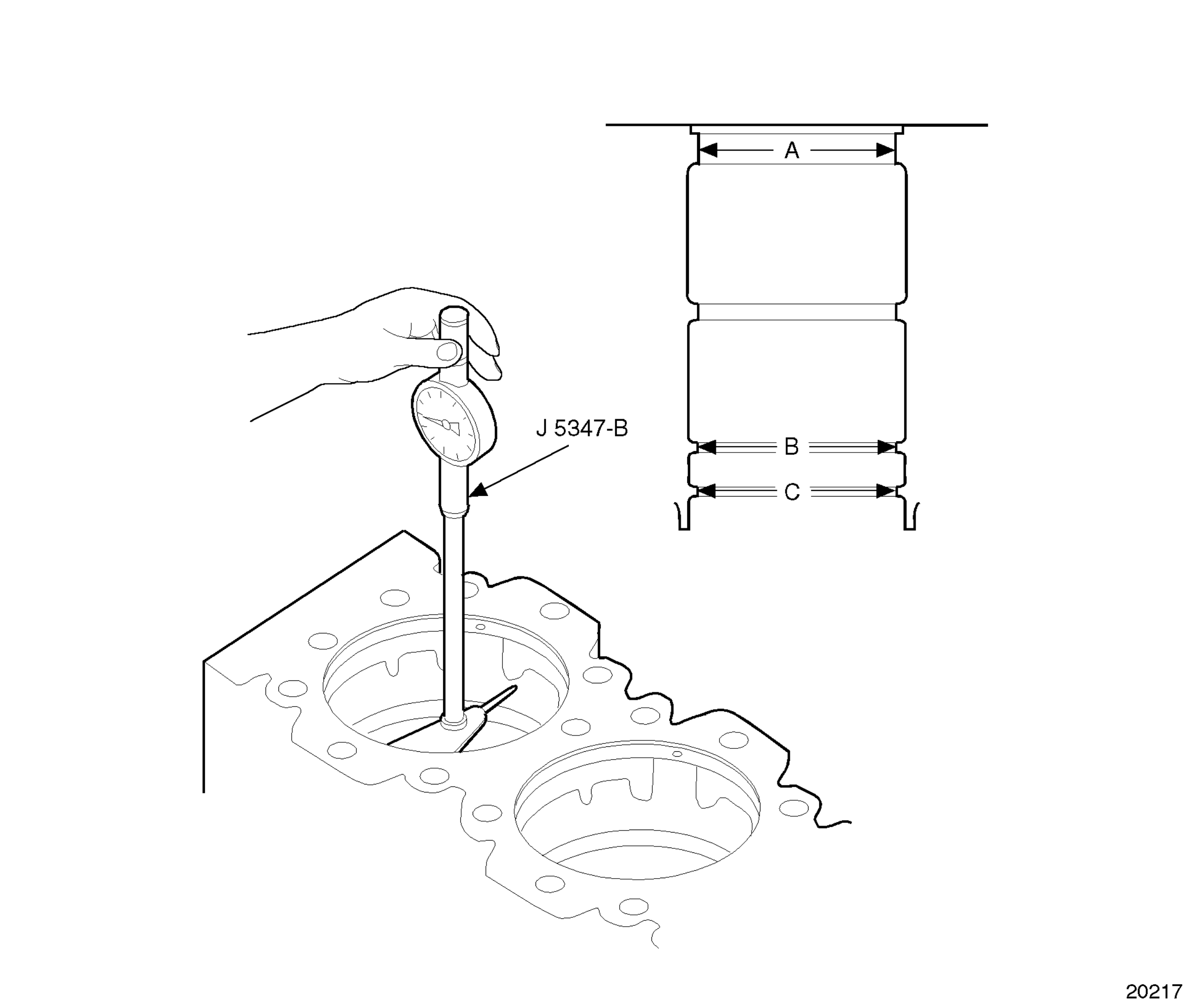


Figure 1-12 Maximum Cylinder Block Bore Diameters by Location (After Clean-up)

Location	Diameter, mm	Diameter, in.
A	149.050-149.120	5.686-5.871
B	146.050-146.120	5.750-5.753
C	146.050-146.120	5.750-5.753

Table 1-1 Acceptable Cylinder Bore Diameters

1.1.4.2 Inspection of Deck Flatness

Check the cylinder block deck for flatness with an accurate straightedge and feeler gage. See Figure 1-13.

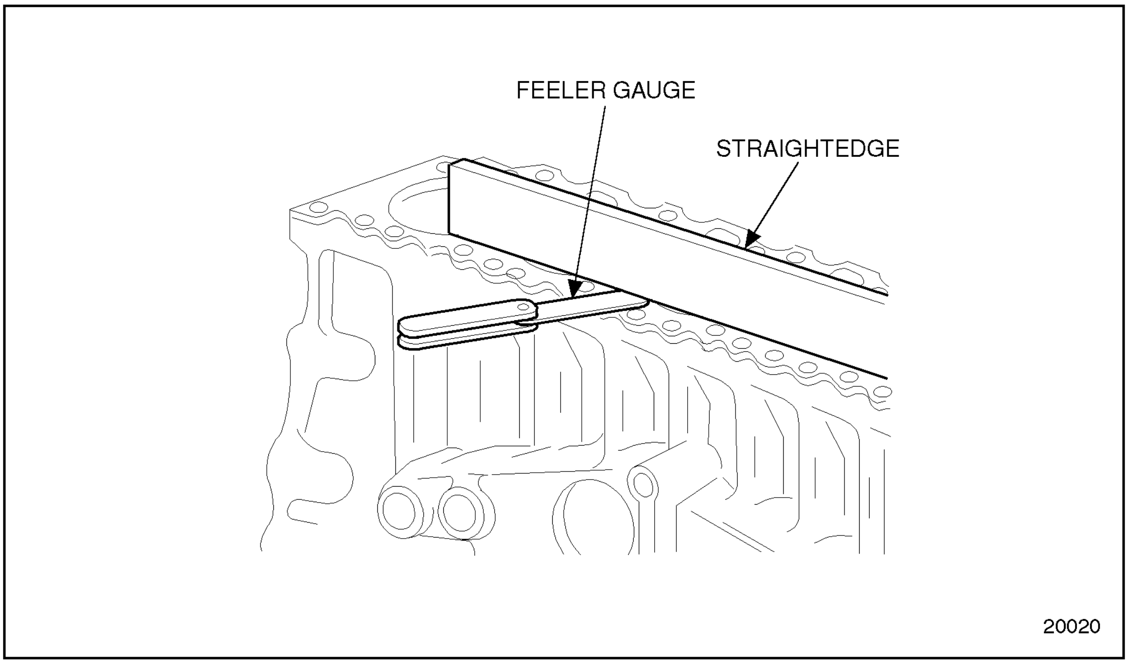


Figure 1-13 Checking Block Deck for Flatness

Check front-to-rear flatness next to the cylinder liner flanges on both sides, and side-to-side flatness between the liner flanges. The deck must be flat within 0.120 mm (0.005 in.) front-to-rear, and flat within 0.076 mm (0.003 in.) side-to-side. If not, the deck must be resurfaced.

NOTICE:
The camshaft is mounted in the cylinder head so resurfacing of the block head affects the position of the camshaft in relation to the adjustable idler gear and gear train.

Record the amount of stock removed from the cylinder block by stamping the amount removed on the cylinder block pad. See Figure 1-14.

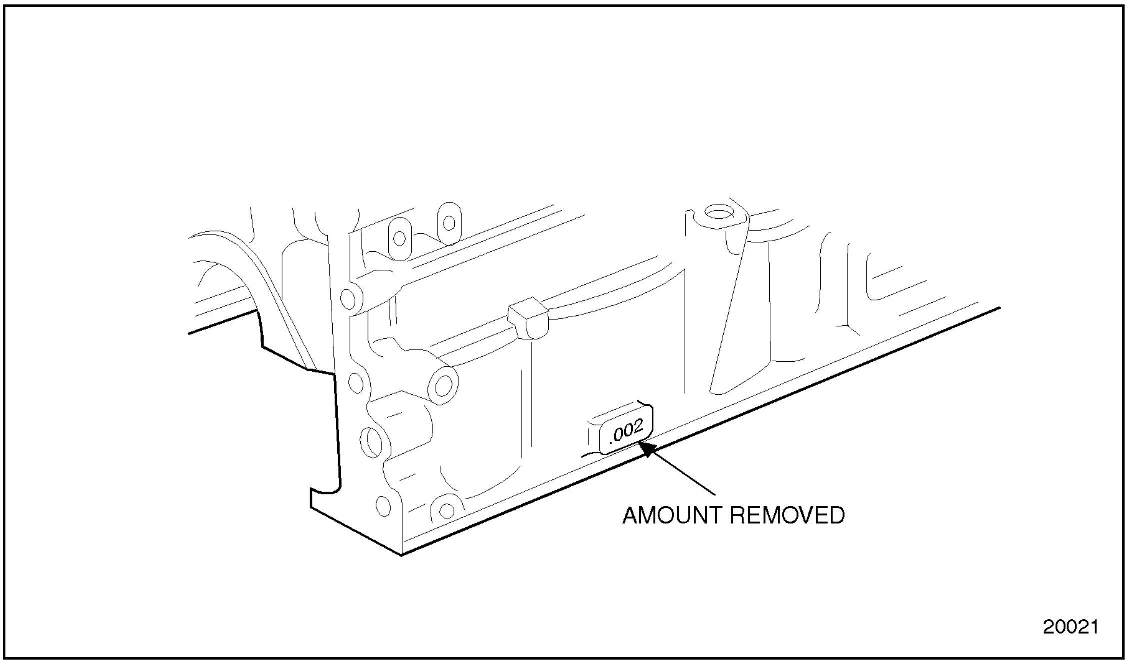


Figure 1-14 Recording Stock Removal on Cylinder Block

1.1.4.3 Inspection of Main Bearing Bores

Perform the following steps for main bearing bore inspection:

1. Install the main bearing caps in their original positions. Lubricate the cap bolt threads and head contact surfaces with a small quantity of International Compound #2®. International Compound #2 is a registered trademark of IRMCO.
2. Install the main cap bolts and torque to 470-530 N·m (347-391 lb·ft).

3. Measure the main bearing bores using dial bore gage J 5347-B which has a dial indicator calibrated in 0.0001 in. increments. Set the cylinder bore gage on zero in master setting fixture, J 23059-01 part of J 23059–4. See Figure 1-15.

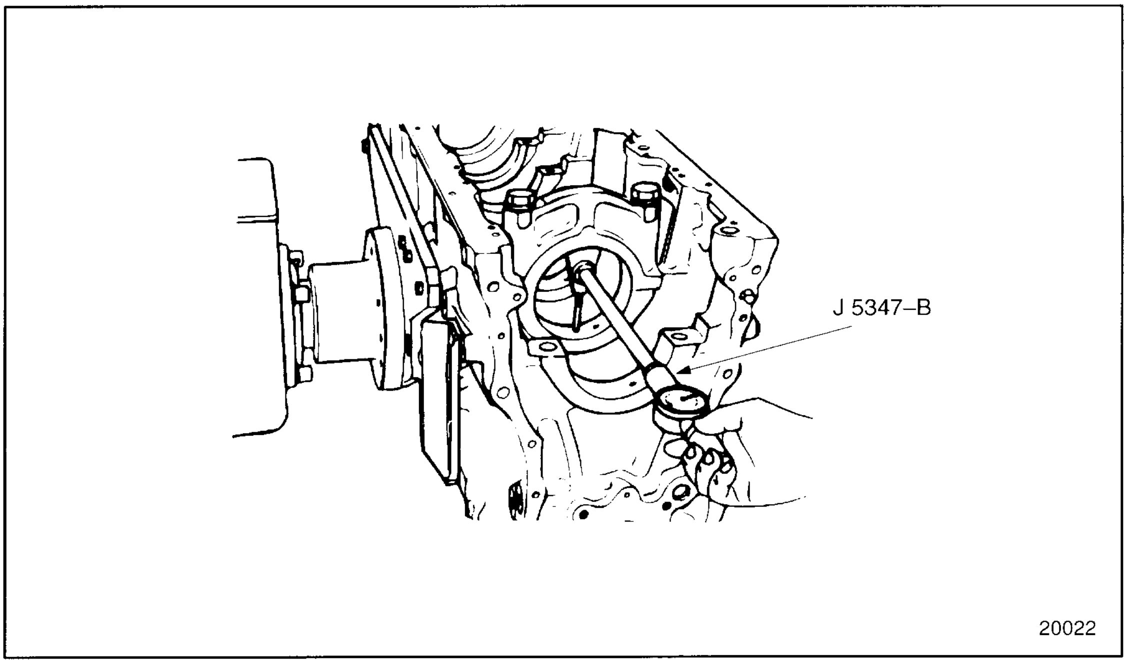


Figure 1-15 Gaging Main Bearing Bores

NOTE:
Dial bore master setting fixture should be used to zero the cylinder bore gage.

The bore diameter specification is 132.994-133.031 mm (5.236-5.237 in.). An oversize main bearing bore may be line-bored to accept a 0.508 mm (0.040 in.) oversize O.D. main bearing. Line boring is also necessary when a bearing cap must be replaced due to breakage or spun-bearing damage. Refer to Section ADDITIONAL INFORMATION for line boring specifications which are listed in Table 1-12.

1.1.4.4 General Inspection

Check all machined surfaces for nicks or burrs that could affect the fit of mating parts. Clean up as necessary by stoning. Also inspect all tapped holes for thread damage and retap or install helical thread inserts as necessary. Replace any loose or damaged dowel pins.

1.1.4.5 Rust Prevention

After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil.

NOTICE:
Castings free of grease or oil will rust when exposed to the atmosphere. Rust on machined surfaces may result in leakage.

If the block is to be stored for extended period of time, spray or dip it in a polar-type rust preventative. Castings which are free of grease or oil will rust when exposed to the atmosphere.

1.1.5 Reassembly of Cylinder Block

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

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. If a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.
2. If a new service replacement block is used, stamp the engine serial number and model number on the pad provided on the left side of the block, just below the deck. See Figure 1-16.

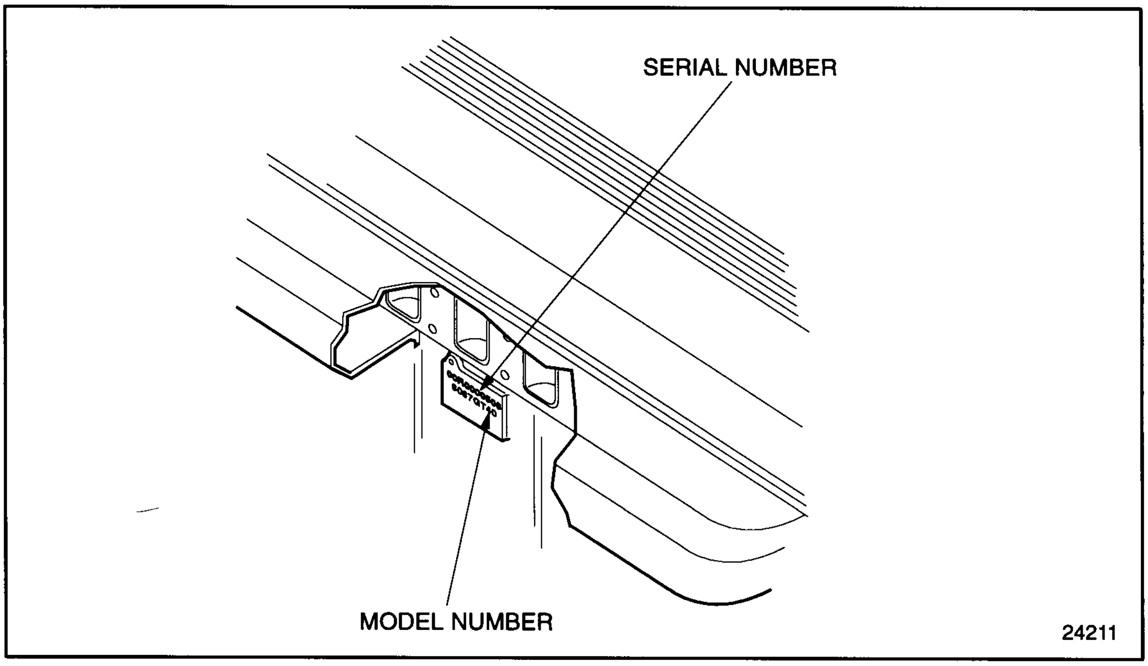


Figure 1-16 Location of Engine Serial and Model Numbers

3. Also stamp the position numbers on the main bearing caps and the position of the No. 1 bearing on the cooler side of the oil pan mounting flange of the block.
4. Install the main bearing caps in their original positions; refer to Section 1.9.3.

NOTICE:
Always check to make sure cooling nozzles are open and aligned after piston installation. An obstructed, misaligned, bent or damaged nozzle may not provide proper piston cooling. A loosened nozzle may cause a loss of main gallery oil pressure. In either case, piston overheating or lack of adequate lubrication may result in severe engine damage.

5. On current non-premium engines with cast iron pistons, install the bolt-on plate over the oil gallery orifice at the base of each cylinder bore. On premium engines with closed-end

rods and forged steel pistons, install oil spray nozzles into these openings. See Figure 1-17 for location of nozzle. Torque plate nozzle retaining bolts to 30-38 N·m (22-28 lb·ft).

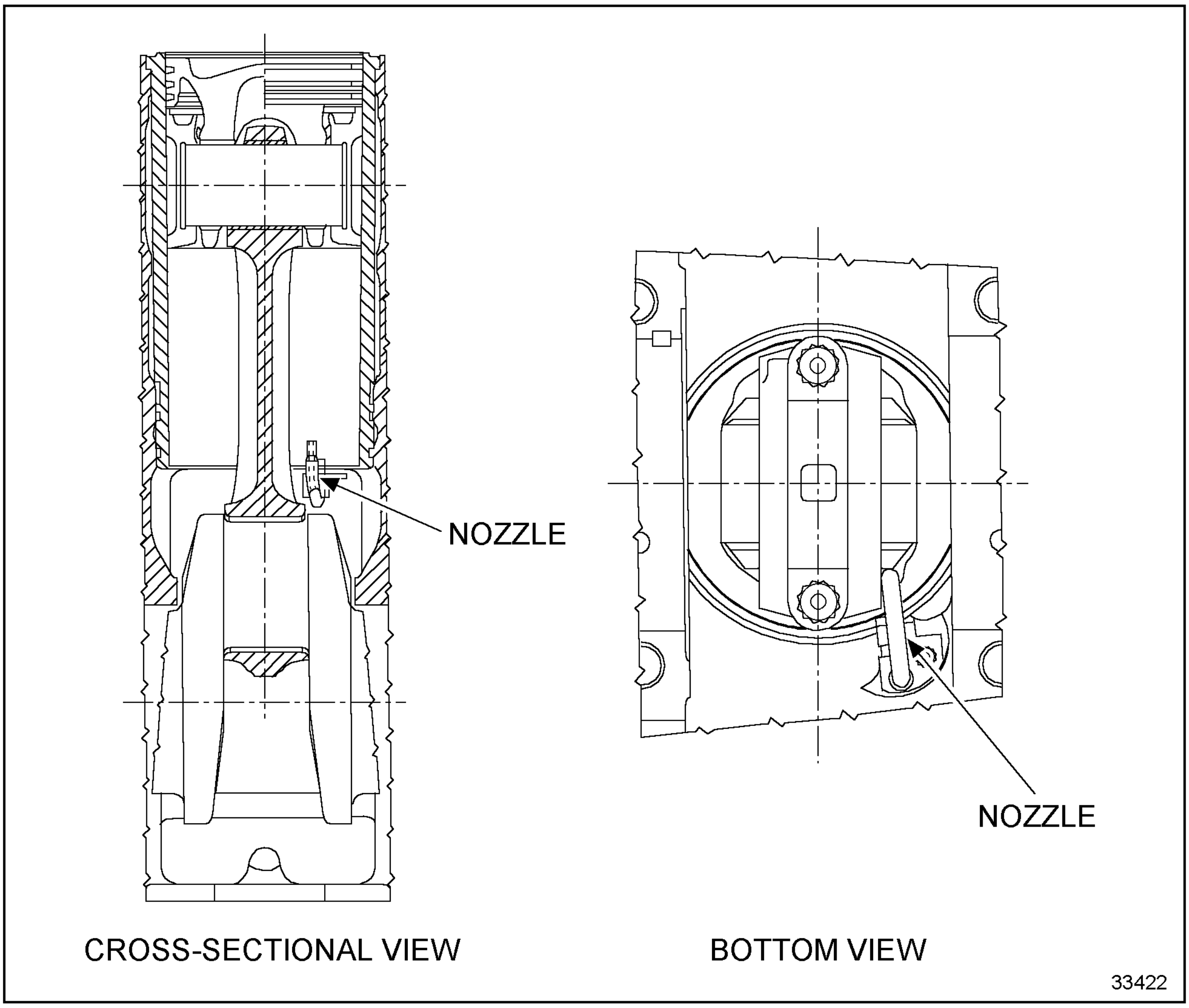


Figure 1-17 Oil Spray Nozzle Location

6. Install all of the required cup plugs. Use a good grade of non-hardening sealant such as Loctite 620 (or equivalent). Apply a thin coat of sealant just inside the chamfer

where the plug is to be installed and install using cup plug installation tool set, J 35653. See Figure 1-18.

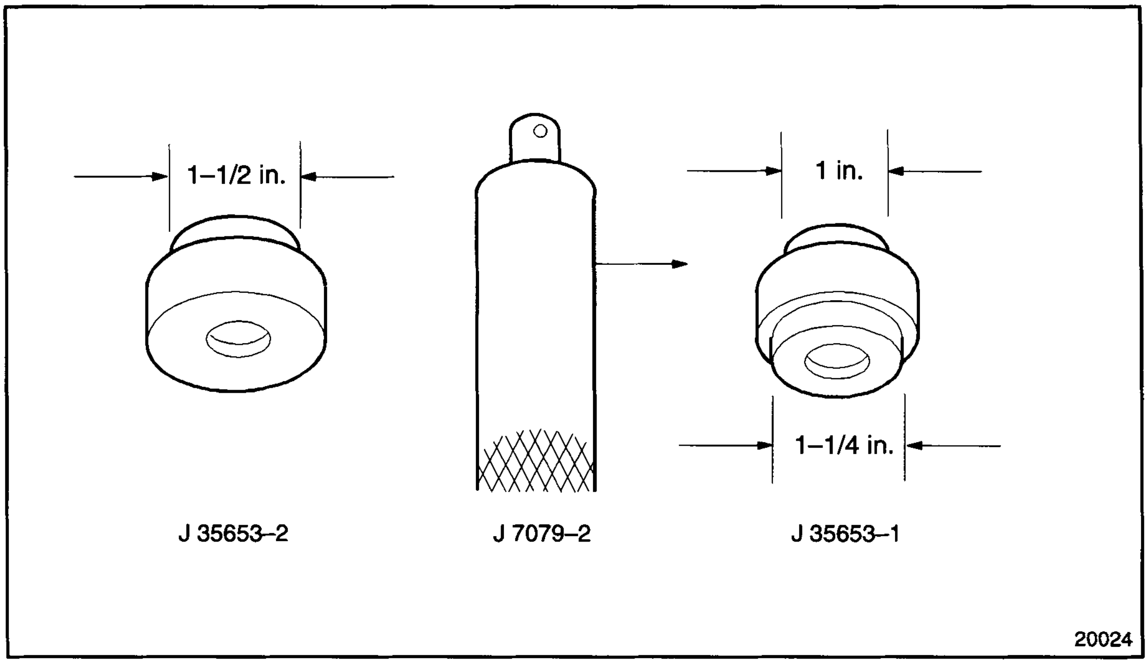


Figure 1-18 Cup Plug Installation Tool Set

7. Install all of the required pipe plugs.

NOTE:
Whenever a pipe plug is installed, the threads must be coated with Loctite, J 26558-92 part of PT-7276, pipe sealant with Teflon, or equivalent, before reassembly. Certain plugs available from the parts depot already have a sealer applied to the threads. Although unnecessary, this pre-coating will not be affected if pipe sealer with Teflon is also applied.

8. Install the crankshaft main bearings, refer to Section 1.9.3.
9. Install the crankshaft, refer to Section 1.7.3.
10. Install cylinder liners if removed, refer to Section 1.20.3.
11. Install the piston and connecting rod assembly, refer to Section 1.18.5.
12. Install the oil pan, refer to Section 3.9.3.
13. Install the flywheel housing, refer to Section 1.16.3.
14. Install the flywheel, refer to Section 1.14.3.
15. Install the cylinder head, refer to Section 1.2.5.
16. Install the camshaft, refer to Section 1.22.5.
17. Install the gear case, refer to Section 1.11.3.

18. Install crankshaft timing gear and timing wheel, refer to Section 1.27.3.
19. Install the adjustable idler gear assembly, refer to Section 1.25.3.
20. Install bull gear and camshaft idler gear assembly, refer to Section 1.26.3.
21. Install the camshaft drive gear, refer to Section 1.24.3.
22. Install the gear case cover, refer to Section 1.10.3.
23. Install the accessory drive, refer to Section 1.29.5.
24. Install the vibration damper, refer to Section 1.12.3.
25. Install the crankshaft pulley, refer to Section 1.13.3.
26. Install the engine lifter brackets, refer to Section 1.5.3.
27. Install the valve rocker cover, refer to Section 1.6.6 and refer to Section 1.6.7.
28. Install any electrical components, connectors or wiring looms that were removed during disassembly.
29. Install the SRS synchronous reference sensor, refer to Section 2.20.3.
30. Install the TRS timing reference sensor, refer to Section 2.21.3.
31. Install the ECM electronic control module and cold plate if required. Refer to Section 2.11.3 for DDEC III ECMs; refer to Section 2.12.4 for DDEC II ECMs.
32. Install a suitable lifting device to the engine. See Figure 1-5.

CAUTION:

To avoid injury from a falling engine, ensure the engine is securely attached to the engine overhaul stand before releasing the lifting sling.

33. Remove the engine from the engine overhaul stand. See Figure 1-6.

Transfer the engine to an engine dynamometer test stand. Operate the engine following the Run-in procedure; refer to Section 11.8.2.

Reinstall the engine in the equipment from which it was removed.

1.2 CYLINDER HEAD

The Series 50 Engines cylinder head combines intake and exhaust valve porting and fuel injector seats with water jacketing to cool the ports, injectors and combustion chamber area. See Figure 1-19.

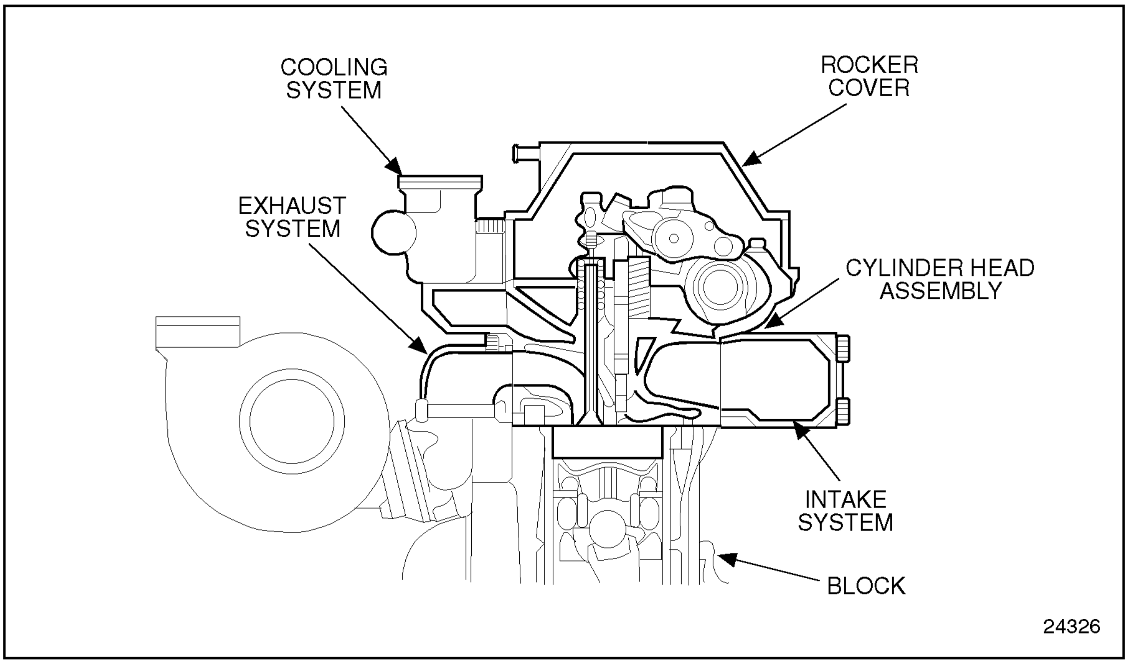
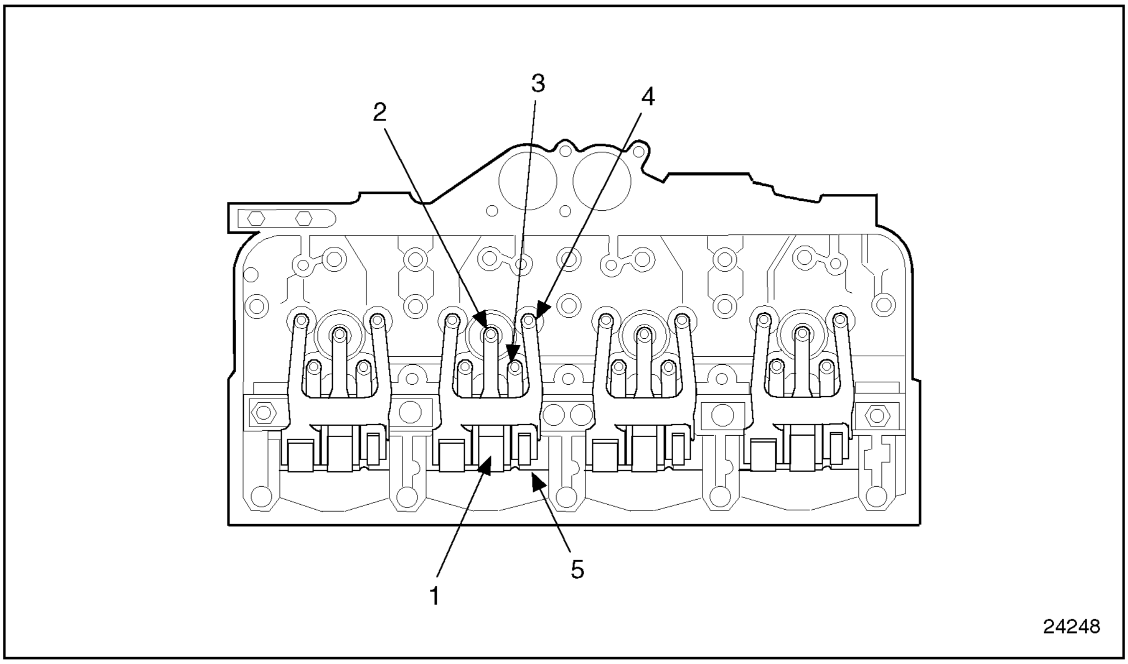


Figure 1-19 Cylinder Head Assembly and Mating Components

With the overhead camshaft design, the cylinder head assembly includes:

- ☐ Cylinder head
- ☐ Valve and injector operating mechanism
- ☐ Injector, valve guide and related parts
- ☐ Camshaft and camshaft bearings

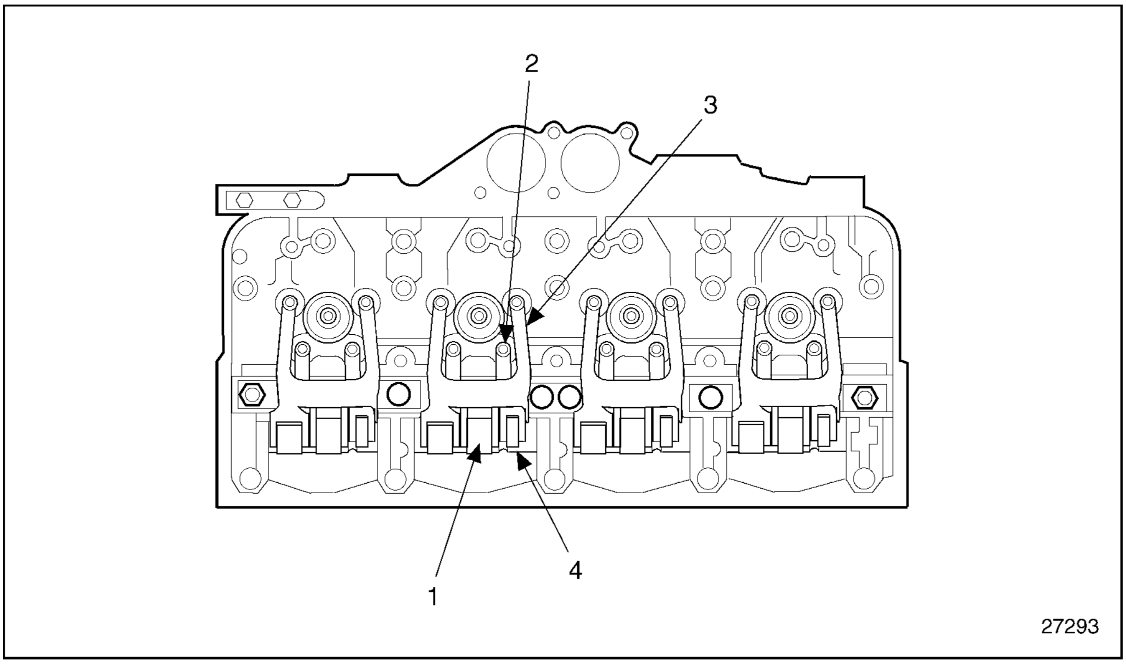
The nested roller follower type rocker arms transmit cam motion directly to the valves and injectors. See Figure 1-20.



1. Roller Follower
2. Injectors
3. Intake Valve Rocker Arm
4. Exhaust Valve Rocker Arm
5. Camshaft

Figure 1-20 Cylinder Head Assembly

The nested roller follower type rocker arms transmit cam motion directly to the valves. See Figure 1-21.



1. Roller Follower
2. Intake Valve Rocker Arm
3. Exhaust Valve Rocker Arm
4. Camshaft

Figure 1-21 Cylinder Head Assembly (Series 50G)

The porting within the cylinder head is cross-flow, with intake and exhaust ports on opposite sides for minimum restriction and maximum exposure to coolant flow. Four valves are used per cylinder, two intake and two exhaust. See Figure 1-22.

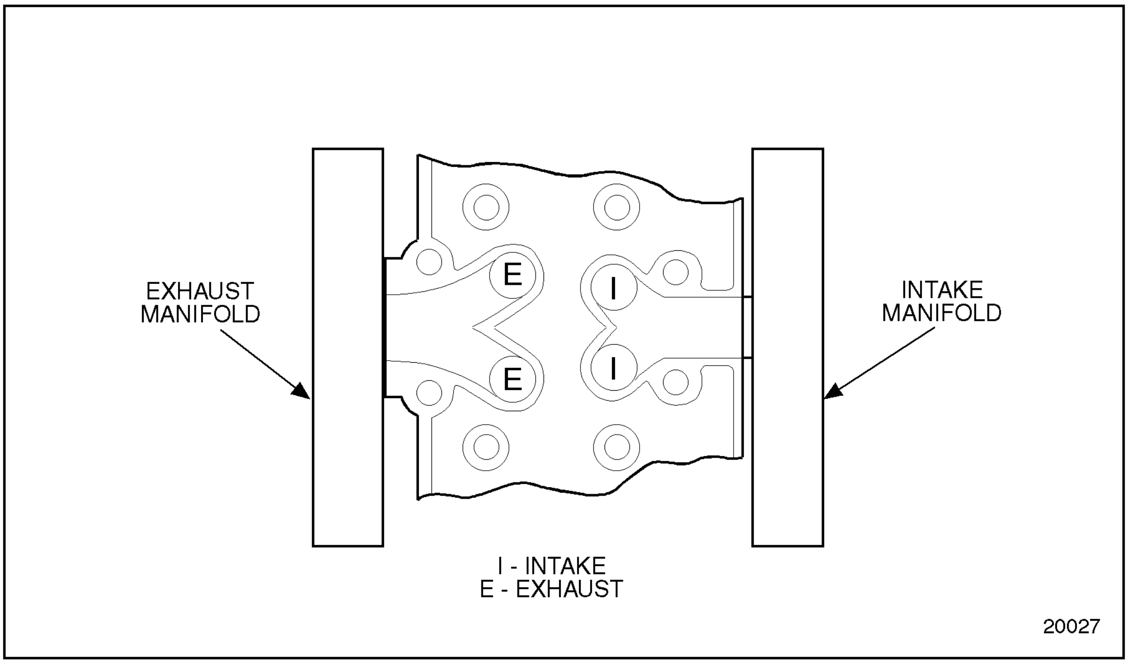
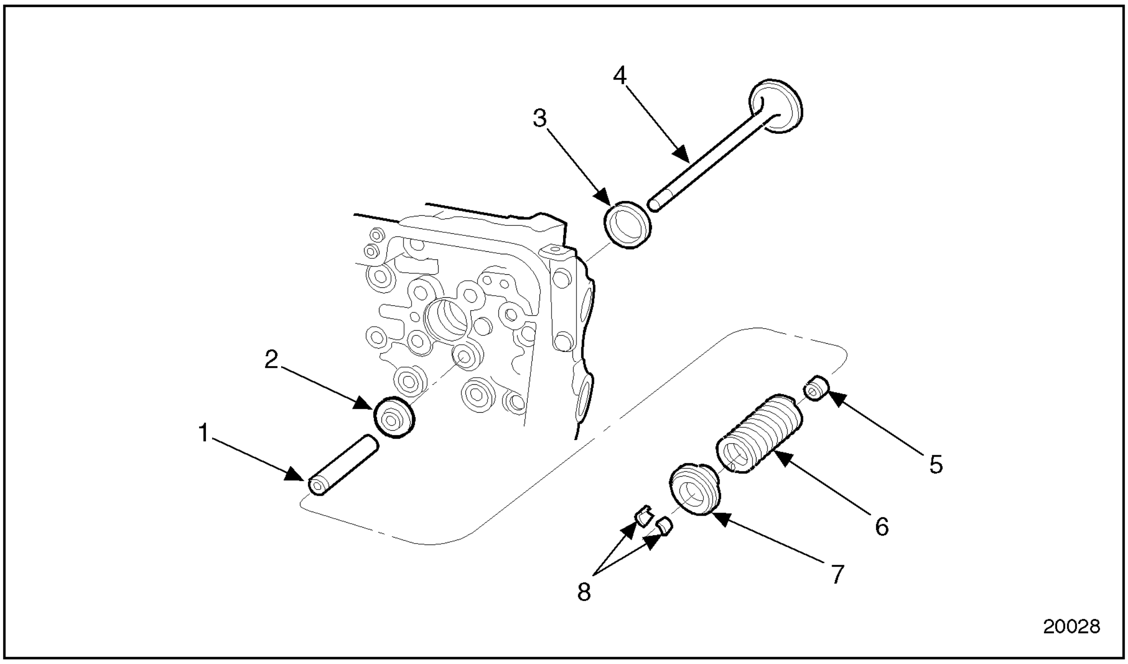


Figure 1-22 Intake and Exhaust Valve Porting

Replaceable valve guides, valve spring seats, valve stem seals, valve rotators and valve seat insert are used on all valves. See Figure 1-23.



1. Valve Guide
2. Valve Spring Seat
3. Valve Seat Insert
4. Valve
5. Valve Stem Oil Seal
6. Valve Spring
7. Valve Rotator
8. Valve Keepers

Figure 1-23 Valve, Valve Guides and Related Parts

Copper injector tubes (not required on natural gas engines) extending through the cylinder head water jacket are required for the fuel injectors. The tubes are directly exposed to the coolant. An O-ring seals the injector tube upper end in the recess. The lower end of the injector tube must be expanded and flared during the installation process to contain a tight fit in the firedeck bore. A beveled seat machined in the tube provides a compression-tight seal when the injector is seated, as well as affording effective heat transfer facilitating injector cooling. Refer to Section 2.4.

Fuel galleries machined into the head supply fuel under fuel pump pressure to all injectors, and excess fuel is returned to the fuel tank. The fuel gallery outlet (restricted) fitting is installed in the rear of the cylinder head. See Figure 1-24.

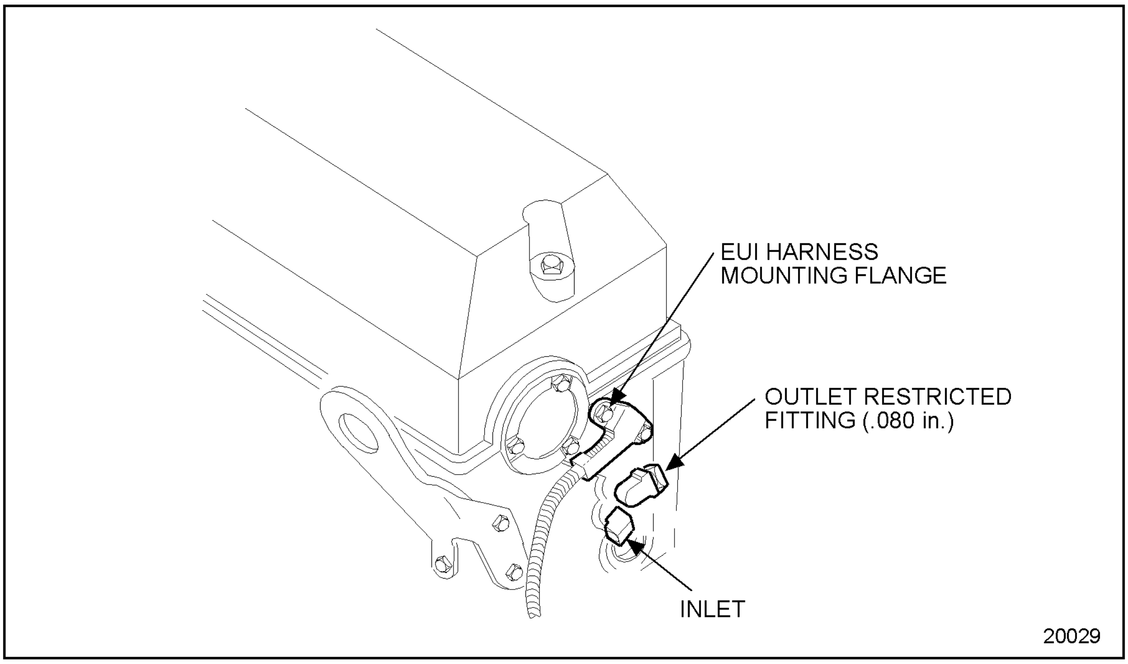


Figure 1-24 Fuel Gallery Inlet and Outlet Fittings

1.2.1 Repair or Replacement of Cylinder Head

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-25.

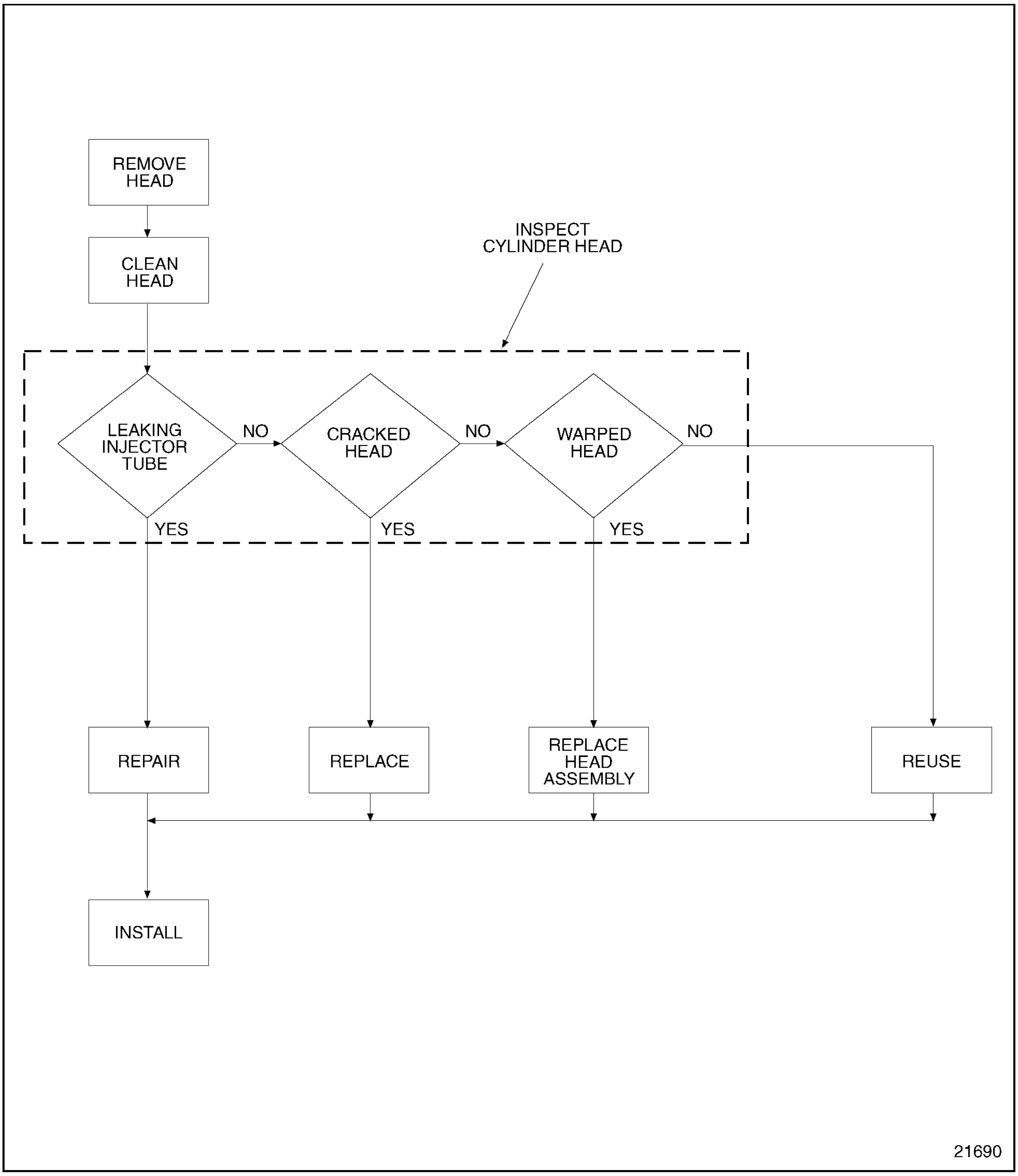


Figure 1-25 Flowchart for Repair or Replacement of Cylinder Head

1.2.2 Removal and Cleaning of Cylinder Head

Because optional and accessory equipment varies with the engine application, this procedure covers only the basic engine. If the engine is equipped with accessories that affect cylinder head removal, note the mounting details of each to assure correct installation at reassembly.

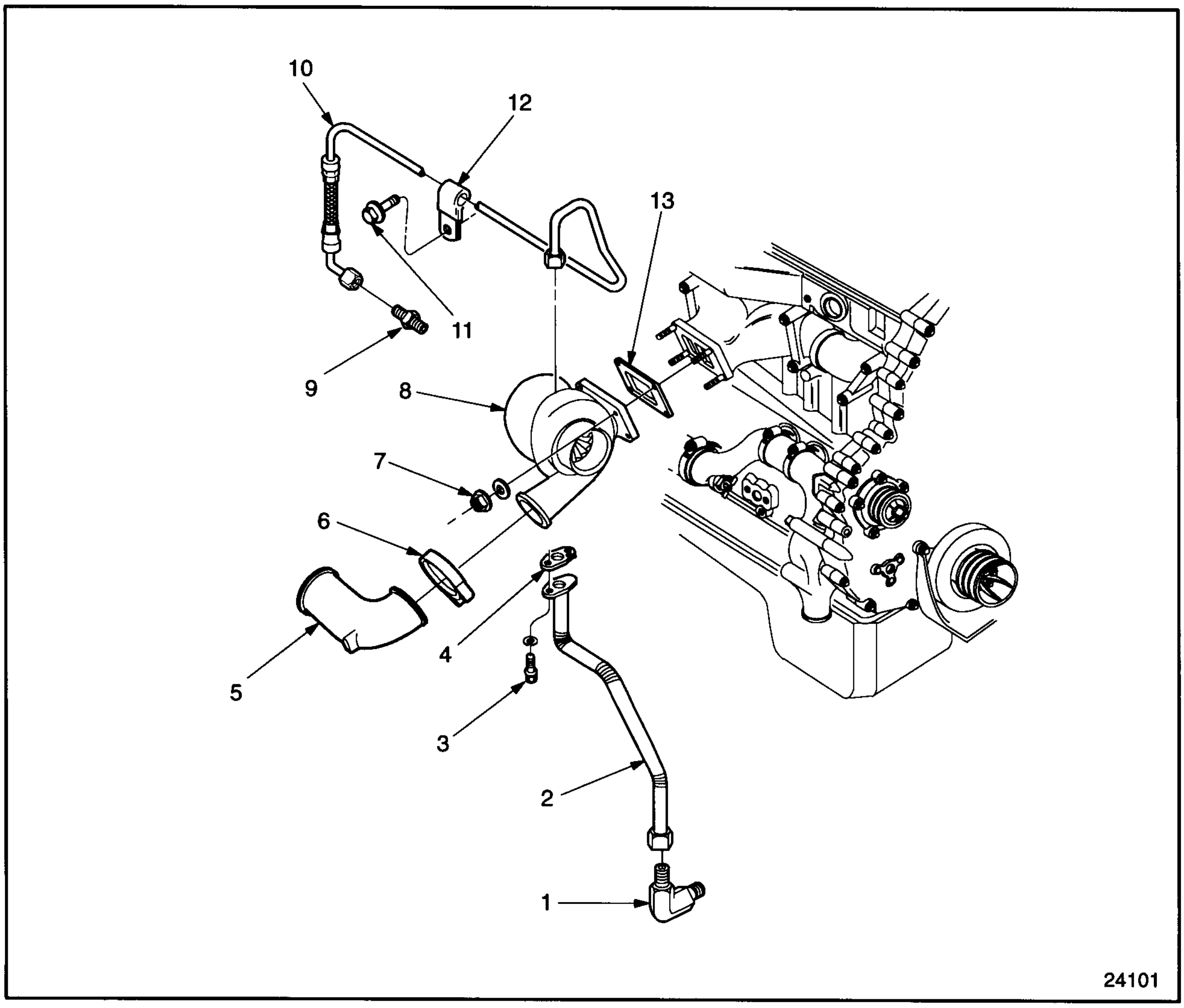
Remove the cylinder head as follows:

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

1. With the engine at ambient temperature and cool to the touch, drain the cooling system. Refer to Section 13.5.4.
2. Disconnect the exhaust pipe at the turbocharger. See Figure 1-26.
3. Remove the air cleaner and charge air cooler ducting from turbocharger and intake manifold. Refer to Section 6.2.2 and refer to Section 6.7.

4. Disconnect the turbocharger oil supply and drain lines, and remove the turbocharger if necessary. See Figure 1-26.

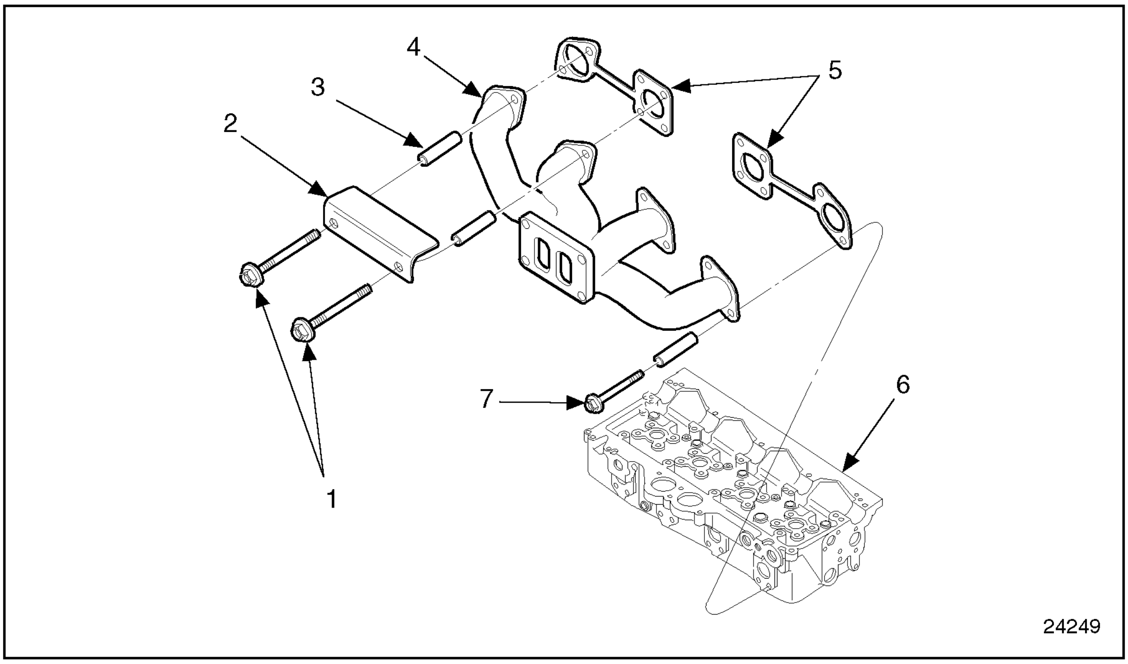


1. Elbow, Oil Drain Tube
2. Tube, Turbo Oil Drain
3. Bolt, Oil Drain Tube Mounting
4. Gasket, Turbo Oil Drain Tube
5. Elbow (Coach Models only)
6. Clamp (Coach Models only)
7. Nut, Turbo Mounting
8. Turbocharger Assembly
9. Connector, Oil Supply Tube (from oil filter adaptor)
10. Tube Assembly, Turbo Oil Supply
11. Bolt, Oil Supply Tube Clip
12. Clip, Oil Supply Tube
13. Gasket, Turbo Exhaust Inlet

Figure 1-26 Turbocharger Oil Lines

5. Seal the turbocharger compressor inlet and discharge with covers or masking tape. Plug the oil supply fitting in the turbocharger housing.

6. Remove the exhaust manifold if necessary. Refer to Section 7.2.2. See Figure 1-27.

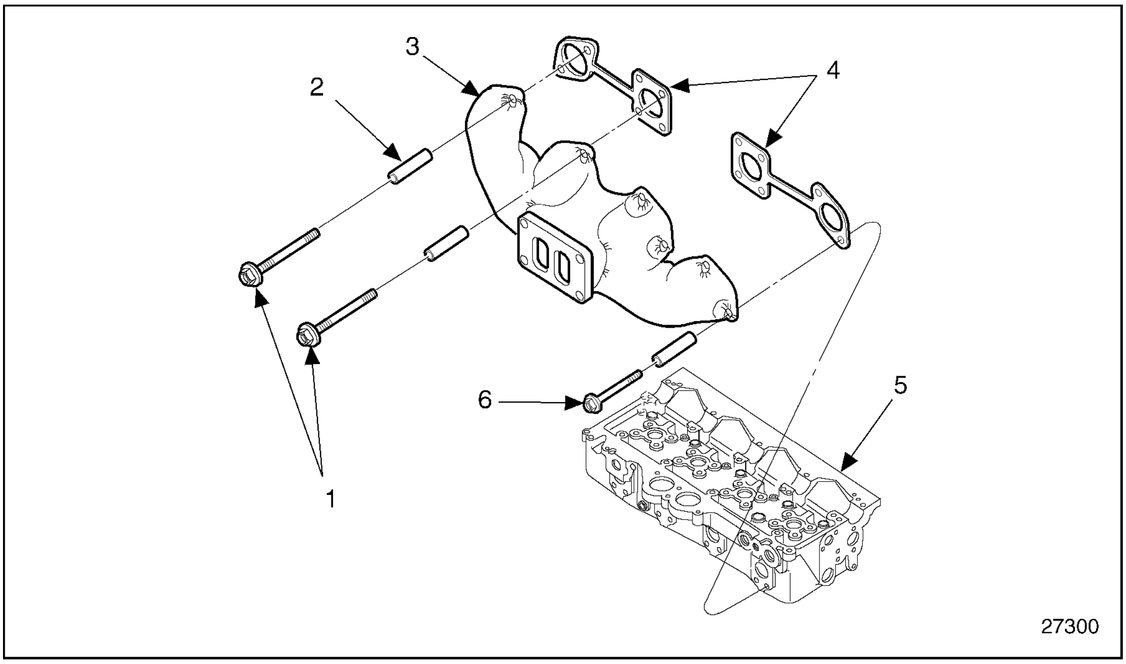


1. Nut
2. Heat Shield
3. Sleeves
4. Exhaust Manifold
5. Gaskets
6. Cylinder Head
7. Bolt

Figure 1-27 Exhaust Manifold

NOTE:

Exhaust manifolds on natural gas engines are thermal wrapped for efficiency. See Figure 1-28.

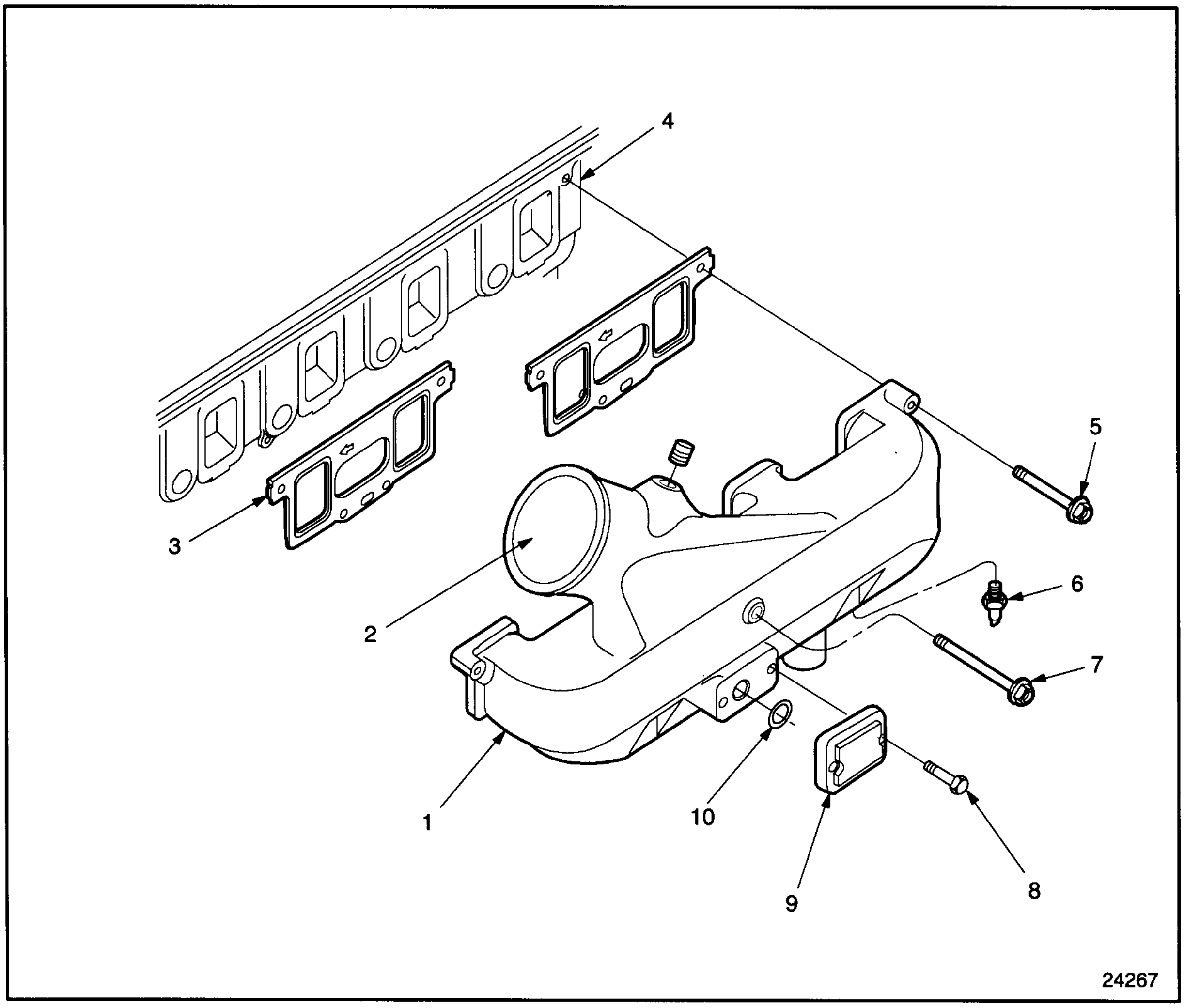


1. Nut
2. Sleeves
3. Exhaust Manifold (Thermo Wrapped)
4. Gaskets
5. Cylinder Head
6. Bolt

Figure 1-28 Exhaust Manifold (Series 50G)

7. Inspect the exhaust manifold. Refer to Section 7.2.2.1.

8. Remove and inspect the intake manifold. See Figure 1-29.

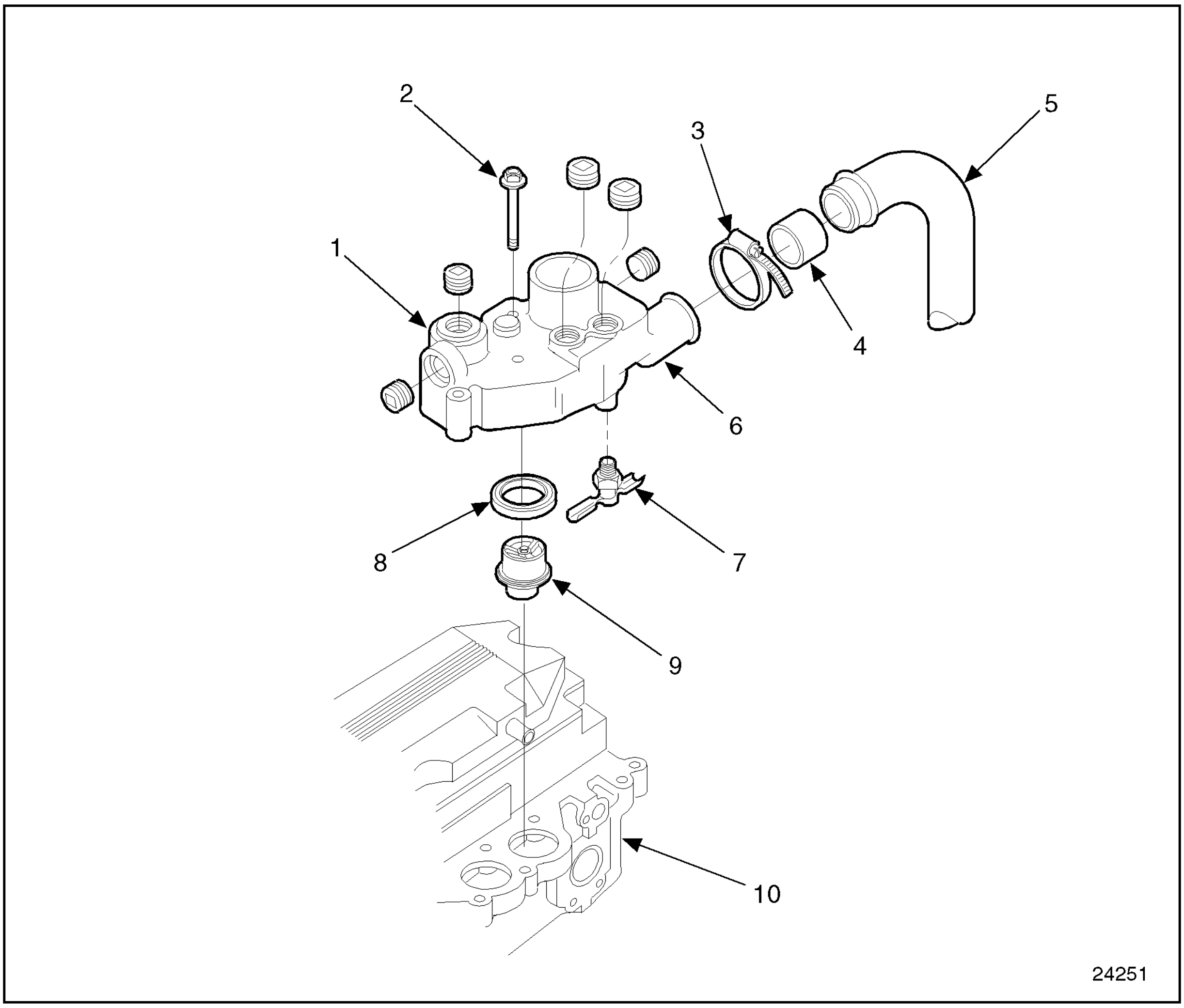


1. Intake Manifold
2. Air Inlet
3 Intake Manifold Gasket (2)
4. Cylinder Head
5. Short Bolt (2)
6. Air Temperature Sensor (DDEC III only)
7. Manifold Bolt (7)
8. Turbo Boost Pressure Sensor Bolt (2)
9. Turbo Boost Pressure Sensor
10. O-ring

Figure 1-29 Intake Manifold and Related Parts

9. Open the drain cock in the bottom of the thermostat housing to allow the coolant in the housing to drain.

10. Disconnect radiator, bypass pipe and hose clamps, and remove the thermostat housing.Refer to Section4.3.2 and see Figure 1-30 .



1. Vent
2. Thermostat Housing-to-Cylinder Head Bolts (4)
3. Hose Clamps (2)
4. Coolant Hose
5. Bypass Tube
6. Thermostat Housing Cover
7. Drain Cock
8. Thermostat Housing Seals (2)
9. Thermostat (2)
10. Cylinder Head

Figure 1-30 Thermostat Housing Removal

11. Remove the valve rocker cover. Refer to Section 1.6.2.
12. Disassemble the valve rocker cover. Refer to Section 1.6.3.
13. Inspect the valve rocker cover. Refer to Section 1.6.3.1.

14. Remove Jacob's Brakes, if equipped. Refer to Section 1.30.2.

NOTE:
Using the camshaft gear pilot tool, J 35906, pull the camshaft gear and thrust plate forward in the gear case until there is approximately a 6.35 mm (1/4 in.) gap between the cylinder head and the diamond-shaped camshaft thrust plate seal when removing the cylinder head. See Figure 1-31.

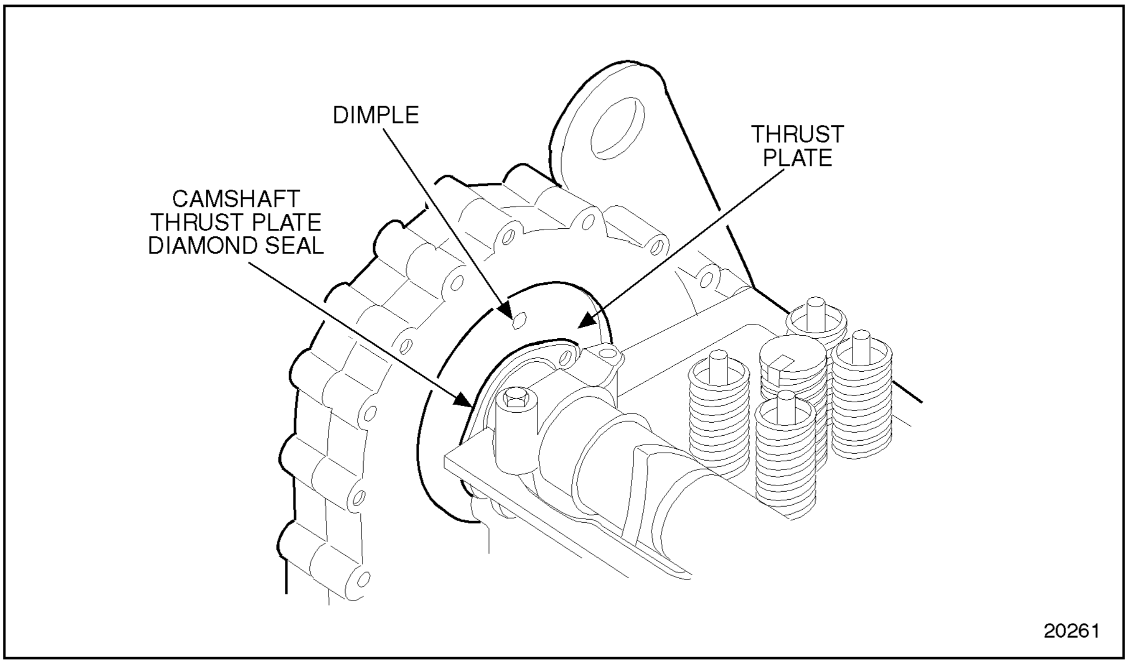


Figure 1-31 Camshaft Thrust Plate

15. Remove the rocker arm assemblies. Refer to Section 1.3.2.
16. Inspect the rocker arm assemblies and camshaft lobes. Refer to Section 1.3.3.1.
17. Remove the camshaft. Refer to Section 1.22.2.

NOTE:
Fuel must be removed from the cylinder head fuel galleries prior to removing the injectors.

18. Disconnect the fuel inlet and outlet lines at the rear of the cylinder head. See Figure 1-32.

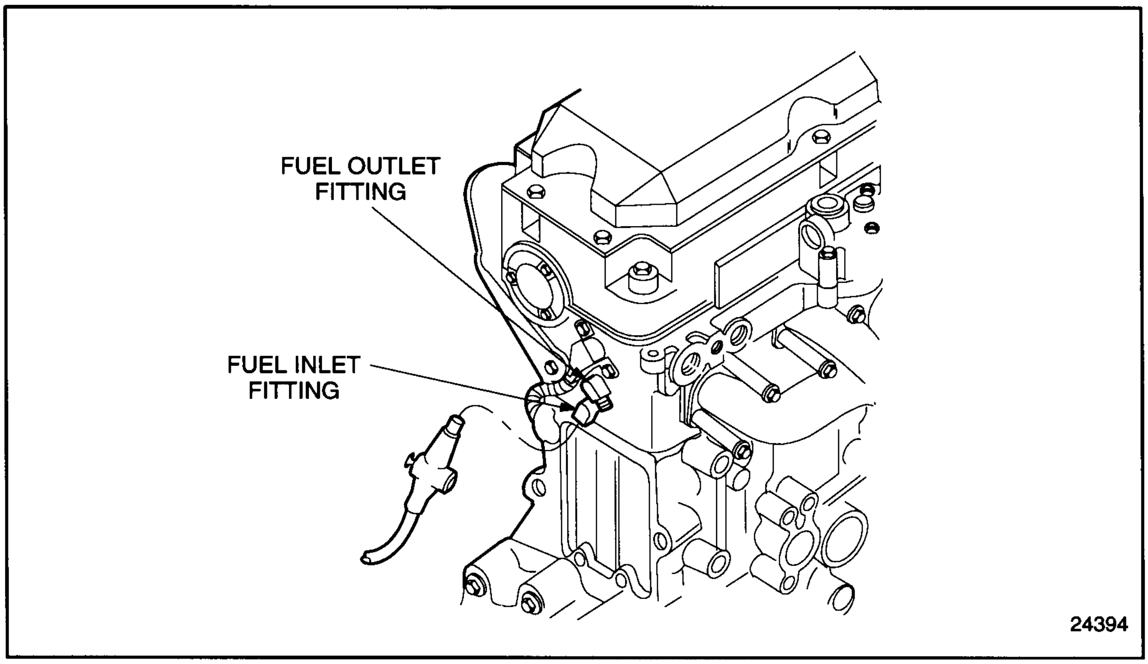


Figure 1-32 Removing Fuel from Cylinder Head Internal Passages

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

19. Blow low pressure compressed air into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head.
20. Disconnect the injector wire harness at each injector. Refer to Section 2.3.2.
21. Remove the harness mounting flange from the rear of the cylinder head and carefully remove the harness from the head by pulling the harness through the hole in the cylinder head. See Figure 1-24.

NOTICE:

To avoid possible damage to the injector spray tips, remove the injectors before lifting the head from the block. If the injectors are not removed, handle the head carefully when it is off the block and support the head firedeck on wooden blocks.

22. Remove the fuel injectors. Refer to Section 2.3.2.
23. Remove the gear case stabilizer bracket at the right front corner of the head.

24. Remove the head bolts and install the cylinder head lift bracket, J 35641-A, using the bolt hole at the inboard center, No. 3 cam cap and two tapped Jacob's Brake bolt holes. See Figure 1-33.

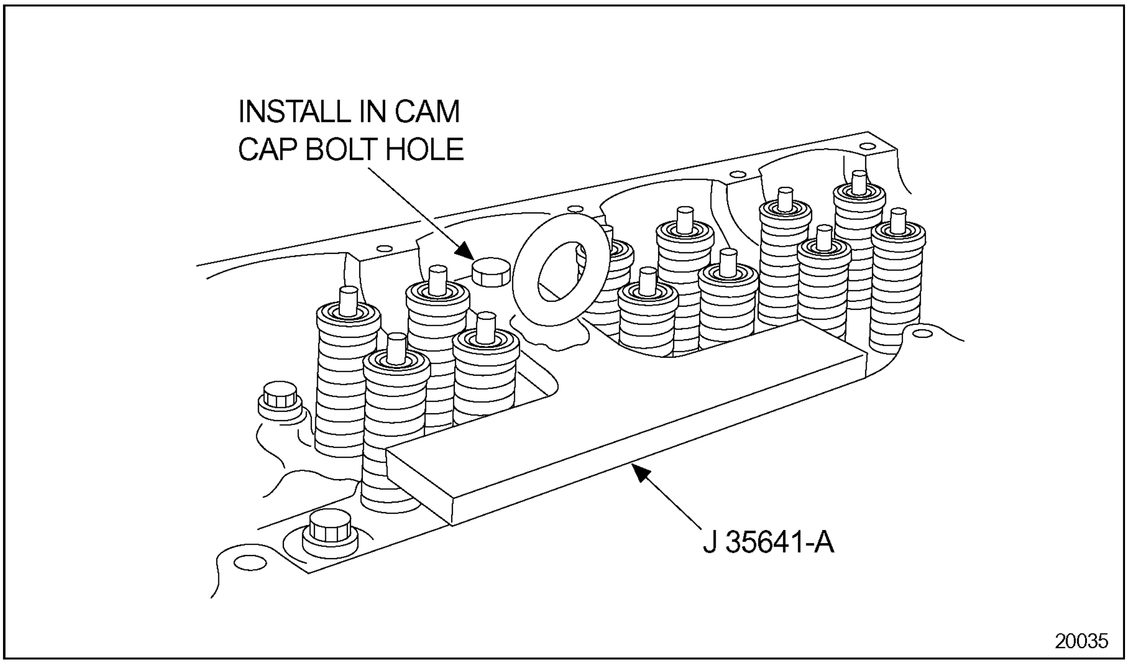


Figure 1-33 Cylinder Head Lift Bracket Installation

25. Attach a suitable lifting hook to the eyelet in the lift bracket, and lift the cylinder head off the engine. See Figure 1-34.

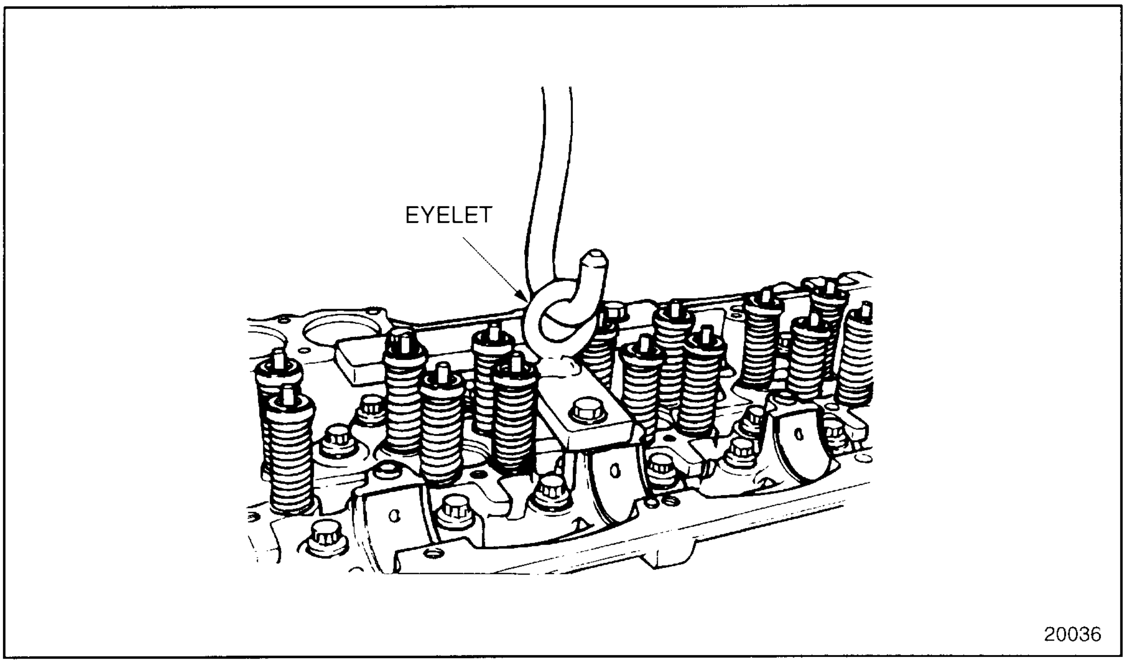


Figure 1-34 Cylinder Head Removal

26. Drain the engine lubricating oil to remove any coolant that may have drained into the oil pan when the water jacket was opened. Remove any coolant from the cylinder bores.

Clean the cylinder head as follows:

1. Keep parts segregated according to original position to assure proper reassembly, if parts are to be reused.
2. Remove all threaded plugs.
3. Steam clean the cylinder head once it has been stripped.
4. If coolant passages are heavily coated with scale, remove the injector tubes and cup plugs and clean the head in a descaling bath, as described under "Removal of Engine from the Vehicle and Disassembly". Refer to Section 1.1.2.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

5. Clean the camshaft and camshaft bearings, valves, springs, valve rotators and rocker arm shafts in fuel oil and blow dry with compressed air.
6. Refer to Section 1.3.2 for cleaning of rocker arm and roller follower assemblies.

1.2.3 Inspection of Cylinder Head

The following steps must be performed before inspecting the cylinder head:

1. Replace the plugs removed for cleaning. If the old plugs are reused, coat the plugs with Loctite; pipe sealant, J 26558-92 part of PT-7276: with Teflon; or equivalent.

NOTE:
If both front fuel galley plugs have been removed, it will be necessary to replace both plugs.

2. If injector tubes have been removed, install new injector tubes. Refer to Section 2.4.5.
3. Install new cup plugs using a good grade non-hardening sealant such as Loctite 620 or equivalent.

Perform the following tests for cylinder head inspection.

- ☐ Pressure test, refer to Section 1.2.3.1
- ☐ Firedeck straightness test, refer to Section 1.2.3.2

1.2.3.1 Pressure Test

Perform the following steps to pressure test the cylinder head:

1. Install the test strips (part of cylinder block pressure test kit) to the firedeck on the cylinder head. See Figure 1-35.

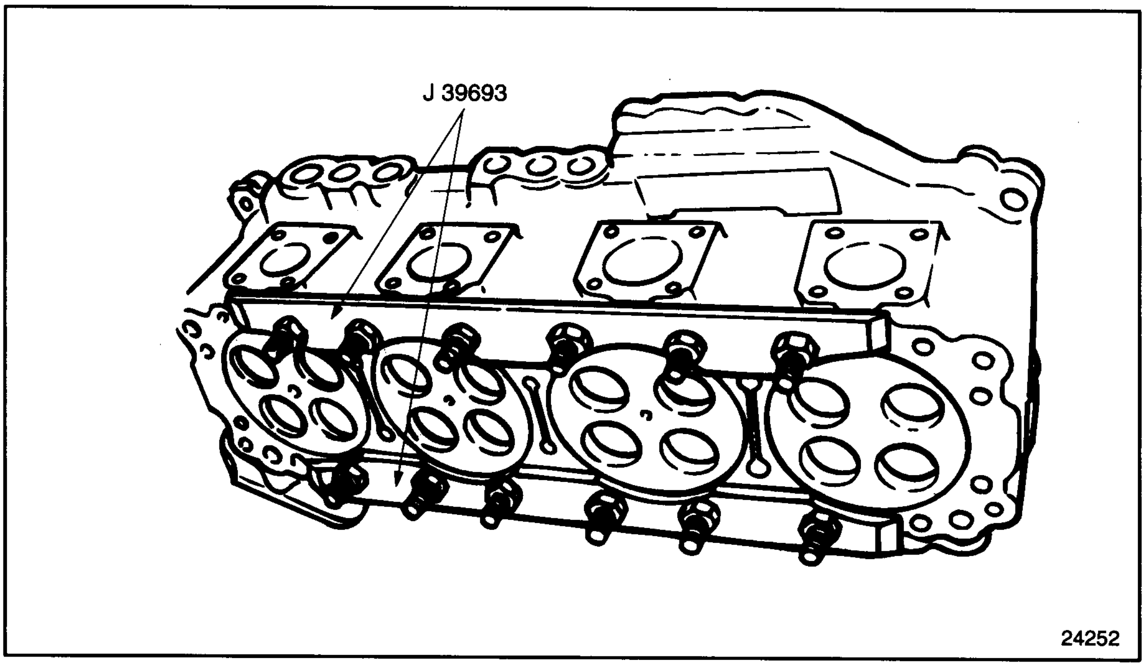


Figure 1-35 Cylinder Head Pressure Test Equipment Installation

2. Insert the cylinder head bolts through the cylinder head and test strips. Attach and torque the nuts (supplied in J 36223-D) to 14 N·m (10 lb·ft).

3. Install the thermostat opening cover plate, J 35984-2 and gasket to the cylinder head using the bolts provided with the cover plate. See Figure 1-36.

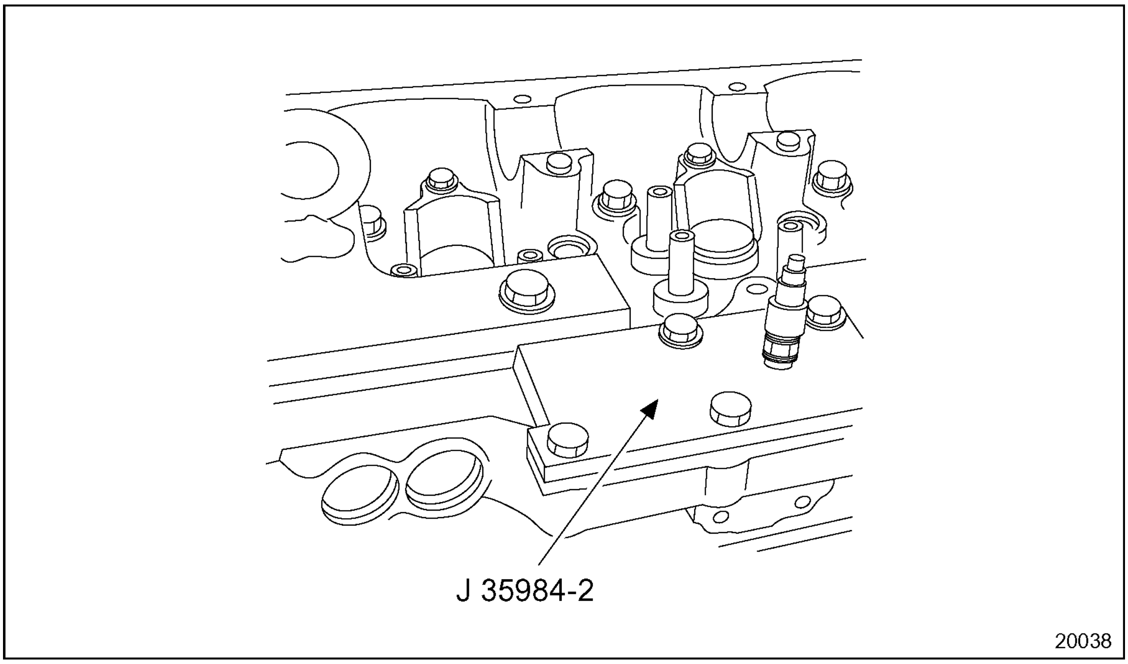


Figure 1-36 Thermostat Opening Cover Plate Installation

4. Install dummy fuel injectors, J 35984-1, to the injector bores to assure proper seating of the fuel injector tubes. See Figure 1-37.

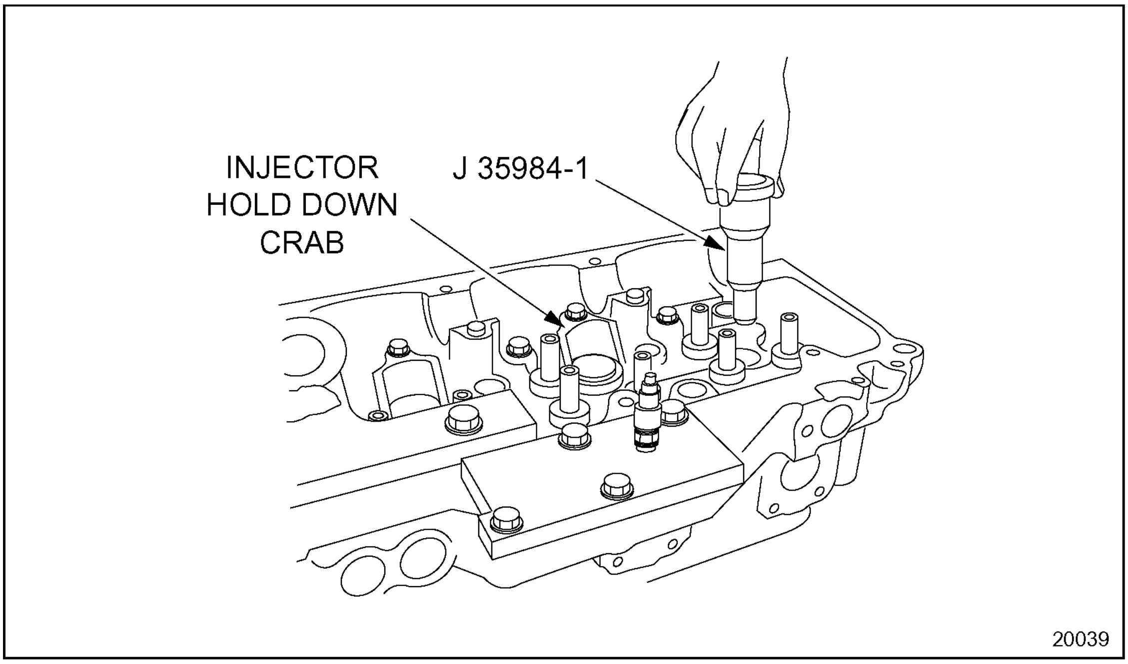


Figure 1-37 Test Injector Installation

5. Install the fuel injector crabs and hold-down bolts. Torque the bolts to 58-66 N ·m (43-49 lb·ft).
6. Attach an air hose to the fitting on the thermostat opening cover plate.
7. Apply 207 kPa (30 lb/in.^{2}) air pressure to the cylinder head and immerse the head in a water bath heated to 82-93°C (180-200°F).
8. Leave the head in the bath for at least 20 minutes to heat thoroughly, while watching for bubbles indicating a crack or leak. Injector tube leaks can be stopped by replacing tubes.
   [a] If an injector tube leaks, replace tube(s). Refer to Section 2.4.2 for removal and refer to Section 2.4.5 for replacement.
   [b] If a cracked head is detected, replace the head. Refer to Section 1.2.1.

1.2.3.2 Inspection and Rework for Firedeck Straightness

The large mass and length of the head casting may contain longitudinal warp after it is unbolted and removed from the engine block. At the time of factory manufacture, the longitudinal warp is normalized by fixturing and clamping the casting during machining. The casting is fixtured and clamped from its locating surfaces (datums). When unclamped, the head casting resumes its original shaped until it is bolted and tightened to the engine block.

Inspect the bottom (firedeck) of the cylinder head for straightness as follows:

1. Use a heavy, accurate straight-edge and feeler gages to check for transverse and longitudinal warpage. See Figure 1-38.

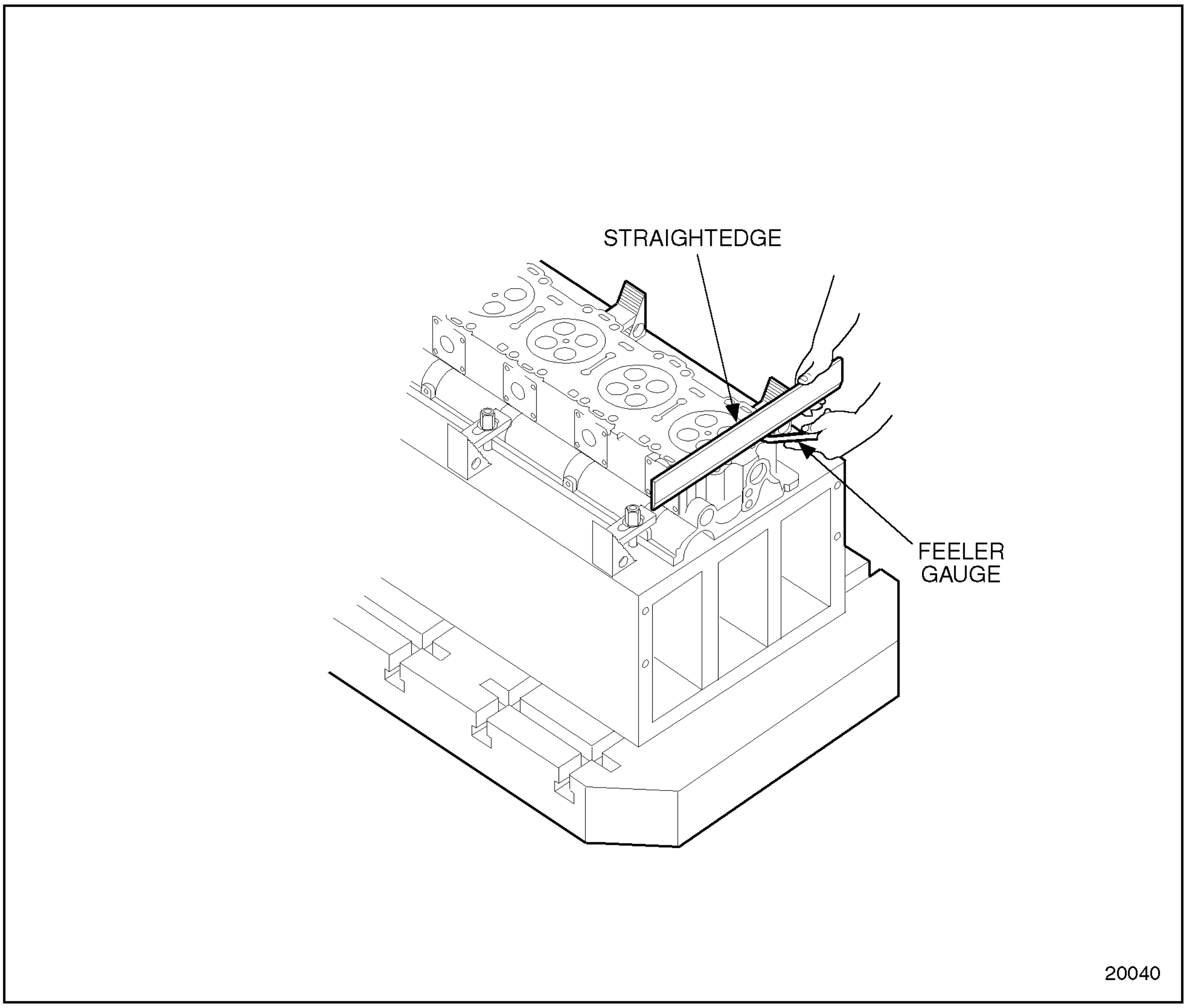


Figure 1-38 Checking Firedeck Straightness

2. Also, check for longitudinal warpage in five places and transverse warpage in 8 places, indicated as A through H in the next illustration. See Figure 1-39.

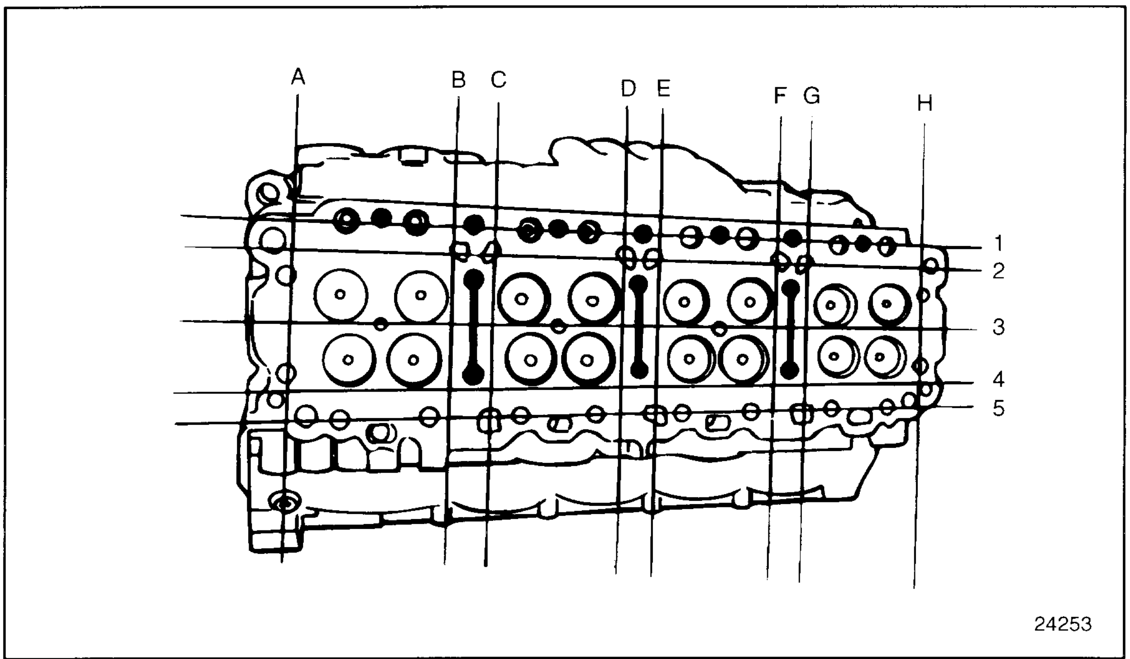


Figure 1-39 Cylinder Head Measurement Locations

3. The natural warp contained in the casting must be considered when inspecting firedeck straightness with the head unbolted and unclamped. Natural warpage is not a cause for correction. The firedeck (unclamped) must be straight within 0.120 mm (0.005 in.) front-to-rear and 0.076 mm (0.003 in.) side-to-side.

   [a] If the cylinder head flatness is outside of the specifications, Detroit Diesel Corporation **does not**recommend firedeck resurfacing.

1.2.3.3 Head Bolt Counterbore Inspection and Rework

To assure clean and non-brinnelled cylinder head bolt counterbores, use tool J 38189 to resurface the head bolt washer area.

The procedure and steps for proper use of the tool are as follows:

NOTICE:
There must be no space between the bottom of the cylinder head and the table top to properly resurface the counterbores.

1. Place the cylinder head on a solid flat surface (preferably a steel table top) that completely covers the bottom of head.

NOTICE:
Proper use of the J 38189is important. Failure to use J 38189 properly, may result in an incorrect counterbore depth.

2. Protect the valve springs and injector counterbore to keep any loose metal shavings from getting into valve springs and counterbore during cutting operation.
3. With cylinder head on a flat surface using the 3.17 mm (1/8 in.) hex wrench supplied with tool, loosen the stop collar and cutter to permit sliding on pilot.
4. Starting at the front of the cylinder head, place the pilot of the cutter into a cylinder head bolt hole until the pilot contacts the flat surface beneath the cylinder head.
5. Allow the cutter to contact the counterbore surface. Lock the stop collar while against the cutter. The cutter now will resurface the counterbore 0.5 mm (0.020 in).
6. Remove the tool and place a 0.5 mm (0.020 in.) feeler gage between the cutter and the locked stop collar.
7. With feeler gage in place, lock the set screw of the cutter, then remove the feeler gage and loosen the set screw on the stop collar and slide it down tight against the cutter and retighten.

Perform the following steps to resurface the counterbore 0.5 mm (0.020 in.):

1. Using a drill motor with a 1/2 in. chuck and a **maximum** of 450 r/min and a suitable cutting oil to prolong the life of the cutter and to lubricate the pilot turning in bolt hole.
2. Apply a moderate pressure on the drill motor, continue cutting operation until pilot bottoms on flat surface and then do not stop drill motor until it is lifted from cutting surface. This is to eliminate surface marks.

NOTE:
The J 38189 tool pilot has a shoulder stop that will not allow the cutter to remove material in excess of the Detroit Diesel Corporation specifications.

3. If some of the bolt holes do not clean up completely, continue resurfacing remaining holes, repeating the operation in 0.5 mm (0.005 in.) increments. This will clean up any holes that may not have cleaned up completely during the first cut.
4. After all counterbores have been resurfaced, remove any loose cutting chips.
5. Steam clean the complete cylinder head.
6. After steam cleaning, inspect the cylinder head for any remaining chips.
7. Reinstall the cylinder head assembly, using 26 of the new ground head bolt washers.

1.2.4 Assembly of Cylinder Head

Perform the following steps for cylinder head assembly:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

If the cylinder head is to be replaced, the new head must be thoroughly cleaned before installation to remove all rust preventive compound, especially from the fuel and oil galleries. This can be done by immersion in a bath of fuel oil or mineral-spirits-based solvent and scrubbing out all openings with a soft bristle brush. When clean, blow the head dry with compressed air.

1. Install new precoated pipe plugs or coat the used plugs with pipe sealant with Teflon, PT-7271, or equivalent, and tighten them as listed in Table 9 which can be found in the "General Information" section at the beginning of the manual.
2. Install all of the required cup plugs using a good grade of non-hardening sealant, such as Loctite 620 or equivalent, on the cup plugs. Use cup plug installation tool set, J 35653.
3. Be sure that all cup and pipe plugs on the front face of the cylinder head are flush or below the surface.
4. Install valve guides and seats, valves, valve stem seals, valve springs and rotators. Refer to Section 1.4.

1.2.5 Installation of Cylinder Head

Perform the following steps for cylinder head installation:

1. Be sure piston domes and the cylinder head and cylinder block firedeck surfaces are clean and free of foreign matter. Inspect the head bolt holes in both block and head for the presence of oil, water, dirt, or damaged threads, and clean or retap as necessary.

NOTE:
Series 50 Engines built after September 2002 will use a new cylinder head gasket. This gasket will be identified with a new part number and date code. This new gasket must be used with the new cylinder head bolts.

2. Position the head gasket on the block and install cylinder head guide studs, J 35784, at front and rear of the block. See Figure 1-40.

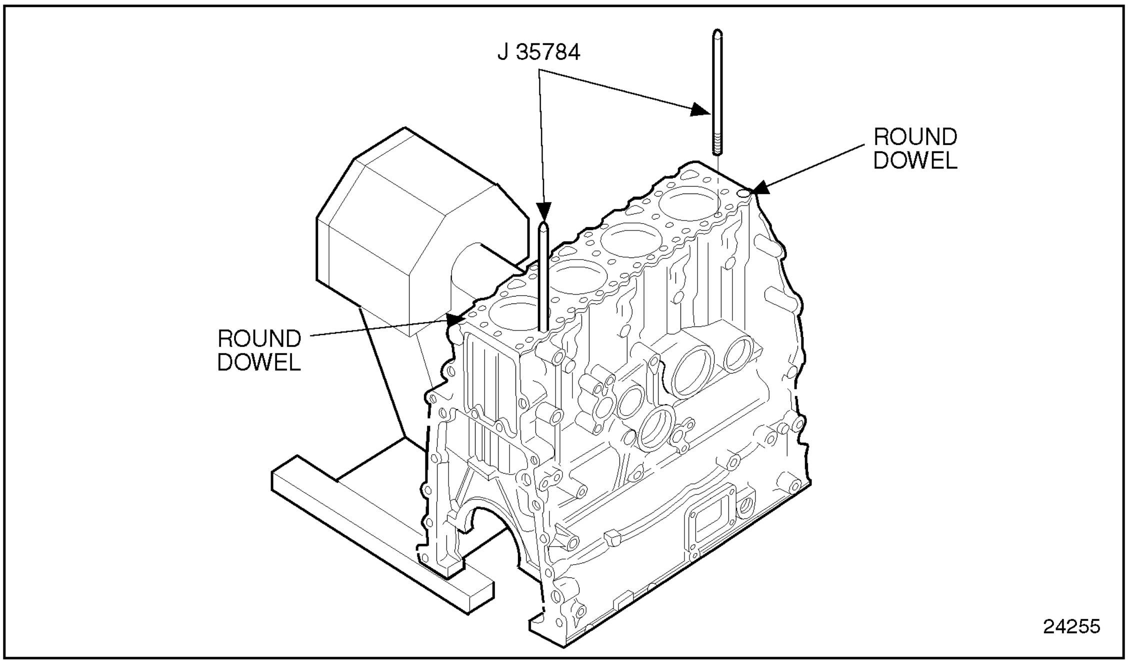


Figure 1-40 Cylinder Head Guide Studs

3. Lift the head into position with lift bracket, J 35641-A. See Figure 1-34. Lower it into place over the guide studs, J 35784, until it seats on the block deck dowels. See Figure 1-40.
4. Remove the guide studs.
5. Install the head bolts with special hardened washers, lubricating the threads and bolt-head contact areas with a small amount of International Compound #2®, or equivalent.

NOTICE:
Cylinder head mounting bolts are considered single-use items and must not be reused. Failure to install new bolts when replacing a cylinder head may result in improper clamp load, which could cause gasket failure and severe engine damage.

6. Torque the head bolts to 250-285 N·m (185-210 lb·ft) in the following sequence. See Figure 1-41. After September 2002 a new cylinder head bolt will be used for all Series 50 engines. The new bolt will be identified with white paint and groove on top of bolt. See Figure 1-42. Torque the new head bolts to 298 N·m (220 lb·ft). There is no change to the procedure other than the new torque value. The new head bolt can be used with the former cylinder head gaskets, the former head bolts cannot be used with the new head gasket. Former and new bolts must not be mixed.

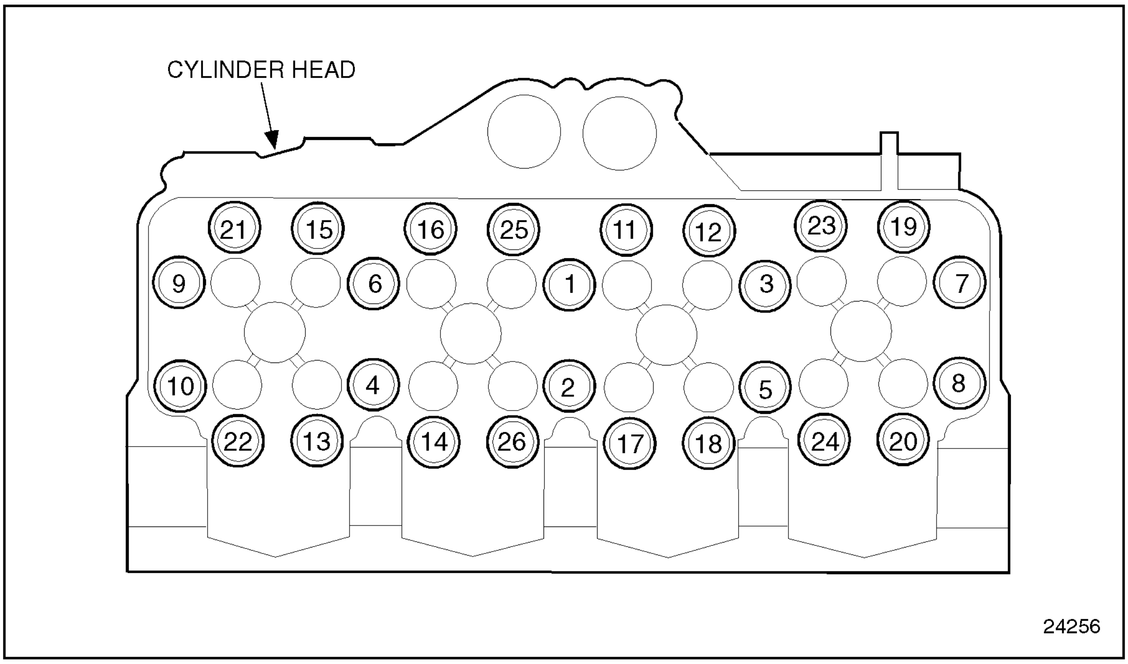


Figure 1-41 Cylinder Head Bolt Tightening Sequence

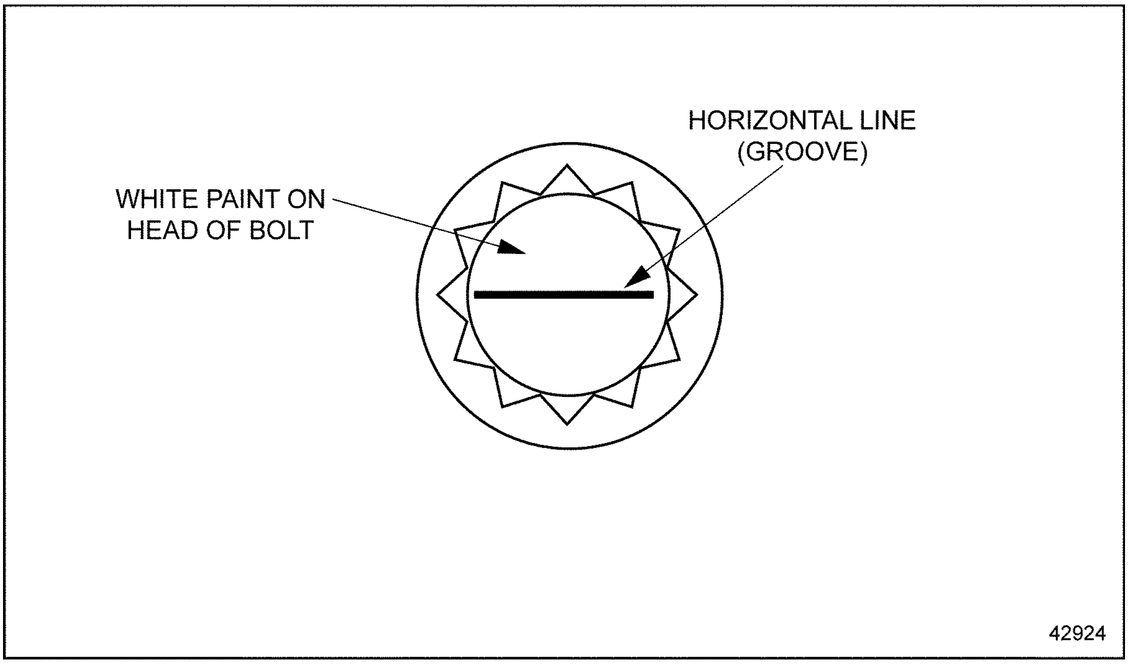


Figure 1-42 Bolt Identification For Series 50 Engines Built After September 2002

NOTICE:
Failure to repeat the cylinder head bolt torque tightening sequence can result in some head bolts may lose their torque when others are tightened resulting in insufficient clamp load.

7. Repeat the torque sequence to verify all of the head bolts are torqued to specification.

NOTE:
If a cylinder head other than the one removed from the engine, or if a resurfaced cylinder head is being installed, the three nuts retaining the adjustable idler gear must be loosened before installing and torquing the camshaft drive gear retaining bolt.

8. Visually inspect each injector hole tube to ensure they are clean. Install the fuel injectors. Refer to Section 2.3.52.3.5. Be sure the injector hold-down crabs are clear of the valve and injector springs.

NOTICE:
The hemispherical portion of the injector hold-down crab washers must be installed facing the crab (pointing down) in order to prevent damage to the washers. See Figure 1-43.

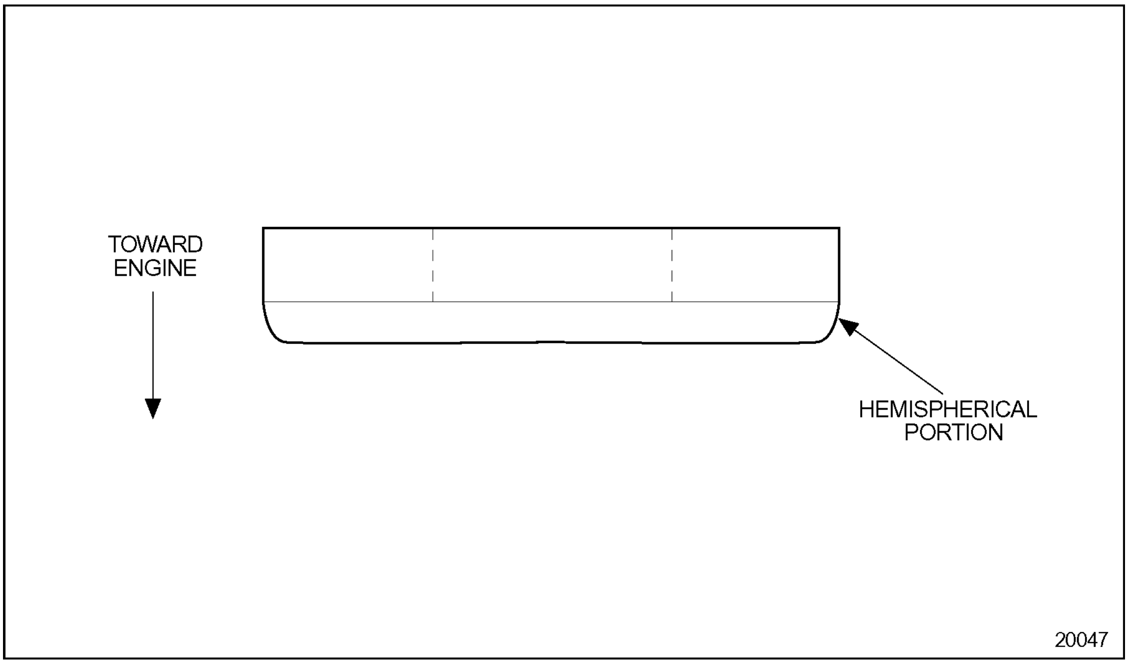


Figure 1-43 Injector Hold-Down Crab Washer Installation

9. Install the clamp bolts with hemispherical washers, torque to 58-66 N·m (43-49 lb·ft).
10. Install the camshaft. Refer to Section 1.22.5.

NOTICE:
The camshaft drive gear-to-adjustable idler gear lash must be measured/adjusted before the rocker arm shaft assemblies are installed.

11. Measure/adjust the camshaft drive gear-to-adjustable idler gear lash. Refer to Section 1.241.24.
12. Install the rocker arm shaft assemblies. Refer to Section 1.3.4.
13. Install Jacob's Brake assemblies (if equipped). Refer to Section 1.30.5.
14. Feed the injector harness wires through the opening at the rear of the cylinder head. Secure the harness mounting flange to the cylinder head by torque the bolts to 10-15 N·m (7-11 lb·ft).
15. Connect the injector harness wires to their respective injectors. Refer to Section 2.3.5.

16. Install the gear case stabilizer bracket at the right front corner of the head. Tighten the stabilizer to gear case bolt first and then the two bolts to the head. Torque the three bolts to 58-73 N·m (43-54 lb·ft).
17. Install the thermostats and seals to the thermostat housing. Refer to Section 4.3.4.
18. Clean the coolant outlet surfaces of the head and thermostat housing.
19. With the thermostats seated in the housing counterbores, install the housing to the cylinder head, torque the housing bolts to 58-73 N·m (43-54 lb·ft). Connect the radiator and bypass hose couplings and vent line.
20. Remove all traces of the old gasket from the cylinder head and intake manifold joint surfaces. Install the intake manifold with new gaskets. Refer to Section 6.3.5. See Figure 1-44.

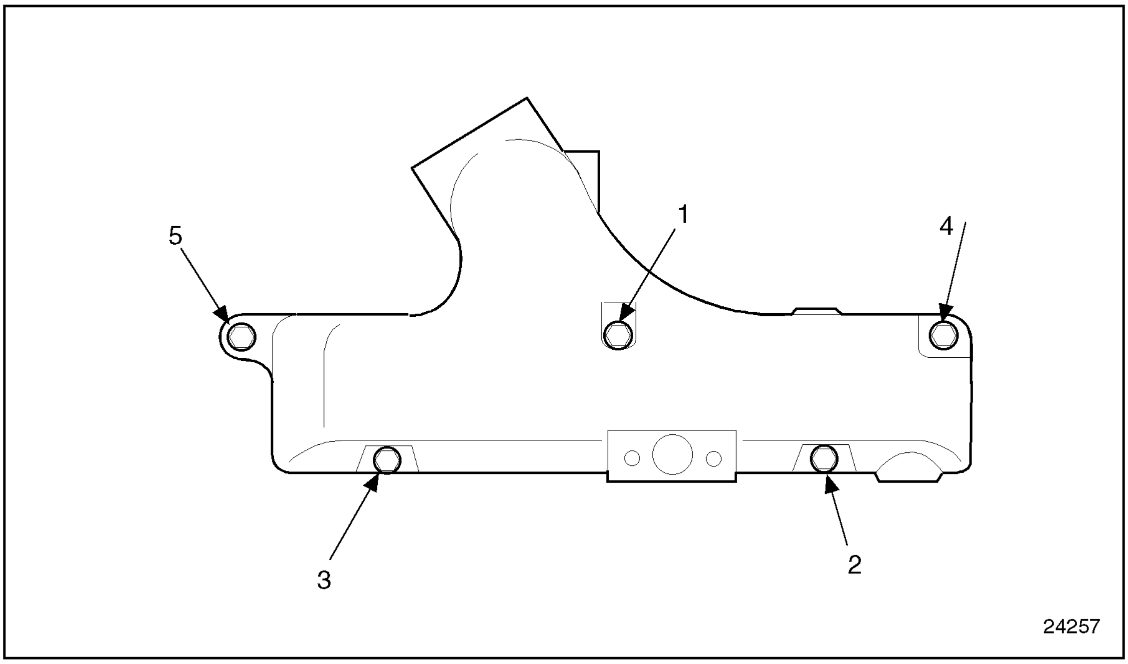


Figure 1-44 Intake Manifold Bolt Tightening Sequence

21. Clean the intake manifold and turbocharger joint surfaces and install the turbocharger with a new gasket. Refer to Section 6.5.7.
22. Fill and vent the cooling system. Refer to Section 13.5.4. Fill the engine lubrication system. Refer to Section 13.5.1.
23. Connect the exhaust and air-to-air cooler air ducting and install the air cleaner, per OEM guidelines.
24. Install any other components that were removed and, if required, fill with the proper fluid, as recommended.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

25. Start the engine and check for fuel, coolant or oil leaks. Keep the engine running while you check.

1.3 VALVE AND INJECTOR OPERATING MECHANISM

The valve and injector operating mechanism is located entirely in the cylinder head.

The Series 50 Engines overhead camshaft design eliminates the need for push rods. Separate camshaft followers are needed, since the rocker arms incorporate follower rollers riding directly on the camshaft lobes, transmitting camshaft motion to the valves and injectors. See Figure 1-45.

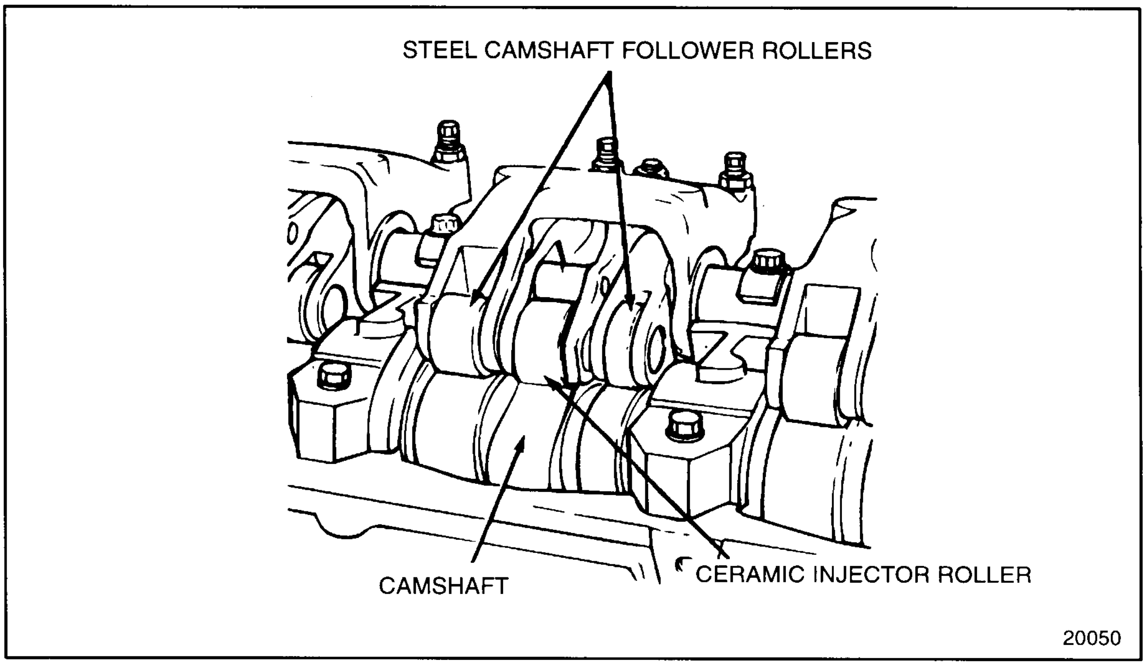


Figure 1-45 Camshaft and Related Parts

Each of the three rocker arm assemblies contain bushings where the rocker arms are supported on the rocker arm shafts. These bushings are not serviced separately. Each intake rocker arm assembly operates two intake valves in each cylinder. Each exhaust rocker arm assembly operates two exhaust valves in each cylinder. In each set of three rocker arm assemblies, the exhaust rocker assembly is the widest, straddling the intake and fuel injector rockers. The center rocker operates the injector follower. See Figure 1-46.

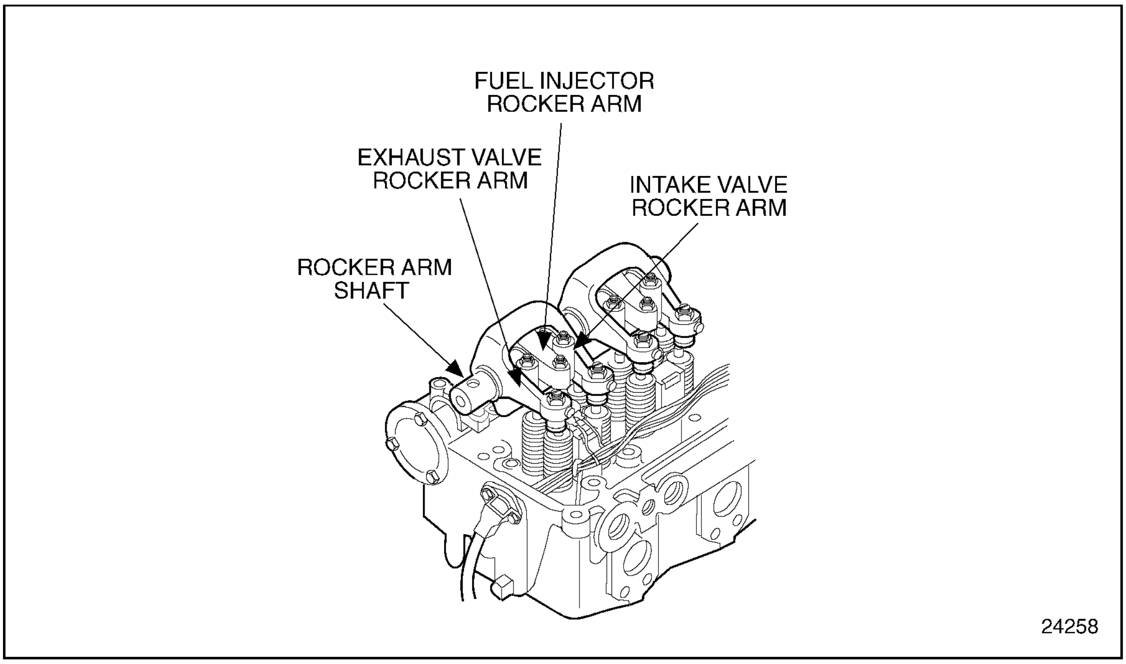
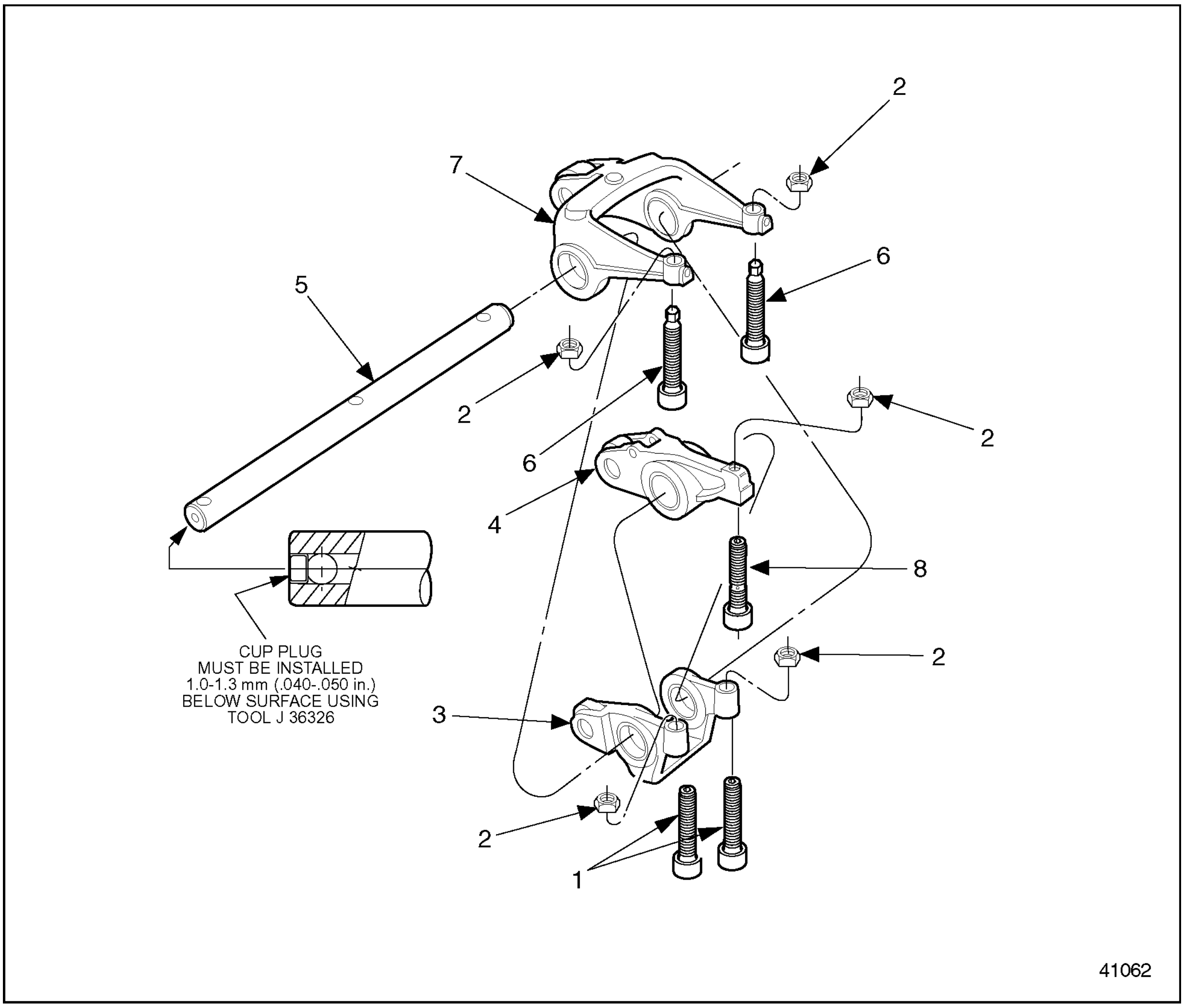


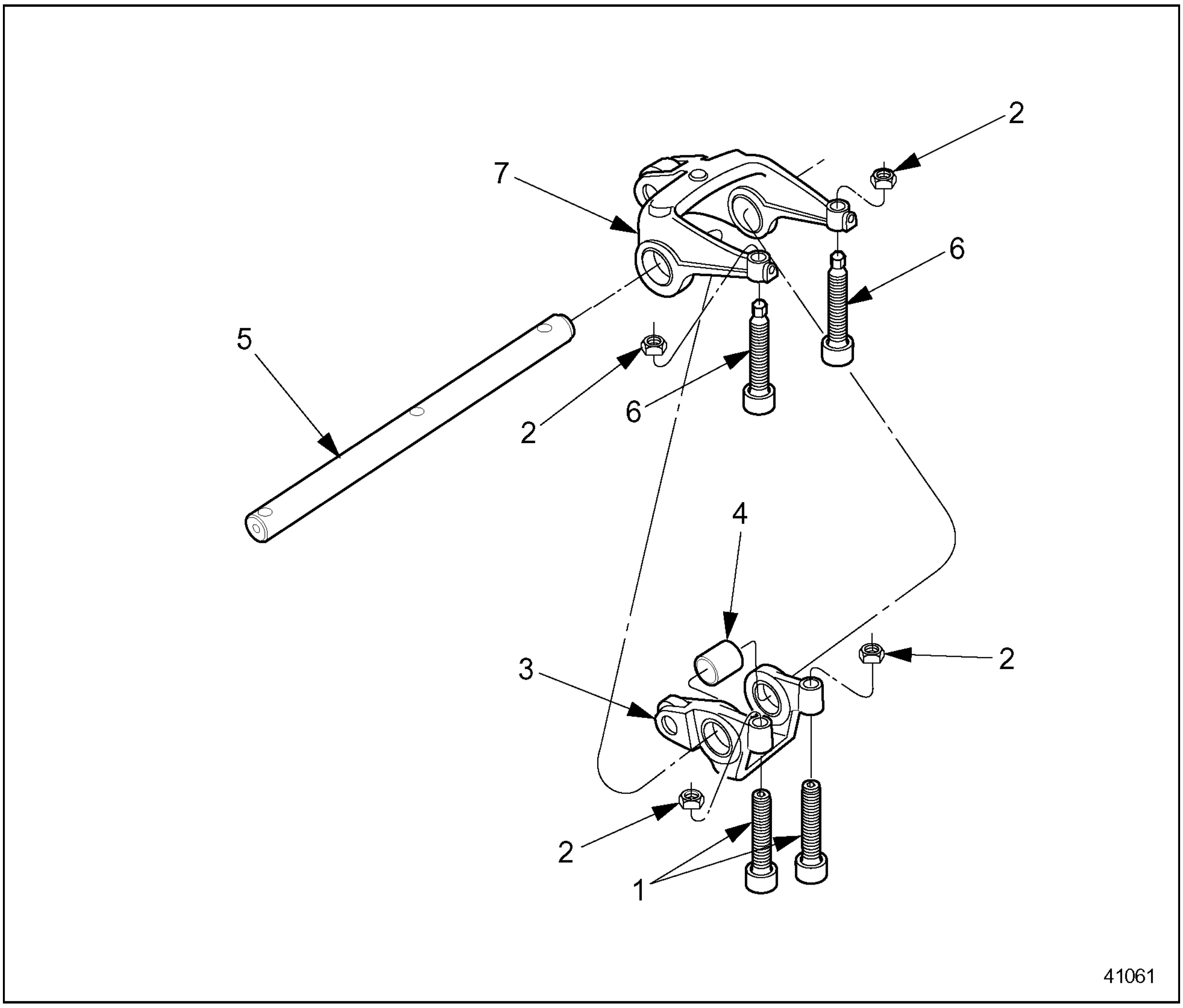
Figure 1-46 Rocker Arm Identification

The fuel rocker arm assembly is located between the intake and exhaust rocker arm assemblies and has a single bushing (not serviced separately). A rocker arm shaft carries three sets of rocker arm assemblies, and is mounted in seats machined into the camshaft bearing caps. See Figure 1-47 for Series 50 Diesel, and see Figure 1-48 for Series 50 Gas.



1. Unitized Valve Adjusting Screw Assembly; Intake position
2. Locknut
3. Intake Rocker Arm Assembly
4. Fuel Injector Rocker Arm Assembly
5. Rocker Arm Shaft
6. Unitized Valve Adjusting Screw Assembly; Exhaust position
7. Exhaust Rocker Arm Assembly
8. Unitized Valve Adjusting Screw Assembly; Injector position

Figure 1-47 Rocker Arm and Related Parts



1. Unitized Valve Adjusting Screw Assembly; Intake position
2. Locknut
3. Intake Rocker Arm Assembly
4. Spacer
5. Rocker Arm Shaft
6. Unitized Valve Adjusting Screw Assembly; Exhaust position
7. Exhaust Rocker Arm Assembly

Figure 1-48 Rocker Arm and Related Parts (Series 50G)

The current assembly has a honed rocker arm shaft bushing, a ceramic cam follower and a new phosphated (black in color) rocker arm shaft which provides improved wear characteristics. The phosphated surface is required for the proper break-in of the steel rocker arm shaft bushings.

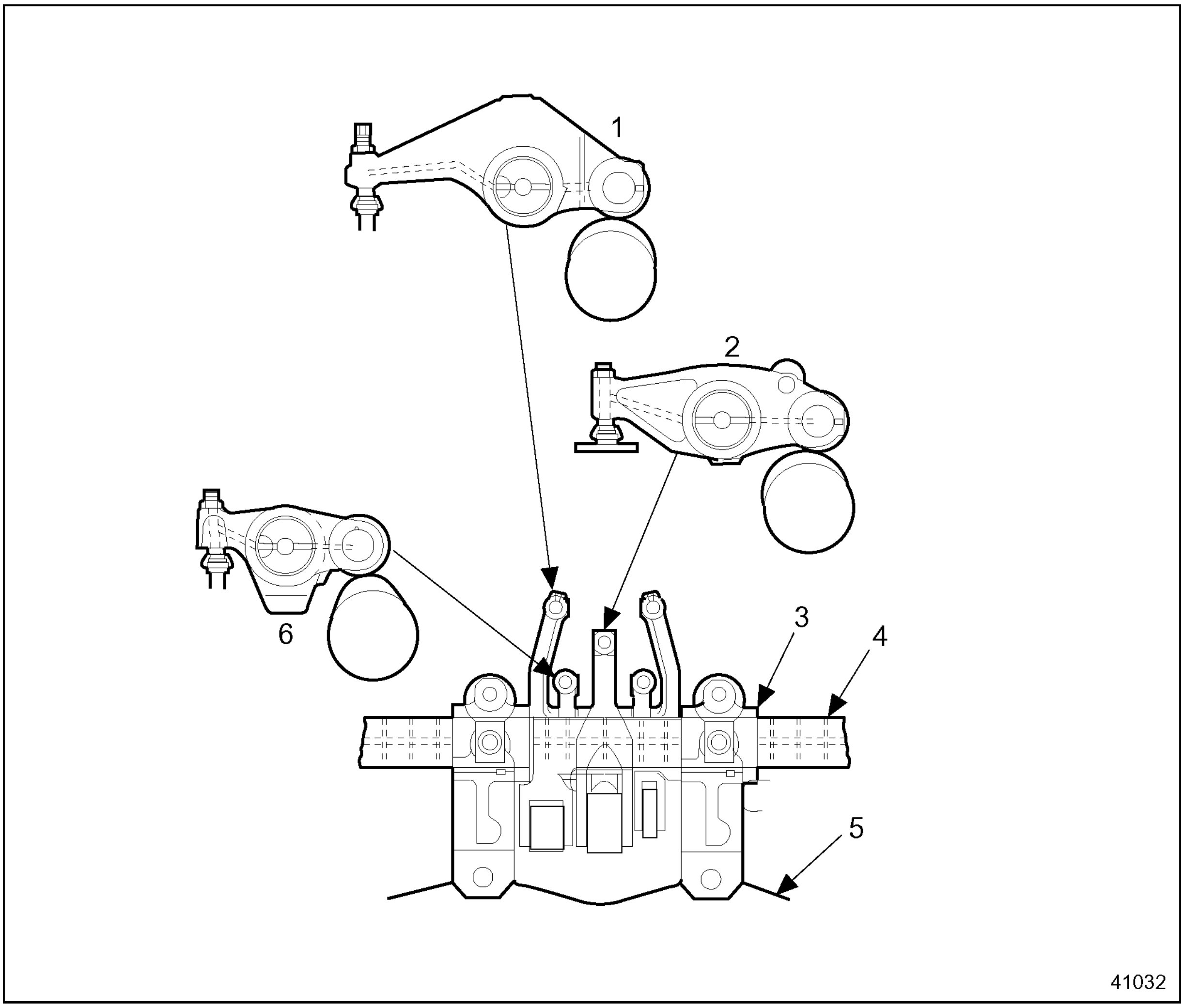
A spacer is installed between the rocker arm shaft and the mounting bolts or nuts rather than a washer. This allows the rocker arm shaft to be rotated when installing new rocker arms. When reusing rocker arm assemblies, the rocker shaft should not be rotated so that the same surfaces of the rocker arm assemblies and rocker arm shafts are in contact with each other.

Vertical oil passages at the front and rear of the cylinder head deliver oil from the cylinder block front and rear oil galleries to the No. 1 and 5 lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 5 upper bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each rocker arm shaft.

The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushings passes through the oil hole in the bushing to the rocker arm assembly. The rocker supplies oil to the camshaft roller follower, the roller pin and the roller bushing. The rocker arm assemblies also contain drilled passages that supply oil to the unitized valve adjusting screw assembly and exhaust valve stems and the fuel injector follower. Engines built after S/N 4R-15547 use valve rocker arms without drilled passages to the Unitized Valve Adjusting Screw assembly.

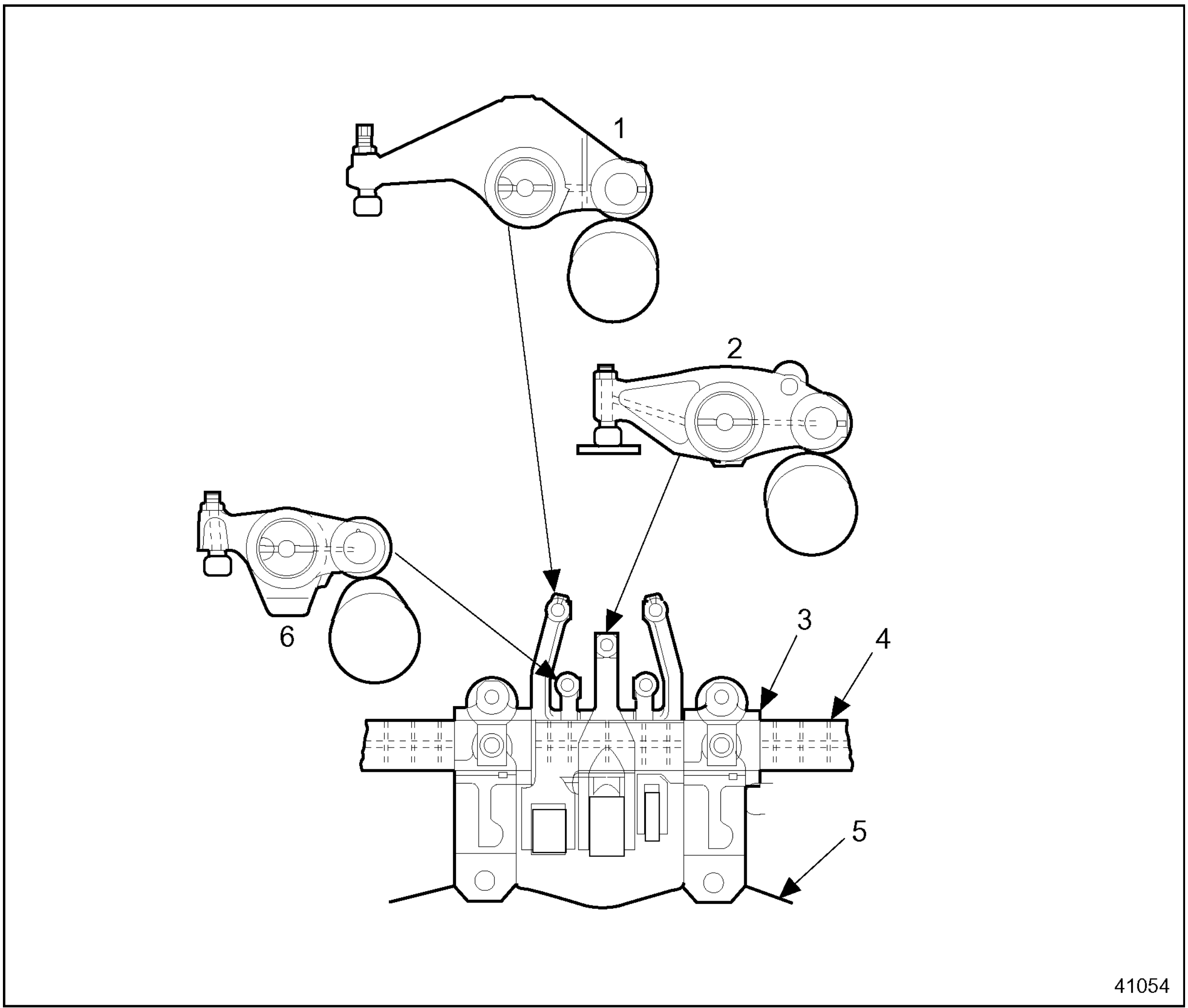
NOTE:
In December 2000, a new unitized adjusting valve screw assembly now replaces the former valve adjusting screw, valve button and retainer clip.

The No. 3 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. The oil passages within one rocker arm cylinder set are illustrated, see Figure 1-49 and see Figure 1-50.



1. Exhaust Rocker Arm Assembly
2. Fuel Injector Rocker Arm Assembly
3. Camshaft Cap
4. Rocker Arm Shaft
5. Cylinder Head
6. Intake Rocker Arm Assembly

Figure 1-49 Rocker Arm Assembly Lubrication Schematic with Former Style Valve Adjusting Screw Assembly



1. Exhaust Rocker Arm Assembly
2. Fuel Injector Rocker Arm Assembly
3. Camshaft Cap
4. Rocker Arm Shaft
5. Cylinder Head
6. Intake Rocker Arm Assembly

Figure 1-50 Rocker Arm Assembly Lubrication Schematic with Unitized Valve Adjusting Screw Assemblies

1.3.1 Repair or Replacement of Valve and Injector Operating Mechanism

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-51.

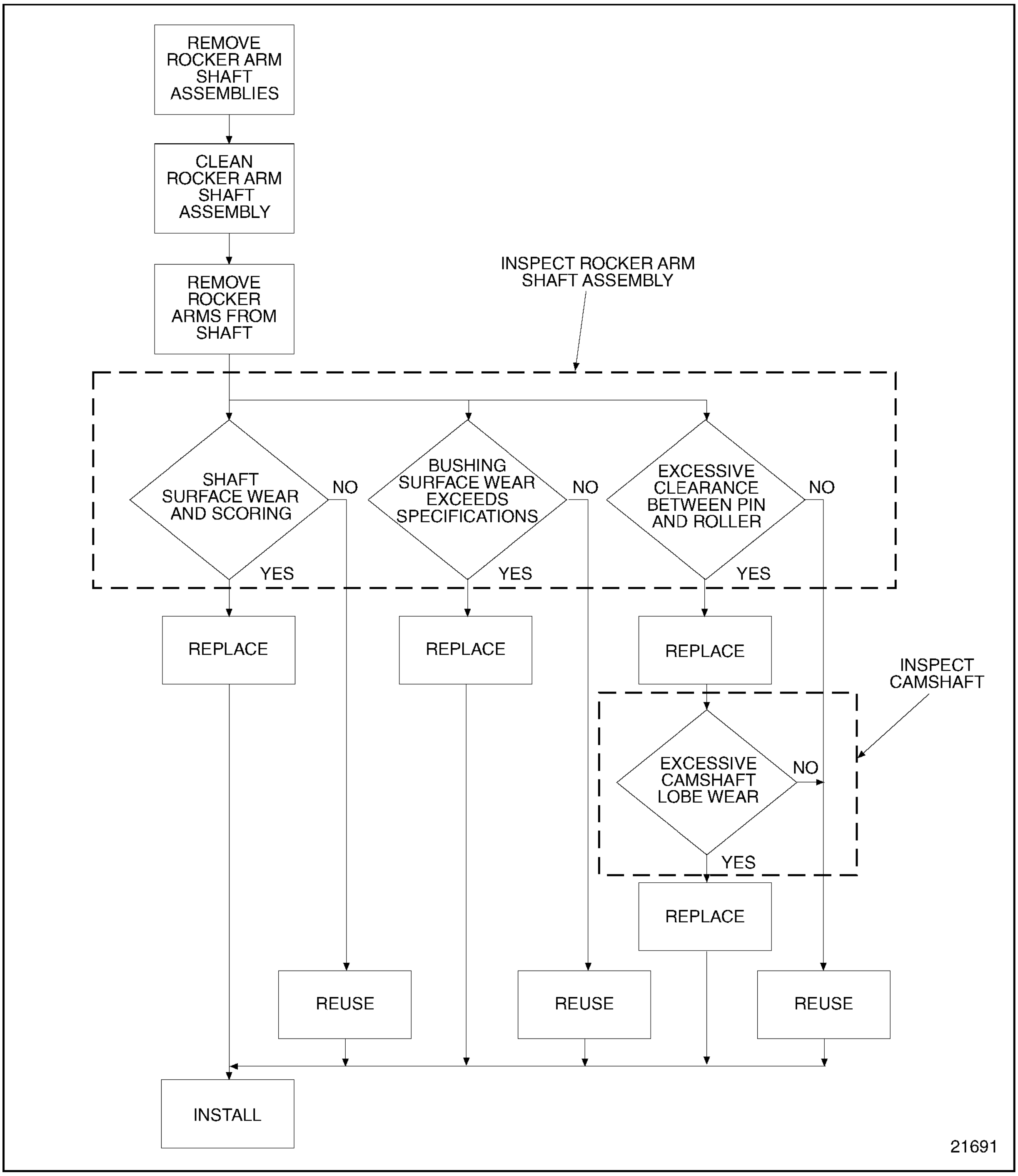


Figure 1-51 Flowchart for Repair or Replacement of Valve and Injector Operating Mechanism

1.3.2 Removal of Rocker Arm Assembly

Perform the following steps for rocker arm assembly removal:

NOTE:
If unit is equipped with a Jake Brake®, remove brake. Refer to Section 1.30.2.

NOTE:
Jake Brakes are not used on the Series 50G engine.

1. If necessary, steam clean the engine around the valve rocker cover/cylinder head mating area.

NOTE:
High pressure water or steam cleaning should be avoided in the valve rocker cover/cylinder head area of the Series 50 gas. The ignition system can be affected.

2. Remove the valve rocker cover. Refer to Section 1.6.2.

NOTE:
Whenever nuts No. 1 or No. 8 are loosened or removed, the torque on the corresponding rocker shaft stud must be checked. Torque to 101-116 N·m (75-86 lb·ft).

3. Remove the rocker arm shaft bolts (No. 2, 3, 4 or 5) and nuts (No. 1 or 6) that retain the rocker arm shaft assembly to the cylinder head. See Figure 1-52 for Series 50 Diesel and see Figure 1-53 for Series 50 Gas. For camshaft or cylinder head removal, both rocker arm shaft assemblies must be removed.

NOTE:
Some engines may be equipped with ceramic injector rollers. Use extra caution while removing and handling.

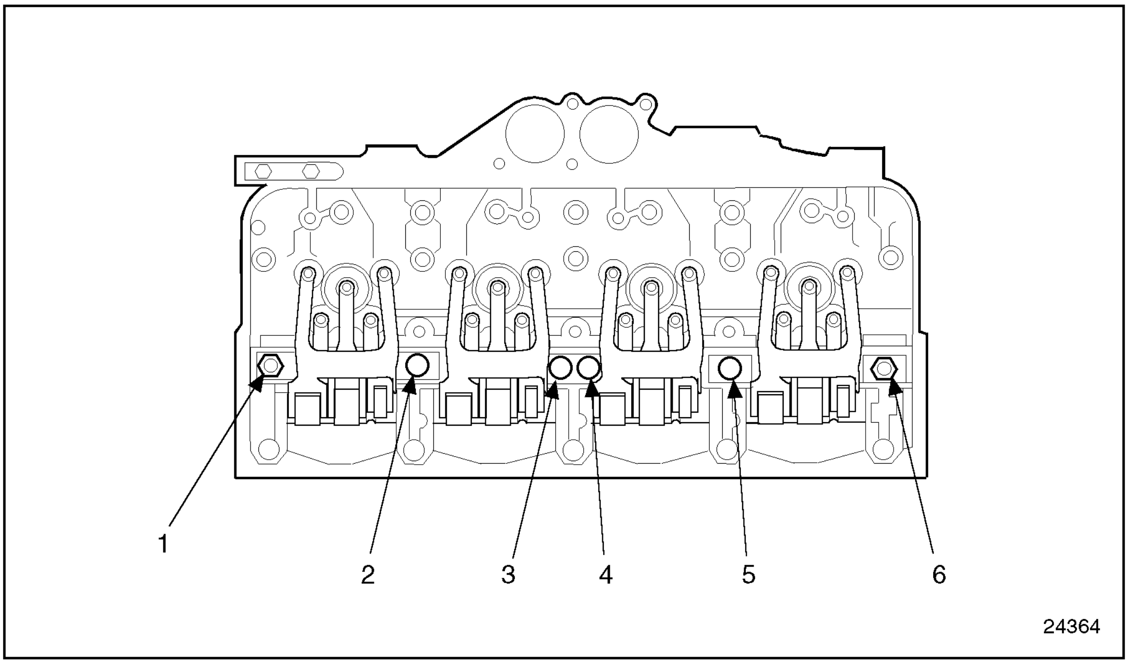


Figure 1-52 Rocker Arm Shaft Bolts and Nut Identification Numbers

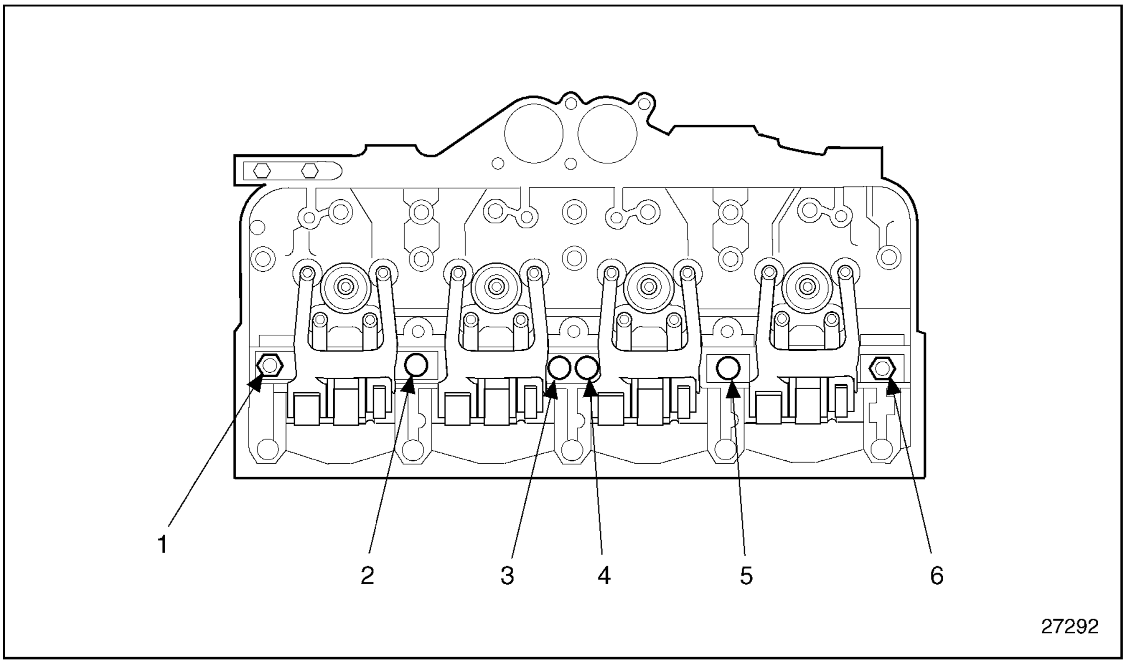


Figure 1-53 Rocker Arm Shaft Bolts and Nut Identification Numbers (Series 50G)

4. Use rocker arm and shaft assembly lifter tool, J 35996–A, to remove the rocker arm shafts, with rocker arm assemblies in place. See Figure 1-54.

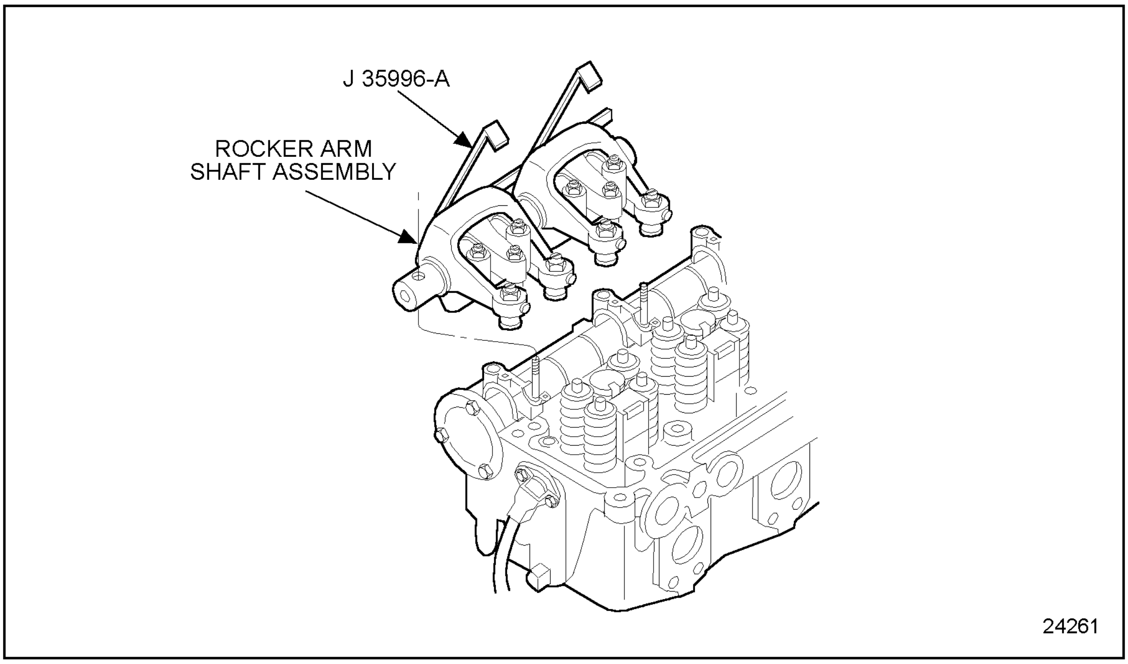


Figure 1-54 Rocker Arm Shaft Assembly Removal and Installation

5. Remove unitized valve adjusting screw assemblies. Then proceed to step 7.

NOTE:
If the unitized valve button separates from the screw, the button and screw must be replaced with a new Unitized Valve Adjusting Screw assembly. Do not attempt to reassemble them for reuse in engine. Unitized Valve Adjusting Screws will not be serviced separately.

NOTE:
If removing a former valve adjusting screw with valve button and retainer clip; replace with the correct unitized valve adjusting screw assembly. Proceed to step6 to remove former valve adjusting screw with valve button and retainer clip.

6. To replace the valve button or valve button retaining clip the valve adjusting screw must be removed from the rocker arm as follows:

NOTICE:
To avoid possible component damage, the valve button retainer MUST NOT be expanded more than 15.5 mm (0.610 in.). An adjusting screw is provided on the expander tool to limit the amount of travel.

[a] Spread the retaining clip with expander, J 36347, and remove the button. See Figure 1-55.

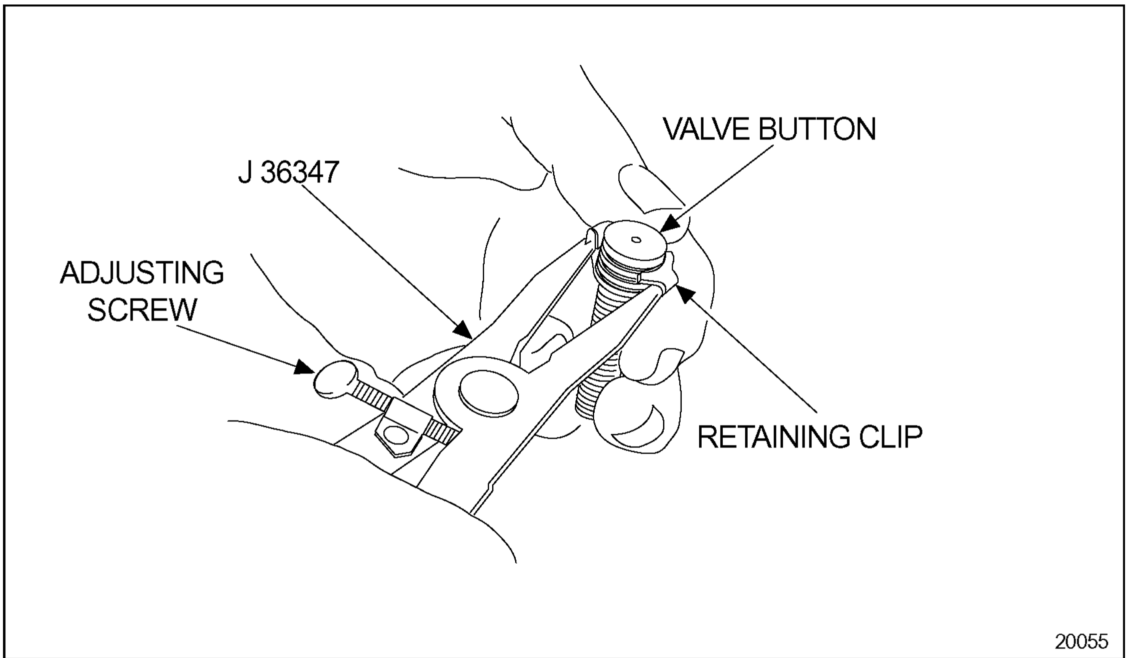


Figure 1-55 Valve Button Retainer Clip Removal

[b] Slide the retaining clip, open end first, down the adjusting screw. It is necessary to spread the clip slightly so that the open end can pass over the ball head of the adjusting screw.

[c] Insert the tips of the expander, J 36347, between the legs of the retaining clip and expand the clip.

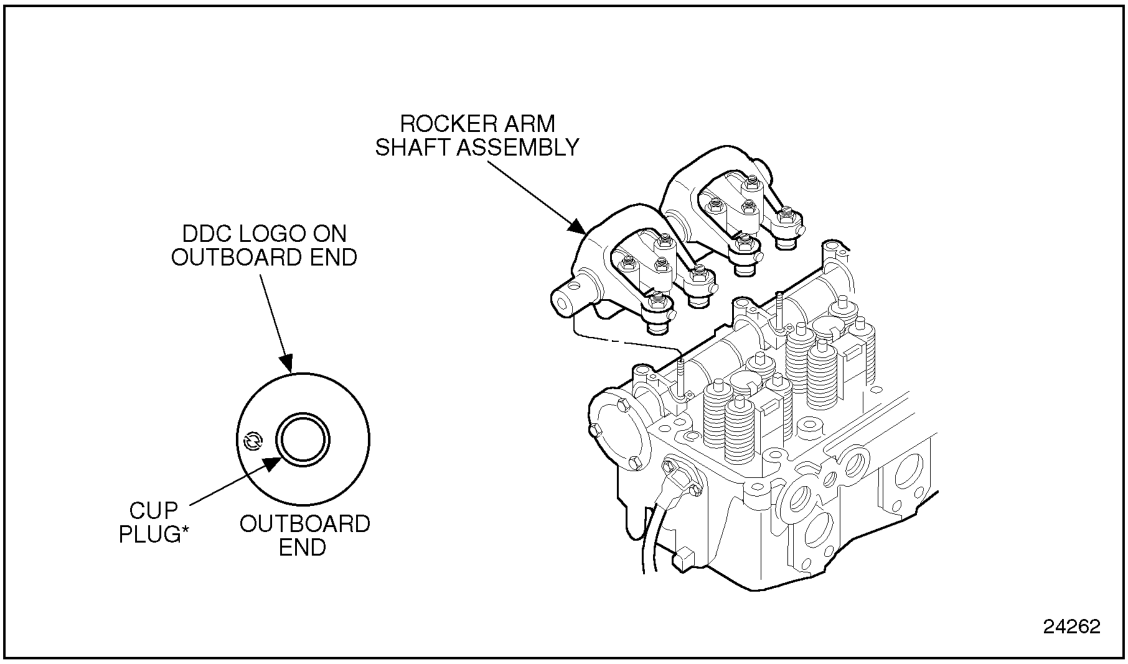
[d] Insert the groove on the valve button into the legs of the retaining clip.

[e] Remove the expander and hold the legs of the retainer with the thumb and index finger.

[f] Press the valve button towards the screw to seat both legs of the retainer completely in the groove.

NOTICE:
Front and rear rocker arm shaft sections look identical, but must not be reversed, and must be installed as removed, due to bolt hole center line distances. The DDC logo is stamped on the outboard end of each rocker shaft to ensure correct assembly and installation. See Figure 1-56.

7. If further disassembly is necessary, slide the rocker arm assemblies off the rocker arm shafts, marking or segregating the parts so that they may be reinstalled in the same position from which they were removed.



*Must be installed 1.0-1.3 mm (0.040-0.050 in.) below surface using tool J 36326

Figure 1-56 Rocker Arm Shaft Identification

1.3.3 Cleaning the Rocker Arm Assemblies

Clean the rocker arm assemblies as follows:

1. Remove the cup plug at one end of the rocker arm shafts to facilitate the removal of any foreign material lodged behind the plug.

NOTICE:
Do not soak the rocker arm assemblies in solvent because this will remove the lubricant from the cam follower roller bushings.

2. Clean the exterior of the rocker arm assemblies only.

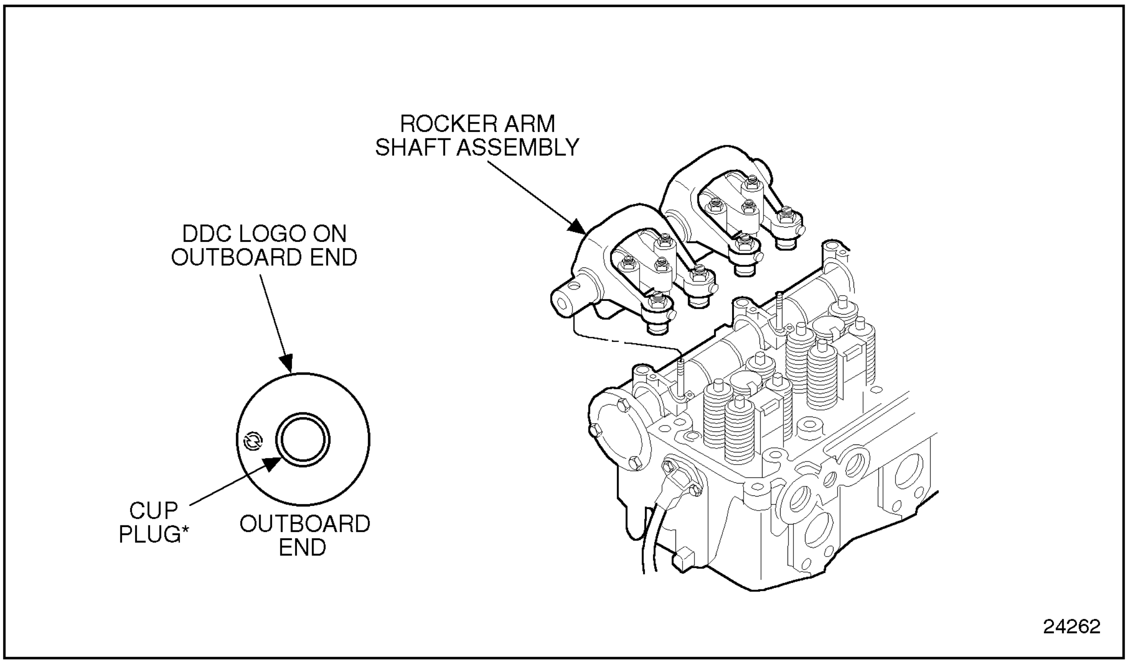
CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Blow dry with compressed air.
4. Soak the rocker arm shaft in clean fuel oil.
5. Run a wire brush through the oil passage to remove any foreign material or sludge.
6. Clean the exterior of the shaft and blow out the passages and oil holes; and dry with compressed air.

1.3.3.1 Inspection of Rocker Arm Assemblies and Camshaft Lobes

Prior to inspection:

1. Install new cup plugs with tool J 36326 until they are 1.0-1.3 mm (0.040-0.050 in.) below the surface of the shaft. See Figure 1-57.



*Must be installed 1.0-1.3 mm (0.040-0.050 in.) below surface using tool J 36326

Figure 1-57 Rocker Arm Shaft Identification

2. Remove all of the old gasket sealer from the joint face of the No. 1 and 5 camshaft bearing caps and the cylinder head.

NOTE:
Refer to "Gasket Eliminator Removal" in the "General Information" section at the beginning of this manual.

Inspect the rocker arm assemblies and camshaft lobes as follows:

1. Inspect the rocker arm shaft bushing surfaces and rocker arm bushing bores.
   [a] Check the rocker arm shaft bushing surfaces and rocker arm bushing bores for wear or scoring. If damage was found, replace component.
   [b] If no damage was found, reuse component.
2. Inspect the cam follower rollers.
   [a] Check the cam follower rollers for scoring, pitting, or flat spots. If damage was found, replace the component.

[b] If no damage was found, reuse component.

3. Check the cam follower rollers to ensure they turn freely on the roller pins.
   [a] Clearance between the rollers and pins should not be more than 0.08 mm (0.003 in.).
   [b] Replace as necessary.
4. Inspect the camshaft lobes and journals.
   [a] Check the camshaft lobes and journals for scoring, pitting, or flat spots. If damage was found, replace the component.
   [b] If there is doubt as to the acceptability of the camshaft for further service, determine the extent of camshaft lobe wear. Refer to Section 1.22.3.1.
5. Inspect the valve adjusting screw assemblies.
   [a] If former style valve adjusting screw assembly is damaged; replace with new unitized valve adjusting screw assembly.

NOTE:
Replace with unitized valve adjusting screw assembly of the correct position.

[b] If any damage is found on the unitized valve adjusting screw assembly; replace with new unitized screw assembly.

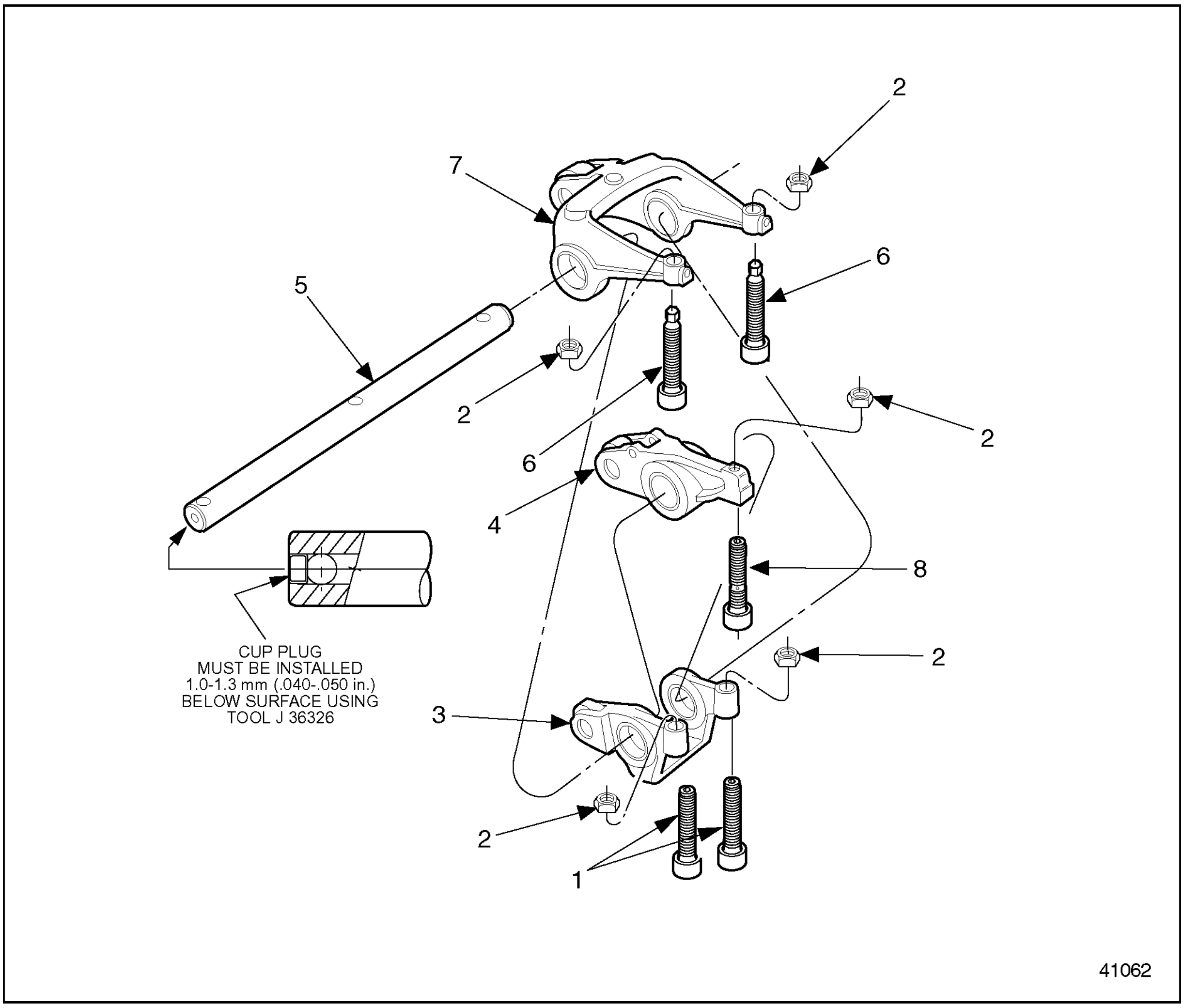
[c] If no damage is found on the former style valve adjusting screw or on the new unitized valve adjusting screw assembly; reuse the components.

NOTE:
Former style valve adjusting screw assemblies and the unitized valve adjusting screw assemblies are interchangeable and can be mixed in the same engine.

1.3.4 Installation of Rocker Arm Shaft Assembly

Perform the following for rocker arm assembly installation:

1. Ensure the cup plugs are properly installed to each end of the rocker arm shafts before the shafts are installed to the engine. See Figure 1-58. Refer to Section 1.3.3.1, step 1.



1. Unitized Valve Adjusting Screw Assembly; Intake position
2. Locknut
3. Intake Rocker Arm Assembly
4. Fuel Injector Rocker Arm Assembly
5. Rocker Arm Shaft
6. Unitized Valve Adjusting Screw Assembly; Exhaust position
7. Exhaust Rocker Arm Assembly
8. Unitized Valve Adjusting Screw Assembly; Injector position

Figure 1-58 Rocker Arm and Related Parts

2. Check the torque on the rocker shaft studs to be sure they were not loosened when the nuts were removed.
3. Torque the studs to 101-116 N·m (75-86 lb·ft).
4. Install the unitized valve adjusting screw assembly to the rocker arm assemblies. See Figure 1-58.

NOTE:
There are three different unitized valve adjusting screw assemblies. Ensure the correct unitized valve adjusting screw assembly is used in the correct location. See Figure 1-59.

NOTE:
Former style valve adjusting screw assemblies can be mixed with new unitized valve adjusting screw assemblies.

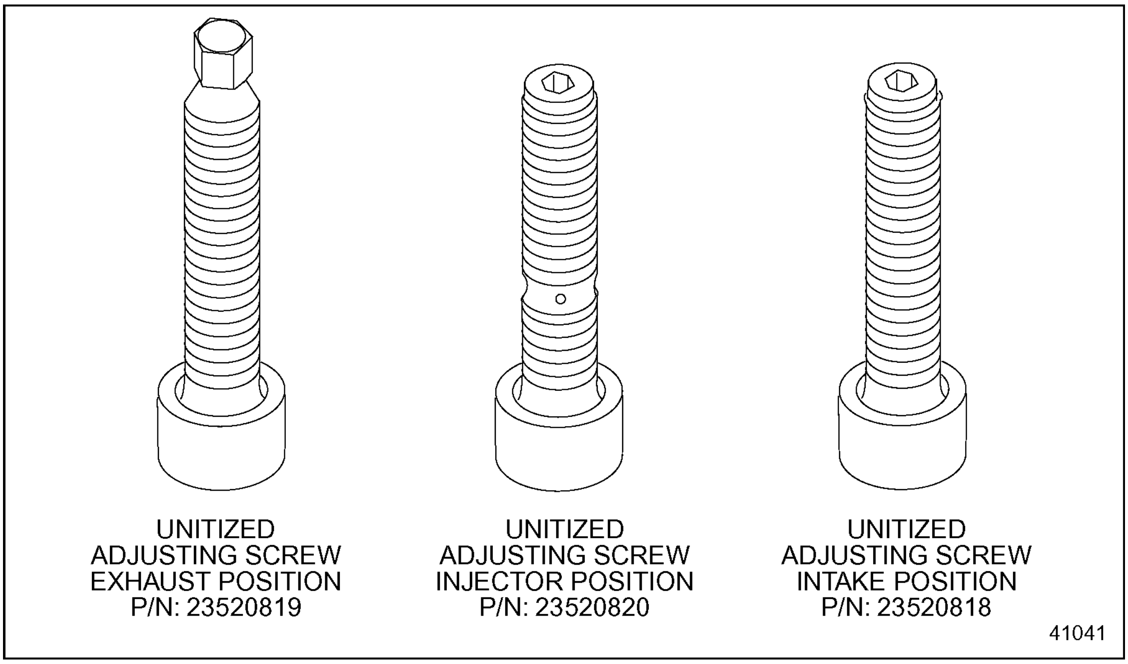


Figure 1-59 Unitized Valve Adjusting Screw Assemblies (Exhaust, Injector and Intake)

5. Install the rocker arms to the rocker arm shafts in their original positions. Use the rocker arm identification marks to ensure correct component assembly. If the rocker shaft does not have flats, decide on the position of the worn surfaces and rotate the rocker shaft accordingly.

NOTE:
When a new rocker arm is installed on a phosphated shaft, the shaft should be turned 180° to present a fresh phosphated area to the loaded region of the bushing.

6. Using care to locate the valve button of the unitized valve adjusting screw assemblies to their respective valve stems and injector followers, install the rocker arm shaft assemblies to the cylinder head using J 35996–A. See Figure 1-54.
7. If the rocker arm shafts do not have flats in the bolt hole locations, rocker shaft spacers are required.
   [a] In this case, install the rocker shaft spacers on the cap bolts and studs.
   [b] If the rocker arm shafts do have flats in the bolt hole locations, rocker shaft spacers are not required.

NOTE:
If new rocker arm components are installed, engine oil should be poured over the rocker arms, rocker shaft, and camshaft as a pre-lubricant.

8. Install the inboard camshaft cap bolt through the rocker arm shaft and camshaft cap and into the cylinder head.
9. Install the nuts to the No. 1 and 5 cap studs.
10. Torque the rocker arm shaft retaining bolts and nuts to 101-116 N·m (75-86 lb·ft) using the sequence. See Figure 1-60.

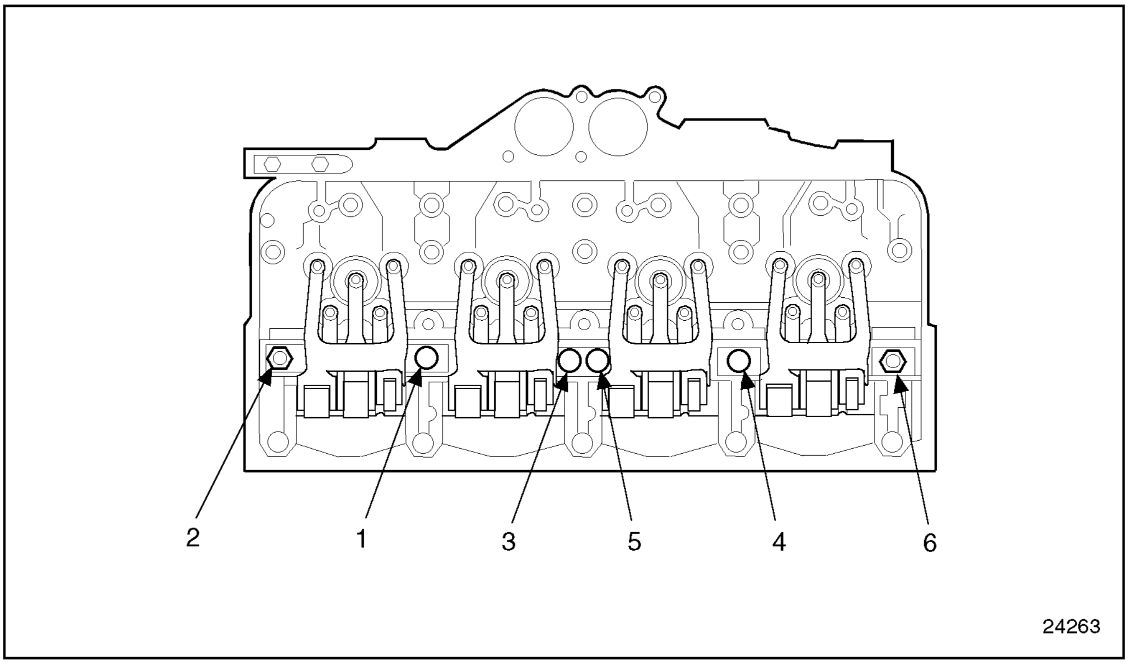


Figure 1-60 Rocker Arm Shaft Retaining Bolt and Nut Tightening Sequence

11. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to Section 12.2.
12. Install the rocker cover. Refer to Section 1.6.6.
13. Install any other components that were removed for this procedure.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

14. Start the engine and check for leaks.

1.4 VALVES, SPRINGS, GUIDES, INSERTS, SEALS AND ROTATORS

Four valves per cylinder, two intake and two exhaust, give the Series 50 Engines excellent breathing and cooling characteristics. See Figure 1-61. Each valve has a single valve spring. See Figure 1-62.

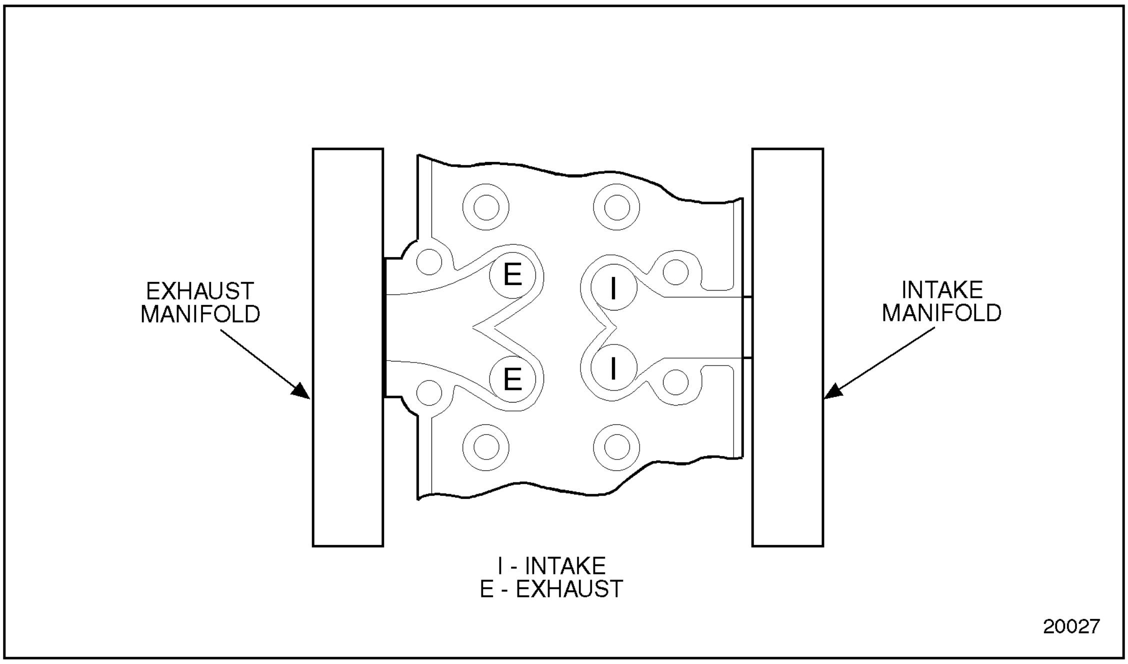
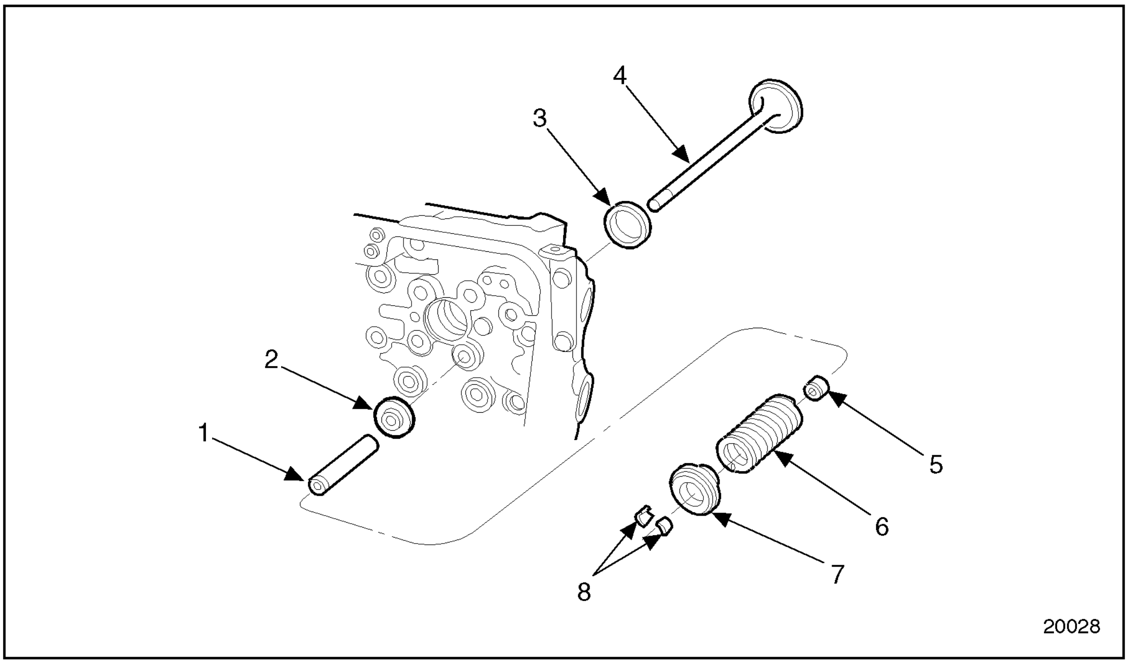


Figure 1-61 Intake and Exhaust Valve Arrangements

Valves are made of heat-treated alloys, with heads and stems precision ground. Stem ends are hardened to minimize wear in contact with the valve rocker buttons.

Hard-alloy valve seat inserts, pressed into both intake and exhaust ports, can be replaced when worn to restore new engine performance.

Valves are positioned and aligned by replaceable valve guides pressed into the cylinder head. See Figure 1-62.



1. Valve Guide
2. Valve Spring Seat
3. Valve Insert
4. Valve
5. Valve Stem Oil Seal
6. Valve Spring
7. Valve Rotator
8. Valve Keepers

Figure 1-62 Valve, Valve Seat, Valve Guide, Springs and Rotators

Replacement guides are reamed to close tolerances, and do not require reaming after installation.

All valves are retained by valve rotator spring caps and two-piece tapered valve locks.

Valve stem oil seals, installed on both intake and exhaust valves, provide controlled valve stem lubrication while limiting oil consumption.

NOTE:
New valve seat inserts are pre-ground and only need to be checked for concentricity after installation. Do not grind a new seat insert unless concentricity exceeds 0.05 mm (0.002 in.). Before grinding, be sure the valve guide is not excessively worn or bent, which could cause an erroneous concentricity reading. If the firedeck has been resurfaced, the valves will have to be seated deeper to restore the valve head recess depth to specification limits. Do not grind seat inserts for this purpose. Reduced thickness inserts are available that are 0.2540, 0.5080 and 0.7620 mm (0.010, 0.020 and 0.030 in.) shallower than standard. When a reduced thickness valve seat insert is used, a correspondingly thicker valve spring seat must be used. Maximum allowable valve seat width and minimum valve stem diameter are illustrated, see Figure 1-63 and see Figure 1-64.

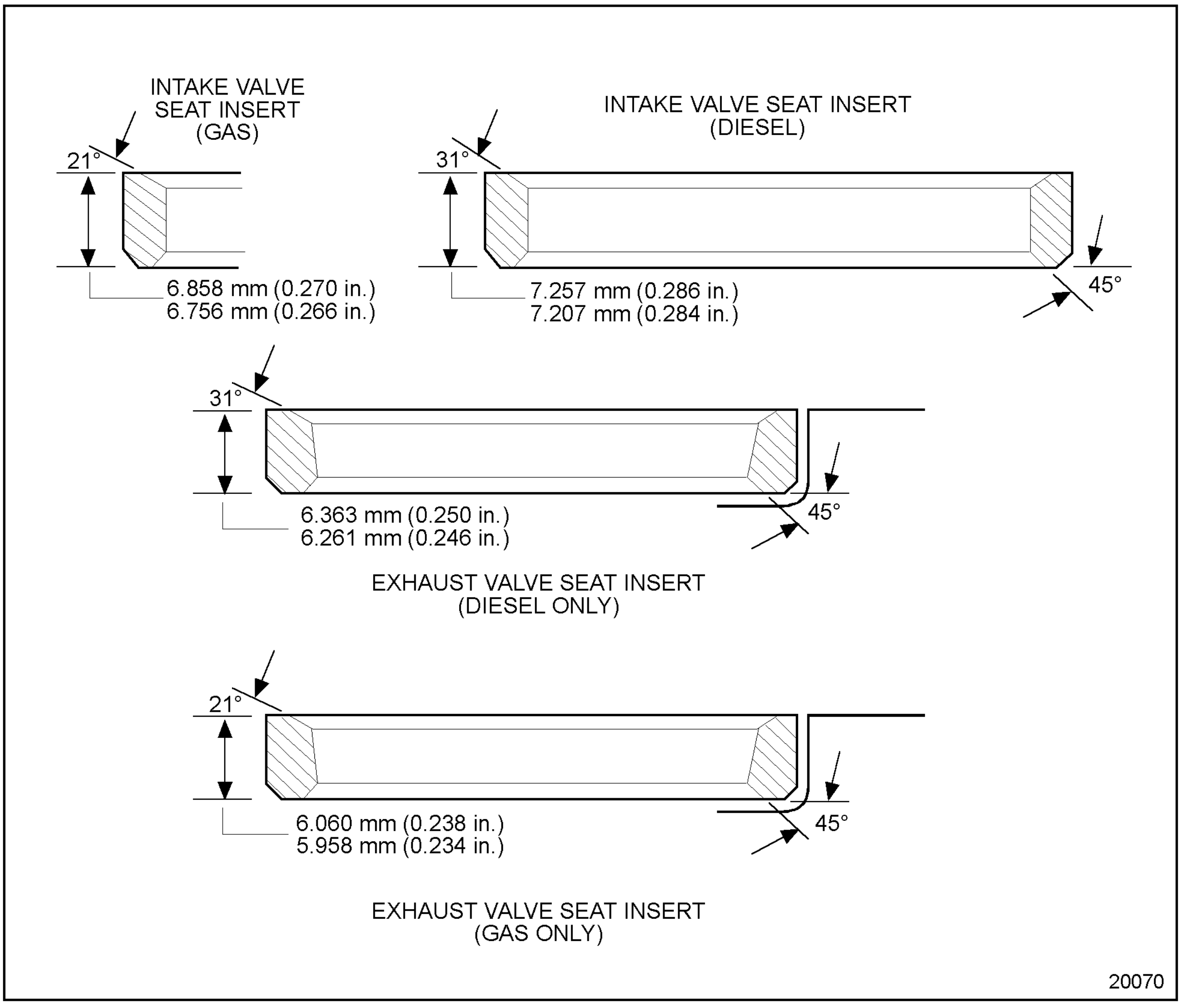


Figure 1-63 Standard Valve Seat Insert Thickness Series 50/50G

When servicing exhaust valves, determine which type of exhaust valve is contained in the engine. If an exhaust valve must be replaced, use the same type that was removed. Do not mix exhaust valve types within an engine. Both exhaust valves are available from service stock for this purpose. Exhaust valve lash settings are affected by the type of exhaust valve that is contained in the engine. The valve lash settings and injector timing height are listed on the rocker cover.

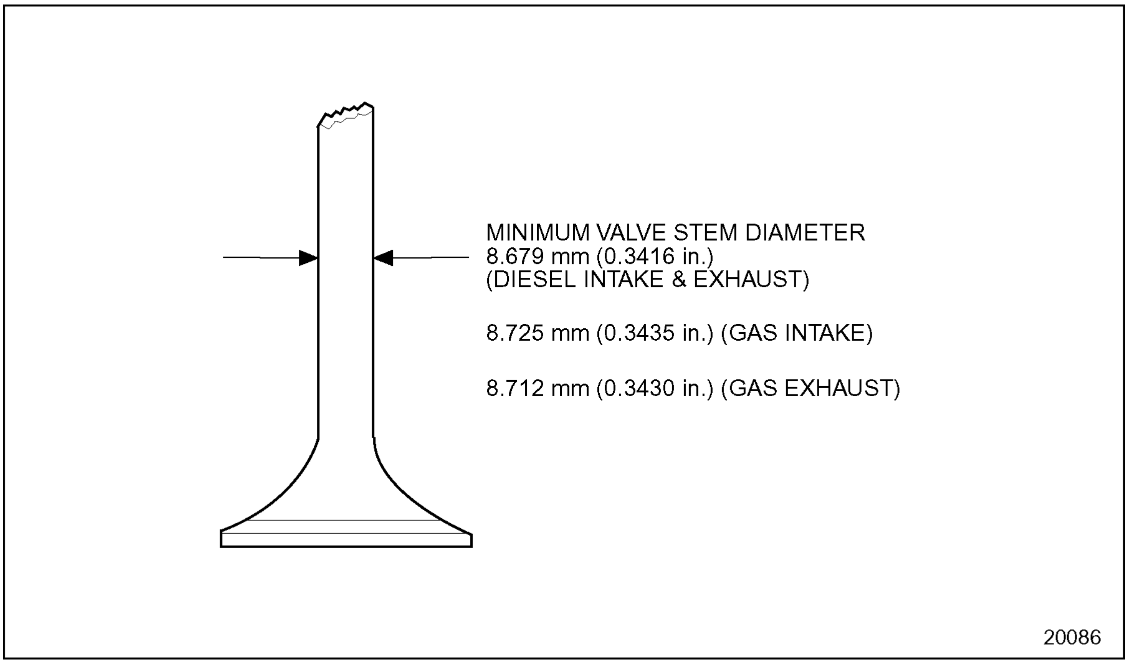


Figure 1-64 Minimum Valve Stem Diameter

Series 50 Engines use an austenitic based alloy which can be identified by a forged H on the combustion face, and by a machined identification ring above the valve lock groove. See Figure 1-65.

S50G exhaust valves for automotive engines are an inconnel based material. They are marked with a "J" on the face of the valve and a "J6-E-5" and a green dot on the top of the stem of the valve.

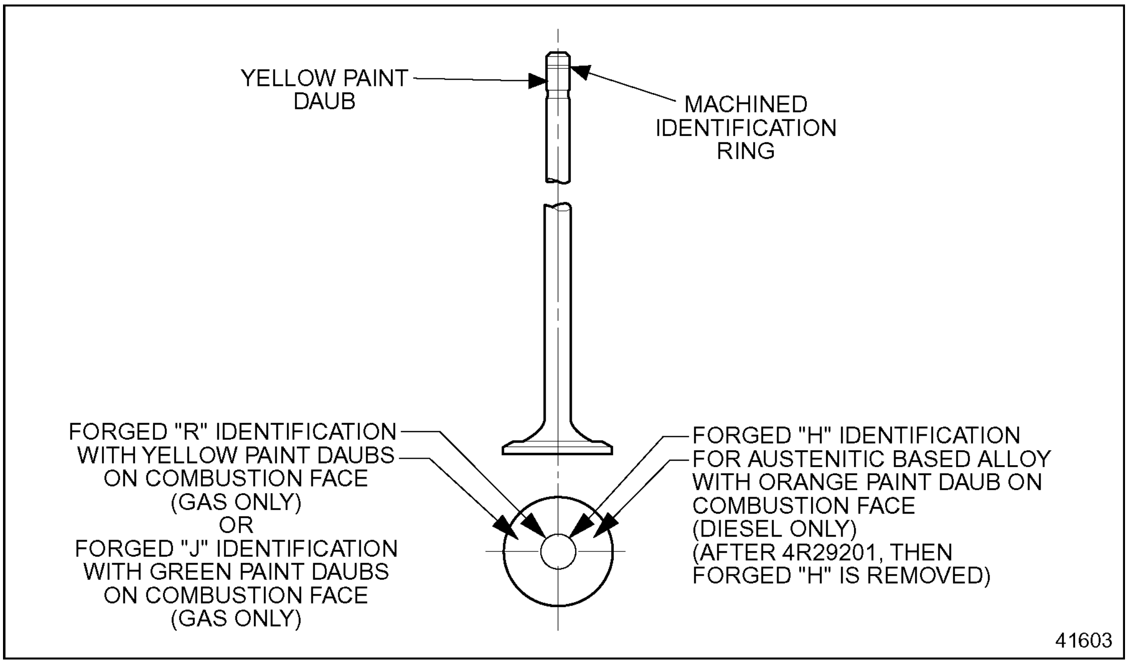


Figure 1-65 Exhaust Valve Identification

Beginning with engine model number 4R29201, distinguishing an intake valve from an exhaust valve can be identified by the different size dimples located on the combustion face of the valve, rather then forged lettering. See Figure 1-65 and see Figure 1-66. This applies to all *Series 50* diesel applications.

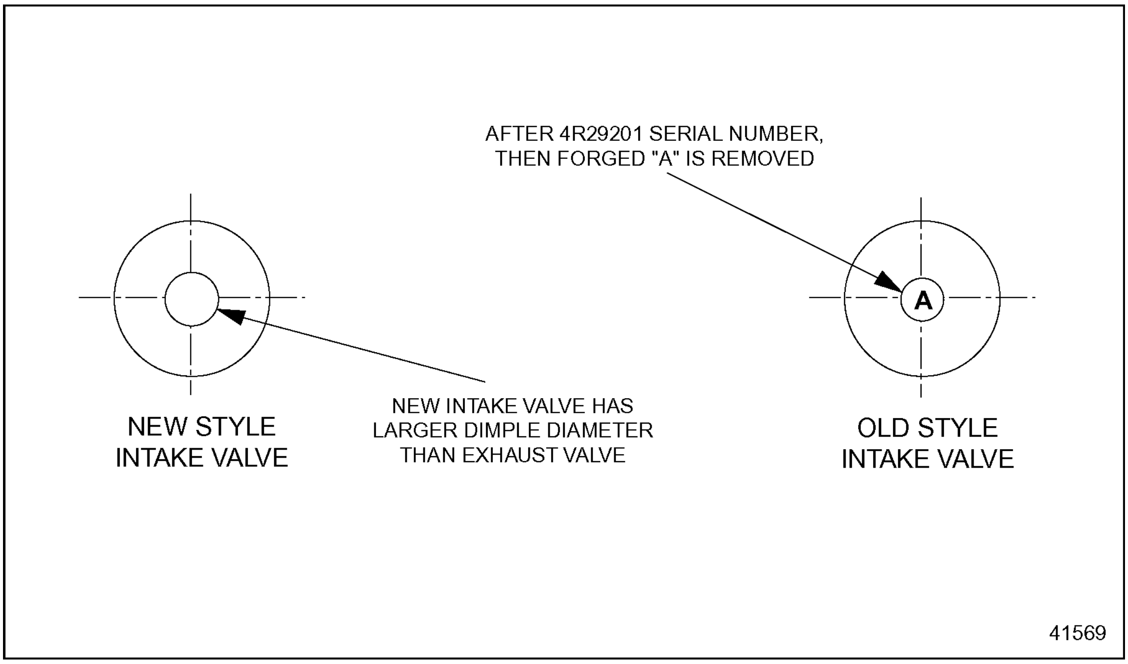


Figure 1-66 Intake Valve Identification

After engine serial number 4R37769 the Series 50 Diesel Engine will use a Nickel Alloy exhaust valve. This valve can be identified by the deletion of the machined identification ring above the keeper groove, and the raised bump on the combustion face of the exhaust valve. See Figure 1-67.

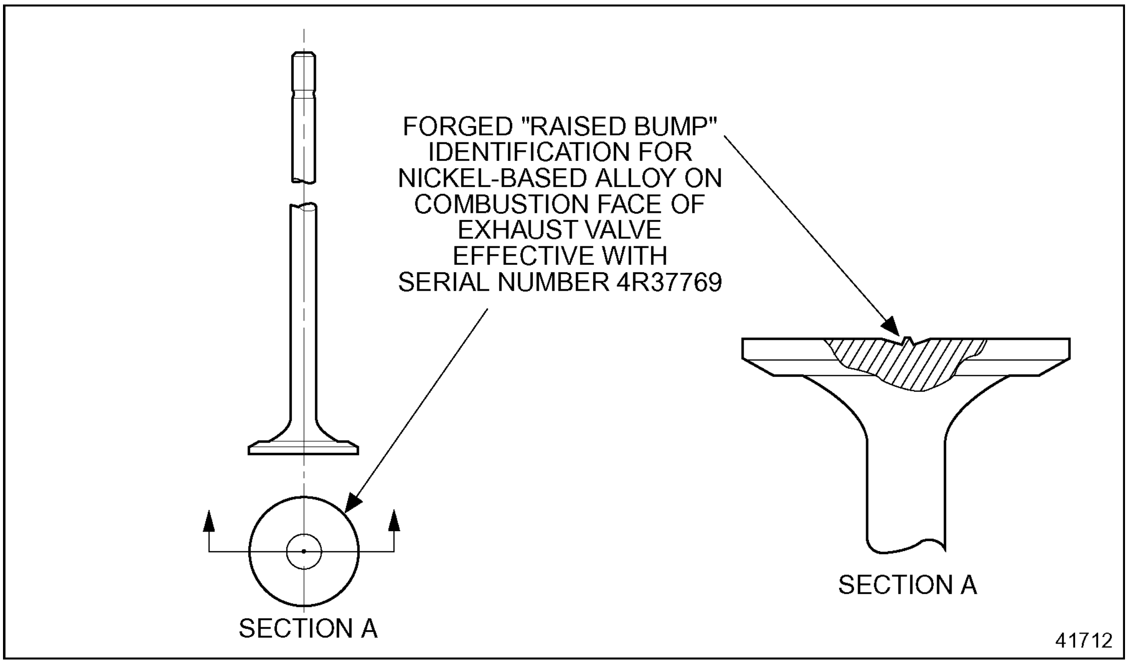


Figure 1-67 Exhaust Valve Identification

1.4.1 Repair or Replacement of Valves

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-68.

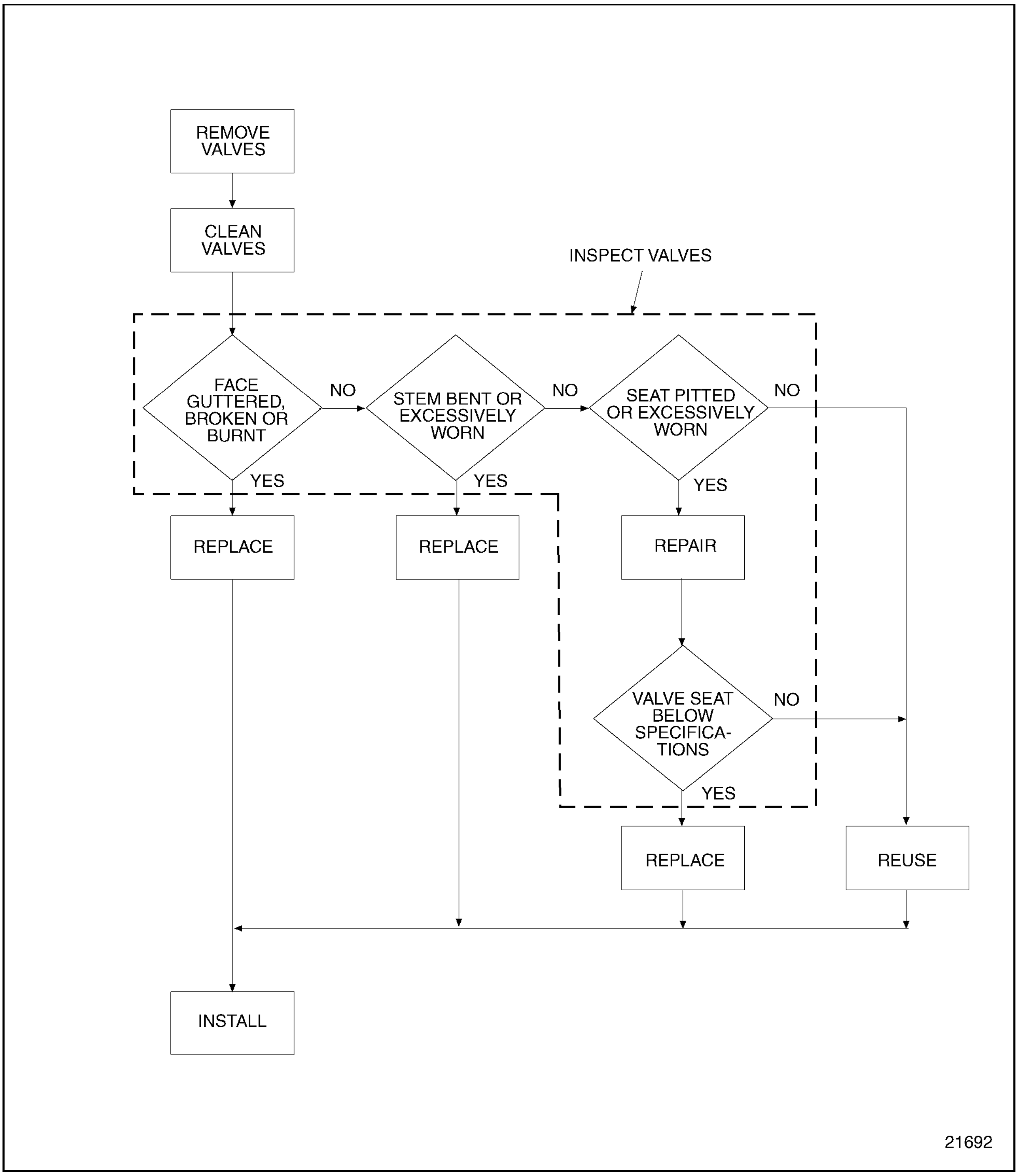


Figure 1-68 Flowchart for Repair or Replacement of Valves

1.4.2 Removal and Cleaning of Valve Spring (Cylinder Head Installed)

Perform the following steps for valve spring removal:

1. Clean any dirt and debris from the rocker cover joint area around the top of the cylinder head. Remove the rocker cover. Refer to Section 1.6.2.
2. If the engine has a Jake Brake, remove the Jake Brake housings that cover the rocker arm and shaft assembly for the valve to be serviced, refer to Section 1.30.2.
3. Remove the rocker arm shaft assembly; refer to Section 1.3.2.

NOTE:
Fuel must be removed from the cylinder head fuel galleries prior to removing the injectors. Refer to Section 2.3.2.

4. Remove the injector from the appropriate cylinder. Refer to Section 2.3.2.
5. Insert the threaded portion of the valve spring compressor, J 35580 into the threaded inboard camshaft cap hole adjacent to the valve being worked on. See Figure 1-69.

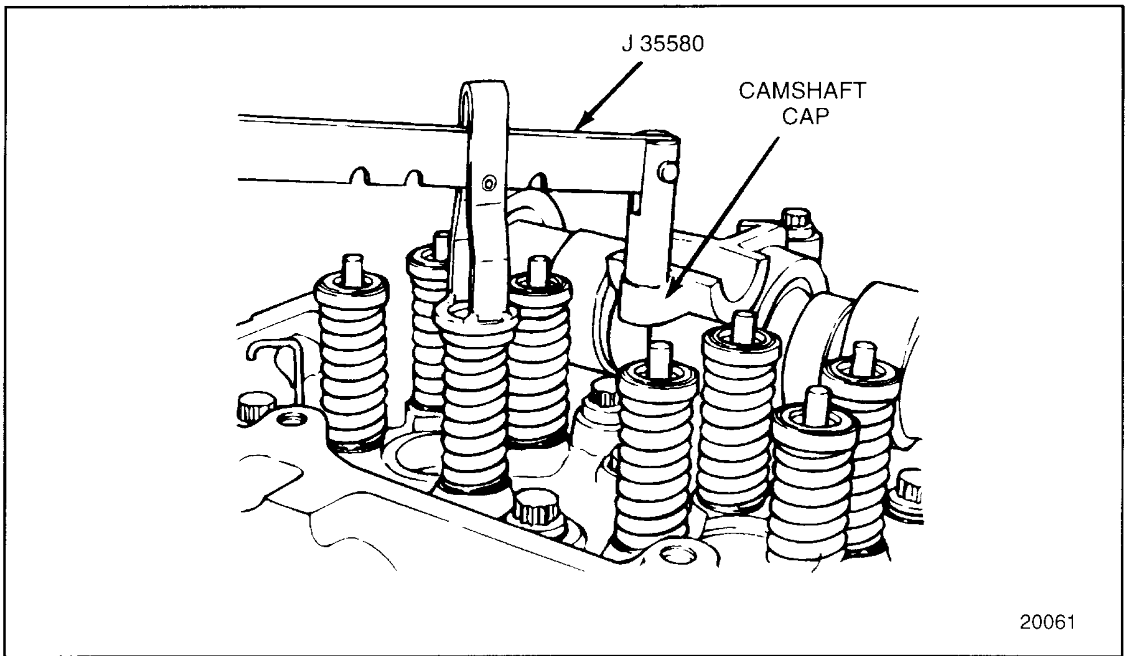


Figure 1-69 Installing Valve Spring Compressor

6. Position the spring compressor cage portion of the valve spring compressor directly over the valve spring to be compressed. Engage the dowel of the cage in the closest slot of the valve spring compressor handle.

NOTICE:
Do not contact the valve with the compressor tool, as the spring will be damaged.

7. Compress the valve spring and remove the valve locks using a small magnet to prevent the locks from falling into the cylinder head oil return galleries. See Figure 1-70.

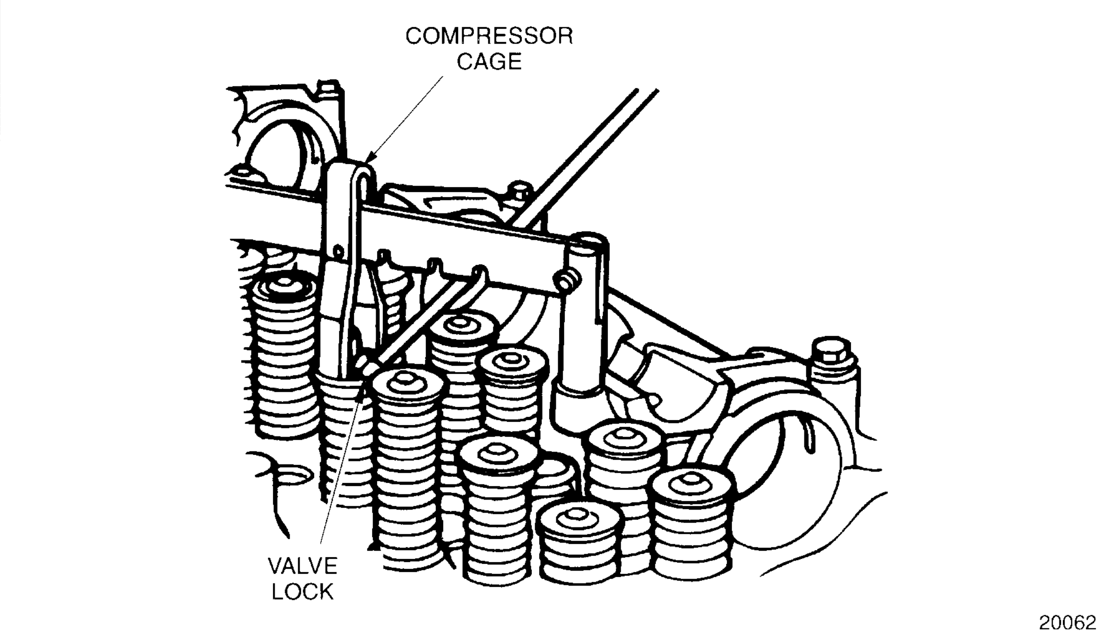


Figure 1-70 Compressing Valve Spring

8. Release the spring and remove the valve rotator and valve spring.

NOTE:
If the valve stem oil seal is to be replaced, remove the seal and discard it.

9. Repeat step 1 through step 8 on the other three valves for the cylinder being worked on.

NOTE:
All valve spring or seal removal and replacement must be completed for each cylinder being serviced while the piston is at top-dead-center, before turning the crankshaft to work on another cylinder.

1.4.3 Removal and Cleaning of Valve Spring (Cylinder Head Removed)

With the cylinder head assembly removed from the engine, remove the valve springs as follows:

1. Bolt the engine overhaul stand adaptor, J 39652, to the engine overhaul stand, J 29109, using the hardware provided with the adaptor. See Figure 1-71.

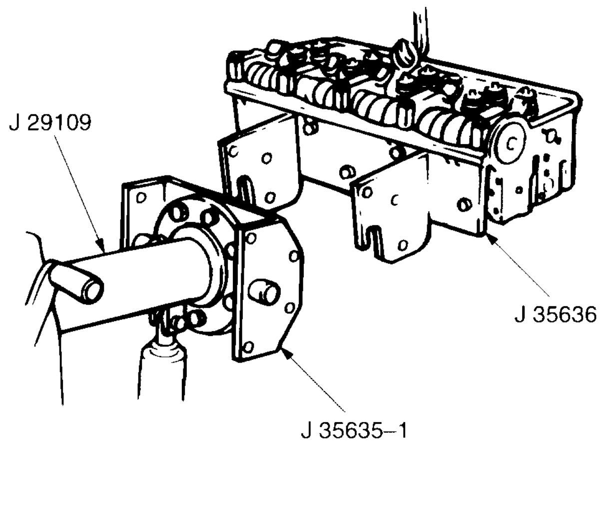


Figure 1-71 Engine Overhaul Stand

2. Bolt the cylinder head adaptor plate, J 35636-A, to the cylinder head using the bolts provided with the adaptor.
3. Mount the cylinder head and adaptor plate to the overhaul stand adaptor by engaging the slots in the cylinder head adaptor plate to the dowels on the overhaul stand adaptor.
4. Install the six nut and bolt assemblies that secure the cylinder head adaptor plate to the overhaul stand adaptor.
5. Remove the cylinder head lifting hardware.
6. Turn the crank of the engine overhaul stand to position the cylinder head in an upright position.

NOTICE:
Do not contact the valve with the compressor tool, as the spring will be damaged.

7. Use valve spring compressor, J 8062-1 part of J 8062, with jaws, J 8062-3 part of J 8062installed, to compress each valve spring and remove the valve locks. See Figure 1-72. Refer to Section 1.4.5.2 for inspection procedures.

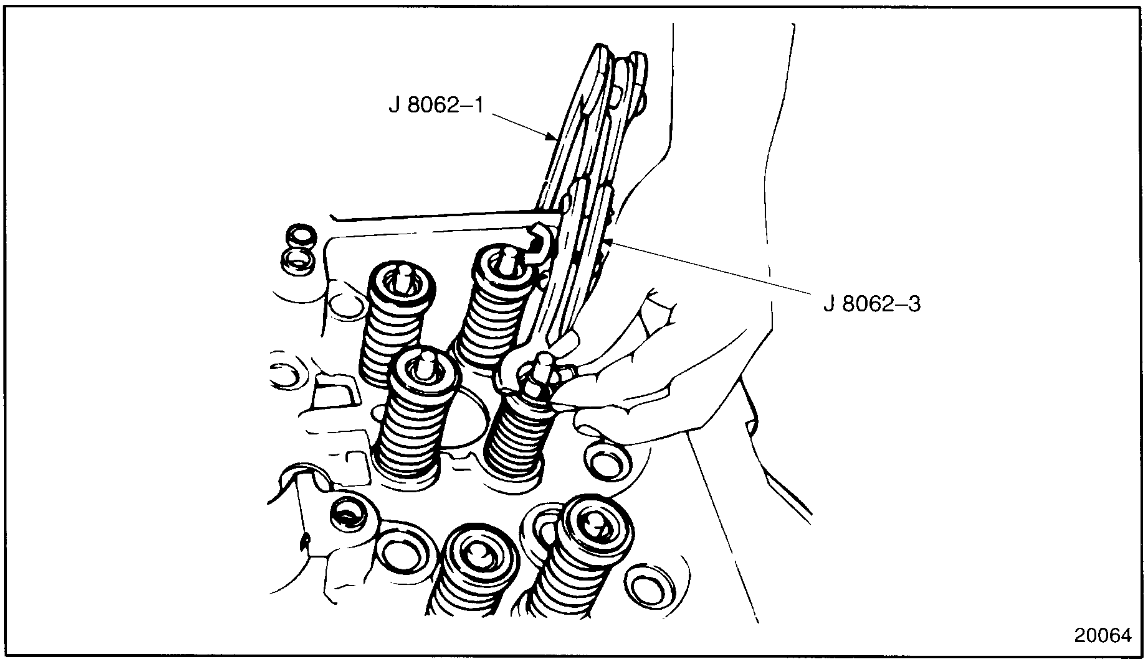


Figure 1-72 Compressing Valve Spring

8. Release the spring and remove the valve, valve rotator and valve spring.
9. Remove the valve stem oil seal and discard the seal.
10. Remove the valve spring seat.
11. As parts are removed, mark or segregate them according to their original position for possible reuse.

1.4.3.1 Cleaning of Valves

Clean the valves and parts as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Using proper eye protection, clean all of the disassembled parts with fuel oil and dry with compressed air.

1.4.3.2 Cleaning of Valve Stems

Perform the following for valve stem cleaning:

1. Clean the carbon from the valve stems and wash the valves with fuel oil.

1.4.3.3 Cleaning of Valve Guide Bore

Perform the following for valve guide bore cleaning:

1. Clean the valve guide bore with bore brush, J 5437 (or equivalent), to remove all gum and carbon deposits.

1.4.4 Valve Guide Removal

Perform the following steps for valve guide removal:

NOTE:
Valve guides are not replaceable on natural gas engines

1. Assemble the valve guide remover, J 34696-B, to an air chisel. See Figure 1-73.

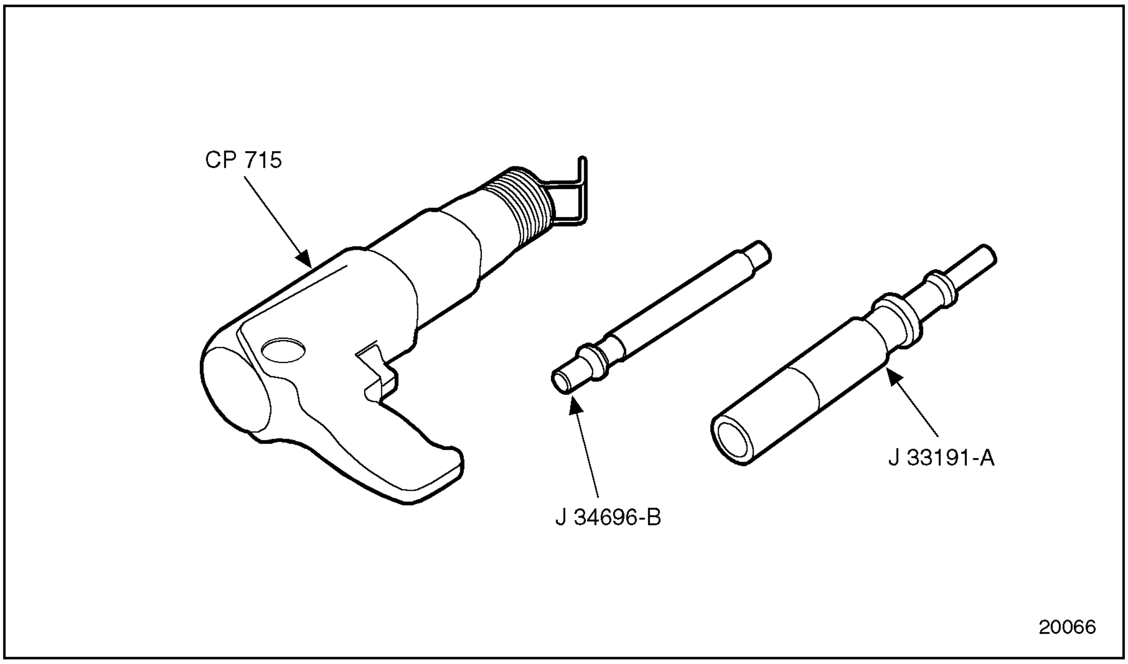


Figure 1-73 Valve Guide Remover

2. Position the cylinder head firedeck side up on a turn over stand or supported on 102 x 102 mm (4 x 4 in.) wooden blocks on a workbench.

3. Insert the tool into valve guide from the firedeck side of the cylinder head. See Figure 1-74.

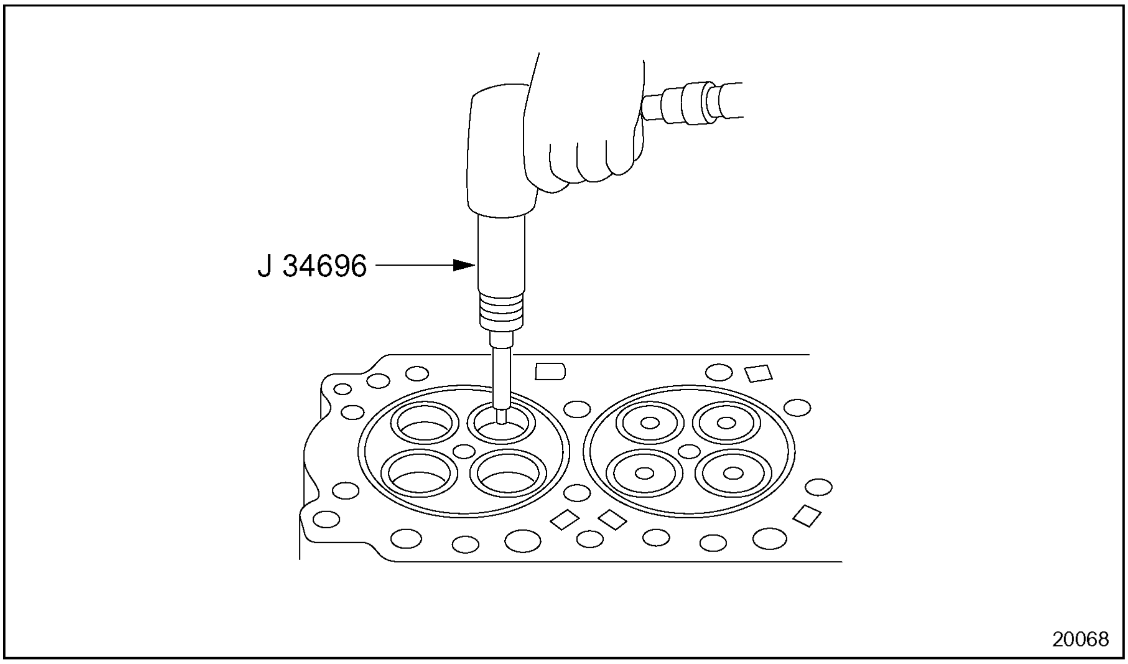
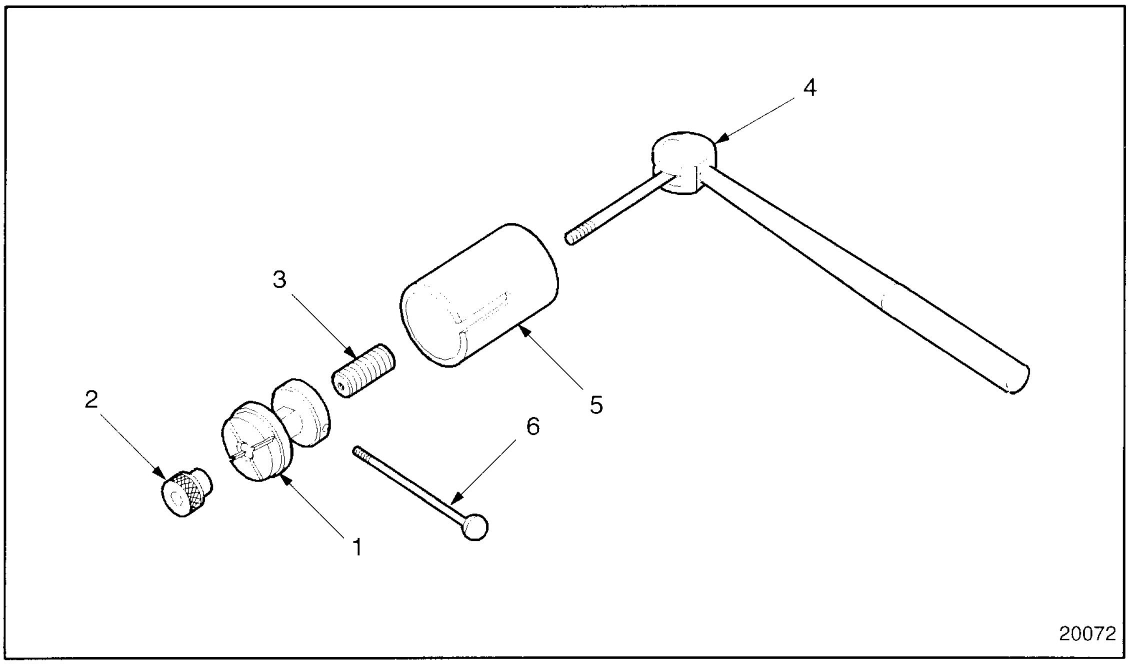


Figure 1-74 Valve Guide Removal

4. Hold the tool vertical to the cylinder head and drive the valve guide until it is free of the cylinder head.

1.4.5 Removal of Intake and Exhaust Valve Seat Insert

As the intake and exhaust valve seats are different in size, two different tools are required for removal. Use the cam-operated valve seat remover, J 23479-460A, with collet, J 23479–100 (Part of J 23469–460A), to remove the larger intake valve seat insert. Use valve seat remover, J 23479-271, with collet J 23479-29 to remove the smaller exhaust valve seat insert. See Figure 1-75.



1. Collet
2. Knurled Knob
3. Spring
4. Valve Seat Insert Puller
5. Collar
6. Collet Lever

Figure 1-75 Valve Seat Insert Remover Tools

Remove the intake and exhaust valve seats as follows:

1. Place the cylinder head in a horizontal position with the valve seats facing up.

NOTICE:
Follow instructions supplied with tools J 23479-460A, J 23479-100-A , J 23479-271, and J 23479-29 to ensure longer tool life and unnecessary collet damage.

2. Follow the instructions furnished with the valve seat remover tool to assemble the remover.
3. Using a new valve seat insert as a guide, turn the knurled knob on the end of the shaft to tighten and expand the collet until the valve seat insert will just slip off the collet. Refer to instructions supplied with the valve seat remover tool for correct tool operation.

1.4.5.1 Inspection of Valve

The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges or cracks. Some pitting of the valve face is normal, and is acceptable as long as no leak paths are evident. If leak paths exist, reface the valves or install new valves. If the valve heads are warped or the valve stem is bent, replace the valves.

If suitable for reuse, a valve may be refaced as long as the valve rim width, after refacing, is not less than 2.0 mm (0.078 in.) for intake valves and 2.2 mm (0.086 in.) for exhaust valves. See Figure 1-76.

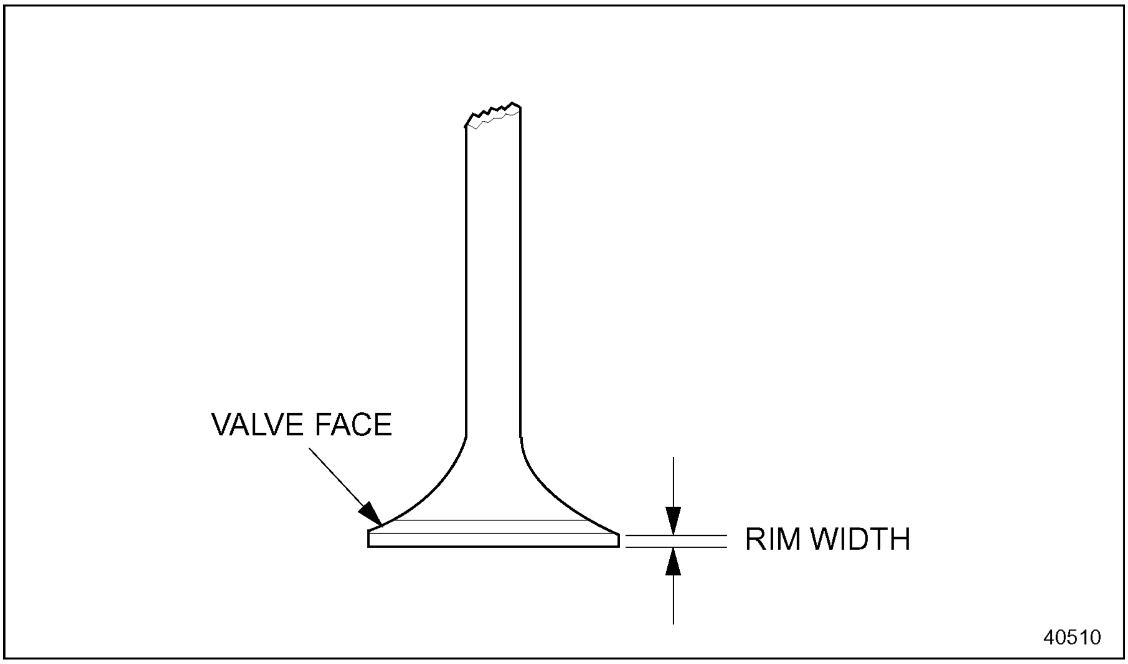


Figure 1-76 Valve Face Refacing and Rim Width

1.4.5.2 Inspection of Valve Springs

Inspect the valve springs and replace any that are pitted or cracked. The entire spring should be inspected. When a broken spring is replaced, the rotator and valve locks for that valve should also be replaced.

Use valve spring tester, J 22738-02, to test the springs. See Figure 1-77.

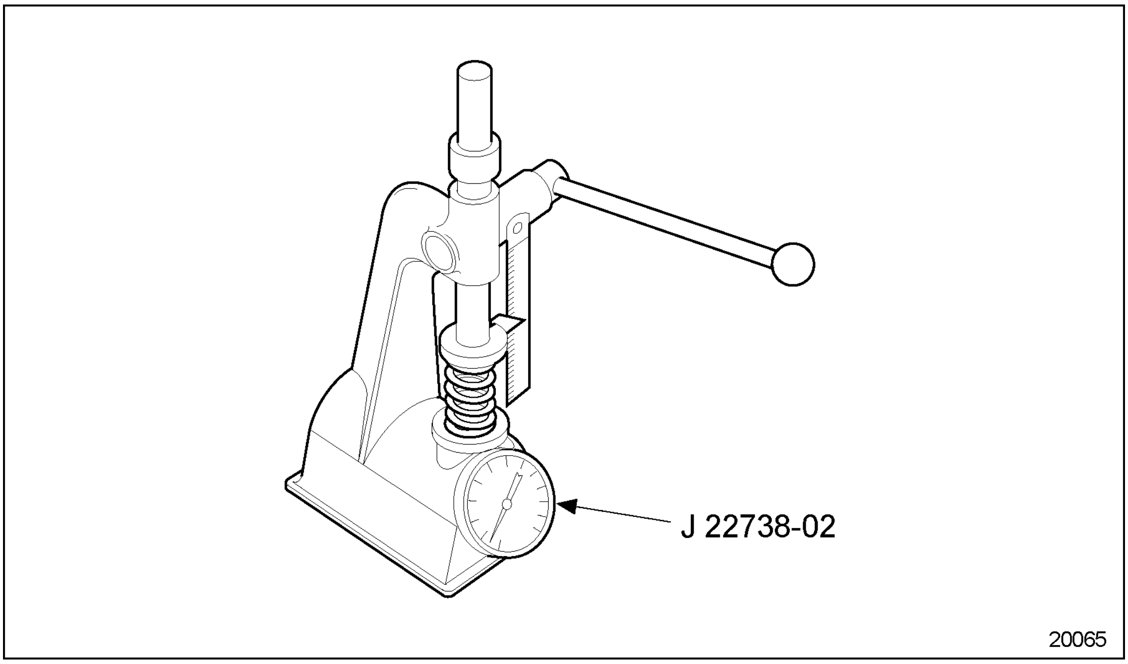


Figure 1-77 Testing Valve Spring

If the spring load is less than 297 N (67 lb) at a compressed length of 67.25 mm (2.648 in.), the spring should be replaced and the valve locks should be discarded.

1.4.5.3 Inspection of Valve Guides

Inspect the guides for cracks, chipping, scoring or excessive wear.

Measure the valve guide bore with a small hole gage or gage pin, and measure the valve stem diameter with a micrometer. Compare the measurements to determine valve stem clearance. If the clearance is greater than 0.13 mm (0.005 in.), the valve guide must be replaced.

1.4.5.4 Inspection of Valve Seat Inserts

Inspect valve seat inserts for wear, cracking or incorrect seat angle, which should be 31°, standard valve seat insert thickness.

1.4.6 Installation of Intake and Exhaust Valve Seat Insert

Perform the following steps for intake and exhaust valve seat insert installation:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Clean the seat insert counterbores and the new seat inserts with a suitable solvent and blow dry with compressed air.
2. Use valve seat insert installers, J 33190 (intake), and J 34983 (exhaust), to install new inserts. See Figure 1-78.

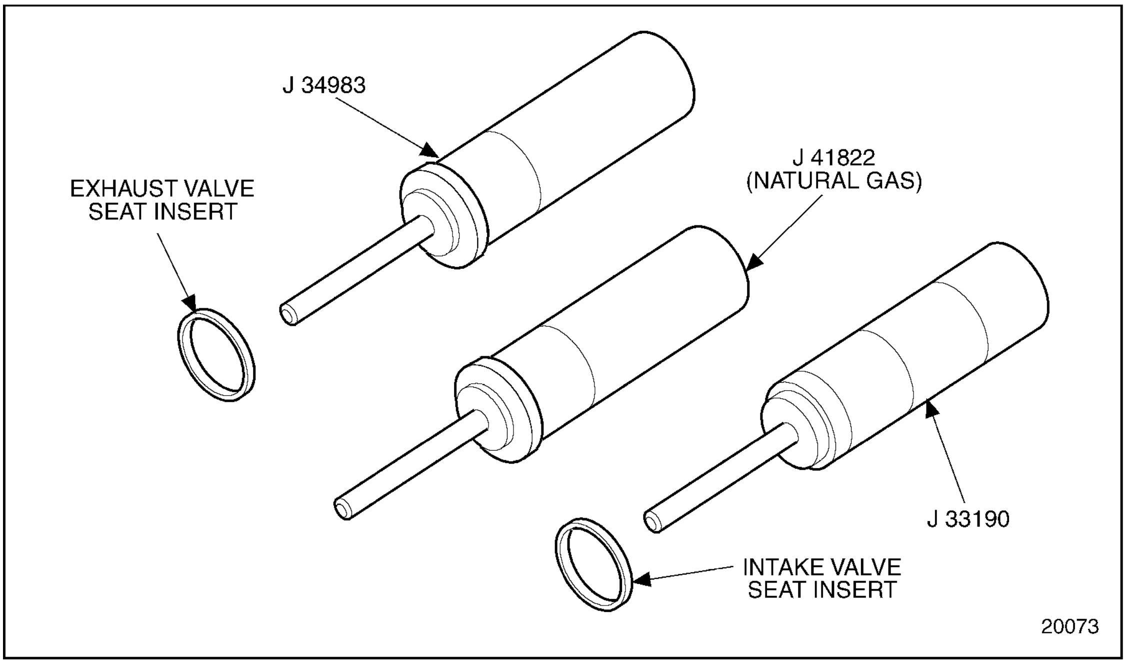


Figure 1-78 Valve Seat Insert Installation Tools

3. Start the insert squarely into its counterbore with the seat facing up. See Figure 1-79.

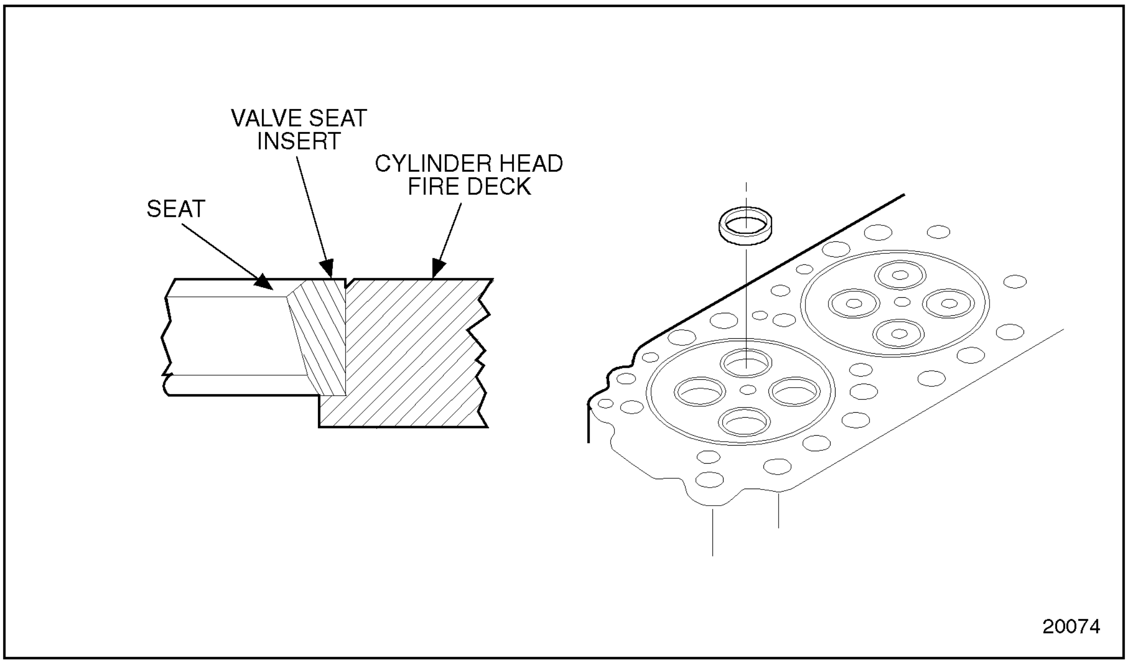


Figure 1-79 Valve Seat Insert Insertion

4. Pilot the installer into the valve guide from the firedeck surface. See Figure 1-80.

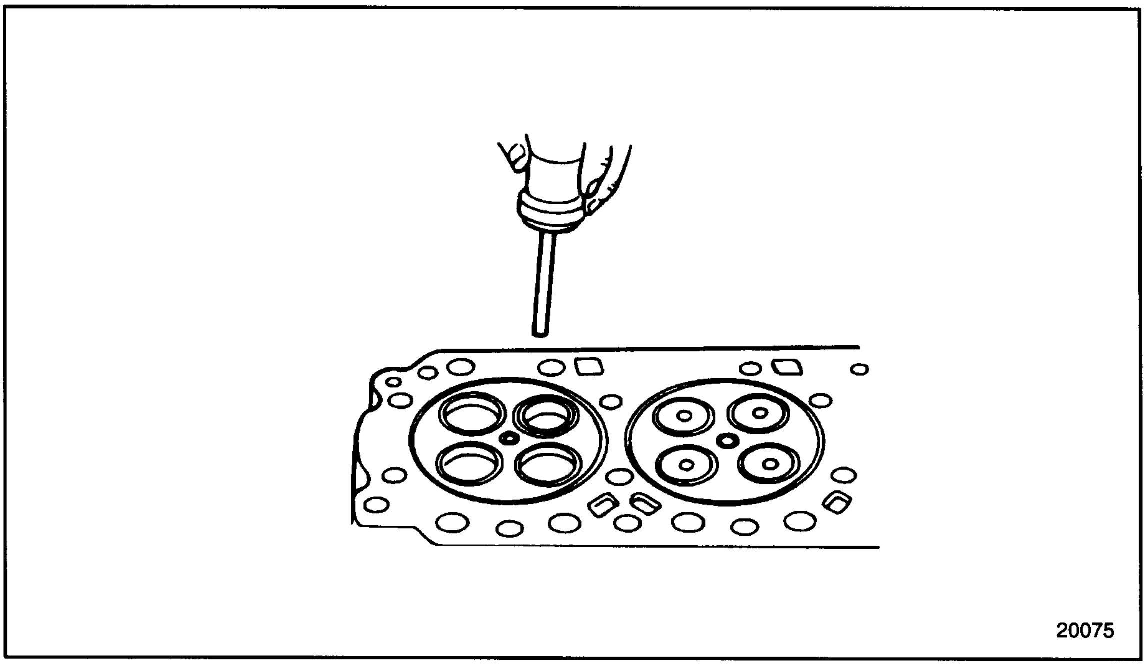


Figure 1-80 Valve Seat Insert Installation

5. Drive the insert solidly into its seat in the cylinder head. See Figure 1-81.

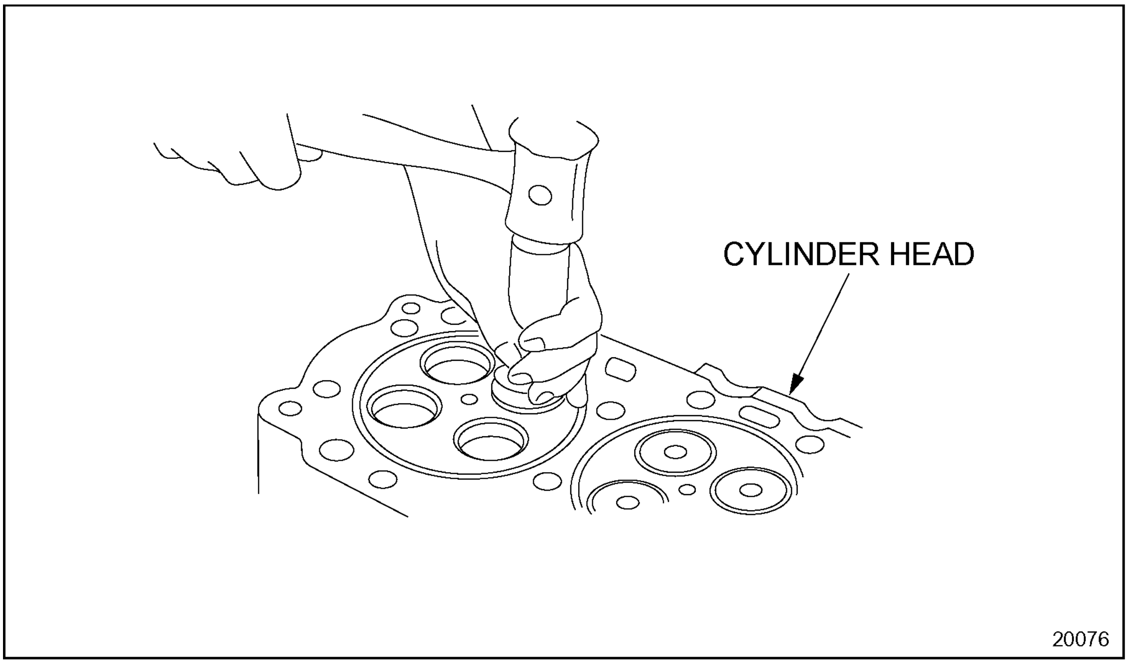


Figure 1-81 Seating Valve Seat Insert

6. Check the concentricity of valve seat with the valve guide using dial indicator, J 8165-2, and pilot, J 35623-A. See Figure 1-82.

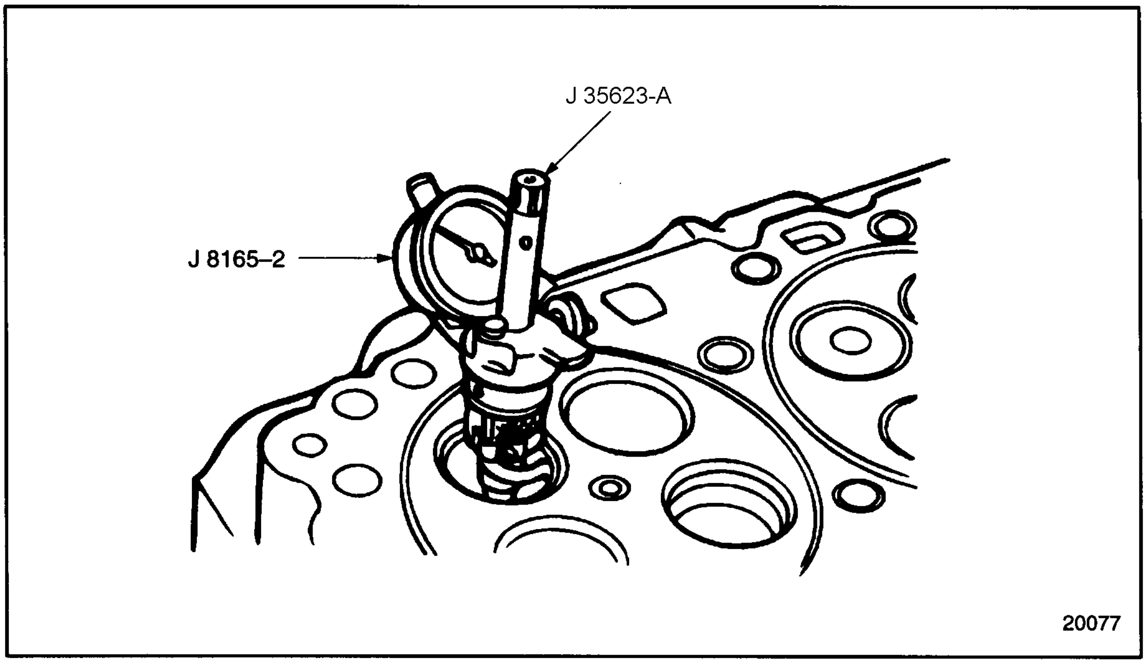


Figure 1-82 Check Valve Seat Concentricity

7. If the concentricity is not within 0.05 mm (0.002 in.), grind the seat only enough to true it up, being sure to lightly grind a full 360°.

Valve seat insert grinding should be limited to light clean-up or concentricity truing. For a fine, accurate finish, the eccentric grinding method using tool J 7040-A is recommended, because the grinding wheel contacts the insert at only one point at any time, and a micrometer feed permits controlled fine adjustment. Seats must be ground to a 31° angle. See Figure 1-83.

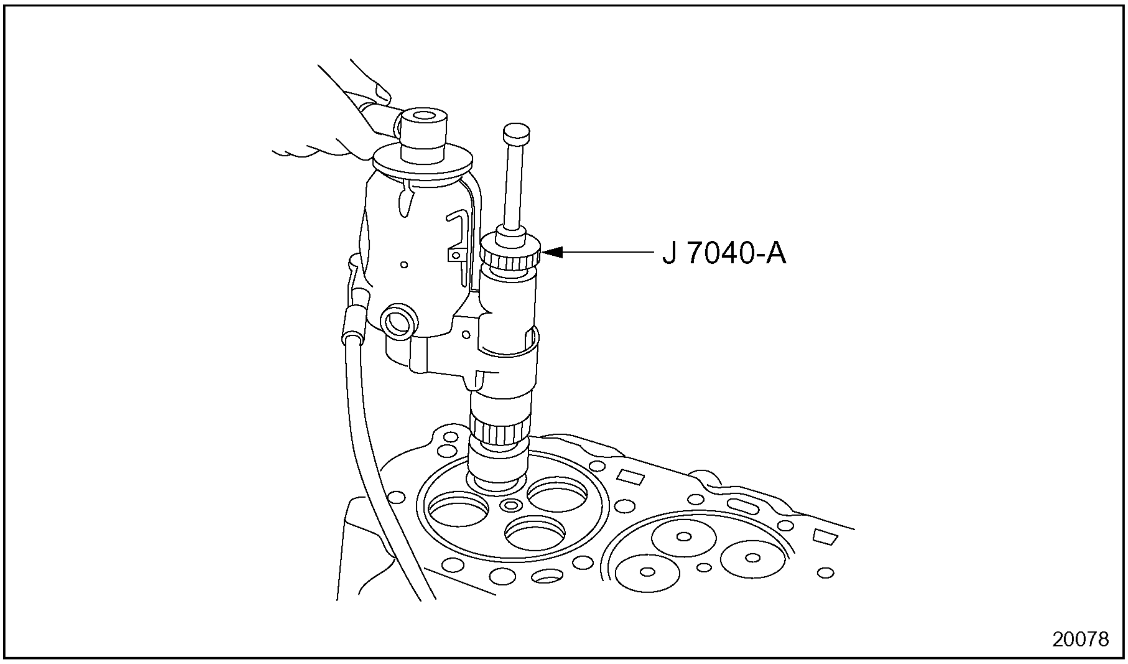


Figure 1-83 Grinding Valve Seat Insert

The valve head recess depth from the firedeck is increased by valve and/or insert grinding. It should be checked with a sled gage, J 22273-01 (or equivalent). See Figure 1-84.

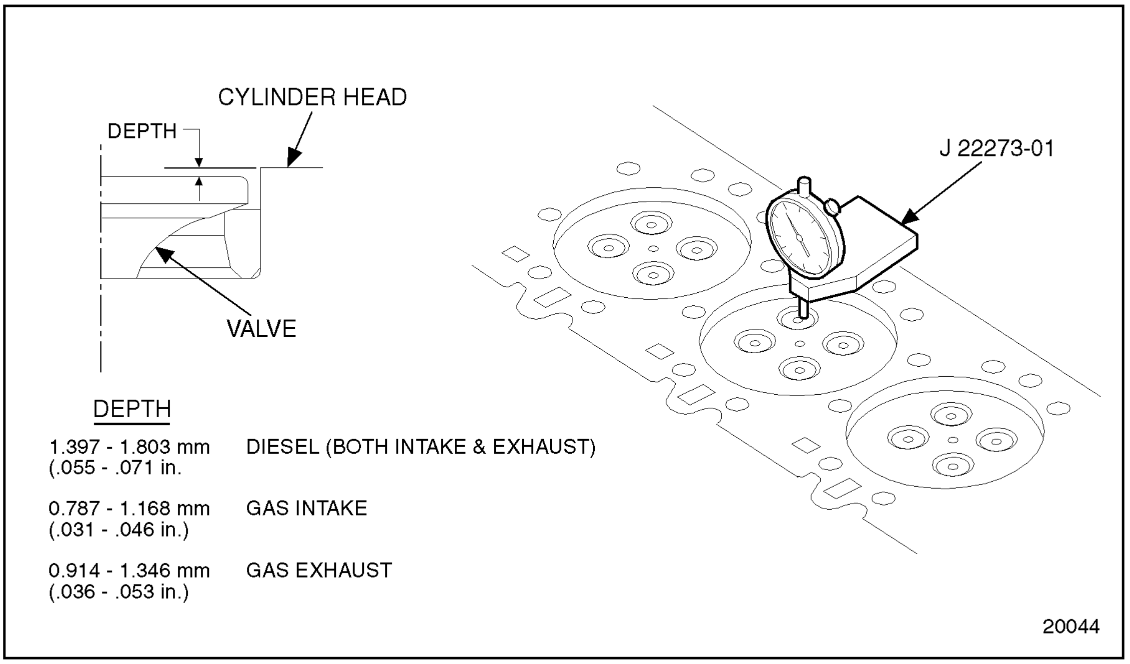


Figure 1-84 Measuring Valve Head Recess Depth

If the valve head recess depth is not between 1.4 to 1.8 mm (0.055-0.070 in.), the valve and seat must be replaced.

If the valve head recess depth is not between 0.91-1.34 mm (0.036-0.053 in.), the exhaust valve and seat must be replaced.

If the valve head recess depth is not between 0.91-1.34 mm (0.036-0.053 in.), the intake 0.79-1.17 mm (0.031-0.046 in.) valve and seat must be replaced for the Series 50G.

After light clean-up, thoroughly clean the valve seat with fuel oil and blow dry with compressed air. Check seat-to-valve face contact by applying a light coat of Prussian Blue (or equivalent) to the valve seat land. Insert the valve in the guide and "bounce" the head on the seat insert without rotating the valve. A full 360° contact line should appear approximately centered on the valve face.

1.4.7 Valve Guide Installation

Perform the following steps for valve guide installation:

NOTE:
Valve guides are not replaceable on natural gas engines

1. Start the chamfered end of the valve guide into the cylinder head from the top. See Figure 1-85.

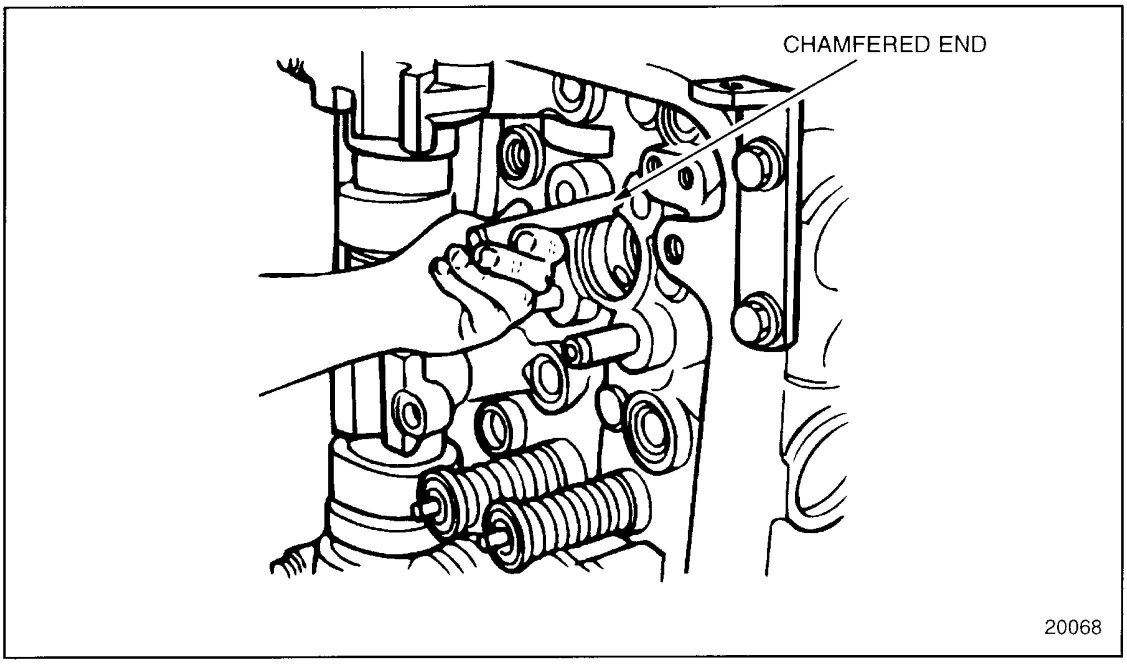


Figure 1-85 Valve Guide Installation

2. Insert the driver into an air chisel. Insert the driver into the valve guide limiting sleeve and install this assembly over the valve guide. Drive the guide into the cylinder head

using valve stem seal installer, J 35599 until the installer bottoms in the limiting sleeve. See Figure 1-86.

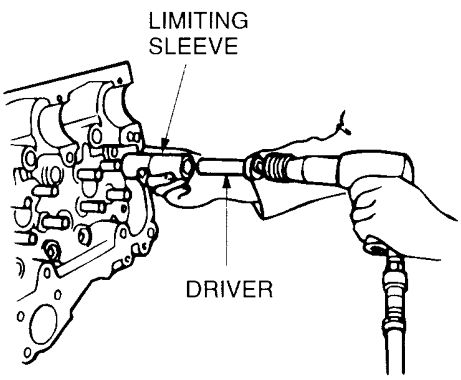


Figure 1-86 Valve Guide Installation

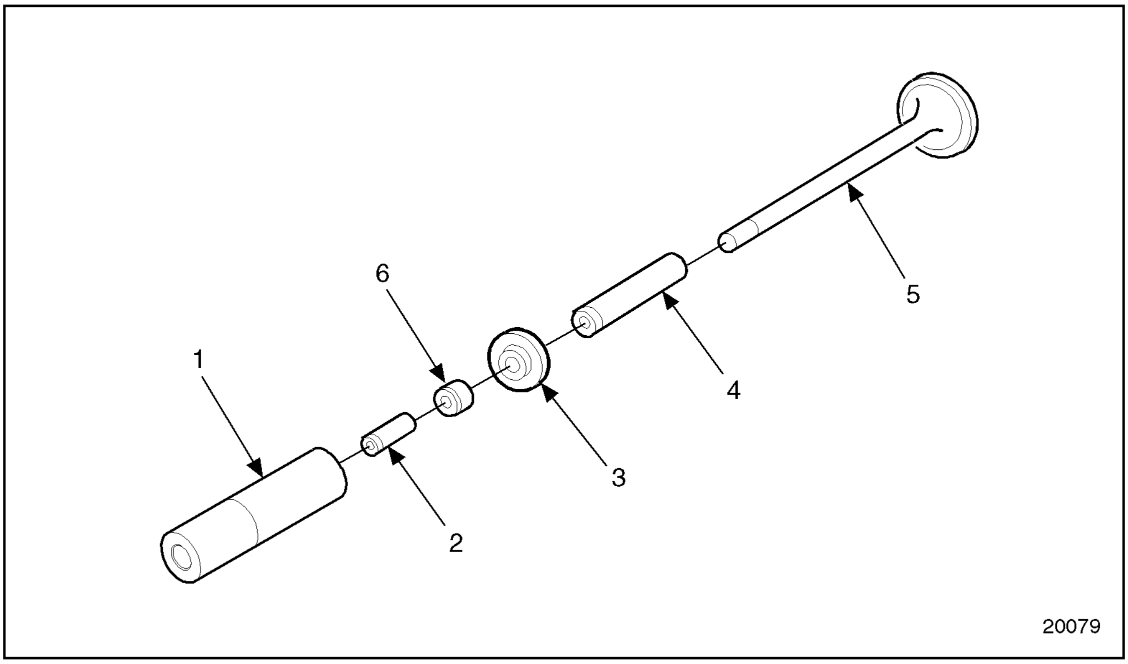
3. Properly used, the installer ensures the correct protrusion of the valve guide from the cylinder head of 37.75 mm (1.486 in.).

1.4.8 Valve Spring, Seal and Rotator Installation

Perform the following steps for valve installation:

1. Position the cylinder head vertically on the overhaul stand. Lubricate the valve stems with clean engine lubricating oil and slide them into their respective valve guides and against the valve seats. If reusing valves, install them to their original positions.

2. Install the valve spring seat over the valve guide. Install the valve stem oil seals using valve stem oil seal installation tools. See Figure 1-87.



1. Valve Stem Seal Installer
2. Oil Seal Protector Cap
3. Valve Spring Seat
4. Valve Guide
5. Valve
6. Valve Stem Oil Seal

Figure 1-87 Valve Stem Oil Seal Installation Tools

3. Check the length of the plastic seal protector cap relative to the lock groove on the valve stem. See Figure 1-88.

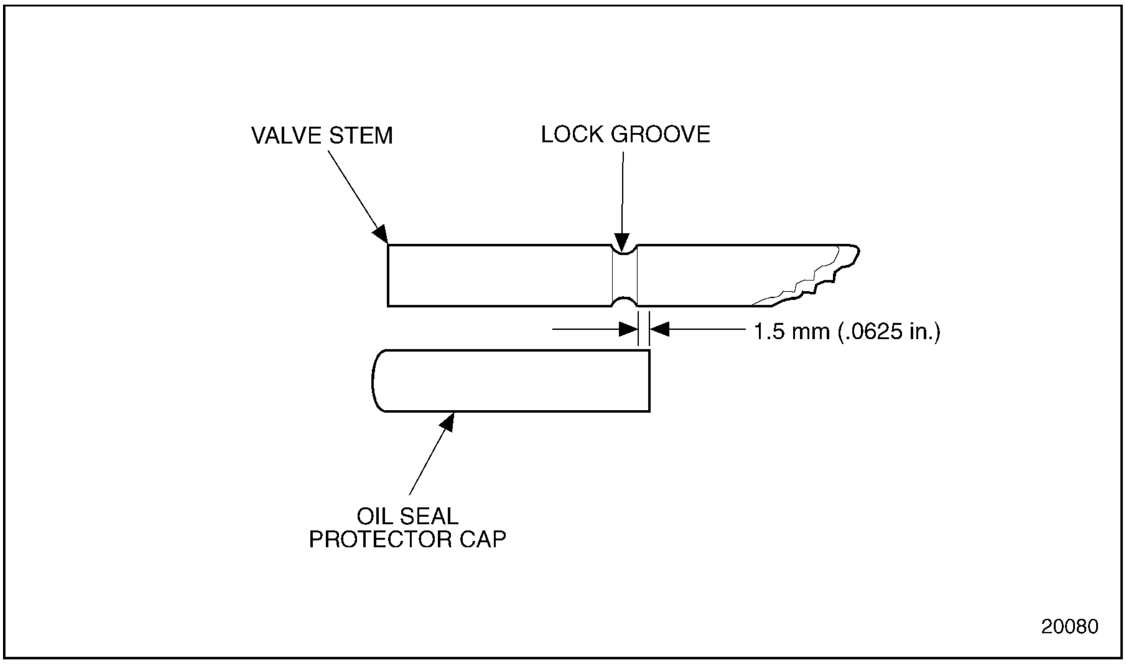


Figure 1-88 Oil Seal Protection Cap Sizing

[a] If the seal protector cap extends more than 1.5 mm (1/16 in.) beyond the groove, trim off the excess length of the cap.

4. Install the cap over the valve stem. See Figure 1-89.

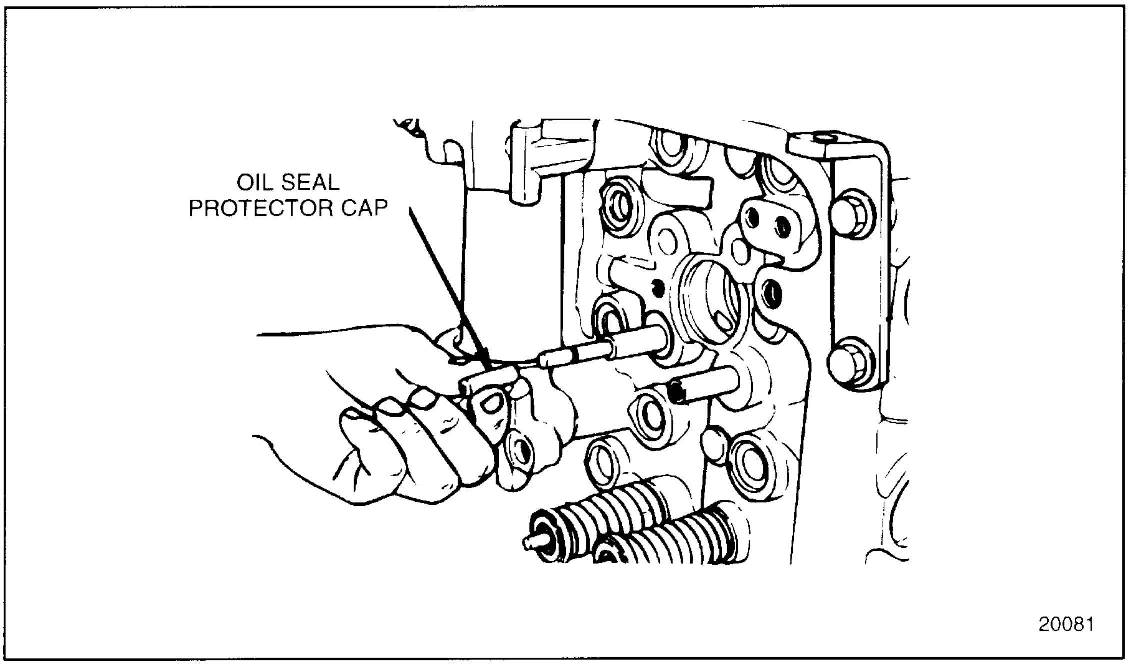


Figure 1-89 Oil Seal Protection Cap Installation

NOTICE:
Be sure that all valve spring seats have been installed before the valve stem seal is installed.

5. The valve stem oil seal may be installed with or without oil. Push the seal over the protector. See Figure 1-90.

NOTE:
The valve stem oil seal on the natural gas engine has a larger inside diameter than the seal on the diesel engine.

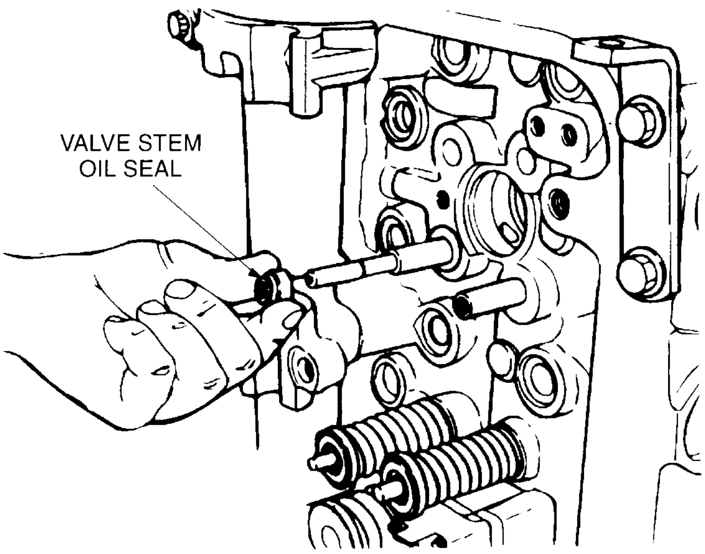


Figure 1-90 Valve Stem Oil Seal Installation

6. Push the seal down on the valve stem using the seal installer, J 39109 while holding the valve head against the sea. See Figure 1-91.

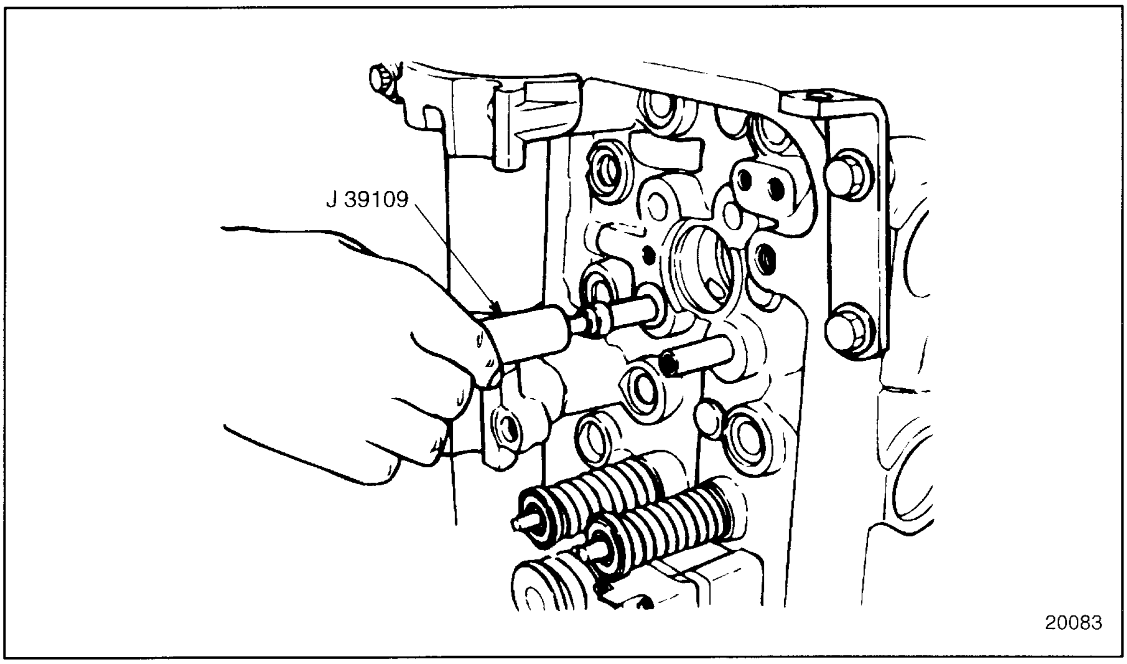
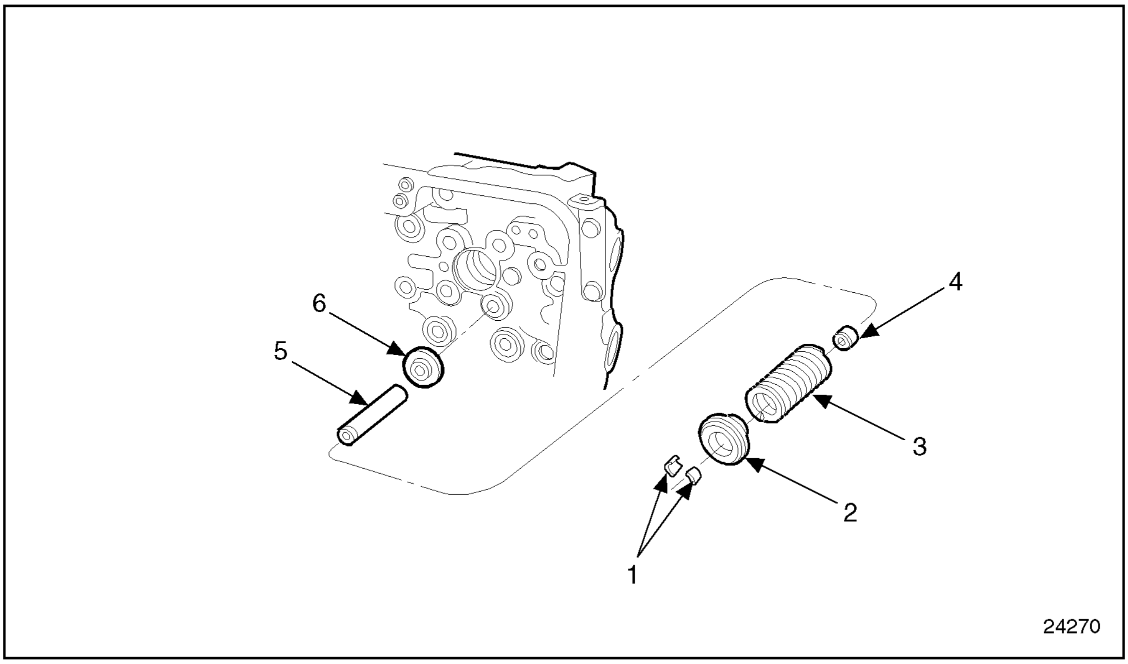


Figure 1-91 Valve Stem Oil Seal Installer

7. When the installer tool contacts the cylinder head, the seal is correctly positioned. Be sure the installer is square against the cylinder head. Remove the seal installer and protector cap.

8. Install the valve spring and rotator. See Figure 1-92. If reusing parts, install them to their original positions.



1. Valve Key Locks
2. Valve Rotator
3. Valve Spring
4. Valve Stem Oil Seal
5. Valve Guide
6. Valve Spring Seat

Figure 1-92 Valve Spring and Related Parts

NOTE:
Always install new valve key locks when installing valves.

9. Using the valve spring compressor tool, J 8062-1 part of J 8062, compress the valve spring only as much as required to install the valve locks. After installing the valve locks, rap the end of the valve stem sharply with a plastic mallet to seat the valve locks.

NOTE:
Be sure the valve rotator is properly centered and aligned to avoid scoring the valve stem. Do not compress the spring any more than necessary to install the locks, to avoid damaging the oil seal.

10. After all of the valves are installed, check the spring opening pressure on each valve using spring load gage, J 25076-B (or equivalent). See Figure 1-93.

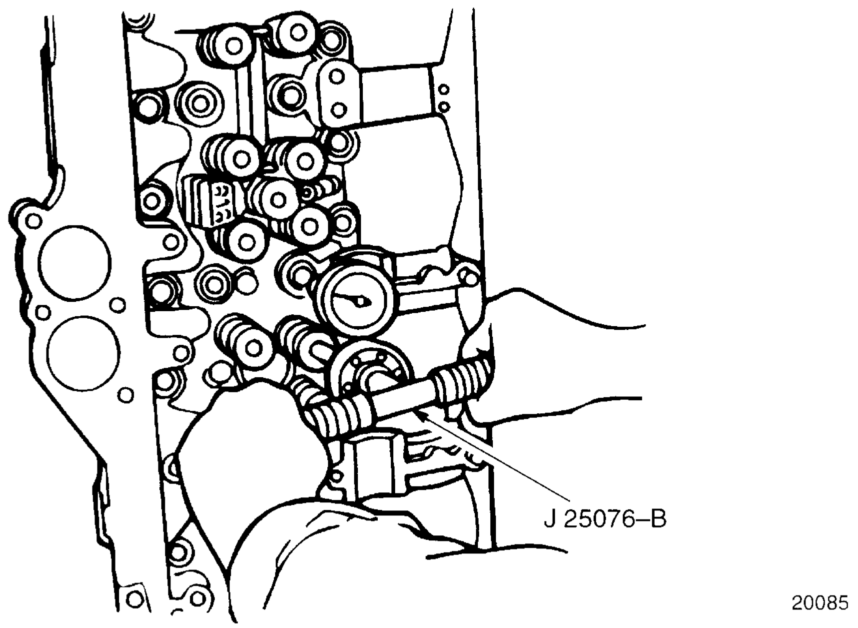


Figure 1-93 Checking Valve Spring Load

11. Note the gage reading when the valve just starts to unseat. The force required to unseat the valve must not be less than 290 N (65 lb).
12. Remove the cylinder head from the overhaul stand and install it on the engine. Refer to Section 1.2.5.
13. Install the camshaft and rocker arm assemblies. Lightly lubricate the overhead assemblies with clean engine oil. Refer to Section 1.22.5.
14. If the engine is equipped with a Jake Brake, install the brake. Refer to Section 1.30.5.
15. Adjust the valve clearance and injector timing. Refer to Section 12.2.
16. If the engine is equipped with a Jake Brake, lash the brake. Refer to Section 1.30.
17. Install any other components that were removed.
18. Fill the engine crankcase, refer to Section 13.5.1, with the proper lubricant. Refer to Section 5.2 for proper lubricant.
19. Close any drain cocks that were opened and fill the cooling system. Refer to Section 13.5.4. Purge the air from the system using the vent in the thermostat housing. Complete filling of the cooling system is essential for proper engine operation.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

20. Start the engine and check for leaks.

1.5 ENGINE LIFTER BRACKETS

A total of three engine lifter brackets are installed on each Series 50 Engines and are utilized when removing and replacing the engine. See Figure 1-94.

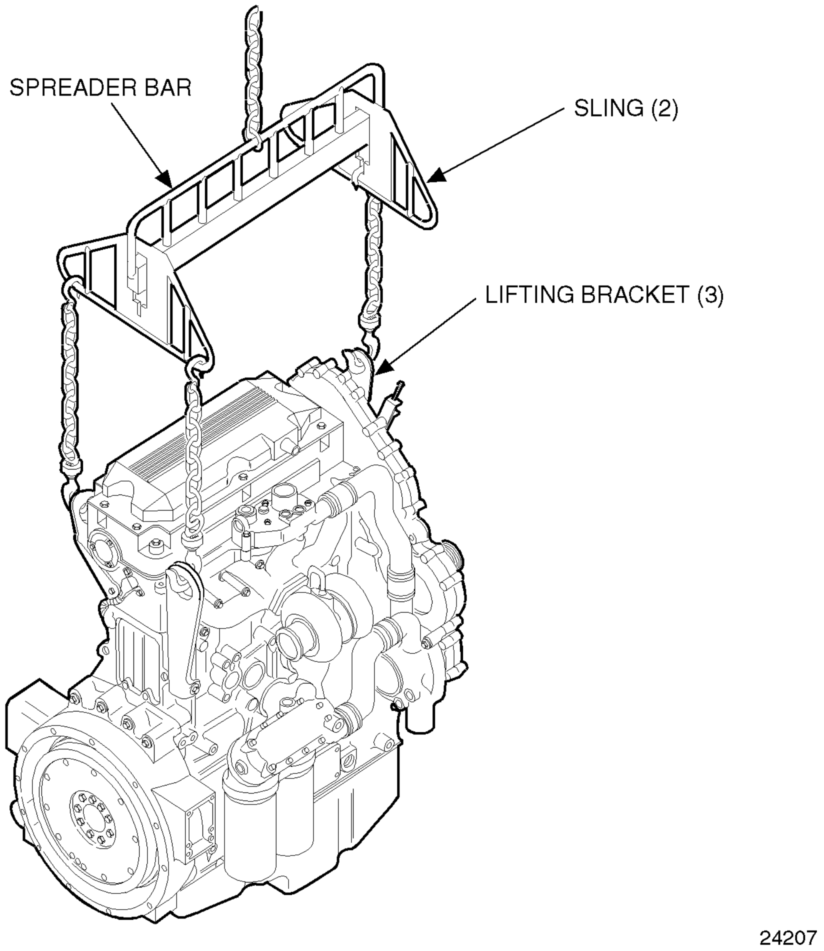


Figure 1-94 Lifting Engine

NOTICE:
To lift the engine, use a suitable lifting device. See Figure 1-94. 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 the engine lift brackets. To ensure proper weight distribution, all three engine lift brackets provided must be used in lifting the engine. Be sure the spreader bar is adequate to prevent lifter brackets from contacting the engine rocker cover and causing damage.

A lifter bracket should always be reinstalled whenever removal is necessary. See Figure 1-95.

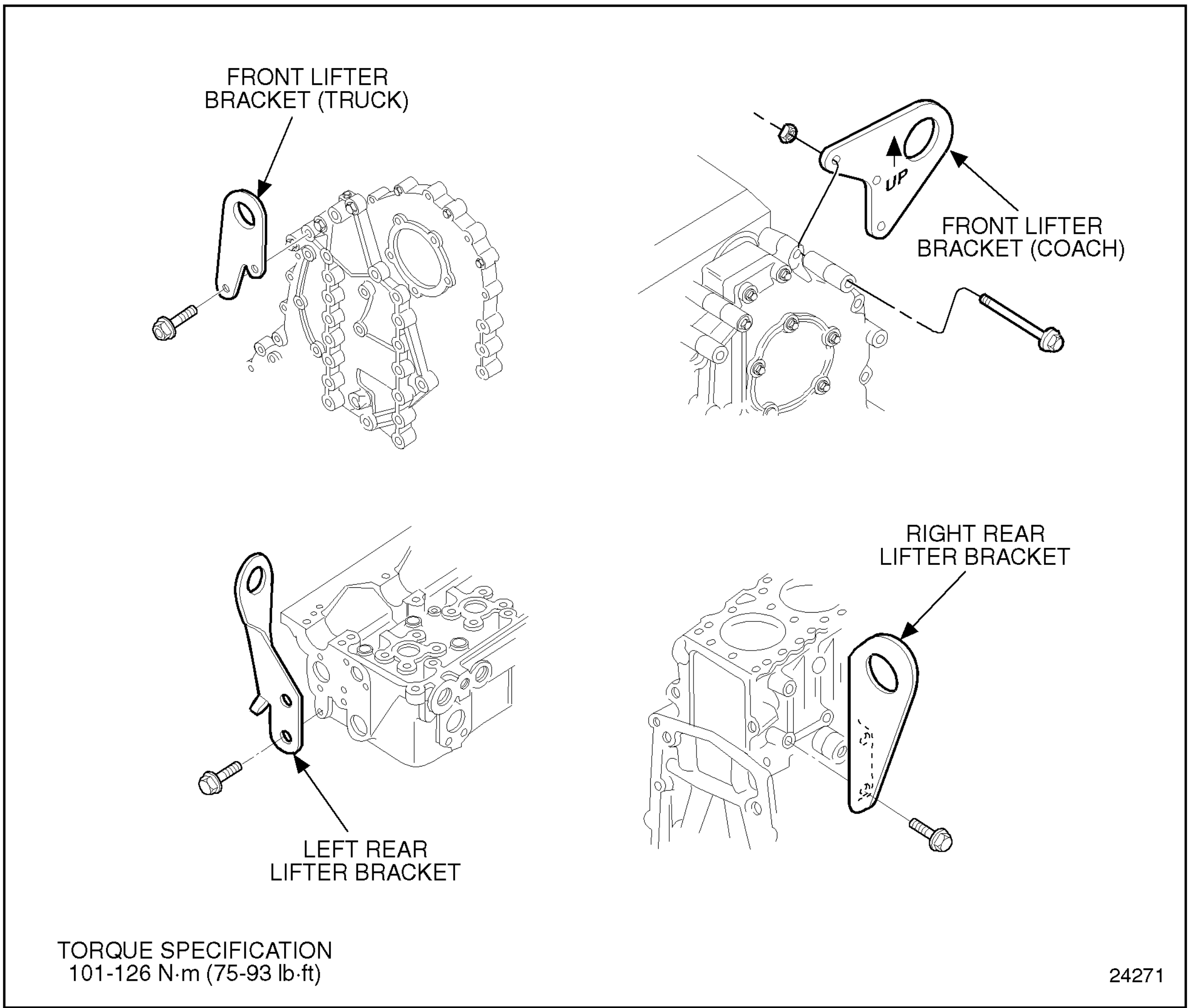


Figure 1-95 Engine Lifter Brackets

1.5.1 Repair or Replacement of the Lifter Bracket

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-96.

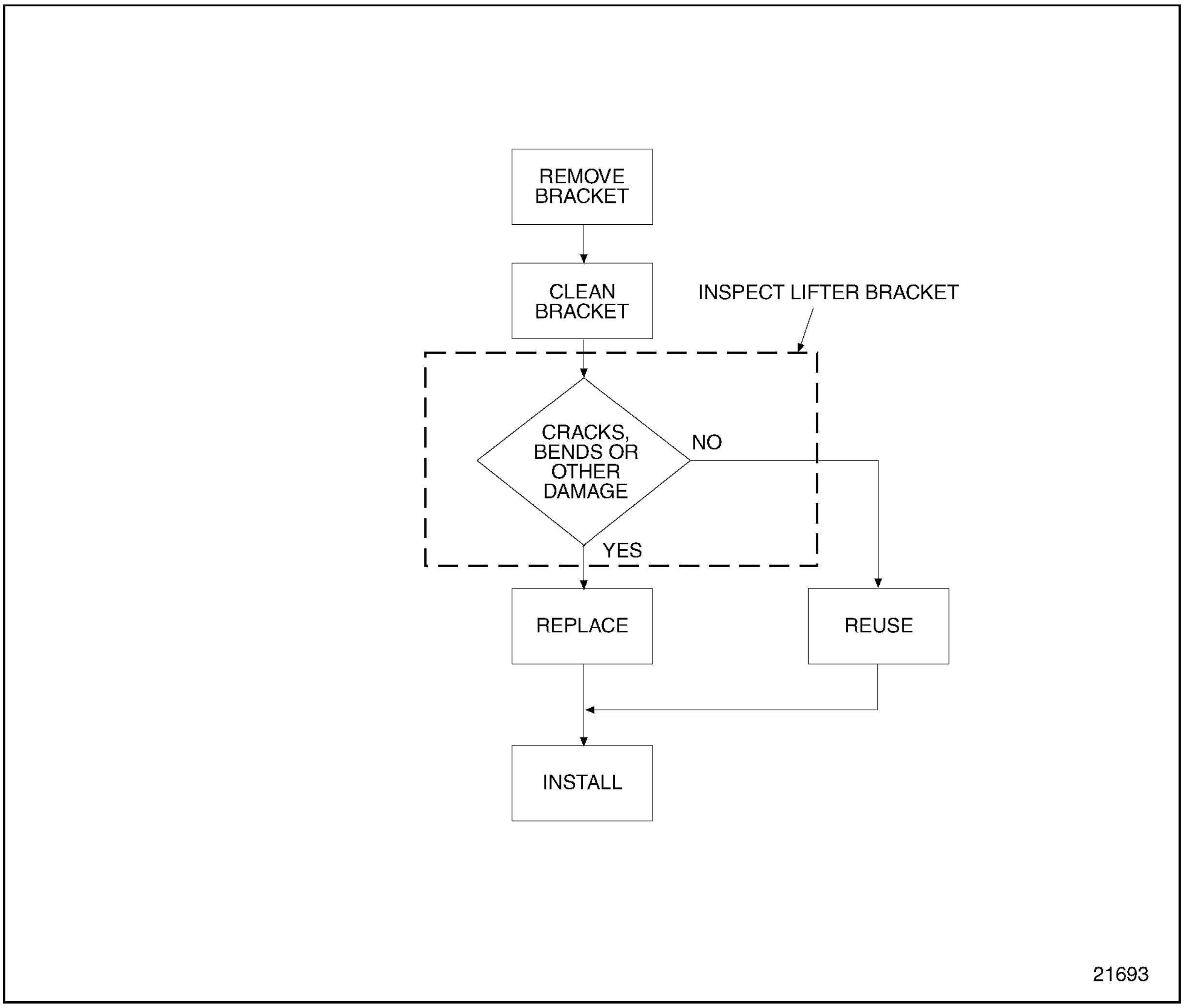


Figure 1-96 Flowchart for Repair or Replacement of Lifter Bracket

1.5.2 Removal and Cleaning of Lifter Bracket

Perform the following steps for lifter bracket removal:

1. Remove the bolts securing the lifter bracket to the engine.

1.5.2.1 Inspection of Lifter Bracket

Perform the following for lifter bracket inspection:

CAUTION:

To avoid injury from a falling engine, do not use a damaged lifter bracket when lifting the engine.

1. Inspect the lifter brackets for cracks, bending or other damage.
2. Replace the bracket if any of these conditions exist.

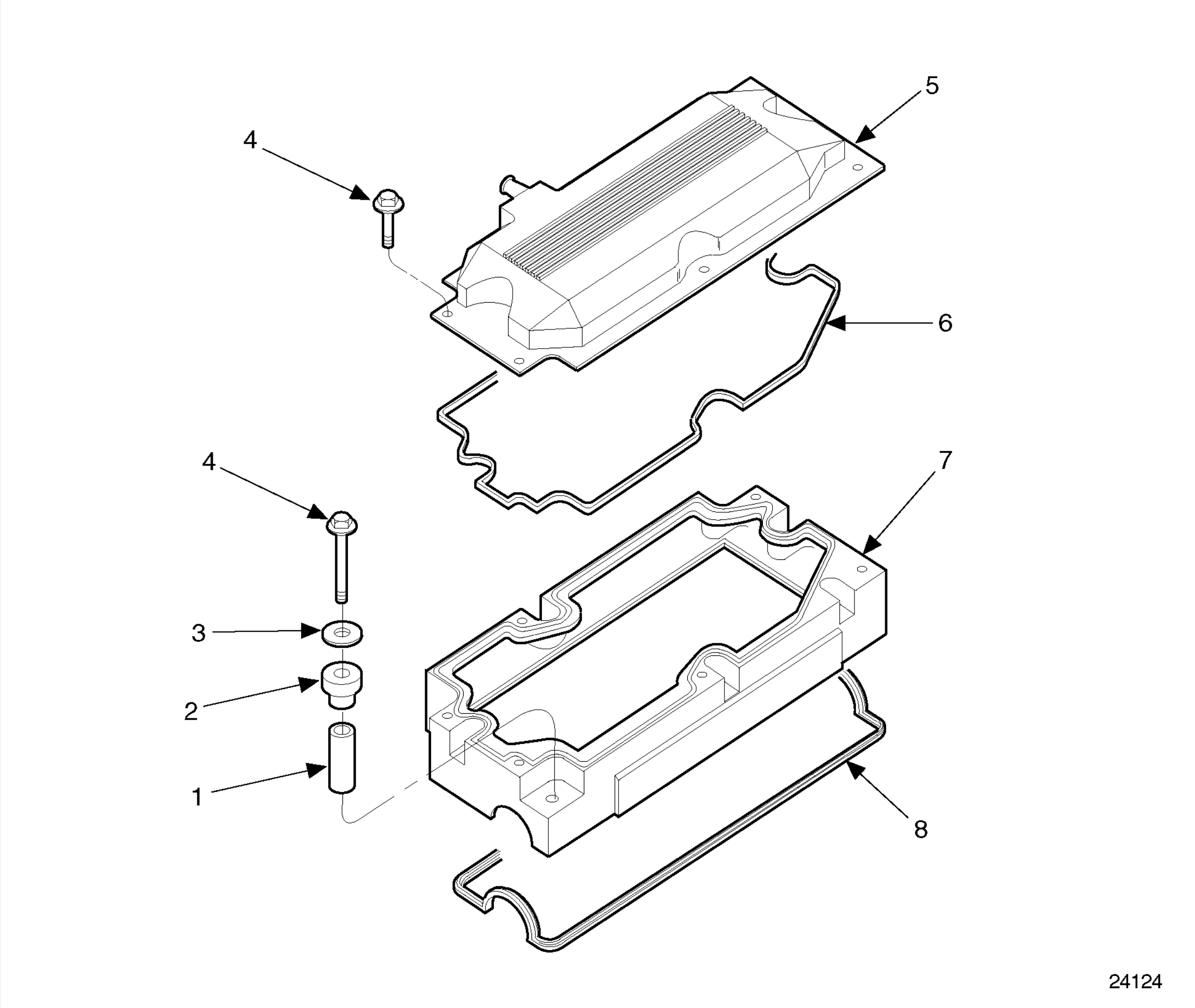
1.5.3 Installation of Lifter Bracket

Perform the following steps for lifter bracket installation:

1. Install the bracket to the engine. Torque the mounting bolts to 101-126 N·m (75-93 lb·ft).
2. Follow the fan support bracket installation instructions, torque specifications, and tightening sequence in "Installation of Gear Case Cover;" refer to Section 1.10.3.

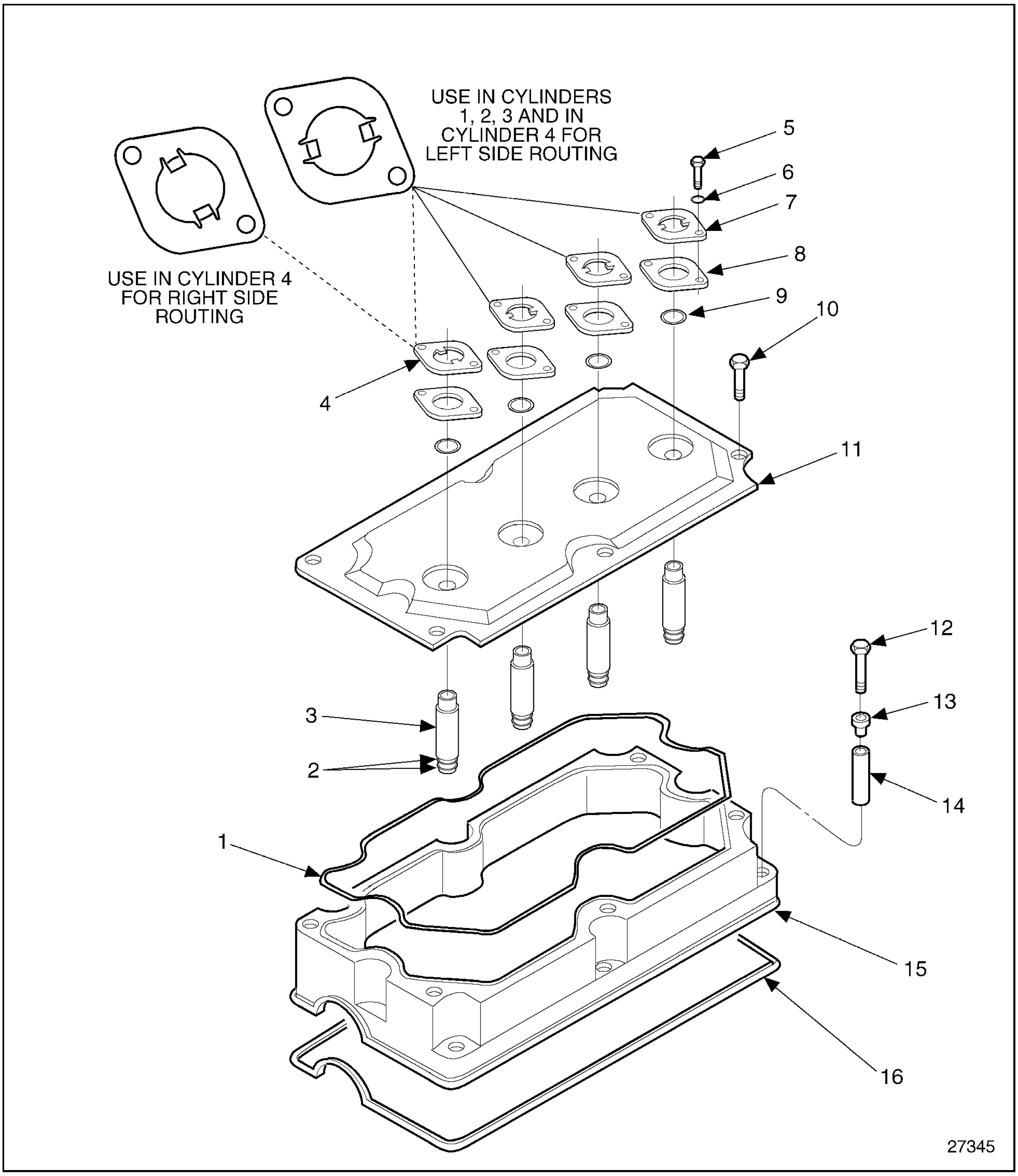
1.6 ROCKER COVER

The Series 50 Engines use a two-piece rocker cover that is constructed of cast aluminum. The top piece or cap is held in place by six bolts and is removable for access to the valve, engine brake and fuel injector adjusting mechanisms. See Figure 1-97, see Figure 1-98and see Figure 1-99.



1. Limiting Sleeve
2. Isolator
3. Washer
4. Bolt
5. Rocker Cover Cap
6. Rocker Cover Gasket
7. Rocker Cover Base
8. Isolator Rim Seal

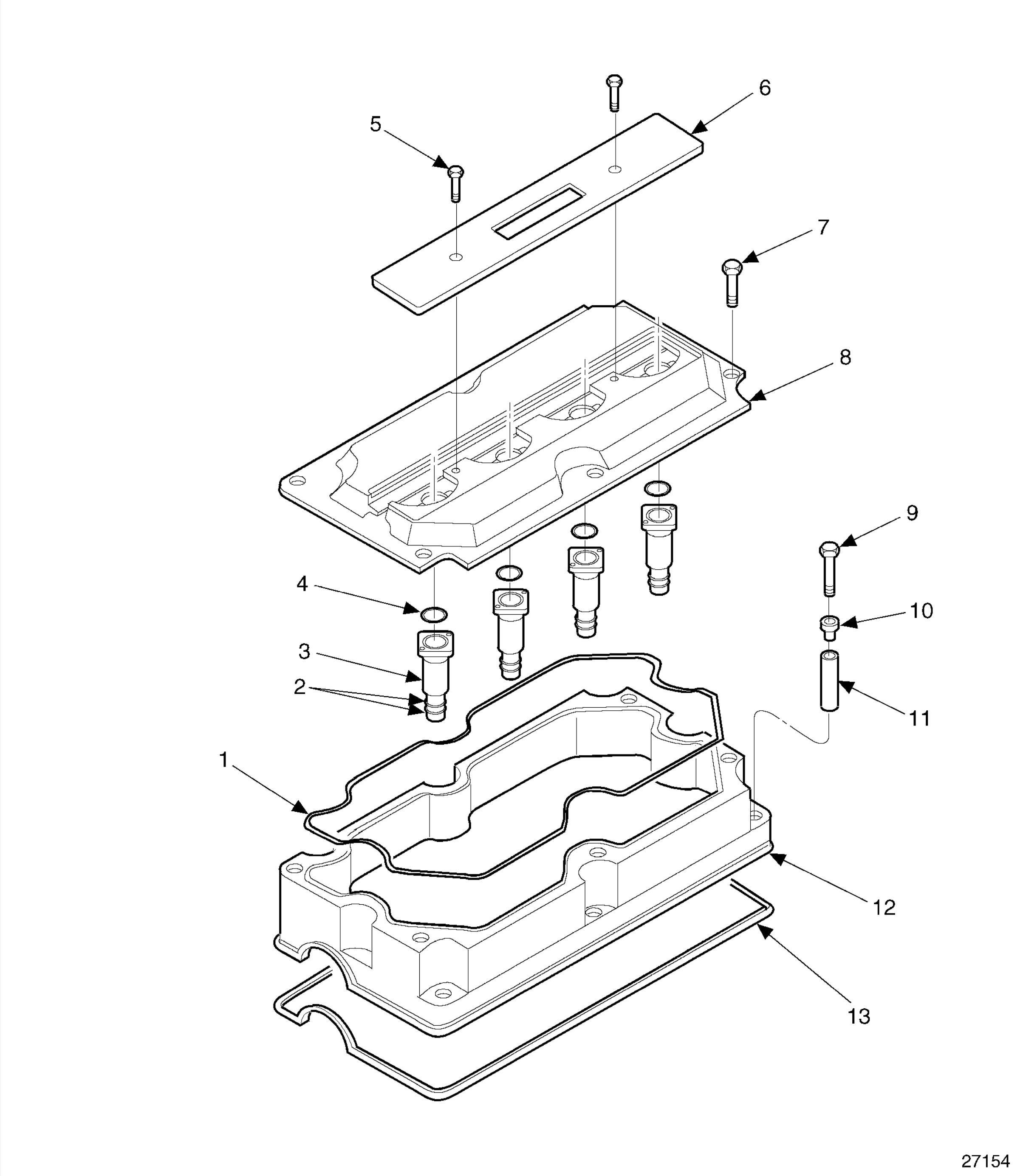
Figure 1-97 Two-piece Rocker Cover-Series 50 Diesel



1. Gasket	9. Ring Seal
2. O-ring Seal	10. Bolt
3. Tube	11. Cover
4. Gasket	12. Bolt
5 Bolt	13. Isolator
6. Washer	14. Spacer

7. Retainer
8. Cover
15. Rocker Cover Base
16. Gasket

Figure 1-98 Two Piece Rocker Cover-Series 50G with Remote Coil Ignition



1. Gasket
2. Seal Ring
3. Tube
4. Seal Ring
5. Screw
6. Cover
7. Bolt
8. Cover
9. Bolt
10. Isolator
11. Spacer
12. Rocker Cover Base
13. Gasket

Figure 1-99 Two Piece Rocker Cover-Series 50G with Coil Over Plug Ignition

A one-piece diamond-shaped perimeter seal is located in a groove in the rocker cover base and seals the cap to the base.

Two caps are available with the Series 50 diesel engines. One is for use with a Jake Brake, and one without a Jake Brake.

Two caps are available with the Series 50G engines. One is used with the remote coil ignition system and one is used with the coil over plug ignition system.

The rocker cover base is attached to the cylinder head using eight assemblies consisting of a bolt, limiter sleeve, isolator and flat washer. All rocker covers use a silicone rim seal, seated in a groove around the edge of the rocker cover to provide an effective oil seal. The two-piece design rocker cover has a provision for a crankcase ventilation breather which is used when the gear case filler breather is not present.

1.6.1 Repair or Replacement of Rocker Cover

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-100.

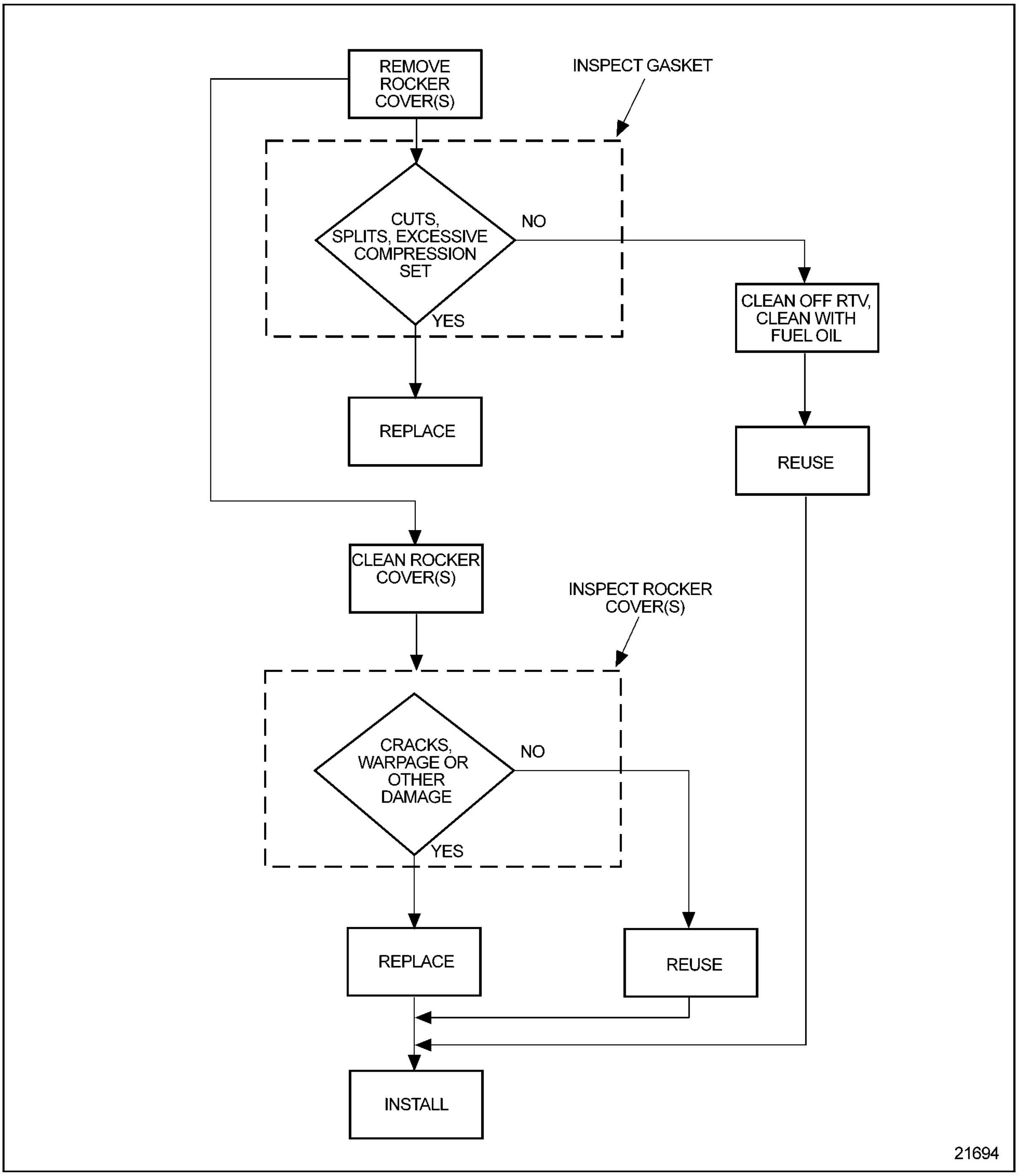


Figure 1-100 Flowchart for Repair or Replacement of Rocker Cover

1.6.2 Cleaning and Removing of Two-piece Rocker Cover-Diesel Engines Only

Preclean the rocker cover, especially around its base on the cylinder head and in the attaching bolt recesses to keep dirt and debris out of the valve gear chamber.

To remove the two-piece rocker cover:

1. Remove the six bolts that attach the rocker cover cap to the base.
2. Lift the cap off the base.
3. Loosen and remove the eight bolt/isolator assemblies that attach the base to the cylinder head.
4. Lift the base straight up off the cylinder head.

1.6.3 Disassembly of Two-piece Rocker Cover-Diesel Engines Only

Disassemble the two-piece rocker cover for diesel engine as follows:

NOTE:
The natural gas engines have a baffle type breather in the base and the rocker cover does not disassemble.

1. Disengage the clip that holds the crankcase vent breather element in the rocker cover by pressing the center of the spring steel retaining clip outward and removing the straight end.
2. Rotate the clip upward to remove the curved end.
3. Remove the wire mesh element.

1.6.3.1 Inspection of Two-piece Rocker Cover-Diesel Engines Only

To inspect the two-piece low profile valve cover cap which had a removable breather housing:

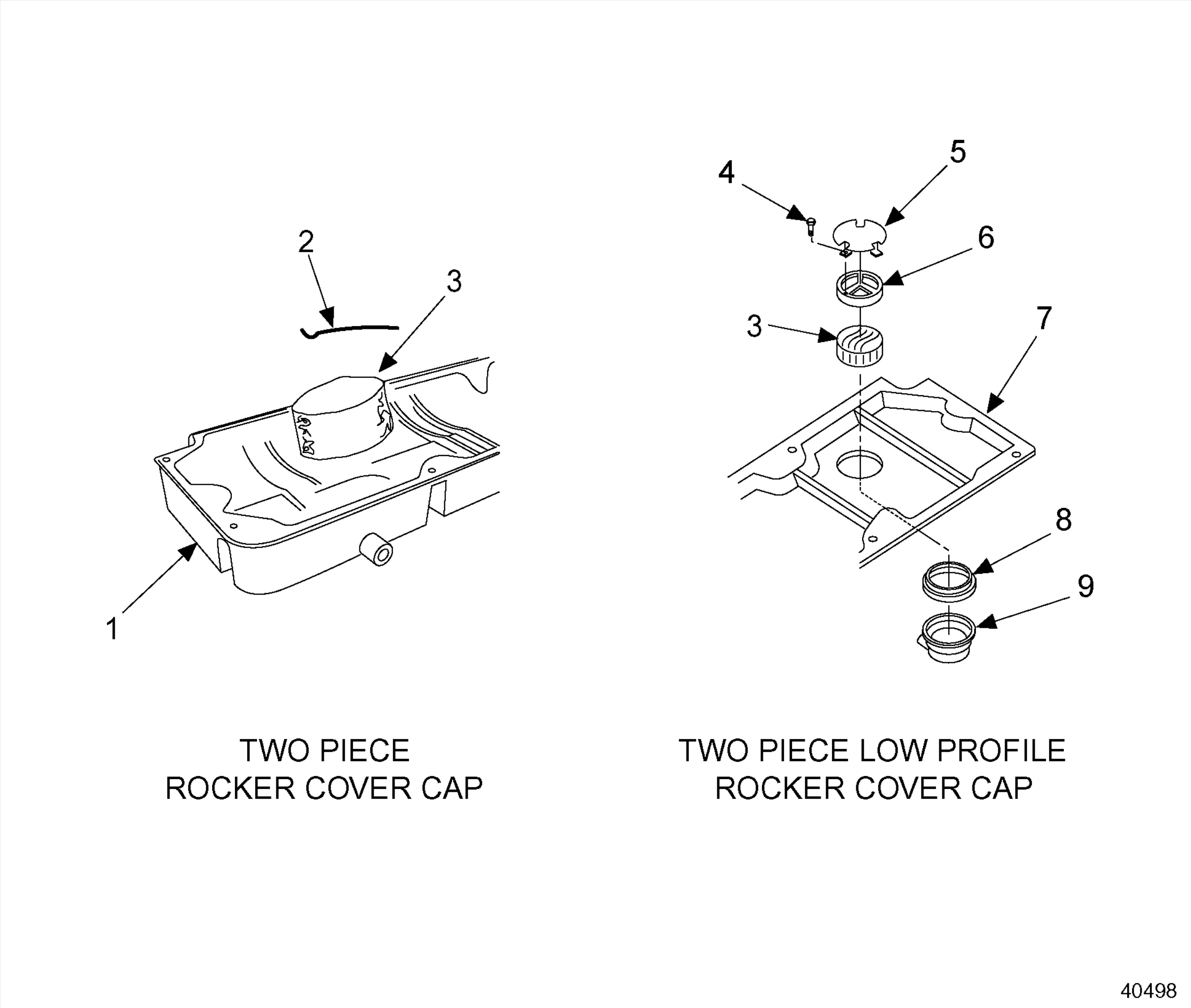
1. Remove the three screws and retainer that retains the breather housing.
2. Remove the breather housing, seal, and wire mesh element.
3. Wash the components in clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

4. Blow dry with compressed air.

5. Reassemble breather housing to rocker cover cap. See Figure 1-101. Torque the screws to 2.5 N ·m (22 lb· in.).



1. Two-piece Valve Rocker Cover
2. Retainer Clip
3. Wire Mesh Element
4. Screw
5. Retainer Cover
6. Retainer
7. Two-piece Low Profile Rocker Cover Cap
8. Seal
9. Breather Housing

Figure 1-101 Crankcase Vent Breather

1.6.4 Cleaning and Removal of Two-Piece Rocker Cover-Gas Engines with Remote Coil Ignition System Only

Preclean the rocker cover, especially around its base on the cylinder head and in the attaching bolt recesses to keep dirt and debris out of the valve gear chamber.

To remove the two-piece rocker cover:

1. Remove the ignition boots from the spark plug wells. Refer to Section 15.5.1.
2. Remove the eight bolts that attach the ignition boot retainer from the rocker cover cap. Lift off the retainers, covers, and O-rings.
3. Remove the six bolts that attach the rocker cover cap to the base.
4. Lift the cap off the base leaving the four extensions tubes in the cylinder head.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

5. Blow any excess oil from the outside of the extension tube so that the oil will not enter the spark plug well when the extensions tubes are removed.
6. Pull the four extension tubes from the cylinder head.
7. Loosen and remove the eight bolt/isolator assemblies that attach the base to the cylinder head.
8. Lift the base straight up off the cylinder head.

1.6.5 Removal and Precleaning of Two-Piece Rocker Cover-Gas Engines with Coil Over Plug Ignition System Only

Preclean the rocker cover, especially around its base on the cylinder head and in the attaching bolt recesses to keep dirt and debris out of the valve gear chamber.

To remove the two-piece rocker cover:

1. Remove the ignition boots from the spark plug wells. Refer to Section 15.5.1.
2. Lift the cap off the base leaving the four extensions tubes in the cylinder head.
3. Blow any excess oil from the outside of the extension tube so that the oil will not enter the spark plug well when the extensions tubes are removed.
4. Pull the four extension tubes from the cylinder head.
5. Loosen and remove the eight bolt/isolator assemblies that attach the base to the cylinder head.
6. Lift the base straight up off the cylinder head.

1.6.6 Pre-installation of Rocker Cover Base

Perform the following steps prior to installing the rocker cover base:

NOTE:
Be sure the rocker cover grooves and the seals are clean, free of oil and dry.

1. Install the rocker cover gasket in corners of the camshaft cap section (arch at each end of the rocker cover) first.
2. Install the cam cap section, starting in the center, by pushing the seal into the groove at the top of the arch. Then install each section at its halfway point. Seat the gasket completely around the arch. Be sure the corners are still firmly seated after the arch is completed. They should present a square corner parallel to the rocker cover rail. Repeat this procedure for the cam cap section on the other end. See Figure 1-102.

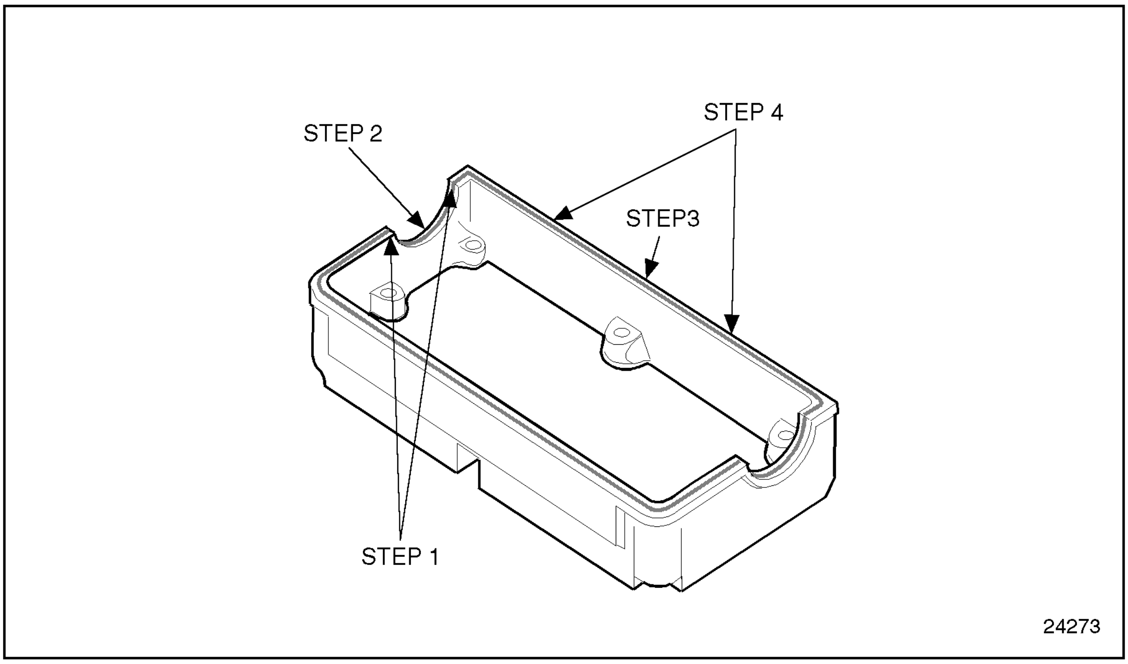


Figure 1-102 Rocker Cover Gasket Installation

3. Install the long runs of the gasket starting in the center, by pushing the seal into the groove.
4. Then install the rail portion at each halfway point. Repeat this procedure for the other rail portion. Make sure the seal is completely seated all the way around the rocker cover.

NOTE:
The corners must be cleaned prior to RTV installation for best results.

5. Apply a small 3.0 mm (3/16 in.) fillet of RTV in the corners formed by the rear camshaft cap and the head, where the cover seal contacts. Repeat this procedure for the corners formed by the front camshaft cap and the head. See Figure 1-103.

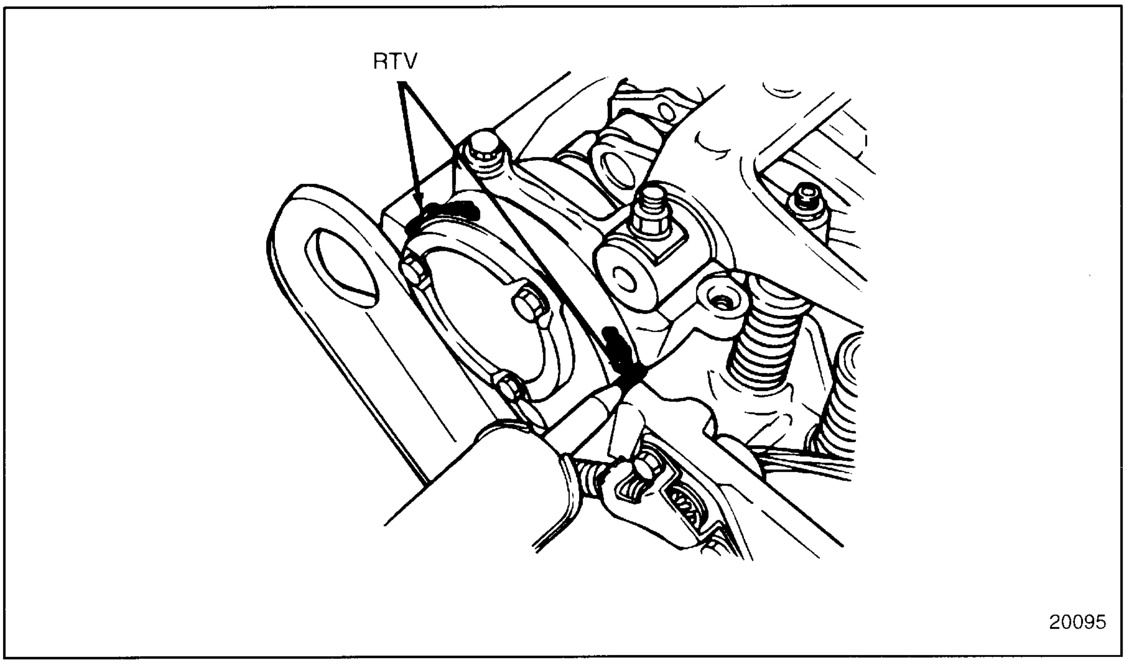


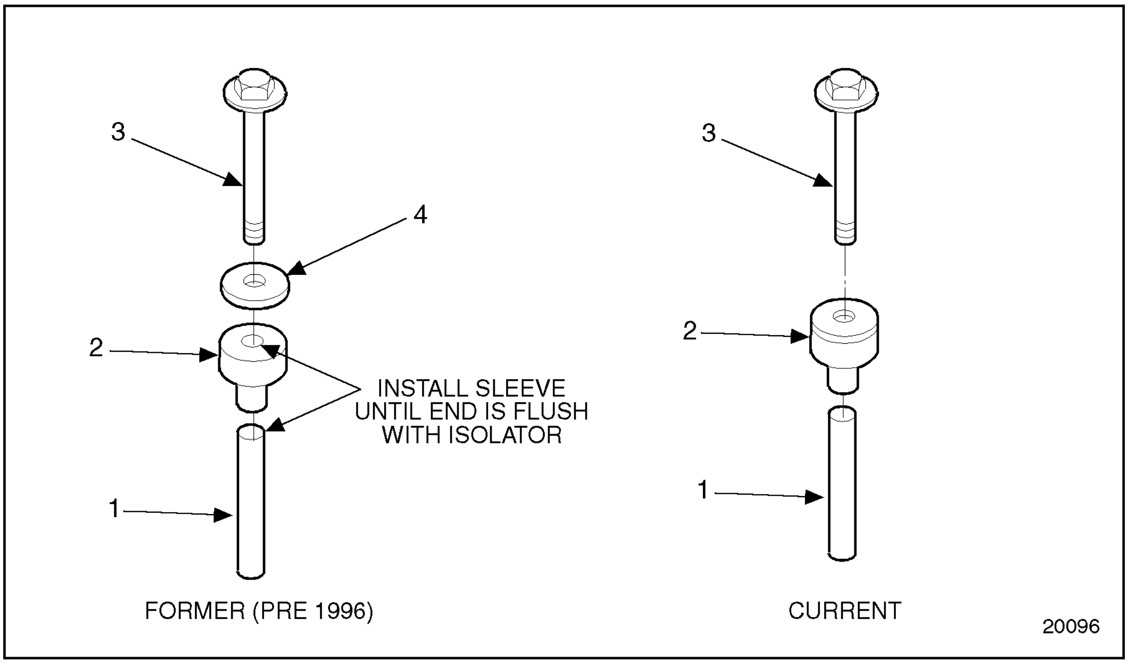
Figure 1-103 RTV Installation

1.6.7 Installation of the Two-piece Rocker Cover Base

Install the two-piece rocker cover as follows:

1. Position the rocker cover base on the cylinder head.

2. Lubricate the valve cover limiting sleeves with clean silicone spray. Insert the sleeves into the isolators until the end of the sleeve is flush with the isolator. See Figure 1-104.



1. Limiting Sleeve
2. Isolator
3. Bolt
4. Flat Washer

Figure 1-104 Rocker Cover Base Hold-down Hardware

3. Install the hold-down bolts, with washers installed, to the limiting sleeves.

4. Install the hold-down assemblies to the rocker cover base, and thread the bolts two-to-three threads into the cylinder head.

NOTE:
Use care when tightening the rocker cover base hold-down bolts that the injector wires do not get caught between the limiting sleeve and the cylinder head. See Figure 1-105.

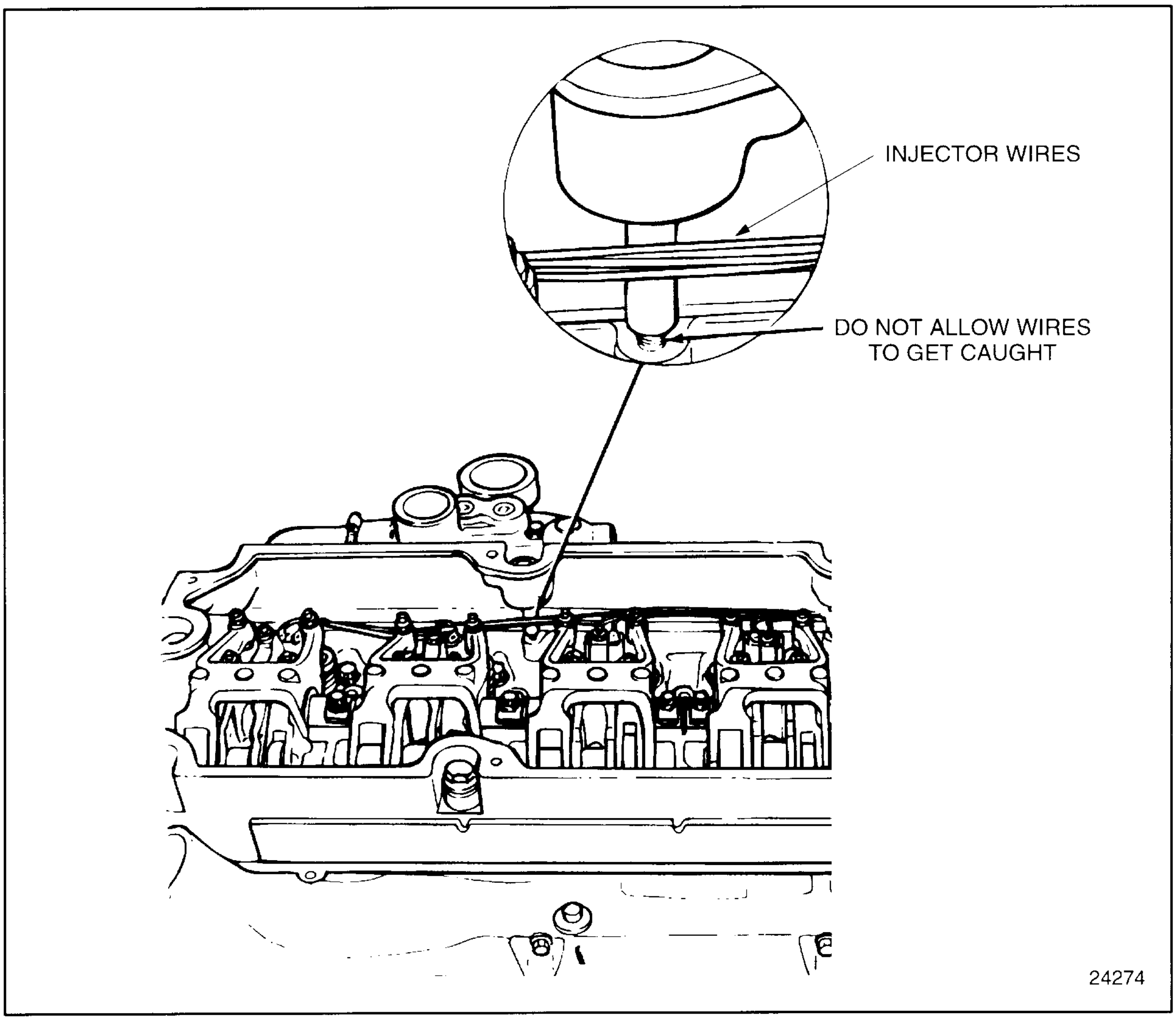


Figure 1-105 Rocker Cover Base Hold-down Bolt Installation

5. Torque the eight rocker cover base hold-down bolts to 30-38 N·m (22-28 lb·ft) using the tightening sequence. See Figure 1-106. Tighten the bolts in two stages, using half-torque value first.

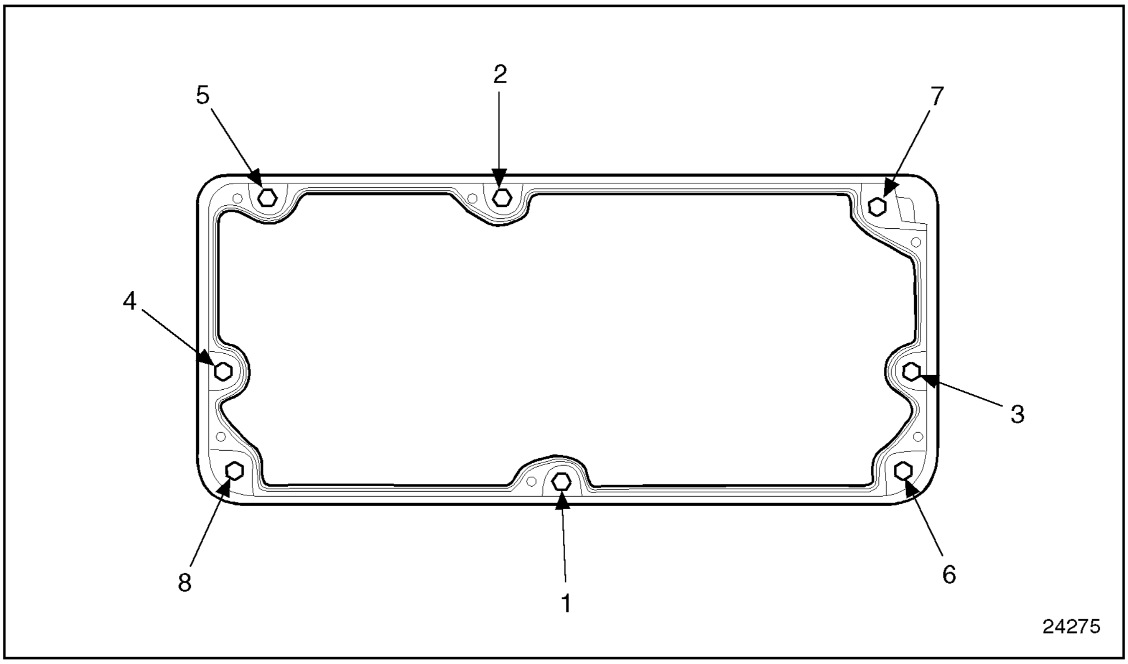


Figure 1-106 Rocker Cover Base Bolt Tightening Sequence

1.6.8 Installation of the Two-Piece Rocker Cover Cap - Diesel Engines Only

Install the two-piece rocker cover as follows:

1. Be sure the groove in the bottom of the rocker cover base, and its mating, diamond-shaped seal are clean and dry. Install the diamond-shaped seal to the groove by pressing the seal into the groove. Use care not to stretch or twist the seal. The seal has a definite shape, and should be installed exactly as removed from the base. If the seal cannot be installed to its groove without bunching or looping, the seal is stretched and must be replaced. The same procedure applies to the intermediate cover diamond seal installation.
2. Install the rocker cover cap to the base. Install the six bolts that attach the cap to the base, and torque to 22-25 N·m (16-18 lb·ft) using the torque sequence. See Figure 1-107.

Tighten the bolts in two stages, using half-torque value first. The same procedure applies to the intermediate cover installation.

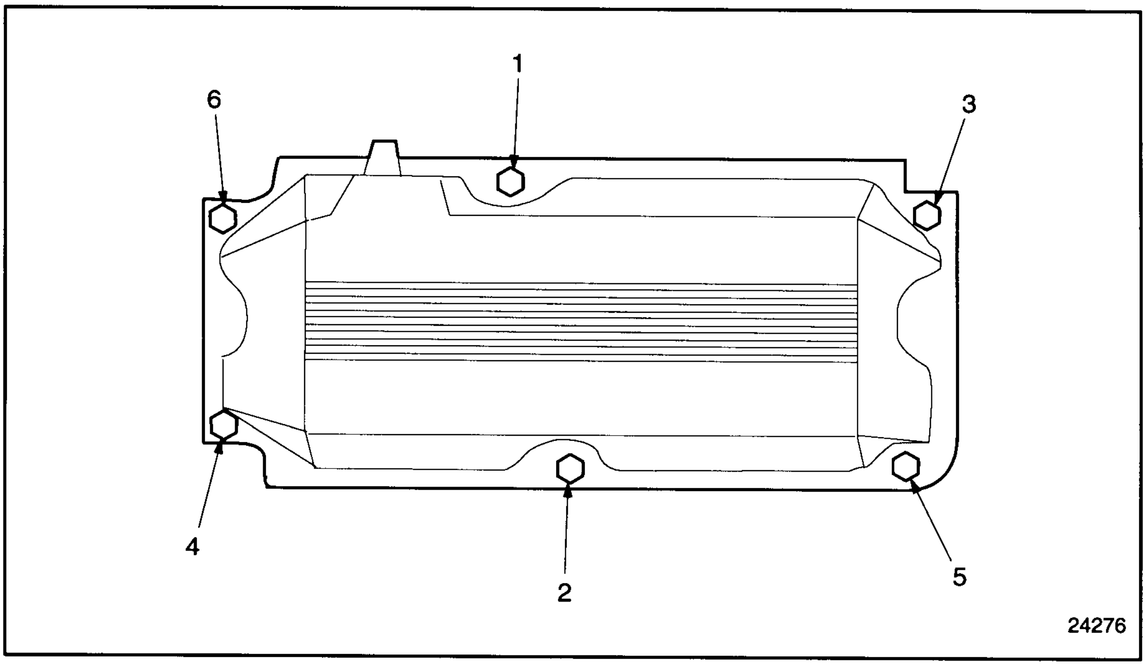


Figure 1-107 Rocker Cover Bolt Cap Tightening Sequence

3. Install any other parts that were removed for this procedure.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

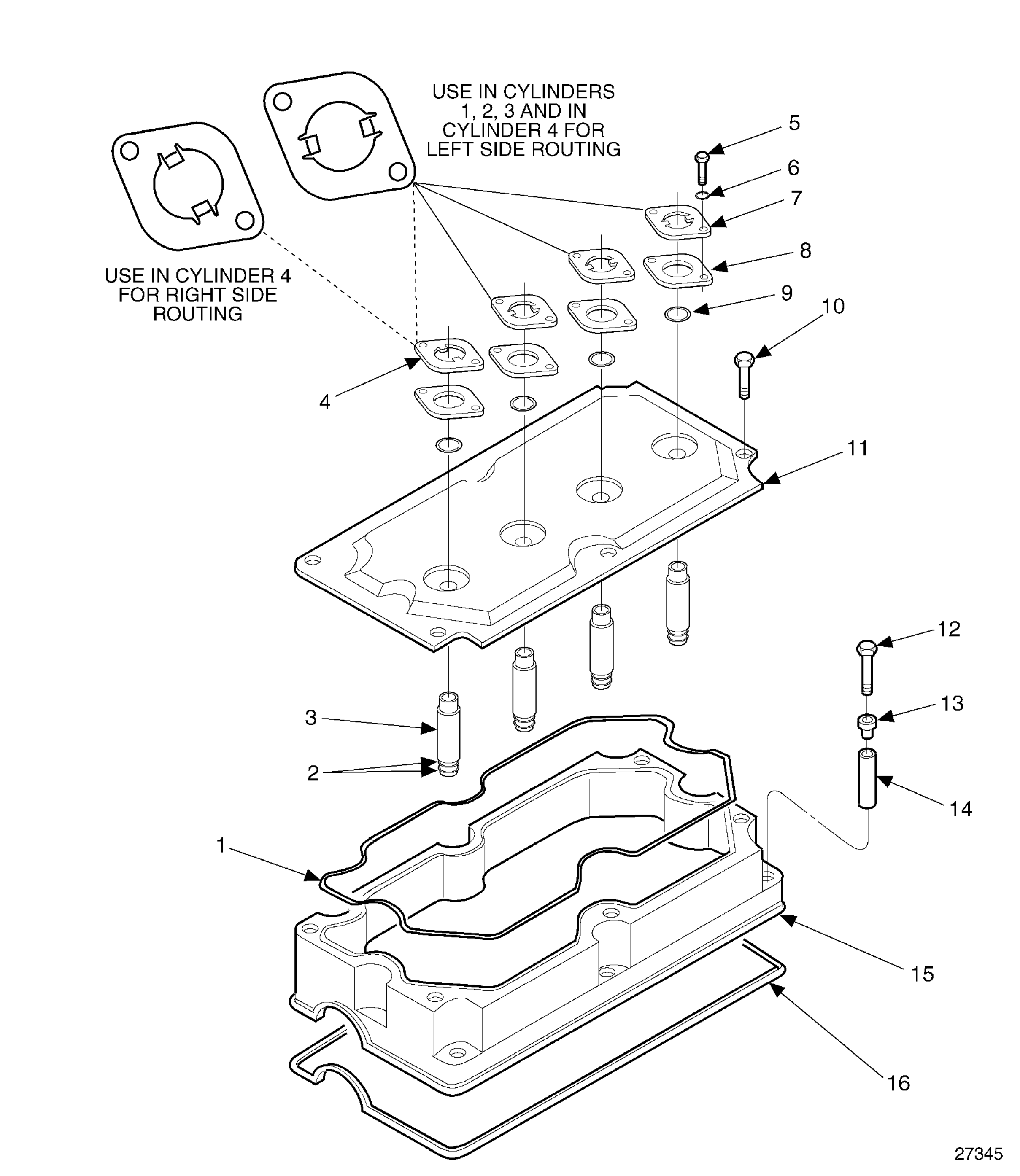
4. Start the engine and check for leaks. Refer to Section 11.8.

1.6.9 Installation of the Two-Piece Rocker Cover Cap (Remote Mount Ignition System Only)

Install the two-piece rocker cover cap as follows:

1. Clean any oil or dirt from the spark plug wells.

2. Insert the four extension tubes with O-rings in the cylinder head.
3. Install the rocker cover cap to the base with the six bolts. Torque the bolts to 22-25 N ·m (16-18 lb·ft). Torque the bolts in two stages, using half torque value first. See Figure 1-108.



1. Gasket
2. O-ring Seal
9. Ring Seal
10. Bolt

3. Tube
4. Gasket
5. Bolt
6. Washer
7. Retainer
8. Cover
11. Cover
12. Bolt
13. Isolator
14. Spacer
15. Rocker Cover Base
16. Gasket

Figure 1-108 Two-Piece Rocker Cover

4. Install the four O-rings, extension tube covers, and ignition boot retainers using the eight attachment bolts. Torque the bolts to 13-16 N·m (10-12 lb·ft).

NOTE:
The two types of ignition boot retainers are used for the right side ignition wire routing and they must be installed.

5. Install the ignition boots into the spark plug wells and any other ignition system parts that were removed. Refer to Section 15.5.2.
6. Install any other parts that were removed for this procedure.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

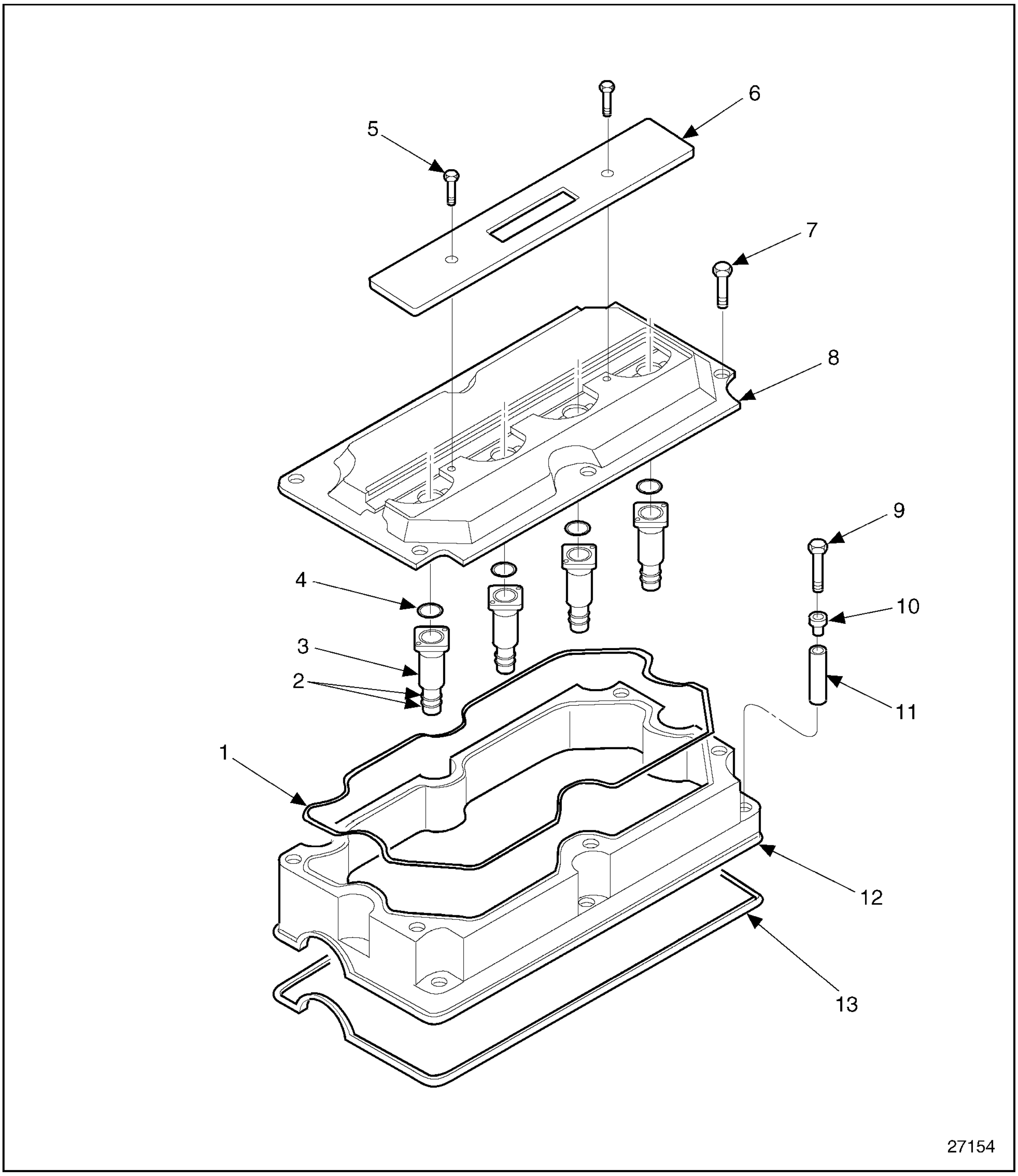
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

7. Start the engine and check for leaks. Refer to Section 11.8.

1.6.10 Installation of the Two-Piece Rocker Cover Cap (Coil Over Plug Ignition System Only)

Install the two-piece rocker cover cap as follows:

1. Clean any oil or dirt from the spark plug wells.
2. Insert the four extensions tubes with O-rings in the cylinder head. See Figure 1-109.



1. Gasket
2. Seal Ring
3. Tube
4. Seal Ring
5. Screw
8. Cover
9. Bolt
10. Isolator
11. Spacer
12. Rocker Cover Base

6. Cover
7. Bolt
13. Seal Ring

Figure 1-109 Two-Piece Rocker Cover

3. Orient the extension tubes so that eight threaded holes are in a straight line. This will allow the coil mounting bolts to engage these holes after the rocker cover cap is installed.
4. Place the rocker cover cap on base without disturbing the extension tube seals. Loosely install the six bolts that attach the cap to the base.
5. Insert the coils into the spark plug wells. Engage the coil mounting bolts into the extensions tubes. Torque the bolts 13-16 N·m (10-12 lb·ft).
6. Torque the six rocker cover cap mounting bolts to 22-25 N·m (16-18 lb·ft). See Figure 1-109.
7. Install the remaining ignition system parts. Refer to Section 15.11.
8. Apply antiseize compound to the coil cover mounting screw holes to aid removal of these parts in the future.
9. Install any other parts that were removed for this procedure.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

10. Start the engine and check for leaks. Refer to Section 11.8.

1.7 CRANKSHAFT

The crankshaft is a one-piece forging of chrome-alloy steel, heat-treated to ensure strength and durability. See Figure 1-110.

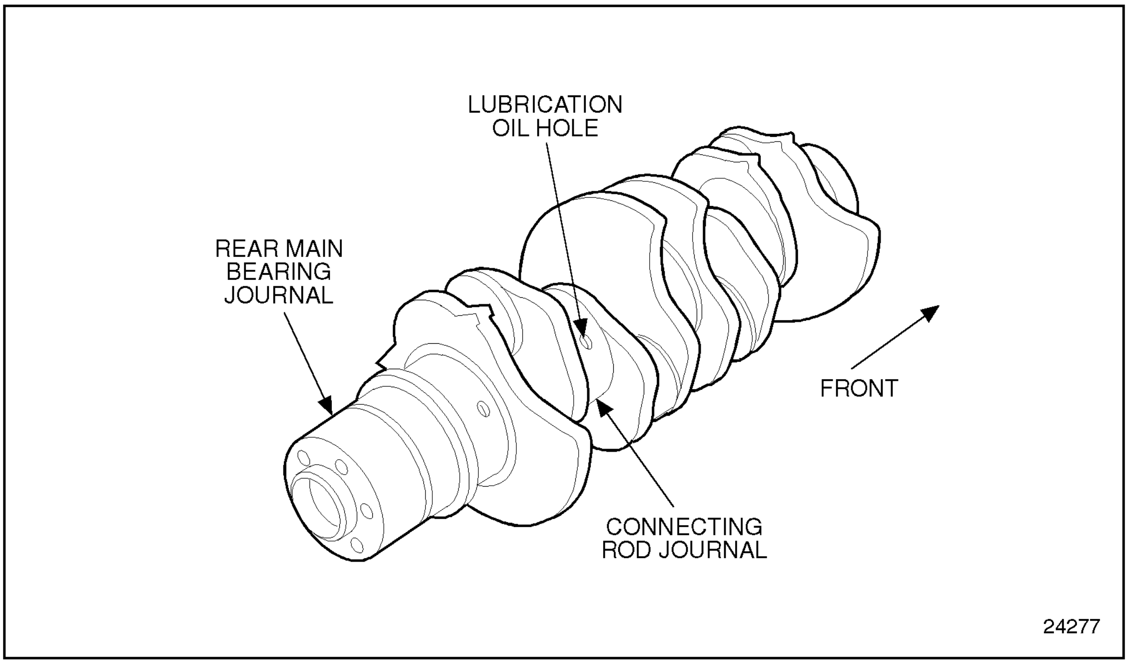


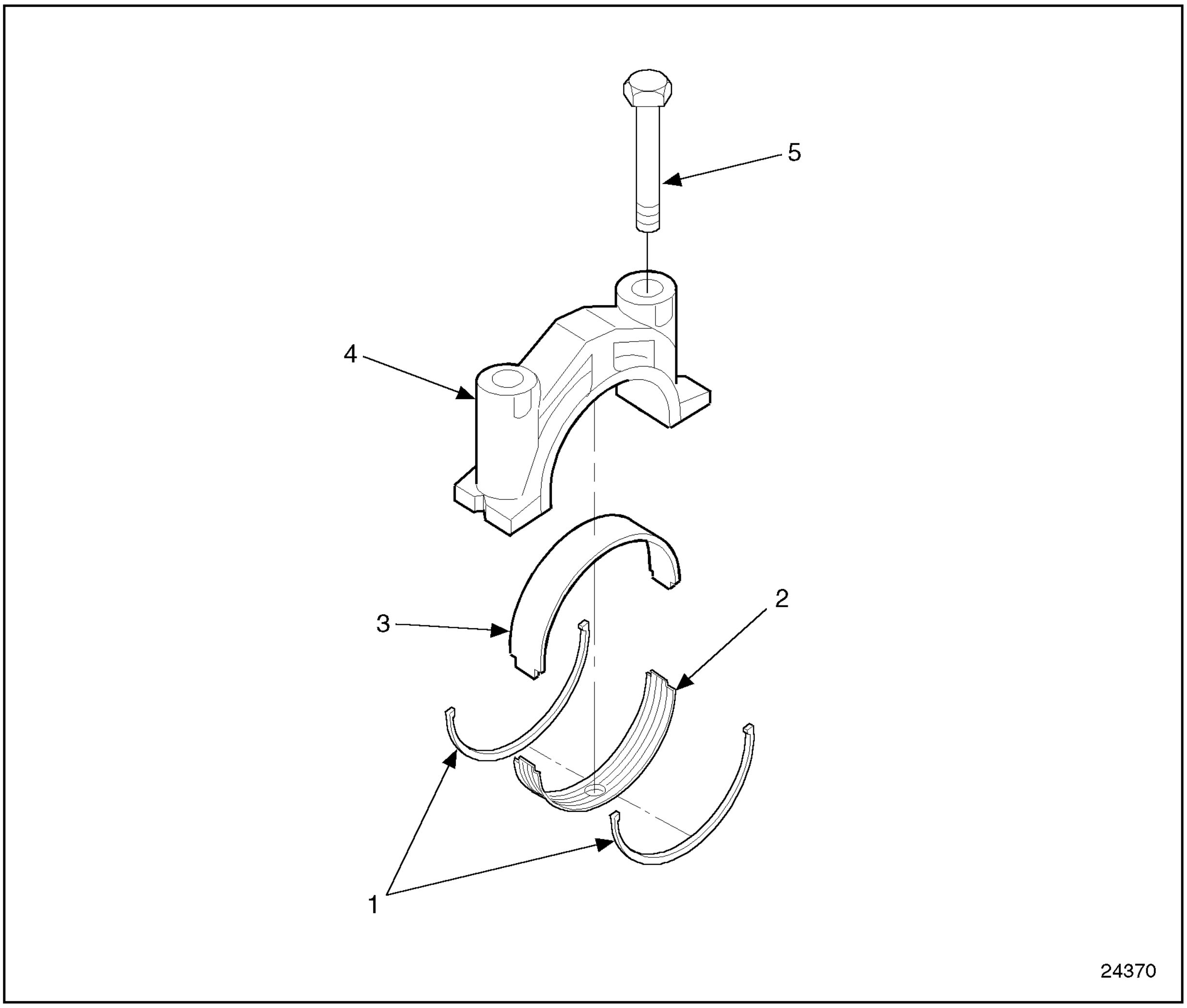
Figure 1-110 Crankshaft

The main and connecting rod bearing journal surfaces and fillets are induction hardened.

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

Crankshafts have a twelve-bolt mounting pattern on the front.

The crankshaft end play is controlled by thrust washers located at the No. 4 main bearing cap and saddle of the engine. See Figure 1-111.



1. Upper Thrust Washer
2. Upper No. 4 Bearing
3. Lower No. 1-5 Bearing Shell
4. No. 4 Main Cap
5. Bolt

Figure 1-111 Crankshaft Thrust Bearing Detail

This design makes use of thrust washers in the upper positions only.

Oversize thrust washers are available to correct for excessive end play.

This design does not use the indexing dowels.

Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block. See Figure 1-112.

NOTE:
The natural gas crankshaft has machined counterweights to allow for shorter rods.

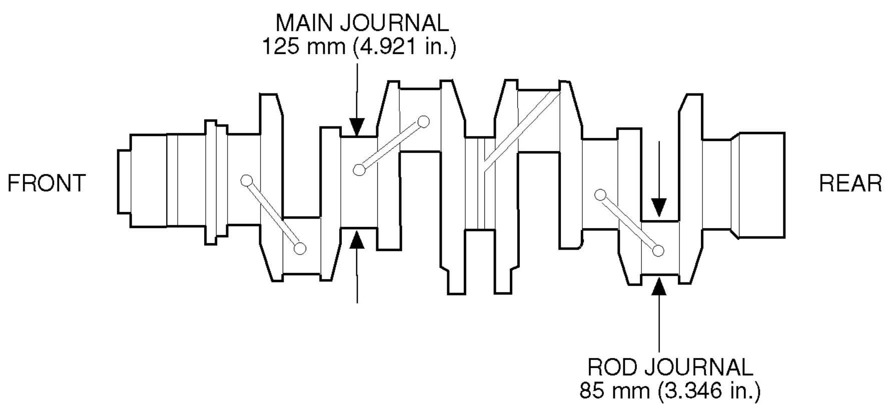


Figure 1-112 Crankshaft Lubricating Oil Holes

Twelve tapped holes, equally spaced, are provided on the rear butt for attaching the flywheel. There are six or twelve equally spaced tapped holes on the front butt of the crankshaft for attaching the crankshaft pulley and vibration damper. No locating dowels are provided at either end.

Each standard main bearing journal is 125.000-124.975 mm (4.921-4.920 in.) in diameter and each standard connecting rod journal is 85.000-84.975 mm (3.346-3.345 in.) in diameter.

New crankshafts with smaller radii fillets replaced the former crankshafts, effective with the following engine serial numbers 4R6665 built October 26, 1994. This change was made to permit installation of new, wider connecting rod bearings that increase rod bearing oil film thickness and reduce bearing pressures. The fillets on the new crankshafts have a radius of 4.0-3.5 mm (0.157-0.138 in.). The fillets on the former crankshafts had a radius of 6.0-5.5 mm (0.236-0.216 in.). To conform with this change, new connecting rods with smaller rod chamfers were also released. Refer to Section 1.19for information on the new connecting rods and bearings.

The new crankshafts, bearings, and connecting rods must be used together to ensure interchangeability. Former parts cannot be mixed with new parts in the same engine. The former crankshafts will no longer be available.

1.7.1 Repair or Replacement of Crankshaft

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-113.

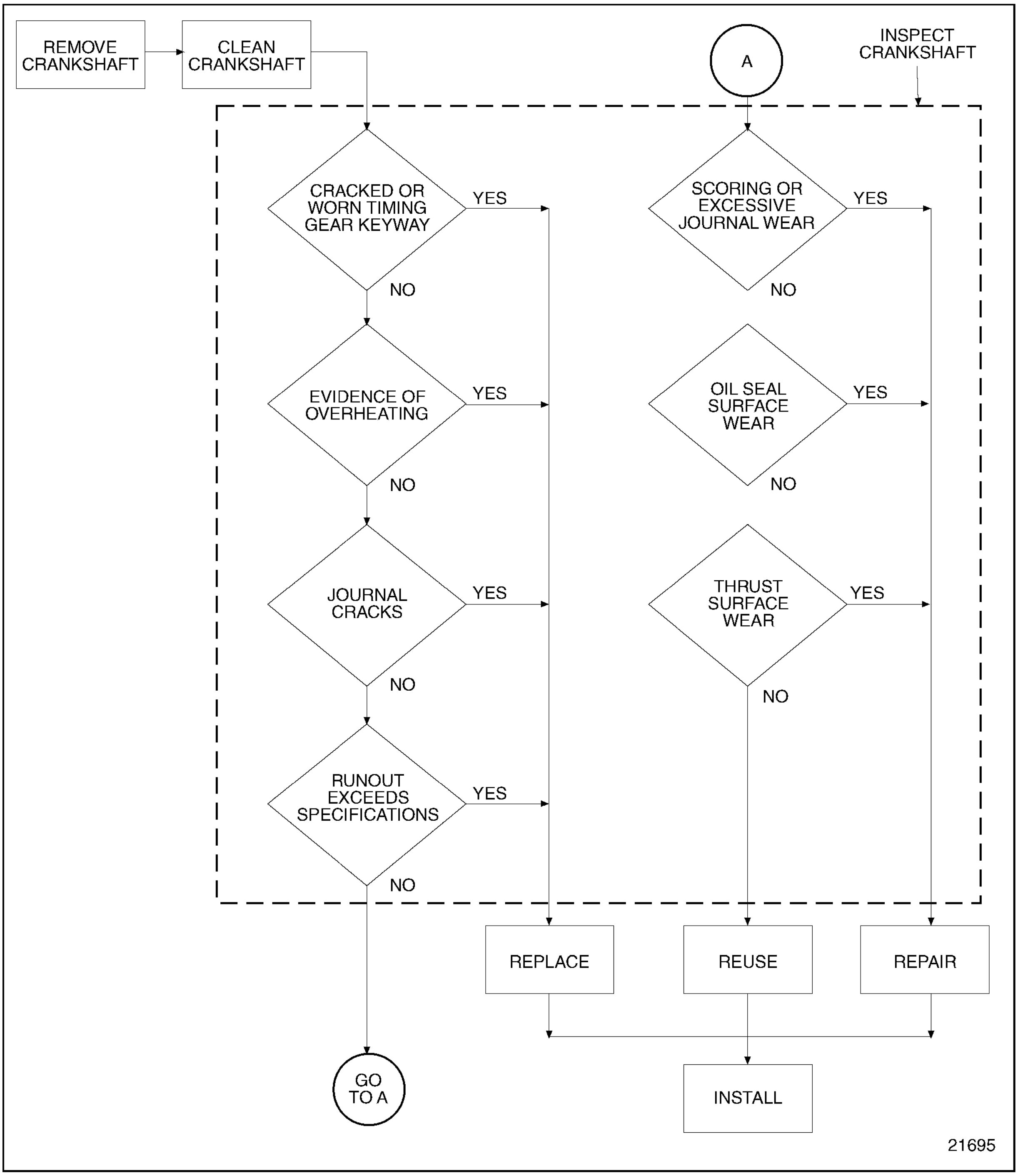


Figure 1-113 Flowchart for Repair or Replacement of Crankshaft

1.7.2 Cleaning and Removal of Crankshaft

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

1. Steam clean the exterior of the engine.
2. Drain the cooling system. Refer to Section 13.5.4.
3. Drain the lubricating oil. Refer to Section 13.5.1.
4. Attach suitable chain hoist and spreader bar with hooks to the three lifter brackets (one at the front and two at the rear). Remove all engine-to-base attaching bolts and remove the engine from its base. Refer to Section 1.1.2. See Figure 1-5.

CAUTION:
To avoid injury from a falling engine, ensure the engine is securely attached to the engine overhaul stand before releasing the lifting sling.

5. Remove and inspect all of the accessories and assemblies with their attaching parts as necessary to permit the engine block adapter, to be bolted to the intake (left) side of the cylinder block. Mount the engine to the overhaul stand, J 29109with adapter, J 39652 attached. Refer to Section 1.1.2. See Figure 1-7.
6. Remove and inspect the oil pan. Refer to Section 3.9.2.
7. Remove and inspect the balance shaft assembly containing the balance shaft, gear, and oil pump. Refer to Section 1.28.2.
8. Remove and inspect the flywheel. Refer to Section 1.14.2.
9. Remove and inspect flywheel housing. Refer to Section 1.16.2.

NOTICE:
Use care when removing the crankshaft pulley as the vibration damper may come off. If the damper is allowed to fall, damage to the internal components of the damper may result.

10. Loosen and remove two of the crankshaft pulley retaining bolts and hardened washers 180° apart and install two flywheel guide studs, J 36235, in their place. Then loosen and remove the remaining four pulley retaining bolts and hardened washers. Refer to Section 1.13.2.
11. Remove and inspect the viscous vibration damper. Refer to Section 1.12.2 for removal and refer to Section 1.12.2.1 for inspection.
12. Remove and inspect the engine front support and gear case cover. Refer to Section 1.10.2 for removal and refer to Section 1.10.2.1for inspection.
13. Remove and inspect the cylinder head. Refer to Section 1.2.2 for removal and refer to Section 1.2.3 for inspection.

14. Remove and inspect the piston and connecting rod assemblies. Refer to Section 1.18.2 and refer to Section 1.18.3.1 for inspection.

NOTE:
The connecting rod caps must be reinstalled to their respective connecting rods. The main bearing caps should be kept in sequence, so that they may be installed to their original positions.

15. Loosen and remove the main bearing cap bolts. Remove the main bearing caps.
16. Remove and inspect the thrust washers from each side of the No. 4 main bearing cap.
17. Remove and inspect the crankshaft, including the crankshaft gear and timing wheel. Refer to Section 1.27.2.
18. Remove and inspect the timing gear and timing wheel.
19. Remove the Woodruff key from the slot in the front crankshaft hub.

1.7.2.1 Inspection of Crankshaft

Perform the following steps for crankshaft inspection:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air.
2. Inspect the crankshaft timing gear keyway for evidence of cracks or wear. Replace the crankshaft if these conditions are evident.
3. If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.
4. Check the crankshaft journal surfaces for score marks and other imperfections. If excessively scored, the journal surfaces must be reground. Refer to Section ADDITIONAL INFORMATION.
5. Carefully, inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surfaces will result in oil leakage at these points.
6. If the crankshaft oil seal contact surfaces are grooved, the seal surfaces must be sleeved and an oversized seal used. Refer to Section 1.8.
7. Check the crankshaft thrust surfaces for excessive wear or grooving. If excessively worn, the thrust surfaces must be reground. Refer to Section ADDITIONAL INFORMATION.

8. Check the crankshaft timing gear for worn or chipped teeth. Inspect the timing wheel for bent or otherwise damaged teeth. Replace as necessary. Refer to Section 1.27.2.1.
9. Check the crankcase journal run-out. Refer to Section 1.7.2.2.
10. Check the journal alignment. Refer to Section 1.7.2.3.
11. Check the journal measurements. Refer to Section 1.7.2.4.
12. Inspect the crankshaft for cracks. Refer to Section 1.7.2.5.

1.7.2.2 Crankshaft Journal Run-out Measurements

Support the crankshaft on its front and rear journals on Vee-blocks or the inverted engine block with only the front and rear upper bearing shells in place. Check the intermediate main journals with a dial indicator for run-out when the crankshaft is rotated.

When checking the crankshaft bow, if the run-out is greater than that listed in Table 1-2, the crankshaft must be replaced.

Journals Supported On	Journals Measured	Maximum Run-out (Total Indicator Reading)
No. 1 and No. 5	No. 2 and No. 4	0.075 mm (0.003 in.)
No. 1 and No. 5	No. 3	0.130 mm (0.005 in.)

Table 1-2 Crankshaft Bow

1.7.2.3 Adjacent Journal Alignment

When run-out on the adjacent journals is in opposite directions, the sum must not exceed 0.076 mm (0.003 in.) total indicator reading. When the high spots of run-out on the adjacent journals are in the same direction, the difference must not exceed 0.076 mm (0.003 in.) total indicator reading.

1.7.2.4 Journal Diameter Measurements

Measure all of the main and connecting rod bearing journals diameters. See Figure 1-114.

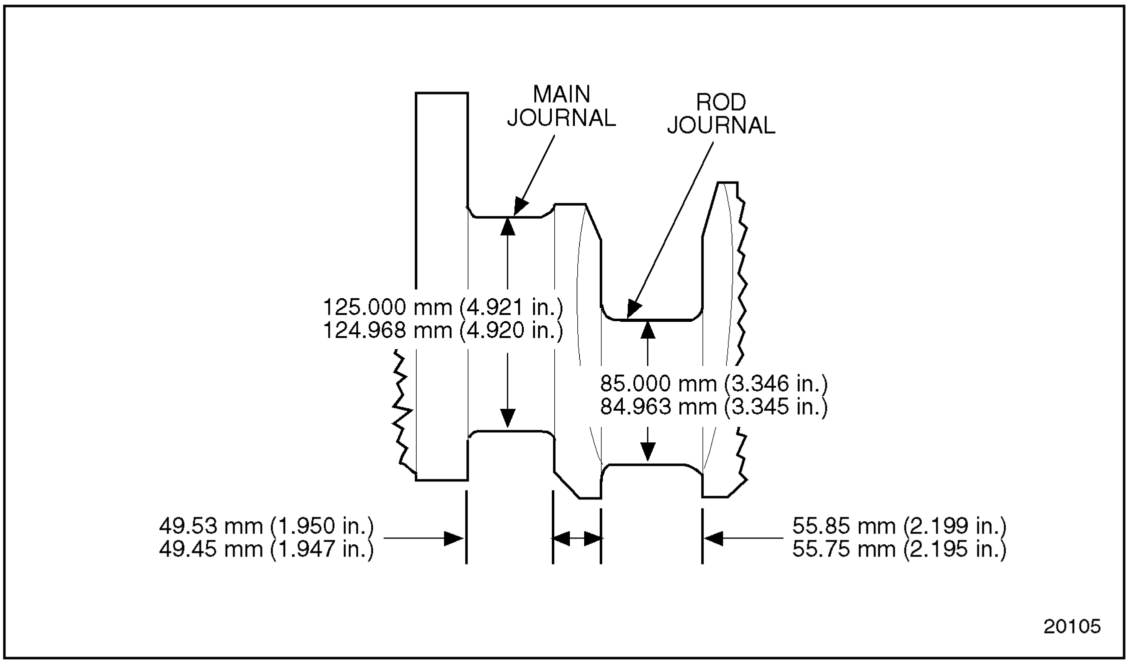


Figure 1-114 Dimensions of Crankshaft Journals

Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod or main bearing journal-to-bearing shell clearance (with new shells) exceeds 0.1270 mm (0.005 in.) (connecting rod journals) or 0.1412 mm (0.0056 in.) (main bearing journals), the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest 0.0025 mm (0.0001 in.). Also, if the main bearing journal taper of a used crankshaft exceeds 0.0381 mm (0.0015 in.) or the out-of-round is greater than 0.0254 mm (0.001 in.), the crankshaft must be reground. Refer to Section ADDITIONAL INFORMATION.

Also, measure the distance between crankshaft thrust washer surfaces. See Figure 1-115.

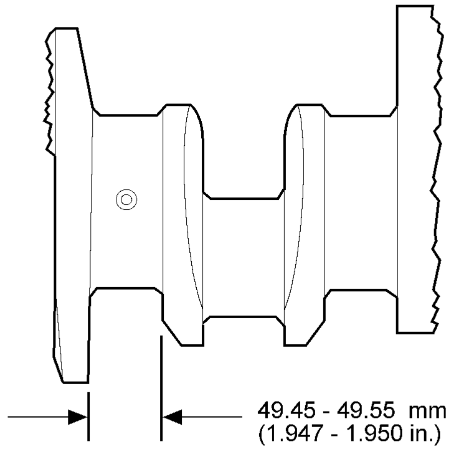


Figure 1-115 Standard Dimensions at No. 4 Main Bearing Thrust Washers

1.7.2.5 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 replaced. Several methods of determining the presence of minute cracks not visible to the eye are available: refer to Section 1.7.2.6 for magnetic particle method, refer to Section 1.7.2.7 for fluorescent magnetic particle method, or refer to Section 1.7.2.8 for fluorescent penetrant method.

1.7.2.6 Magnetic Particle Method

Magnetize the crankshaft and then cover it 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.

NOTICE:
Very fine cracks may be missed using the magnetic particle method especially on discolored or dark surfaces.

NOTICE:
The crankshaft must be demagnetized after the test to avoid engine damage.

If the crankshaft is discolored or has dark surfaces, the magnetic particle method should not be used. Refer to Section 1.7.2.7 for suitable alternate method.

1.7.2.7 Fluorescent Magnetic Particle Method

This method is similar to the magnetic particle method, refer to Section 1.7.2.6, 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.

NOTICE:
The crankshaft must be demagnetized after the test to avoid engine damage.

1.7.2.8 Fluorescent Penetrant Method

This is a method which may be used on both non-magnetic and magnetic materials. A highly fluorescent liquid penetrate 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 a 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.

After manufacture, all crankshafts are magnetic-particle-inspected to eliminate the possibility of defective shafts being placed into original equipment.

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

There are two types of loads imposed on a crankshaft in service: a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load. See Figure 1-116.

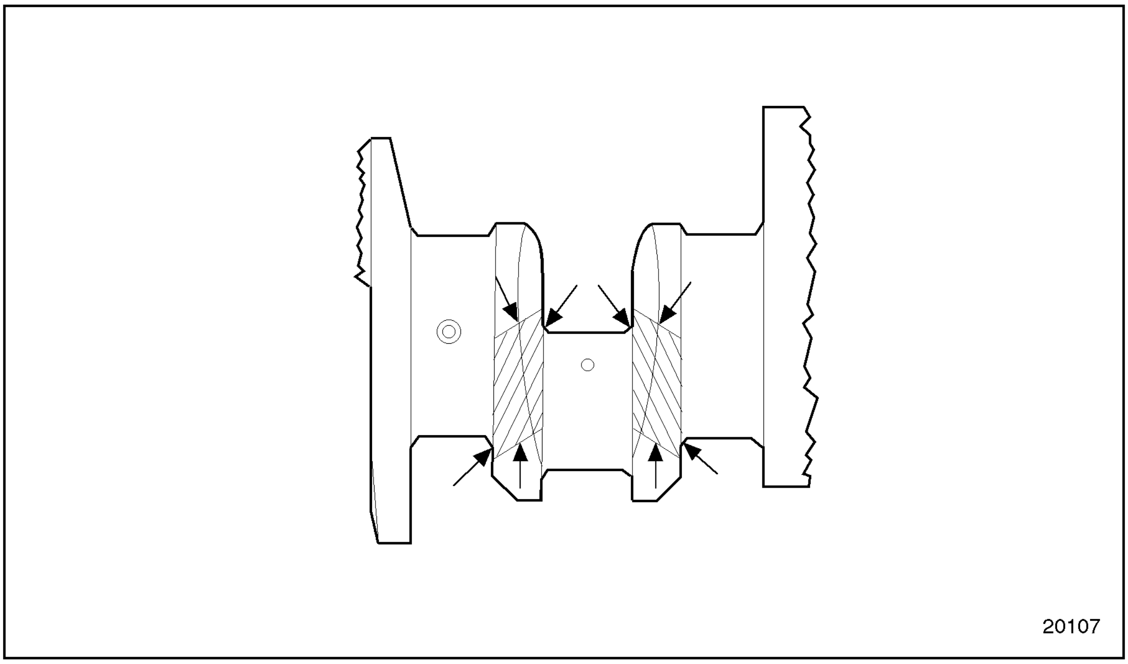


Figure 1-116 Critical Crankshaft Loading Zones

1.7.2.9 Bending Fatigue

Failures can result from bending of the crankshaft.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, loose or broken bearing caps, or unbalanced pulleys. Also, drive belts which are too tight will impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the main journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

1.7.2.10 Torsional Fatigue

Failures result from torsional vibration which takes place at high frequency. A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations. See Figure 1-117.

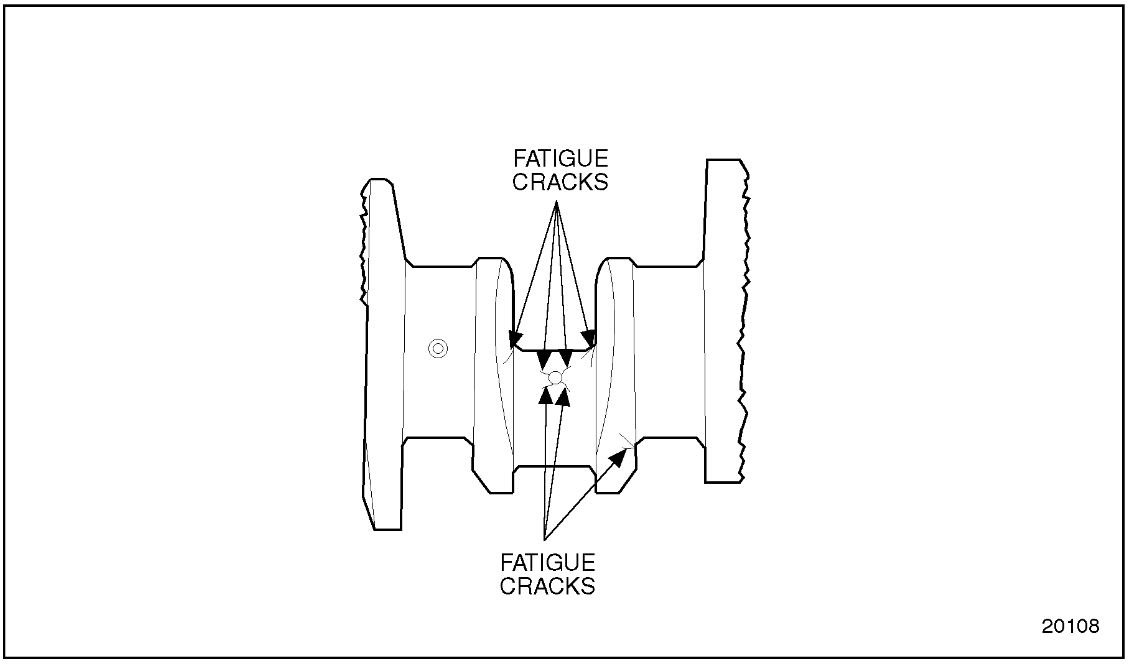


Figure 1-117 Crankshaft Fatigue Cracks

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek in the rear. Torsional failures may also occur at the front end of the crankshaft at the crankshaft timing gear drive key slot. Connecting rod journal failures are usually at the fillet or oil hole at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or overriding the engine electronic control system to allow engine overspeeding may be contributory factors.

1.7.2.11 Crankshaft Cracks

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° to the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes. See Figure 1-117. Replace the crankshaft when cracks of this nature are found. Refer to Section 1.7.3.

1.7.2.12 Crankshaft Grinding

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

Remanufactured crankshafts must conform to specifications. Refer to Section ADDITIONAL INFORMATION. The dimensional requirements for journal axial profile, radial chatter and oil hole washout require confirmation with a Gould 1200 Surface Analyzer (or equivalent). Information on Gould 1200 is available in the "Glossary". Refer to Section ADDITIONAL INFORMATION.

NOTE:
Visual inspection cannot be relied upon to confirm the compliance to journal quality specifications.

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

All used crankshafts that have not been reground must meet the dimensional specifications standard or be reground to specifications. Refer to Section ADDITIONAL INFORMATION.

In addition to standard size crankshaft thrust washers, 0.127 mm (0.005 in.) and 0.254 mm (0.010 in.) oversize thrust washers are available. Refer to Section ADDITIONAL INFORMATION thrust surface specifications are listed in Table 1-16.

Remanufactured crankshafts should be stamped on the edge of the No. 1 crank throw (counterweight) with the appropriate undersize dimensions for identification purposes.

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

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

1.7.3 Installation of Crankshaft

Install the crankshaft using the following procedure:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Steam clean it to remove the rust preventative and blow out the oil passages with compressed air.
2. Refer to Section 1.9 for main bearing details and install the upper 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.

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

NOTE:
If the crankshaft surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the No. 4 main journal. See Figure 1-111.

3. Install the thrust washer upper halves in the counterbores on either side of the No. 4 bearing saddle. Coat the backs of the thrust washers (without oil grooves) with petroleum jelly and stick them in place with the oil-grooved sides facing away from the saddle.

NOTE:
It may be easier to remove the bull gear assembly and re-time the engine; refer to Section 1.21.

4. Apply clean engine oil 360° around all crankshaft bearing journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the bull gear are aligned. Refer to Section 1.21.
5. Install the main bearing shells in the main bearing caps as follows:
   [a] Align the tang on the lower main bearing shell with the groove in the main bearing cap. Install the bearing shell to the main bearing cap.

NOTE:
The main bearing caps are bored in position and stamped with a position number. They must be installed in their original positions, with the marked (numbered) side of each cap toward the cooler (right) side of the cylinder block.

   [b] 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 main bearing caps together with lower bearing shells in place. Install the main bearing cap bolt. See Figure 1-118.

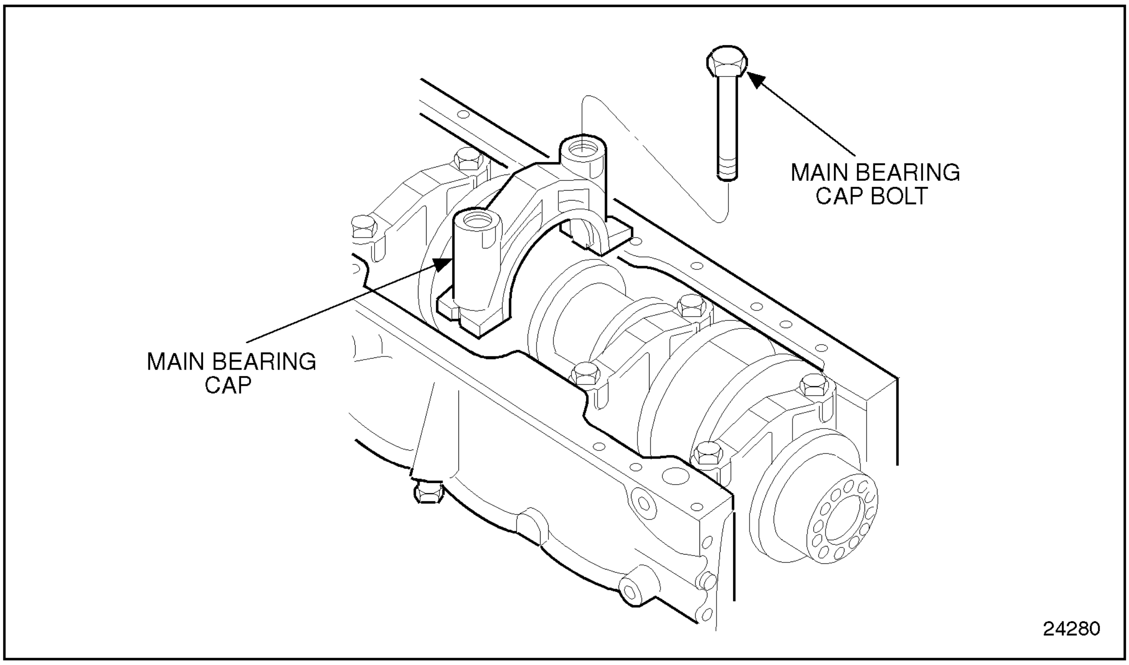


Figure 1-118 No. 4 Main Bearing Cap Installation

7. Apply a small quantity of International Compound #2® (or equivalent) to the bolt threads and underside of the bolt heads. Install the main bearing cap bolts and draw them up snug. Rap the main bearing caps sharply with a fiber mallet or plastic hammer to insure the caps are fully seated.

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.

8. Torque all of the main bearing cap bolts to 470-530 N·m (347-391 lb·ft). Begin at the center caps and work progressively toward each end. Tighten the bolts to half the specified torque and then repeat the tightening sequence to the torque limit.
9. Install a dial indicator to the cylinder block. See Figure 1-119.
10. Check the crankshaft end by moving the crankshaft toward the gage with a small (less than 12 in., 0.3 m) pry bar. See Figure 1-119. Keep a constant pressure on the pry bar and zero the pointer on the dial indicator. 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 0.097-0.419 mm (0.004-0.017 in.). Insufficient

end play can be the result of a misaligned No. 4 main bearing, a mislocated upper thrust washer or a burr or dirt on the inner face of one or more of the thrust washers.

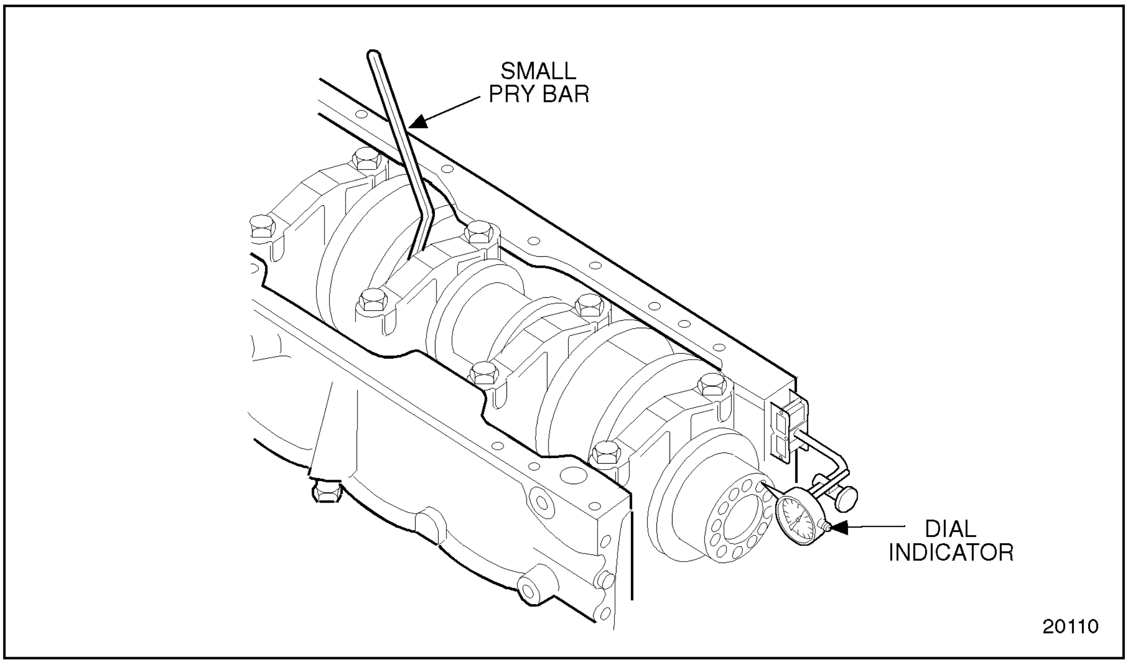


Figure 1-119 Measuring Crankshaft End Play

11. Assemble the timing wheel and crankshaft gear on the crankshaft. Refer to Section 1.27.3.
12. Install the piston and connecting rod assemblies. Refer to Section 1.18.5. Torque the connecting rod cap nuts to 160-185 N·m (118-137 lb·ft).
13. Install the cylinder head. Refer to Section 1.2.5.
14. Install the flywheel housing. Refer to Section 1.16.3.
15. Replace the rear crankshaft seal with new seal and sleeve assembly. Refer to Section 1.8.7.
16. Install the flywheel. Refer to Section 1.14.3.
17. Install the lubricating oil pump, inlet and outlet pipes. Refer to Section 3.2.5.
18. Install the gear case cover and engine front support. Refer to Section 1.10.3.
19. Replace the front crankshaft seal with new seal and sleeve assembly. Refer to Section 1.8.7.
20. Install the viscous vibration damper. Refer to Section 1.12.3.
21. Install the crankshaft pulley. Refer to Section 1.13.3.
22. Install the oil pan. Refer to Section 3.9.3.
23. Use a chain hoist and spreader bar with hooks attached to the lifting brackets at each end of the engine and remove the engine from the overhaul stand.
24. Remove the overhaul stand adapter plate from the engine block.

25. Install any accessories that were removed.
26. Install the engine to the equipment from which it was removed.
27. Fill the cooling system. Refer to Section 13.5.4.
28. Fill the engine crankcase to correct operating level. Refer to Section 13.5.1.
29. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the "Run-In Schedule." Refer to Section 11.8.2.

1.8 CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing element of the crankshaft oil seal runs against a wear sleeve which is pressed onto the crankshaft, thus preventing oil from escaping from the engine crankcase.

A unidirectional laydown-lip crankshaft oil seal, with a dust lip, is used at the front of the crankshaft. The rear oil seal is pressed into the flywheel housing. With dry flywheel housings, a single Teflon-lip seal is used. With a wet flywheel housings, a two-lip, laydown type seal is used. See Figure 1-120.

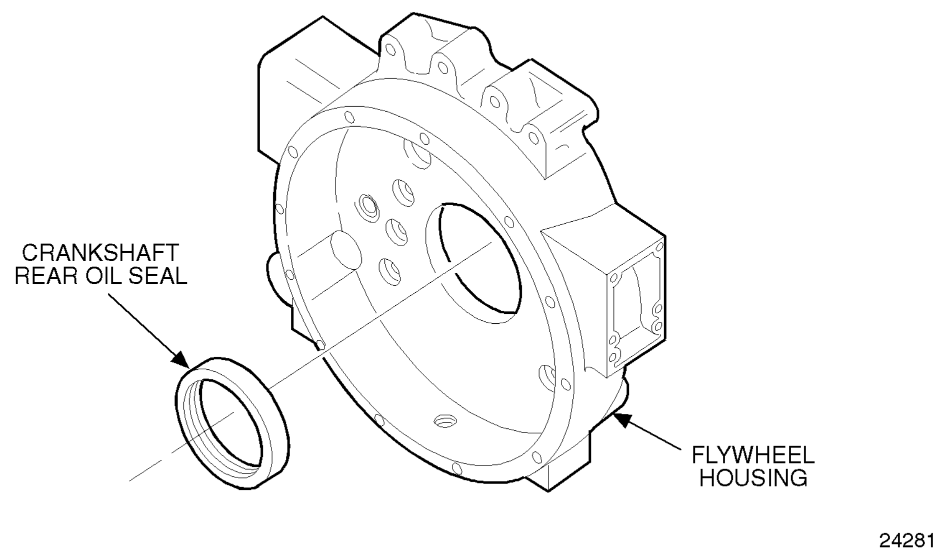


Figure 1-120 Crankshaft Rear Oil Seal

NOTICE:
Failure to use the required seal in a dry or wet flywheel housing environment may result in seal damage and oil leakage.

Teflon ® is a registered trademark of E.I. DuPont de Nemours and Co., Inc.

The Chicago Rawhide® unitized front oil seal is pressed onto the crankshaft and into the gear case cover after the cover is installed. See Figure 1-121.

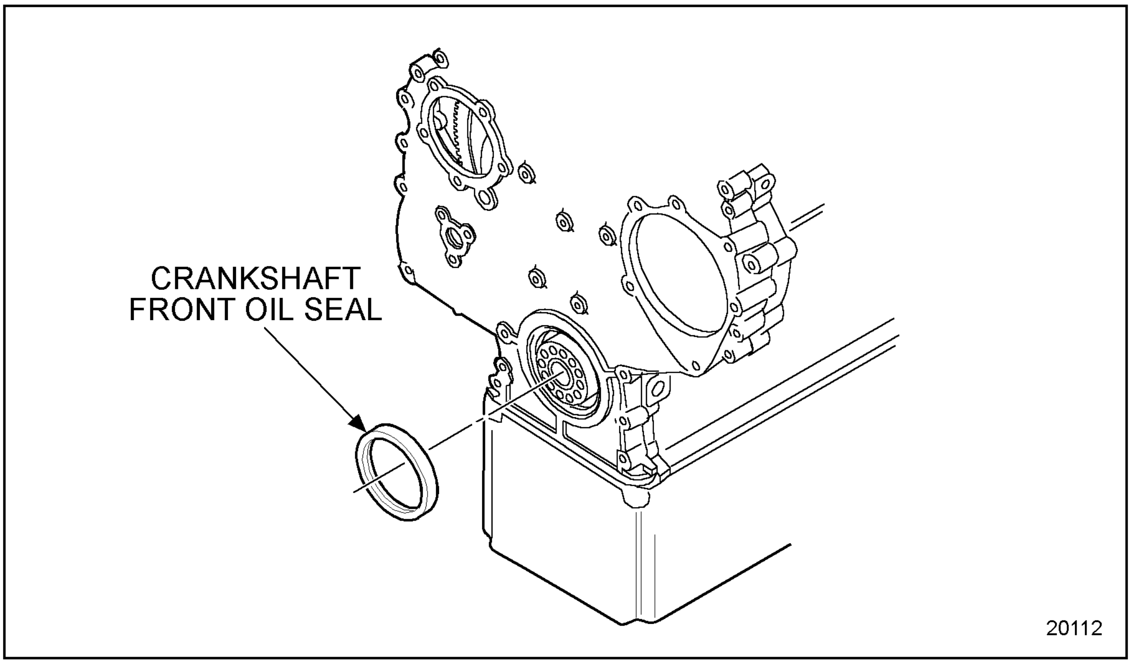


Figure 1-121 Crankshaft Front Oil Seal

The seal element runs against a wear sleeve which is an integral part of the seal assembly for the Chicago Rawhide® seal.

Chicago Rawhide® is a registered trademark of CR Industries.

1.8.1 Repair or Replacement of Oil Seal

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-122.

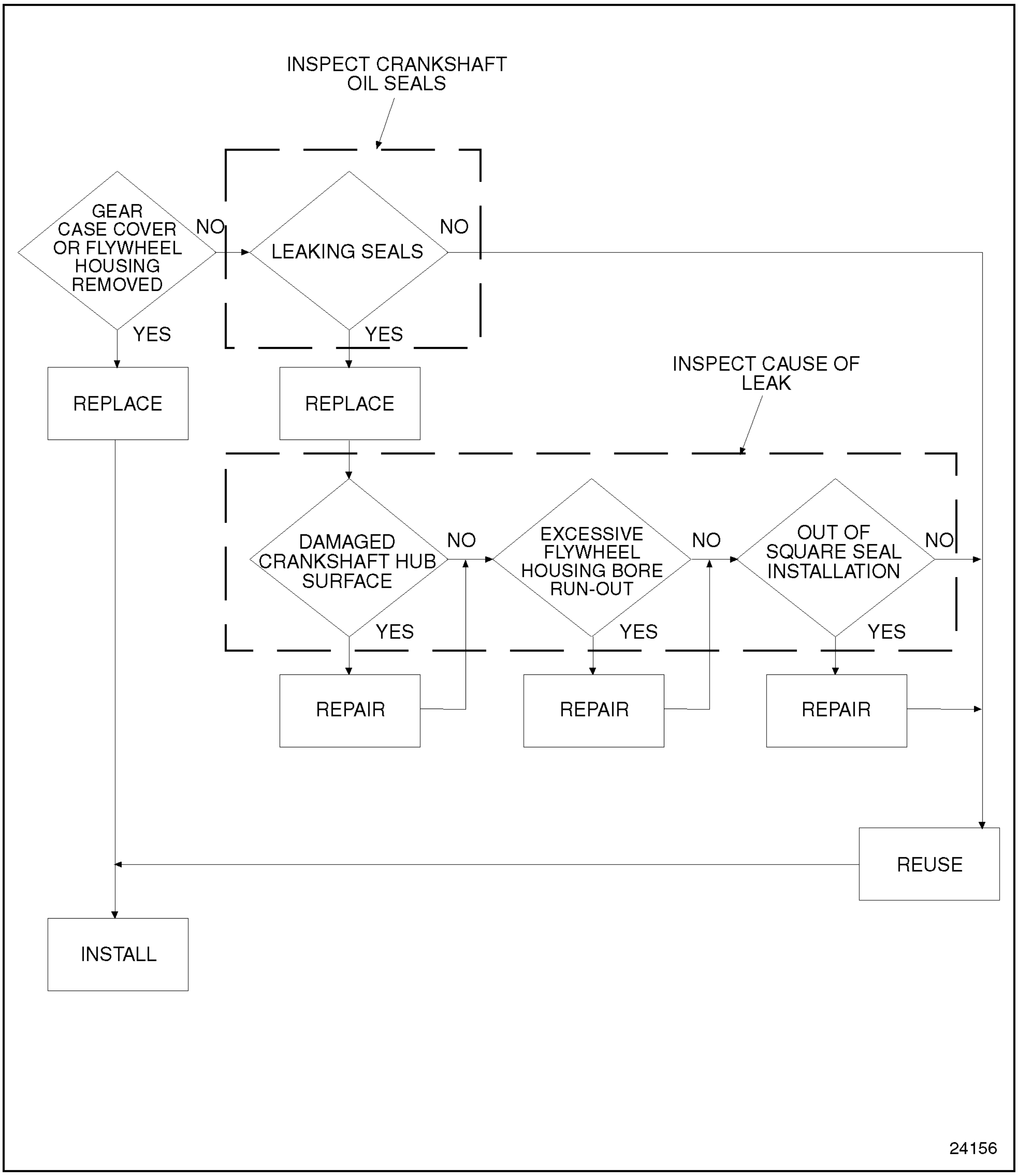


Figure 1-122 Flowchart for Repair or Replacement of Crankshaft Oil Seal

1.8.2 Removal of Front and Rear Crankshaft Oil Seal

The rear crankshaft oil seals can be removed with either the flywheel housing installed or removed. The front crankshaft seal can be removed with the front gear case housing removed or installed.

NOTICE:

Due to the possibility of damage to the crankshaft oil seals, any time the gear case cover or flywheel housing is removed from the engine, the crankshaft oil seals must be replaced.

1. Remove the crankshaft oil seal as follows:
   [a] If the gear case housing is installed, refer to Section 1.8.3.
   [b] If the gear case housing is removed, refer to Section 1.8.4.
2. For the flywheel housing seal, refer to Section 1.8.5.

1.8.3 Removal of Front Crankshaft Oil Seal (Gear Case Housing Installed)

The front crankshaft oil seal may be taken out without removing the gear case housing. This may be done by using oil seal removal tool J 41329 part of J 35993.

NOTE:
Before proceeding, determine if seal to be removed is Federal Mogul® or Chicago Rawhide® brand. Remove and clean all rust and dirt from the crankshaft surface.

Remove the Federal Mogul seal as follows:

1. Install puller, J 41329 part of J 35993, over crankshaft and hold against seal. See Figure 1-123.

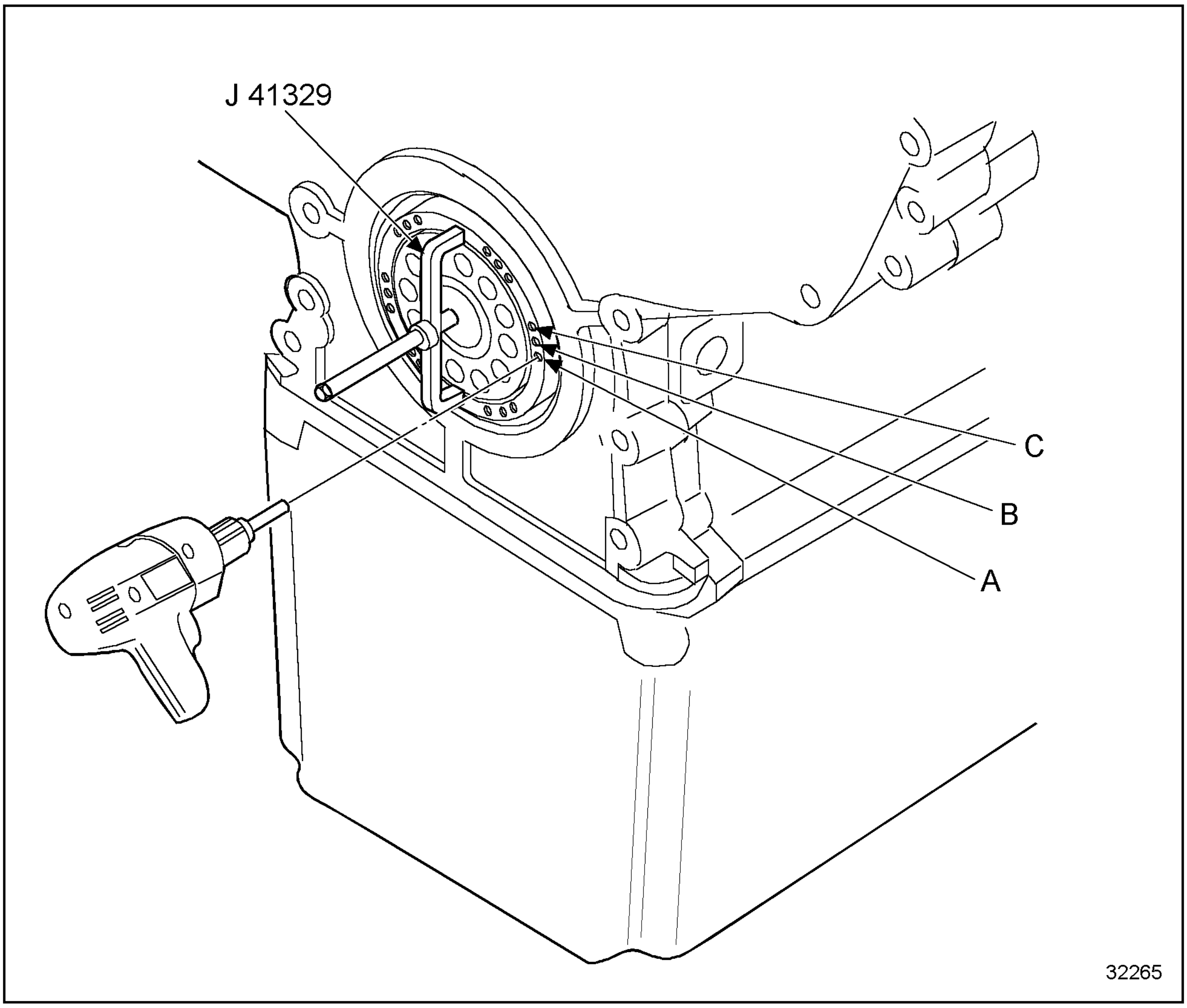


Figure 1-123 Removing Front Crankshaft Oil Seal from Gear Case Cover

2. Using variable speed drill motor and 5/32" bit, drill through outer and inner case of seal using smallest hole "A" as a guide.
3. Without moving J 41329 part of J 35993, drill two additional "A" holes equally spaced.

NOTE:
All six holes may be drilled if using three holes proves unsuccessful in pulling seal.

4. Rotate J 41329 part of J 35993 clockwise until the "B" holes align with drilled holes and install sheet metal screws.
5. Apply thread lubricant, J 23444-A part of J 35686–A, to forcing screw and remove seal.
6. Remove the sheet metal screws from the tool. Discard the oil seal.

7. Remove oil sleeve using crank oil sleeve remover, J 37075-A. See Figure 1-124.

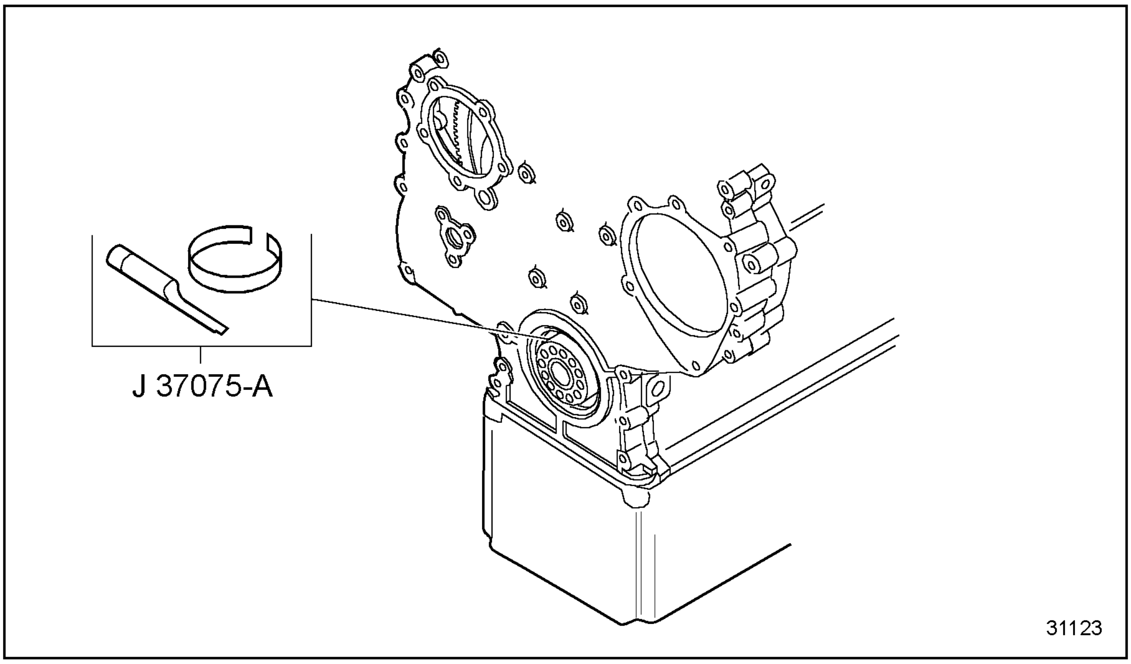


Figure 1-124 Oil Seal Sleeve Removal Tool for the Federal Mogul Seal

8.
   [a] Install hardened steel sleeve removal tool into flywheel housing bore. using socket and breaker bar, rotate tool in three different locations, 2, 4, and 8 o'clock positions, to score the sleeve until the sleeve stretches sufficiently so it can be slipped off the end of the crankshaft.

   [b] Crocus cloth may be used to clean up the high spots from the surface of the crankshaft. Clean the crankshaft contact surface thoroughly.

Remove the Chicago Rawhide® seal as follows:

Chicago Rawhide® is a registered trademark of CR Industries.

1. Install puller, J 41329 part of J 35993, over crankshaft and hold against seal. See Figure 1-125.

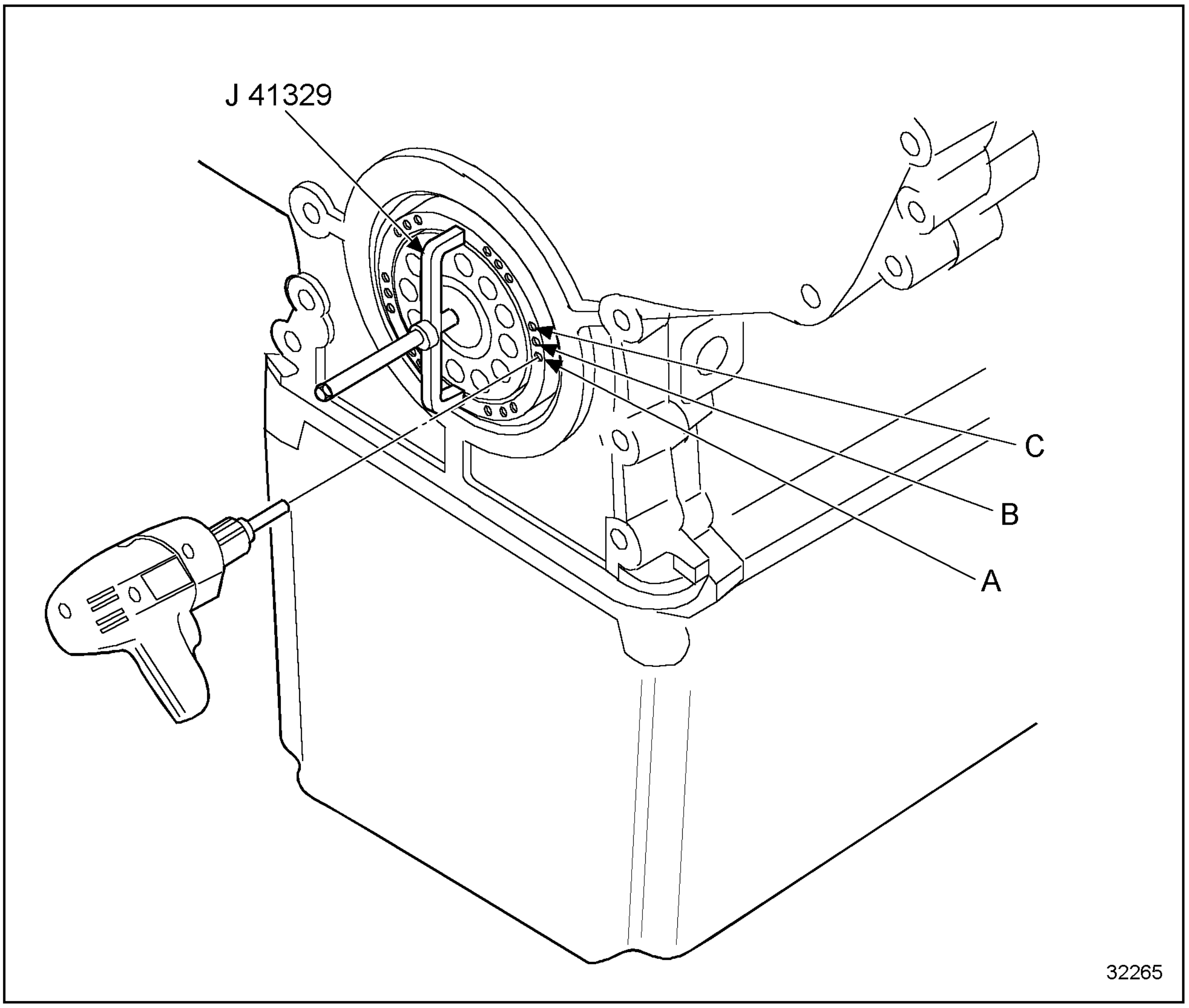


Figure 1-125 Removing Front Crankshaft Oil Seal from Gear Case Cover

2. Using variable speed drill motor and 5/32" it, drill through outer and inner case of seal using smallest hole "A" as a guide.
3. Without moving J 41329 part of J 35993, drill two additional "A" holes equally spaced.

NOTE:
All six holes may be drilled if using three holes proves unsuccessful in pulling seal.

4. Rotate J 41329 part of J 35993 clockwise until the "A" holes align with drilled holes and install sheet metal screws.

5. Apply thread lubricant, J 23444-A part of J 35686–A, to forcing screw and remove seal.

NOTE:
If seal is difficult to remove, there is probably debris on the crankshaft preventing the wear sleeve from passing over the crankshaft. push the seal in 1/8", clean crankshaft surface thoroughly and repeat the removal procedure.

6. Remove the sheet metal screws from the tool. Discard the oil seal.

1.8.4 Removal of Front Crankshaft Oil Seal (Gear Case Housing Removed)

The Federal Mogul front crankshaft oil seal may be removed with the gear case housing removed from the engine.

Perform the following steps if the gear case housing has been removed from the engine.

NOTE:
The crankshaft oil seal must be removed if the gear case housing has been removed from the engine.

1. Support the outer face of the gear case housing on wood blocks.
2. Drive the oil seal out with a brass drift and hammer. Clean the seal bore in the housing. See Figure 1-126.

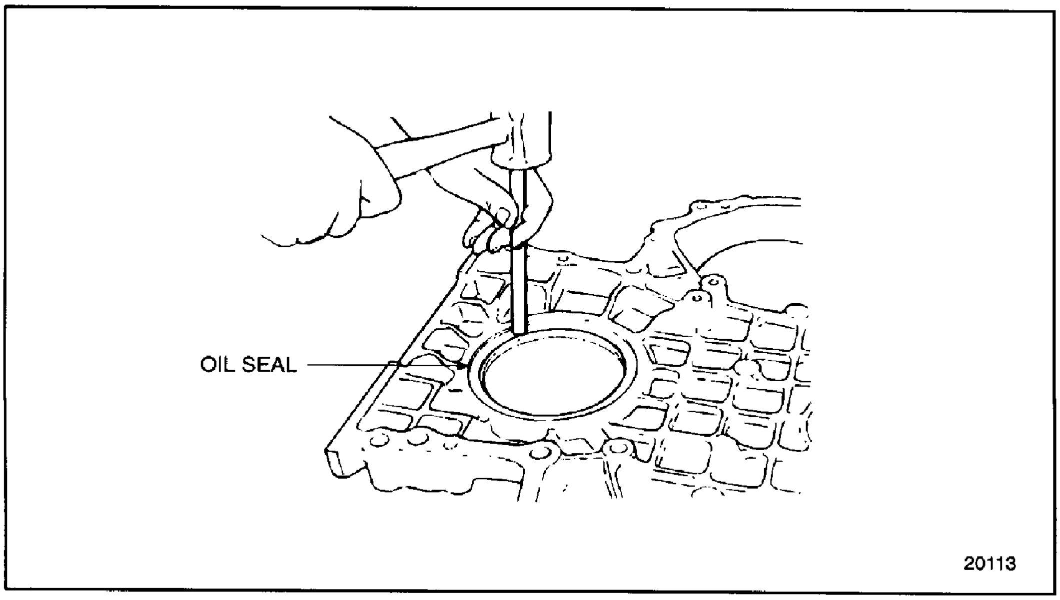


Figure 1-126 Front Crankshaft Oil Seal Removal

1.8.5 Removal of Rear Crankshaft Oil Seal (Flywheel Housing Installed)

The rear crankshaft oil seal may be taken out without removing the flywheel housing. This may be done by using oil seal removal tool, J 41329 part of J 35993.

1. To replace the rear oil seal, with transmission removed, remove the flywheel. Refer to Section 1.14.2.

NOTE:
Before proceeding, determine if seal to be removed is Federal Mogul or Chicago Rawhide brand. Remove and clean all rust and dirt from the crankshaft surface.

Remove the Federal Mogul seal as follows:

1. Install puller, J 41329 part of J 35993, over crankshaft and hold against. seal.

2. Using variable speed drill motor and 5/32" bit, drill through outer and inner case of seal using smallest hole "A" as a guide. See Figure 1-127.

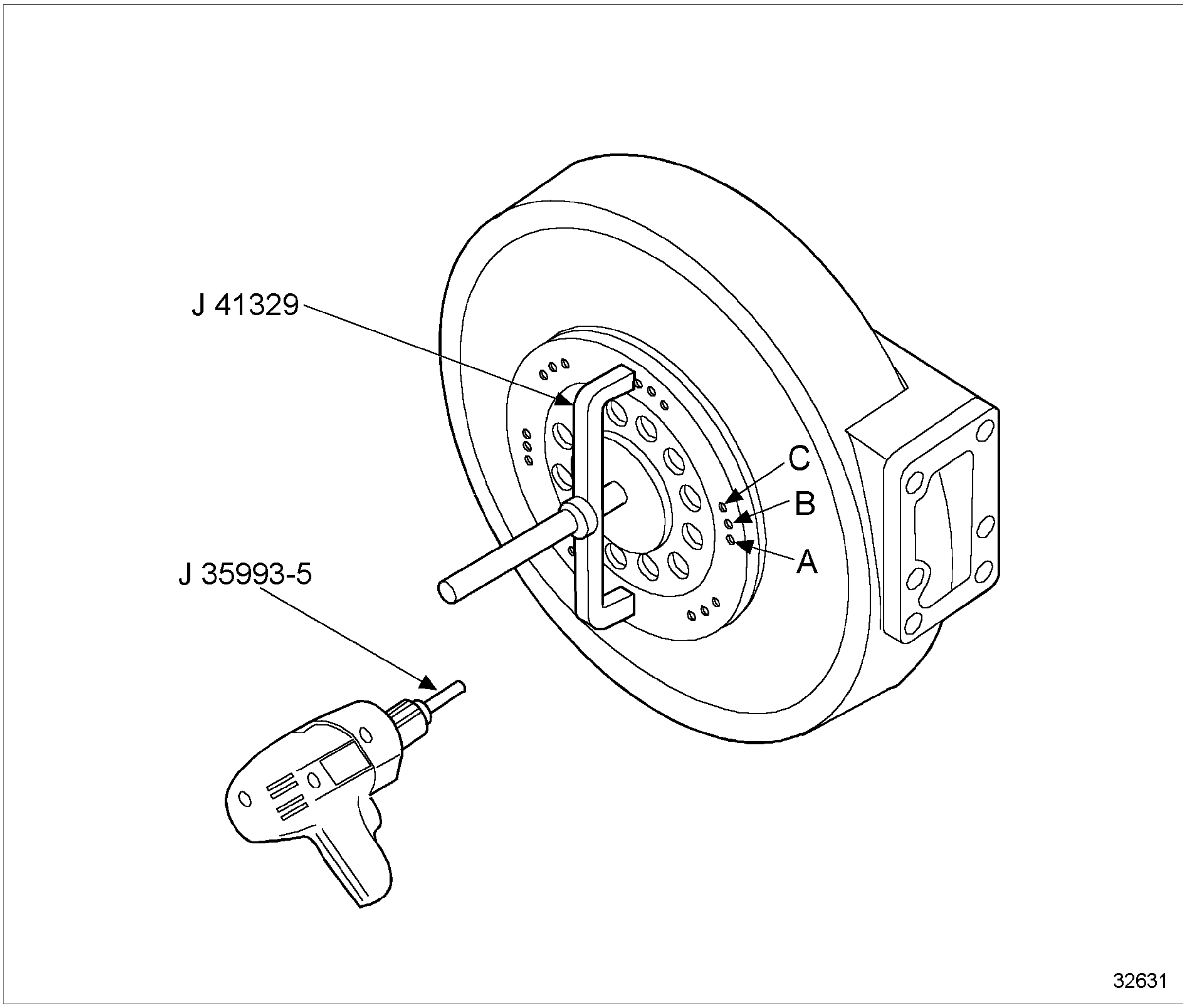


Figure 1-127 Rear Oil Seal Removal

3. Without moving J 41329 part of J 35993, drill two additional "A" holes equally spaced.

NOTE:
All six holes may be drilled is using three holes proves unsuccessful in pulling seal.

4. Rotate J 41329 part of J 35993 clockwise until the "B" holes align with drilled holes and install sheet metal screws.
5. Apply thread lubricant, J 23444-A part of J 35686–A, to forcing screw and remove seal.
6. Remove the sheet metal screws from the tool. Discard the oil seal.

Remove the Chicago Rawhide seal as follows:

1. Install puller, J 41329 part of J 35993, over crankshaft and hold against. seal.

2. Using variable speed drill motor and 5/32" bit, drill through outer and inner case of seal using smallest hole "A" as a guide. See Figure 1-128.

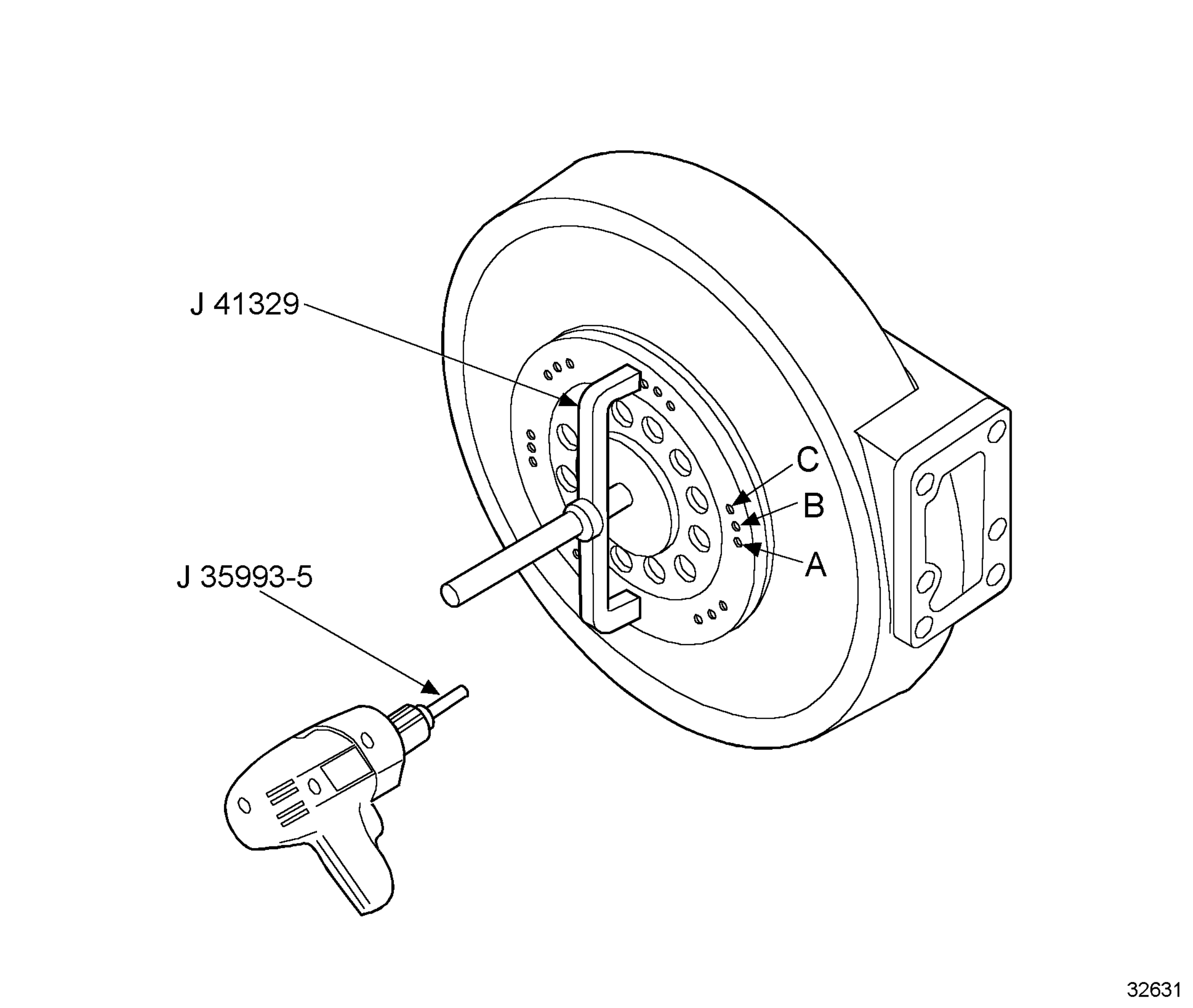


Figure 1-128 Rear Oil Seal Removal

NOTE:
All six holes may be used if using three holes proves unsuccessful in pulling seal.

3. Apply thread lubricant J 23444-A part of J 35686–A to forcing screw and remove seal.

NOTE:
If seal is difficult to remove, push seal in 1/8", clean crankshaft surface thoroughly and repeat the removal procedure above.

4. Remove the sheet metal screws from the tool. Discard the oil seal.

1.8.6 Removal of Rear Oversized Seal with Wear Sleeve

If seal removed is an oversized seal with wear sleeve, the oil wear sleeve must also be removed.

1. To remove a worn wear sleeve, use crankshaft wear sleeve remover, J 37075-A. See Figure 1-129.

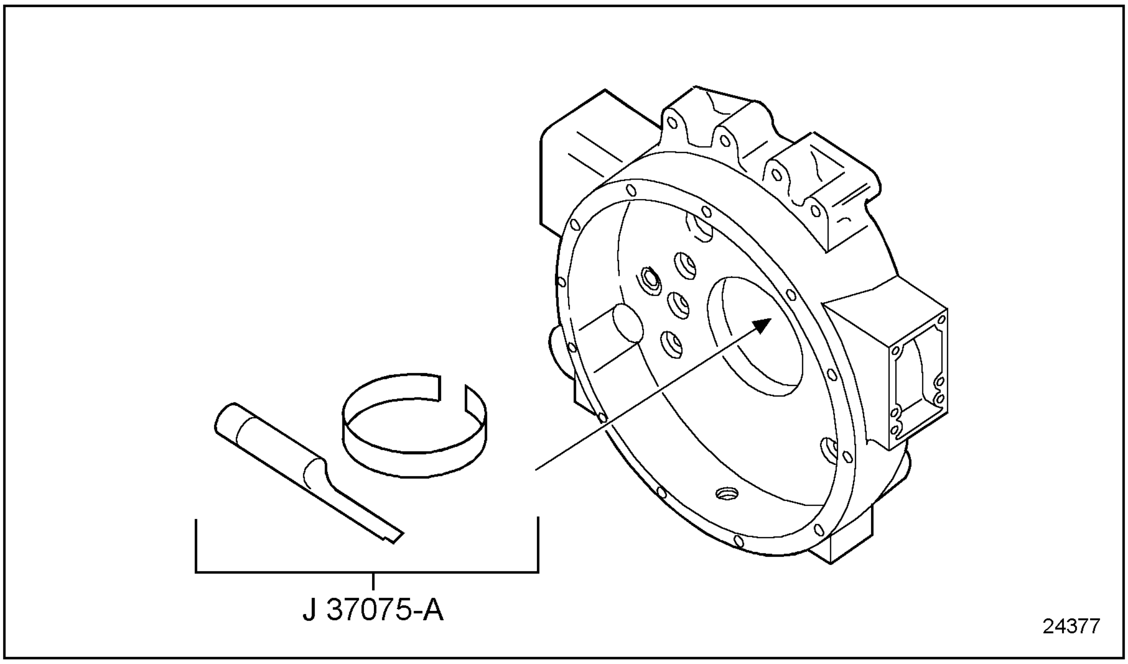


Figure 1-129 Rear Oil Seal Wear Sleeve Removal

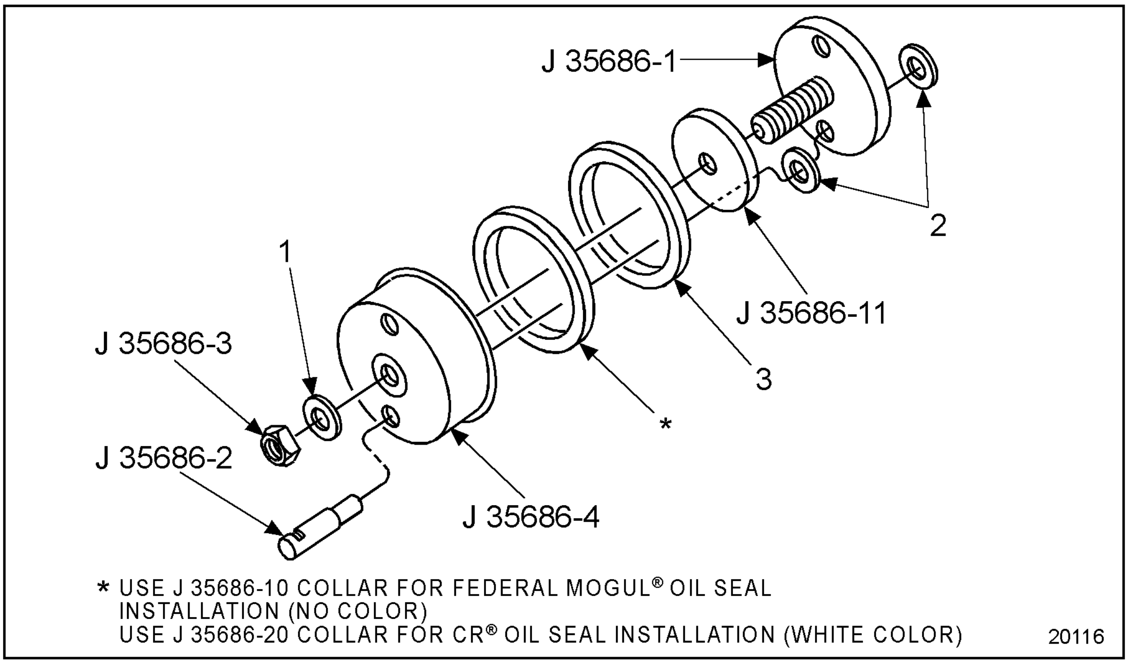
[a] Install hardened steel sleeve removal tool into flywheel housing bore. Using socket and breaker bar, rotate tool in three different locations, 2, 4, and 8 o'clock positions, to score the sleeve, until the sleeve stretches sufficiently so it can be slipped off the end of the crankshaft.

[b] Crocus cloth may be used to clean up the high spots from the surface of the crankshaft. Clean the crankshaft contact surface thoroughly.

1.8.7 Installation of Front and Rear Crankshaft Oil Seal and Wear Sleeve

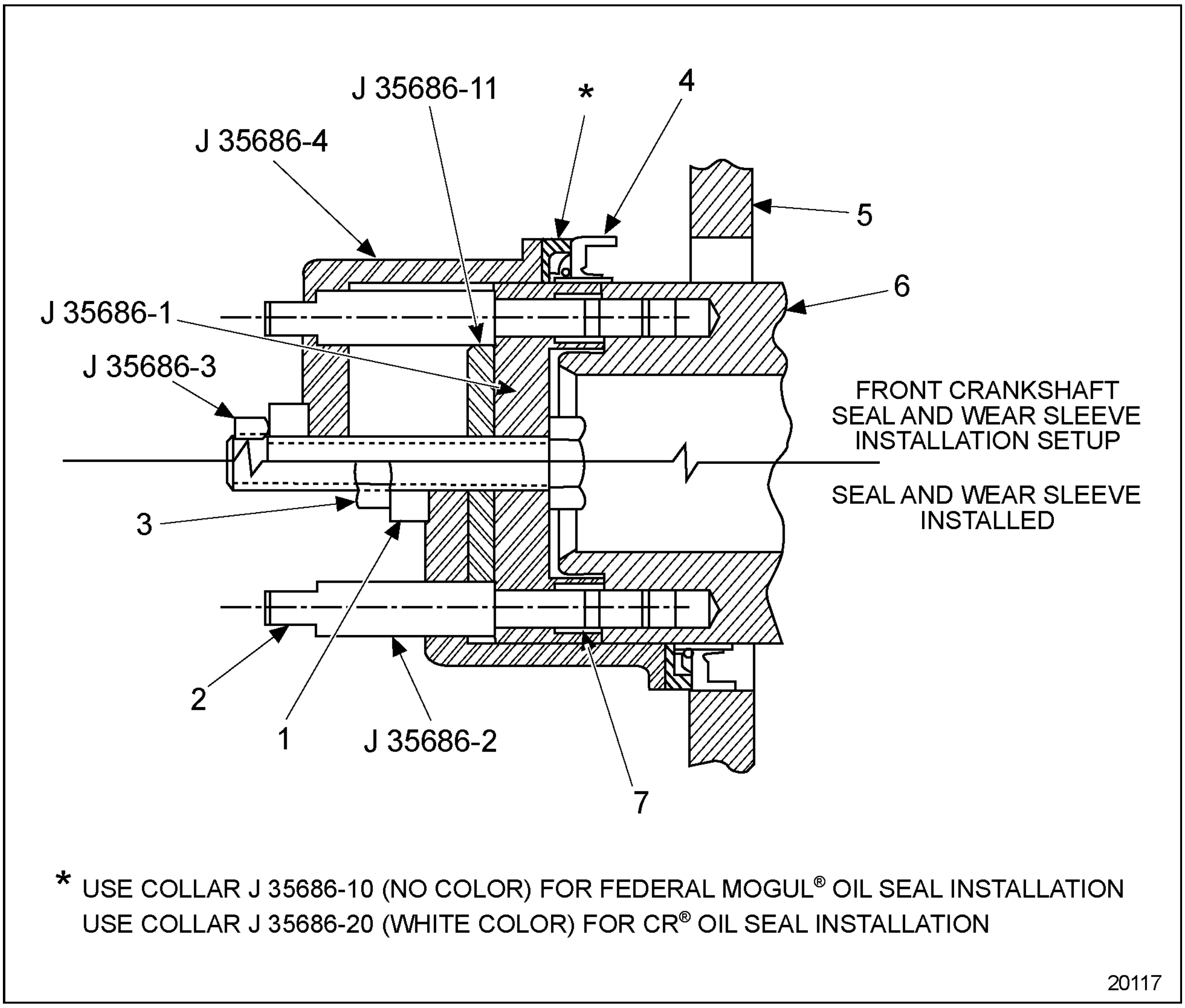
Install the oil seal as follows:

An oil seal sleeve, integral to the seal assembly, is pressed onto the end of the crankshaft and provides a replacement wear surface at the point of contact with the oil seal. The sleeve and seal are supplied assembled. The assembly is installed using the crankshaft oil seal and sleeve installation tool. The Federal Mogul® oil seal is installed using tool, J 35686-A, with collar J 35686-10. The Chicago Rawhide® (CR) oil seal is installed using tool, J 35686-A, but uses collar J 35686-20. See Figure 1-130and see Figure 1-131.



1. Washer
2. Washer
3. Seal

Figure 1-130 Crankshaft Oil Seal and Sleeve Installation Tool Set



1. Thrust Plate
2. Wrench Flat 1/2 in., Guide Stud
3. 3/4-10 Hex Nut
4. Seal and Wear Sleeve Assembly DDC Part No. 23513485
5. Gear Case/Flywheel Housing
6. Crankshaft
7. Guide Stud Retainer (O-ring)

Figure 1-131 Crankshaft Oil Seal Installer Stack-up (Front)

Install an oversize oil seal/sleeve, as follows:

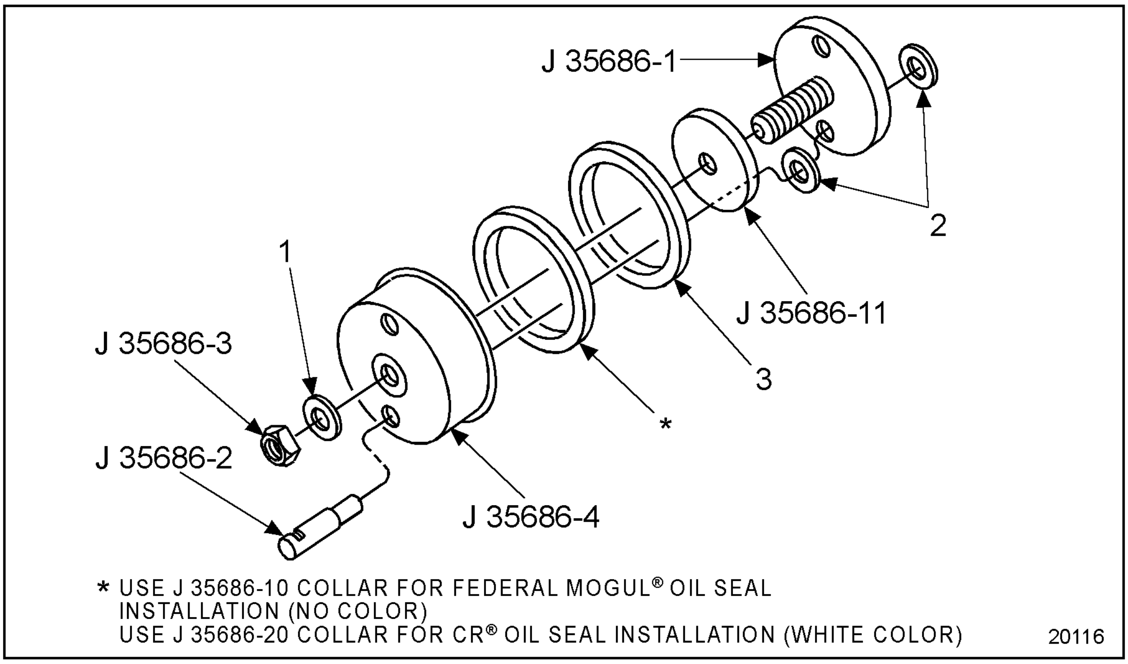
1. Install the new, oversize oil seal and wear sleeve assembly to the housing, J 35686-4.
2. Add new J 35686-10 adapter ring and J 35686-11 spacer along with J 35686-6 spacer. Do not separate the two.

Install the rear oil sleeve as follows:

NOTE:
The assembly used in dry flywheel housings has a unidirectional, laydown type Teflon inner sealing lip and a forward facing Teflon dust lip. The assembly used in wet flywheel

housings has a double-lip seal with unidirectional inner and outer laydown type Teflon sealing lips.

1. Install the two guide studs, J 35686-2, through the holes provided in the base, J 35686-1 and into two of the tapped holes in the crankshaft, 180° apart. See Figure 1-132. Tighten the guide studs using the appropriate wrench on the flats of the studs. The base must be tight against the end of the crankshaft.



1. Washer
2. Washer
3. Seal

Figure 1-132 Rear Oil Seal Installation

2. For rear crankshaft oil seal installations only, install spacer J 35686-6and J 35686-11, to the center screw of the base. See Figure 1-133 and see Figure 1-131.

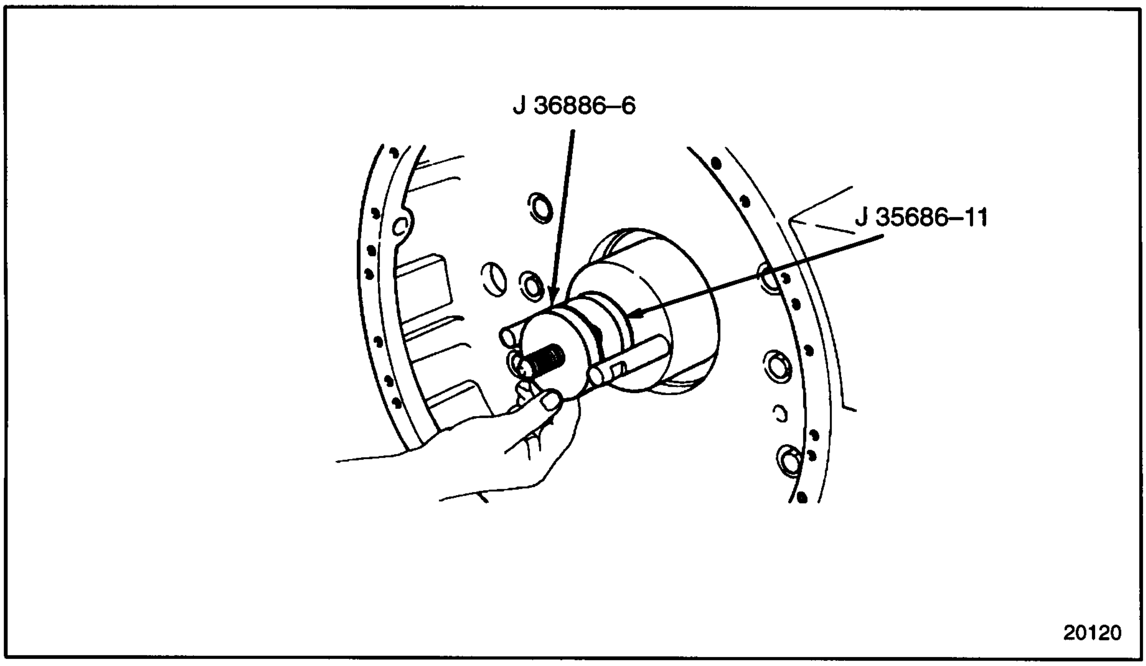


Figure 1-133 Rear Oil Seal Installation

3. Install the rear housing and adapter ring with seal and sleeve assembly in place on the guide studs. See Figure 1-134.

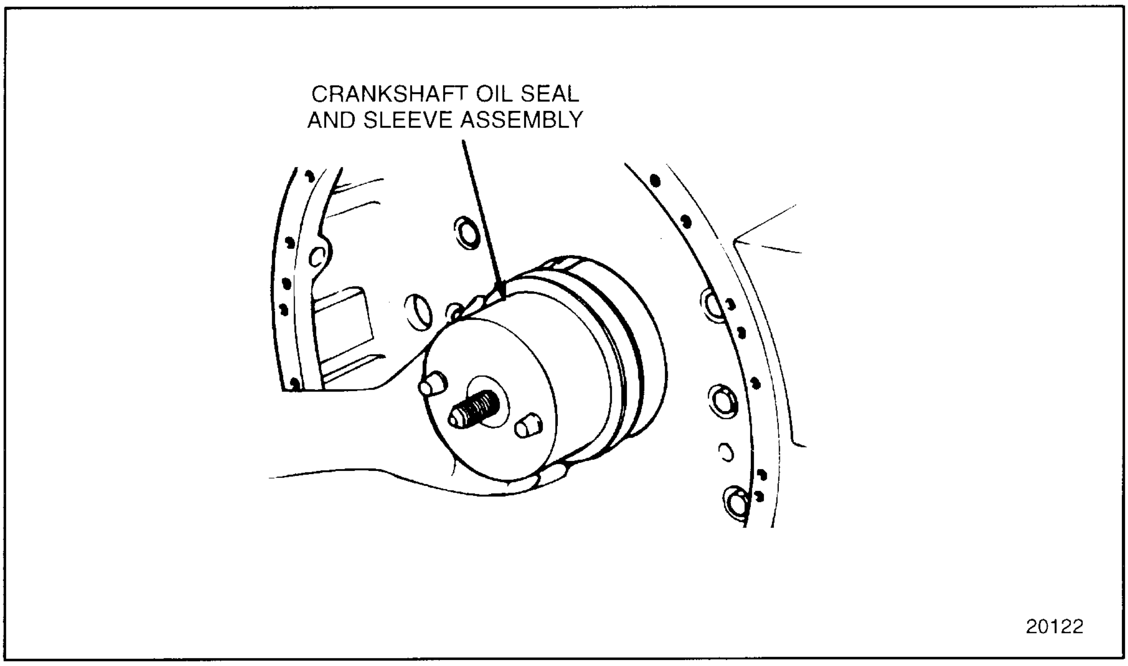


Figure 1-134 Rear Oil Seal and Sleeve Installation

4. Install the thrust bearing tool with the case side toward the installer housing. Install the hex nut to the center screw of the base. See Figure 1-135.

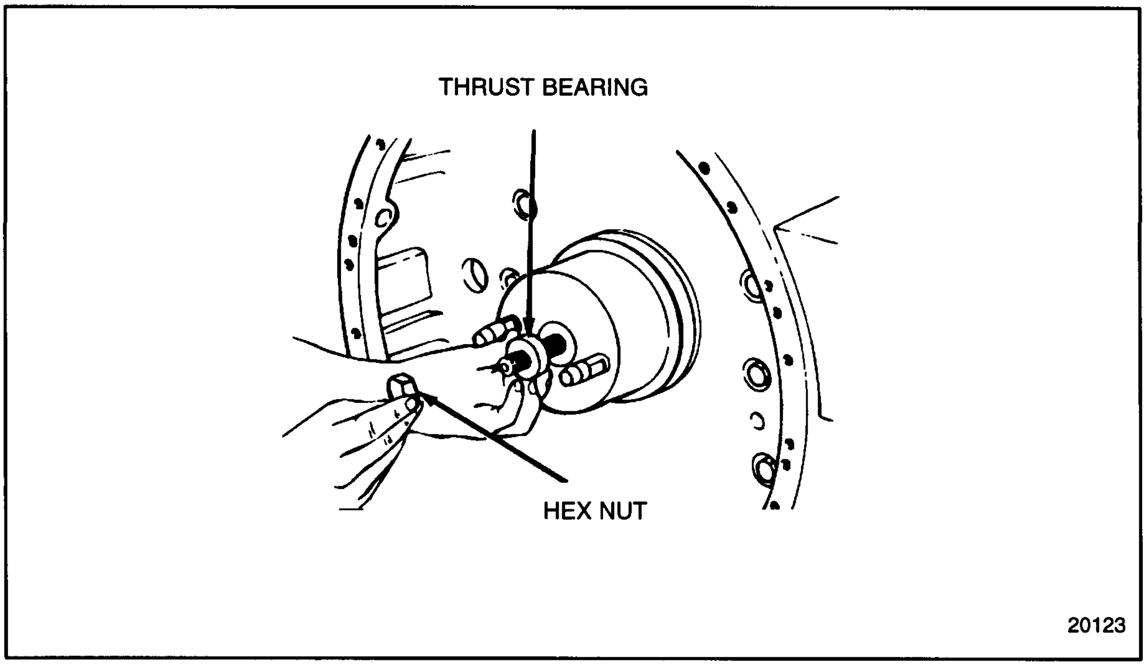


Figure 1-135 Thrust Bearing Installation

5. Tighten the hex nut by hand until all the slack is taken up. Use a ratchet and socket to tighten the hex nut, and install the wear sleeve to the crankshaft and the oil seal to the flywheel housing and/or gear case cover. See Figure 1-136.

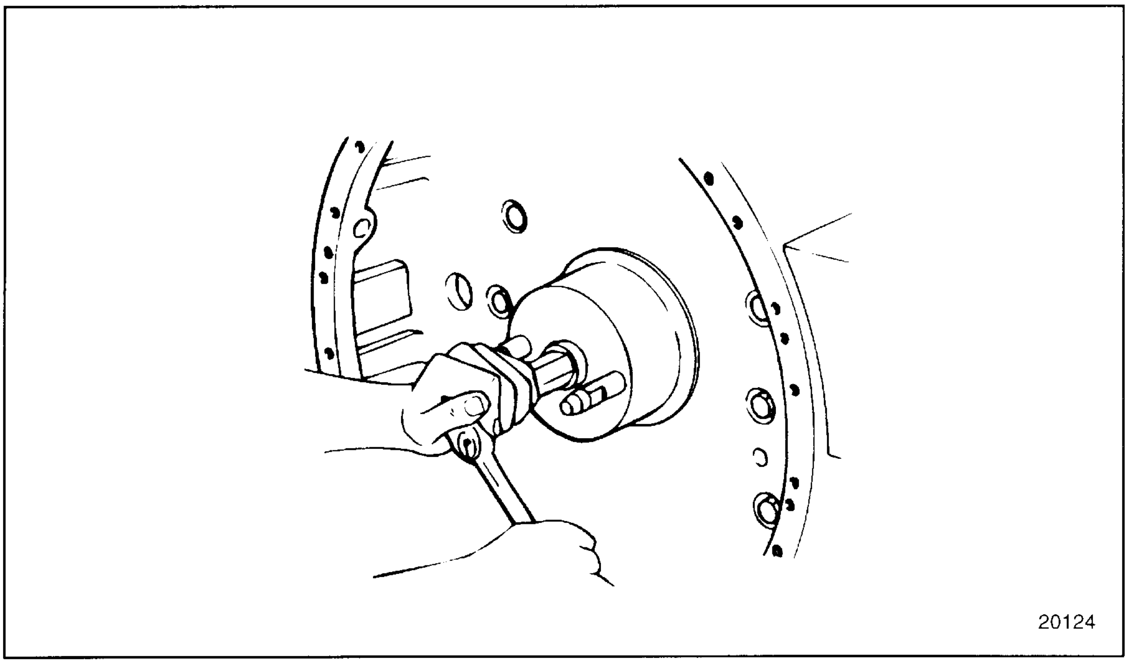


Figure 1-136 Oil Seal and Sleeve Installation

6. When the inside surface of the housing is seated against the base (or spacers on rear oil seal installation), the seal and sleeve are properly positioned and installed.

1.8.7.1 Inspection of Crankshaft Oil Seal

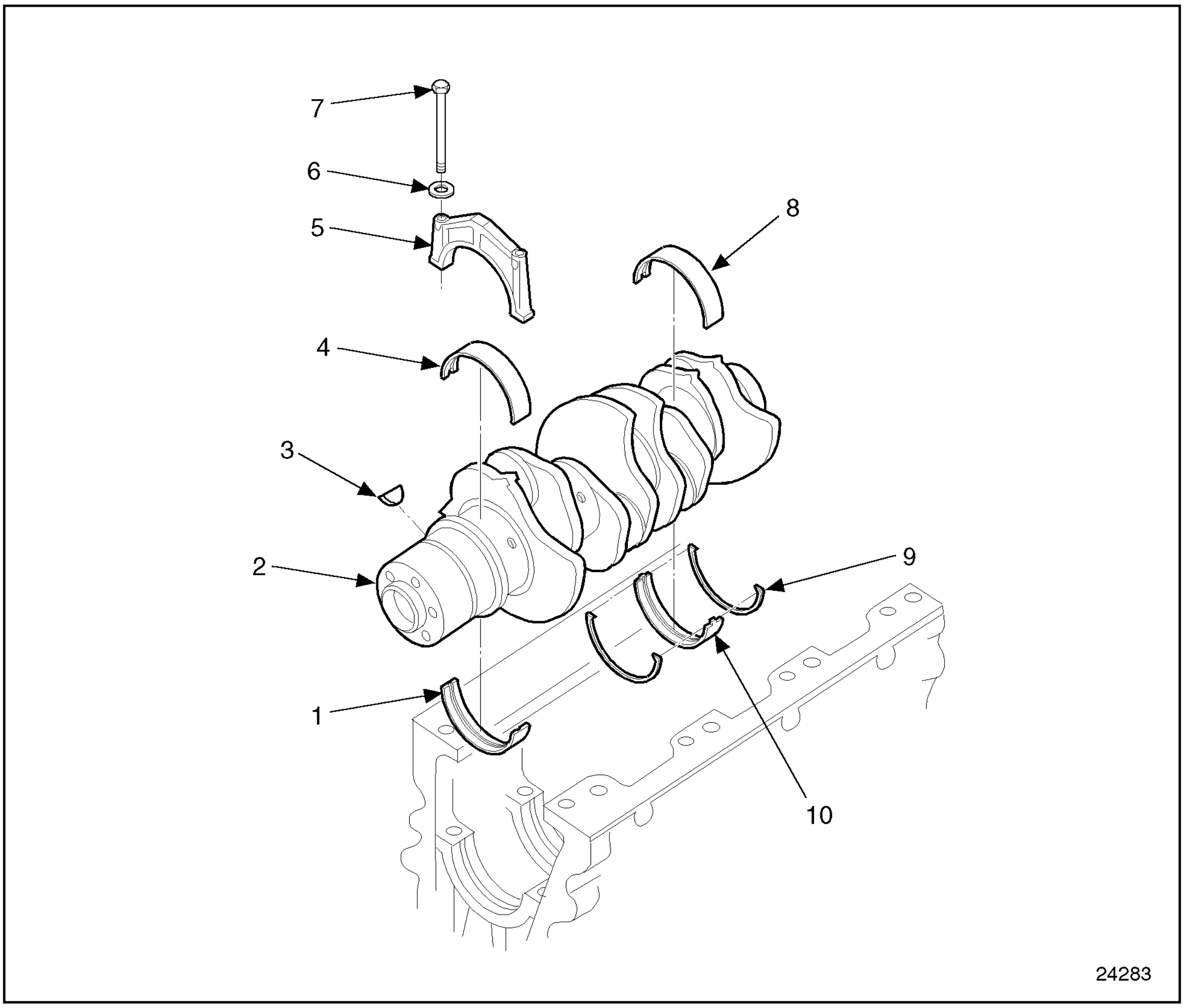
Crankshaft oil seal leaks may indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore run-out, grooved sealing surfaces on the crankshaft hubs or out of square installation. To prevent a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

The maximum run-out of the oil seal bore in the gear case cover or flywheel housing is 0.330 mm (0.013 in.). 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. Refer to Section 1.16.3.1. This check must be made with the flywheel housing or gear case cover in place on the engine and the oil seal removed.

Inspect the seal contact surface of the crankshaft for wear caused by the rubbing action of the oil seal, dirt buildup or by the fretting action of the flywheel. The crankshaft surface must be clean and smooth when a new wear sleeve and seal are installed.

1.9 CRANKSHAFT MAIN BEARINGS

The crankshaft main bearing shells are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. See Figure 1-137.



1. Upper Bearing Shell
2. Crankshaft
3. Key
4. Lower Bearing Shell
5. No. 1 Main Bearing Cap
6. Flat Washer
7. Bolt
8. No. 4 Lower Bearing Shell
9. Upper Thrust Washer
10. No. 4 Upper Bearing Shell

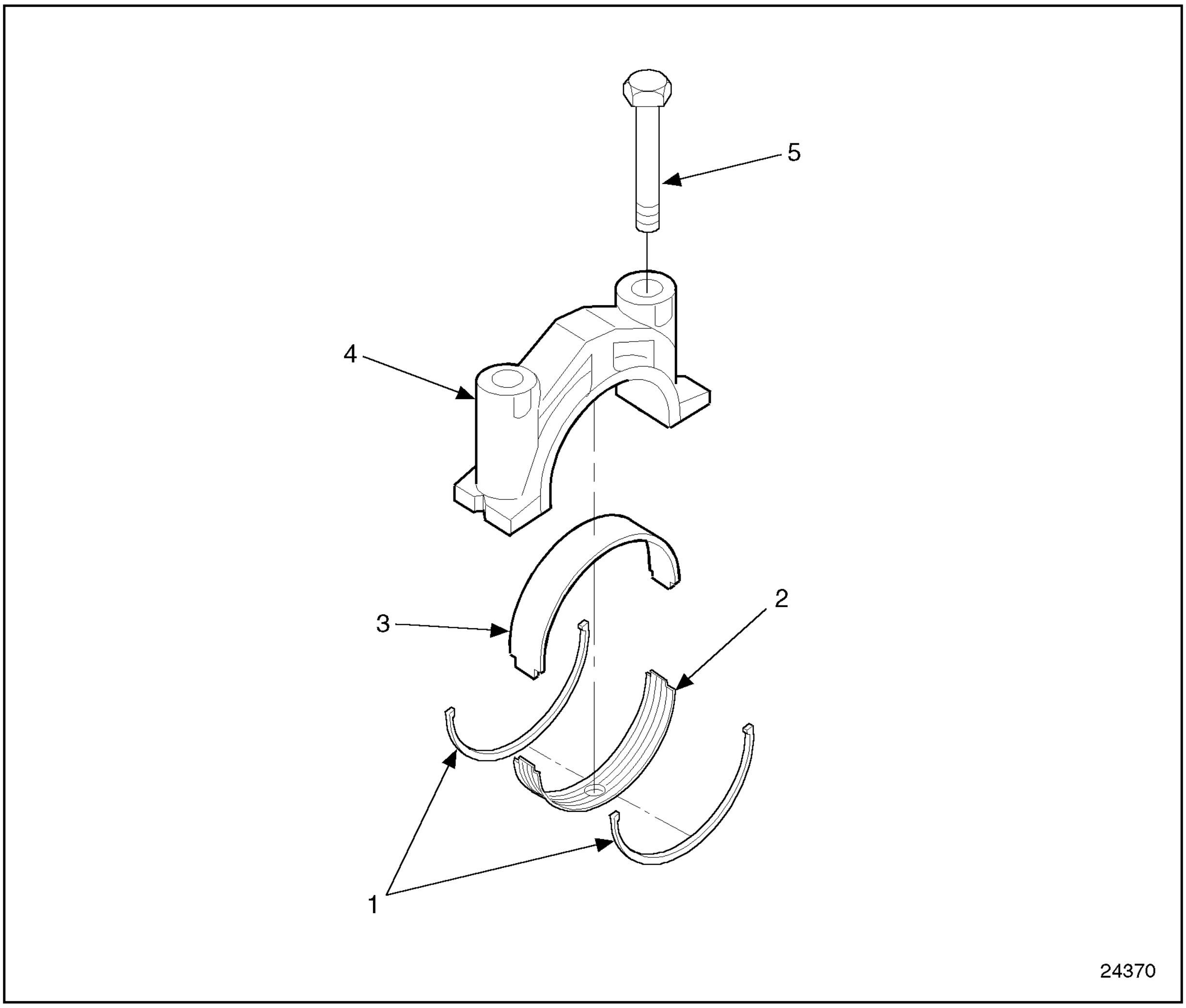
Figure 1-137 Main Bearings Caps, Bearing Shells and Crankshaft Thrust Washers

The upper and lower bearing shells are located in the respective block and bearing cap by a tang. The tang is located at the parting line at one end of each bearing shell. The tangs are offset from center to aid correct insertion. Bearing shell sets are supplied as a matched assembly and should not be mixed.

A hole in each upper bearing shell registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passage in the crankshaft, then to the connecting rods and connecting rod bearings. The upper bearing shell is also grooved.

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

Thrust washers on each side of the No. 4 main bearing absorb the crankshaft thrust. The two-piece washers utilize locking tangs that register with locating notches in the bearing shell. See Figure 1-138.



1. Upper Thrust Washer
2. Upper No. 4 Bearing Shell
3. Lower No. 4 Bearing Shell
4. No. 4 Main Cap
5. Bolt

Figure 1-138 No. 4 Thrust Bearing Detail

The condition of the lower bearing shells may be observed by removing the main bearing caps.

1.9.1 Repair or Replacement of Crankshaft Main Bearings

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-139.

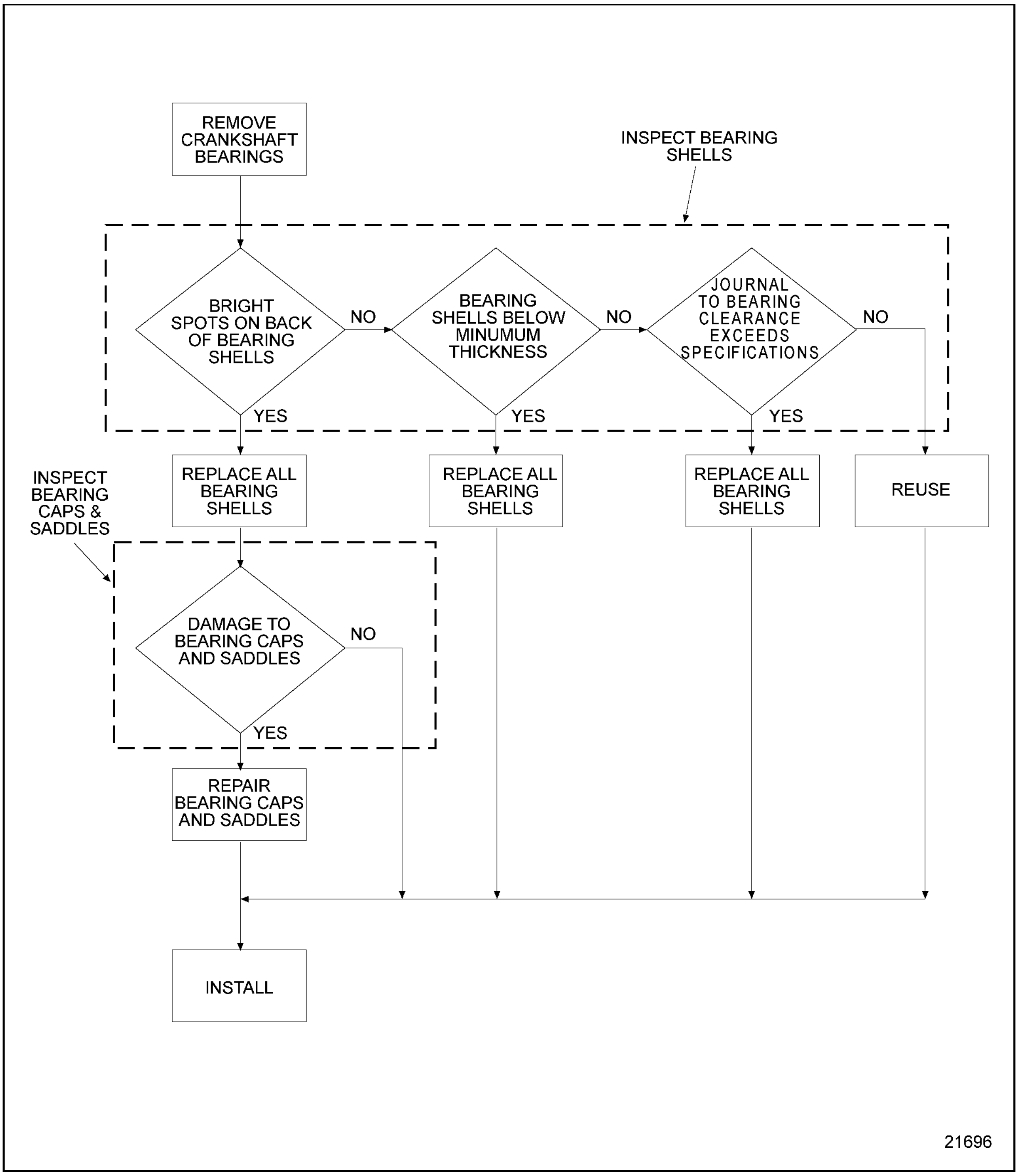


Figure 1-139 Flowchart for Repair or Replacement of Crankshaft Main Bearings

1.9.2 Removal of Main Bearing Shell

The main bearing caps are numbered consecutively, indicating their respective positions. When removed, the bearing caps (and the bearing shells, if they are to be reinstalled) must always be reinstalled in their original position.

1. Drain and remove the oil pan to expose the main bearing caps. Refer to Section 3.9.2.

NOTE:
If shims are used between the oil pump and the cylinder block, save the shims so that they can be reinstalled in exactly the same location as removed. The shims are used to adjust the crankshaft timing gear-to-oil pump drive gear lash.

2. Remove the oil pump pickup and outlet pipes, and the oil pump. Refer to Section 3.2.2.
3. Remove one bearing cap at a time and inspect the lower bearing shell. Refer to Section 1.9.2.1.

NOTE:
Remove and reinstall both upper and lower bearing shells for each main journal being inspected before moving on to the next main journal. Never remove more than one main bearing cap at a time except for No. 4 and No. 5.

4. To remove the upper main bearing shells without crankshaft removal, it will be necessary to use the main bearing shell remover and installer tool set, J 36187-A. See Figure 1-140.

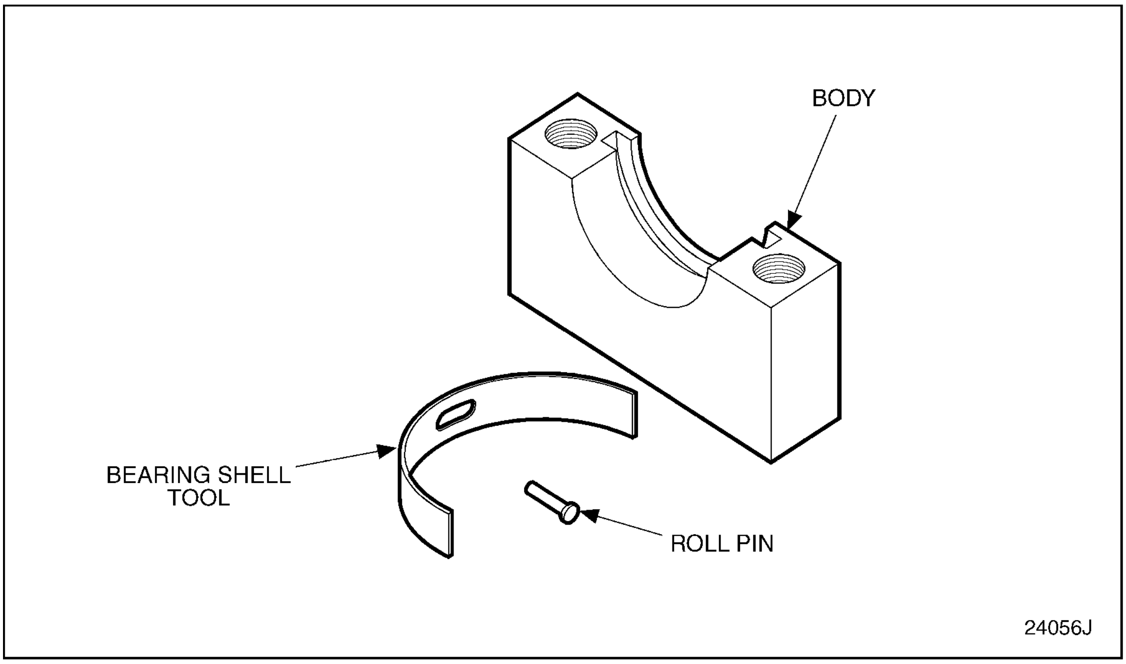


Figure 1-140 Main Bearing Shell Remover and Installer Tool Set

5. To bar the engine over, use the square hole in the middle of the crankshaft pulley, to position the crankshaft throw. Position the crankcase throw for the main bearing being worked on so that the oil delivery hole is pointing upward. See Figure 1-141.

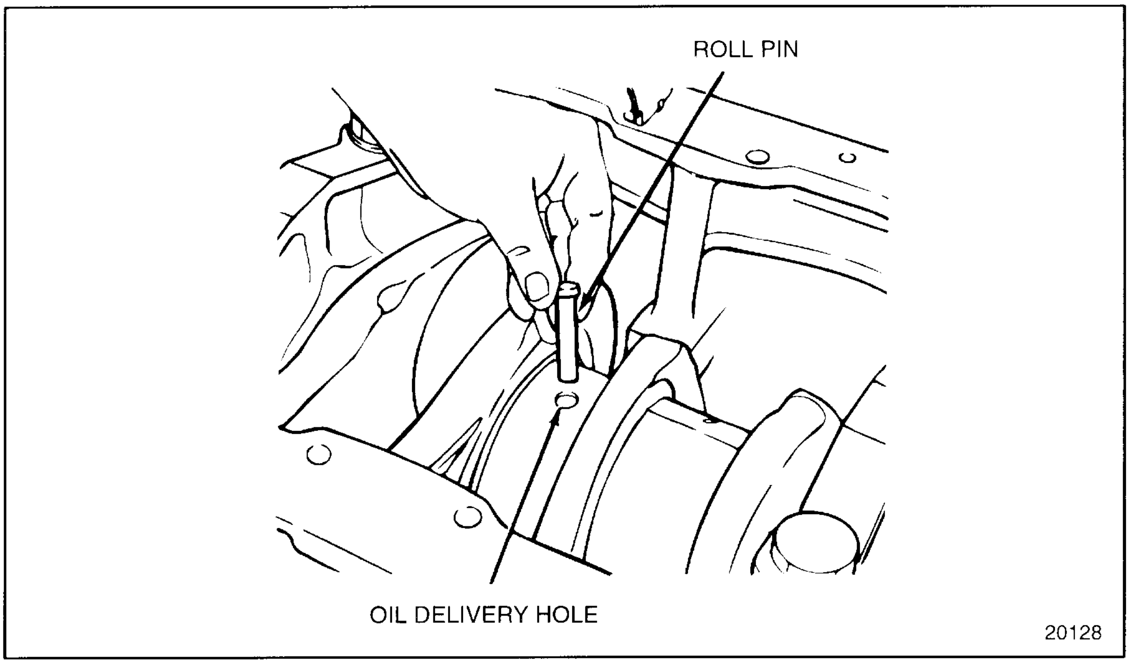


Figure 1-141 Upper Main Bearing Shell Removal and Roll Pin Installation

6. Install the roll pin to the oil delivery hole in the crankshaft journal. See Figure 1-141. If this operation is being performed in-frame, use petroleum jelly to retain the roll pin in the hole.
7. For the No. 4 main bearing journal, it will be necessary to install the lower main bearing thrust washers (previously removed) to the machined faces of the body from the tool kit.

Stick the thrust washers to the main cap using petroleum jelly. Index the locating tangs on the thrust washers with the cut-outs on the bearing shell. See Figure 1-142.

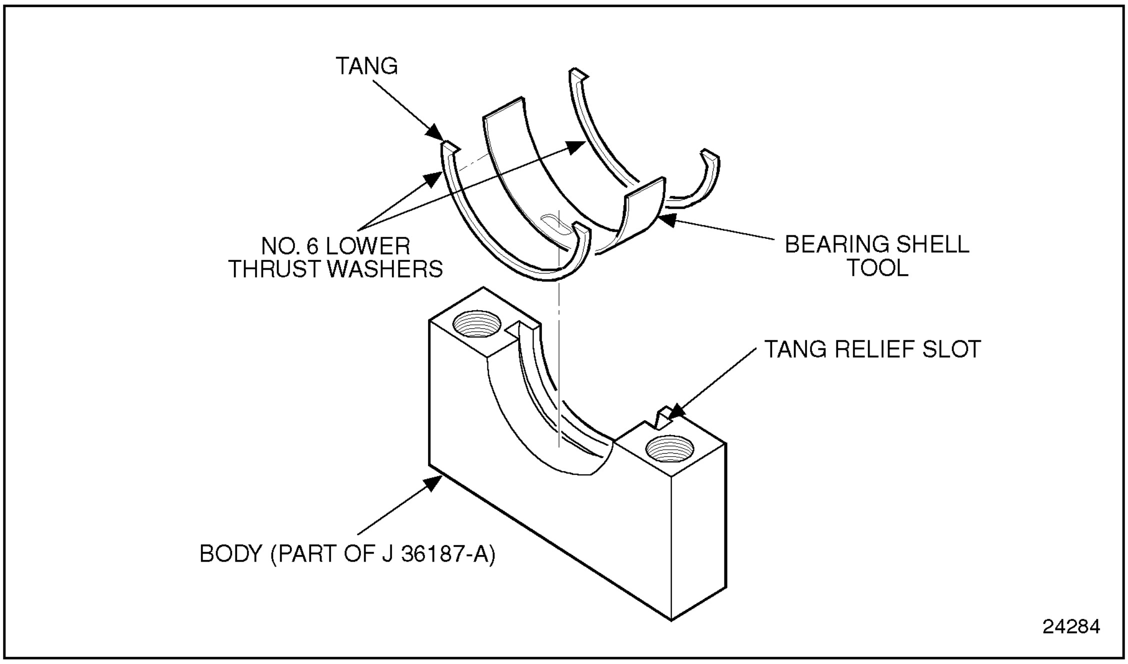


Figure 1-142 Upper Main Bearing Shell Removal-Tool Set-up

8. Using the main bearing cap bolts and washer removed from the engine, install the assembled main bearing cap remover and installer tool to the main bearing saddle being worked on. The word "Front" stamped on the tool must face the front of the engine. Be

sure that the roll pin in the oil delivery hole registers with the cut-out section of the bearing shell tool before tightening the main bearing cap bolts. See Figure 1-143.

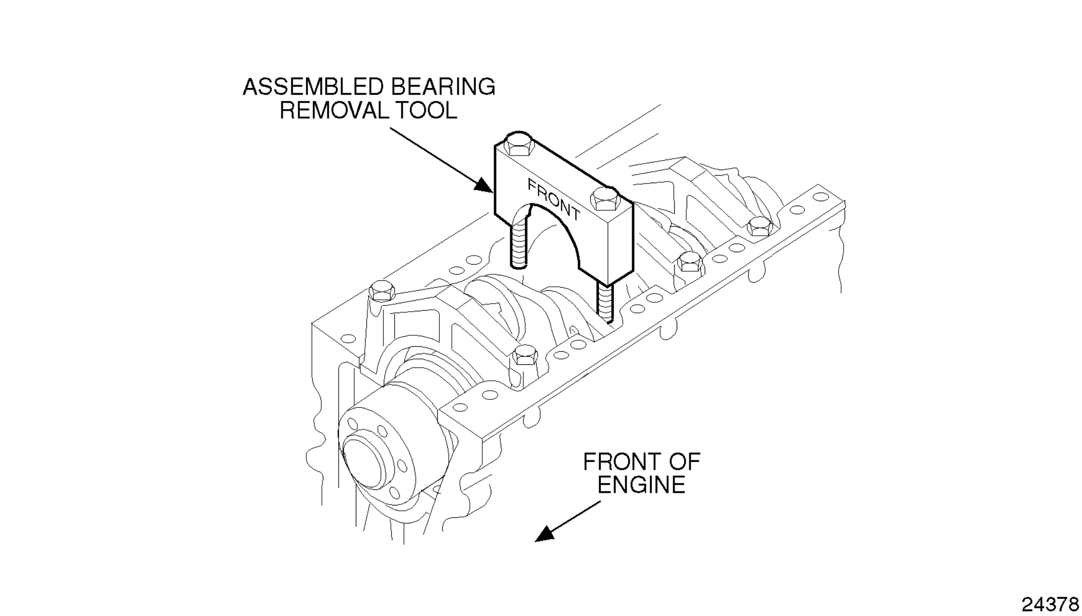


Figure 1-143 Upper Main Bearing Shell Remover Tool Installation

NOTE:
Only the No. 4 main bearing shell requires use of the thrust washers on the sides of the remover tool. For main bearings No. 1, 2, 3, and 5, it will not be necessary to install the thrust washers to the tool.

9. Torque the main bearing cap bolts until they are snug 13-27 N·m (10-20 lb·ft).
10. Using the square hole in the middle of the crankshaft pulley, bar the engine over in a clockwise direction when viewed from the front, approximately 180° until the tang of the upper main bearing contacts the block. This will roll the bearing shell tool (and the thrust washers for No. 4 main bearing) into the upper main bearing saddle.

NOTE:
Keep all bearing shells and thrust washers segregated by number, so that they may be reinstalled exactly as removed if the bearing shells are reused. Shells and washers may be marked with a permanent marker or equivalent. Do not punch mark or otherwise disturb the surface of the shells and washers to mark them.

11. Remove the main bearing cap tool from the saddle.
12. Remove the upper shell (and two thrust washers when working on No. 4 main) from the tool.
13. Inspect the bearing shells (and thrust washers for No. 4 main). Refer to Section 1.9.2.1.

14. Install the upper main bearing to be used, in the main bearing installer and remover with the word "Front" facing the front of the engine. If the No. 4 main bearing is being done, install the thrust washers to the bearing. Refer to step 8 and refer to step 9 in this procedure.
15. Position the remover and installer with the bearings in the saddle being worked on and install the main bearing cap bolts and washers. Torque the bolts until they are snug 13-27 N·m (10-20 lb·ft).
16. Using the square hole in the crankshaft pulley, bar the engine over slowly, in a counterclockwise direction, approximately 180°, until the bearing split line is even with the cap and block joint face. Care must be taken not to bar the engine over too far and damage the bearing tang.
17. Remove the bearing remover and installer assembly, J 36187-A.
18. Install the lower main bearing shell to be used, into the engine main bearing cap.
19. Coat the threads and underside of the heads of the main bearing cap bolts with International Compound #2®. Position the main bearing cap, with bearing(s) in place into the saddle and install the bolts and washers. Rap the main bearing caps sharply with a fiber mallet or plastic hammer to insure the caps are fully seated. Torque the bolts to 470-530 N·m (347-391 lb·ft).
20. It will be necessary to reinstall the upper and lower main bearing shells (and the upper thrust washers for the No. 4 main) and the main bearing cap, for the bearings being inspected or replaced before proceeding to the next main bearing saddle. Refer to Section 1.9.3.
21. Repeat this procedure for each main bearing saddle until all seven sets of main bearings have been removed and inspected or replaced.

NOTE:
No. 5 main bearing journal does not have an oil hole, so the bearing remover cannot be used at that position. The No. 5 upper main bearing should be removed with both No. 4 and No. 5 main bearing caps off. Using a suitable tool, push on the No. 5 upper bearing on the side opposite the tang and dislodge the bearing tang from the tang slot in the cylinder block. Carefully push/pull the bearing the rest of the way out, taking care not to damage the bearing shell. Rotate the crankshaft, and apply some pressure to the side of the bearing while rotating.

22. After removal, clean the bearings.

1.9.2.1 Inspection of Crankshaft Main Bearings

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.

Inspect the bearings for scoring, pitting, flaking, etching; or signs of overheating. The bearing overlay may develop minute cracks or small isolated cavities (checking) on the bearing surface during normal 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. If such spots are present, discard the bearing shells, and inspect the bearing caps and upper bearing saddles.

Measure the thickness of the bearing shells at a point 90° from the parting line. See Figure 1-144.

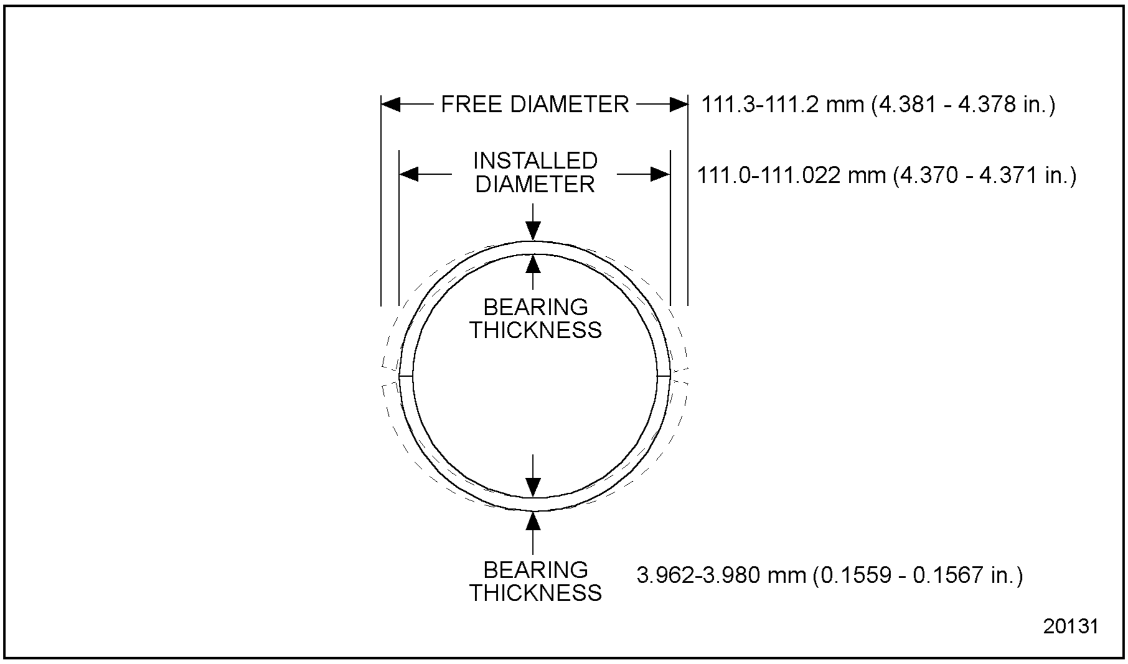


Figure 1-144 Main Bearing Measurements

A tool 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 3.937 mm (0.155 in.). 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 3.962-3.980 mm (0.1560-0.1567 in.). If any bearing shell shows wear through the overlay across the width of the shell, all bearing shells must be replaced.

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 that is squeezed between the journal and the bearing as described in "Checking Bearing Clearance". Refer to Section ADDITIONAL INFORMATION. With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque 470-530 N·m (347-391 lb·ft) torque on the bearing cap bolts. When installed, the bearing shells are 0.0254 mm (0.001 in.) larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle out of the engine. 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 0.152 mm (0.006 in.), all of the bearing shells must be discarded and replaced. This clearance is 0.040-0.126 mm (0.0016-0.005 in.) with new parts.

If installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Section 1.7.2.11.

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

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

Bearing shells are available in 0.250, 0.500 and 0.750 mm (approximately 0.010, 0.020 and 0.030 in.) undersize for service with reground crankshafts as listed in Table 1-8to determine what size bearings are required. Be sure the correct bearing to journal clearance is maintained when using these parts.

Inspect the crankshaft thrust washers. If the washers are discolored or worn excessively, or if the crankshaft end play is excessive, replace the thrust washers. Inspect the crankshaft thrust surfaces. Refer to Section 1.7. 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 No. 4 main bearing. A new standard size thrust washer is 3.56-3.48 mm (0.140-0.137 in.) thick. Thrust washers are available in 0.125 and 0.250 mm (0.005 and 0.010 in.) oversize.

1.9.3 Installation of Main Bearings Shells (Crankshaft Removed)

Install the main bearing shells as follows:

1. Check that all of the parts are clean and dry.

2. Apply clean engine oil 360° around each crankshaft main journal and install the upper main bearing shells to their respective saddles in the cylinder block. Note the locating tangs and be sure the oil holes register with the galleries in the cylinder block.
3. Be sure to install the drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps. The upper and lower main bearing shells are not alike; the upper shell is drilled for lubrication, the lower bearing shell is not. If they are not installed correctly, 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.
4. Perform all of the steps under "Installation of Crankshaft." Refer to Section 1.7.3. Be sure to check the main bearing clearances with plastic gaging strips. Refer to Section ADDITIONAL INFORMATION.
5. Be sure to check the crankshaft end play. The minimum and maximum values are listed in Table 1-16.
6. Torque all of the main bearing cap bolts to 470-530 N·m (347-391 lb·ft).
7. Measure the main bearing bores with dial bore gage, J 5347-B. Refer to Section ADDITIONAL INFORMATION for reuse and replacement guidelines. The minimum and maximum values are listed in Table 1-18.

1.10 GEAR CASE COVER

The gear case cover and gear case housing bolt together at the front of the engine to form a sealed compartment for the engine gear train. See Figure 1-145.

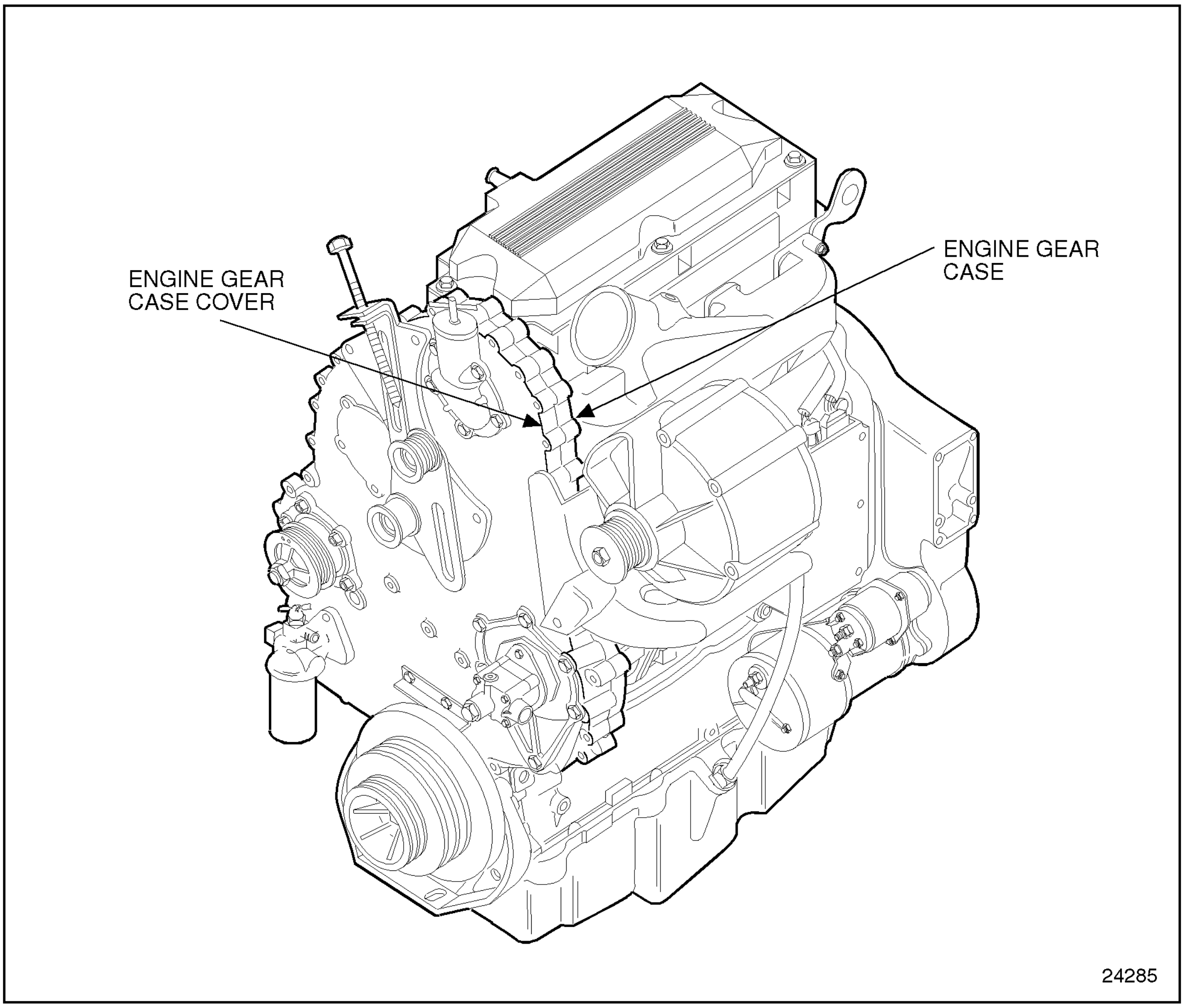


Figure 1-145 Engine Gear Case and Cover

The gear case cover also serves as a retainer for the crankshaft front oil seal. See Figure 1-146.

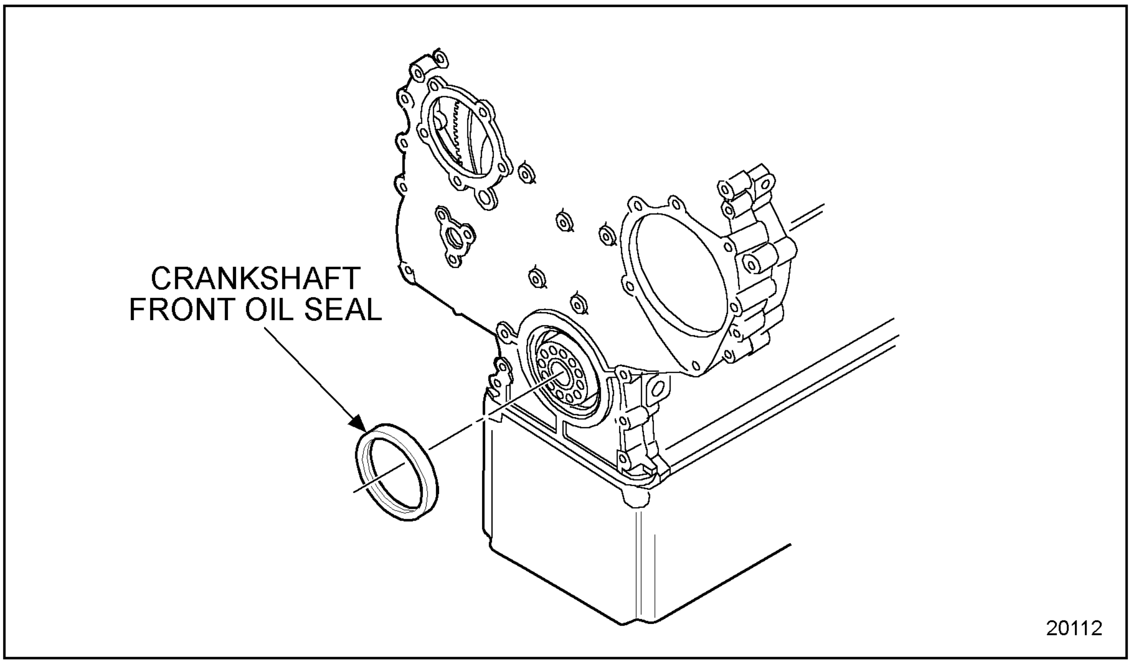
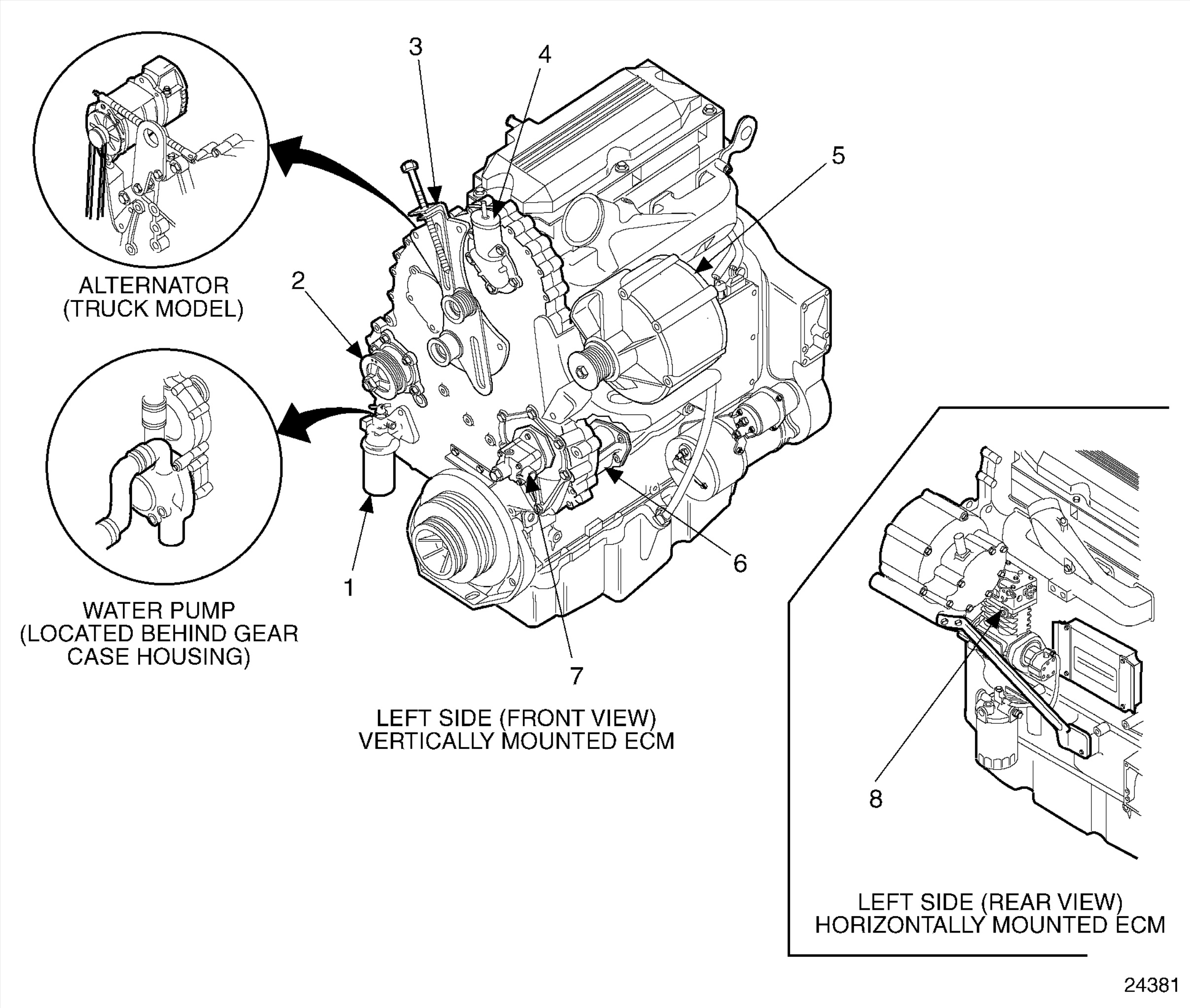


Figure 1-146 Crankshaft Front Oil Seal

Several components that are mounted to the gear case cover include the water pump, accessory drive assembly, and fan support bracket. See Figure 1-147.



1. Coolant Inhibitor Element
2. Accessory Drive
3. Front Pulley Support
4. Oil Filter
5. Alternator (Coach)
6. Air Compressor Drive Adaptor
7. Power Steering Pump
8. Adaptorless Air Compressor

Figure 1-147 Gear Case Cover-mounted Components

The front engine support is bolted to the front of the gear case cover, directly behind the crankshaft pulley and vibration damper. See Figure 1-148.

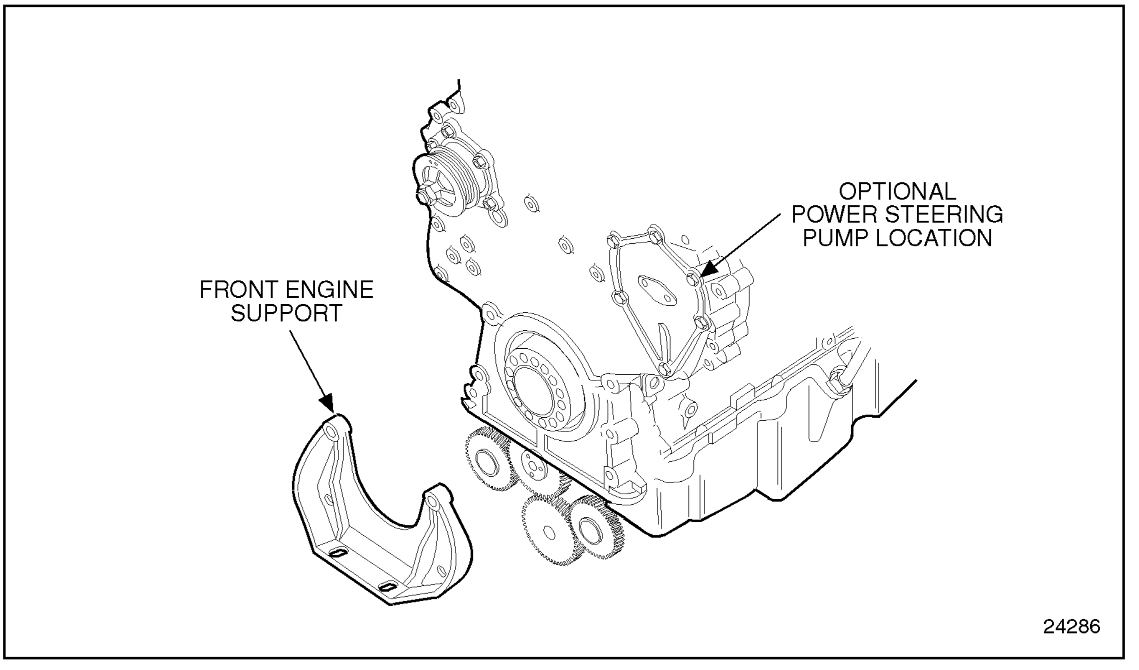
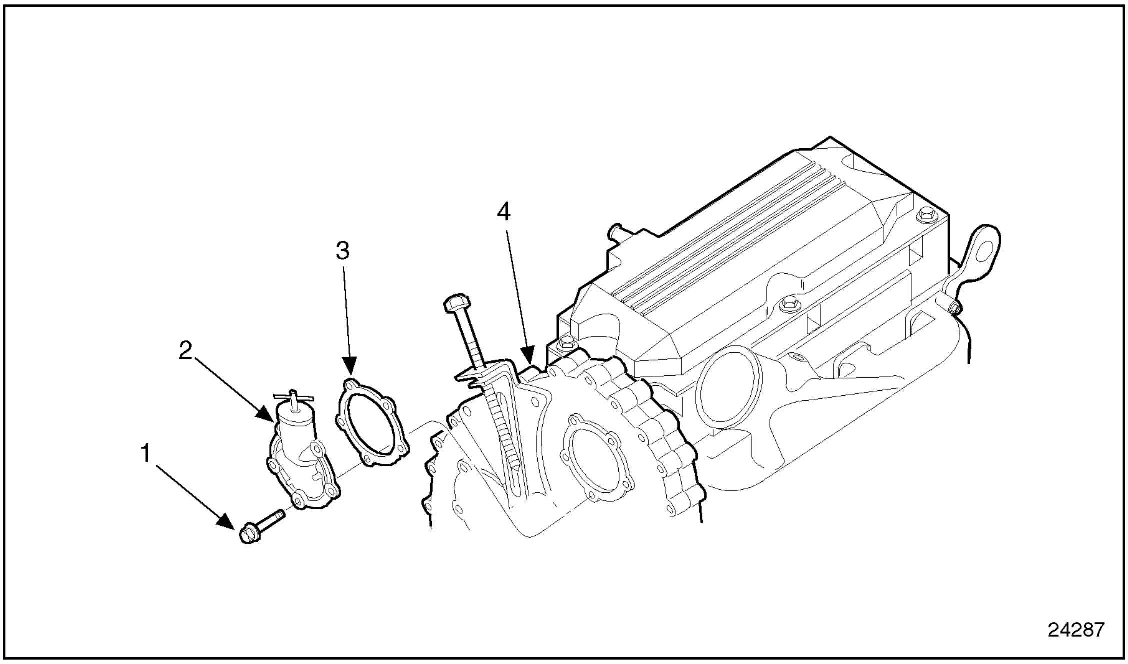


Figure 1-148 Typical Front Engine Support

Several access covers are provided on the gear case cover for service of the engine without removing the gear case cover. Removal of the camshaft drive gear access cover will allow the removal of the camshaft drive gear-to-camshaft bolt for camshaft and/or cylinder head removal without removing the gear case cover. See Figure 1-149.



1. Bolt
2. Access Cover/Oil Filler Assembly
3. Gasket
4. Gear Case Cover

Figure 1-149 Camshaft Drive Gear Access Cover

The fan support bracket includes the access cover for the adjustable idler gear. See Figure 1-150.

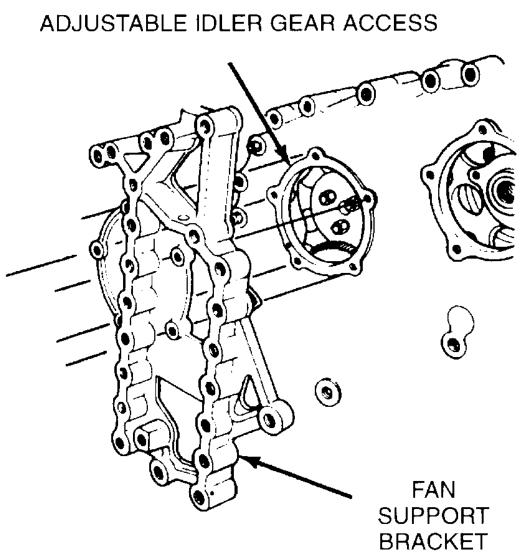


Figure 1-150 Fan Support Bracket for Truck Models

With the fan support bracket and the camshaft drive gear access cover removed, the gear lash between the adjustable idler gear and the camshaft drive gear can be measured and adjusted. Refer to Section 1.21.2.1.

On vehicles without power steering, an access cover is provided for inspection of the air compressor drive gear. See Figure 1-151.

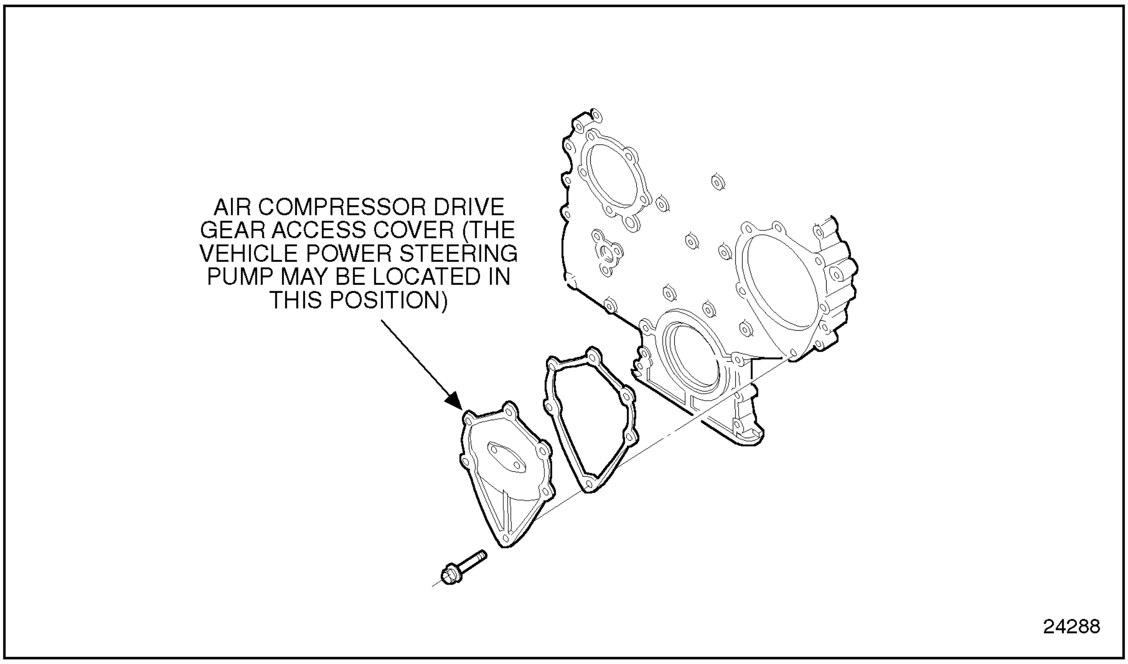


Figure 1-151 Air Compressor Drive Gear Access Cover

On some vehicles equipped with power steering, the power steering hydraulic pump is mounted to the gear case cover in the place of the access cover, and is driven by a short coupling that fits in the splined hole in the center of the air compressor drive gear. The pump is installed with a gasket.

1.10.1 Repair or Replacement of Gear Case Cover

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-152.

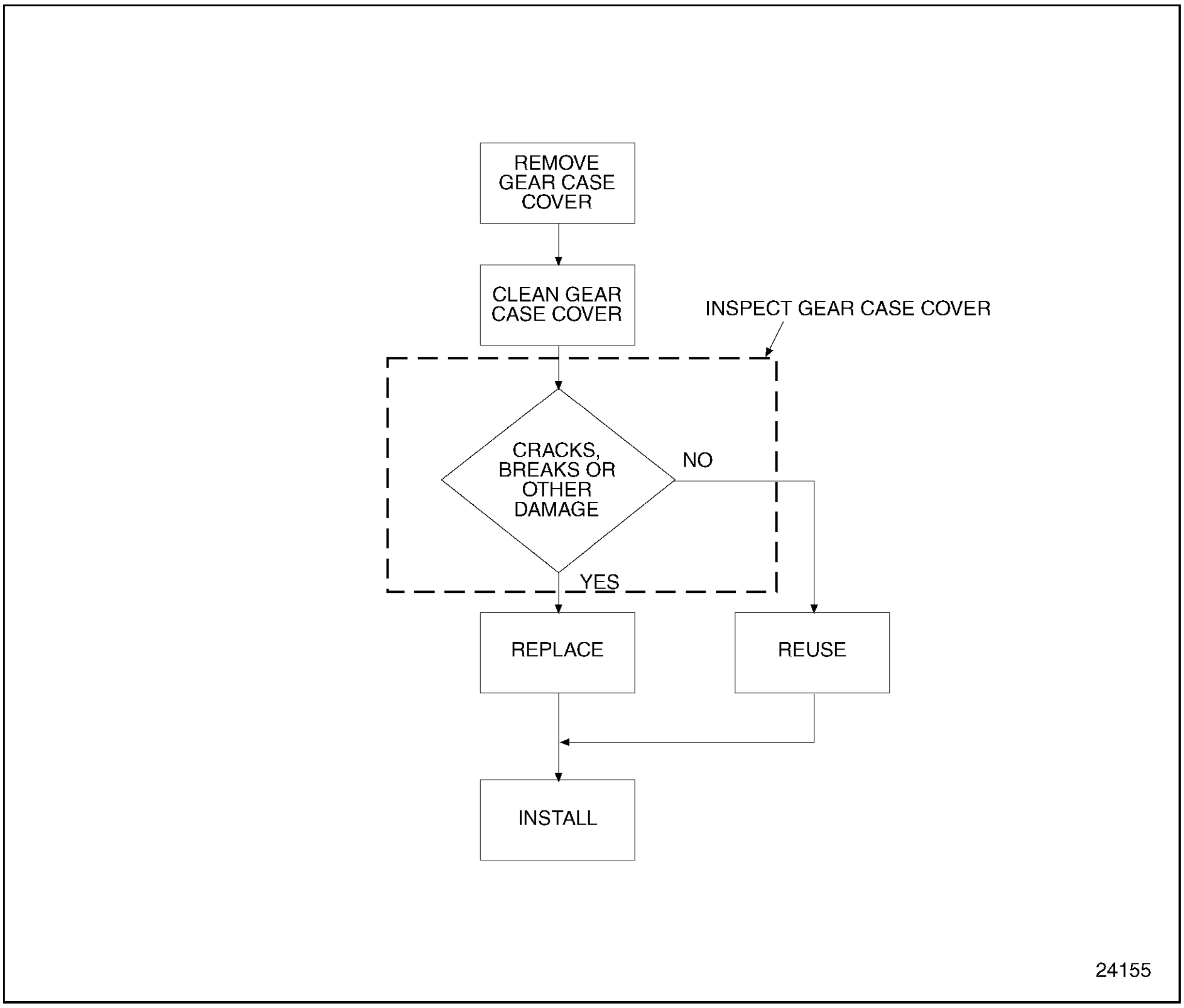


Figure 1-152 Flowchart for Repair or Replacement of Gear Case Cover

1.10.2 Removal of Gear Case Cover

With the engine mounted on an overhaul stand. Remove the gear case cover as follows:

1. Drain the engine oil and remove the engine oil pan. Refer to Section 3.9.2.
2. Loosen the fan hub mounting bolts. Loosen the fan adjusting bolt. Back the adjuster off far enough to remove the drive belts. Remove the fan and fan hub assembly. Refer to Section 4.5.2.

3. Loosen the alternator mounting bolts. Remove the alternator drive belts, alternator, and mounting brackets (if so equipped). See Figure 1-153.

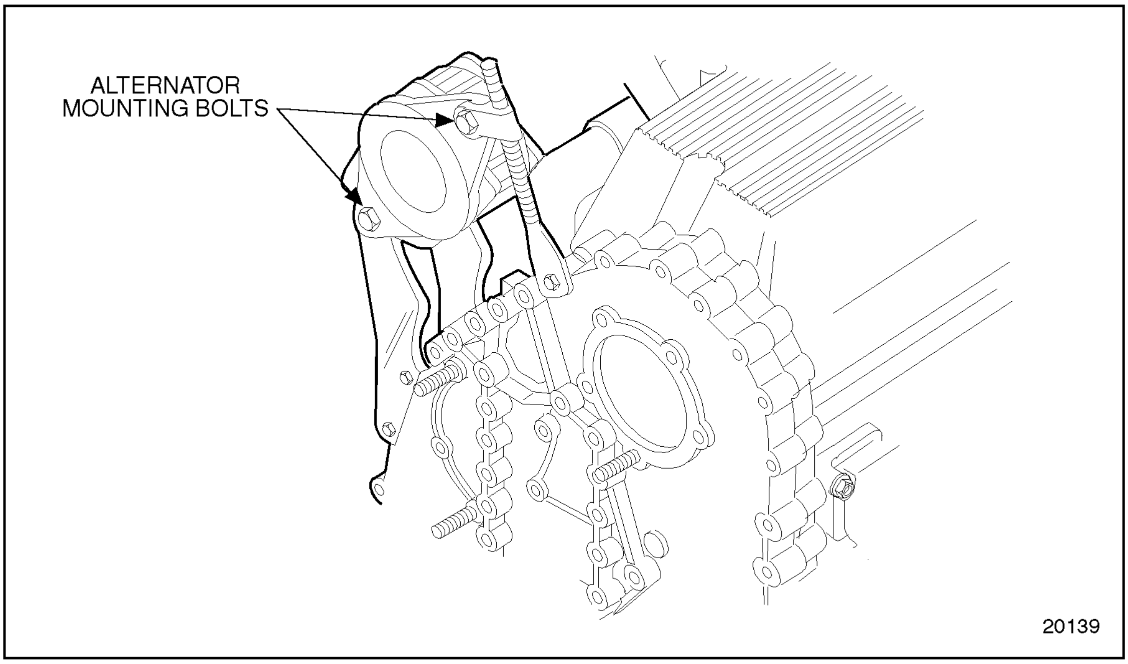


Figure 1-153 Alternator and Related Parts

4. Loosen the air conditioner compressor and mounting brackets (if so equipped).
5. Remove the water pump assembly. Refer to Section 4.2.2.
6. Remove the power steering pump (if so equipped).

NOTICE:
Damage to the internal components may result. The oil pan cannot be used to support the front of the engine in a vehicle, as its thermoplastic construction will not support the weight.

7. Remove the crankshaft pulley. Refer to Section 1.13.2.

NOTE:
Do not hit the face of the damper to loosen it.

8. Remove the vibration damper. Refer to Section 1.12.2.
9. Loosen and remove the four bolts securing the front engine mount to the gear case cover. Remove the front engine mount.
10. Loosen and remove the five bolts that secure the accessory drive assembly to the gear case cover.

11. Remove the accessory drive assembly by pulling it straight out of the gear case cover to avoid damaging the rubber O-ring. See Figure 1-154.

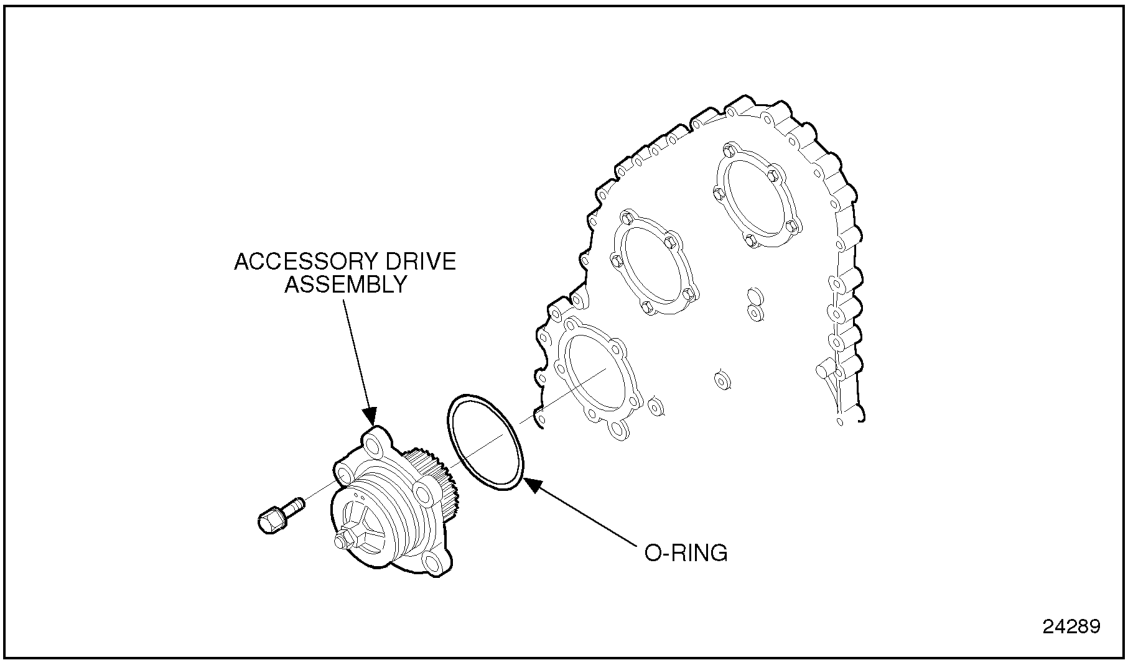


Figure 1-154 Accessory Drive Assembly

12. There are a total of 34 bolts that secure the gear case cover to the gear case. Bolts 17, 18, 19 and 20 were removed with the front engine mount. Bolts F1 through F5 were

removed in a previous step; refer to step 11 Loosen and remove bolts 1 through 16, 21, 22. See Figure 1-155.

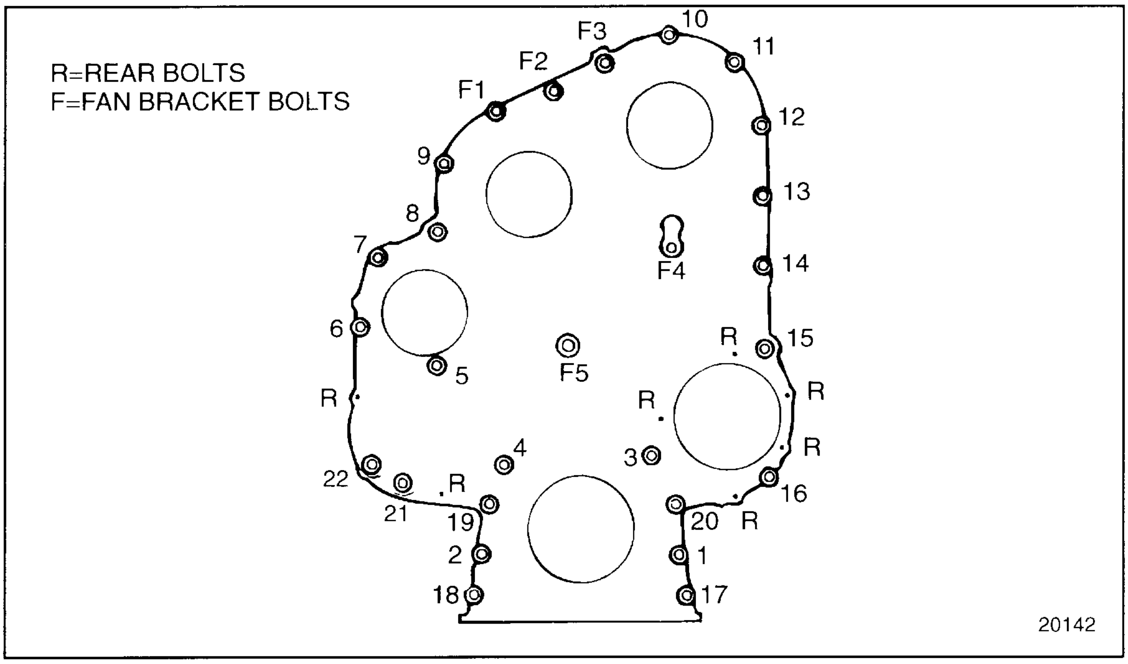


Figure 1-155 Gear Case Cover Bolt Arrangement (Front)

[a] Remove the SRS. Refer to Section 2.20.2. Loosen and remove the six bolts on the back of the gear case on the intake side of the engine located around the air

compressor drive assembly. See Figure 1-156. Remove the air compressor drive assembly.

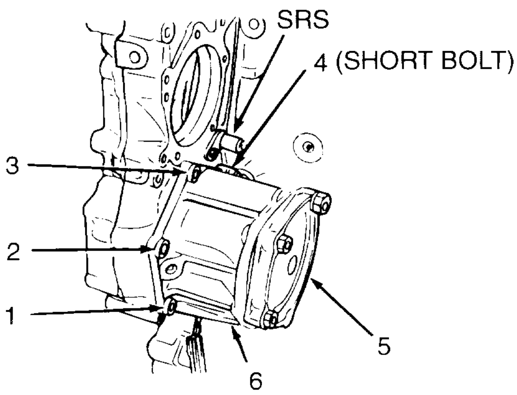


Figure 1-156 Gear Case Cover Bolt Arrangement (Left Rear)

[b] Loosen and remove the bolts on the back of the gear case on the water pump (right) side of the engine. See Figure 1-157.

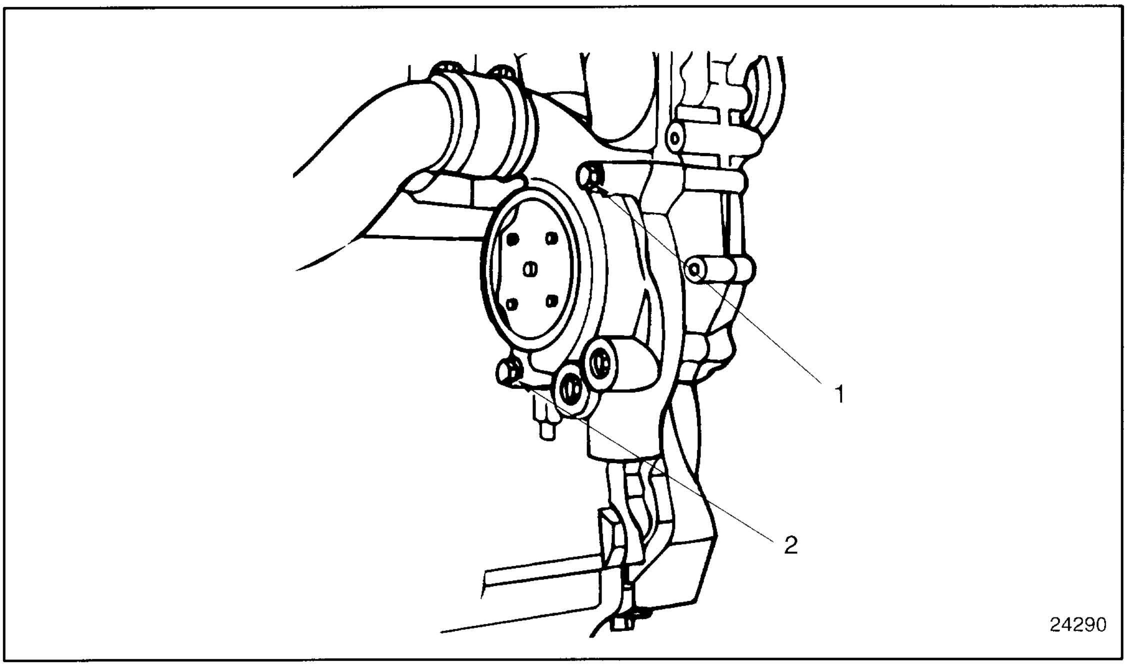


Figure 1-157 Gear Case Cover Bolt Arrangement (Right Rear)

13. Support the gear case cover with a suitable lifting device, using the front engine lift bracket. See Figure 1-158.

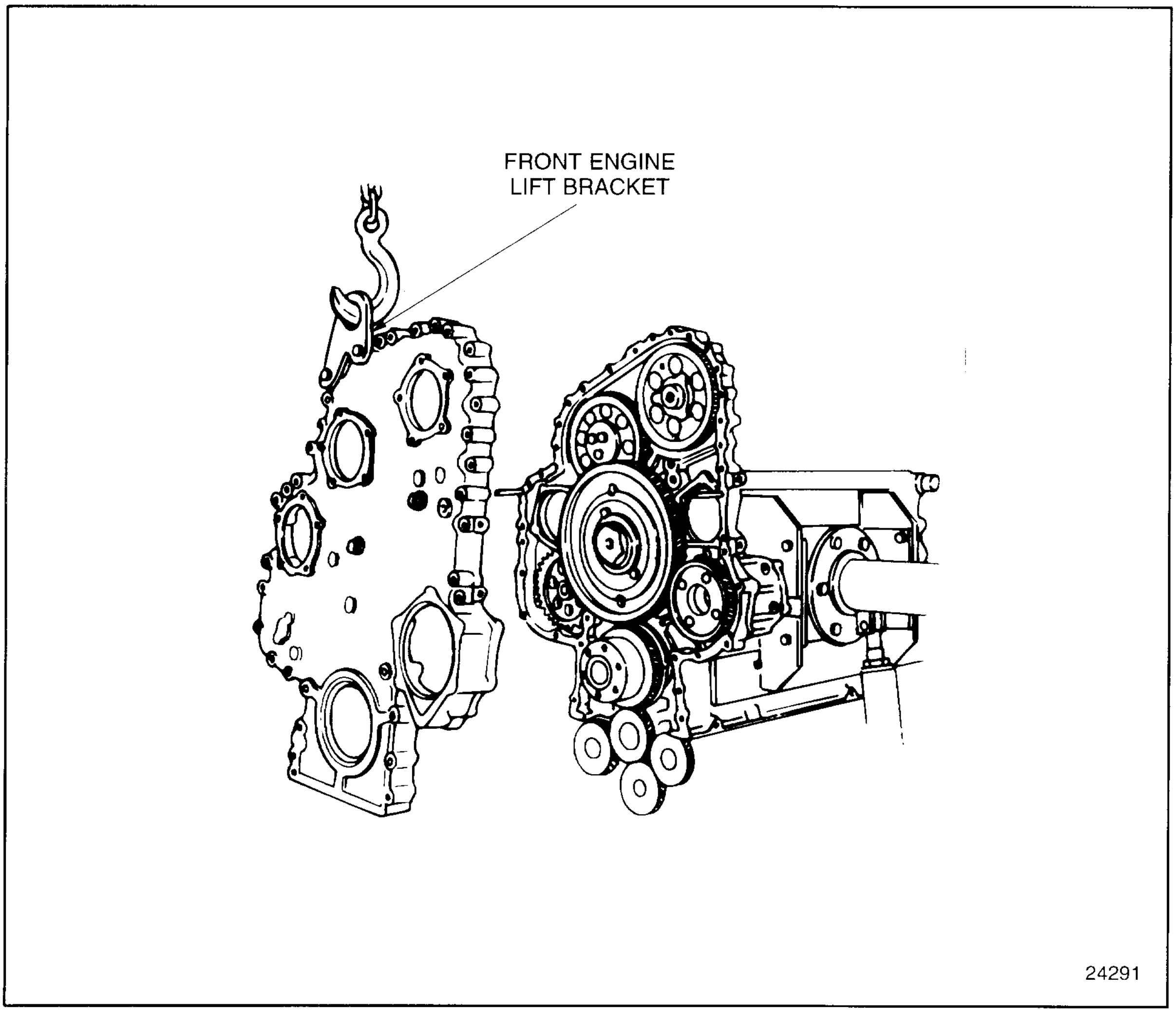


Figure 1-158 Engine Gear Case Cover Removal

NOTE:
There is a rubber O-ring installed between the center of the bull gear hub and the gear case cover. The ring may adhere to the cover when it is removed. Be sure the ring is not lost. See Figure 1-159.

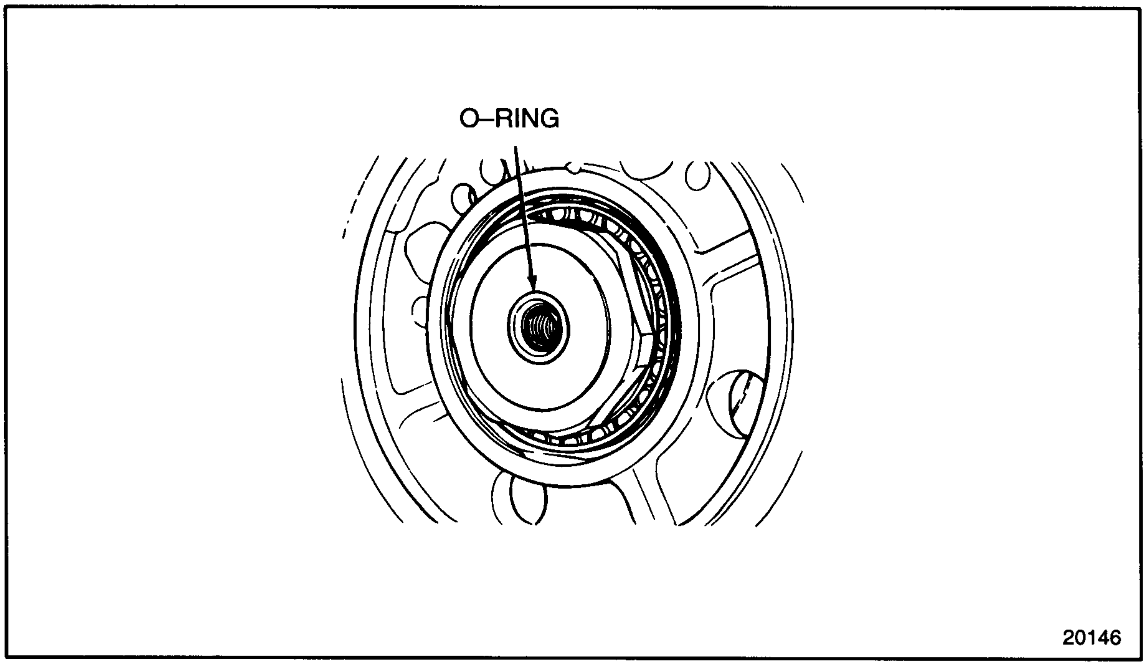


Figure 1-159 Bull Gear O-ring

14. Tap the gear case cover with a fiber mallet or plastic hammer to loosen it from the gear case. Remove the engine gear case cover.

1.10.2.1 Inspection of Gear Case Cover

Inspect the gear case cover as follows:

1. Clean all of the old gasket sealer from the mating surfaces of the gear case and gear case cover.
2. Clean the gasket material from the mating surfaces of any components or access covers that were removed from the gear case cover, and the gear case cover itself.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Clean all of the removed parts except the electrical components with clean fuel oil and dry with compressed air.

NOTE:
Any time the gear case cover is removed, the crankcase oil seal must be replaced. Install the new front oil seal after the gear case cover has been installed to the engine.

4. If necessary, remove the crankshaft front oil seal at this time. Refer to Section 1.8.2. Inspect the gear case cover for stress cracks or breaks in the casting. Repair or replace as necessary.
5. Inspect all O-rings for signs of dryness or splitting. Replace as necessary.

1.10.3 Installation of Gear Case Cover

Perform the following steps for gear case installation:

NOTE:
Gasket eliminator cures with the absence of air. The length of time between gear case cover installation and torquing of the bolts that secure the gear case cover to the gear case should be kept to a minimum.

1. Apply a continuous 1/16 in. bead of gasket eliminator PT-7276 (Loctite 51580) or equivalent to the mating surface of the gear case.

2. Install two guide studs, J 36107, to the gear case. See Figure 1-160.

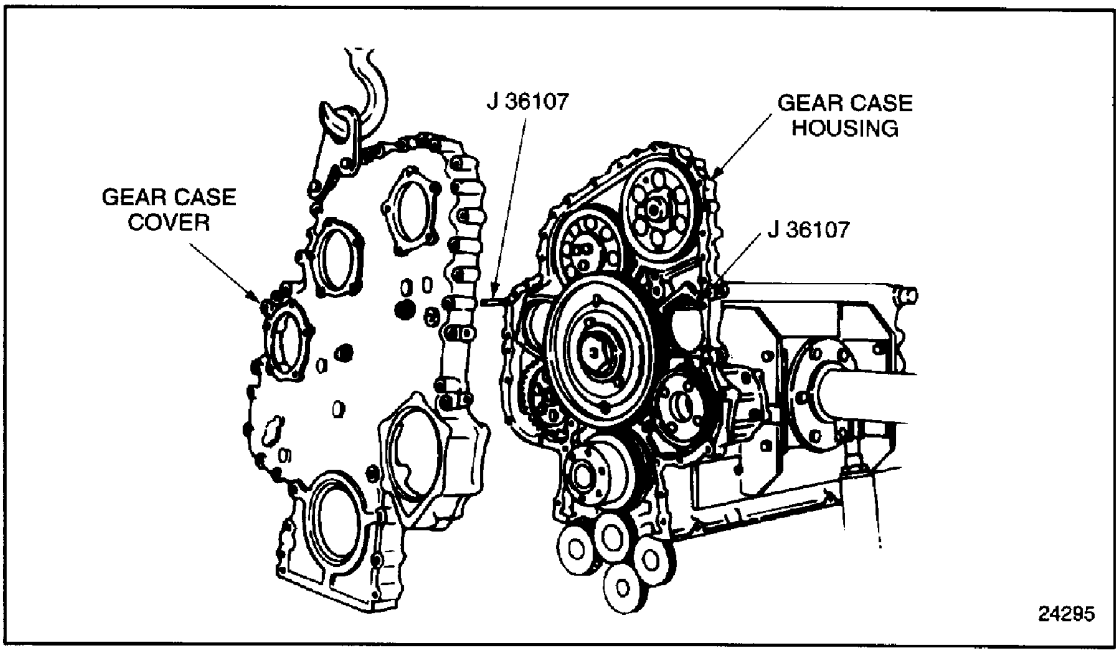


Figure 1-160 Gear Case Cover Locating Dowels

3. Support the gear case cover with a suitable lifting device, using the front engine lift bracket. Position the gear case cover on the guide studs and slide it forward. Index the two dowels in the gear case. See Figure 1-160.
4. There are 34 bolts that secure the gear case cover to the gear case (including five for the fan support bracket). Install them as follows:

NOTICE:
With gasketless parts such as the gear case cover, the torque values and tightening sequences are critical to prevent parts warpage.

[a] Install the shorter bolts, No. 1 through 16, 21, 22, in various locations at the front of the gear case cover. Tighten them finger tight. See Figure 1-161. Remove the guide studs when installing bolts 7 and 14.

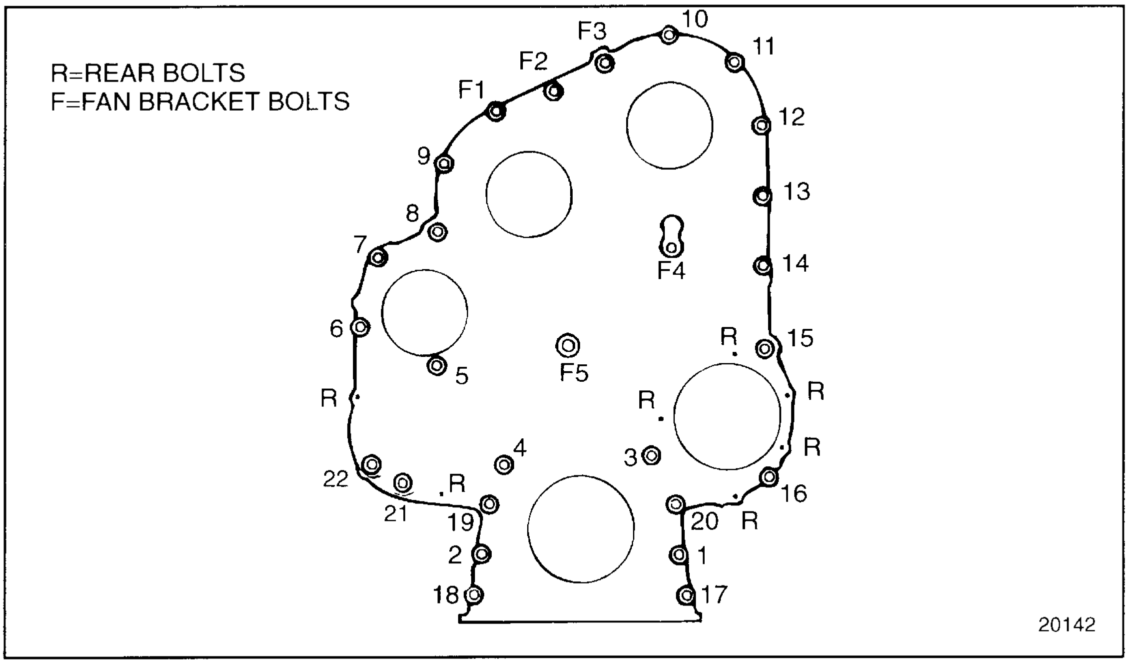


Figure 1-161 Gear Case Cover Bolt Torque Sequence (Front)

[b] Torque bolts 1 through 16, 21, 22, to 58-73 N·m (43-54 lb·ft).

[c] Install the front engine mount to the gear case cover. Install the four, longer, front engine mount-to-gear case cover bolts, finger tight.

[d] Torque bolts 17, 18, 19 and 20 to 160-200 N·m (118-148 lb·ft). See Figure 1-161.

[e] Bolts F1 through F5 are fan support bracket bolts. Install the fan support bracket and torque bolts F1, F2 and F3 to 58-73 N·m (43-54 lb·ft). Torque bolts F4 and F5 to 160-200 N·m (118-148 lb·ft).

[f] Install the six bolts on the intake (left) side of the engine around the air compressor drive. Torque the bolts to 58-73 N·m (43-54 lb·ft), using the sequence. See Figure 1-162. Install the SRS to the gear case; refer to Section 2.20.3.

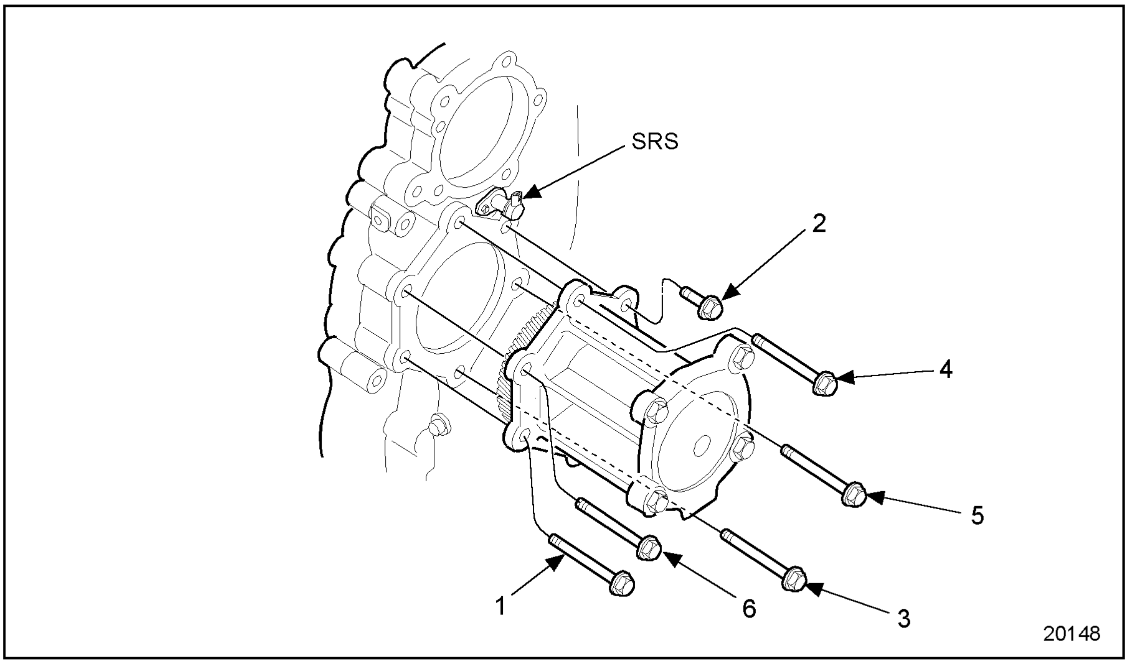


Figure 1-162 Gear Case Cover Bolt Torque Sequence (Left Rear)

[g] Install the bolts on the exhaust (right) side of the engine. Torque the bolts to 58-73 N·m (43-54 lb·ft). See Figure 1-163.

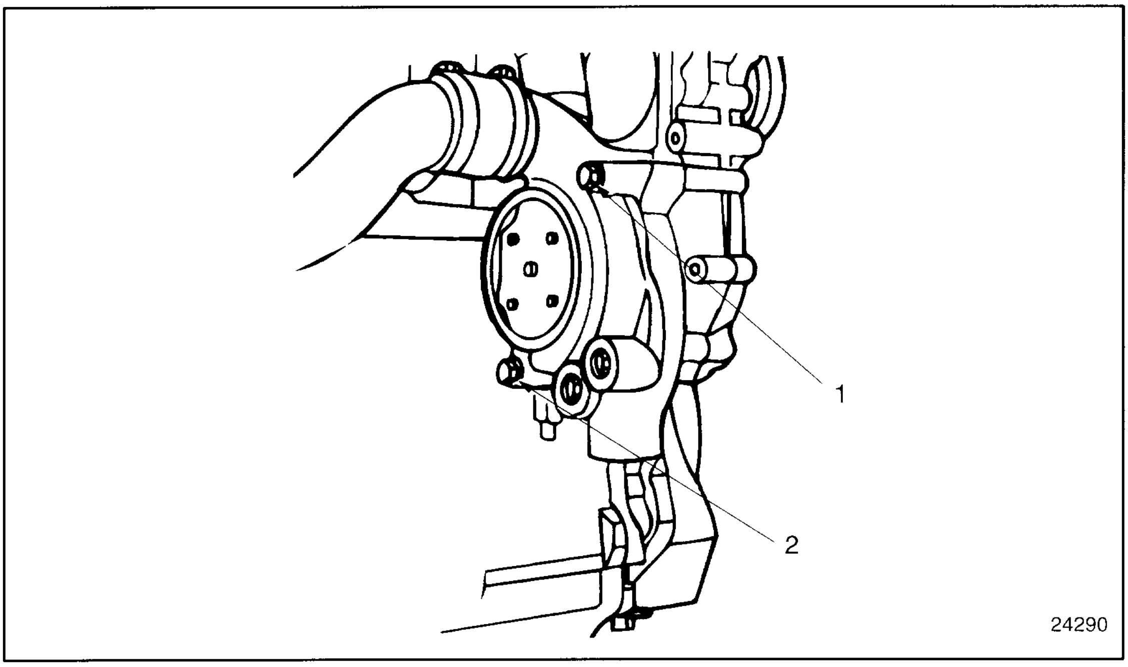


Figure 1-163 Gear Case Cover Bolt Torque Sequence (Right Rear)

5. Install a new crankshaft front oil seal. Refer to Section 1.8.

6. Install the accessory drive assembly to the gear case. Refer to Section 1.29.5. Torque the bolts to 30-38 N·m (22-28 lb·ft), using the sequence. See Figure 1-164.

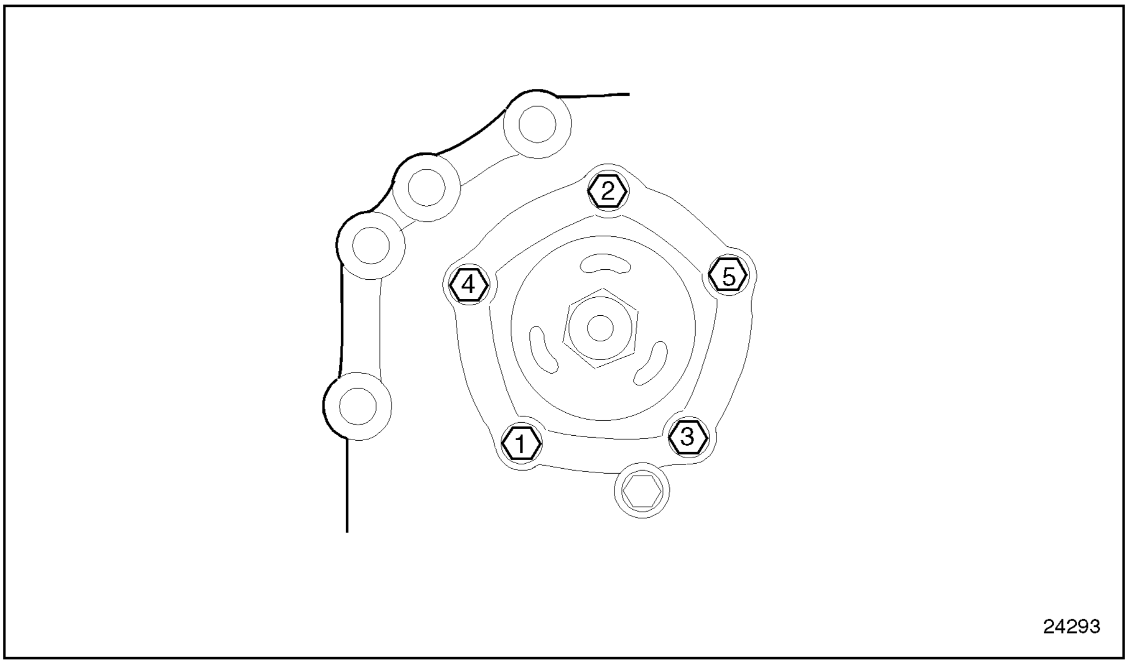


Figure 1-164 Accessory Drive Assembly Bolt Torque Sequence

7. Install the vibration damper to the crankshaft. Refer to Section 1.12.3.
8. Install the crankshaft pulley to the end of the crankshaft. Refer to Section 1.13.3.
9. Torque the six pulley bolts to 182-210 N·m (134-155 lb·ft). Mark the first bolt and work in a clockwise direction.
10. Install the water pump assembly. Refer to Section 4.2.7.
11. Install a new O-ring between the power steering pump cover and the gear case (if so equipped). Install the power steering pump cover to the gear case cover with the six bolts. Tighten the bolts progressively in a star-shaped pattern to draw the power steering pump in evenly. Torque the bolts to 30-38 N·m (22-28 lb·ft), using a star-shaped pattern.

12. Insert a new gasket between the camshaft drive gear access cover and the gear case cover. Install the camshaft drive gear access cover to the gear case cover. Torque the bolts to 30-38 N·m (22-28 lb·ft), using the tightening sequence. See Figure 1-165.

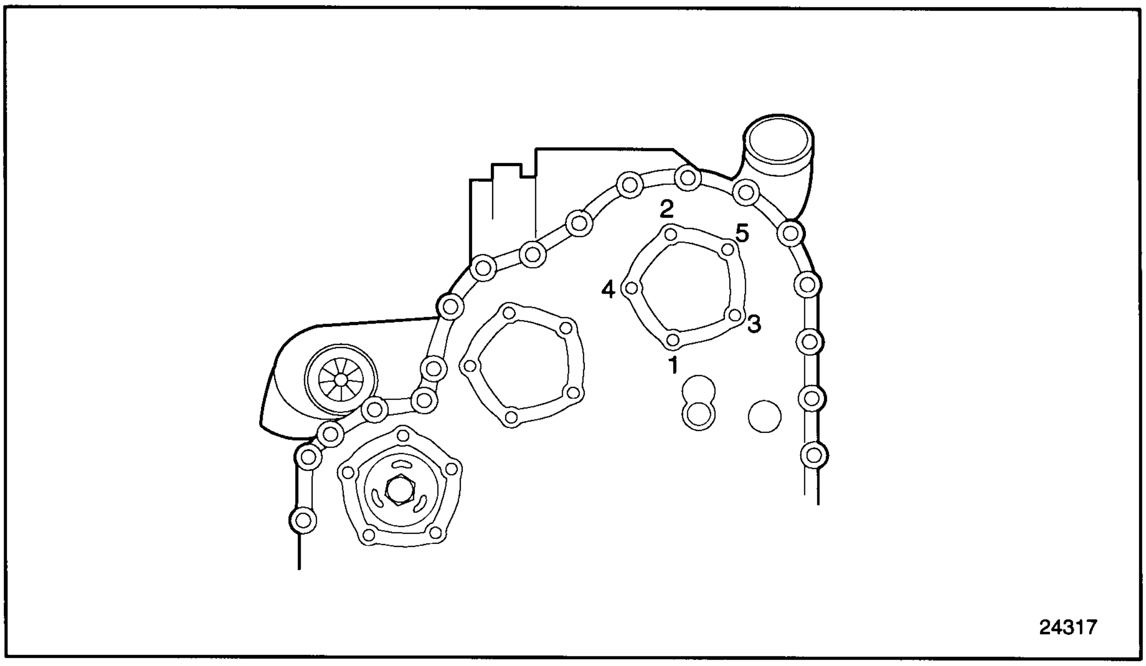


Figure 1-165 Access Cover Bolt Torque Sequences

13. Install the air conditioner compressor and brackets. Install the air conditioner compressor drive belt.
14. Install the alternator and brackets. Install the alternator drive belts.
15. Adjust the alternator and air conditioner compressor drive belts to the specifications. Refer to Section 13.5.7.
16. Install the engine oil pan and fill the crankcase. Refer to Section 13.5.1.

1.11 GEAR CASE

The gear case housing is constructed of cast iron, with machined mating surfaces, and is bolted to the front of the engine cylinder block. The gear case and gear case cover are bolted together to provide a sealed compartment for the engine gear train. See Figure 1-166.

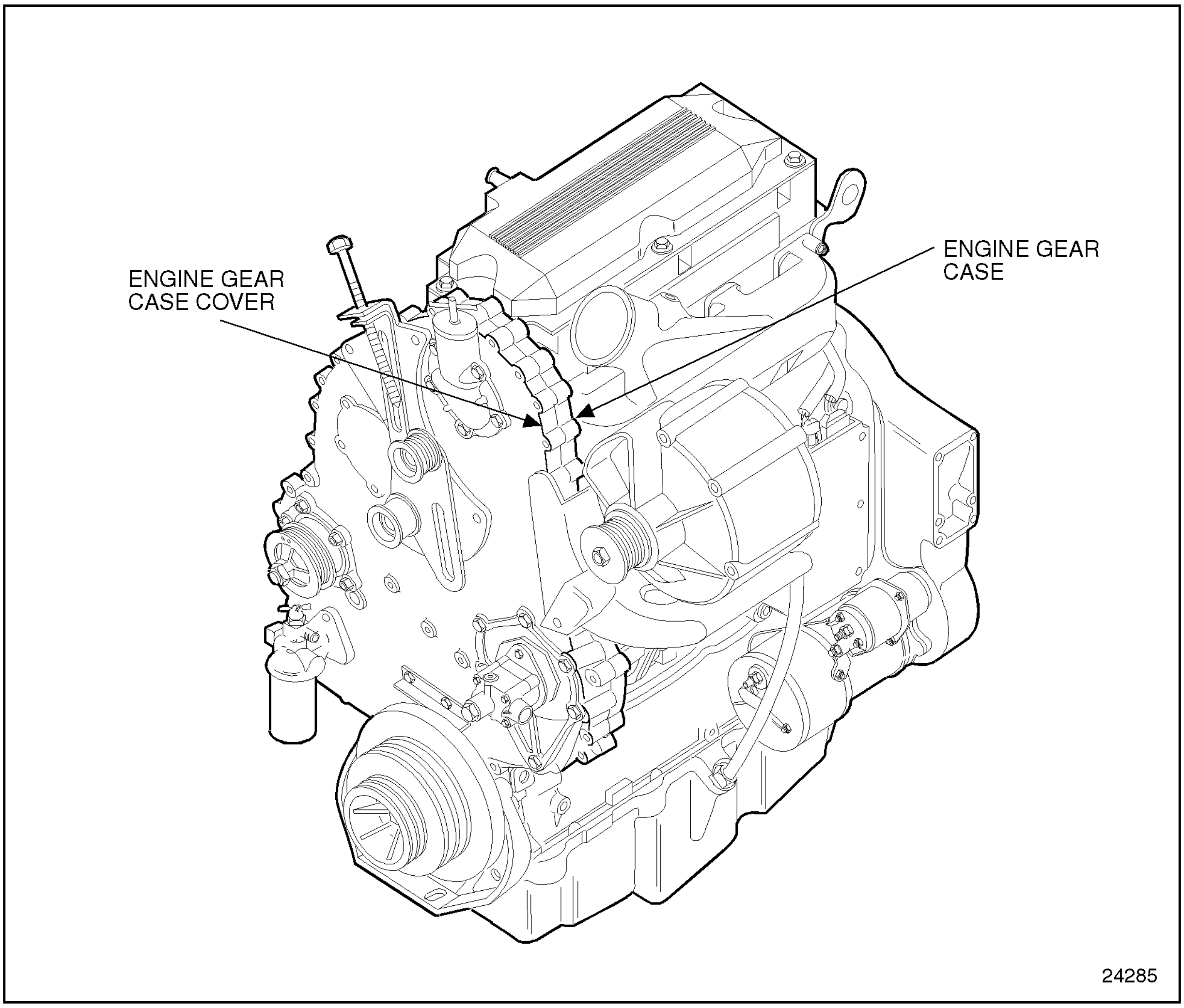


Figure 1-166 Gear Case and Related Parts

In July 2001,a new right side gear case stiffening bracket was added to provide: reduce engine noise, increase belt-driven accessory life, reduce gear case vibration amplitude and reduce wear on the cam thrust plate perimeter seal. See Figure 1-167.

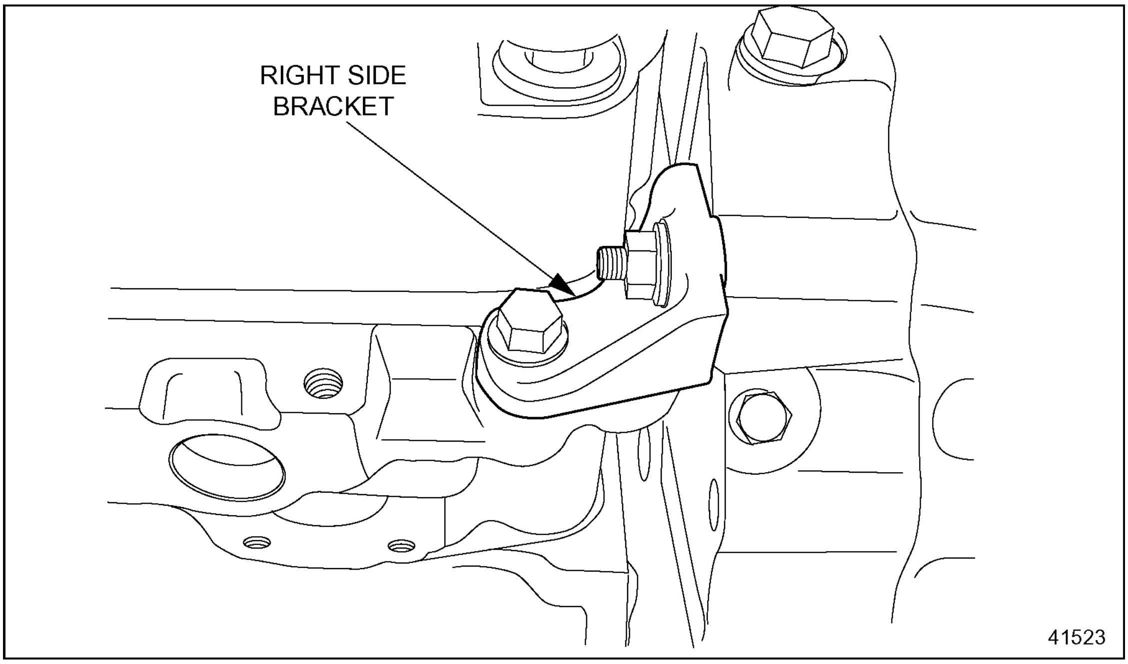
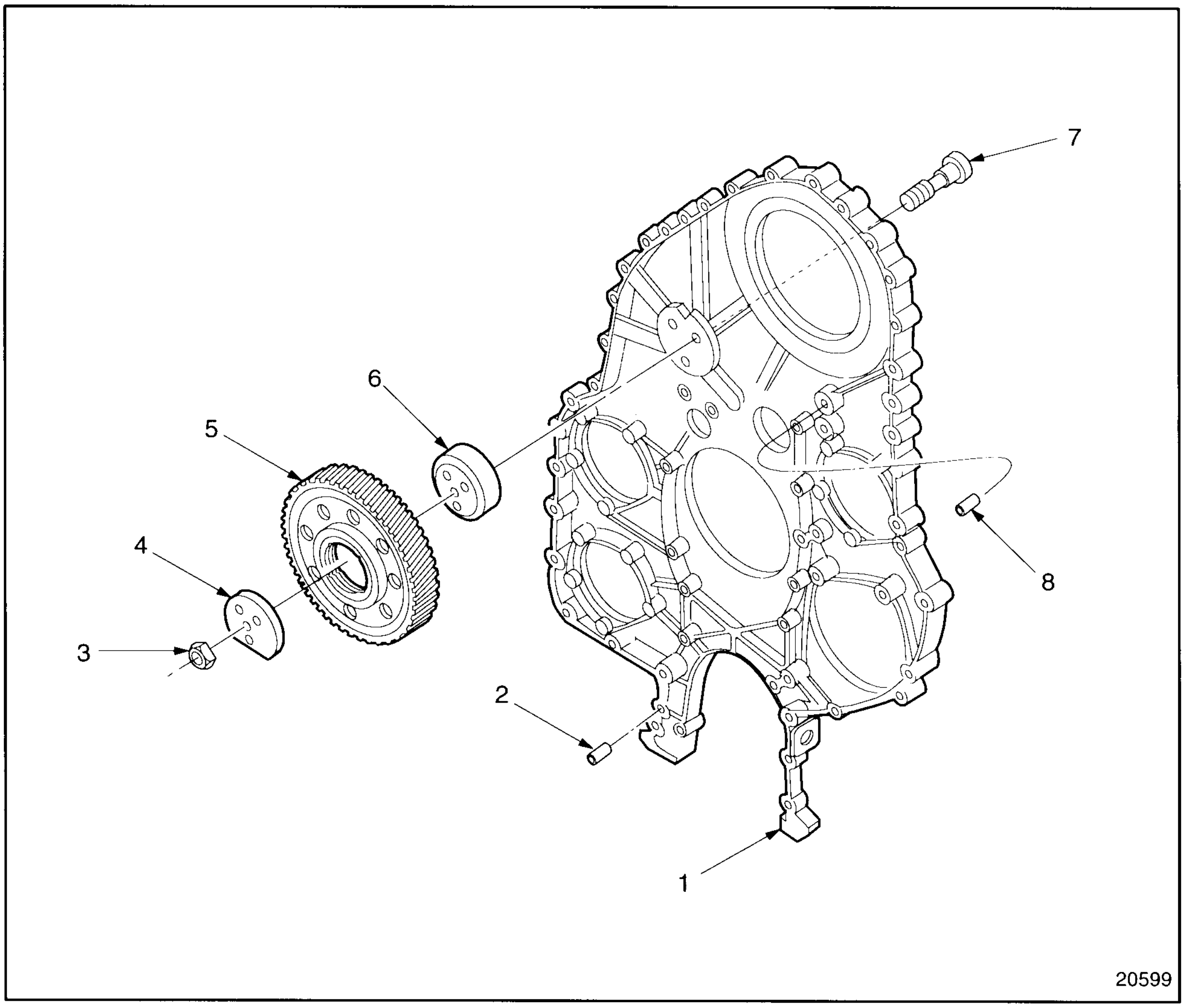


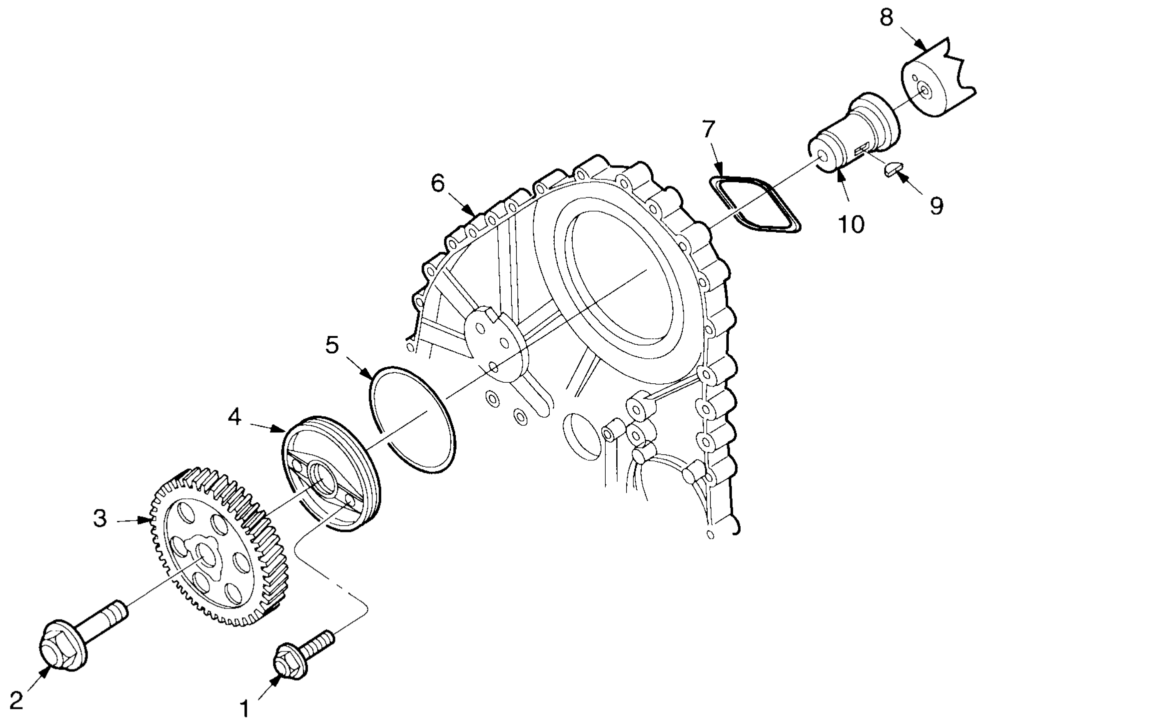
Figure 1-167 Gear Case Stiffening Bracket (Right Side)

Several components are mounted to the gear case, including the adjustable idler gear assembly. See Figure 1-168. The camshaft drive gear assembly, see Figure 1-169; the air compressor drive assembly, see Figure 1-170; and the water pump assembly, see Figure 1-171.



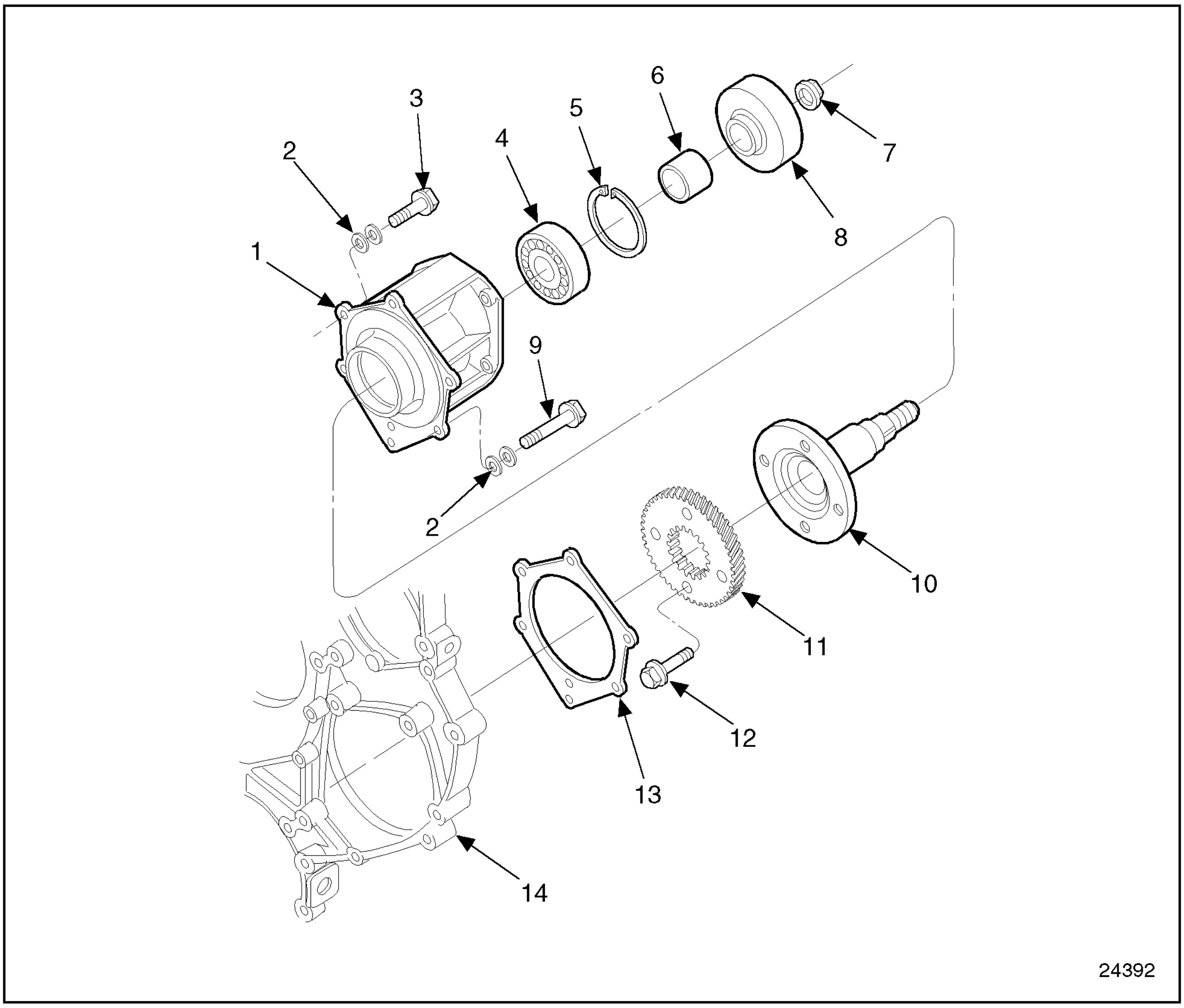
1. Gear Case Housing
2. Diamond Dowel
3. Adjustable Idler Gear Locknut (3)
4. Adjustable Idler Gear Hub Retaining Plate
5. Adjustable Idler Gear
6. Adjustable Idler Hub
7. Adjustable Idler Gear Stud (3)
8. Round Dowel

Figure 1-168 Adjustable Idler Gear Assembly



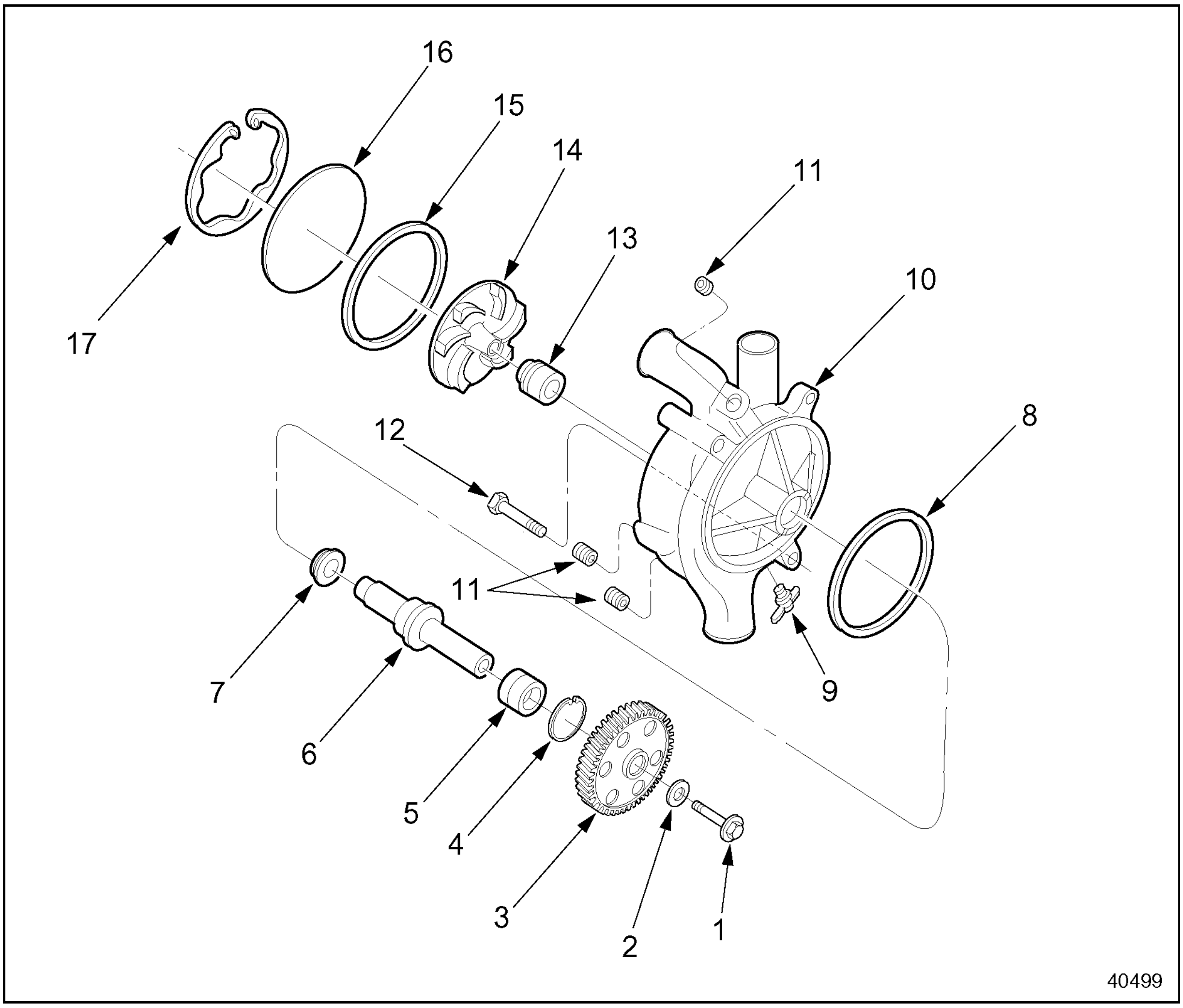
1. Bolt, Thrust Plate Retaining (2)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear, Camshaft
4. Thrust Plate, Camshaft
5. O-ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

Figure 1-169 Camshaft Drive Gear Assembly



1. Air Compressor Drive Housing
2. Washers
3. Air Compressor Drive Housing Short Bolt
4. Air Compressor Drive Ball Bearing
5. Snap Ring
6. Spacer
7. Air Compressor Drive Hub
8. Air Comp. Drive Hub Flange Nut
9. Air Comp. Drive Housing Long Bolt
10. Air Compressor Drive Shaft
11. Air Comp. Drive Gear
12. Air Comp. Drive Gear Bolt
13. Air Compressor Drive Housing Gasket
14. Gear Case Housing

Figure 1-170 Air Compressor Drive Assembly



1. Retaining Bolt
2. Washer
3. Water Pump Drive Gear
4. Snap Ring
5. Bearing Race Assembly
6. Drive Shaft
7. Oil Seal
8. Water Pump Housing O-ring
9. Drain Cock
10. Water Pump Housing
11. Pipe Plug
12. Water Pump Housing Retaining Bolt
13. Water Seal
14. Impeller
15. Water Pump Cover O-ring
16. Water Pump Cover
17. Water Pump Cover Snap Ring

Figure 1-171 Water Pump Assembly

To eliminate the possibility of oil leakage at the adjustable idler gear stud location, Detroit Diesel recommends the following:

When rebuilding a Series 50 Engine, **or** if the gear case is removed for any reason, the three original adjustable idler gear studs should be removed and replaced with new studs.

Before pressing studs into the gear case, coat the shanks and underside of the stud heads with Loctite No. 242 Sealant **.** This will prevent any oil leakage around the studs during engine operation.

The Timing Reference Sensor (TRS) is an electronic component that is bolted to the side of the gear case on the intake (left) side of the engine just above the oil pan. See Figure 1-172.

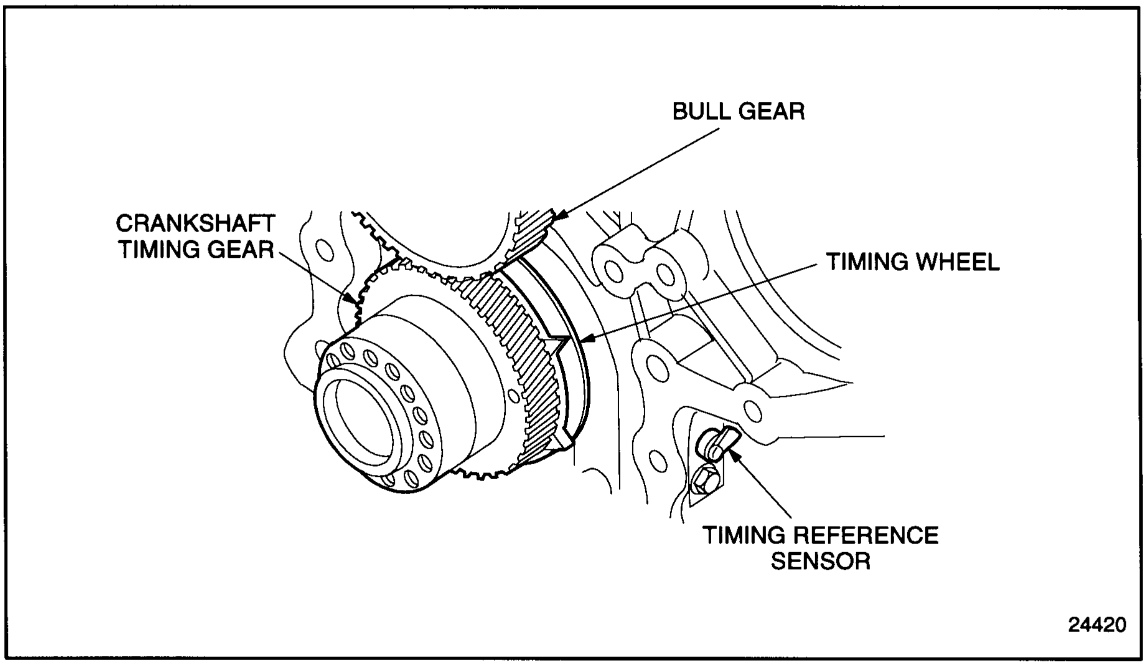


Figure 1-172 Timing Reference Sensor (TRS)

The Synchronous Reference Sensor (SRS) is an electronic component that is bolted to the gear case at the lower, intake (left) side of the engine. See Figure 1-173.

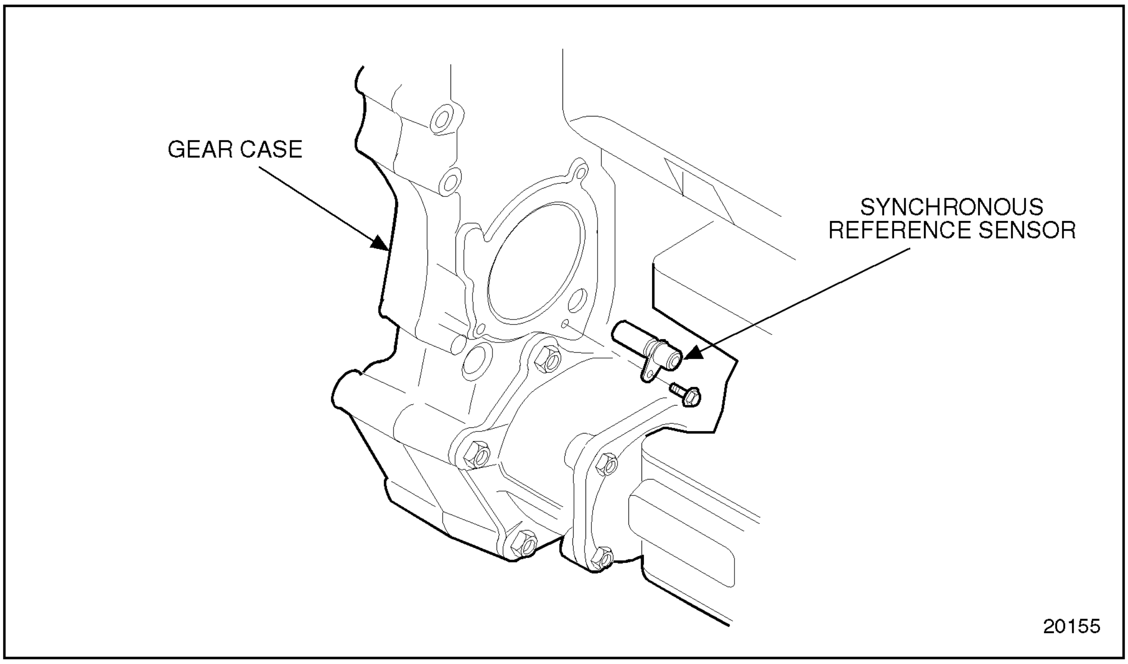


Figure 1-173 Synchronous Reference Sensor

An opening is provided in the center of the gear case, for the bull gear and camshaft idler gear assembly, which bolts directly to the engine block. See Figure 1-174.

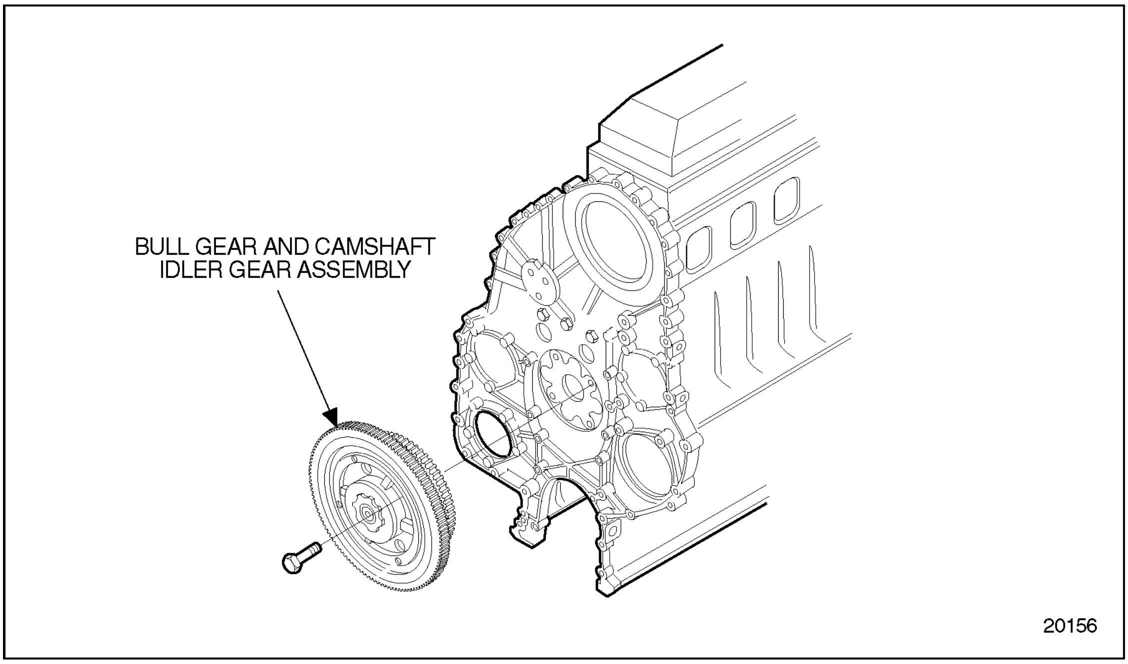


Figure 1-174 Bull Gear and Camshaft Idler Gear Assembly

An access cover is provided at the rear of the gear case on the cooler (right) side of the engine. This access cover provides an opening for inspection of the accessory drive assembly drive gear. See Figure 1-175.

NOTE:
This access cover opening may be cast closed on the rear of the gear case.

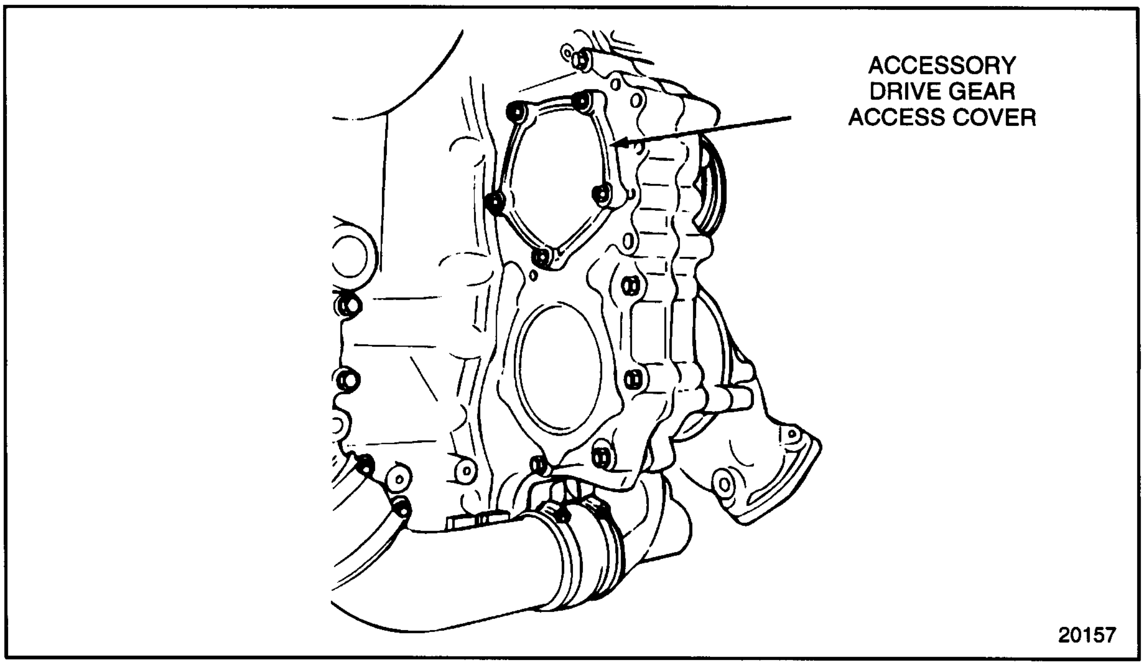


Figure 1-175 Accessory Drive Assembly Drive Gear Access Cover

Gear lash measurement and adjustment procedures for the gears in the engine gear train. Refer to Section 1.21.2.1.

NOTE:
Do not use the oil plug location for oil supply or for checking oil pressure.

An oil gallery is drilled in the gear case casting, for lubrication of the adjustable idler gear assembly. A hole in the front of the cylinder block, indexes with the gear case gallery. At the edge of the gear case the gallery is threaded for insertion of a plug. An exit hole feeds the adjustable idler gear assembly. See Figure 1-176.

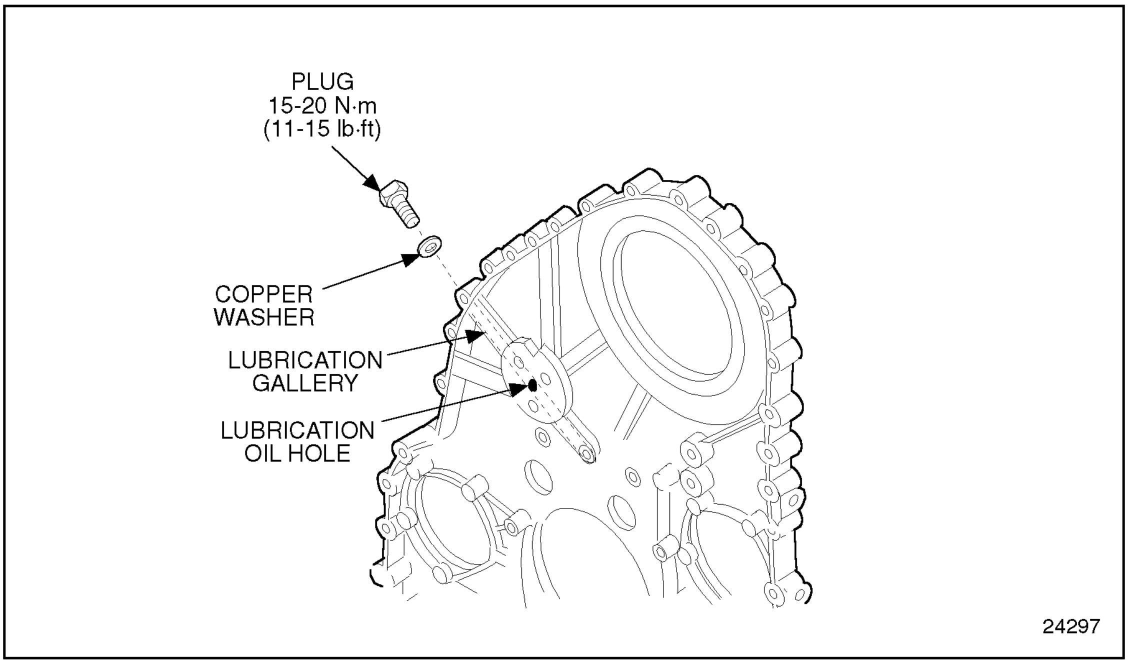


Figure 1-176 Adjustable Idler Gear Lubrication Gallery

1.11.1 Repair or Replacement of Gear Case

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-177.

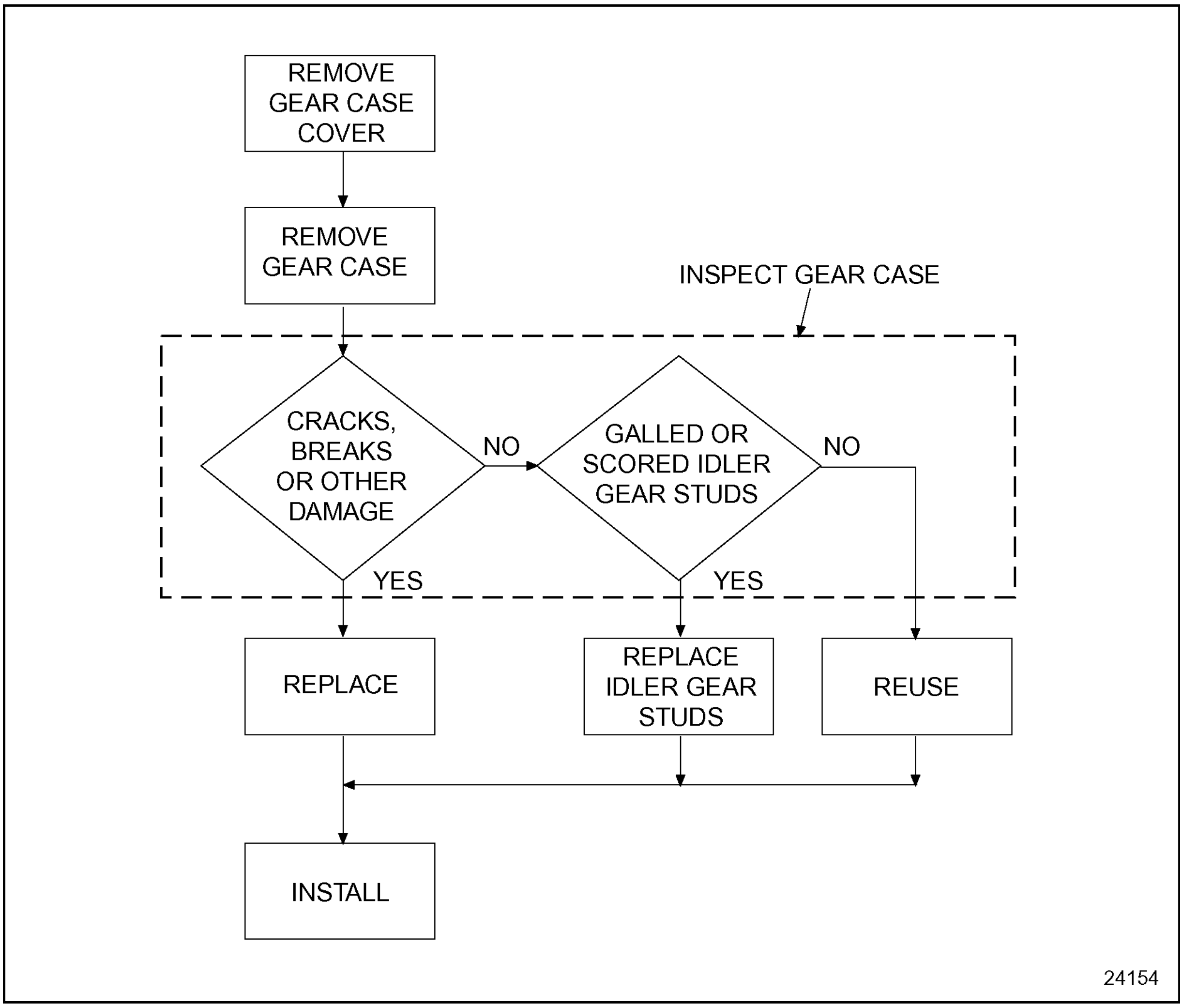


Figure 1-177 Flowchart for Repair or Replacement of Gear Case

1.11.2 Removal of Gear Case

To remove the gear case:

1. Remove the SRS. Refer to Section 2.20.2.
2. Remove the TRS from the gear case to prevent their damage on removal of the gear case. Refer to Section 2.21.2.
3. Remove the rocker arm assemblies. Refer to Section 1.3.2.
4. Perform all of the steps for camshaft removal; refer to Section 1.22.2.

5. Remove the 3 bolts that secure the camshaft gear pilot tool, J 35906, to the gear case and remove the tool.
6. Remove the two bolts securing the right side gear case stiffening bracket. See Figure 1-178.

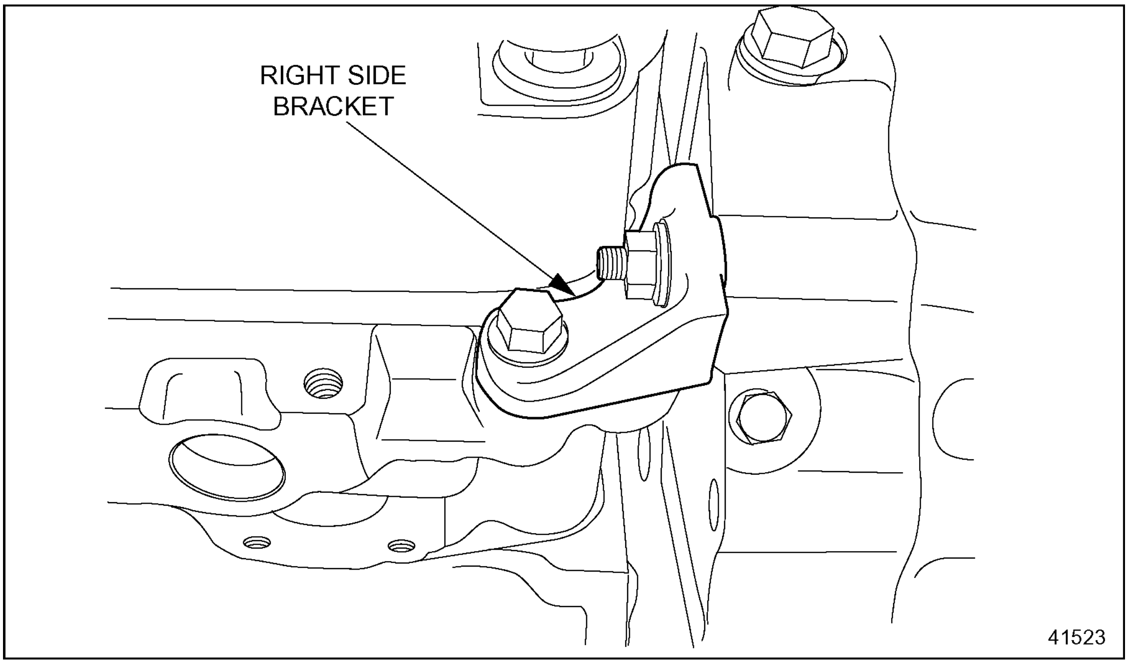


Figure 1-178 Gear Case Stiffening Bracket (Right Side)

7. Refer to Section 1.10.2, for case cover removal and perform the steps up to but not including, supporting the gear case cover with a suitable lifting device. For the final step, refer to step 15. See Figure 1-179.

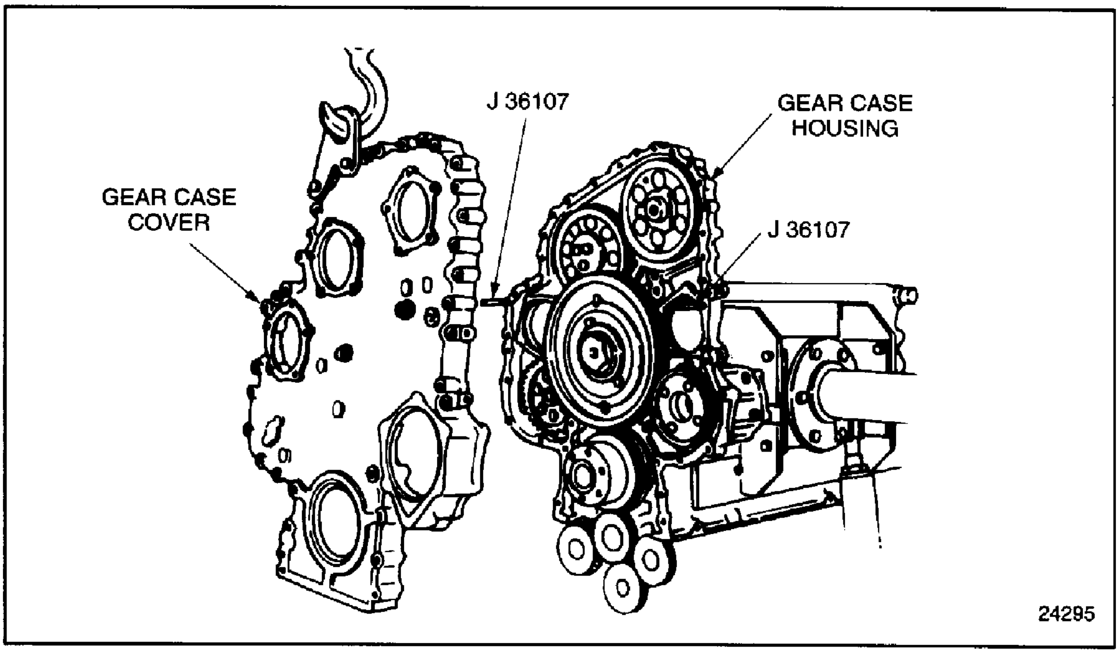


Figure 1-179 Gear Case Cover Removal

8. Remove the fuel pump from the fuel pump drive assembly (or air compressor). Refer to Section 2.5.2.
9. Remove the air compressor. Refer to Section 10.1.2.
10. Remove the air compressor drive assembly. Refer to Section 10.2.2.

11. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft. This will help to protect the crankshaft seal surface when removing the bull gear and camshaft idler gear assembly. See Figure 1-180.

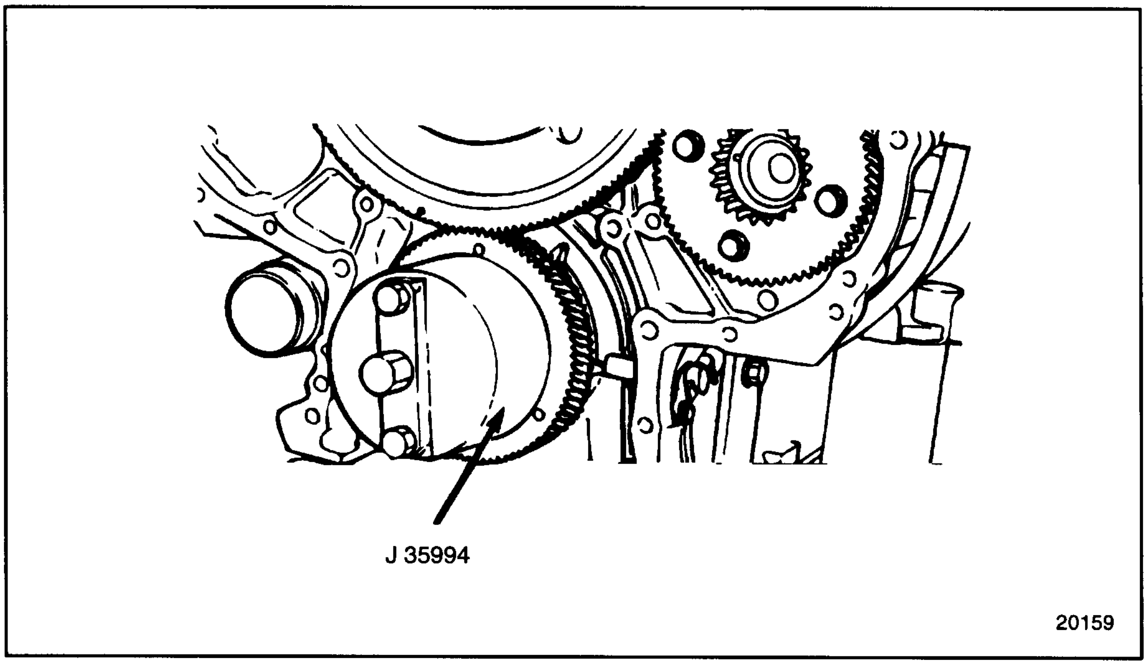


Figure 1-180 Crankshaft Protector Installation

12. Remove the bull gear and camshaft idler gear assembly from the engine.
    Refer to Section 1.26.2.
13. Remove the adjustable idler gear assembly from the gear case. Refer to Section 1.25.2.
14. Using a plastic hammer or fiber mallet, tap the rear face of the camshaft thrust plate to remove the thrust plate, camshaft drive gear hub and camshaft drive gear from the gear case.

15. Remove the 12 bolts that secure the gear case to the engine block. See Figure 1-181. Also remove the bolt that secures the gear case stabilizer bracket to the gear case.

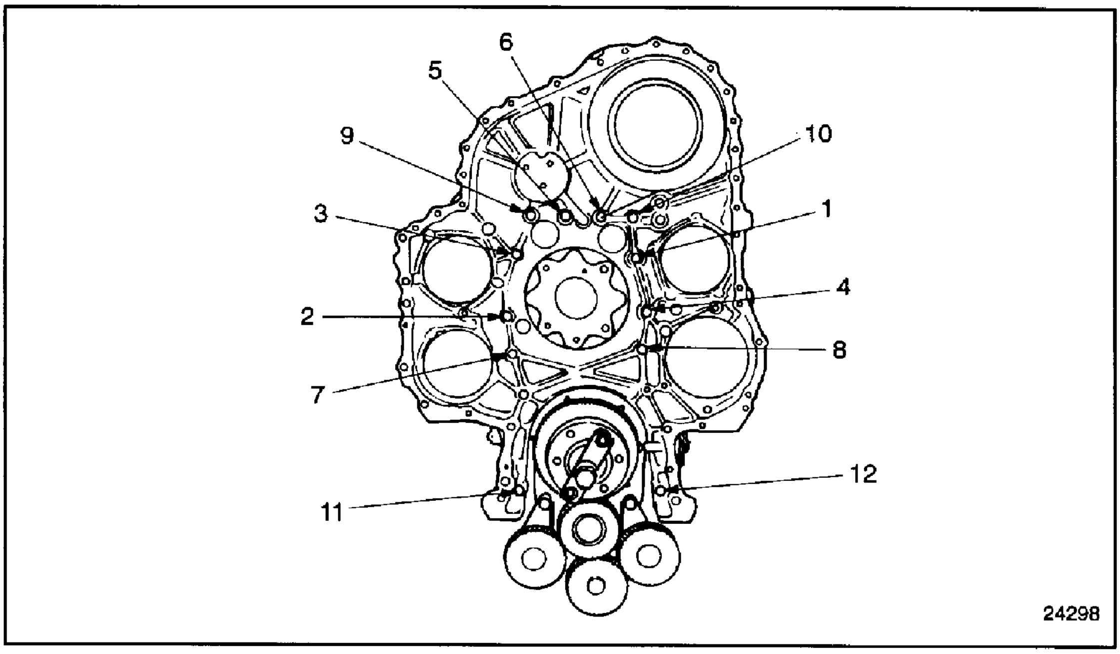


Figure 1-181 Gear Case Mounting Bolt Locations

16. Using a leather or cloth-wrapped strap, support the gear case. See Figure 1-182.

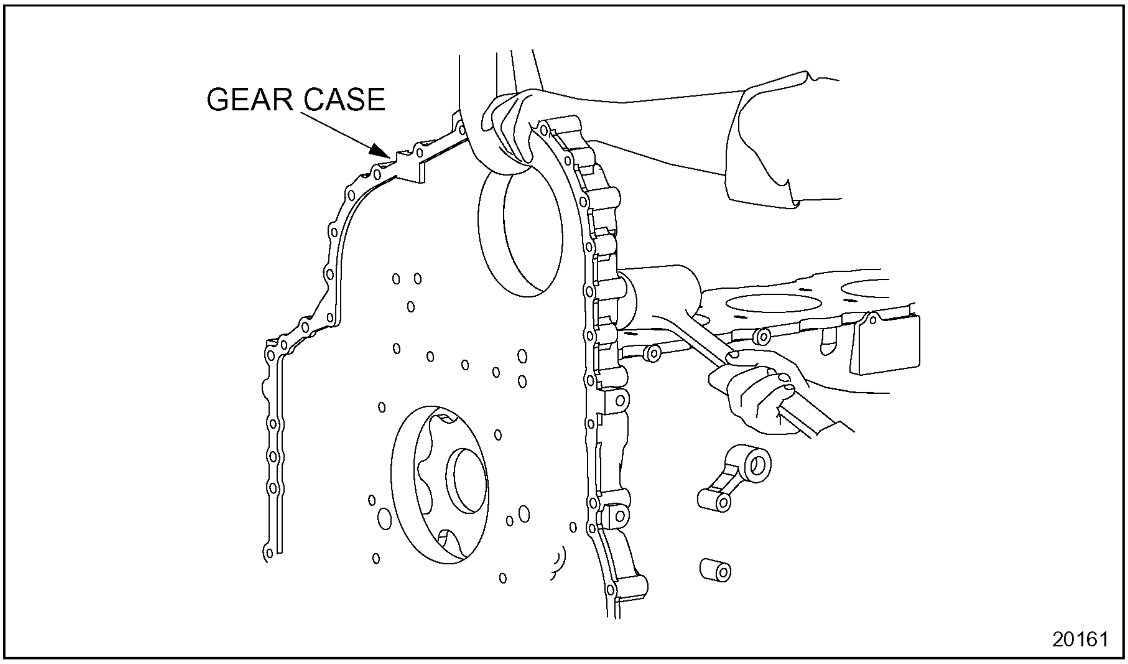


Figure 1-182 Gear Case Removal

17. Use a rubber hammer or plastic mallet to loosen the gear case from the cylinder block dowels.

1.11.2.1 Inspection of Gear Case

Clean all of the old gasket sealer from the mating surfaces of the gear case, gear case cover and engine block. Clean the gasket material from the mating surfaces of any components or access covers that were removed from the gear case cover or gear case.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

Clean all of the parts with clean fuel oil and dry with compressed air. Remove the oil gallery plug at the edge of the gear case. See Figure 1-176. Use compressed air to ensure the oil gallery is completely free of blockage. If necessary, use a wire brush to clean the gear case oil gallery.

Inspect the gear case for stress cracks, breaks, or other damage. Repair or replace as necessary. Inspect the adjustable idler gear studs for signs of galling or scoring. Replace as necessary. Inspect all the individual components as outlined under the appropriate section.

1.11.3 Installation of Gear Case

Use the following instructions for gear case installation:

NOTE:
The installation of Gasket Eliminator to the gear case-to-block mating surfaces at the top of the block is critical. Excess gasket eliminator material can extrude into the oil passage between the block and gear case, causing early failure of components. In addition, the bull gear recess area MUST be cleaned of any and all foreign material after installation of the gear case to the engine block.

1. Apply a thin film of gasket eliminator PT-7276 (Loctite 51580) or equivalent to the cylinder block. See Figure 1-183. Carefully smooth the bead around the block-to-gear case oil passage to avoid contamination.

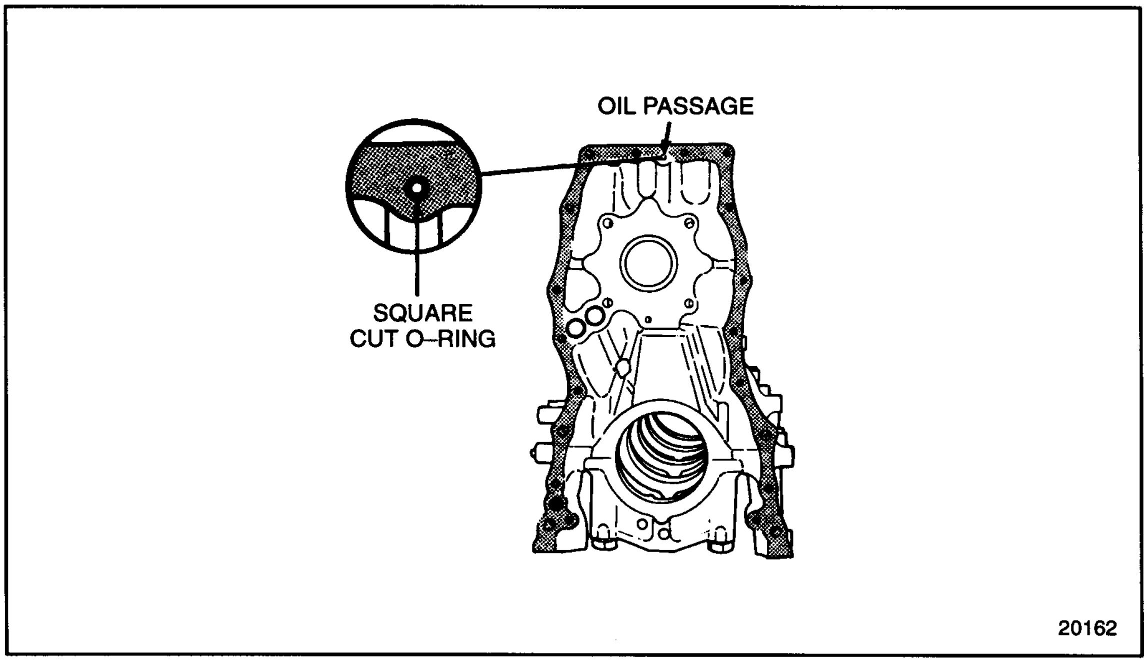


Figure 1-183 Gasket Eliminator Application (Cylinder Block)

2. Insert Gear Case Alignment Plug, J 35651, into the bull gear and camshaft idler gear hub recess in the cylinder block. See Figure 1-184.

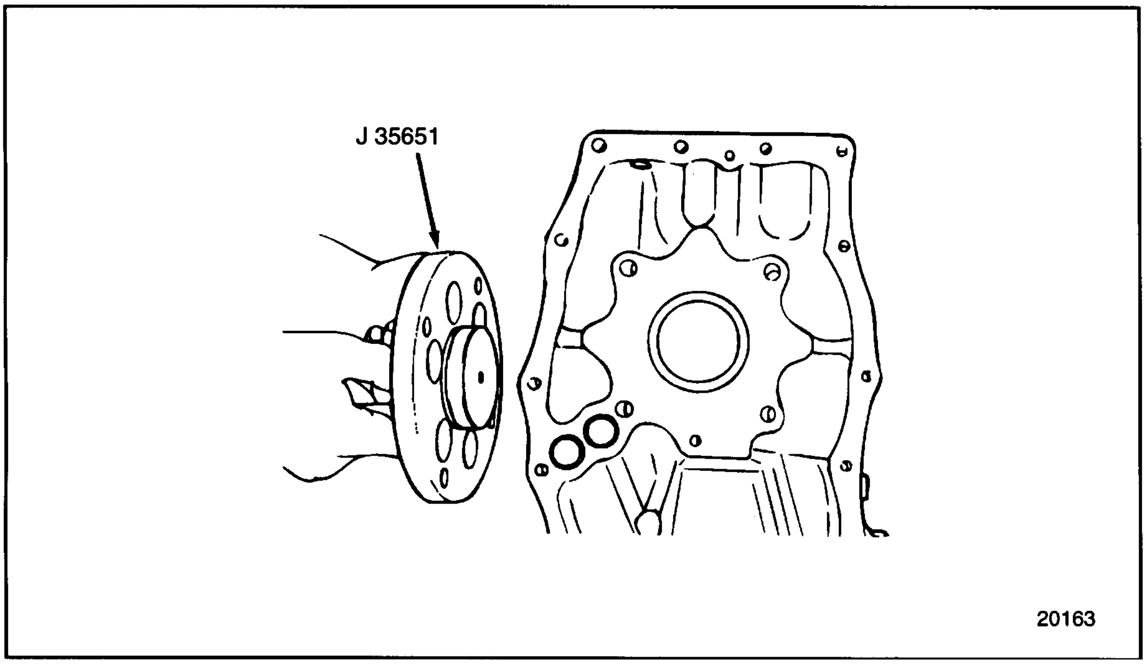


Figure 1-184 Gear Case Alignment Plug

3. Using a suitable lifting sling made of cloth or leather, position the bull gear and camshaft idler gear opening of the gear case over the gear case alignment plug. Index the hole

in the gear case mating surface with the diamond dowel at the lower left corner of the cylinder block. See Figure 1-185.

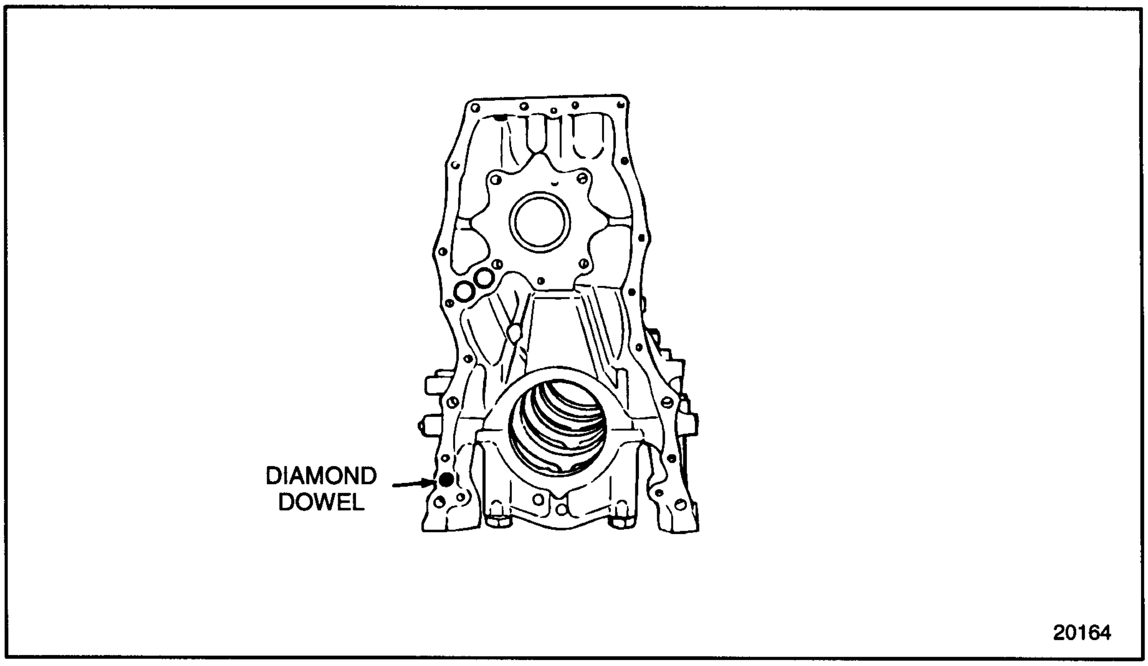


Figure 1-185 Cylinder Block Locating Dowel

4. With the gear case alignment plug fully seated, the gear case centered on the alignment plug and the diamond dowel in the cylinder block indexed with its mating hole in the gear case, the gear case is positioned properly for bolt installation. See Figure 1-186.

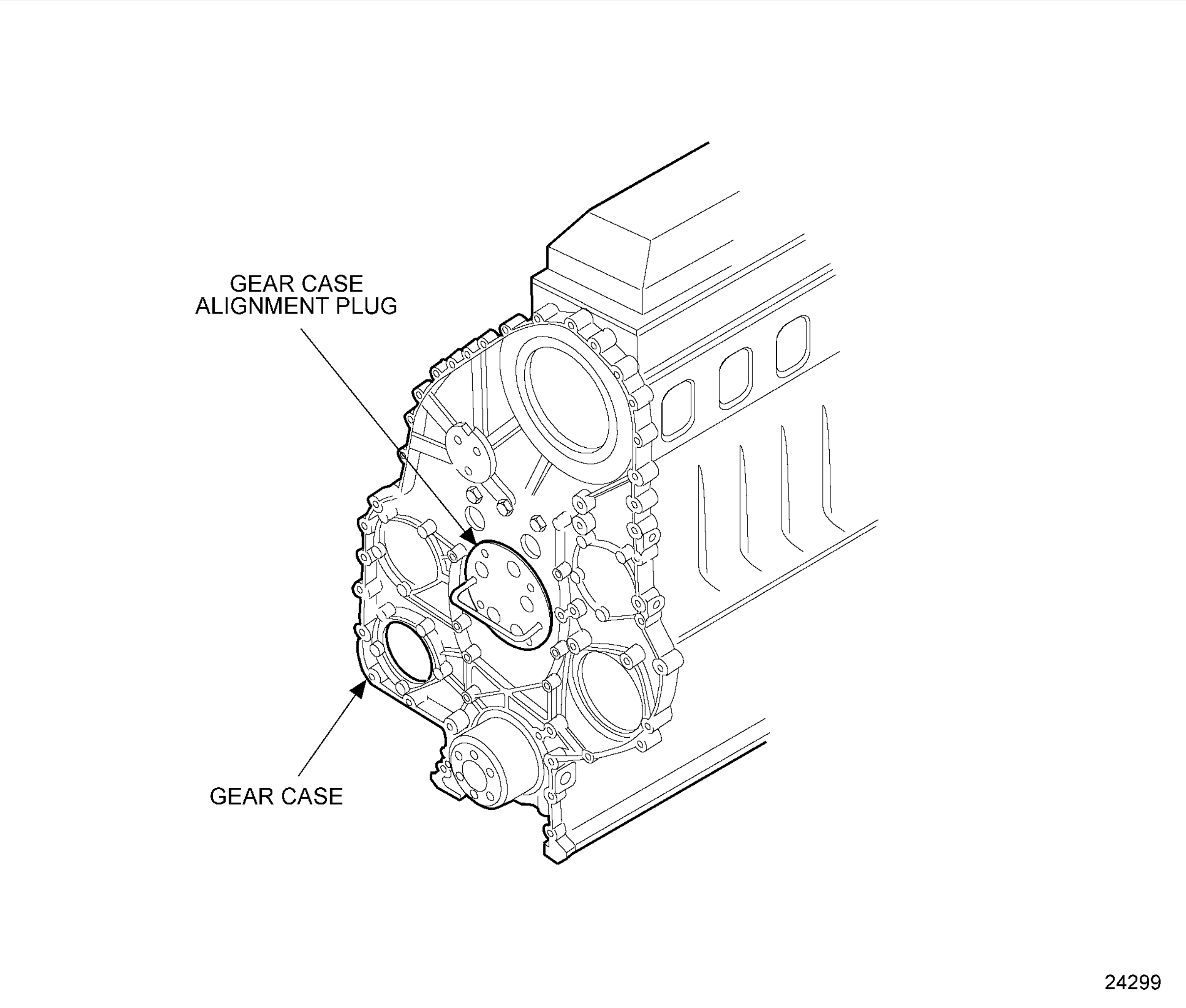


Figure 1-186 Gear Case Positioning

NOTE:
Gasket Eliminator cures with the absence of air. The time between the installation of the gear case, and torquing of the bolts that secure the gear case to the cylinder block should be kept to a minimum.

5. Install the 12 gear case-to-cylinder block retaining bolts, finger-tighten.

6. See Figure 1-187, and torque the gear case-to-cylinder block bolts to 58-73 N·m (43-54 lb·ft) using the sequence shown.

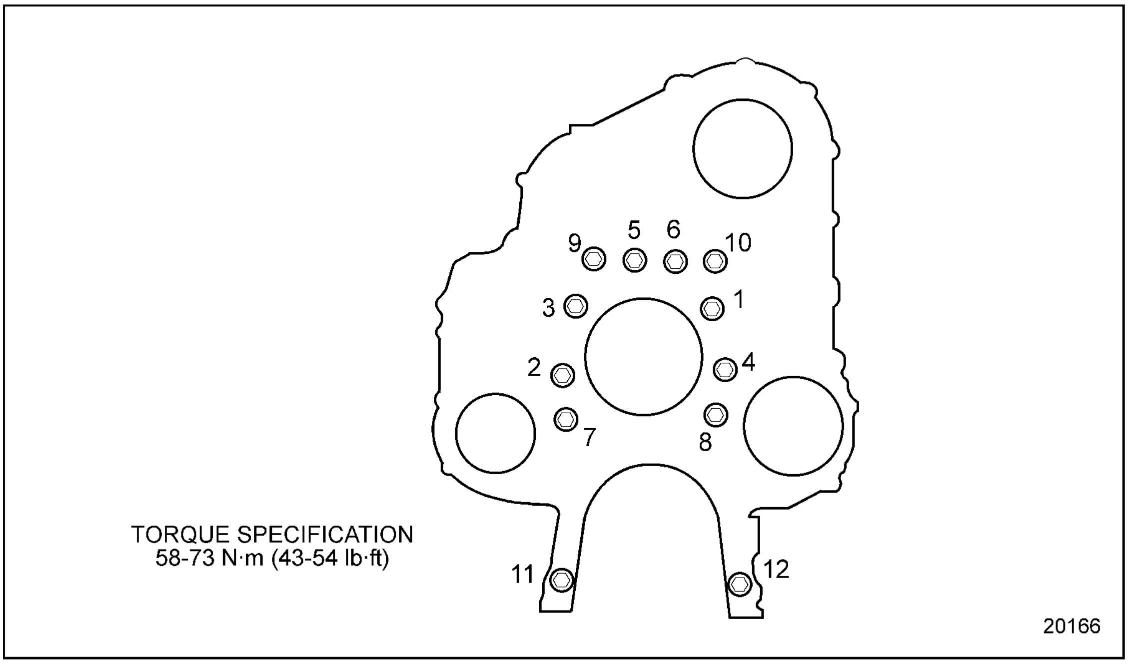


Figure 1-187 Gear Case Bolt Torque Sequence

7. Remove the gear case alignment plug from the gear case.
8. Install the air compressor. Refer to Section 10.1.4.
9. Install the air compressor drive assembly. Refer to Section 10.3.5.
10. Install the fuel pump to gear case. Refer to Section 2.5.5.
11. Refer to Section 4.2.7 and install the water pump assembly.
12. Lubricate the rubber O-ring on the camshaft thrust plate with clean engine oil. Install the camshaft thrust plate assembly, with the camshaft drive gear and hub in place to the gear

case, using a plastic hammer or fiber mallet to tap the thrust plate rearward in the gear case just enough to start it in the gear case. See Figure 1-188.

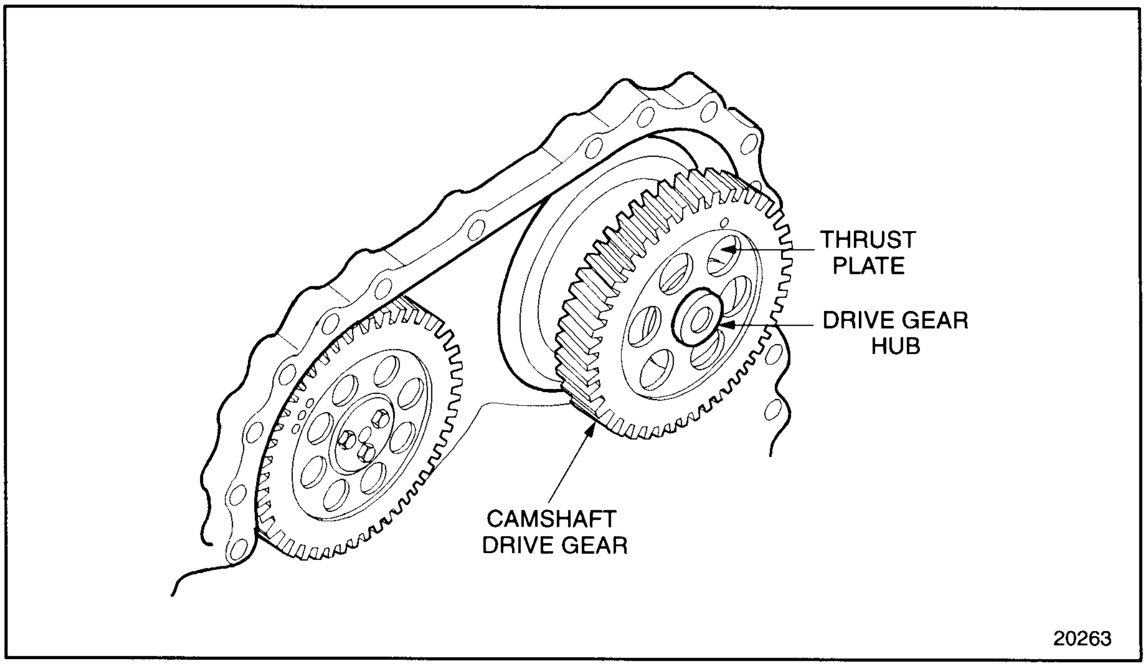
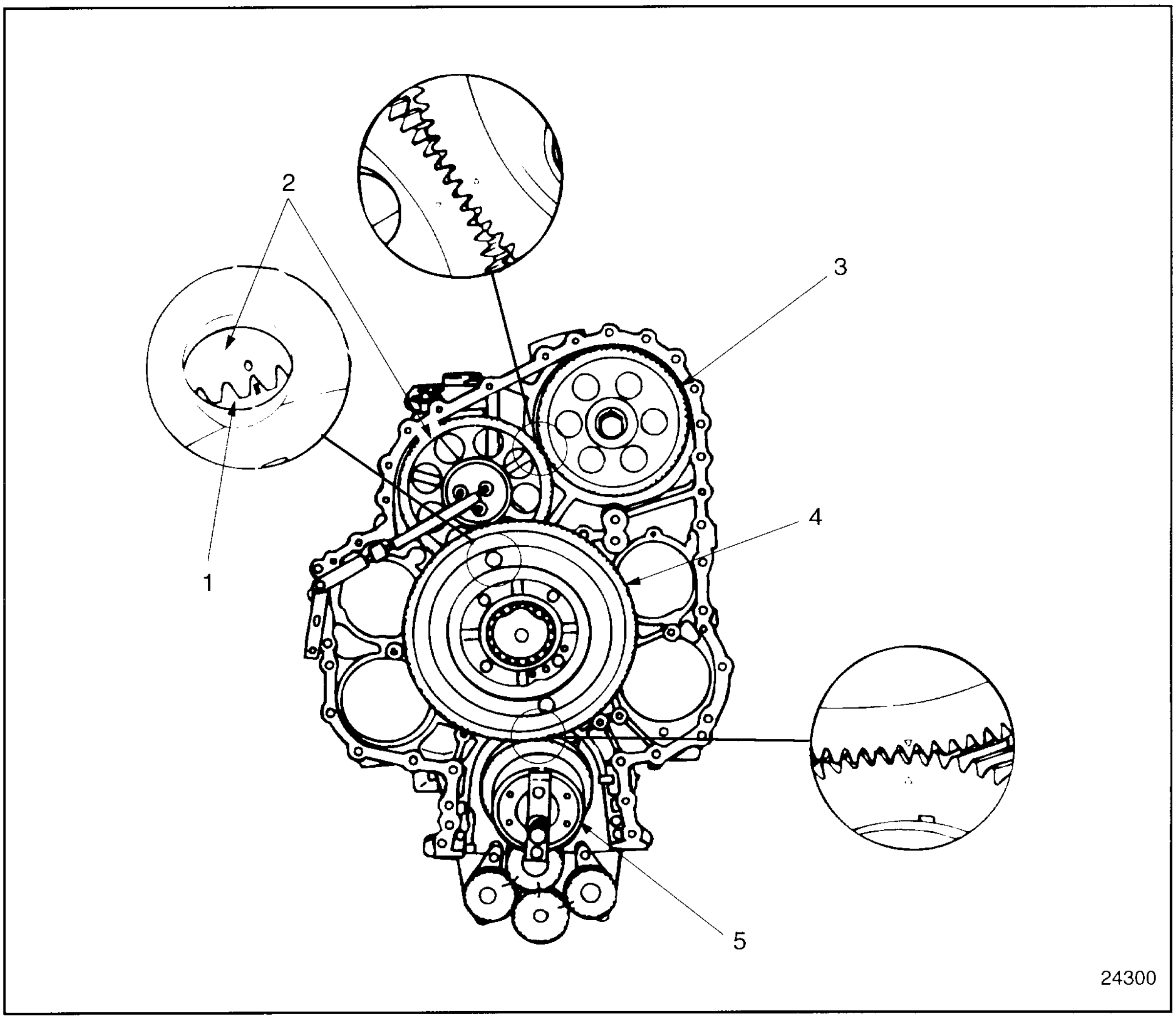


Figure 1-188 Camshaft Thrust Plate Installation

13. Install the adjustable idler gear assembly to the gear case. Refer to Section 1.25.3. Align the timing marks of the adjustable idler gear and camshaft drive gear. See Figure 1-189.



1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

Figure 1-189 Engine Gear Train Timing Marks

14. Inspect the bull gear and camshaft idler gear access opening in the gear case and remove any foreign material.

15. Install two bull gear guide studs, J 35785 to the cylinder block. See Figure 1-190.

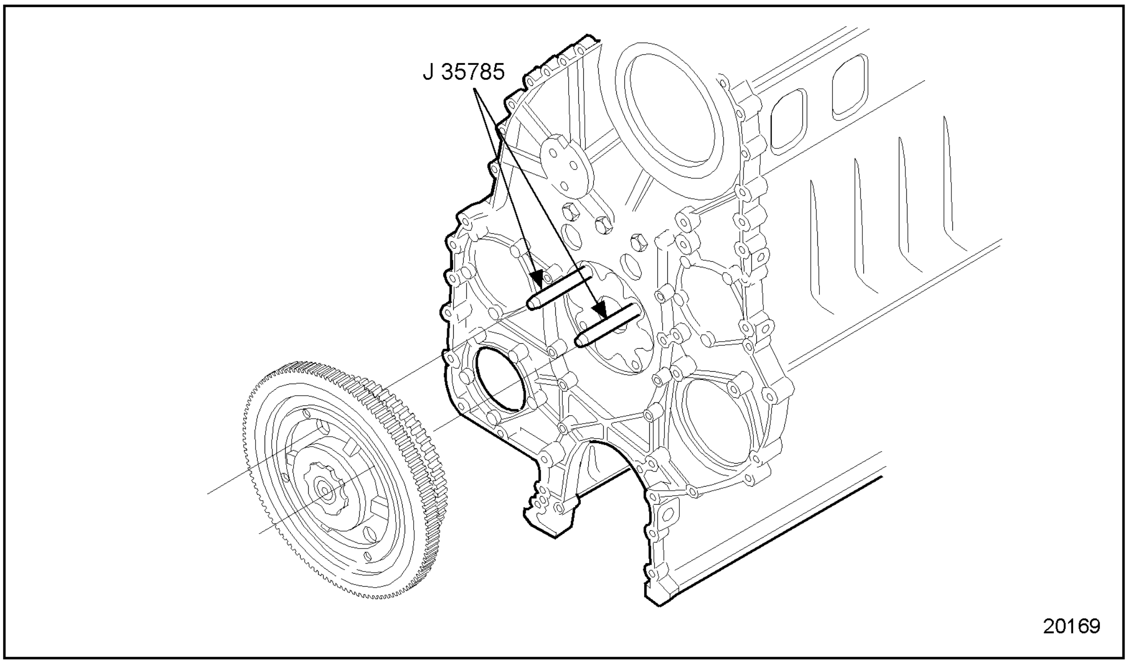


Figure 1-190 Bull Gear Guide Stud Installation

16. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft. This will help to protect the crankshaft seal surface when installing the bull gear and camshaft idler gear assembly.

NOTICE:
Always install crankshaft protector when installing the bull gear and camshaft idler gear assembly to prevent damaging the crankshaft oil seal contact surface.

17. Install the bull gear and camshaft idler gear assembly to the guide studs. Align the timing marks on the bull gear and the crankshaft timing gear and the camshaft idler gear and adjustable idler gear; see Figure 1-189, and slide the bull gear and camshaft idler gear assembly forward to seat it in the recess in the gear case and cylinder block.
18. Working through the lightening holes in the bull gear, install two of the bull gear assembly mounting bolts through the hub and into the cylinder block. Tighten the bolts finger tight.
19. Remove the two bull gear guide studs. Install the remaining two bull gear assembly mounting bolts. Torque the bolts to 101-126 N·m (75-93 lb·ft). Tighten in a clockwise sequence.
20. Check the timing marks on the gears to ensure the gear train is properly timed. See Figure 1-189.
21. Perform the following:

[a] Crankshaft timing gear-to-oil pump idler gear lash measurement. Refer to Section 1.21.2.1, step 2.

[b] Crankshaft timing gear-to bull gear lash measurement. Refer to Section 1.21.2.1, step 3.

[c] Refer to Section 1.10.3 for gear case cover installation.

[d] Install the bolt securing the right side gear case stiffening bracket to the gear case first and torque to 74.57–81.35 N·m (55–60 lb·ft). Then install the bolt attaching bracket to the cylinder head and torque to 58.30–73.21 N·m (43–54 lb·ft). See Figure 1-191.

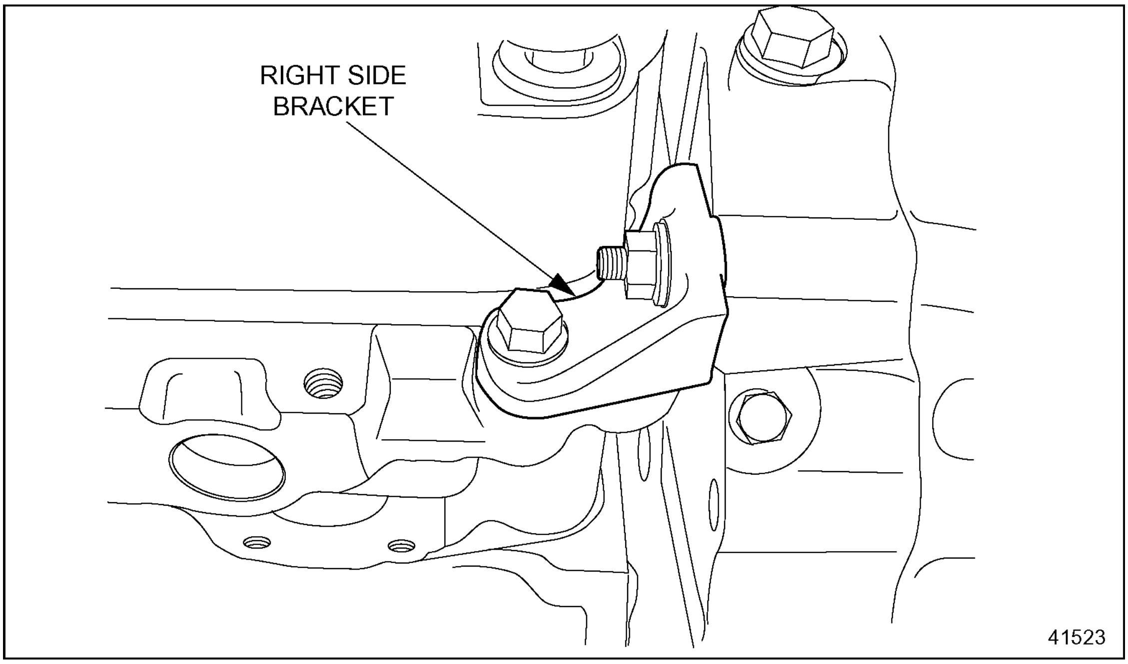


Figure 1-191 Gear Case Stiffening Bracket (Right Side)

22. Refer to Section 1.22.5, "Installation of Camshaft and Camshaft Bearings" and perform the necessary steps.
23. Refer to Section 1.21.2.1 for bull gear-to-accessory pulley drive gear lash measurement and perform step 10.
24. If the former stabilizer bracket has not been removed, loosen the two bolts securing the bracket to the cylinder head. Install the gear case stabilizer bracket-to-gear case bolt and torque to 58-73 N·m (43-54 lb·ft). Then, retighten the stabilizer bracket-to-cylinder head bolts to 58-73 N·m (43-54 lb·ft) torque.
25. Continue engine assembly.

1.12 CRANKSHAFT VIBRATION DAMPER

A viscous type vibration damper is mounted on the front end of the crankshaft to reduce torsional vibrations to a safe value. See Figure 1-192.

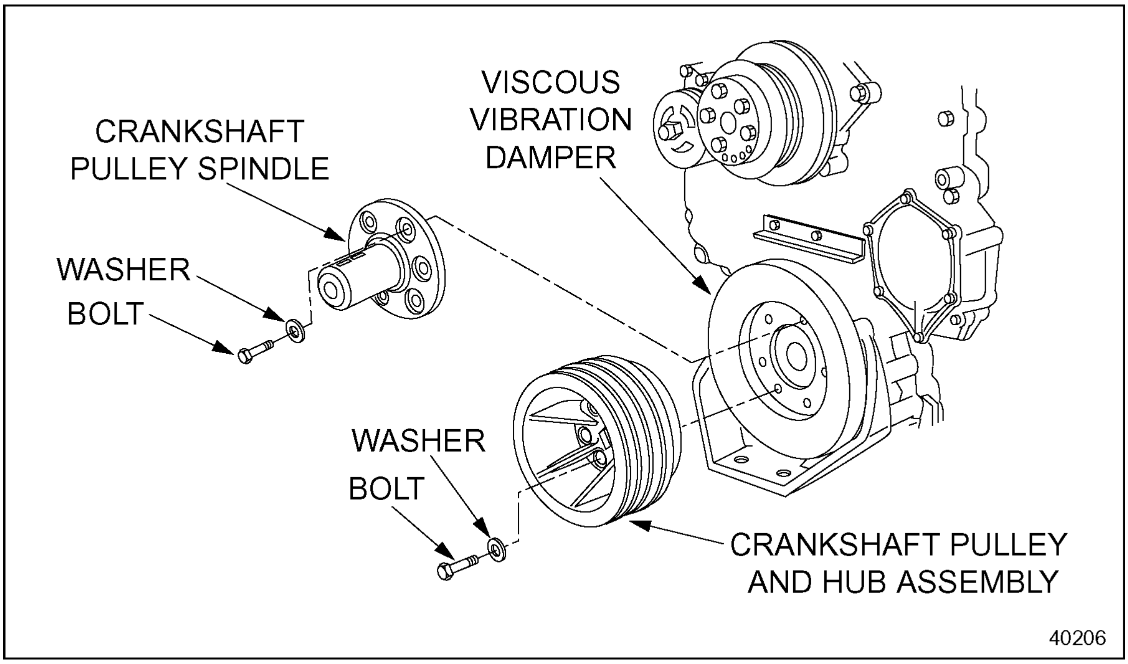


Figure 1-192 Viscous Vibration Damper Mounting with Crankshaft Pulley or Crankshaft Pulley and Hub Assembly with Spindle

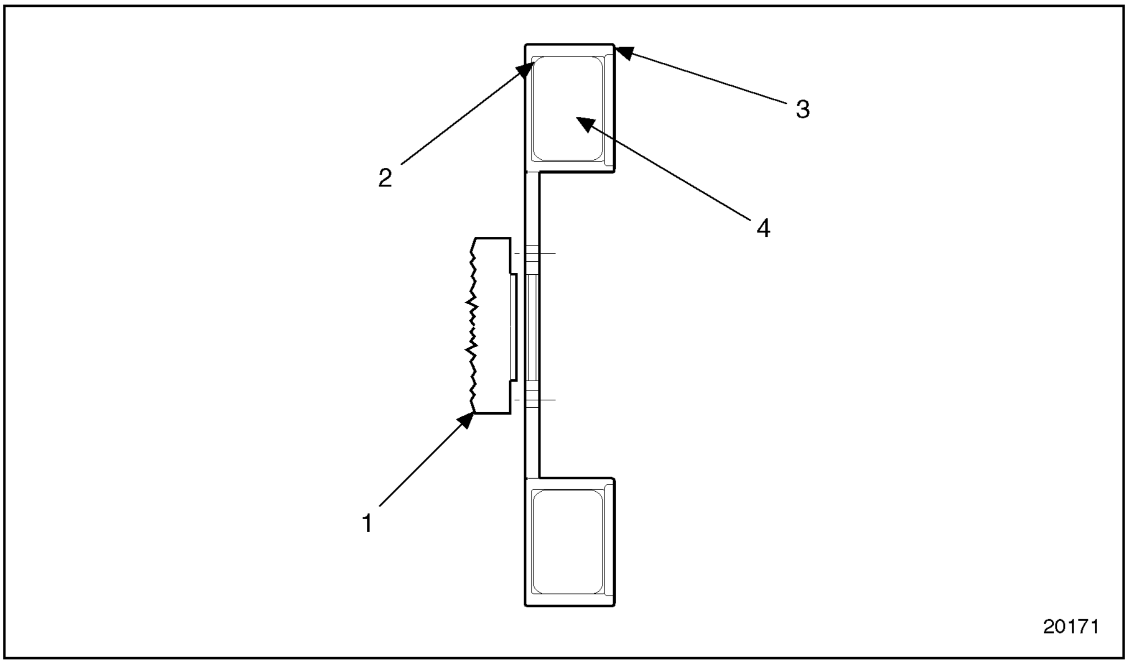
The viscous damper assembly consists of a sealed outer shell, an internal flywheel and a quantity of highly viscous fluid. See Figure 1-193.

A vibration damper safety shield is recommended in industrial and marine applications in which the engine operates without a hood or other protective covering in an open or unprotected area.

A properly designed and installed safety shield protects the damper from damage, prevents direct physical contact with the damper during engine operation, and significantly reduces the potential for damper-related personal injury.

Detroit Diesel Corporation does not manufacture, sell or install vibration damper safety shields due to the wide variety of installations in which Detroit Diesel engines are applied. Space restrictions in these numerous applications make it necessary to design an appropriate type of shield for each installation.

The responsibility for designing and installing properly shaped and constructed safety shields, therefore, rests with the OEM (Original Equipment Manufacturer), distributor, or other fabricator designing or manufacturing products in which they apply to Detroit Diesel engines.



1. Crankshaft
2. Viscous
3. Damper Shell
4. Internal Flywheel

Figure 1-193 Viscous Vibration Damper Detail

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. Since "fluid-drive" is more or less inefficient with frequent speed changes, considerable flywheel slippage 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 vibration amplitude, reducing its effects to a level harmless to the engine.

1.12.1 Repair or Replacement of Crankshaft Vibration Damper

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-194.

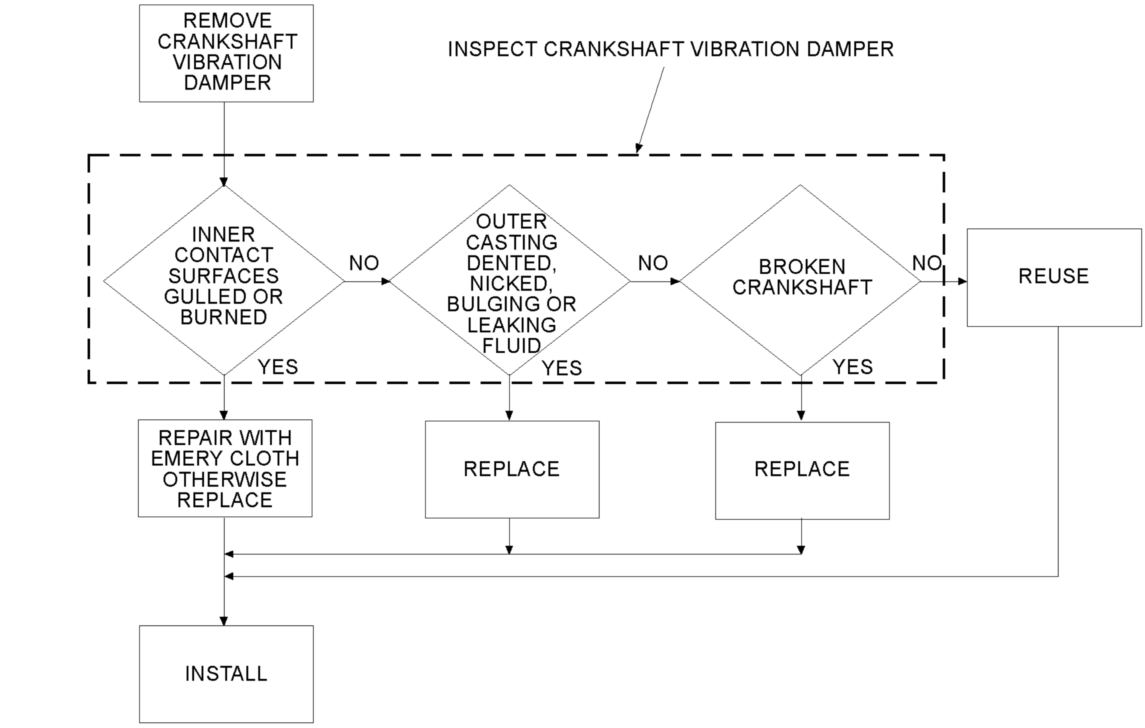


Figure 1-194 Flowchart for Repair or Replacement of Crankshaft Damper

1.12.2 Cleaning and Removal of Crankshaft Vibration Damper

Precleaning is not necessary.

CAUTION:

To avoid injury from the projection of tools or other objects that may fall on or behind the vibration damper of an engine, always check and remove these items before starting the engine.

Remove crankshaft vibration damper as follows:

1. Remove the drive belts from the crankshaft pulley.
2. Remove the inspection plug in the bottom of the flywheel housing and install the flywheel lock, J 36375–A. See Figure 1-195.

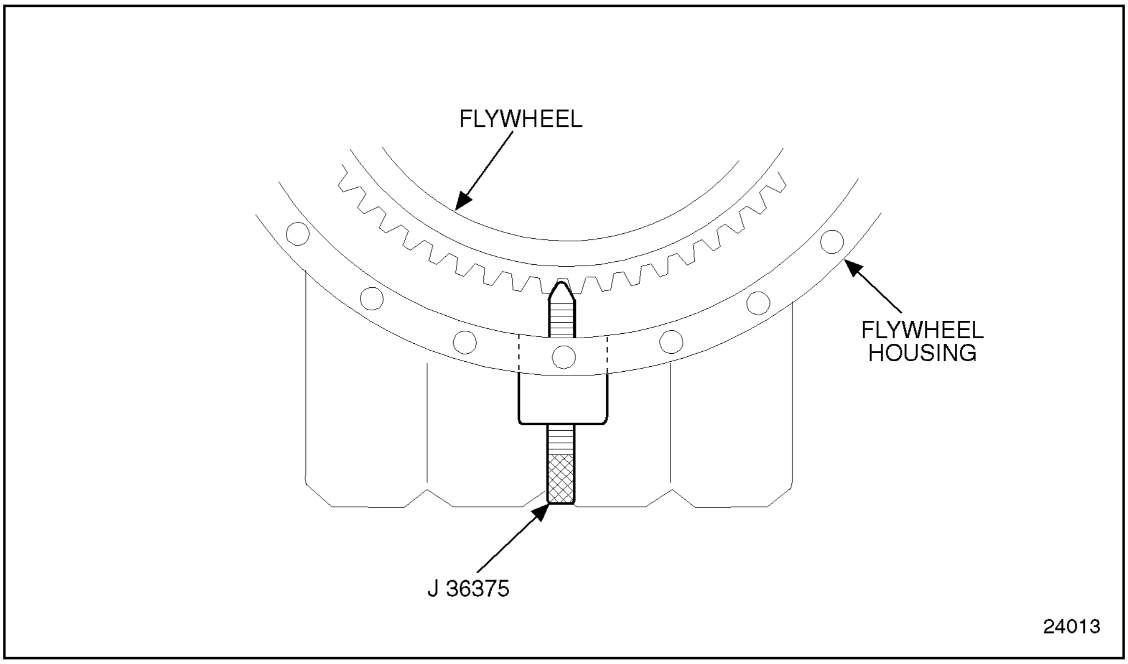


Figure 1-195 Flywheel Lock

3. Thread the center screw of the tool in until the tip of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley or the center bolt when the pulley and hub assembly with spindle is used) so that the tool center screw is exactly between two teeth.

4. Finger-tighten the knurled knob.
5. On keel-cooled marine engines, remove the charge air cooler tank. Refer to section 4.4.2.

6. Remove the isolated pulley from the spindle by removing the large center bolt (if equipped with this pulley style). Refer to section 1.13.2.
7. Remove two of the six crankshaft pulley or crankshaft pulley spindle-to-crankshaft special attaching bolts and hardened washers that are 180 ° apart. Discard the bolts. These bolts are not reusable.
8. Install two guide studs, J 36235, into the holes where the bolts were removed.

NOTICE:
Use care when removing the crankshaft pulley as the vibration damper may come off. If the damper is allowed to fall, internal damage to the damper will result.

9. Remove the remaining four special crankshaft pulley bolts and hardened washers. Discard the bolts. These bolts are not reusable.

NOTICE:
Do not pound with a hammer or pry with other tools to remove the viscous 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. This renders the damper ineffective. The damper CANNOT be repaired.

10. Remove the vibration damper by sliding it off the guide studs.
11. Remove the flywheel lock and guide studs.

1.12.2.1 Inspection of the Vibration Damper

Inspect the vibration damper as follows:

NOTICE:
Dents may render the damper ineffective.

1. Inspect the outer casing of the damper for damage.
   [a] Check outer casing for dents, cracks, nicks, fluid leaks or bulges.
   [b] If any dents or cracks are detected, replace with new damper.
   [c] Bulges or splits indicate that the damper fluid has deteriorated. If any are detected, replace with new damper.
2. Inspect the damper inner contact surfaces and the crankshaft end for damage. See Figure 1-196
   [a] Check for galling or burrs.
   [b] Slight scratches or burrs may be removed with an emery cloth.

[c] If deep scratches are detected, replace with new damper.

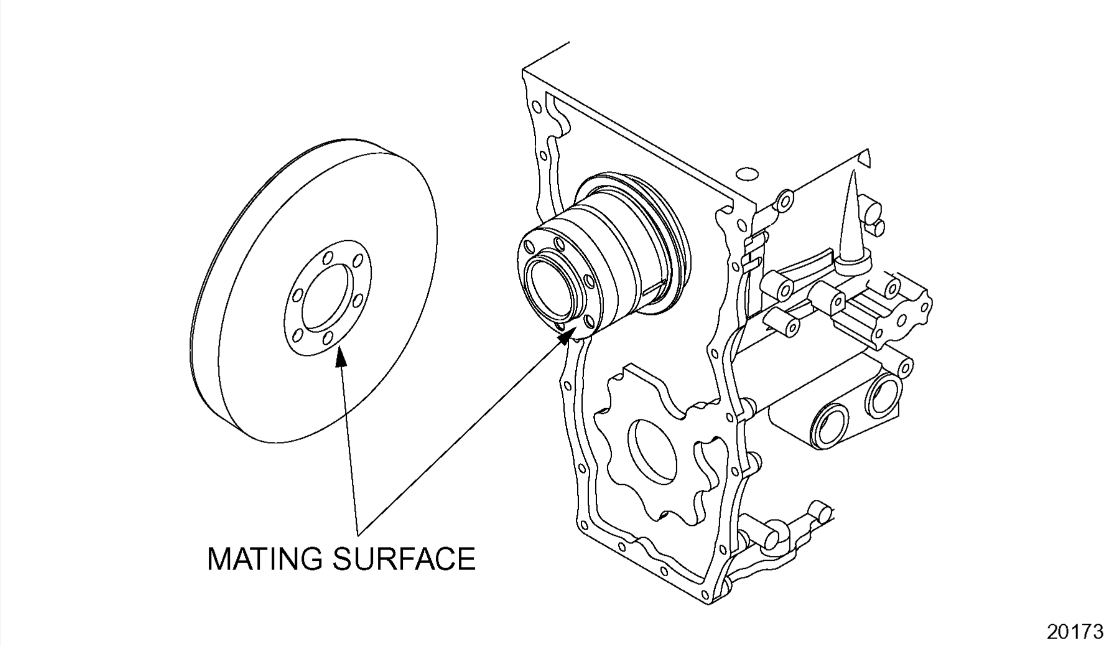


Figure 1-196 Damper and Crankshaft Contact Surfaces

3. Regardless of its condition, a viscous type damper must be replaced at normal engine overhaul or whenever the engine has experienced crankshaft breakage.
4. If the vibration damper has been damaged, inspect the crankshaft. Refer to section 1.7. Crankshaft damage may have resulted.

NOTICE:
A loose engine mount could lead to damage of the vibration damper by allowing the engine to move slightly during operation.

5. Inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

1.12.3 Installation of Crankshaft Vibration Damper

Install the crankshaft vibration damper as follows:

1. Install the flywheel lock, J 36375–A, to the inspection plug hole in the bottom of the flywheel housing. See Figure 1-195.

NOTE:
It may necessary to bar the engine over (using barring Tool J 36237) so that the tool center screw is exactly between two teeth.

2. Thread the center screw of the tool in until the tip of the tool rests between two teeth of the flywheel ring gear. Finger-tighten the knurled knob.
3. Install two guide studs, J 36235, to two of the holes in the crankshaft pulley 180 ° apart. A light coating of an anti-seize compound should be applied to the pilot diameter (not the face of the crankshaft) to reduce future removal difficulty.
4. Install the vibration damper to the end of the crankshaft. The six holes in the damper are equally spaced, and the damper may be installed in any position. The part No. on the face of the damper should face out, away from the engine.
5. Install the crankshaft pulley or crankshaft pulley spindle to the crankshaft. The crankshaft pulley or crankshaft pulley spindle may be installed in any position. Refer to section 1.13.3.

NOTICE:
Crankshaft pulley and spindle mounting bolts are considered single-use items and *must not be used.* Always use new bolts when mounting the crankshaft pully or spindle. Reusing bolts may result in excessive bolt stretch during installation, leading to loss of bolt torque and loosening during engine operation, which may cause severe engine damage.

6. Install four new special bolts, with hardened washers installed, through the pulley or crankshaft pulley spindle and damper and into the crankshaft. Finger-tighten the bolts.
7. Remove the two guide studs.
8. Install the remaining two new special bolts with hardened washers installed.
9. Torque the six bolts to 182-210 N·m (134-155 lb·ft). Proceed in a clockwise direction until all bolts are torqued.
10. Install crankshaft pulley and hub assembly (if equipped with this pulley style). Refer to section 1.13.3.
11. Remove the flywheel lock tool.
12. Install the pipe plug to the inspection hole in the flywheel housing.
13. Install the drive belts to the crankshaft pulley. Adjust the belt tensions to the specifications. Refer to section 13.5.7.
14. Install any other components that were removed for this operation.
15. Refer to section 11.8 for verification of proper crankshaft vibration damper installation.

1.13 CRANKSHAFT PULLEY

Two crankshaft pulley arrangements exist. Some early engines were built with a pulley, a crankshaft pulley hub and woodruff keys. Later engines are built with the crankshaft pulley bolted directly to the crankshaft.

The crankshaft pulley bolted directly to the crankshaft. See Figure 1-197. In this case the pulley is attached to the crankshaft with six special bolts and washers. The vibration damper is clamped between the crankshaft pulley spindle and the crankshaft.

NOTE:
Do not substitute any other bolts or washers. The crankshaft pulley bolts and washers are special parts. These bolts are not reusable.

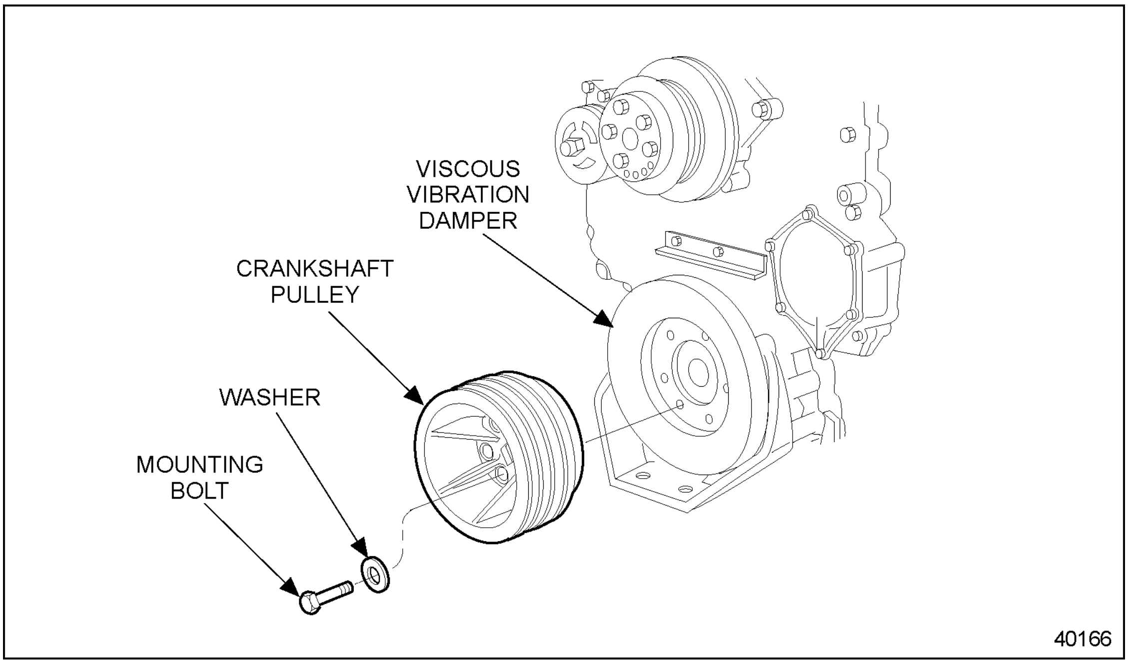


Figure 1-197 Crankshaft Pulley Mounted Directly to the Crankshaft

The crankshaft pulley is of the rigid design. Six bolt holes through the pulley are equally spaced. A relief area is machined around each bolt hole and acts as a seating surface for the hardened washers. See Figure 1-198.

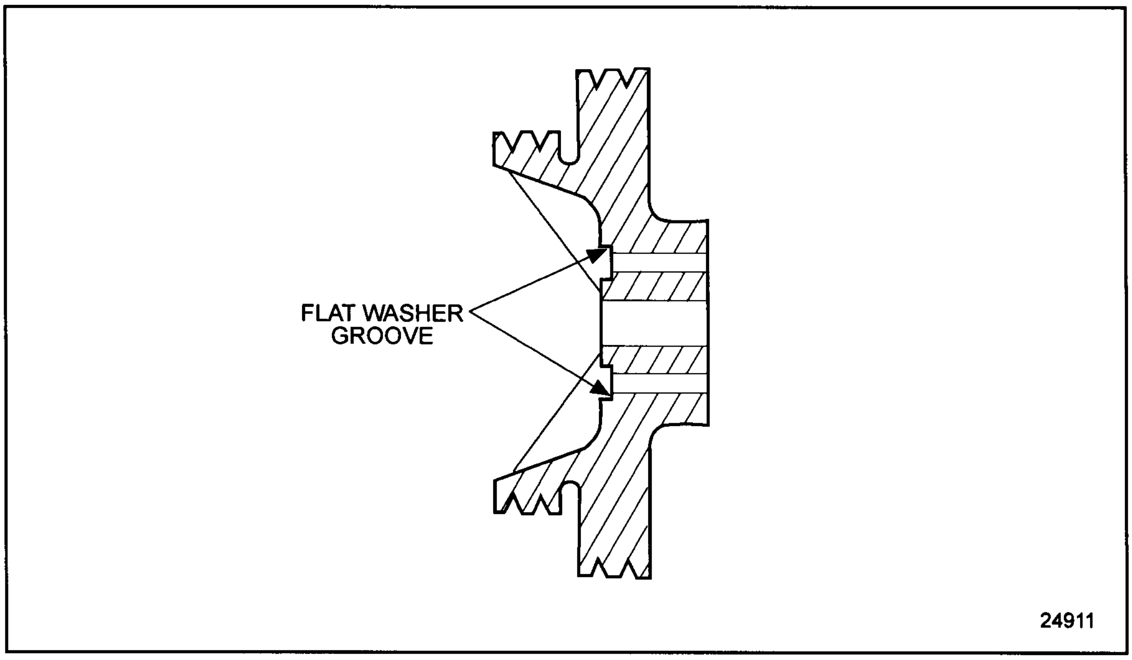


Figure 1-198 Crankshaft Pulley Cross-section

Four 12.7 mm (0.50 in.) vee-type grooves in the crankshaft pulley provide drive belt seating surfaces.

A 3/4 in. square drive hole in the center of the crankshaft pulley allows the use of a 3/4 in. drive breaker bar or ratchet for barring the engine over. See Figure 1-199.

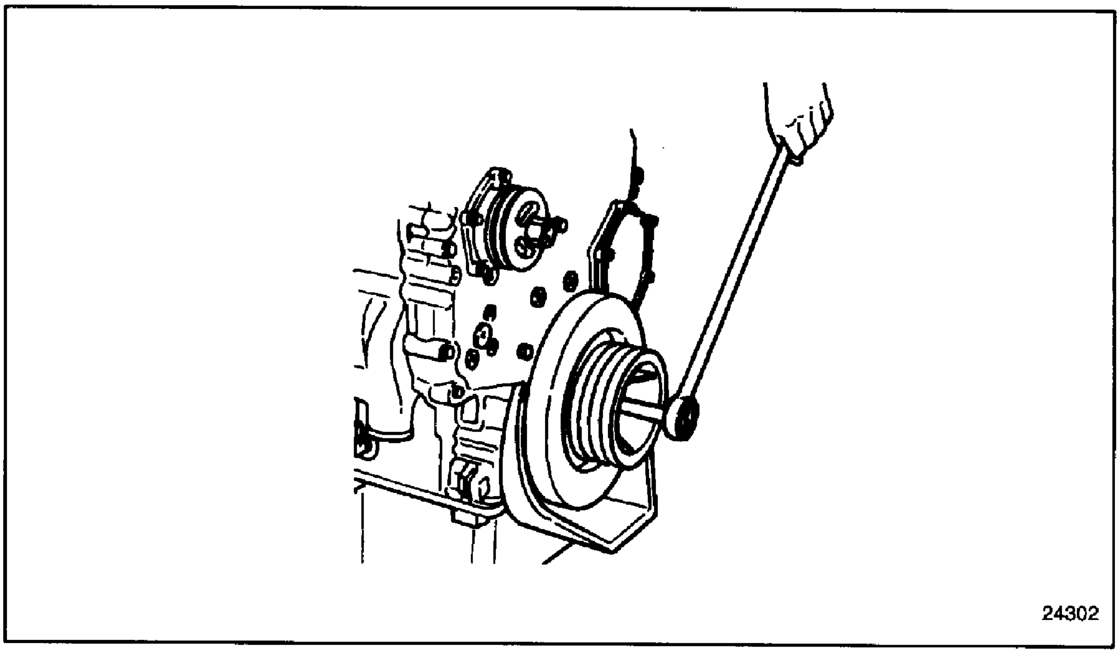
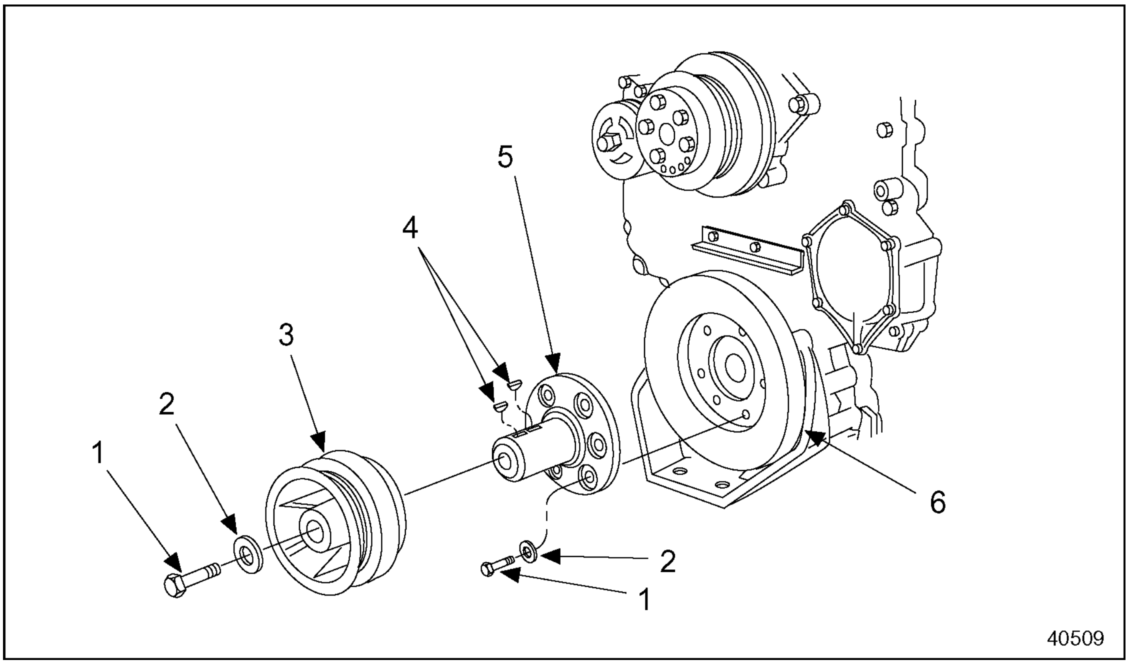


Figure 1-199 Barring Engine Over

The crankshaft pulley and hub assembly with spindle. See Figure 1-200. The spindle is attached to the crankshaft with six special bolts and washers, which also secure the vibration damper to the crankshaft. Two woodruff keys and the crankshaft pulley bolt secure the crankshaft pulley and hub assembly to the spindle.

NOTE:
Do not substitute any other bolts or washers. The spindle bolts and washers are special parts. These bolts are not reusable.



1. Bolt
2. Washer
3. Crankshaft Pulley and Hub Assembly
4. Woodruff Key
5. Crankshaft Pulley Spindle
6. Viscous Vibration Damper

Figure 1-200 Crankshaft Pulley and Hub Assembly Installation with Spindle

The spindle has six equally spaced mounting holes. A relief area is machined around each bolt hole and acts as a seating surface for the hardened washers. See Figure 1-201.

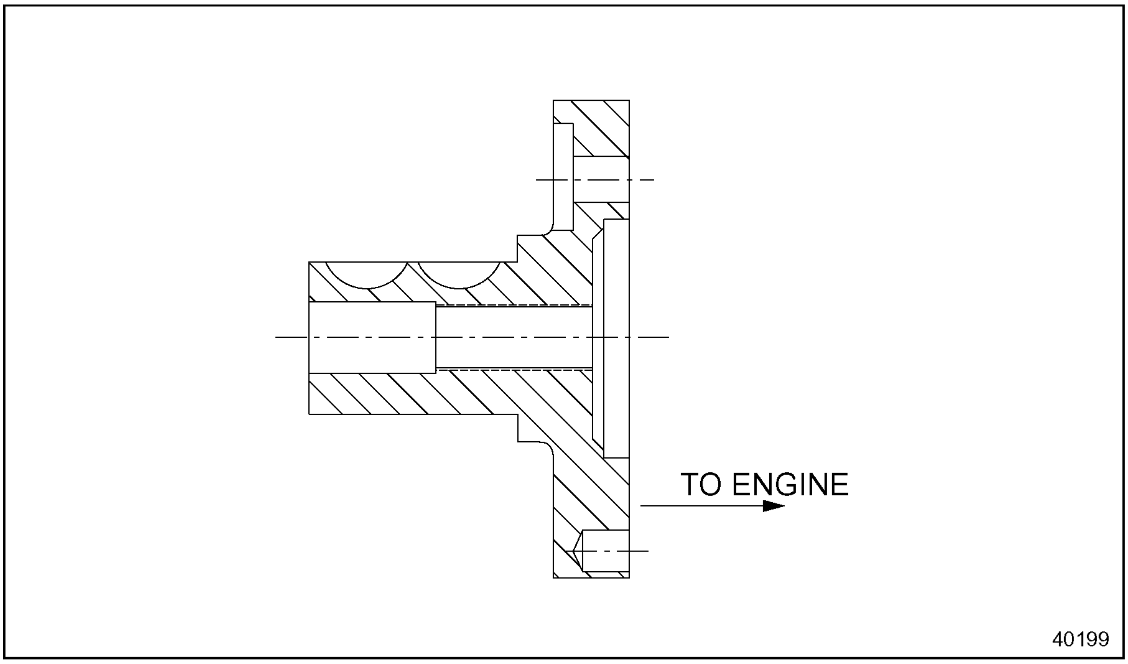


Figure 1-201 Crankshaft Pulley Spindle

The crankshaft pulley assembly is secured to the spindle with two woodruff keys, a crankshaft pulley bolt and hardened washer. The crankshaft pulley bolt is also used to bar the engine over. See Figure 1-200.

1.13.1 Repair or Replacement of Crankshaft Pulley

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-202.

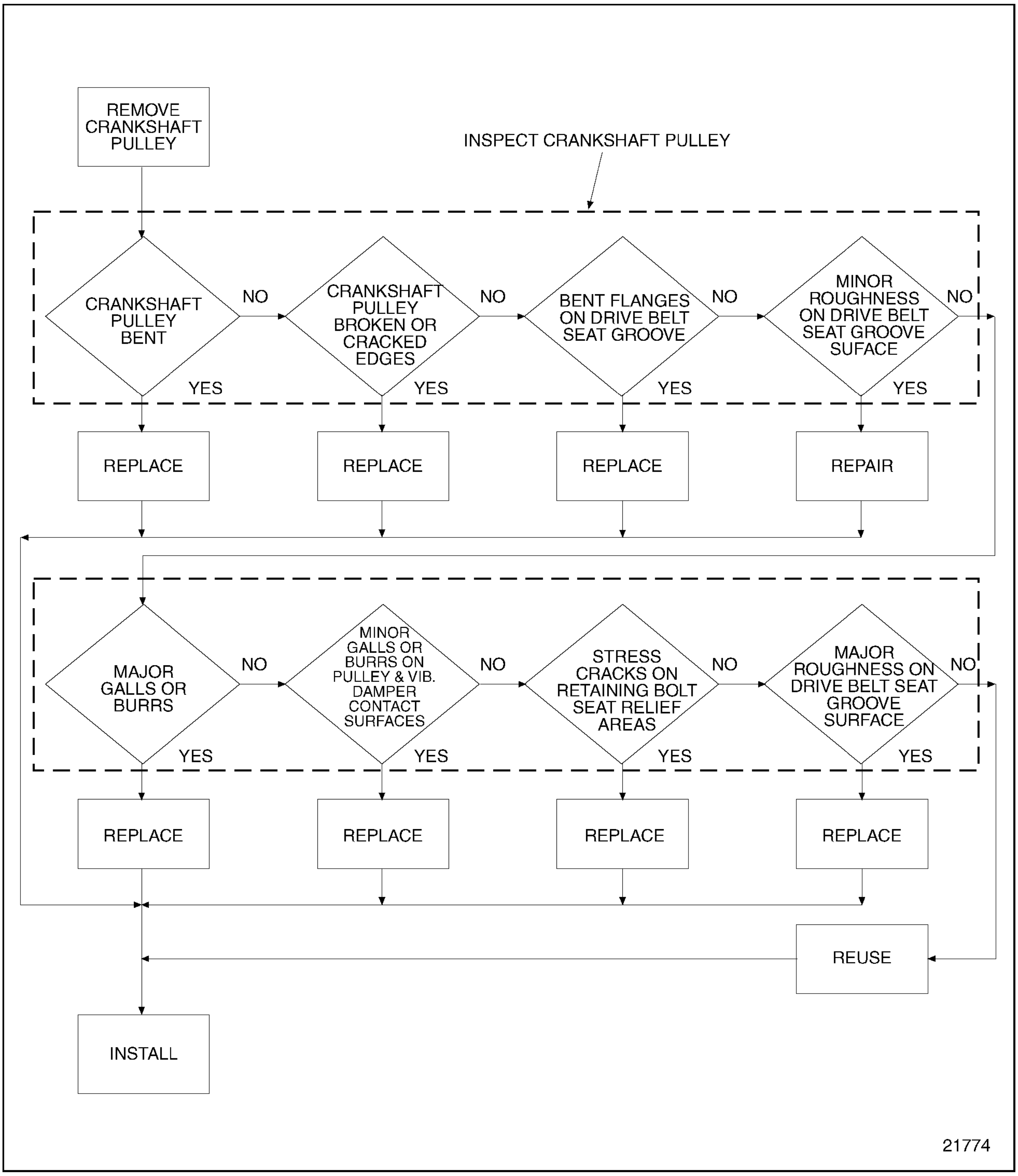


Figure 1-202 Flowchart for Repair or Replacement of Crankshaft Pulley

1.13.2 Removal and Cleaning Crankshaft Pulley

Precleaning is not necessary.

Remove a crankshaft mounted pulley as follows:

1. Remove the drive belts from the crankshaft pulley.
2. Remove the inspection plug in the bottom of the flywheel housing.
3. Install the flywheel lock, J 36375–A. See Figure 1-195.
4. Thread the center screw of the tool in until the top of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

5. Finger-tighten the knurled knob.
6. Remove two of the six crankshaft pulley-to-crankshaft attaching bolts and hardened washers that are 180 ° apart. Discard the bolts. These bolts are not reusable. See Figure 1-203.

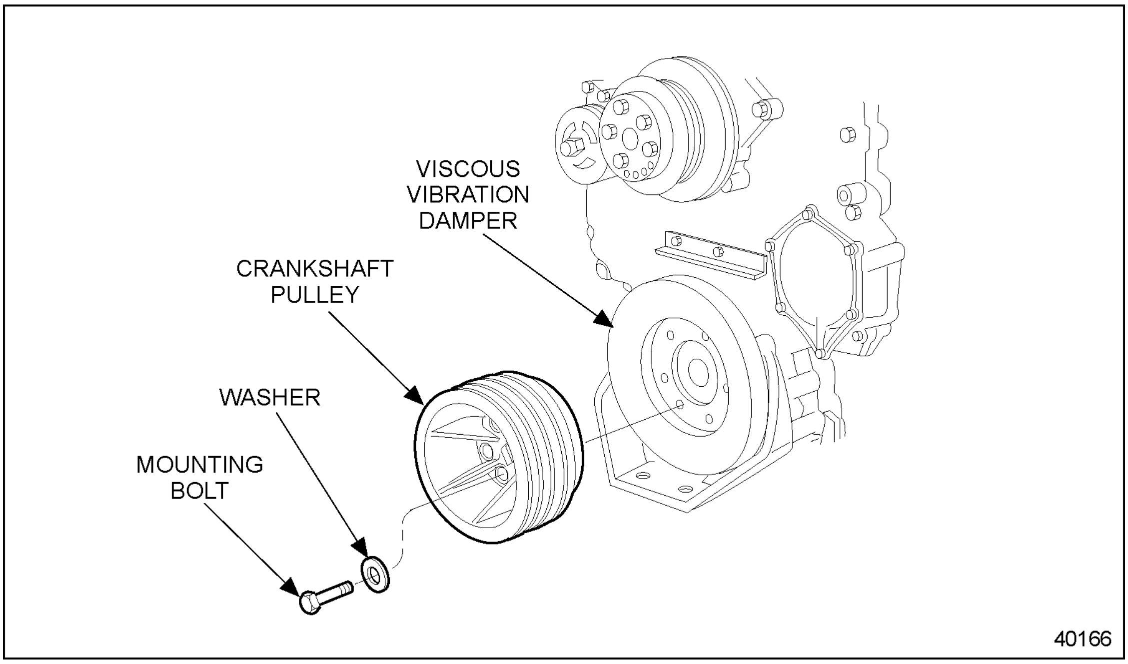


Figure 1-203 Crankshaft Pulley Mounted Directly to the Crankshaft

7. Install guide studs, J 36235, to the holes where the bolts were removed.

NOTICE:
Use care when removing the crankshaft pulley as the vibration damper, which is slip fitted over a pilot diameter of the crank, may come off. If the damper is allowed to fall, internal damage to the damper will result.

8. Remove the remaining four crankshaft pulley bolts and hardened washers. Discard the bolts. These bolts are not reusable.
9. Remove the crankshaft pulley by sliding it off the guide studs.

NOTE:
Leave the guide studs in place to prevent the vibration damper from falling off.

Remove a spindle mounted pulley and hub assembly as follows:

1. Remove the drive belts from the crankshaft pulley.
2. Remove the inspection plug in the bottom of the flywheel housing.
3. Install the flywheel lock, J 36375–A. See Figure 1-195.
4. Thread the center screw of the tool in until the top of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over using the crankshaft pulley bolt so that the tool center screw is exactly between two teeth.

5. Finger-tighten the knurled knob.

6. Loosen the center bolt holding the pulley and hub assembly to the spindle. See Figure 1-204.

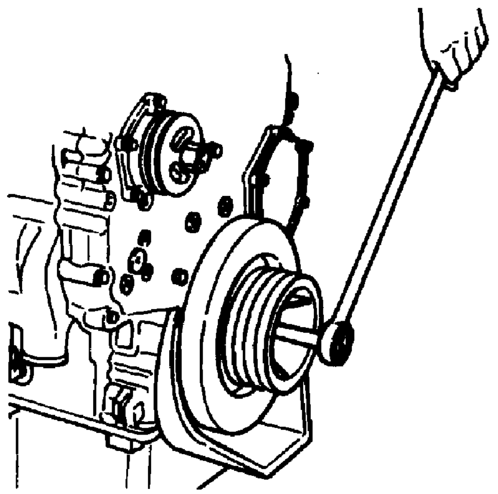


Figure 1-204 Barring Engine Over

7. With the pulley properly supported, remove the bolt and washer and pull the pulley and hub assembly off of the spindle.
8. Remove two of the six spindle to crankshaft attaching bolts and hardened washers that are 180 degrees apart. Discard the bolts. These bolts are not reusable.
9. Install two guide studs, J 36235, to the holes from which the bolts were removed.

NOTICE:
Use care when removing the spindle as the vibration damper, which is slip fitted over a pilot diameter of the crank, may come off. If the damper is allowed to fall, internal damage to the damper will result.

10. Remove the remaining four spindle attaching bolts and hardened washers. Discard all six bolts. These bolts are not reusable.
11. Remove the spindle by sliding it off the guide studs.

NOTE:
Leave the guide studs in place to prevent the vibration damper from falling off.

1.13.2.1 Inspection of Crankshaft Pulley

Inspect the crankshaft pulley or spindle and crankshaft pulley and hub assembly as follows:

1. Inspect the crankshaft pulley or spindle and crankshaft pulley and hub assembly.

NOTICE:
A loose or bent crankshaft pulley, after extended operation, may result in a cracked crankshaft.

   [a] Determine if the crankshaft pulley or spindle is bent, broken or has cracked edges.

   [b] If damage is detected, replace with a new part.

   [c] If damage to the crankshaft pulley, pulley and hub assembly or spindle is extensive, Refer to section 1.12.2.1, and inspect the vibration damper. Refer to section 1.7.2.1 and inspect the crankshaft.

2. Inspect the drive belt seat grooves.

   [a] Check drive belt seat grooves for bent flanges or a rough belt seating surface.

   [b] Smooth rough seating surfaces with an emery cloth or a stone.

   [c] If flanges are bent, replace the pulley.

3. Inspect the retaining bolt seat relief areas.

   [a] Check relief area for stress cracks.

   [b] If stress cracks are discovered, replace the pulley or spindle.

4. Inspect the direct mounted pulley (or spindle) and vibration damper inner contact surfaces. See Figure 1-205.

   [a] Check for galling or burrs.

   [b] Minor galls burrs may be smoothed with an emery cloth.

[c] If galls or burrs are major, the pulley or spindle will need to be replaced.

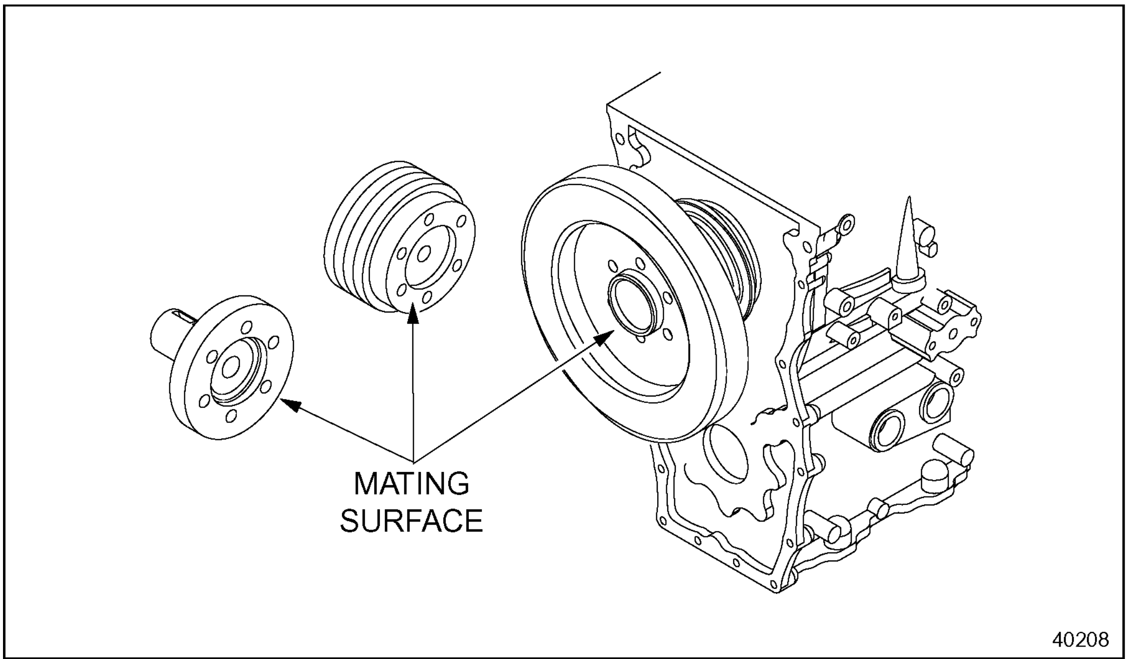


Figure 1-205 Crankshaft Pulley (or Spindle) and Vibration Damper Inspection

1.13.3 Installation of Crankshaft Pulley

Install a crankshaft pulley as follows:

1. If removed, install the flywheel lock, J 36375–A, to the inspection plug hole in the bottom of the flywheel housing. See Figure 1-195.
2. Thread the center screw of the tool until the tip of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine slightly using engine barring tool, J 36237, so that the tool center screw is exactly between two teeth.

3. Finger-tighten the knurled knob.

NOTICE:
Use care when removing the spindle as the vibration damper, which is slip fitted over a pilot diameter of the crank, may come off. If the damper is allowed to fall, internal damage to the damper will result.

4. Install two guide studs, J 36235, to two of the holes in the crankshaft that are 180 degrees apart.
5. Install the vibration damper over the guide studs and onto the crankshaft. Refer to section 1.12.3.
6. Install the crankshaft pulley over the guide studs and onto the crankshaft. The crankshaft pulley may be installed in any position.

NOTICE:

Crankshaft pulley and spindle mounting bolts are considered single-use items and *must not be reused.*Always use new bolts when mounting the crankshaft pulley or spindle. Reusing bolts may result in excessive bolt stretch during installation, leading to loss of bolt torque and loosening during the engine operation, which may cause severe engine damage.

7. Install four new special crankshaft pulley-to-crankshaft attaching bolts with hardened washers installed, through the pulley and damper and into the crankshaft. Finger tighten the bolts. See Figure 1-206.

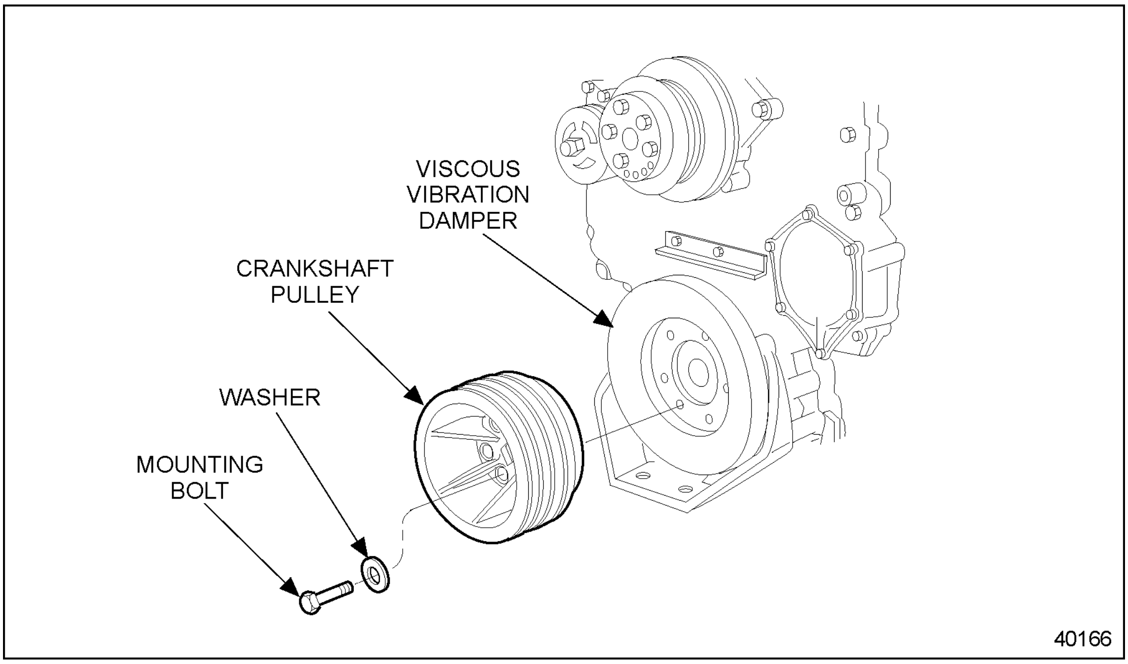


Figure 1-206 Crankshaft Pulley Mounted Directly to the Crankshaft

8. Remove the two guide studs.
9. Install the remaining two new special crankshaft pulley-to-crankshaft attaching bolts with hardened washers installed.
10. Torque the six new special bolts to 182-210 N·m (134-155 lb·ft). Proceed in a clockwise direction until all bolts are torqued.
11. Remove the flywheel lock tool.
12. Install the pipe plug to the inspection hole in the flywheel housing.
13. Install the drive belts to the crankshaft pulley. Adjust the belt tensions to the specifications. Refer to section 13.5.7.
14. Install any other components that were removed for this operation.

Install the spindle mounted pulley and hub assembly as follows:

1. If removed, install the flywheel lock, J 36375–A. See Figure 1-195.
2. Thread the center screw of the tool in until the top of the tool rests between two teeth of the flywheel ring gear.
3. Finger-tighten the knurled knob.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

4. Install two guide studs to two of the holes in the crankshaft that are 180 degrees apart.
5. Install the vibration damper over the guide studs and onto the crankshaft.
   Refer to section 1.12.3.

NOTICE:
Use care when removing the spindle as the vibration damper, which is slip fitted over a pilot diameter of the crank, may come off. If the damper is allowed to fall, internal damage to the damper will result.

6. Install the crankshaft pulley spindle over the guide studs, onto the crankshaft and against the vibration damper. The crankshaft pulley spindle may be installed in any position. See Figure 1-207.

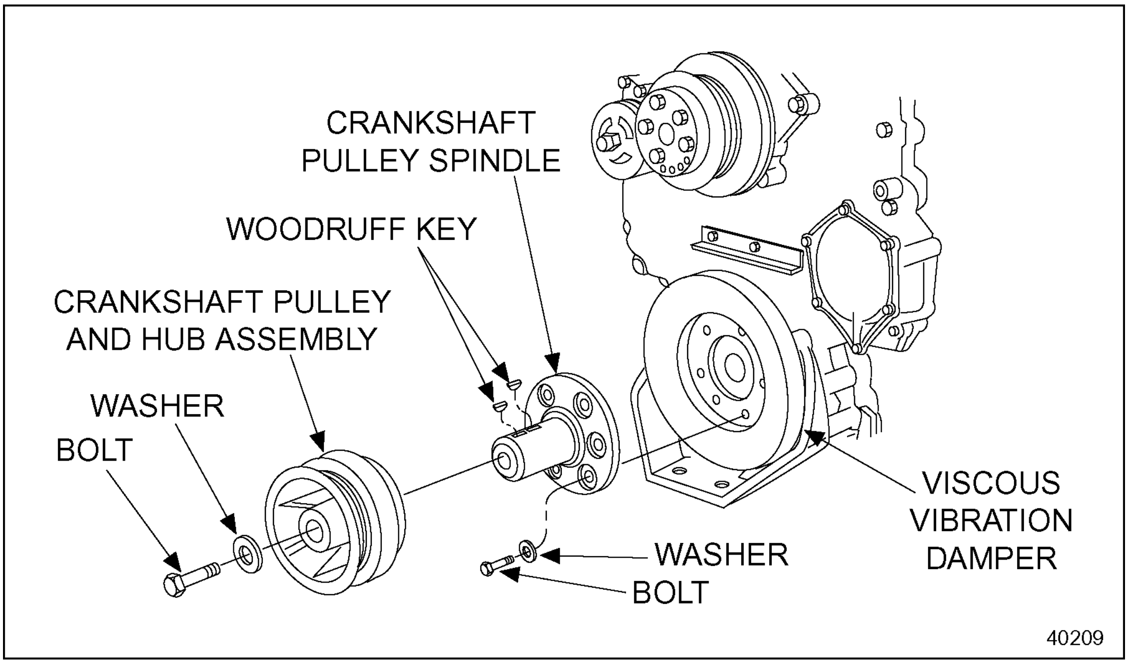


Figure 1-207 Crankshaft Pulley and Hub Assembly Installation with Spindle

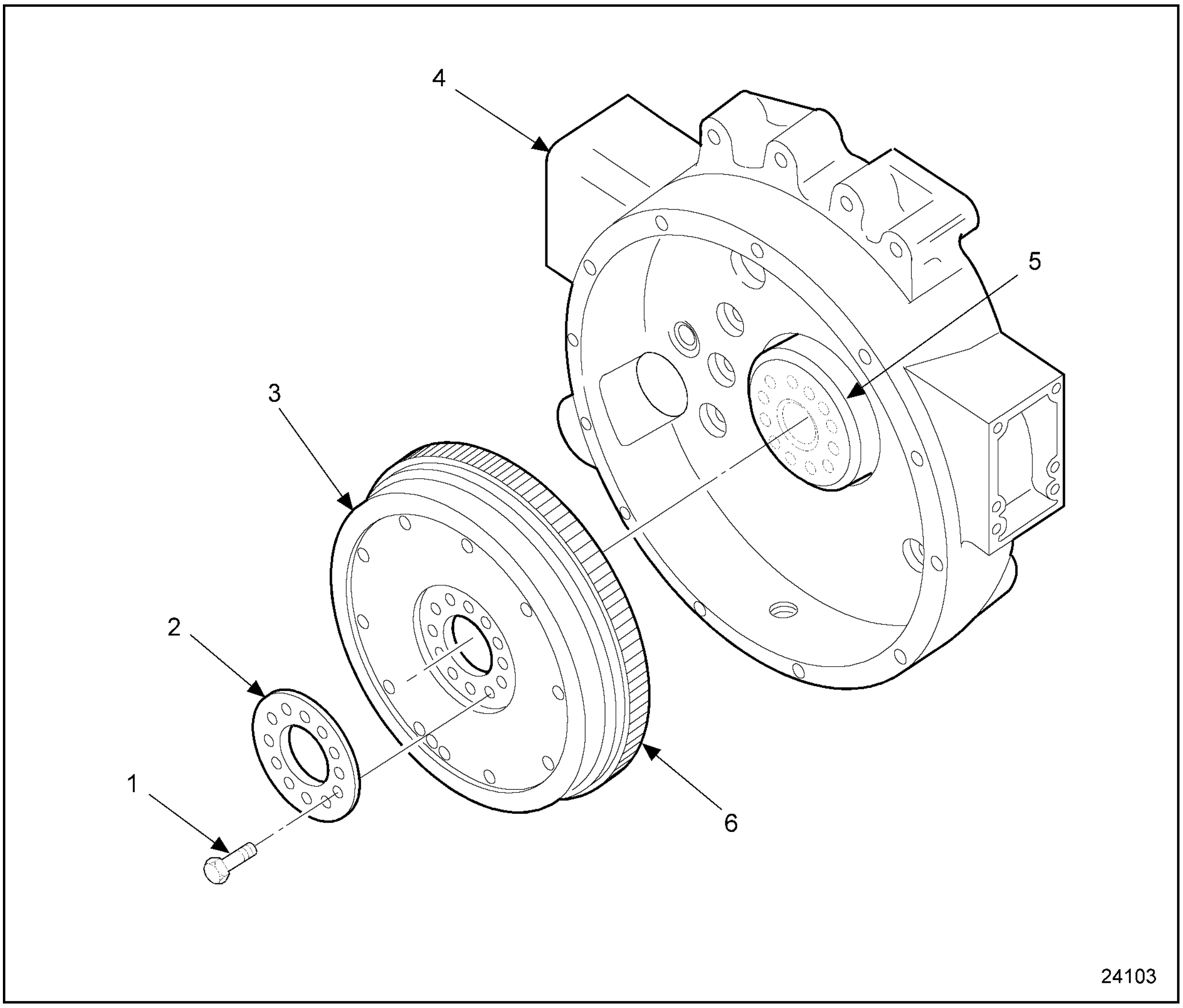
NOTICE:
Crankshaft pulley and spindle mounting bolts are considered single-use items and *must not be reused.*Always use new bolts when mounting the crankshaft pulley or spindle. Reusing bolts may result in excessive bolt stretch during installation, leading to loss of bolt torque and loosening during the engine operation, which may cause severe engine damage.

7. Install four new special crankshaft pulley spindle-to-crankshaft attaching bolts with hardened washers installed.
8. Remove the two guide studs, J 36235, from the holes.
9. Install the remaining two new special crankshaft pulley spindle-to-crankshaft attaching bolts with hardened washers installed.

10. Torque the six new special bolts to 182-210 N·m (134-155 lb·ft). Proceed in a clockwise direction until all bolts are torqued.
11. With the pulley properly supported, install the bolt and washer and pull the pulley to the spindle.
12. Torque the center bolt holding the pulley to the spindle to 610 N·m (450 lb·ft).
13. Remove the flywheel lock tool.
14. Install the pipe plug to the inspection hole in the flywheel housing.
15. Install the drive belts to the crankshaft pulley. Adjust the belt tensions to the specifications. Refer to section 13.5.7.
16. Install any other components that were removed for this operation.
17. Refer to section 11.8 for verification of proper crankshaft pulley installation.

1.14 FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with twelve bolts. The bolt holes in the crankshaft and flywheel are equally spaced. The flywheel is not indexed to the crankshaft, and may be installed in any position. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface. See Figure 1-208.



1. Bolt (12)
2. Scuff Plate
3. Flywheel
4. Flywheel Housing
5. Crankshaft
6. Ring Gear

Figure 1-208 Typical Flywheel Assembly

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel. Refer to Section 1.15.

The flywheel is machined to provide true alignment with the clutch. The clutch plate, if used, is bolted to the flywheel with 3/8 in.-16 bolts.

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

1.14.1 Repair or Replacement of Flywheel

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-209.

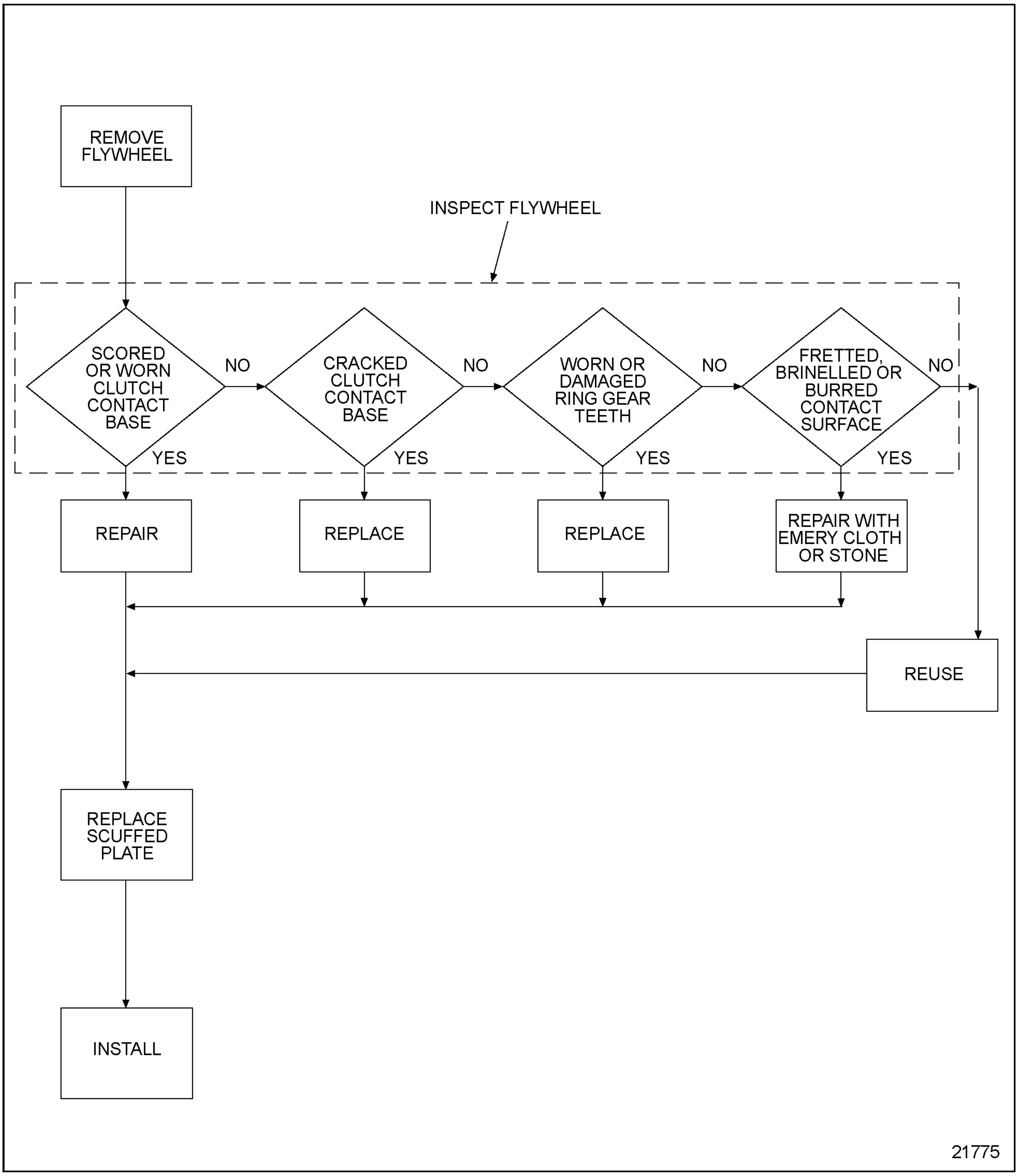


Figure 1-209 Flowchart for Repair or Replacement of Flywheel

1.14.2 Cleaning and Removal of Flywheel

Precleaning is not necessary.

Remove the flywheel as follows:

1. Remove the inspection plug in the bottom of the flywheel housing.
2. Install the flywheel lock, J 36375–A. See Figure 1-195.
3. Thread the center screw of the tool in until the tip of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

4. Finger-tighten the knurled knob.
5. Remove eleven of the twelve flywheel attaching bolts, leaving one bolt at the 12 o'clock position.
6. Install two flywheel guide studs, J 36235, through the flywheel and into the crankshaft at the 3 and 9 o'clock positions. See Figure 1-210.

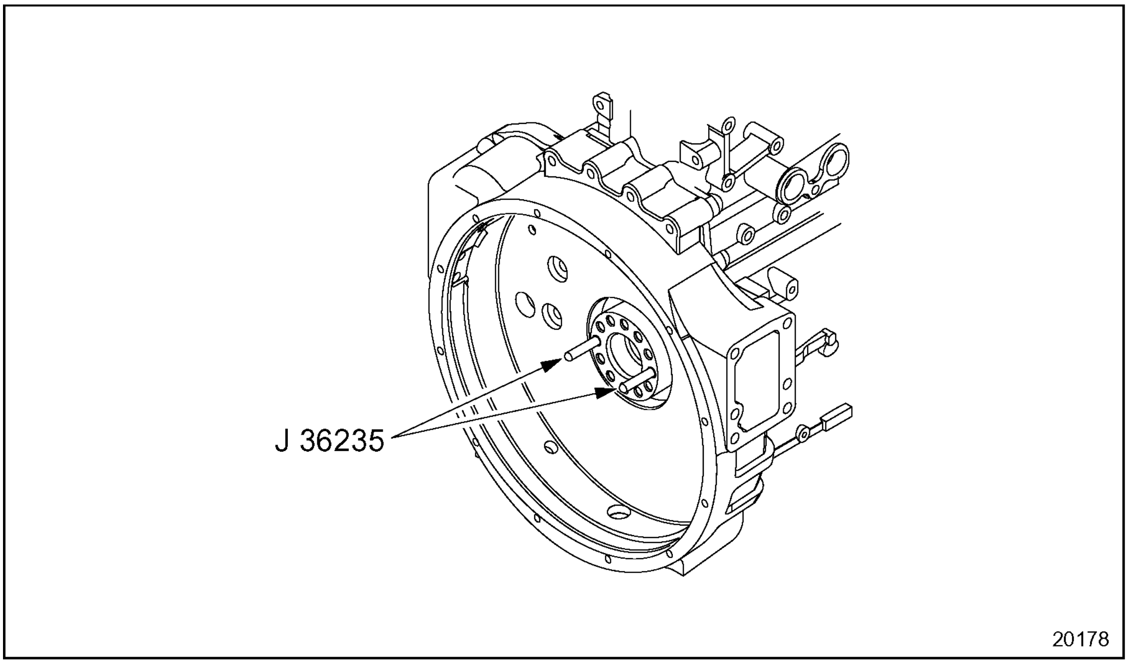


Figure 1-210 Flywheel Guide Studs

7. Attach the flywheel lifting tool, J 25026 part of J 25026–A, or some other suitable lifting device, to the flywheel. See Figure 1-211.

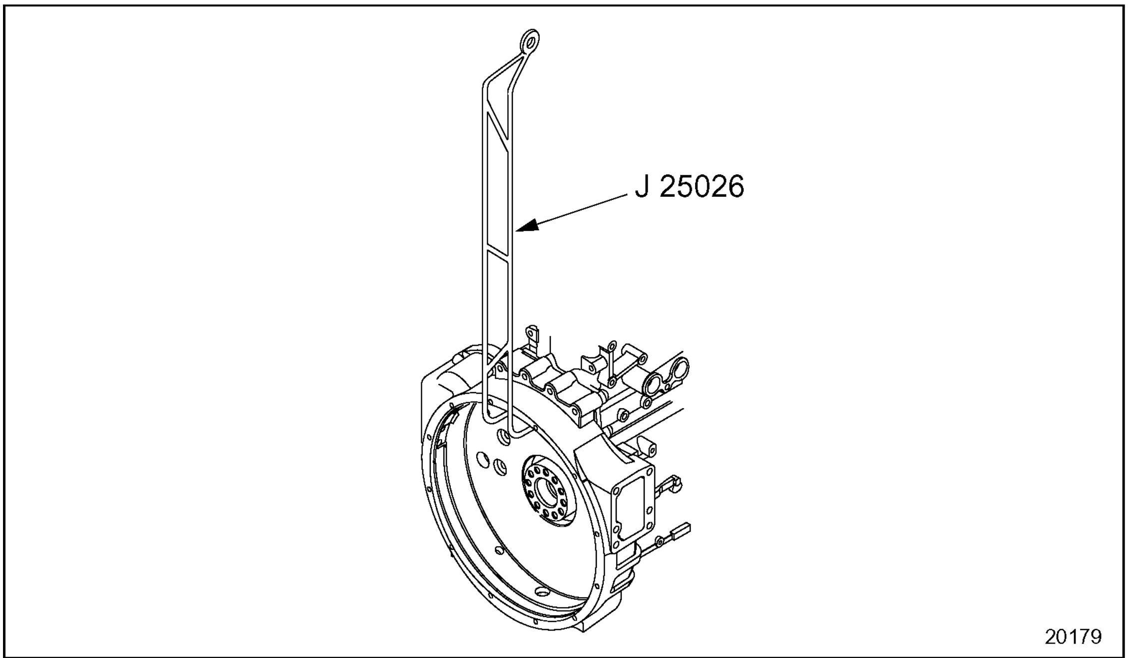


Figure 1-211 Flywheel Removal

8. Attach a chain hoist to the lifting tool.
9. Loosen, but do not remove the last flywheel attaching bolt.
10. Remove the flywheel lock.

CAUTION:

To avoid injury from a falling flywheel when removing the last bolt, hold the flywheel against the crankshaft by hand to prevent it from slipping off the crankshaft. The flywheel is not doweled to the crankshaft.

11. Remove the last flywheel attaching bolt and scuff plate.
12. Remove flywheel.

1.14.2.1 Inspection of Flywheel

Inspect the flywheel as follows:

1. Inspect the clutch contact base of the flywheel.
   [a] Check clutch contact base for scoring, wear, or cracks.

[b] If clutch contact face is scored or worn, the flywheel may be refaced.

[c] If clutch contact face is cracked, the flywheel must be replaced.

NOTE:
Do not remove more than 0.508 mm (0.020 in.) material from the flywheel. Maintain all of the radii when resurfacing.

2. Inspect the ring gear.

   [a] Check ring gear for excessively worn or damaged gear teeth.

   [b] If damaged gear teeth are detected, replace the ring gear. Refer to Section 1.15.3.

3. Inspect crankshaft and flywheel contact surface.

   [a] Check the butt end of the crankshaft and flywheel contact surface for fretting, brinelling, or burrs. See Figure 1-212.

   [b] Lightly stone the contact surface to remove any fretting, brinelling, or burrs.

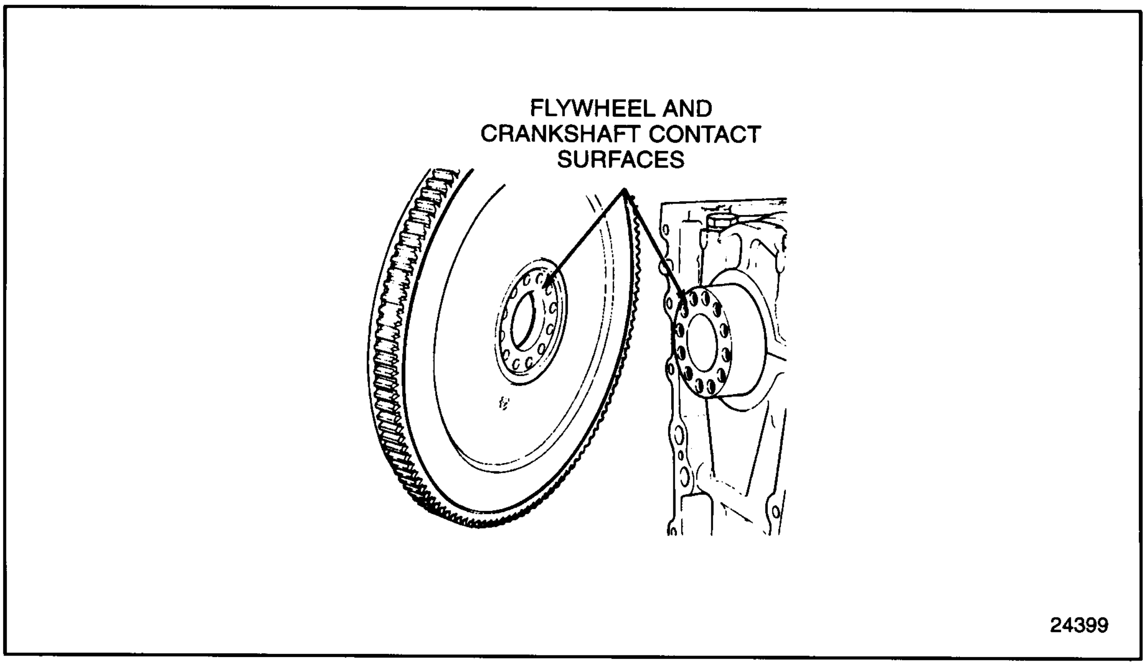


Figure 1-212 Crankshaft and Flywheel Mating Surfaces

1.14.3 Installation of Flywheel

Install the flywheel as follows:

1. Install two flywheel guide studs, J 36235, into two of the tapped holes in the crankshaft at the 3 and 9 o'clock position.
2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing. Align the flywheel bolt holes with the crankshaft bolt holes.

NOTICE:
A new scuff plate must be used whenever the flywheel is removed. Failure to replace the scuff plate may cause the flywheel bolts to loosen, even when torqued correctly.

3. Using a new scuff plate, install two bolts with International Compound #2® (or equivalent) through the plate 180° from each other.
4. Install the flywheel lock, J 36375–A. See Figure 1-195.
5. Remove the flywheel lifting tool and guide studs.
6. Apply International Compound #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 #2® (or equivalent). Any excess must be wiped off. See Figure 1-213.

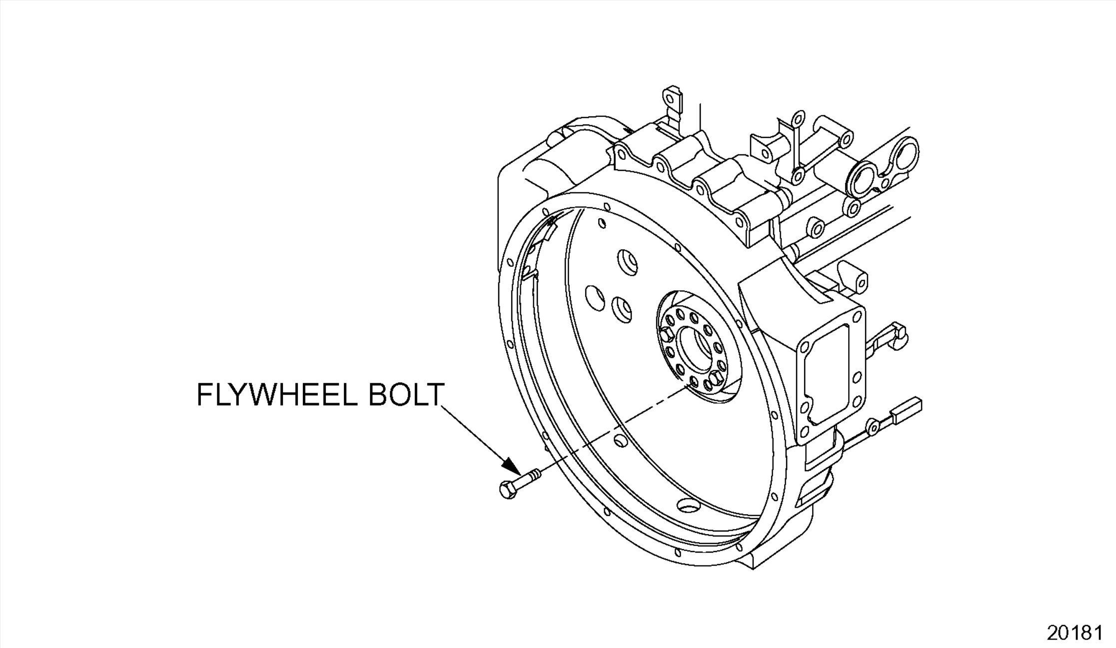


Figure 1-213 Flywheel Bolt Preparation

NOTE:
International Compound #2® or equivalent must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

7. Install the bolts and torque them to 68 N·m (50 lb·ft).

8. Turn the bolts an additional 120 degrees, or 2 flats on a six-point bolt. See Figure 1-214.

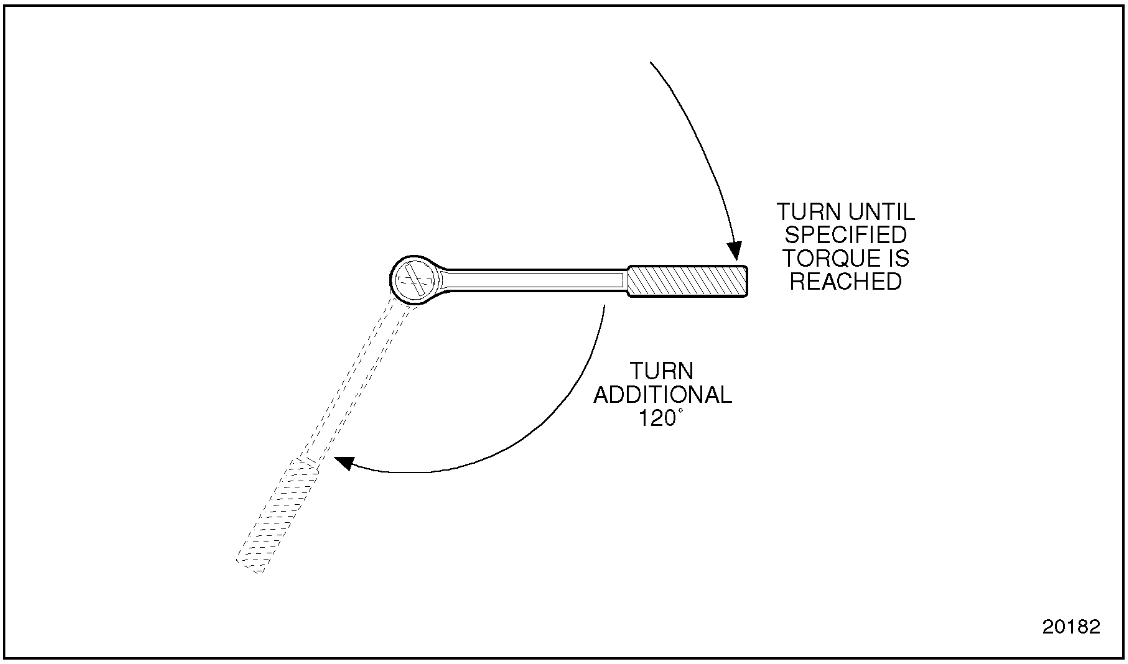


Figure 1-214 Torque Turn Limits

9. Remove the flywheel lock tool, J 36375–A.
10. Install the pipe plug and torque to 45-56 N·m (33-41 lb·ft).
11. Mount a dial indicator with a magnetic base on the flywheel housing. See Figure 1-215.

12. Check the run-out of the flywheel at the clutch contact face.

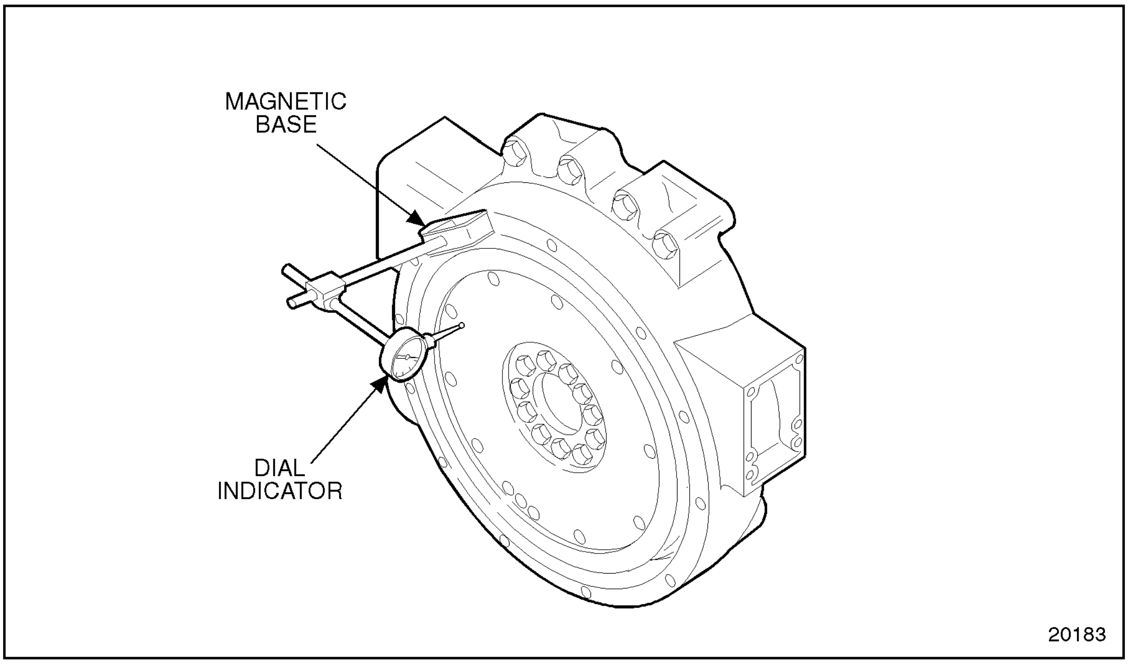


Figure 1-215 Measuring Flywheel Runout

13. The maximum allowable run-out is 0.025 mm (0.001 in.) total indicator reading per inch of radius (or 0.001 mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel. Example: A 14 in. clutch would allow 0.175 mm (0.007 in.) total indicator reading.
14. If maximum total indicator reading exceeds, 0.025 mm (0.001 in.) per inch of radius, it may be necessary to repeat the assembly procedure until the cause can be detected and eliminated.

1.15 RING GEAR

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

1.15.1 Repair or Replacement of Ring Gear

Inspection of the flywheel indicated that ring gear replacement is necessary. See Figure 1-216.

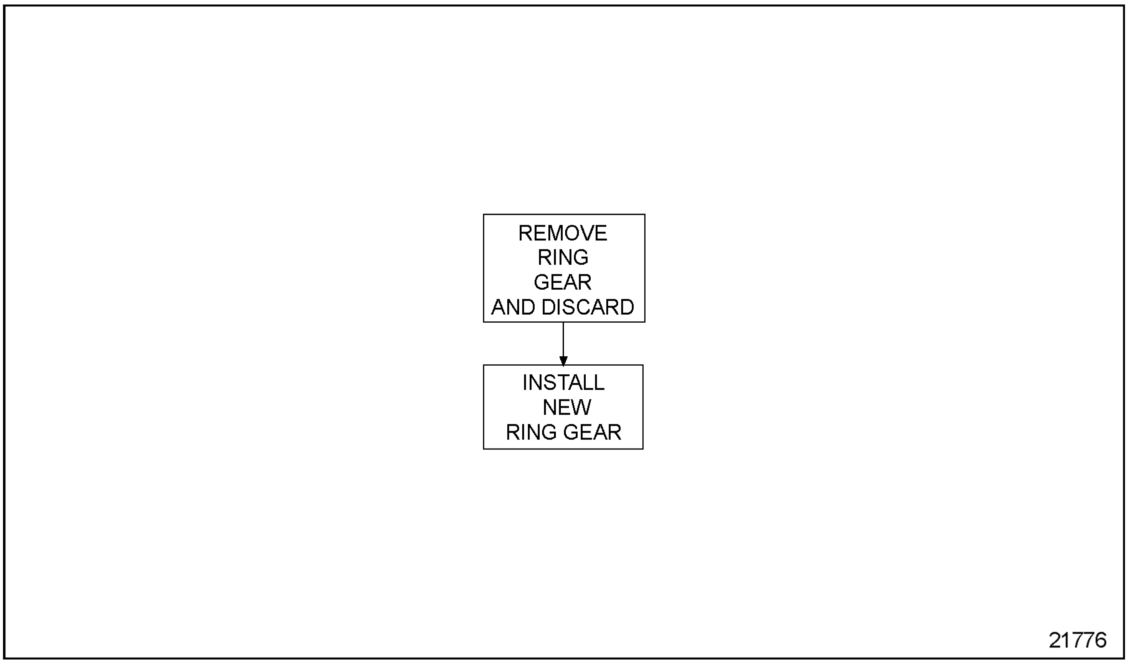


Figure 1-216 Flowchart for Repair or Replacement of Ring Gear

1.15.2 Cleaning and Removal of Ring Gear

Precleaning is not necessary.

Remove the ring gear as follows:

1. Using an acetylene torch, cut the ring gear 1/2 to 3/4 of the way through, without allowing the flame to touch the flywheel.
2. The uncut portion will now yield. Tap the ring gear to remove it from the flywheel.

1.15.3 Installation of Ring Gear

Install the ring gear as follows:

1. Support the flywheel, ring gear side up, on a solid flat surface.

CAUTION:

To avoid injury from burning, use lifting tools and heat-resistant gloves when handling heated components.

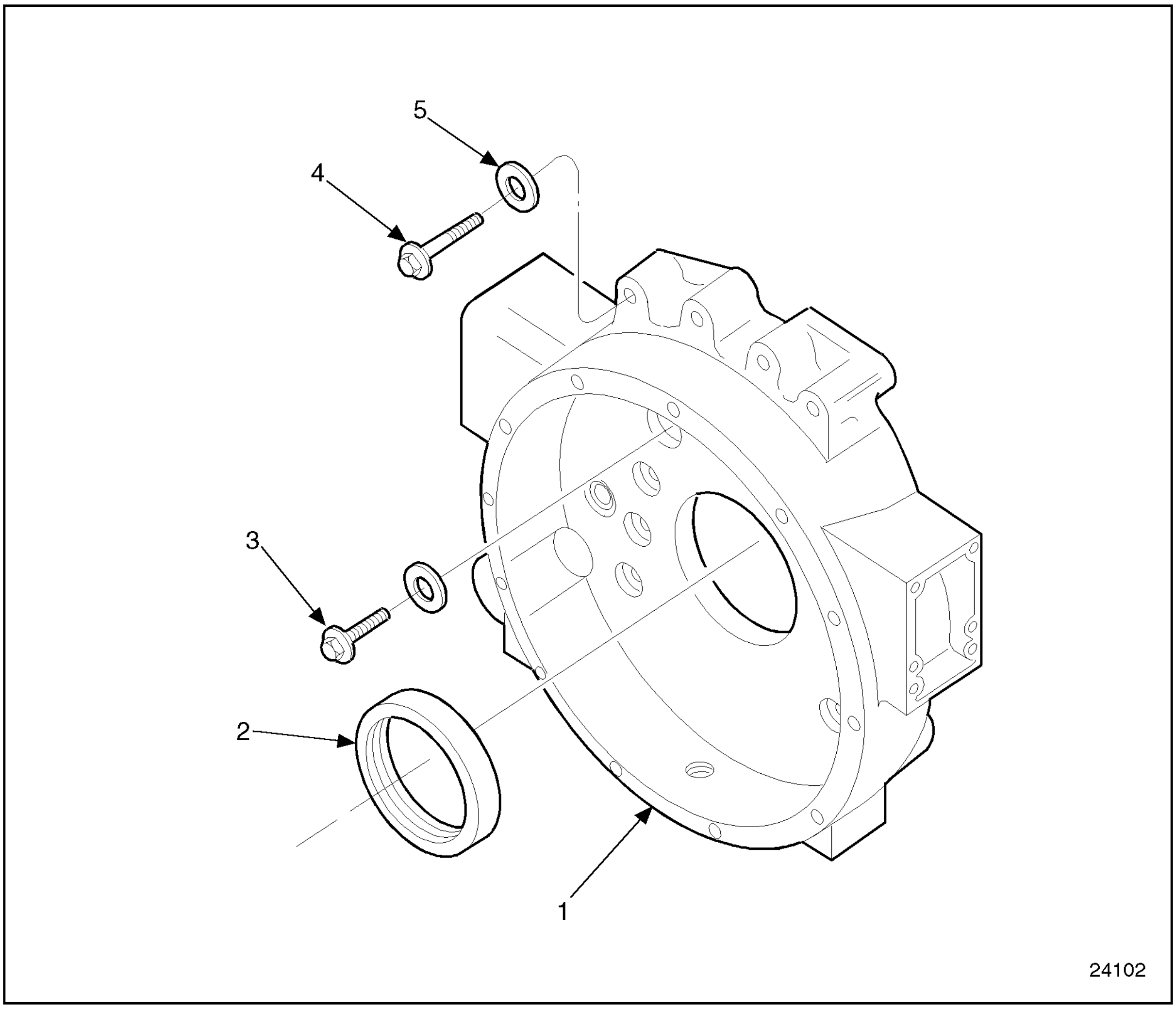
NOTICE:

Do not under any circumstances, heat the gear over 204°C (399°F). 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.

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.
3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it, and apply additional heat.

1.16 FLYWHEEL HOUSING

The flywheel housing is a one-piece casting mounted against the rear of the cylinder block. It provides a cover for the flywheel and serves as a support for the cranking motor and the transmission. See Figure 1-217.



1. Flywheel Housing
2. Crankshaft Rear Oil Seal
3. Inner Bolt (8 short)
4. Outer Bolt (4 long)
5. Washer (12)

Figure 1-217 Flywheel Housing and Related Parts

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing. Refer to Section 1.8.2.

1.16.1 Repair or Replacement of Flywheel Housing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-218.

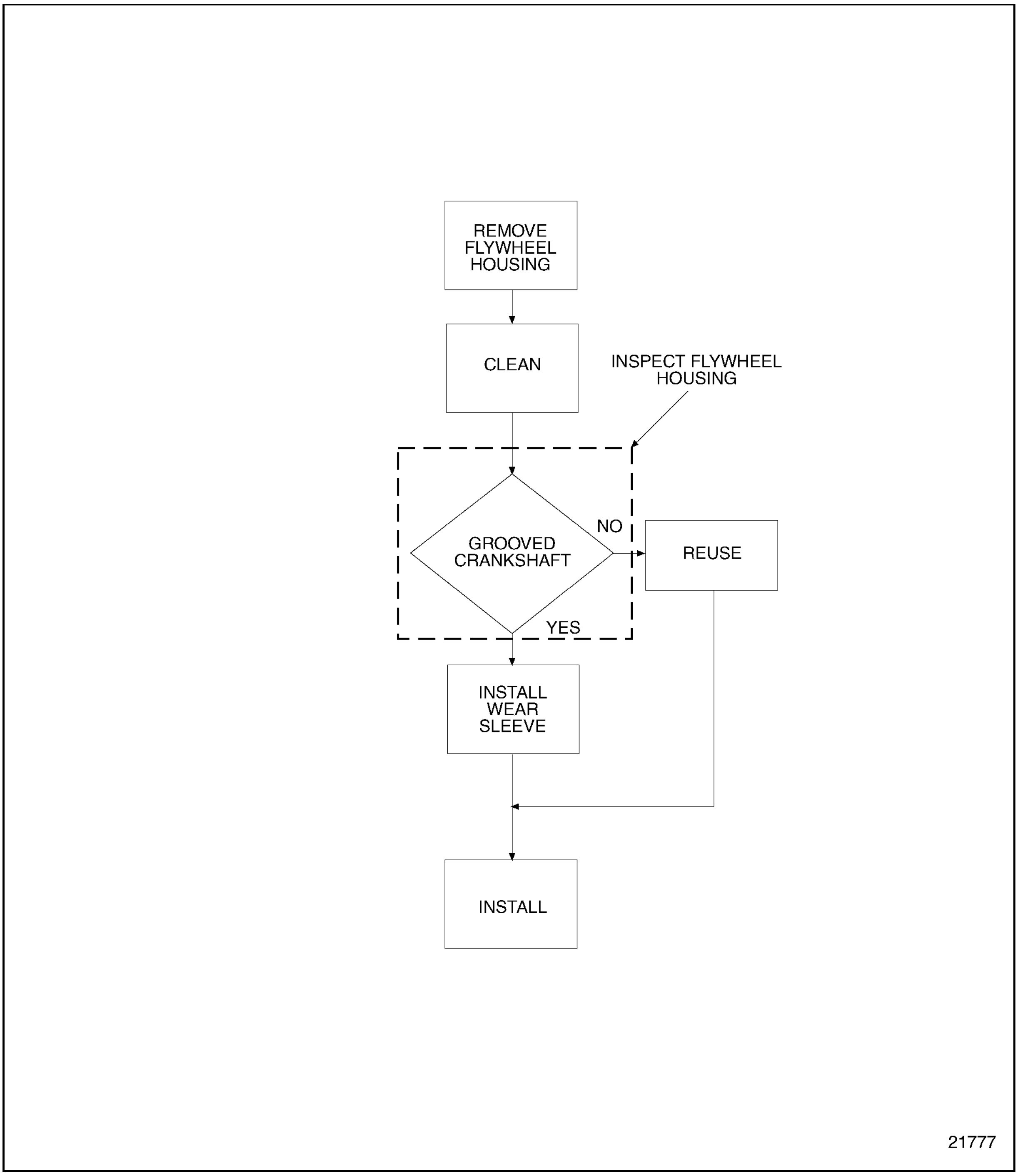


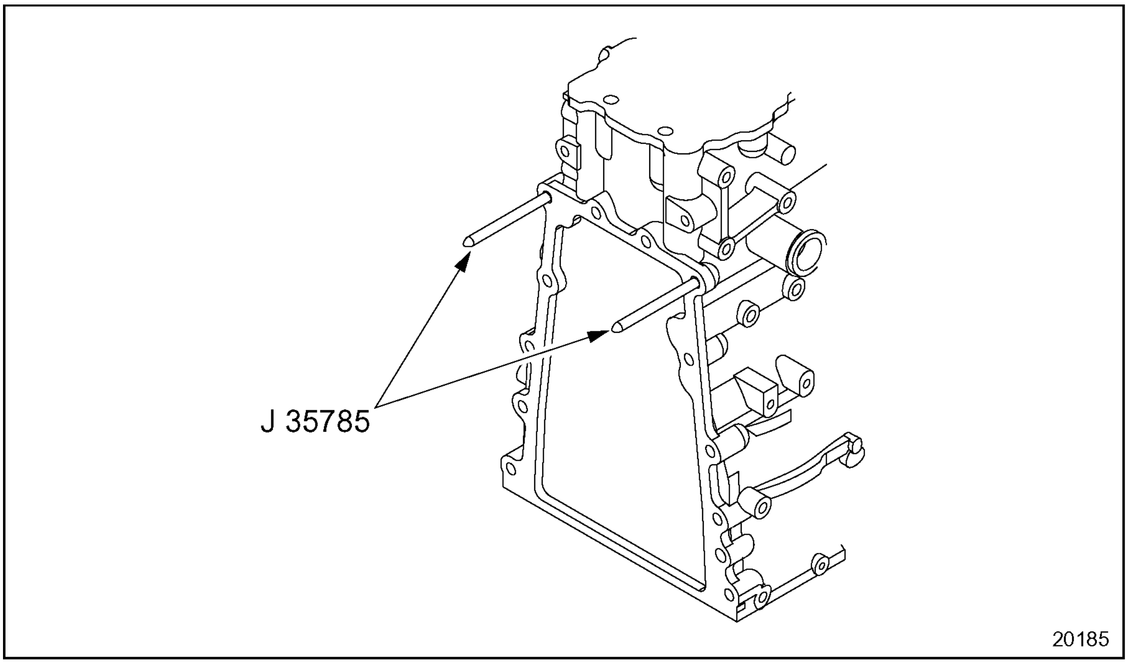
Figure 1-218 Flowchart for Repair or Replacement of Flywheel Housing

1.16.2 Cleaning and Removal of Flywheel Housing

Precleaning is not necessary.

Remove the flywheel housing as follows:

1. If the engine is removed from the vehicle, mount the engine on an overhaul stand. Refer to Section 1.1.2.
2. Drain engine oil and remove the oil pan. Refer to Section 3.9.2.
3. Remove the flywheel and scuff plate. Refer to Section 1.14.2.
4. Remove the four long outer bolts and the eight short inner bolts that secure the flywheel housing to the engine. See Figure 1-217.
5. To guide the flywheel housing until it clears the end of the crankshaft, thread two guide studs, J 43431 for 14 mm bolts or J 35785 for 12 mm bolts, into the cylinder block. See Figure 1-219.



NOTE: The illustration is shown with the flywheel housing already removed for clarity.

Figure 1-219 Pilot Stud Installation

6. Thread eye bolts into the tapped holes in the side pads of the flywheel housing.
7. Attach a suitable sling to the eye bolts.
8. Strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.
9. Remove and discard the crankshaft rear oil seal.

10. Remove all sealing material from the flywheel housing.

1.16.2.1 Inspection of Flywheel Housing and Rear Oil Seal Area of Crankshaft

Inspect the flywheel housing as follows:

1. Inspect flywheel housing for cracks and any other damage.
   [a] If sealing surface is damaged, repair with emery cloth.
   [b] If cracked, repair is not possible.
2. Inspect the crankshaft where the rear oil seal makes contact.
   [a] Check for groove in crankshaft.
   [b] If crankshaft is grooved, install a wear sleeve over the crankshaft end. An oversized I.D. rear oil seal must be used with the rear sleeve.

1.16.3 Installation of Flywheel Housing

Install the flywheel housing as follows:

1. Apply a continuous 1.6 mm (1/16 in.) bead, of gasket eliminator, PT-7276(Loctite 51580), or equivalent, to the cylinder block where it mates with the flywheel housing. See Figure 1-220.

NOTE:
Whenever crankshaft rear seal is put over the crankshaft, use crankshaft oil seal expander.

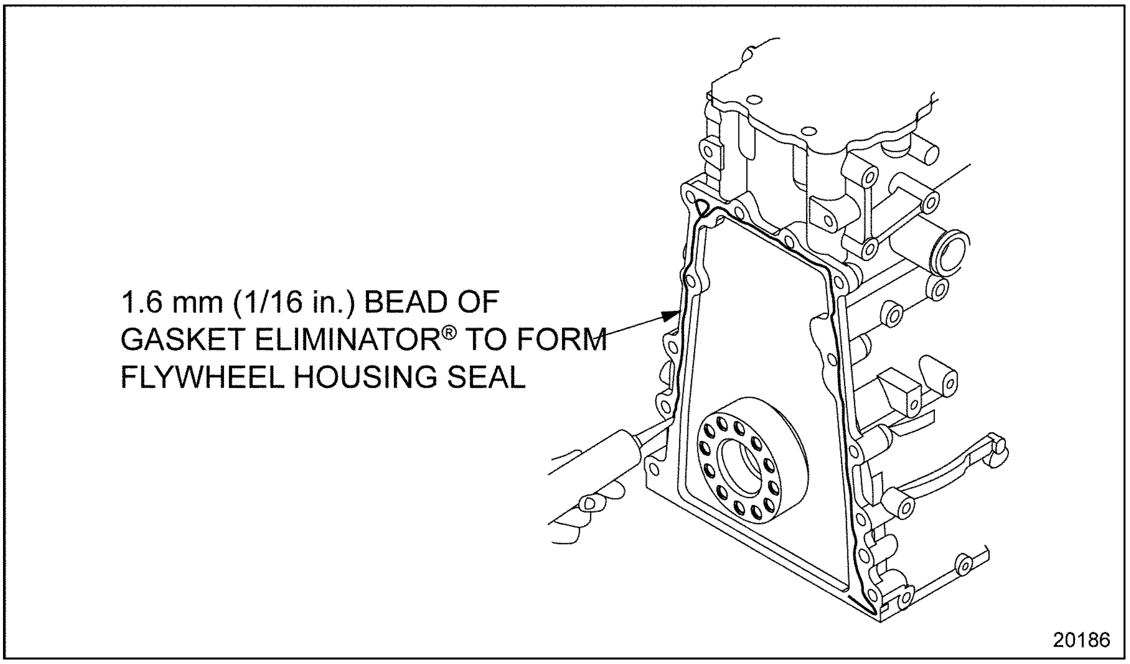


Figure 1-220 Gasket Eliminator Installation

2. Thread two aligning studs, J 43431 for 14 mm bolts or J 35785 for 12 mm bolts, into the cylinder block to guide the housing in place. See Figure 1-219.
3. Support the housing and position it over the crankshaft and against the cylinder block.
4. Install all of the housing bolts in their proper location, finger-tighten.
5. Remove the pilot studs.
6. Tighten the eight short and four long flywheel housing bolts to the cylinder block using the proper tightening sequence. See Figure 1-221.
   [a] If the bolts are 12 mm, torque to 112–126 N·m (83–93 lb·ft).

[b] If the bolts are 14 mm, torque to 160–200 N·m (118–148 lb·ft).

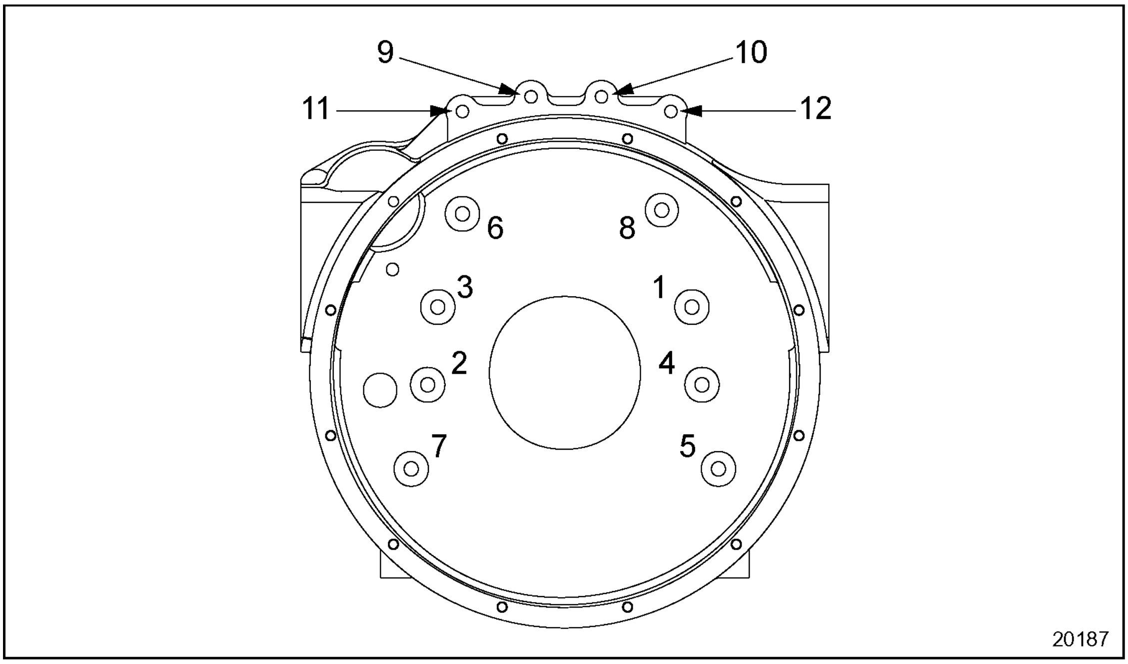


Figure 1-221 Flywheel Housing Bolt Torque Sequence

7. Install the crankshaft rear main oil seal. Refer to Section 1.8.7, step 1.
8. Install the flywheel. Refer to Section 1.14.3.
9. Install oil pan. Refer to Section 3.9.3.
10. Refill with engine oil. Refer to Section 13.5.1.

1.16.3.1 Test for Flywheel Housing Bore Concentricity

Check the flywheel housing bore concentricity, and bolting flange run-out with tool set, J 9737-C part of J 9737–D , as follows:

1. Thread the base post, J 9737-3 part of J 9737–D, into one of the tapped holes on the outer edge of the flywheel.
2. Assemble the dial indicators on the base post with the attaching parts provided in the tool set.

3. 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. See Figure 1-222.

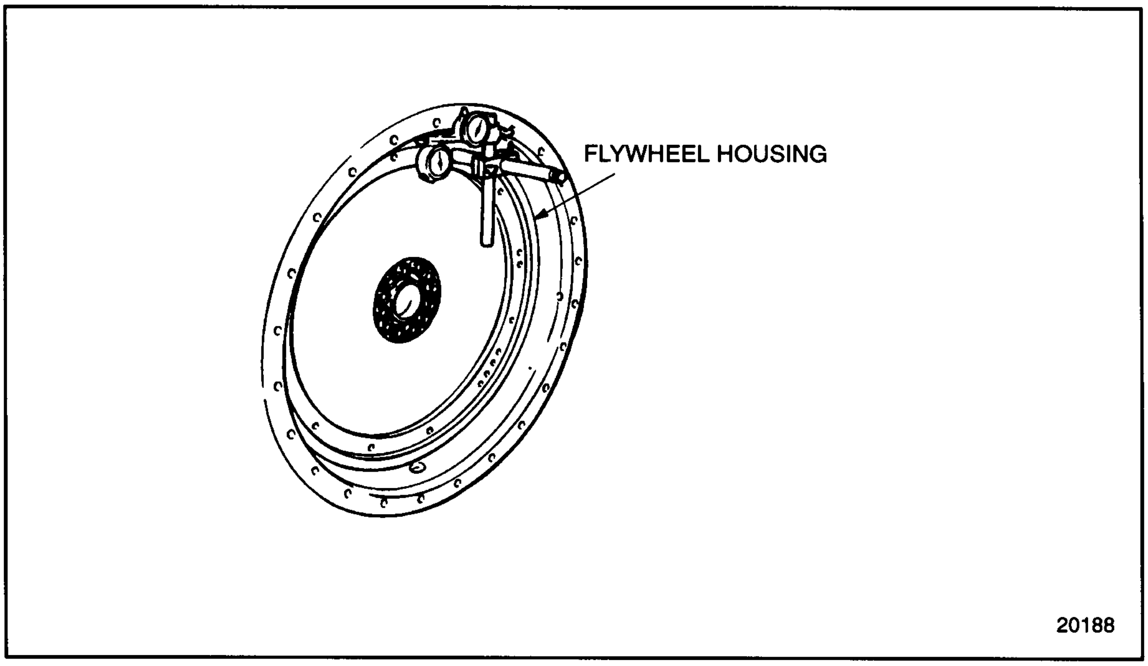


Figure 1-222 Measuring Flywheel Housing Bore Concentricity and Bolting Flange Run-out

4. Tap the end of the crankshaft (not the crankshaft pulley) with a soft hammer to force it toward one end of the block to ensure end play is in one direction only.
5. Adjust each dial indicator to read zero at the twelve o'clock position.

6. Rotate the crankshaft one complete revolution, taking readings at 90° intervals (4 readings each for the bore and bolting flange face). See Figure 1-223.

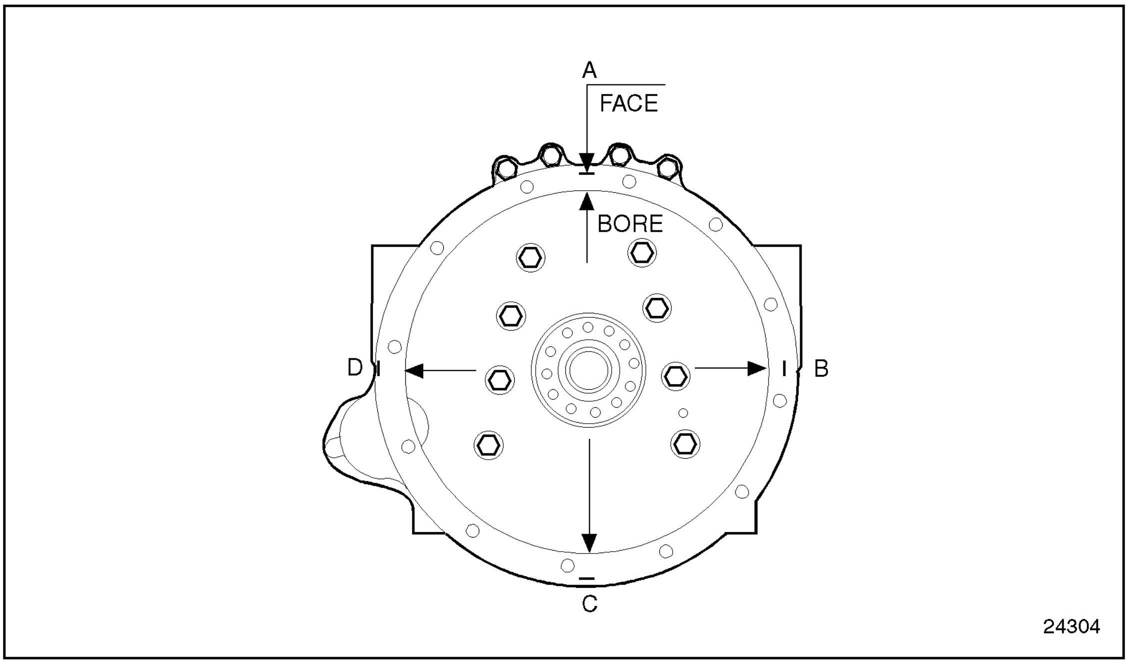
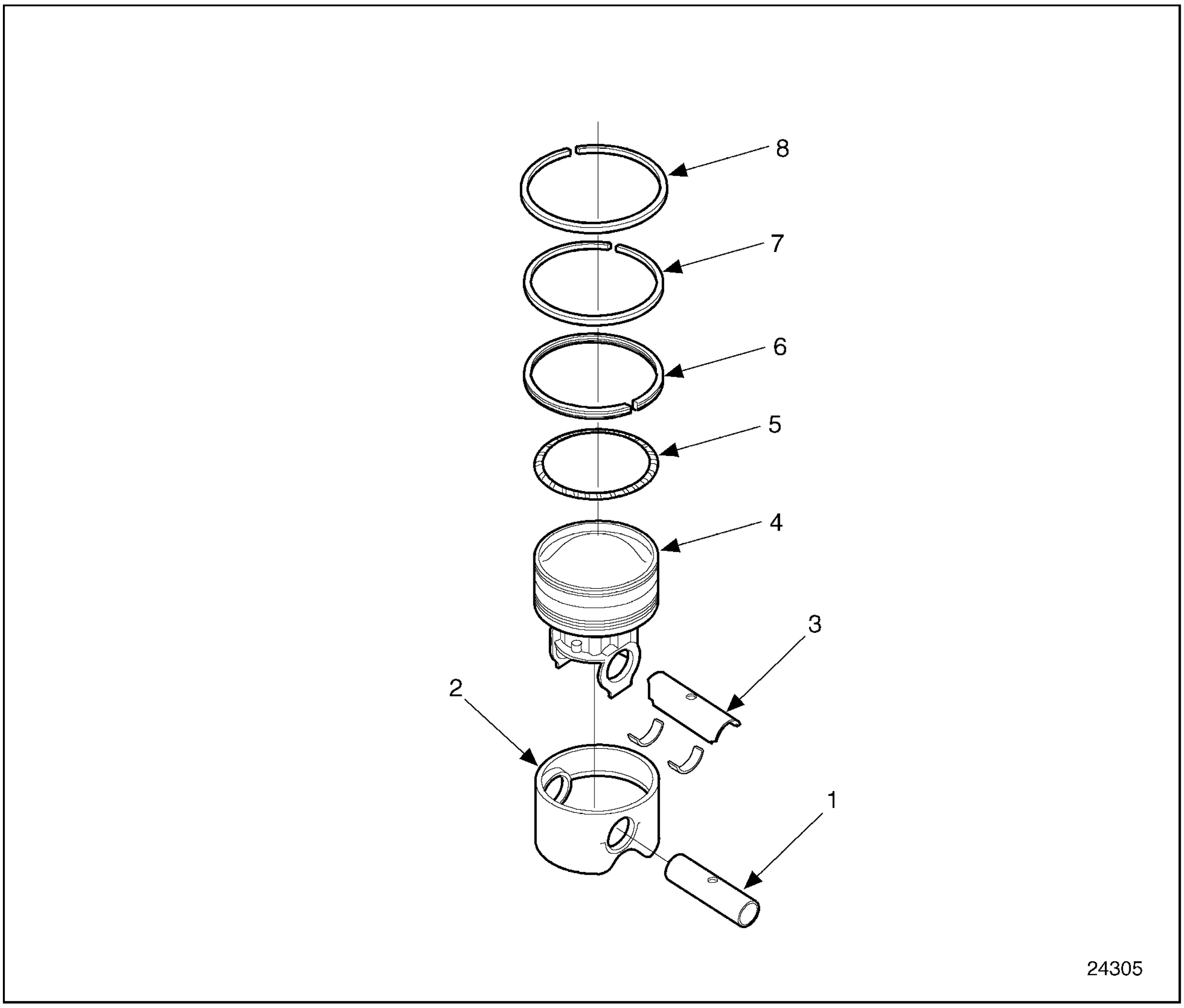


Figure 1-223 Flywheel Housing

7. Remove the wrench or cranking bar before recording each reading to ensure accuracy.
   [a] The maximum total indicator reading must not exceed 0.33 mm (0.013 in.) for either the bore or the face.
   [b] If the run-out exceeds the maximum limits, remove the flywheel and flywheel housing and check for dirt or foreign material between the flywheel housing and the cylinder block or oil pan.
8. Clean the mating surfaces once again. Refer to Section "General Information, Cleaning" in the beginning of this manual.
9. Install flywheel housing. Tighten the eight short and four long bolts to the cylinder block using the tightening sequence. See Figure 1-221.
   [a] If the bolts are 12 mm, torque to 112–126 N·m (83–93 lb·ft).
   [b] If the bolts are 14 mm, torque to 160–200 N·m (118–148 lb·ft).
10. Install the flywheel. Refer to Section 1.14.3.
11. Check the run-out again. If desired run-out cannot be accomplished replace the flywheel housing.

1.17 PISTON AND PISTON RING

The cross-head piston is a two-piece piston consisting of a dome and a skirt. The dome and skirt are held together by the piston pin. Ring grooves are machined in the piston dome. See Figure 1-224.



1. Piston Pin
2. Piston Skirt
3. Three-piece Bushing
4. Piston Dome
5. Oil Ring Expander
6. Oil Control Ring
7. Compression Ring
8. Fire Ring

Figure 1-224 Piston and Related Parts

NOTE:
Series 50G engine has a 3.5 mm fire ring, a rectangular cut compression ring and a 3-piece oil ring. See Figure 1-225 and see Figure 1-226.The compression ring is identified with a purple stripe.

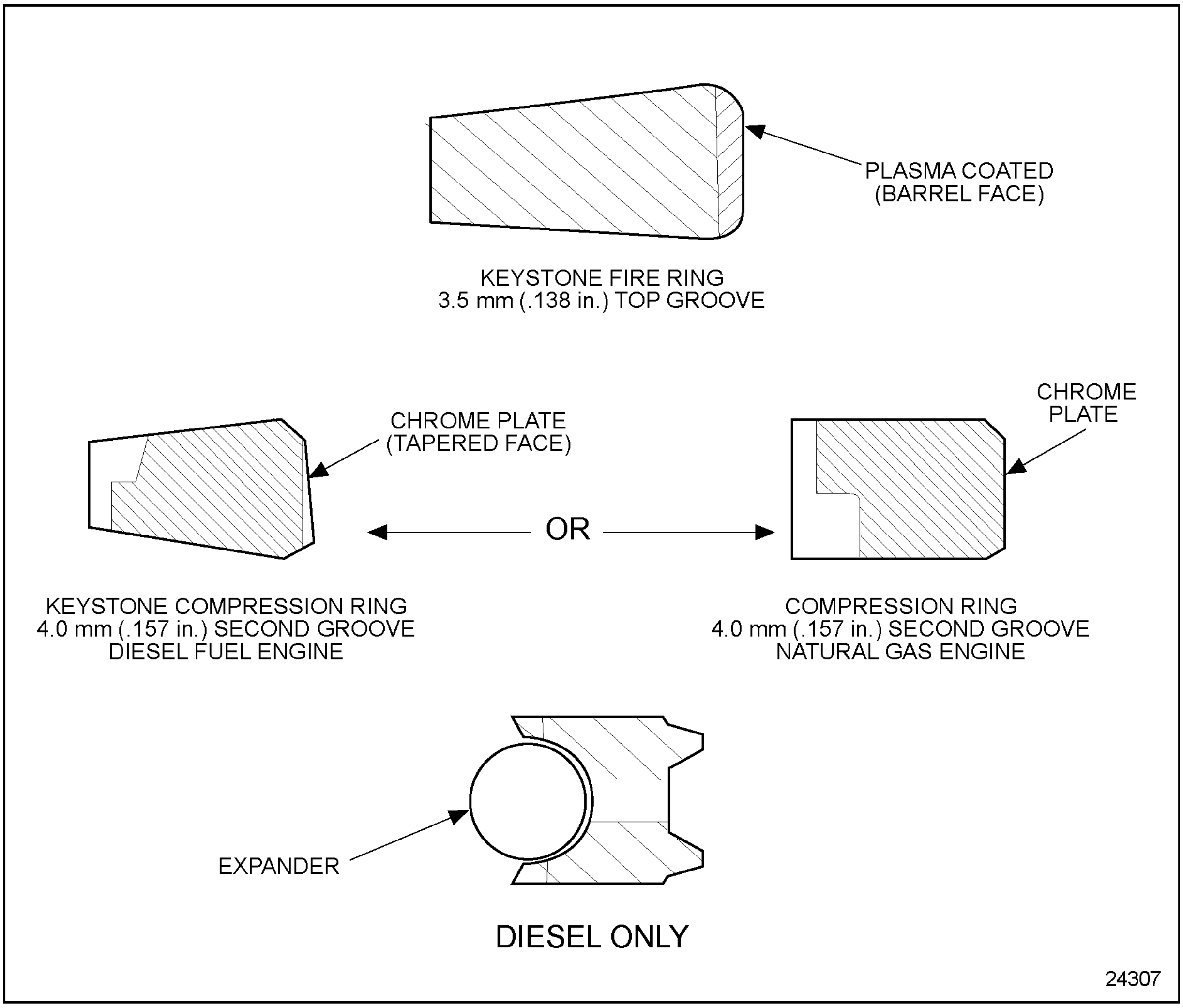


Figure 1-225 Piston Ring Packs

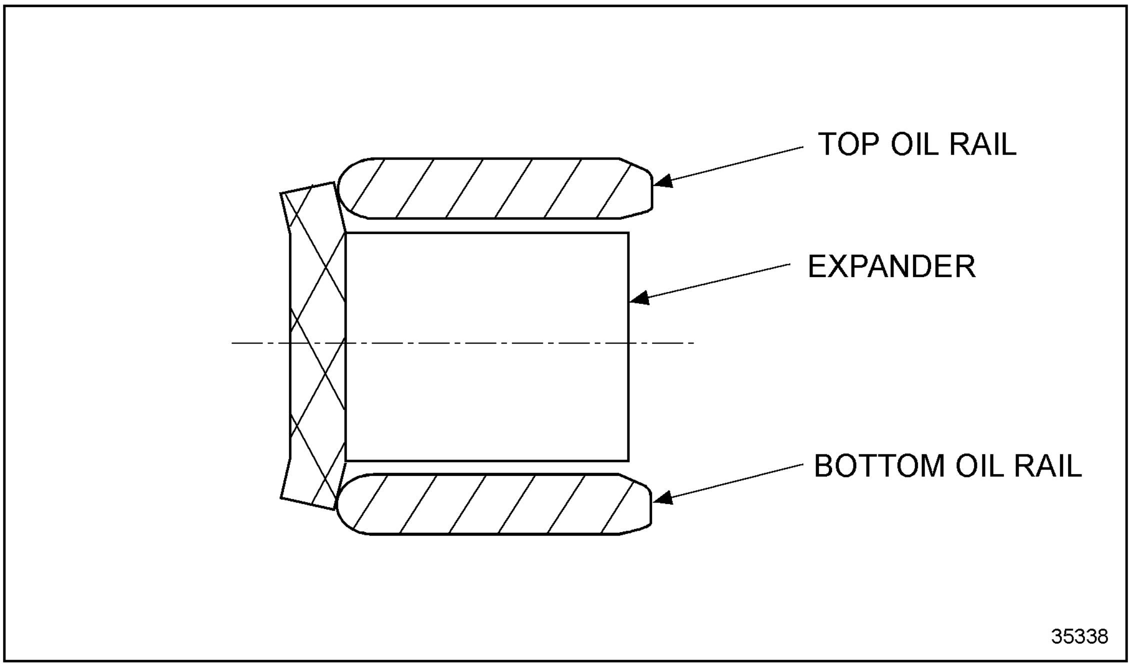
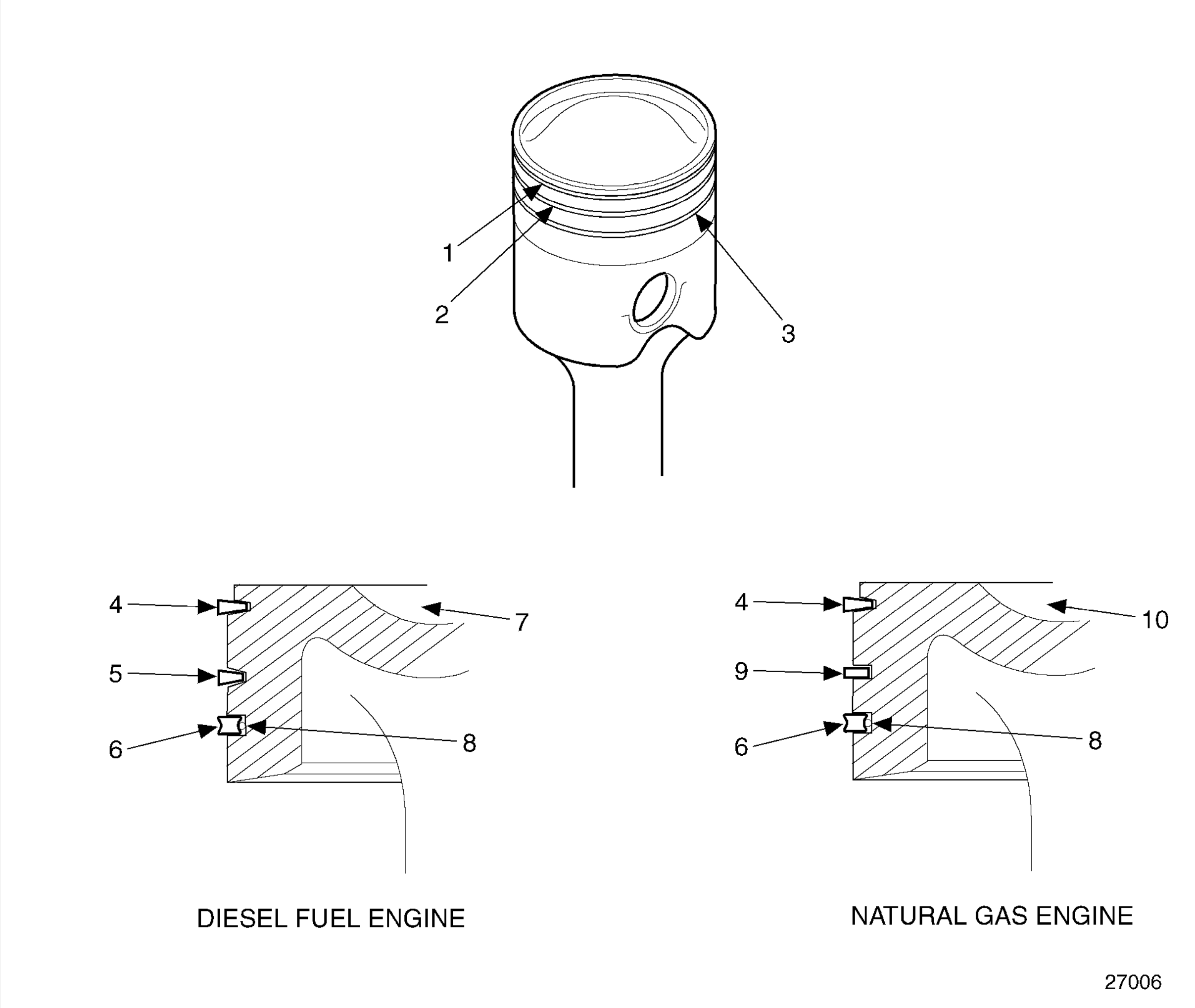


Figure 1-226 3–piece Gas Oil Ring

To improve oil control, an improved 4.0 mm rectangular compression ring 23518373 was released to replace former keystone compression ring 8929845 in the second ring position. Due to this ring change the former piston dome 23516677 was replaced by current piston dome 23518374, part of current piston dome assembly 23518380. This change became effective on May 18, 1995, with production unit 4R9198. See Figure 1-227, see Figure 1-225and see Figure 1-226.



1. Fire Ring
2. Compression Ring
3. Oil Control Ring
4. Fire Ring*
5. Compression Ring*
6. Oil Control Ring
7. Piston Dome
8. Oil Ring Expander
9. Compression Ring* (Retangular)
10. Piston Dome (Retangular)

* Note: Identification Mark to Face Top of Dome

Figure 1-227 Piston Ring Location

As with the former ring, the current ring will be installed with the "football" mark facing up, see Figure 1-228. Due to the lower compression ratios from that of the diesel engines, there is no need to measure ring groove wear in the piston dome assembly of the 50G engine.

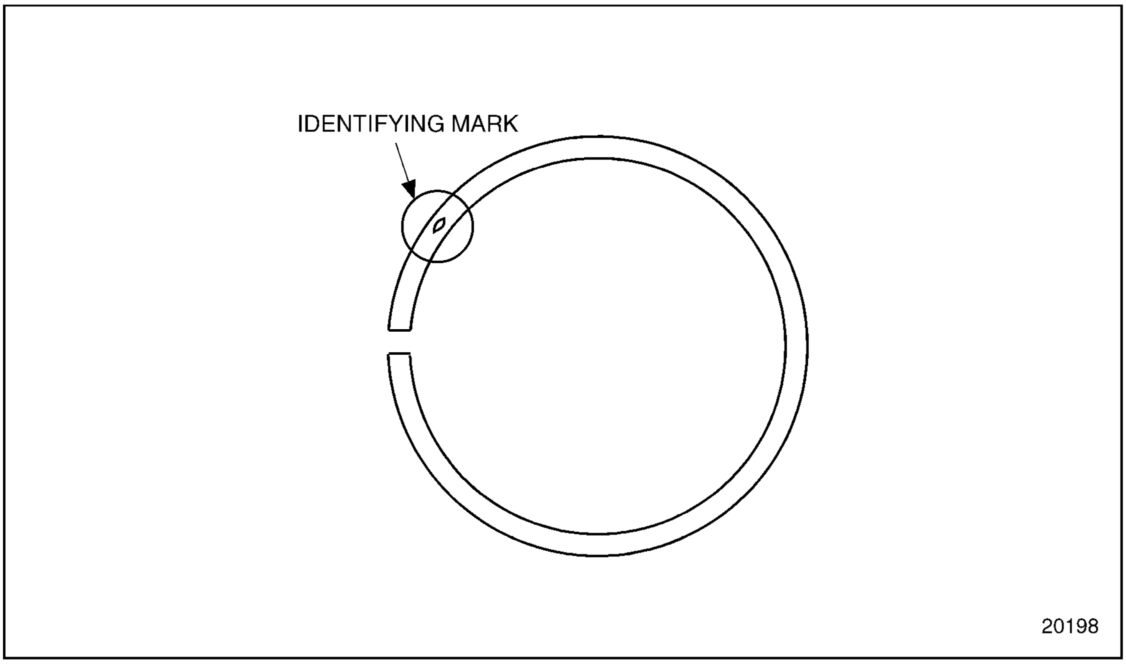


Figure 1-228 Fire and Compression Ring Identification

All former parts and kits will be retained for service of diesel engines. Ring service kits are listed in Table 1-3.

Service Kit	Former Part Number	Interim Part Number	Current Part Number
Piston Kit	23516781	23518758	23519644
Cylinder Kit	23516783	23518759	23519645
Ring Kit	23505729	-	23518760

Table 1-3 Crankshaft Part Number History

A one-piece oil control ring is used in the third groove. The expander is of Spira-Lox construction.

These channels are not drilled through the piston. The channels help the excess oil, scraped from the cylinder walls, return to the crankcase. See Figure 1-229.

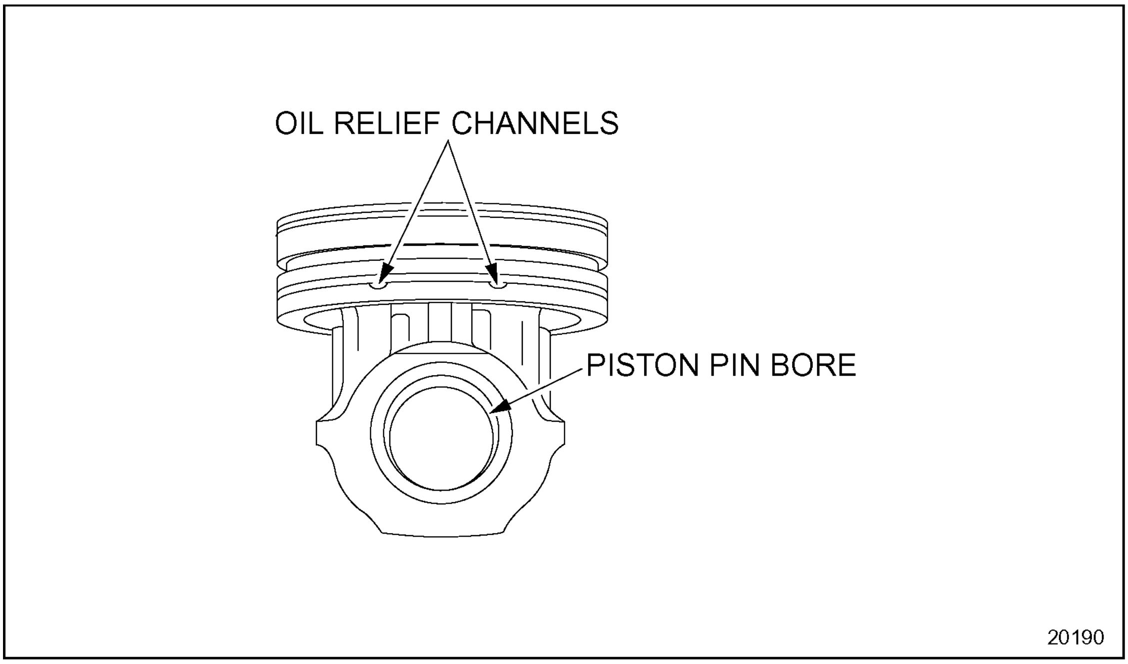


Figure 1-229 Piston Oil Relief Channels

The piston dome and piston pin bearing of the most recent design are separate parts and may be serviced separately.

Two special bolts and spacers are used to attach the connecting rod to the piston pin.

The solid-core piston pin has a drilled hole through the center to provide lubricating oil to the piston dome for cooling. A threaded hole on each side of the oil hole receives the connecting rod attaching bolts. See Figure 1-230.

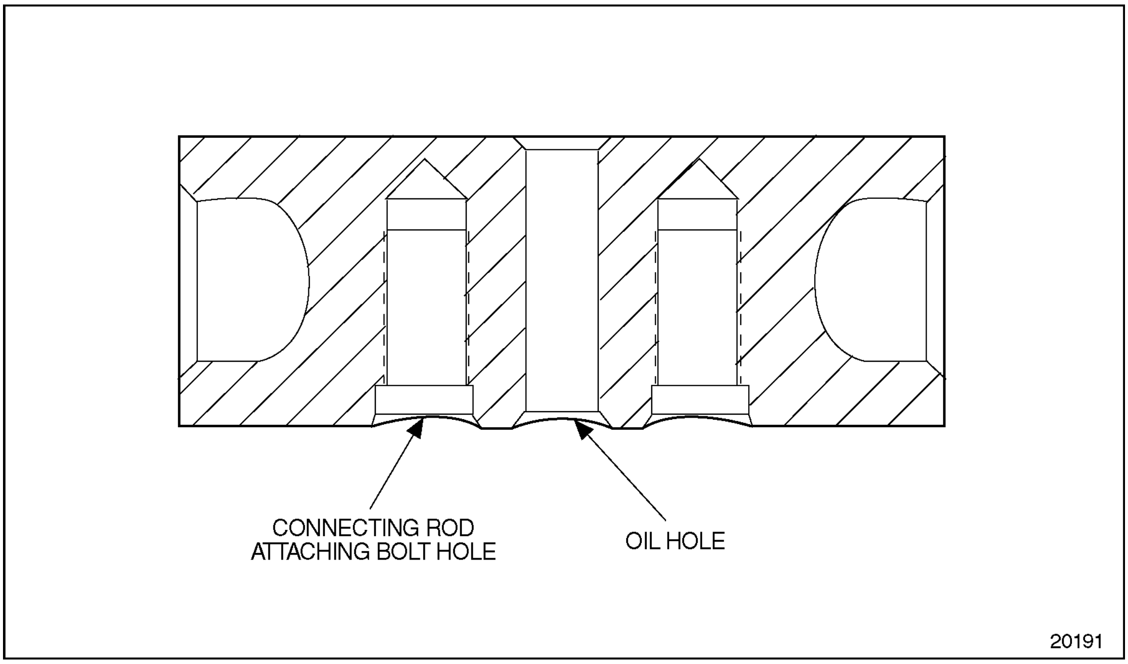


Figure 1-230 Piston Pin Cross Section

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 piston pin, then through the center hole in the bearing to the underside of the piston dome. A portion of the oil lubricates the piston pin and bearing.

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

1.17.1 Repair or Replacement of Piston and Piston Ring

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-231.

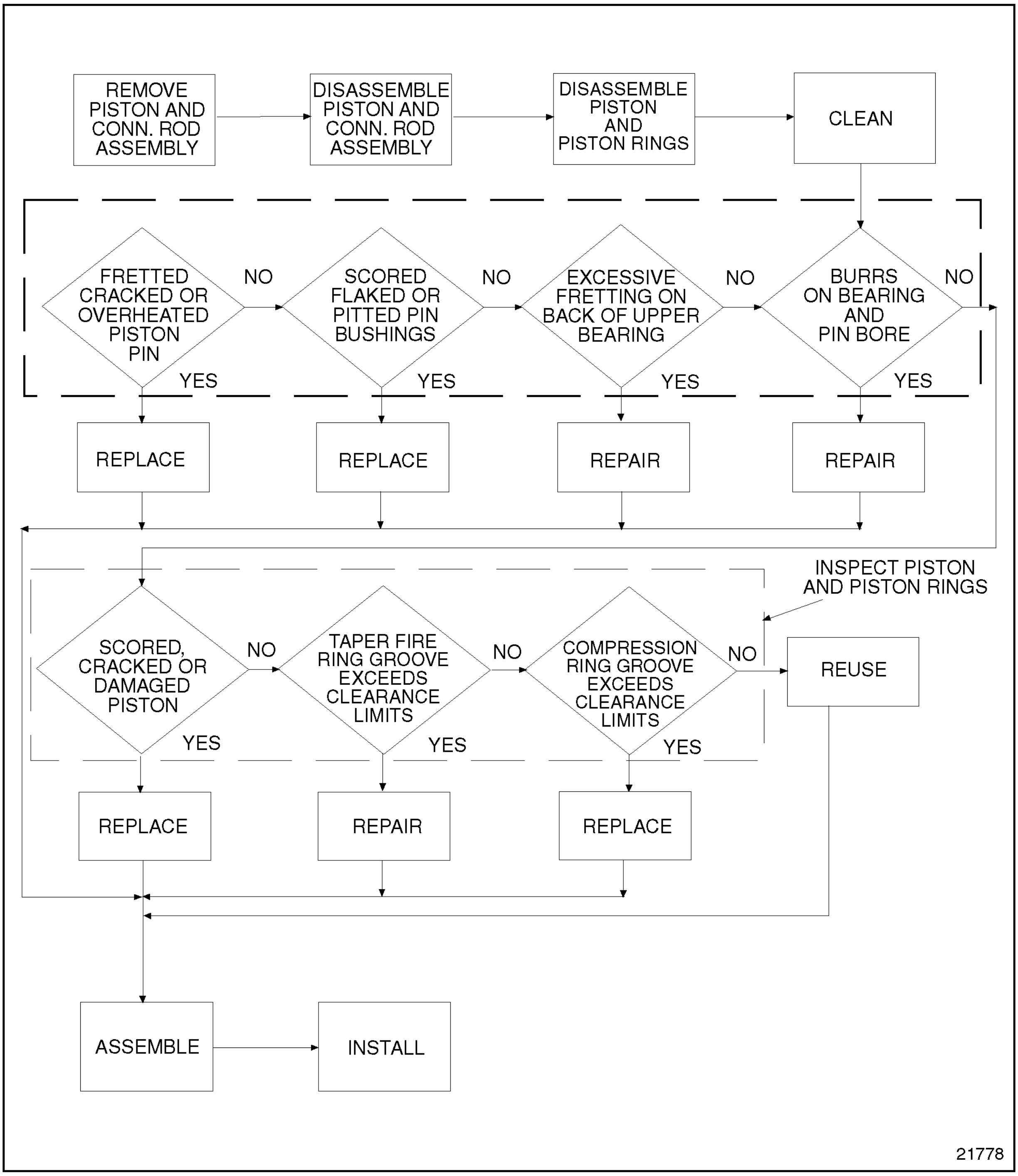


Figure 1-231 Flowchart for Repair or Replacement of Piston and Piston Rings

1.17.2 Cleaning and Removal of Piston and Piston Ring

Refer to Section 1.18.2 for piston and connecting rod assembly removal procedure.

1.17.3 Disassembly of Piston and Piston Ring

Disassemble the piston and piston rings as follows:

1. Remove the piston rings with tool J 22405-02. See Figure 1-232.

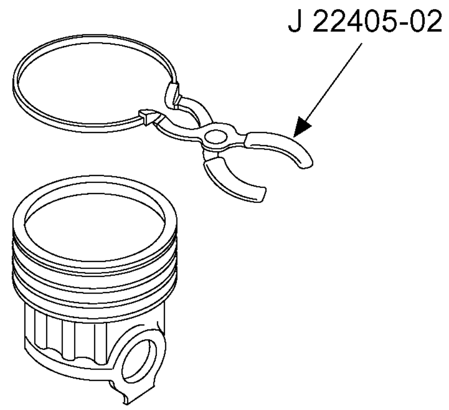


Figure 1-232 Removing Piston Rings

NOTICE:
The pin, bushing, skirt and dome must be match-marked to assure proper position and orientation.

2. Withdraw the piston pin and mark or etch the front of the piston, so it can be returned to the correct cylinder location.
3. Separate the piston skirt from the piston dome and mark or etch the front of the dome ear and skirt, so they can be returned to the correct location.
4. Remove the piston pin bearings, marking the front of them, so they can be returned to the correct location.

NOTE:
The lower pin bore bearings are removed from the pin bore first, by pushing the bearing legs outward by hand at the split lines from inside the dome saddle ear. The upper bearing may be held in the bore by oil on the back of the bearing, making removal from the pin bore by hand difficult.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

Prying between the bearing back and dome bore may damage the dome saddle bore or raise burrs which will make installation of new bearings difficult.

DDC recommends that compressed air be directed between the dome pin bore and back of the bearing at one end until the bearing pops up out of the bearing retaining hole.

1.17.3.1 Inspection of Piston and Piston Ring

Clean the piston and piston rings prior to inspection as follows:

NOTICE:

Do not attempt to clean the piston skirt by glass beading. It will remove the tinplating. Do not refinish or polish the piston pin.

1. Clean the piston components with fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the piston components with compressed air.
3. If fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tinplate on the piston skirt.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

After cleaning, do not leave glass beads in the piston dome. **Do not allow the glass beading to contact any area of the piston pin bushing or pin bore.** Glass beading will remove the tin plating.

4. The piston dome, including the compression ring grooves, is not tin plated and may be wire-brushed to remove any hard carbon. Glass beading can be used to clean a piston dome. Micro Bead Glass Shot MS-M (0.0029-0.0058 in.) is recommended. Allowable air pressure is 552-689 kPa (80-100 lb/in.^{2}).

NOTE:
Do not wire-brush the piston skirt.

5. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.
6. Clean the inside surfaces of the piston dome and skirt and the oil relief channels in the oil ring grooves.

Inspect the piston and piston rings as follows:

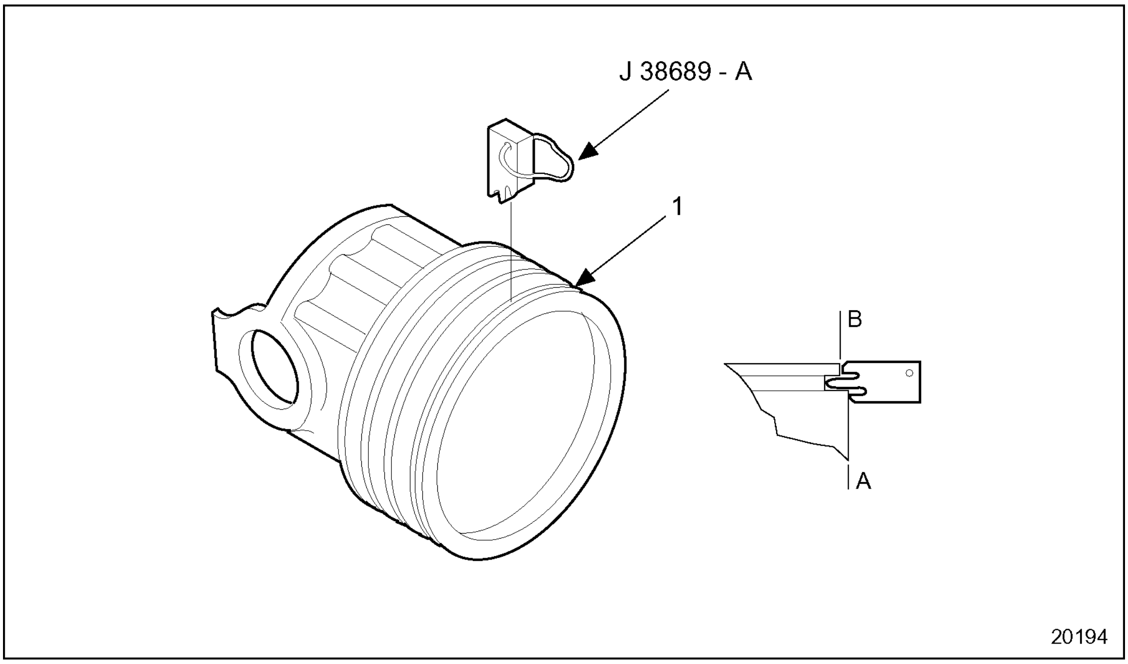
1. Inspect the piston skirt and dome.
   [a] Check the skirt and dome for score marks, cracks, damaged ring grooves or overheating indications.
   [b] If any of these indications are present, the piston must be replaced.

NOTE:
Burn spots may indicate an obstruction in the connecting rod or piston pin oil passage.

2. Inspect the tapered fire ring groove (top) in the piston dome.
   [a] Using the piston ring land step gage, J 35884-A or J 38609-A, check tapered fire ring groove. See Figure 1-233.
   [b] Insert the center tang of the tool gage into the top piston ring groove ash. See Figure 1-233.
   [c] Hold the tool at a 90° angle to the ring groove to prevent false readings.
   [d] With the center tang into the ring groove as far as it will go, there should be no contact of the piston with the shoulder of the gage. If the gage makes contact at point A or point B, the fire ring groove is worn beyond usable limits. Check the groove

clearance at 4 spots, at 90° intervals. Measure the ring land parallel to and at 90° to the wrist pin.

[e] If fire ring groove is worn beyond usable limits, replace piston dome.



1. Fire Ring Groove

Figure 1-233 Checking Fire Ring Groove

3. Inspect tapered compression ring groove (second) in the piston dome.
   [a] Using piston ring land step gage, J 38689-A, check the groove.
   [b] If the compression ring groove is worn beyond usable limits, replace piston dome.
4. Inspect the piston pin.

NOTICE:
If piston pin is replaced for any reason, the piston pin bushing for that cylinder must also be replaced.

   [a] Check the piston pin for fretting, cracking or signs of overheating.
   [b] If these are detected, replace piston pin.
   [c] Measure piston pin outside diameter. Specifications are listed in Table 1-15.
   [d] If piston pin is out of specs, replace with new part.
5. Inspect the piston pin bushings.

NOTICE:
If a piston pin bushing is replaced for any reason, the piston pin for that cylinder must also be replaced.

[a] Check the piston pin bushings for scoring, pitting, flaking, cracking, excessive wear, or signs of overheating.

[b] If these conditions are present, the bearings must be replaced.

6. Inspect the back of the upper bushing.

   [a] Check the bushing for excessive fretting.

   [b] If excessive fretting is evident, replace all three bushings.

   [c] The corresponding fretting in the piston dome can be removed using crocus cloth, wet with fuel oil.

7. Inspect the edges of the bearings and piston dome pin bore.

   [a] Check the edges of the bearing and piston dome pin bore for dents and dings.

   [b] If any are found, it is acceptable to remove burrs at the bearings or pin bore edges by careful filing.

NOTE:
Remove any dirt or debris on the backs of the bearing or dome pin bore that may take up clearance required for bearing or piston pin installation.

8. Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston. Specifications are listed in Table 1-13.
9. Check the block bore for excessive out-of-round, taper, and high spots which could cause failure of the piston. Specifications are listed in Table 1-12.

1.17.4 Assembly of Piston and Piston Rings

Prior to installing the piston rings, the ring gap of each piston ring must be measured.

1. Insert the piston rings inside of the cylinder liner one at a time, using a piston dome (inserted upside down into the liner) to push the ring down. The piston dome should be inserted into the liner, to the same depth as the ring being positioned.
2. For the oil control ring, insert the piston dome down into the liner, until the oil control ring land is just into the liner. This will ensure that the rings are parallel with the top of the liner, and that they are positioned in the liner within the normal area of ring travel.
3. After the three rings have been positioned in the liner, measure the ring gap of the top ring with a feeler gage. See Figure 1-234. Remove the ring from the liner after the measurement is complete.

4. Repeat this procedure for each ring, and record your measurements. Allowable ring end gaps are listed in Table 1-4.

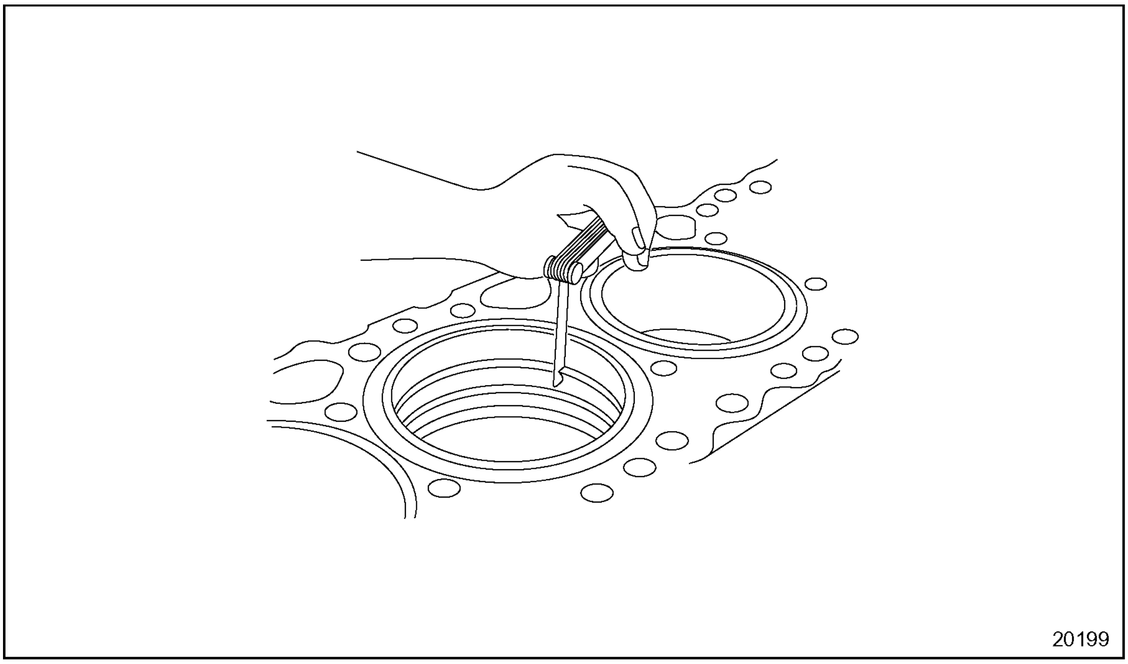


Figure 1-234 Piston Ring Location

Ring	Ring End Gap
Fire Ring (2.5 mm [0.098 in.] chrome)	0.40-0.87 mm (0.016-0.034 in.)
Fire Ring (3.5 mm [0.138 in.] plasma)	0.51-0.87 mm (0.020-0.034 in.)
Compression Ring	0.81-1.31 mm (0.032-0.051 in.)
Oil Control Ring	0.40-0.81 mm (0.016-0.032 in.)

Table 1-4 Allowable Ring End Gap

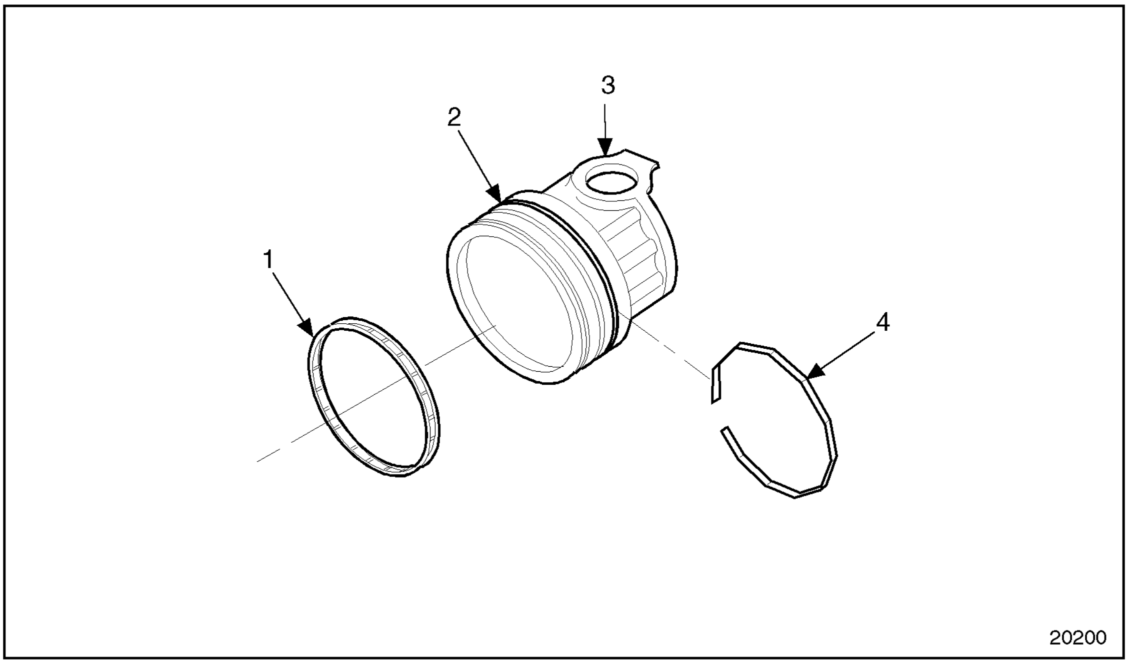
5. Refer to Section 1.17.5 for assembly of rings for diesel engines or refer to Section 1.17.6 for S50G engines.

1.17.5 Assembly of S50 Diesel Piston Rings

Assemble the S50 diesel engine piston and piston rings as follows:

1. Install the ring expander in the oil control ring groove in the piston. See Figure 1-235.

NOTE:
Install expander into inside diameter groove of ring with expander spring gap located 180° from the oil control ring gap.



1. Oil Control Ring
2. Oil Control Ring Groove
3. Piston
4. Oil Control Ring Expander

Figure 1-235 Piston Ring Installation

2. Install the oil control ring by hand. See Figure 1-236.

NOTE:
The oil control ring may be installed in either direction.

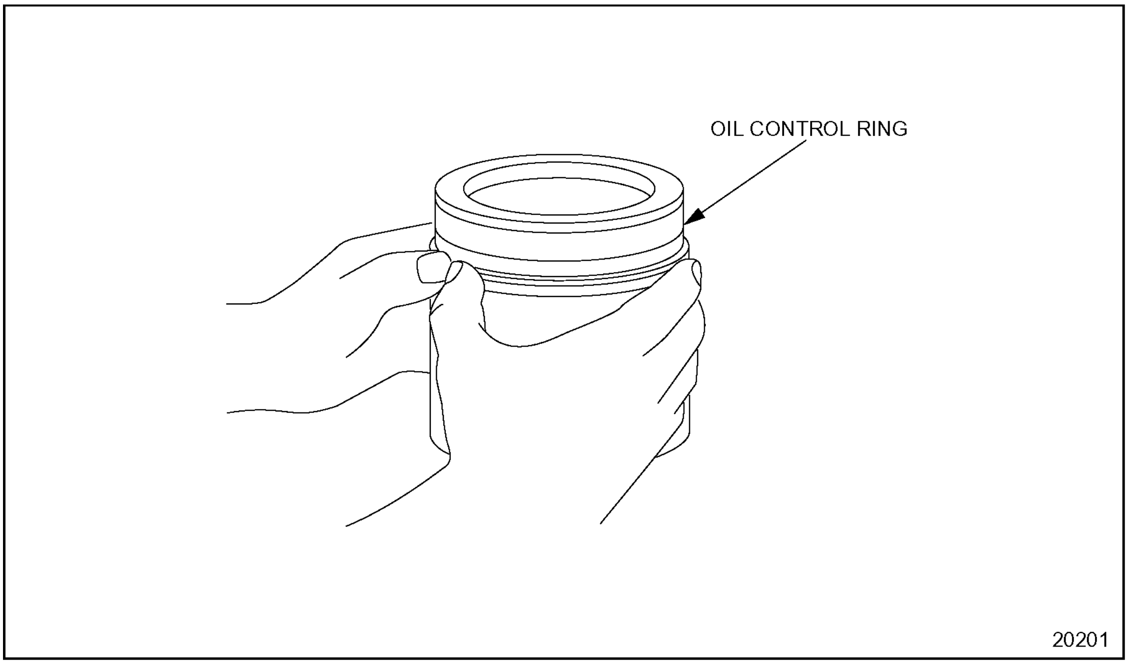


Figure 1-236 Oil Control Ring Installation

The oil control ring expander has a white paint stripe. Make sure the paint mark can be seen after the oil control ring is installed at ring gap.

Install the S50 diesel engine fire and compression rings as follows:

NOTICE:
To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston dome.

1. Starting with the compression ring (second groove), install the compression ring and fire ring with tool J 22405-02. See Figure 1-237. Make sure the identifying dimple on the rings is installed up, toward the dome of the piston. See Figure 1-228 for ring identification and locations.

2. Stagger the ring gaps around the piston. See Figure 1-237.

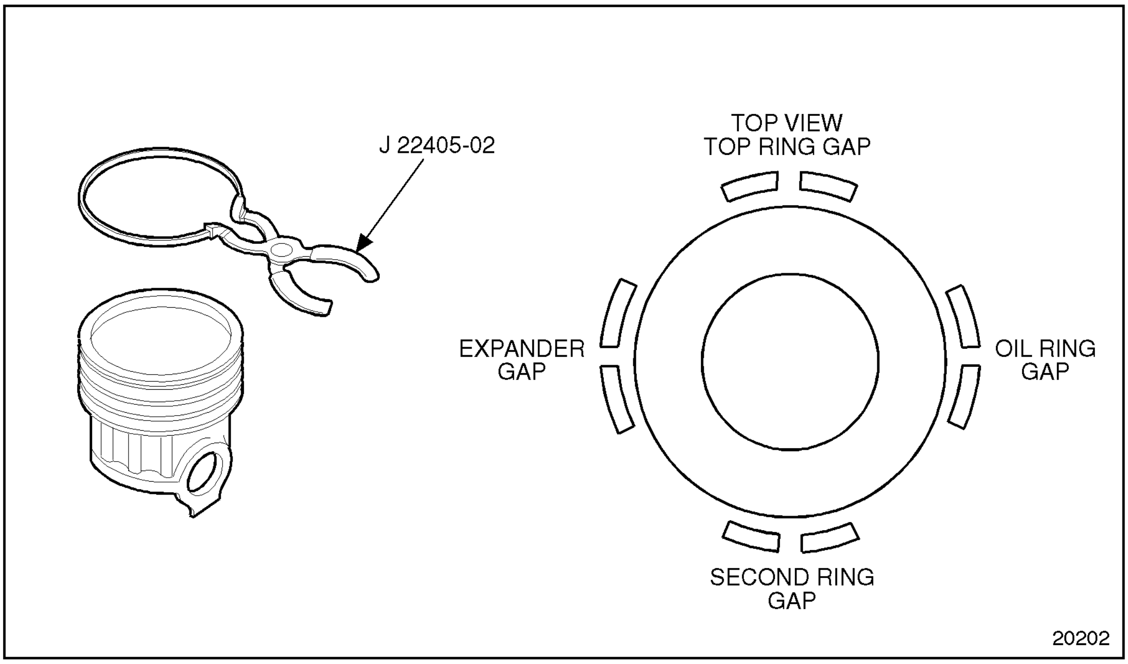


Figure 1-237 Piston Ring Positioning

3. Refer to Section 1.18.4 for piston and connecting rod assembly procedure.

1.17.6 Assembly of S50G Piston Rings

Install the oil control ring for the S50G engine as follows:

1. Install the expander in the bottom groove of the piston.
2. Install the upper and lower rails ensuring one is on the upper side of the expander and the other is on the lower side of the expander.

NOTE:
The expander and both rails may be installed with either side up. There is no "football" mark on any of the three oil ring components for natural gas engines.

3. Orient the ring gaps of the rails 180 degrees apart so that they align with the paint marks on the expander. The expander should be 90 degrees from the oil ring gaps.

Install the compression and fire ring for the S50G engine as follows:

1. Install the compression ring (rectangular cut shape) in the second groove of the piston, using tool J 22405-02.
2. Install the fire ring in the top groove of the piston, using tool J 22405-02.

3. Stagger the ring gaps around the piston. See Figure 1-238.

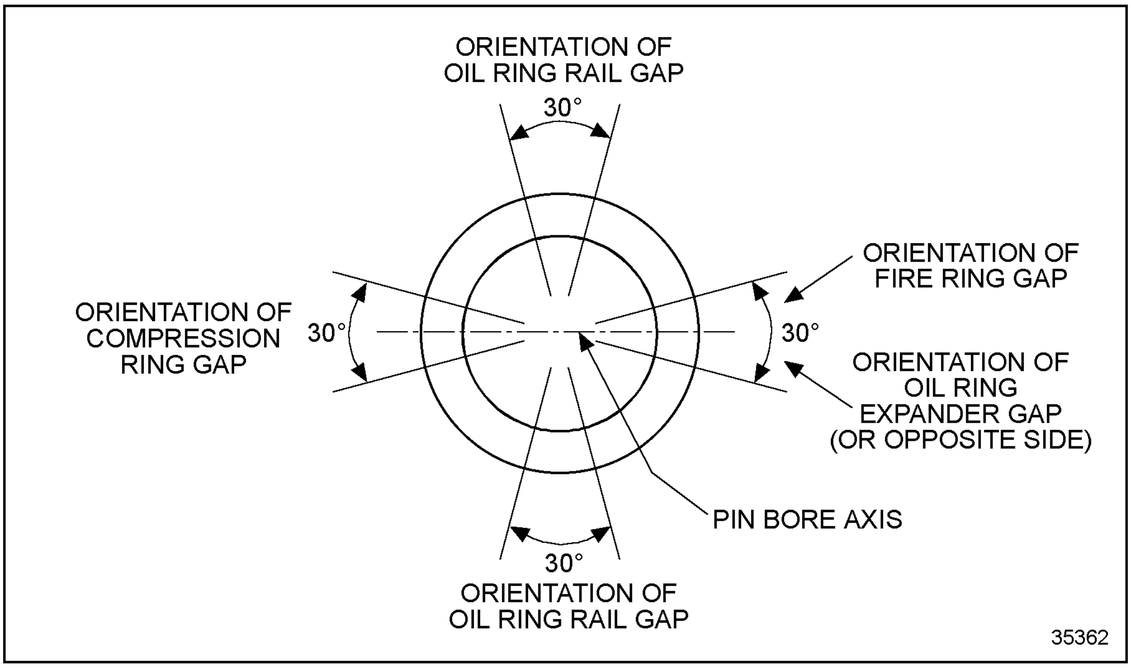


Figure 1-238 Top View of Piston Dome

4. Refer to Section 1.18.4 for piston and connecting rod assembly procedure.

1.18 PISTON AND CONNECTING ROD ASSEMBLY

The piston and connecting rod assembly is one unit made of two separate components.

For general information, refer to Section 1.17.

For connecting rod assembly information, refer to Section 1.19.

1.18.1 Repair or Replacement of Piston and Connecting Rod

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-239.

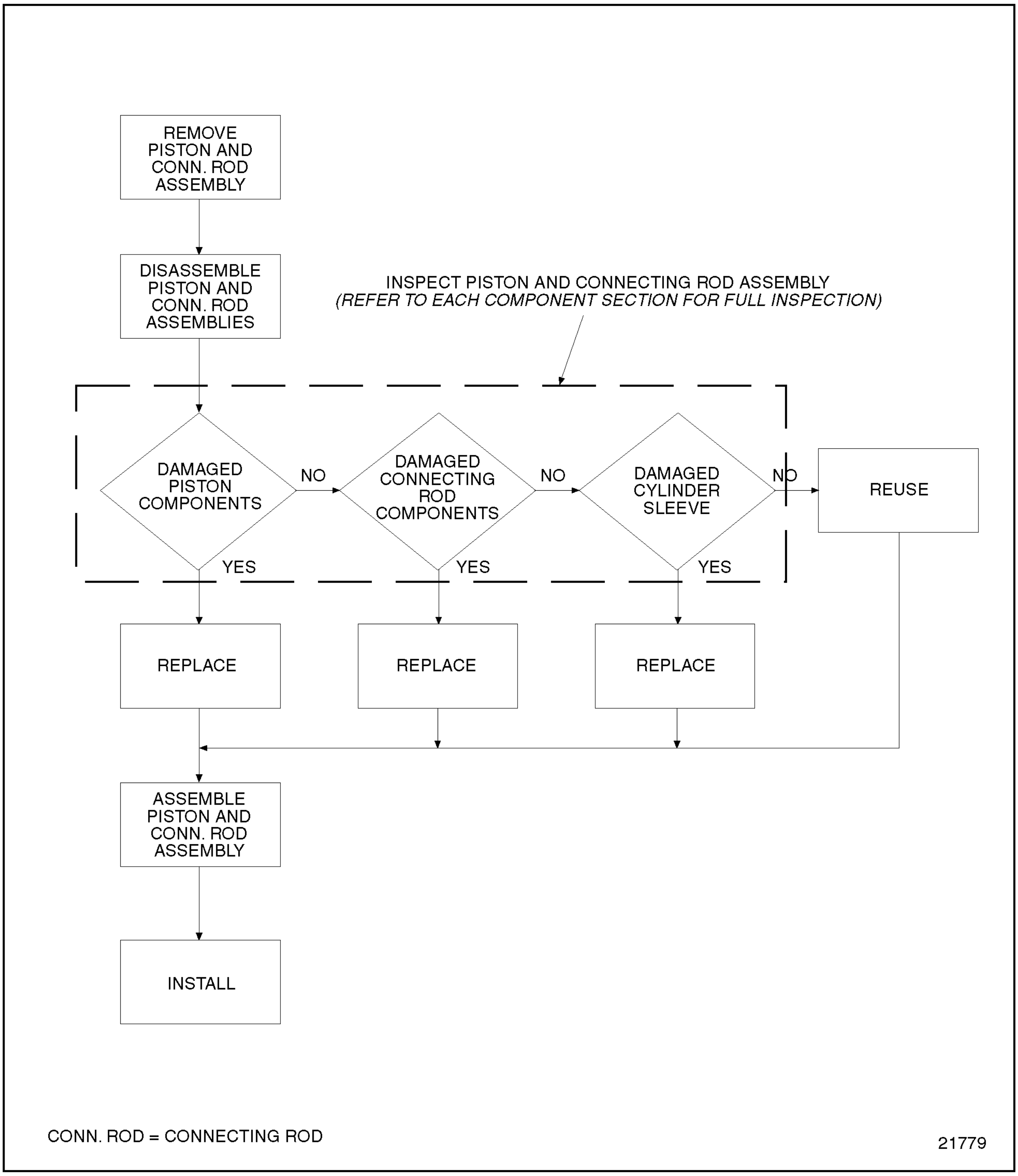


Figure 1-239 Flowchart for Repair or Replacement of Piston and Connecting Rod

1.18.2 Cleaning and Removal of Piston and Connecting Rod

Precleaning is not necessary.

Remove the piston and connecting rod assembly as follows:

1. Drain the engine cooling system. Refer to Section 13.5.4.
2. Drain the engine oil and remove the oil pan. Refer to Section 3.9.2.
3. Remove the cylinder head. Refer to Section 1.2.2.
4. Use an emery cloth to remove any carbon deposits from the upper surface of the cylinder liner.
5. Remove the bearing cap and lower bearing shell from the connecting rod.
6. Install connecting rod guides, J 35945 (or equivalent), to protect the crankshaft journals.
7. Push the piston and rod assembly out through the top of the cylinder block.

NOTE:
The piston cannot be removed from the bottom of the cylinder block.

8. Assemble the bearing cap and lower bearing shell to the connecting rod after removal. If not already marked, match-mark the rod and cap (on the tang side) with the cylinder No. where they were removed. See Figure 1-240.

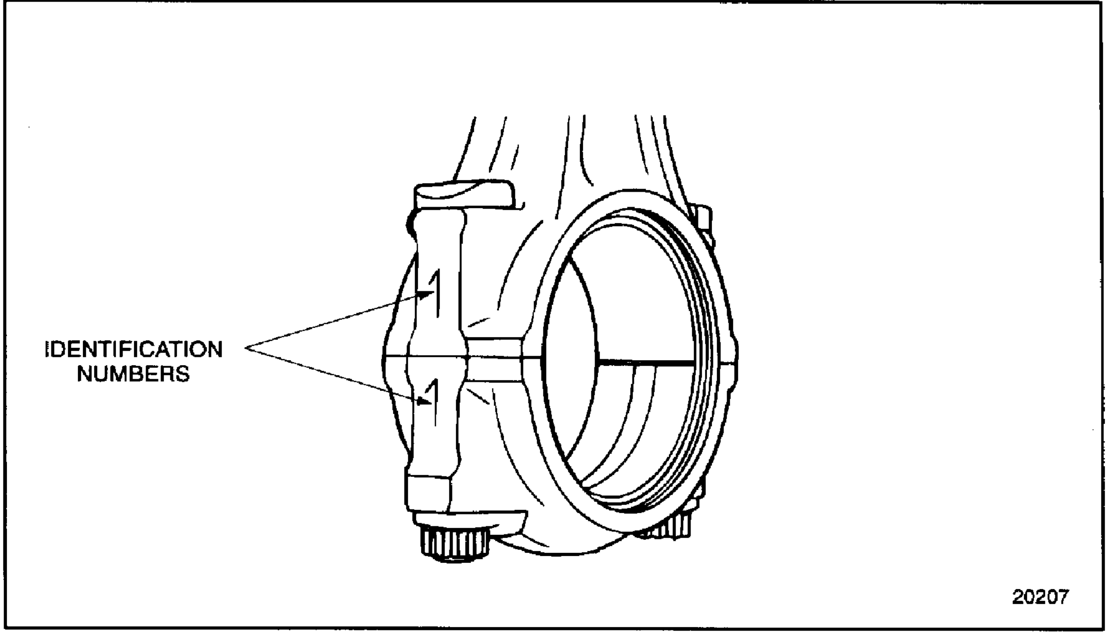


Figure 1-240 Connecting Rod and Cap Identification

NOTE:
When removed, the bearing cap and the bearing shell must be reinstalled on the original connecting rod before another connecting rod bearing cap is removed.

NOTE:
If removing the piston and connecting rod assembly to work on the cylinder liner, stop here. Refer to Section 1.20.2 for cylinder liner removal procedure.

1.18.3 Disassembly of Piston and Connecting Rod Assembly

Piston assembly components should be segregated by cylinder and match-marked during disassembly to ensure they are assembled in the same position and orientation.

NOTICE:
Stamping cylinder numbers would damage the components.

It is best to use a paint pencil. Mark the pin, skirt, bushing, and dome ear at the front.

Disassemble the piston and connecting rod assembly as follows:

1. Place the piston, dome down, on the round plate of the piston and connecting rod holding fixture, J 36211. See Figure 1-241.

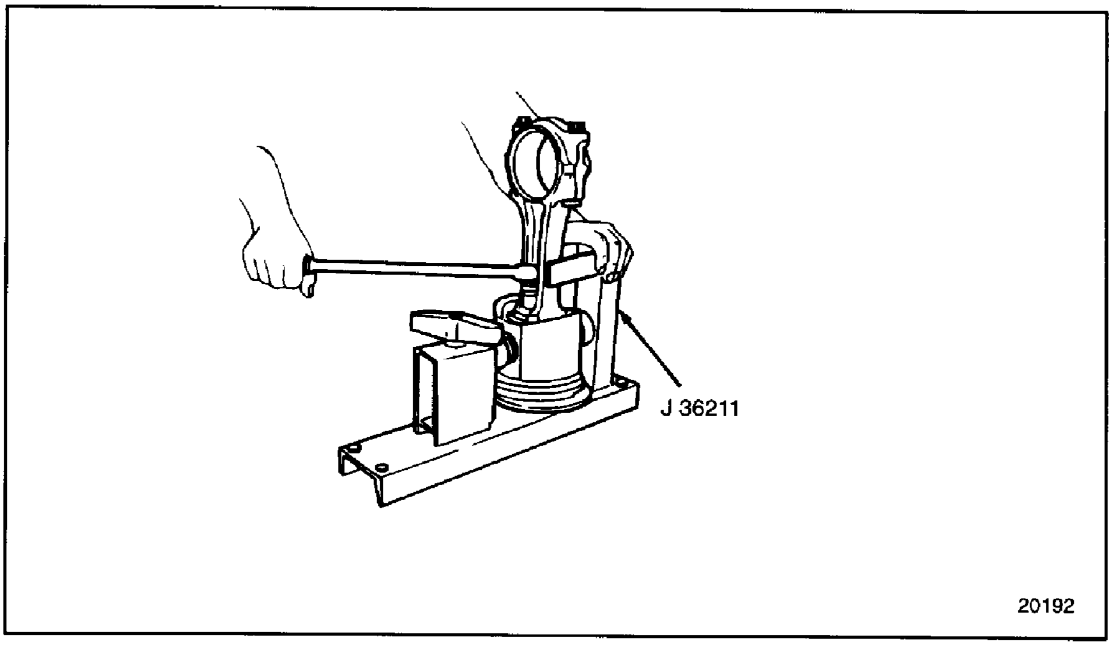


Figure 1-241 Piston Connecting Rod Holding Fixture

2. Slide the movable portion of the fixture until it contacts the piston pin and tighten the handle.
3. Loosen the two bolts that secure the connecting rod to the piston pin and remove the two bolts and spacers.
4. Remove the connecting rod.
5. Remove the piston, pin and skirt from the holding fixture.

1.18.3.1 Inspection of the Piston and Connecting Rod Assembly

Refer to Section 1.17.3 for disassembly and inspection of the piston and piston rings.

Refer to Section 1.19.3 for disassembly and inspection of the connecting rod.

1.18.4 Assembly of the Piston and Connecting Rod Assembly

Assemble the piston and connecting rod assembly as follows:

NOTICE:

The connecting rod-to-piston pin attaching bolts and spacers are specially designed components. No other bolts or spacers may be used. Piston pin bolts are considered one-use items and **must** be replaced with new bolts when removed for any reason. Failure to observe this precaution may result in bolt loosening or breaking during engine operation, which may cause serious engine damage.

1. Discard used piston pin bolts and replace with new bolts.
2. For specifications on reusing piston assembly components. Refer to Section 1.18. Because of the low clearance fit between the piston pin and three-piece pin bearing, care in handling and cleanliness of piston dome bore, bearings and, piston pin are important. Otherwise, assembly may be impossible.
3. The pin bore and bearing backs should be wiped clean prior to installation of the bushings in the piston dome.
4. Installing piston pin bearings (with the piston dome standing on the rim) requires the upper bearing piece to be inserted through the end of the pin bore and dropped over the retaining pin.
5. The lower bearing pieces are inserted flat side in by tilting the bearing at approximately a 30° angle from the vertical away from the dome ear.
6. Set the edge of the bearing parting line on the edge of the upper piece notch and rotate the lower bushing up and into place.

7. The lower bearing can then be pushed full into the bore with the thumb. See Figure 1-242.

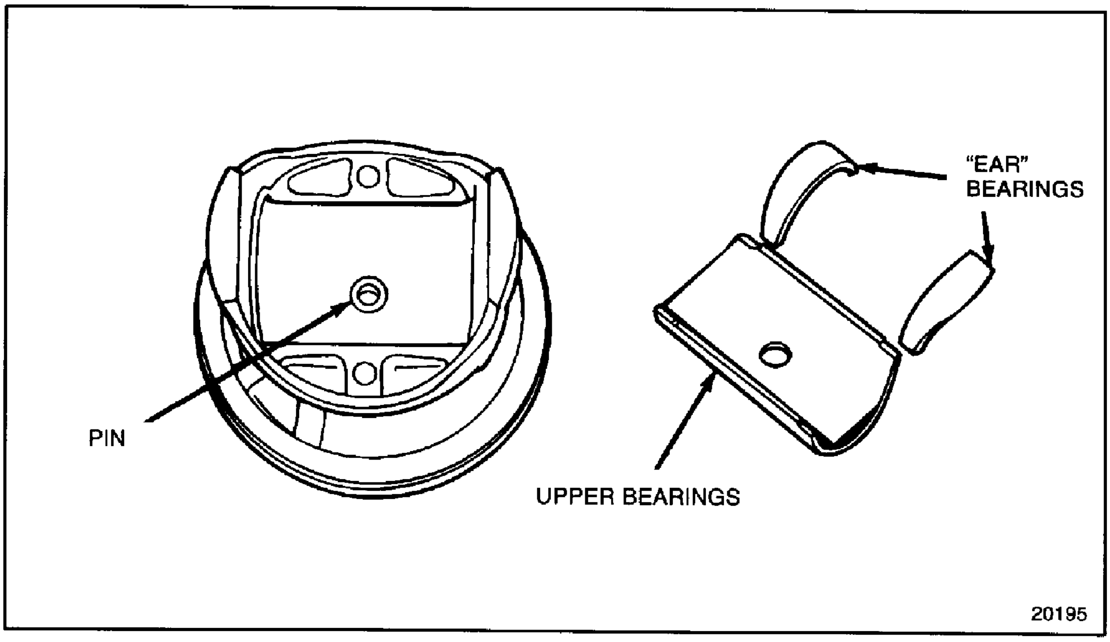


Figure 1-242 Piston Dome and Bearing Details

8. Lubricate the piston pin bearings with clean engine oil.
9. Set the piston skirt on the piston dome.
10. Align the piston pin holes in the dome and skirt.
11. Check the piston pin for foreign matter in the bolt holes.
12. Lubricate the pin with clean engine oil and install in the bores with the bolt holes facing the connecting rod, away from the dome.

NOTE:
The piston pin may feel considerably tighter than with conventional designs and possibly may not be turned easily by hand. Proper pin and bearing installation should result in a piston assembly in which the pin can be turned with the connecting rod while the piston dome is standing on the rim and the piston skirt is held with the other hand.

13. Apply a small amount of International Compound #2®, or equivalent, to the bolt threads and bolt head contact surfaces and both ends of the spacers.

NOTICE:
The connecting rod-to-piston pin attaching bolts and spacers are specially designed components. No other bolts or spacers may be used. Piston pin bolts are considered one-time use items and must be replaced with new bolts when removed for any reason. Failure to observe this precaution may result in bolt loosening or breakage during engine operation, which may cause serious engine damage.

14. Install the spacers on the two special connecting rod-to-piston attaching bolts.
15. After clamping the connecting rod in holding fixture, J 36211, torque each piston pin bolt to 95-122 N·m (70-90 lb·ft).
16. Complete the process by tightening the bolts to 157 ± 6.8 N·m (115 ± 5 lb·ft) final torque.

1.18.5 Installation of Piston and Connecting Rod Assembly

Use piston ring compression tool, J 35598–A, to install the piston and connecting rod assembly to the engine as follows:

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

1. Add clean engine oil to a clean drain pan at least 305 mm (12 in.) in diameter, until the level reaches approximately 76 mm (3 in.).
2. Place the piston and connecting rod assembly into the pan, with the dome of the piston on the bottom of the pan.

3. Coat the piston liberally with the engine oil, saturating the piston rings and lands. See Figure 1-243.

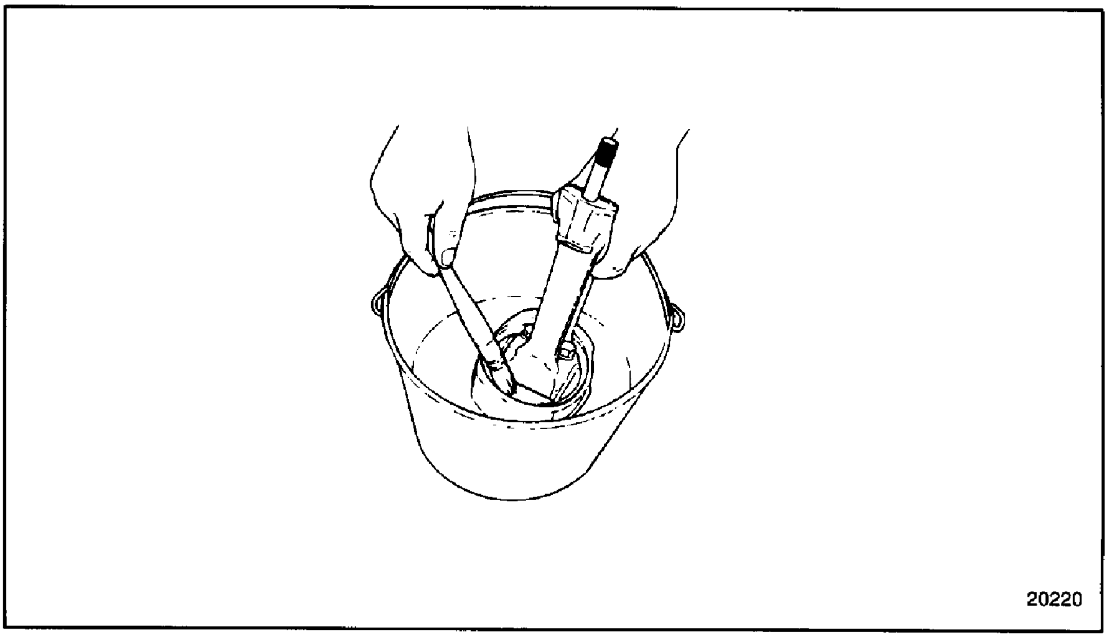


Figure 1-243 Piston and Connecting Rod Assembly Lubrication

4. Position (stagger) the piston ring gaps properly on the piston at 90° intervals. See Figure 1-244 for diesel and see Figure 1-245 for natural gas engines.

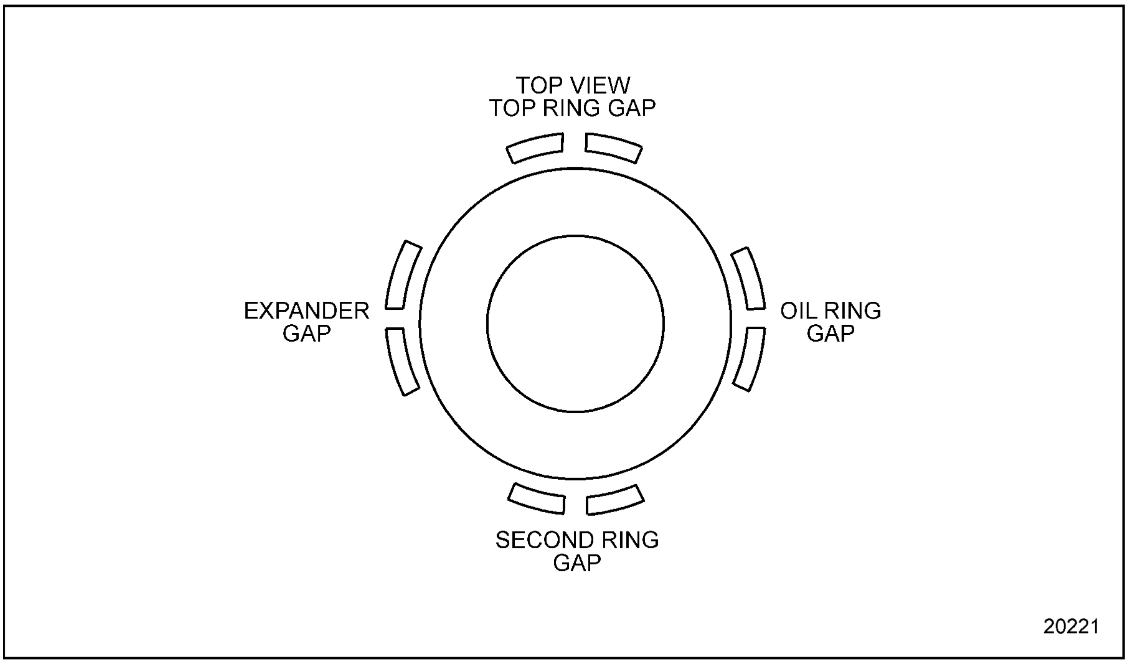


Figure 1-244 Piston Ring Positioning (Diesel)

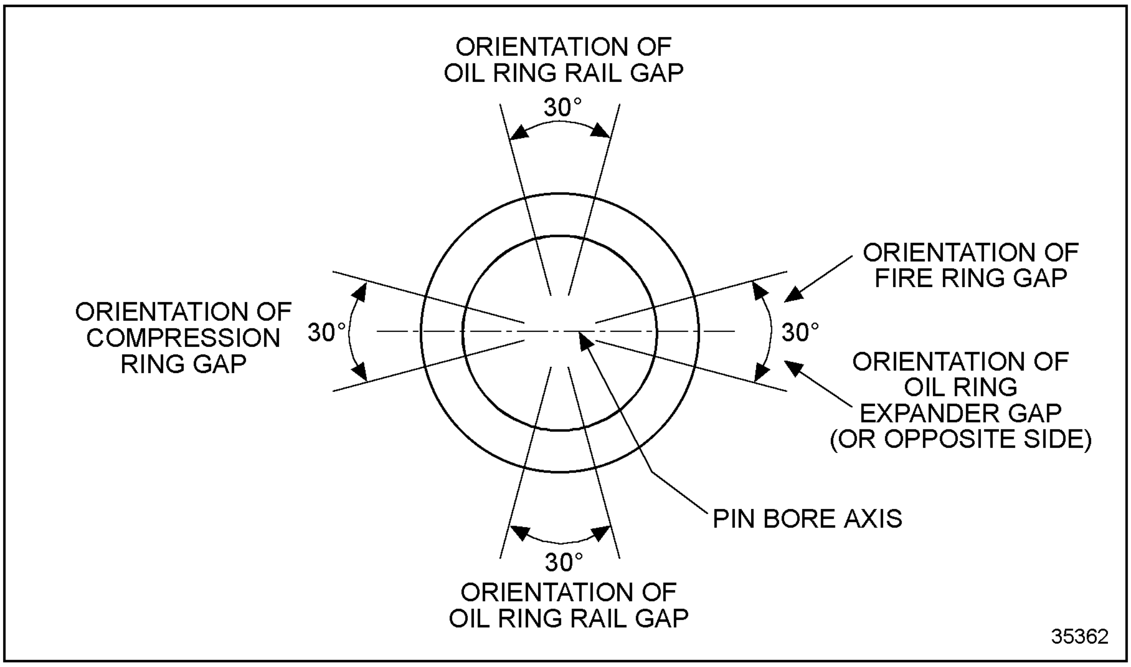


Figure 1-245 Piston Ring Positioning (Natural Gas)

5. Place the piston, dome down, in the bottom of the pan. Center the dome of the piston. See Figure 1-246.

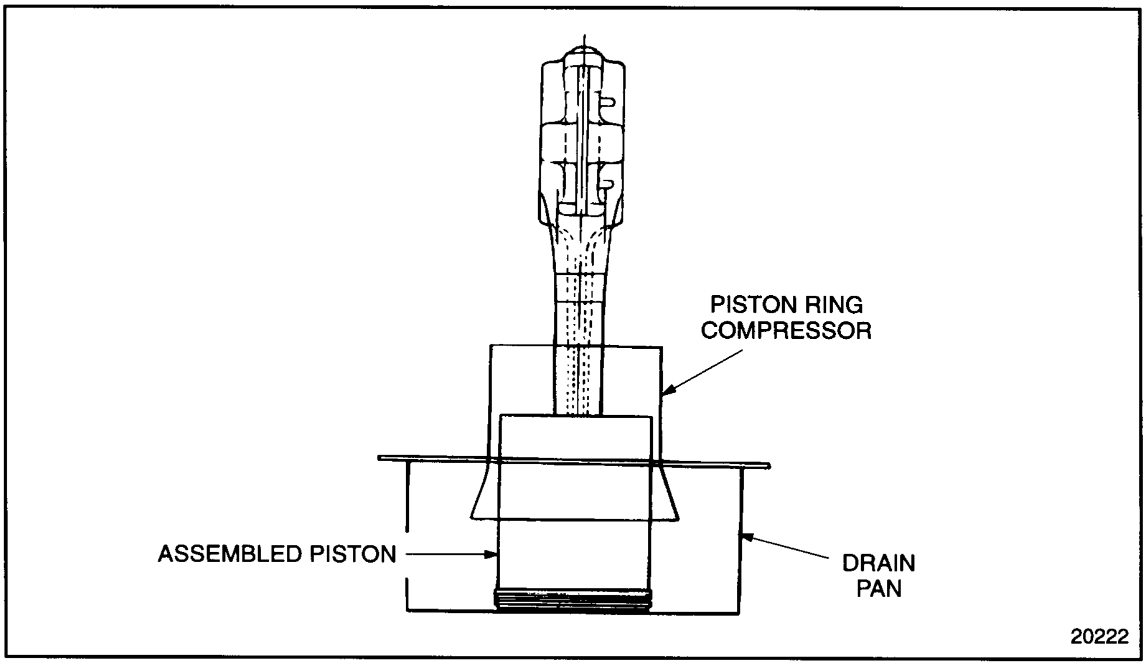


Figure 1-246 Installing Piston and Connecting Rod Assembly into Ring Compressor

6. Coat the inside diameter of the ring compressor liberally with clean engine oil from the pan.
7. Install the tapered end of the piston ring compressor over the end of the connecting rod, and down onto the piston. As the ring compressor slides down the piston to the piston ring area, apply slow, even pressure on both sides of the ring compressor to compress the rings.
8. Slide the ring compressor down until it contacts the bottom of the drain pan.
9. Position the crankshaft so that the connecting rod journal for the cylinder being worked on is at bottom-dead-center.
10. Remove the cap from the connecting rod.

NOTICE:

Do not allow the connecting rod to contact the cylinder liner on installation, or damage to the liner may occur. 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 (on the tang side of the rod and cap) as on the connecting rod that was replaced.

11. Install connecting rod guides, J 35945, over the ends of the connecting rod bolts to prevent damaging the crankshaft journals or the joint face of the rod. The guides also prevent the connecting rod from contacting the liner and damaging the surface. See Figure 1-247.

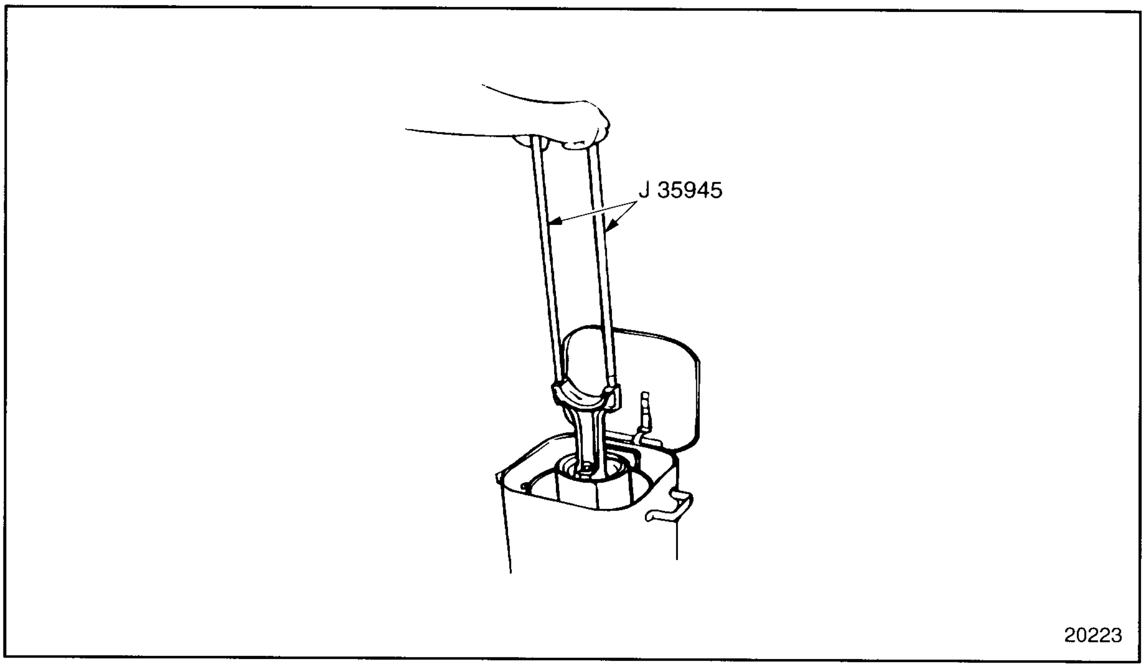


Figure 1-247 Connecting Rod Guides Installation

NOTE:
The connecting rod guides are threaded at the upper end and attach to the rod bolts.

12. Grasp the connecting rod assembly with one hand, and the piston ring compressor with the other. Lift the assembly out of the pan, and allow excess oil to drain back into the pan.

NOTE:
Do not allow the piston to slide out of the bottom of the ring compressor. DO NOT lift the assembly using the connecting rod guides.

13. With the crankshaft throw in the bottom position, place the ring compressor and the piston and connecting rod assembly over the cylinder it is to be installed in, being sure the No. on the connecting rod is towards the cooler side of the engine. See Figure 1-248.

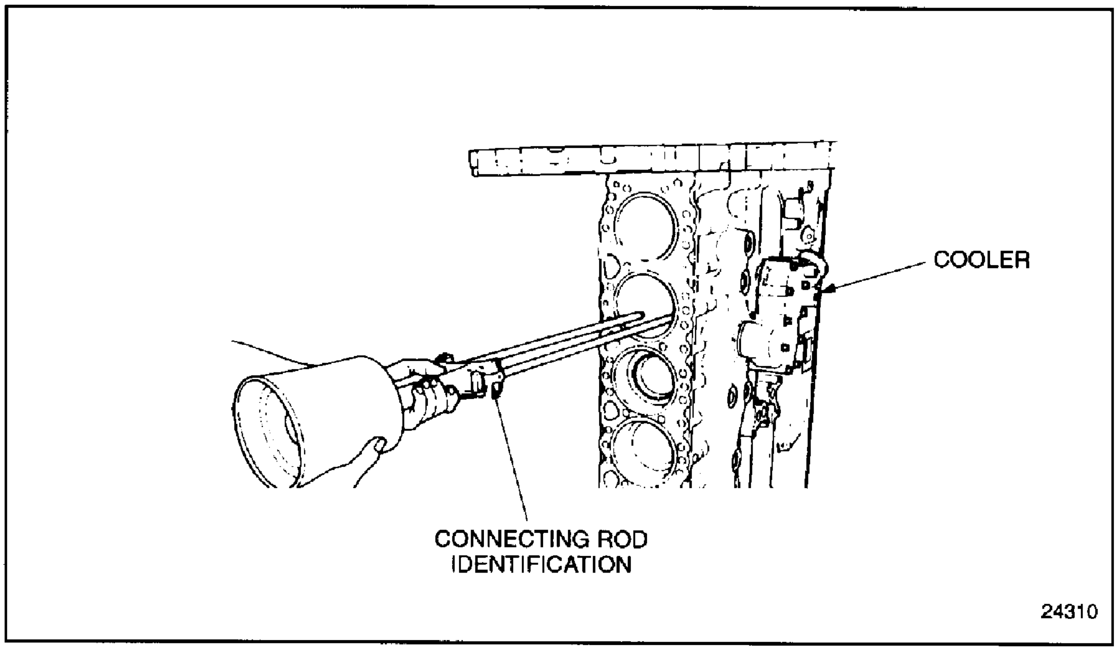


Figure 1-248 Connecting Rod Indexing

NOTE:
There are orientation lugs cast into one side of the upper and lower sections of the connecting rod. These orientation lugs face the front of the engine. See Figure 1-249.

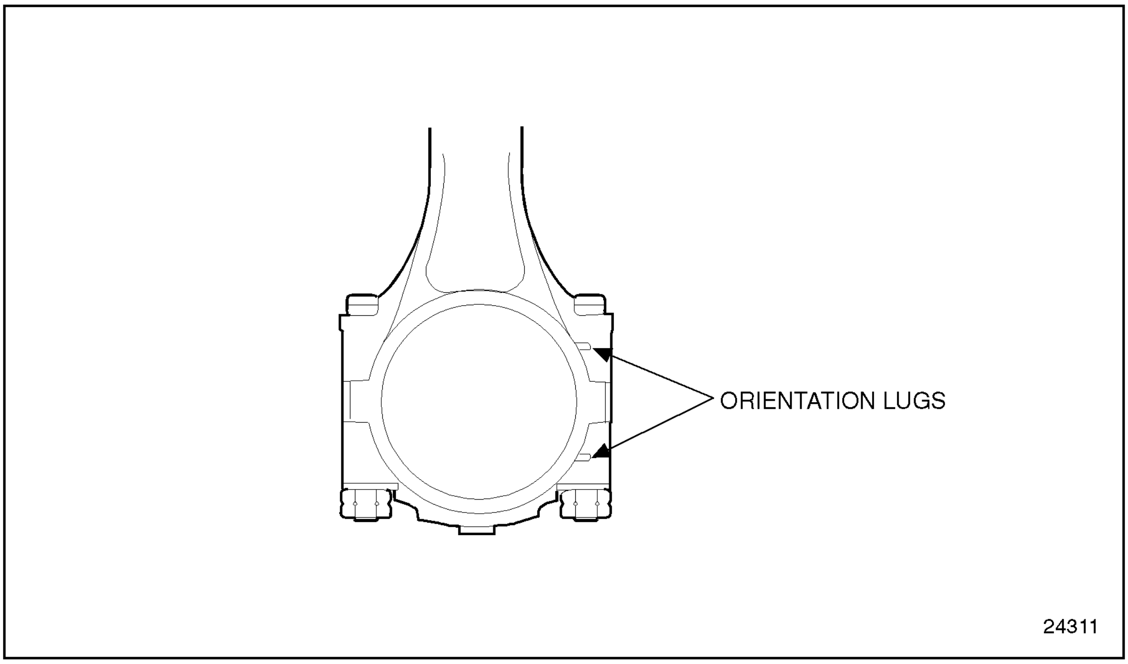


Figure 1-249 Orientation Lugs

14. Install the ring compressor, with piston and connecting rod inside, into the proper cylinder until the ring compressor is resting squarely on the cylinder liner. See Figure 1-250.

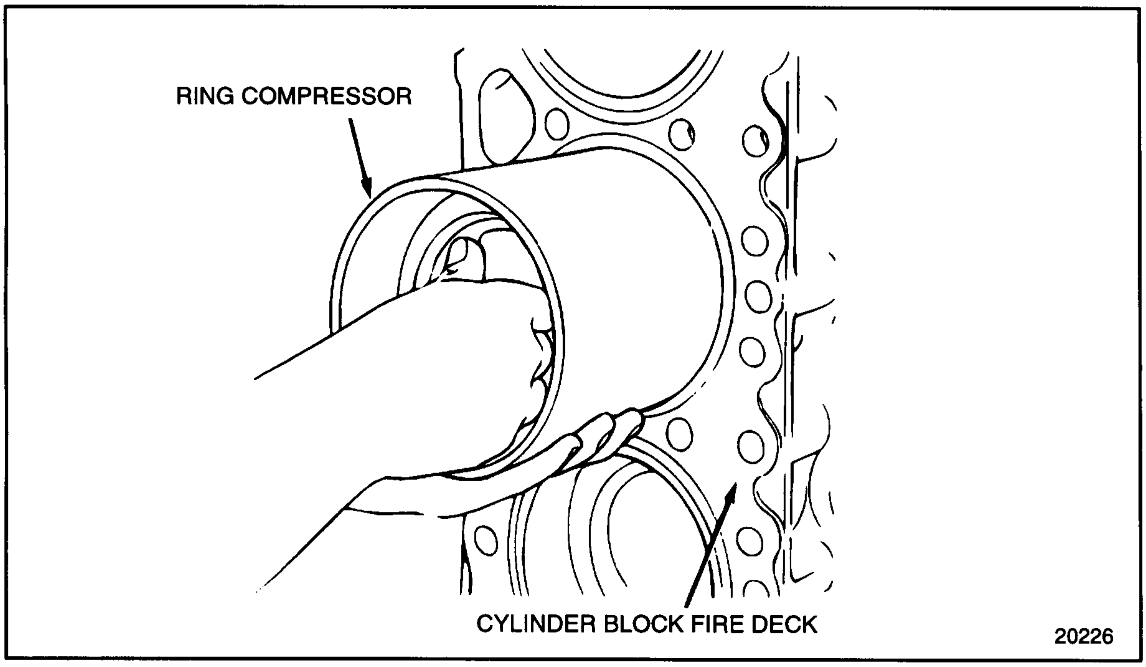


Figure 1-250 Use of Ring Compressor

NOTICE:
Do NOT force the piston into the liner. The oil ring expander applies considerable force on the oil ring. Therefore, care must be taken during the loading operation to prevent ring breakage.

15. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.
16. Remove the piston ring compressor.
17. Push or tap the piston and connecting rod assembly into the liner until the upper bearing shell is firmly seated on the appropriate crankshaft journal.
18. Remove the protective sleeves from the ends of the connecting rod bolts.

NOTE:
Be sure the connecting rod bolts have not been unseated or turned and the bearing locating tang is in its proper location.

19. Place the lower bearing shell in the connecting rod cap, indexing the tang on the bearing with the notch in the cap.
20. Lubricate the bearing shell with clean engine oil.
21. Install the bearing cap. The No. on the cap and rod should be on the same (oil cooler) side. See Figure 1-251.

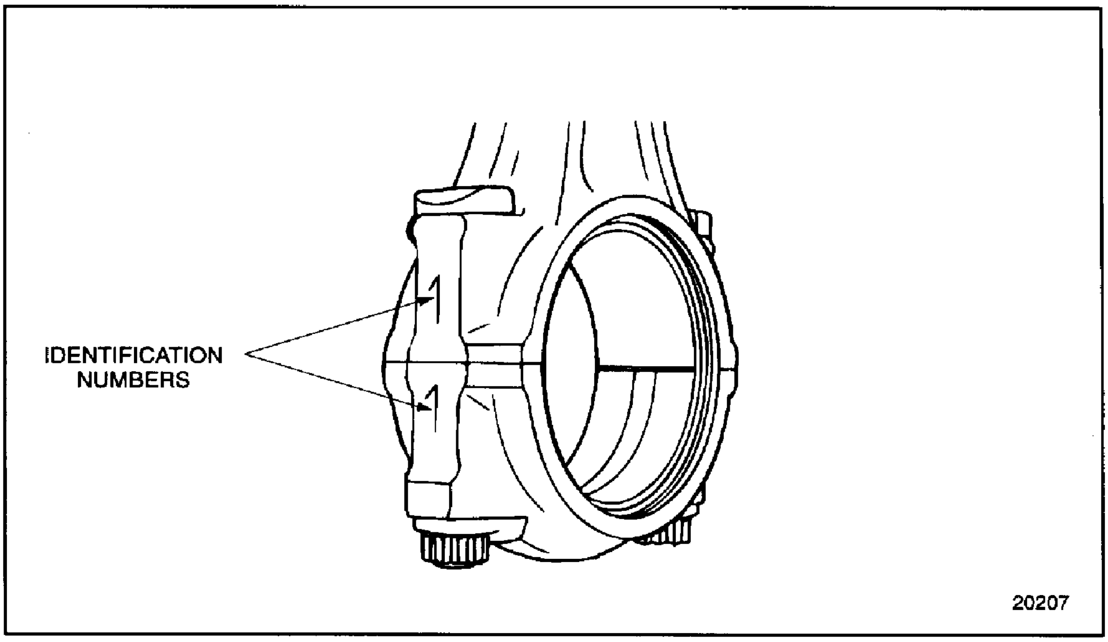


Figure 1-251 Connecting Rod and Cap Identification

22. Torque the connecting rod bolts alternately to 160-185 N·m (118-137 lb·ft).

23. Check connecting rod side clearance by moving the rod from crank cheek-to-crank cheek. If there is no clearance, check bearing cap installation.
24. Install the remaining piston and rod assemblies in the same manner.
25. Install a new head gasket. Refer to Section 1.2.5.
26. Install the cylinder head. Refer to Section 1.2.5.
27. Install the lubricating oil pump and balance shaft assembly inlet pipe and screen assembly, and the lubricating oil pump. Refer to Section 3.2.5.
28. Install the oil pan. Refer to Section 3.9.3.
29. Complete any other engine assembly as necessary.
30. After the engine has been completely assembled, refill the crankcase to the proper level on the dipstick. Refer to Section 13.5.1.
31. Close the drain cocks and fill the engine with the recommended coolant. Refer to Section 13.5.4.

NOTE:
Coolant system maintenance is very important. Bleed off all of the air from the system and top off.

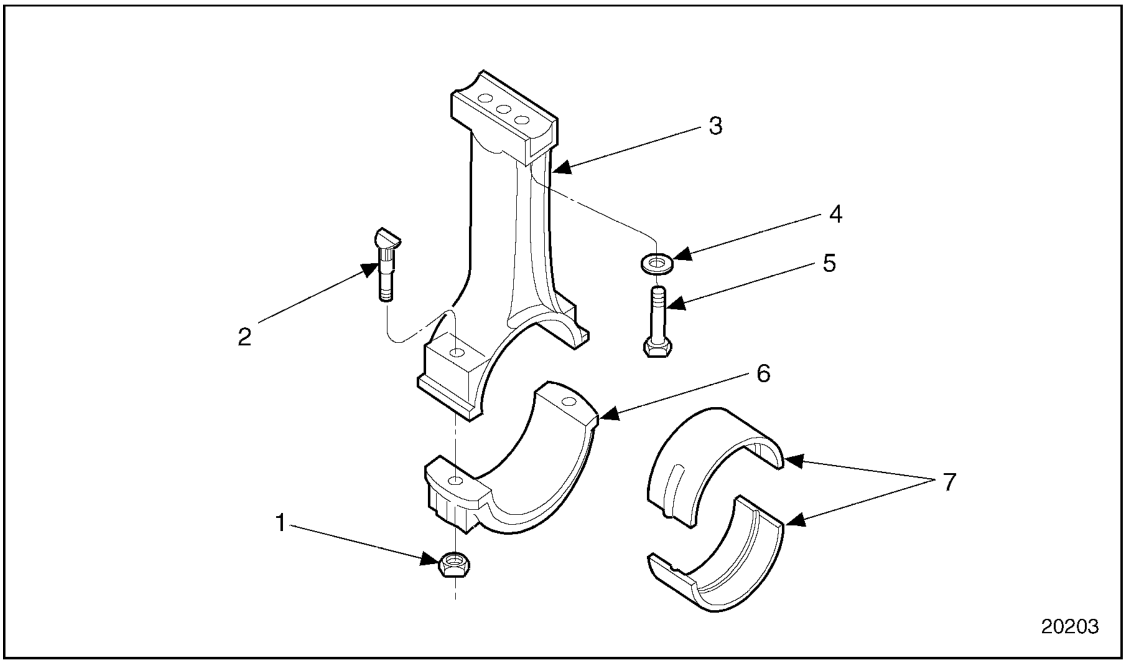
32. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run-in schedule. Refer to Section 11.8.2.
33. Refer to Section 11 for verification of proper piston and connecting rod assembly installation.

1.19 CONNECTING ROD

The connecting rod is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end. The surface of the connecting rod is shot peened for added strength. Therefore, no grinding is permitted since it will remove the benefits of shot peening. See Figure 1-252.

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

The two special bolts locate the cap relative to the upper end. The assembly is machined as a unit and must not be used in the engine with any other cap or upper end. Orientation of the cap to the upper end is identified by stamped numbers.



1. Rod Bolt Nut
2. Connecting Rod Cap Bolt (2)
3. Connecting Rod
4. Spacer
5. Piston Pin Bolt (2)
6. Connecting Rod Bearing Cap
7. Bearing Shells

Figure 1-252 Connecting Rod and Bearing Shells

The connecting rods replaced the former connecting rods, effective with the following engine serial numbers as listed in Table 1-5:

ENGINE MODEL	ENGINE SERIAL No.
All Series 50 Engines	4R6665

Table 1-5 New Connecting Rod Replacement

This change was made to allow installation of new, wider connecting rod bearings that provide improved oil film thickness and reduced bearing pressures.

The rod chamfers on the new connecting rods are smaller than those on the former rods. This has been done to provide proper support for the wider bearings. To conform with this change, new crankshafts with smaller fillet radii have been released. Refer to Section 1.7 for information of the new crankshafts.

NOTE:
The new connecting rods, bearings, and crankshafts *must* be used together to ensure interchangeability. Former parts cannot be mixed with new parts in the same engine. The former connecting rods will continue to be available for engines built prior to the unit serial numbers as listed in Table 1-5.

The connecting rod bearing shells are precision made and are of the replaceable type. The upper bearing shell is seated in the connecting rod and a lower bearing shell is seated in the connecting rod cap. These bearings are not identical. 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. See Figure 1-252.

The tri-metal bearing wear surfaces use a steel backing. First, an optimum composition (copper, tin and lead) lining is bonded to the steel back. A nickel barrier above the lining and the overlay serves to prevent tin migration. A soft lead overlay, 0.025 mm (0.001 in.) thick, provides run-in protection, and an initial wear surface. A flash tin plate, front and back, is for added corrosion protection and resistance during shipping and handling. These bearings are identified by the satin silver sheen of the tin when new, and a dull gray of the overlay after being in service.

The oil hole through the upper bearing shell supplies oil to the oil passage in the connecting rod, thereby providing a supply of lubricating oil from the crankshaft to the connecting rod bearings, piston-pin bushing, and underside of the piston dome. The upper shell is grooved from one edge to the oil hole. The lower shell has a full-length (180°) groove. See Figure 1-253.

The connecting rods bearing caps are numbered according to the cylinder position with matching numbers stamped on the connecting rod tang side.

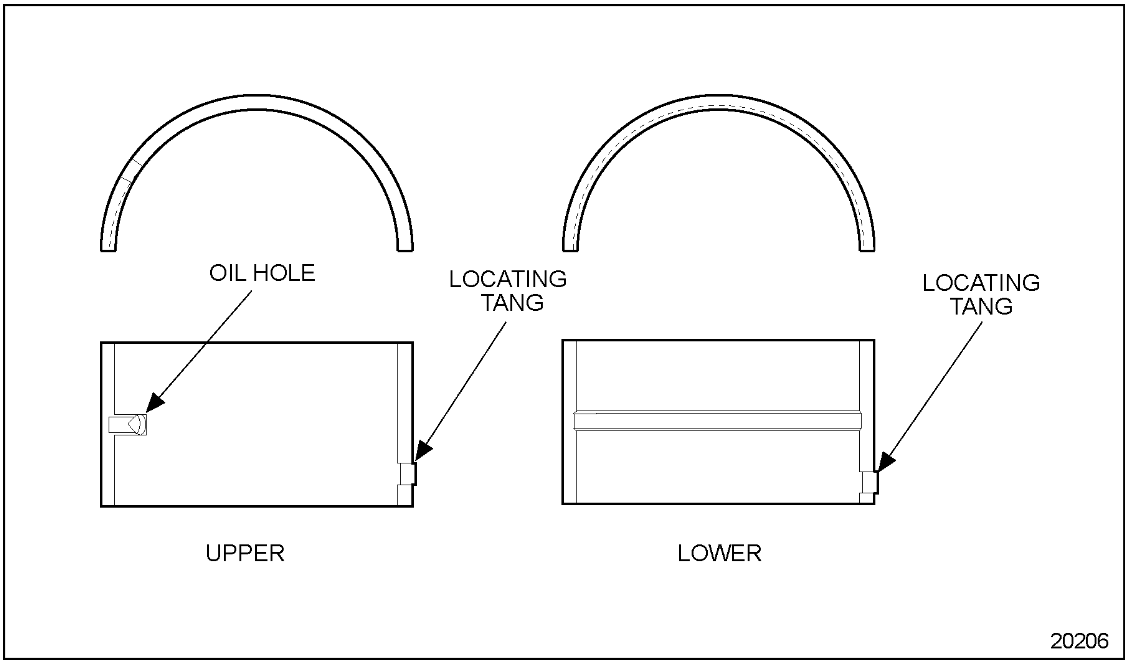


Figure 1-253 Connecting Rod Bearing Detail

New, wider connecting rod bearings replaced the former connecting rod bearings as listed in Table 1-5.

This change was made to improve oil film thickness and reduce bearing pressures. The new bearings are 47.44-47.14 mm (1.868-1.856 in.) wide. The former bearings were 43.44-43.14 mm (1.710-1.698 in.) wide. To provide full support for the wider bearings, new connecting rods with smaller rod chamfers and new crankshafts with smaller fillet radii were also released. Refer to Section 1.7 for information on the new crankshafts.

NOTE:
The new connecting rod bearings, connecting rods, and crankshafts *must* be used together to ensure interchangeability. Former parts cannot be mixed with new parts in the same engine. The former bearing shells will be available for engines built prior to the unit serial numbers as listed in Table 1-5.

1.19.1 Repair or Replacement of Connecting Rod

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-254.

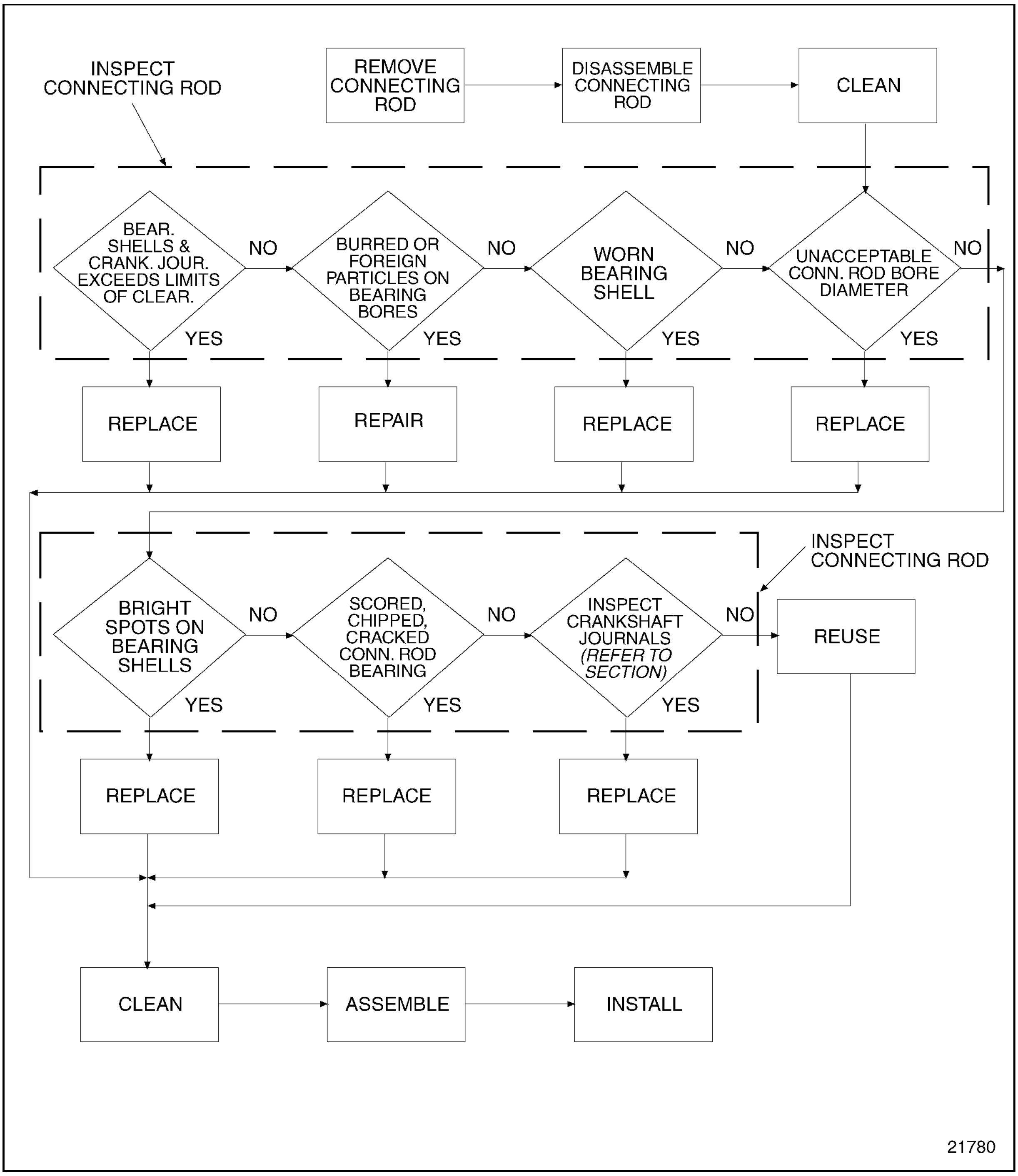


Figure 1-254 Flowchart for Repair or Replacement of Connecting Rod

1.19.2 Cleaning and Removal of the Connecting Rod

Before removal, make sure the connecting rods and caps are stamped with their correct cylinder location. If not marked, stamp location (1-4) on the tang side (cooler side) of the rod and cap.

Refer to Section 1.18.2 for piston and connecting rod assembly removal procedure.

1.19.3 Disassembly of Connecting Rod

Disassemble the connecting rod as follows:

NOTE:
It is best to disassemble, inspect and assemble each connecting rod separately. It's very important to keep the connecting rod cap, and the upper and lower bearing shells to the original connecting rod.

1. Loosen and remove the two bolts.
2. Remove connecting rod cap and bearings shells.

1.19.3.1 Inspection of Connecting Rod

Clean the bearings prior to inspection as follows:

1. Clean the bearings with fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the bearings with compressed air.

Inspect the connecting rod as follows:

1. Inspect the connecting rod saddle at the piston pin contact surface for traces of fretting and corrosion.
2. To repair, wet with fuel oil and smooth with crocus cloth.

1.19.4 Assembly of Connecting Rod

Assemble connecting rod as follows:

1. Install the connecting rod cap with the numbers on the same (oil cooler) side on the connecting rod.
2. Lubricate the bolt threads with clean engine oil.

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

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

3. Torque the bolt nuts to 160-185 N·m (118-137 lb·ft).

1.19.4.1 Inspection of Assembled Connecting Rod

Measure the connecting rod bearing diameter at five locations. See Figure 1-255.

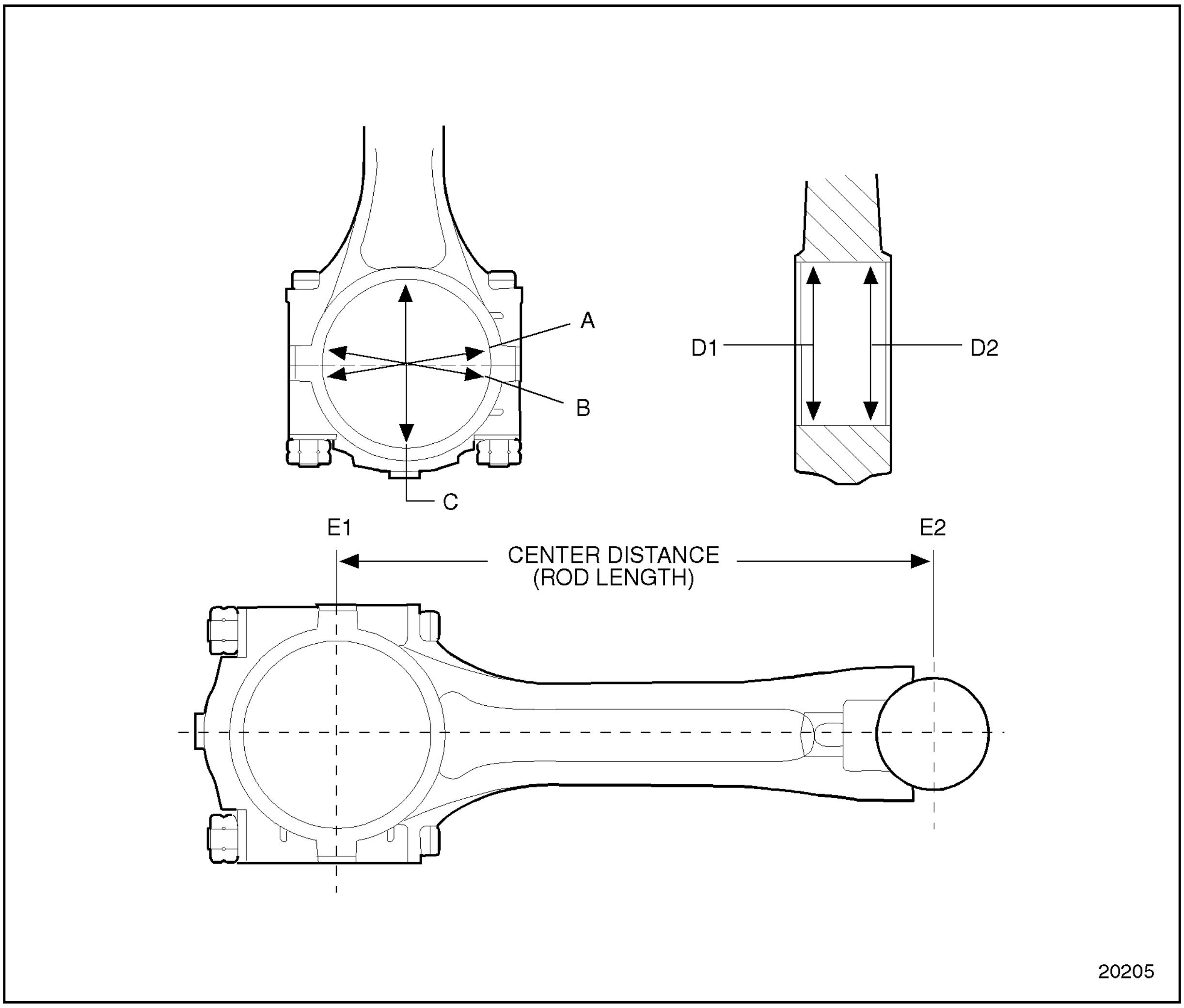


Figure 1-255 Dimensional Inspection of Cross-head Piston Connecting Rods

1. Calculate size of diameter at split line, W. [W=(A+B) ÷ 2].
2. Calculate the average bore out-of-round, X. [X=W-C] X must be between -0.012 and 0.012 mm (-0.0005 and 0.0005 in.).
3. Calculate the average connecting rod bearing bore size, Y. [Y=(W+X) ÷ 2] Y must be between 91.288 and 91.313 mm (3.594 and 3.595 in.).
4. Determine taper, Z. [Z=D2-D1] Z must be between -0.012 and 0.012 mm (-0.0005 and 0.0005 in.).
5. Determine the rod length by finding the distance between E1 and E2. See Figure 1-255.
   [a] The acceptable rod length specification for the Series 50 Engine is: 269.25-269.35 mm (10.6004-10.6043 in.), for Series 50G Engines is: 262.90-263.00 mm (10.3504-10.3543 in.).
   [b] If the connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.
6. If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap. Refer to Section 1.18.2.

1.19.4.2 Inspection of Connecting Rod Bearings and Bearing Bores

Inspect the connecting rod bearing as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clean of obstructions. Also make sure the split line (cap to rod) is thoroughly cleaned.
2. Check connecting rod bearing wear surfaces for scoring, pitting, flaking, chipping, cracking, loss of overlay, or signs of overheating.
   [a] Overlay plated bearings may develop very small cracks or small isolated cavities ("checking") 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 most of the load, will normally show signs of distress before the lower bearing shells do. If the overlay is worn through to the copper across the bearing shell, all the bearing shells must be replaced.
   [b] If any of these conditions are detected, replace the bearings.
3. Inspect the backs of the connecting rod bearing shells.
   [a] Check for bright spots that indicate shells have been shifting in their bores.

[b] If bright spots are evident, replace the bearings shells.

4. Inspect the connecting rod bearing bores.
   [a] Check for burrs or foreign particles.
   [b] Use an emery cloth to smooth bore surface, otherwise replace part.
5. Inspect the bearings shells.
   [a] Measure the thickness of the bearing shells, using a micrometer and ball attachment, refer to Section 1.9.2.1. The minimum thickness of a worn standard connecting rod bearing shell should not be less than 3.086 mm (0.1215 in.).
   [b] If either bearing shell is thinner than this dimension, replace both bearing shells.
6. Inspect the bearing shells and the crankshaft journals.
   [a] Check the clearance between the connecting rod bearing shells and the crankshaft journals using a soft plastic measuring strip which is squeezed between the journal and the bearing. Refer to Section ADDITIONAL INFORMATIONand see Figure 1-440.
   [b] If the connecting rod bearing-to-journal clearance exceeds 0.151 mm (0.006 in.) with used parts, replace with a new bearing.

NOTE:
Before installing the bearings, inspect the crankshaft journals. Refer to Section 1.7. 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.

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

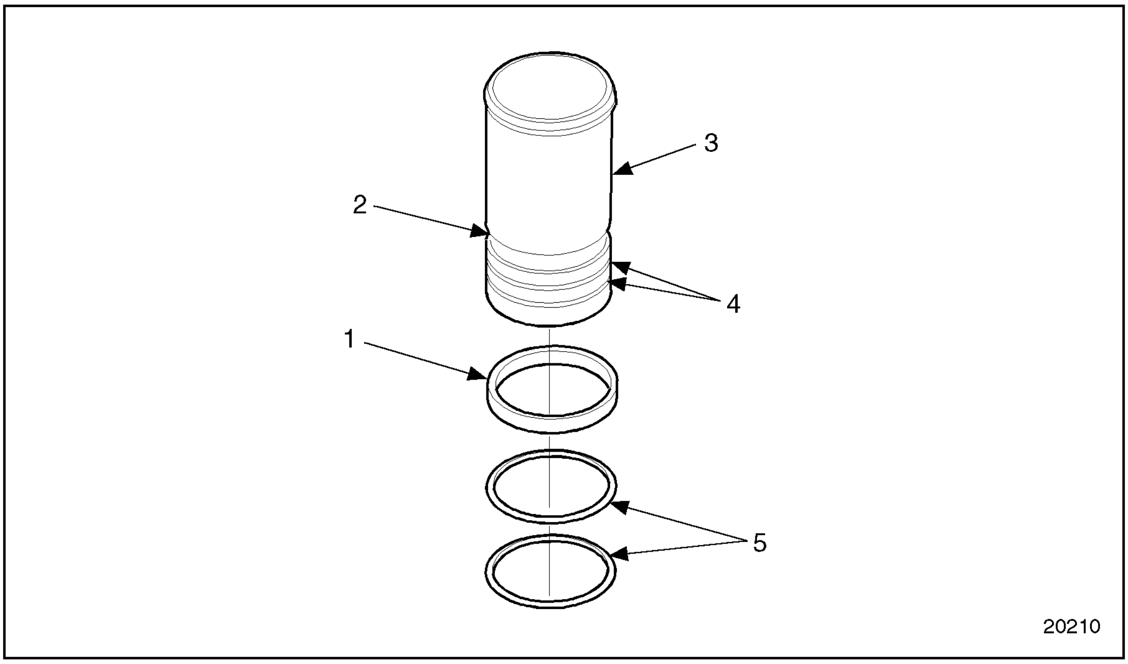
Bearing shells are available in 0.250, 0.500 and 0.750 mm (approximately 0.010, 0.020, and 0.030 in.) undersize for service with reground crankshafts. To determine the bearing size required, refer to Section ADDITIONAL INFORMATION, and listed in Table 1-8.

1.19.5 Installation of Connecting Rod

Refer to Section 1.18.5 to install the piston and connecting rod assembly.

1.20 CYLINDER LINER

The cylinder liner is of the replaceable wet type, made of hardened alloy cast iron, and is slip fit in the cylinder block. See Figure 1-256.

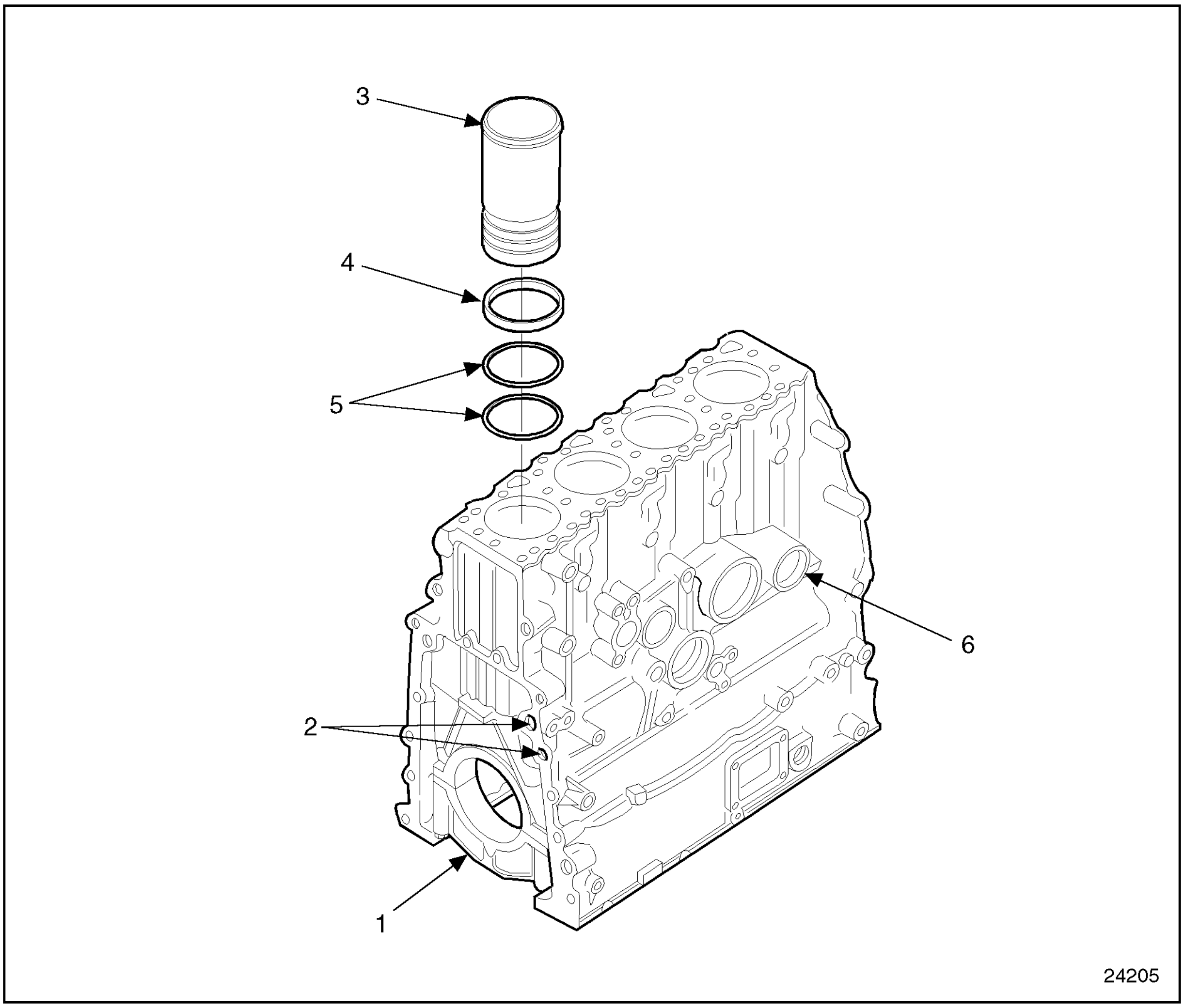


1. Crevice Seal
2. Crevice Seal Groove
3. Cylinder Liner
4. D-ring Grooves
5. D-ring Seals

Figure 1-256 Cylinder Liner and Related Parts

Coolant in the cylinder block water jacket surrounds the liner and cools it directly. A cooling channel is also cut into the liner immediately below the flange. Coolant flow through this channel and around the rest of the liner controls critical ring and liner temperatures for long cylinder component life.

The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner fits into a counter bore in the cylinder block. See Figure 1-257.



1. Rear Main Bearing Cap
2. Oil Galleries
3. Cylinder Liner
4. Crevice Seal
5. D-ring Seals
6. Integral Coolant Inlet Manifold

Figure 1-257 Cylinder Liner Installation

NOTICE:
The crevice seal prevents coolant from being pumped in and out of the area adjacent to the liner lower block location which could result in cavitation and corrosion damage to the liner and the block.

A crevice seal, fitting in the wide uppermost groove in the liner helps to stabilize the liner in the cylinder block bore.

This seal also keeps any debris that is in the cooling system from causing abrasion damage to the upper "D" liner seal ring. See Figure 1-258.

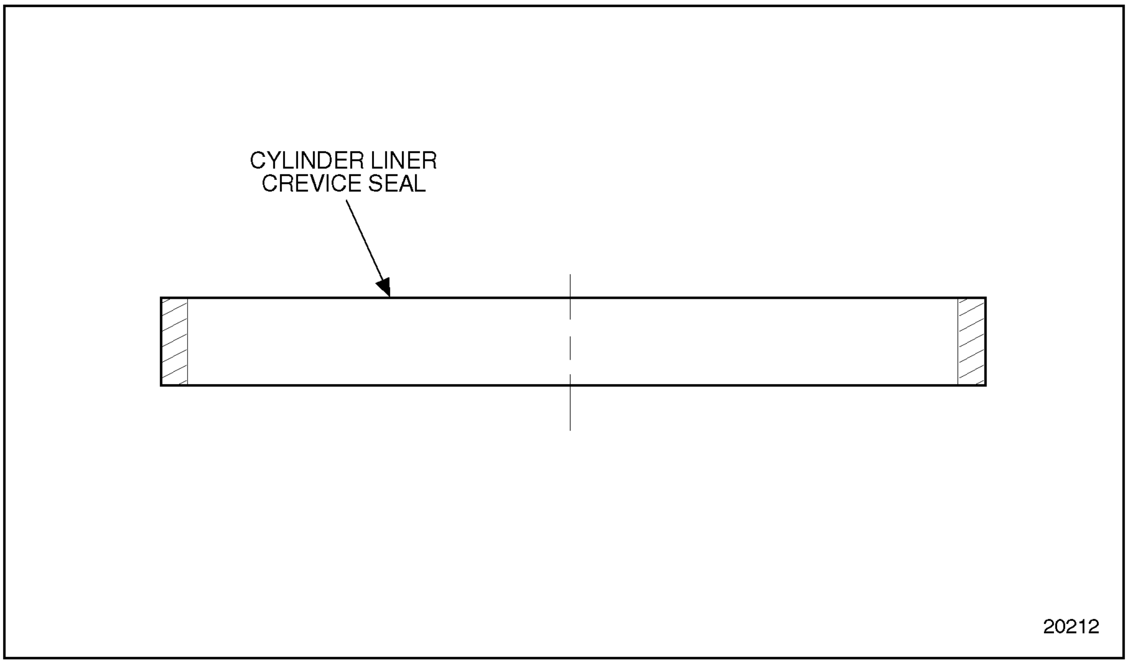


Figure 1-258 Cylinder Liner Crevice Seal Cross Section

Two Teflon-coated, D-shaped seal rings, recessed in the lower two grooves in the cylinder liner, are used between the liner and the block to prevent coolant and oil leakage. See Figure 1-259.

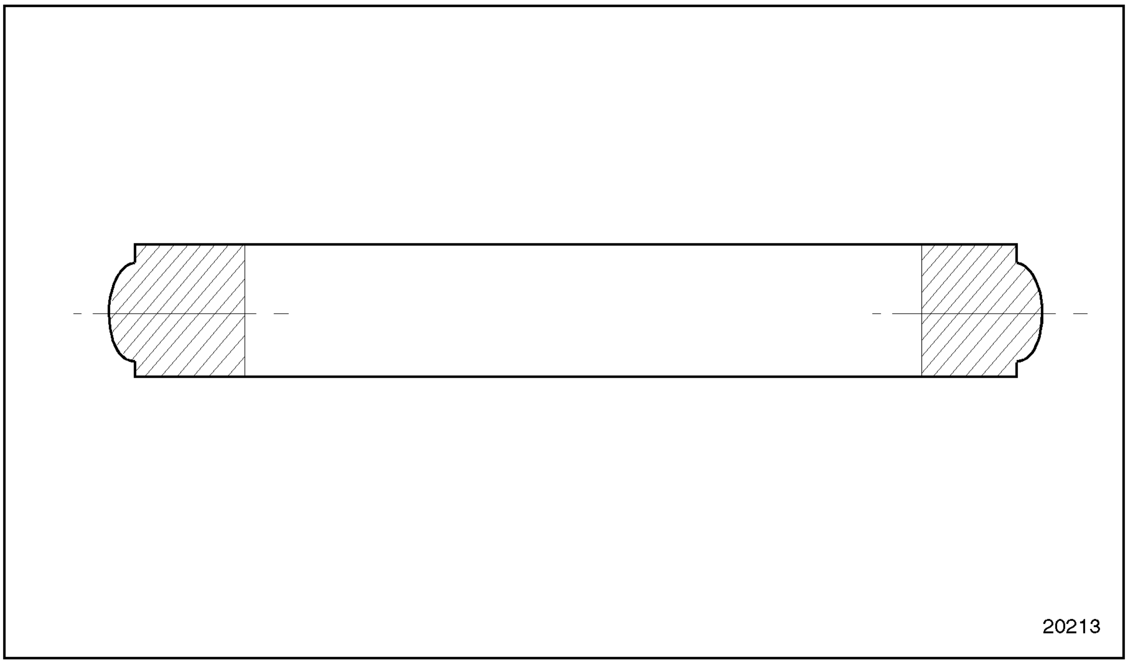


Figure 1-259 Cylinder Liner Seal Ring Cross-Section

A weep hole for each cylinder is drilled through the cylinder block exterior, into the cylinder bore area. This weep hole is located between the two D-shaped seal rings. It is used to determine if engine coolant is leaking past the upper liner seal, or if oil is leaking past the lower liner seal. See Figure 1-260. A special rubber plug prevents dirt from getting into the "D" seal ring areas and causing abrasive damage. At the same time it allows leaking oil or coolant a path out of the engine for detection.

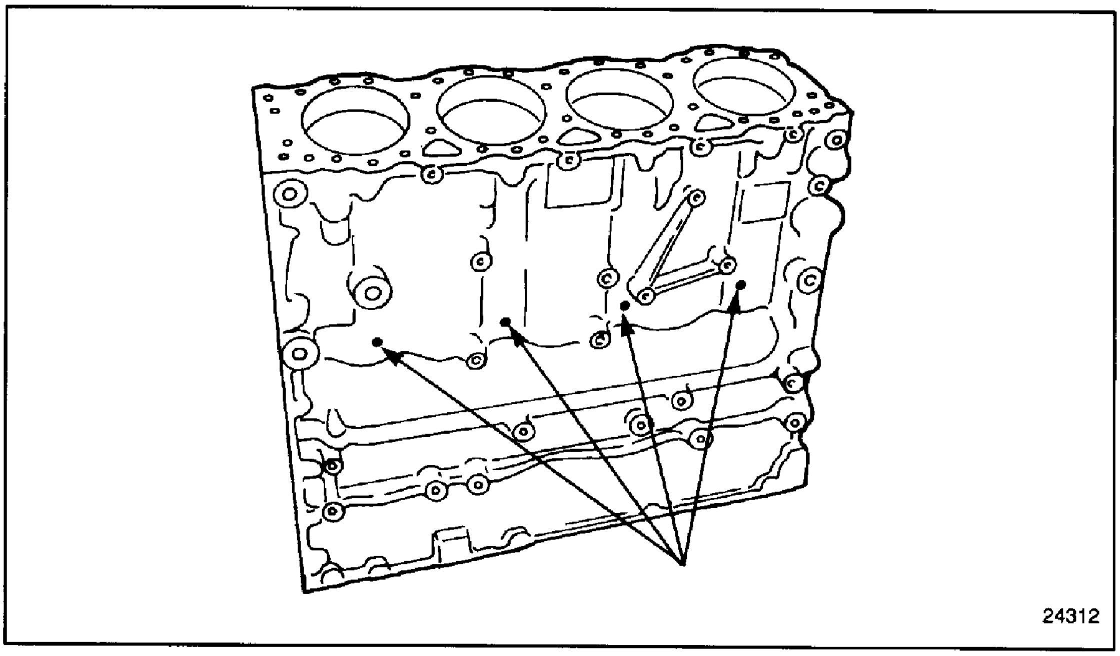


Figure 1-260 Weep Hole Plug Locations

1.20.1 Repair or Replacement of Cylinder Liner

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-261.

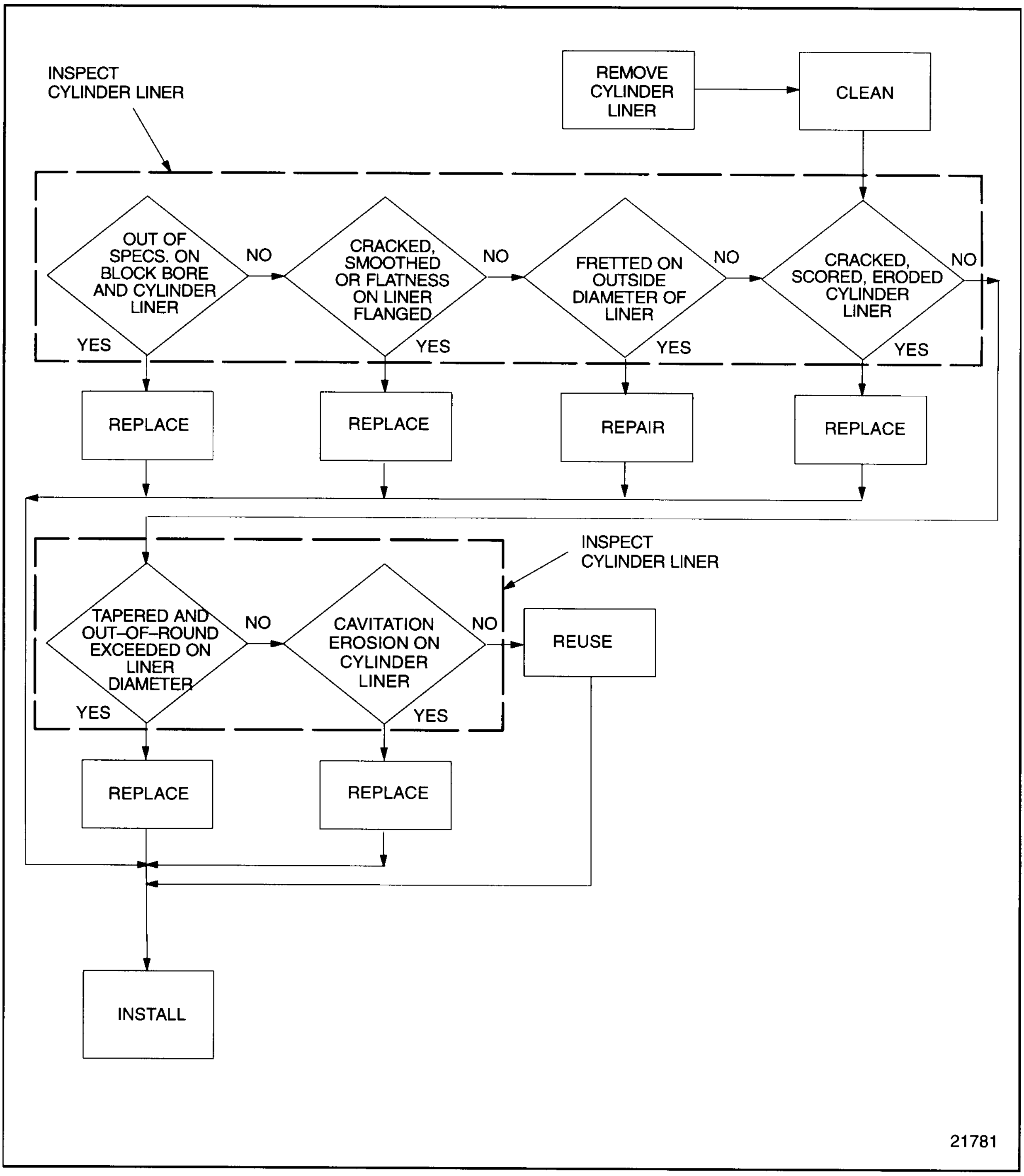


Figure 1-261 Flowchart for Repair or Replacement of Cylinder Liner

1.20.2 Cleaning and Removal of Cylinder Liner

Precleaning is not necessary.

NOTICE:
The proper method must be followed when removing a cylinder liner. Damage to the liner and the cylinder block may occur if the proper tools and procedures are not used.

1. Remove the piston and connecting rod as an assembly. Refer to Section 1.18.2.
2. Remove the cylinder liner with cylinder liner remover, J 35791. See Figure 1-262 and see Figure 1-263.

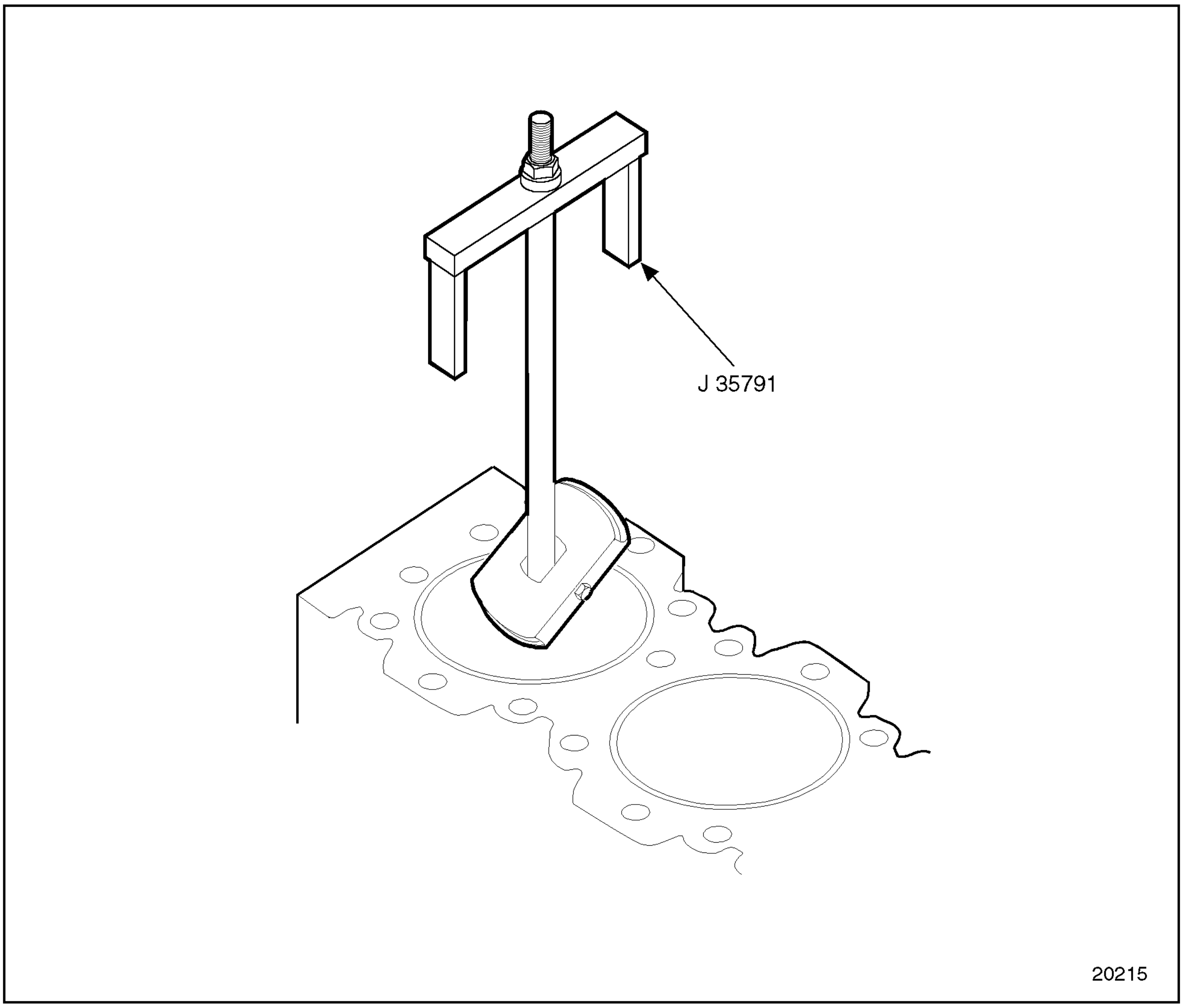


Figure 1-262 Cylinder Liner Remover

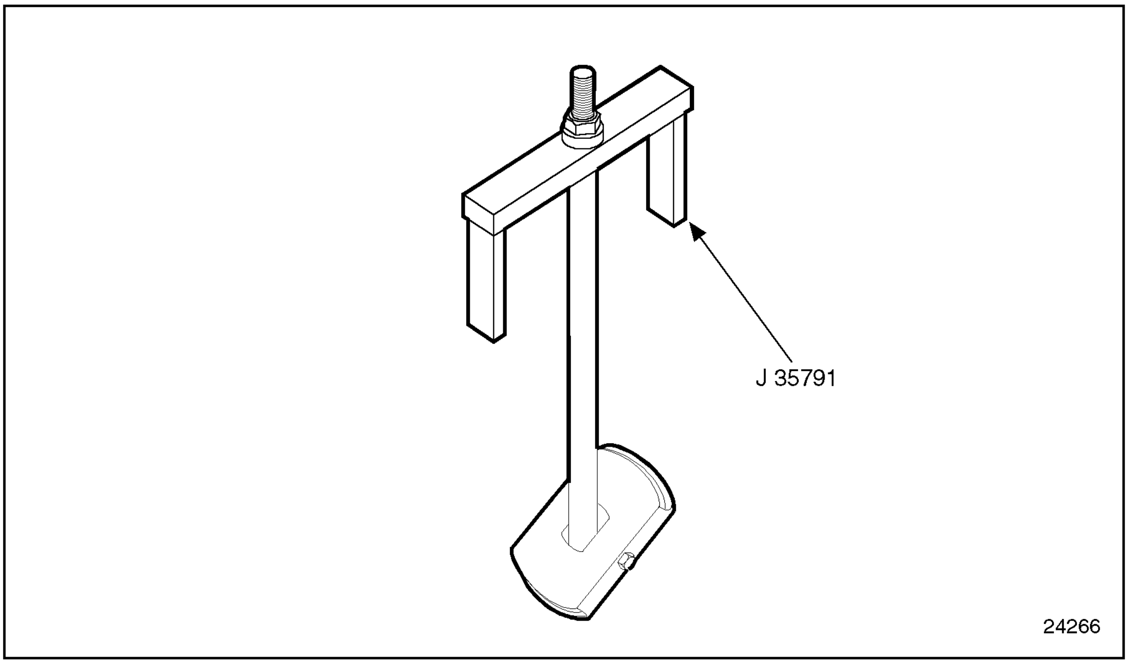


Figure 1-263 Cylinder Liner Removal Tool

[a] Ease the shoe of the liner removal tool down into the liner.

[b] Place the shoe into the bottom edge of the liner.

[c] Turn the nut on the tool in a clockwise direction to remove liner from the block.

NOTE:
After removing liners from an engine and prior to installing liners, always store them in an upright position until ready for use. Liners left on their side for any length of time can become egg-shaped and distorted, making installation in cylinder bores difficult or impossible. If the cylinder liners are to be reused, they should be marked so they may be installed to the same cylinder from which they were removed.

[d] Remove the tool from the liner

[e] Remove the seals (all 3) from the liner and discard them.

Clean the cylinder liner prior to inspection as follows:

1. Wash new and used cylinder liners with a strong detergent and warm water solution. Scrub the cylinder liners with a non-metallic bristle brush.
2. Rinse the cylinder liners with hot water or steam.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Dry the liner with compressed air.
4. Coat the bore of the liner with clean engine lubricating oil.
5. Allow the liner to sit for 10 minutes (to allow the oil to work into the surface finish).
6. Wipe the inside of the liner with clean, white paper towels.
7. If a dark residue appears on the towels, repeat the oiling and wiping procedure until residue no longer appears.

NOTICE:

If the liners are not to be installed at this time, oil them lightly with clean engine lubricating oil and store them upright in a clean, dry area. Do not allow the liners to rest on their sides and do not store anything on top of the liners.

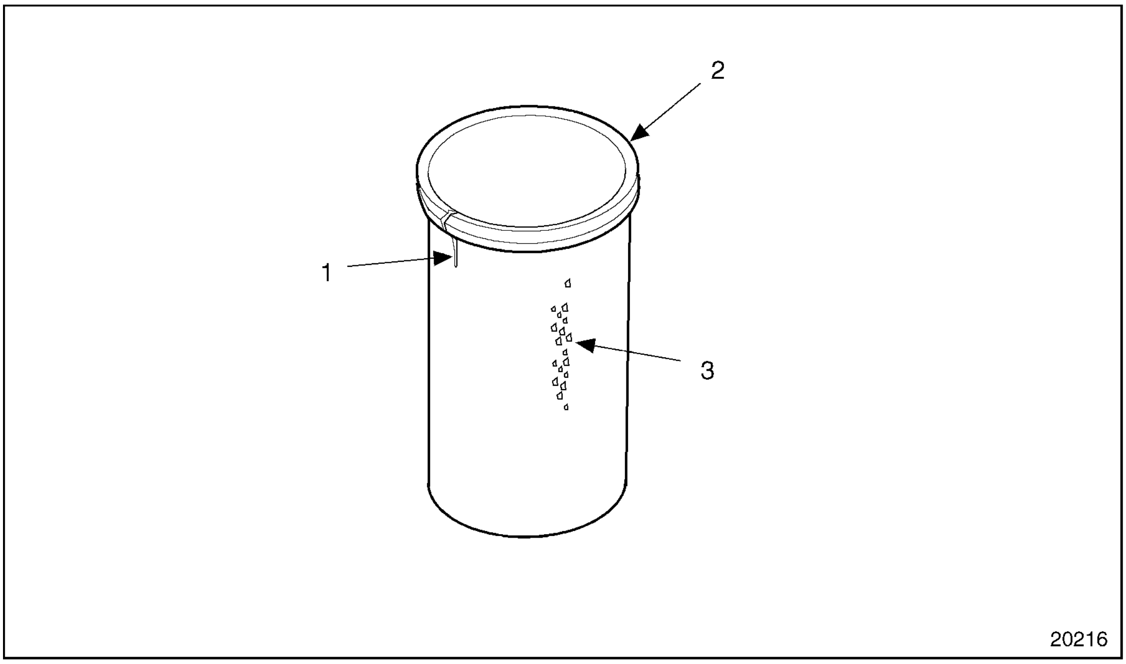
1.20.2.1 Inspection of Cylinder Liner

Inspect the cylinder liner as follows:

1. Inspect the cylinder liner.
   [a] Check the cylinder liner for cracks or scoring.
   [b] If any of these are detected, replace with a new part.

NOTICE:
Series 50 Engines cylinder liners are honed at the factory with a process that cannot be duplicated in the field. For this reason, honing of used liners should not be attempted.

[c] Check the cylinder liner for cavitation erosion. See Figure 1-264.



1. Cracks
2. Cylinder Liner
3. Erosion

Figure 1-264 Cavitation Erosion

NOTICE:
Erosion is due to poor cooling system maintenance. If uncorrected, it will eventually make holes through the liner. This can result in combustion gases blowing water out of the radiator, oil in the coolant, or when the engine is stopped will allow water to flow into the cylinder and result in major engine damage due to water in the oil or hydraulic lockup.

[d] If cavitation erosion occurs, replace with a new part. Refer to Section 1.20.3.

2. Inspect the outside diameter of the liner.

    [a] Check liner for fretting.

    [b] If any fretting is found, remove it from the surface of the liner with a coarse, flat stone.

3. Inspect the liner flange.

[a] Check the liner flange for cracks, smoothness and flatness on both the top and bottom surfaces.

[b] If these are detected, replace with a new part.

4. Inspect the block bore and cylinder liner.

[a] Measure the block bore and the outside diameter of the liner. Refer to Section 1.1.4.1. The liner specifications are listed in Table 1-13. The block specifications are listed in Table 1-12 in refer to Section ADDITIONAL INFORMATION.

[b] If the liner does not meet specs, replace with a new part.

5. Inspect inside diameter of cylinder liners.

[a] Set the cylinder bore gage on zero in master setting fixture. Use cylinder bore gage, J 5347-B, to measure diameter of the liner of various points. The maximum diameter of a used liner after is 130.100 mm (5.122 in.) at any measurement location. See Figure 1-265. Also check the liner for taper and out-of-round.

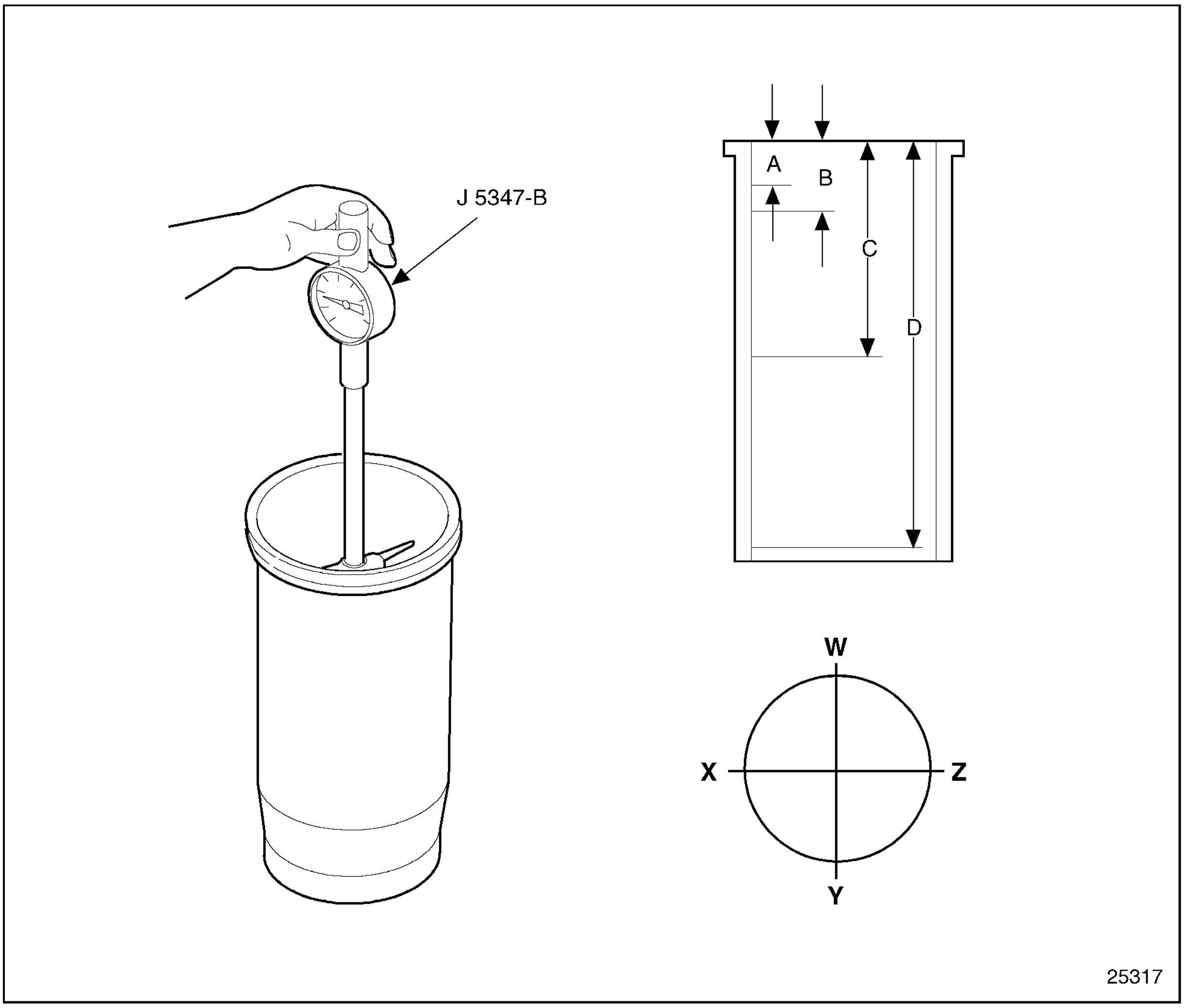


Figure 1-265 Cylinder Liner Measurement Diagram

[b] If the taper and out-of-round exceed 0.025 mm (0.0001 in.), replace with a new part.

6. Inspect the cylinder liner.
   [a] Check the seal ring and crevice seal grooves for burrs or sharp edges.
   [b] If any are detected, smooth with an emery cloth.

1.20.3 Installation of Cylinder Liner

Install the cylinder liner as follows:

1. Wipe the inside and outside of the liner clean. Be sure the block bore and counter bore are clean, so the liner flange will seat properly. The block counter bore depth must be 8.9246-8.9746 mm (0.3514-0.3533 in.) and must not vary more than 0.04 mm (0.0015 in.) in depth around the circumference. No two adjacent block counter bores may range in depth more than 0.025 mm (0.001 in.) when gaged along the longitudinal cylinder block centerline.

NOTE:
Thoroughly clean the cylinder block liner counter bores to remove any foreign material. Foreign material in the cylinder liner counter bores can cause the liner to seat improperly.

NOTE:
If the firedeck surface of the cylinder block has been machined, the counter bores must be machined the same amount to keep the cylinder liner counter bore depth within limits.

2. Lubricate the seal rings and crevice seal with clean petroleum jelly.
3. Install two new seal rings and a new crevice seal into their respective grooves in the liner.
4. Insert the cylinder liner into the cylinder bore.

NOTE:
Do not exert excessive force on the liner, while pushing it down.

5. Install the cylinder liner installation tool, J 35597–A, over the liner to be installed. See Figure 1-266.

NOTE:
It is necessary to leave the cylinder liner installation tool in place until after the liner protrusion is measured.

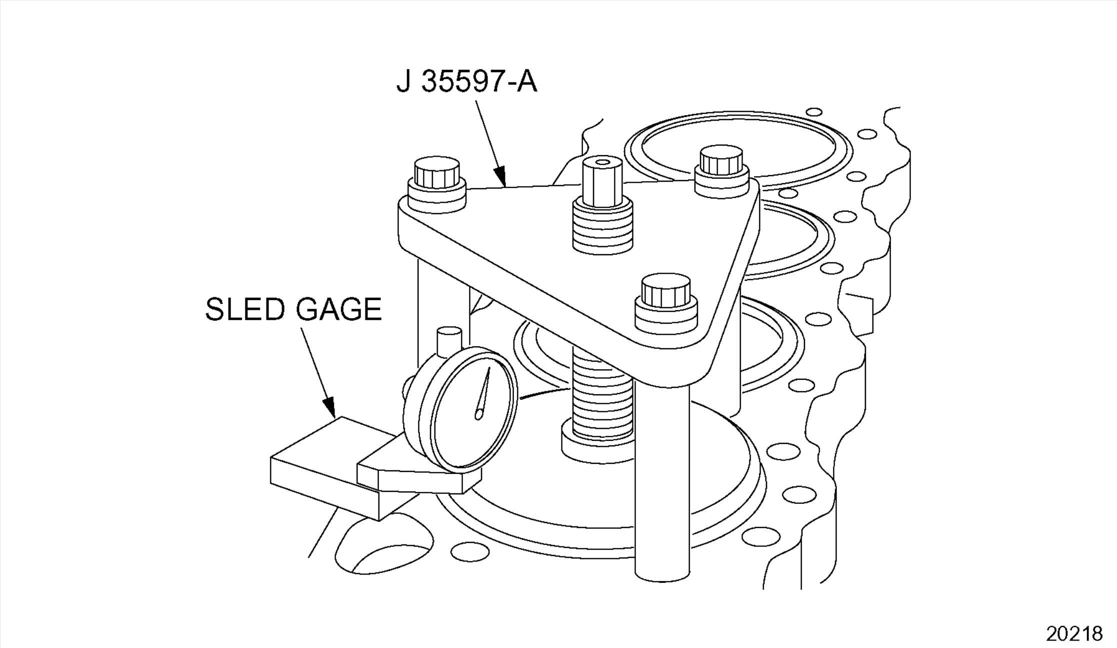


Figure 1-266 Cylinder Liner Installation Tools

6. Thread three cylinder head bolts through the tool and into a head bolt hole, so that the round shoe of the tool is centered over the liner.
7. Tighten the bolts.

NOTE:
It is not necessary to torque the bolts.

8. Turn the threaded center bolt in a clockwise direction. As the round shoe of the tool reaches the liner, ensure that the shoe is properly positioned into the cylinder liner.
9. Continue turning the bolt until the liner bottoms in the cylinder counterbore. Apply a tightening torque of 60 N·m (44 lb·ft) to the installation tool center bolt.
10. Install a dial indicator sled gage. See Figure 1-266.
11. Measure the distance from the top of the liner flange to the top of the block. See Figure 1-267.
    [a] Allowable liner protrusion is -0.0127-0.0762 mm (-0.0005-0.003 in.) with no more than 0.05 mm (0.002 in.) variation between any two adjacent cylinders.

[b] If the liner protrusion exceeds the maximum allowable, remove the liner and check for debris under the liner flange.

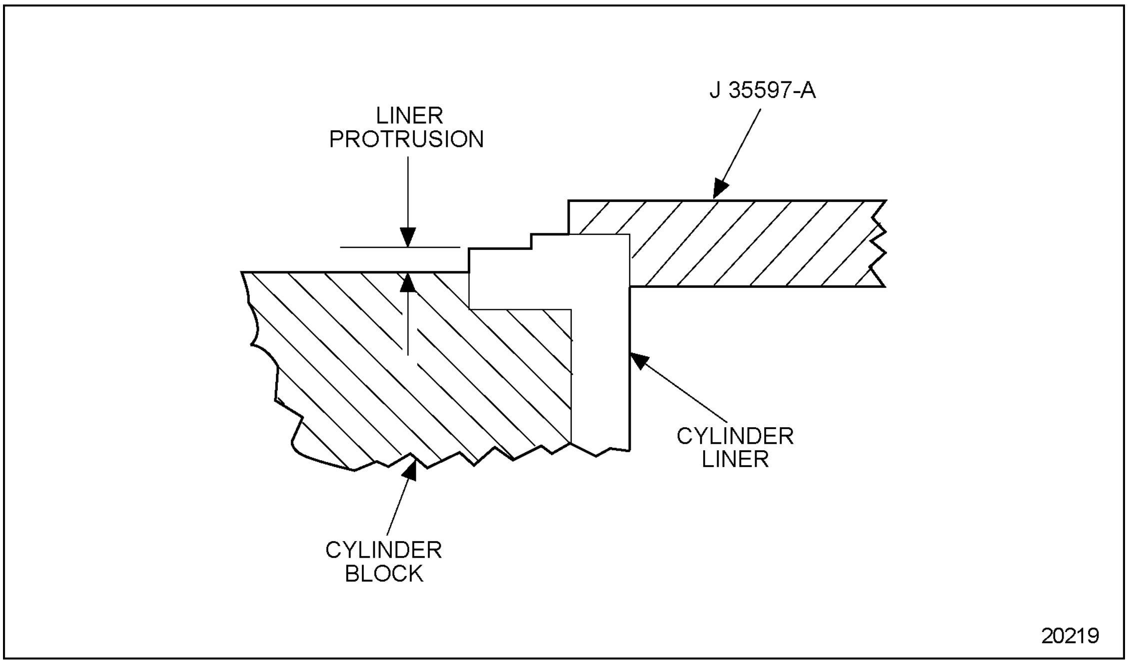


Figure 1-267 Cylinder Liner Protrusion

12. Remove the cylinder liner tool.
13. With all of the cylinder liners installed and the liner protrusion measurements within specifications, install the piston and connecting rod assemblies. Refer to Section 1.18.5.
14. Refer to Section 11.8for verification of proper cylinder liner installation.

1.21 GEAR TRAIN AND ENGINE TIMING

The gear train is completely enclosed between the gear case and gear case cover and is located at the front of the engine. The gear train consists of a camshaft drive gear, camshaft idler gear, fuel pump drive gear, air compressor and power steering pump drive gear, bull gear, oil pump drive gear, crankshaft timing gear, water pump drive gear, accessory pulley drive gear, and adjustable idler gear. The gear ratio of each gear in relationship to the crankshaft timing gear is shown directly below the gear title. See Figure 1-268.

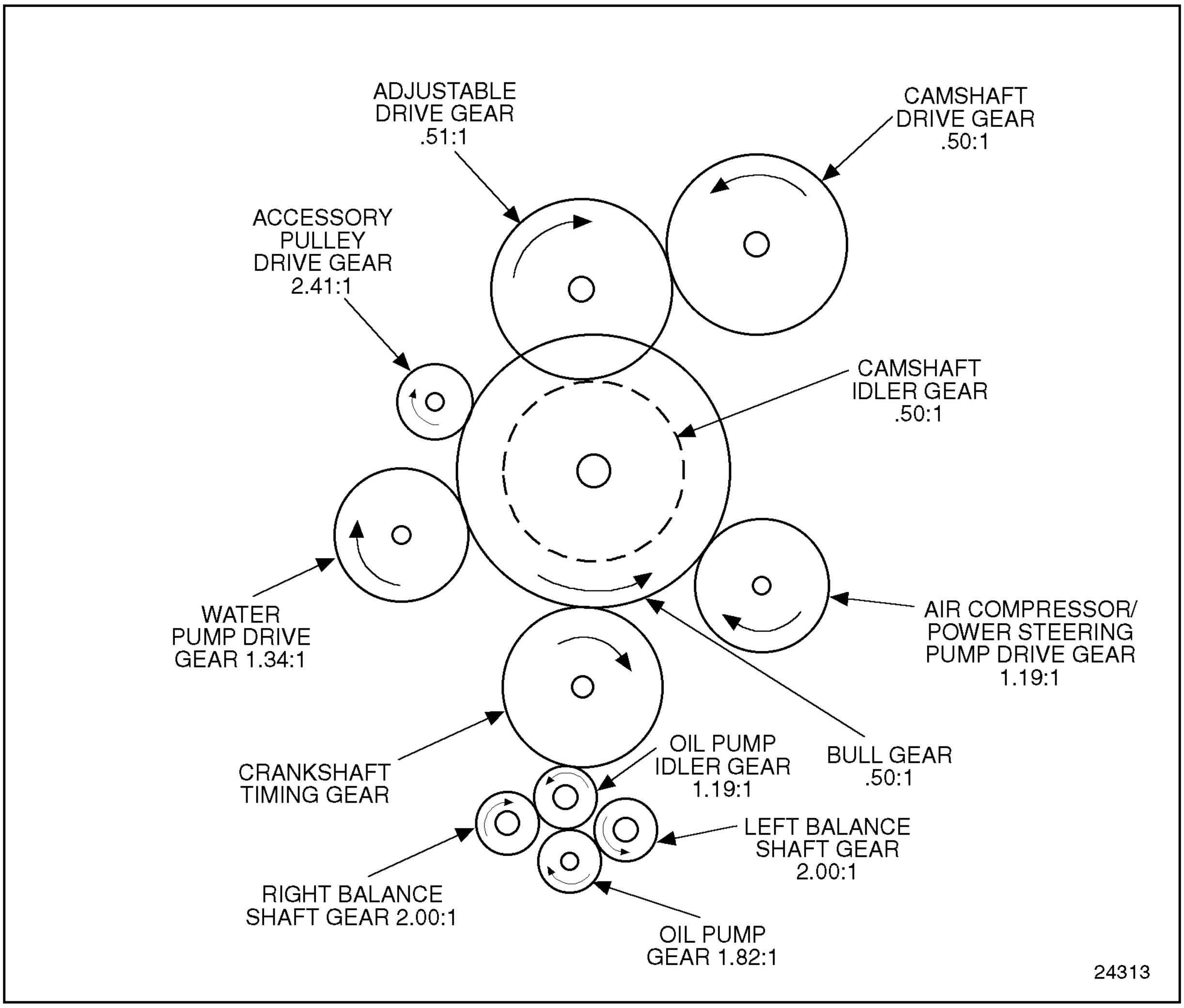
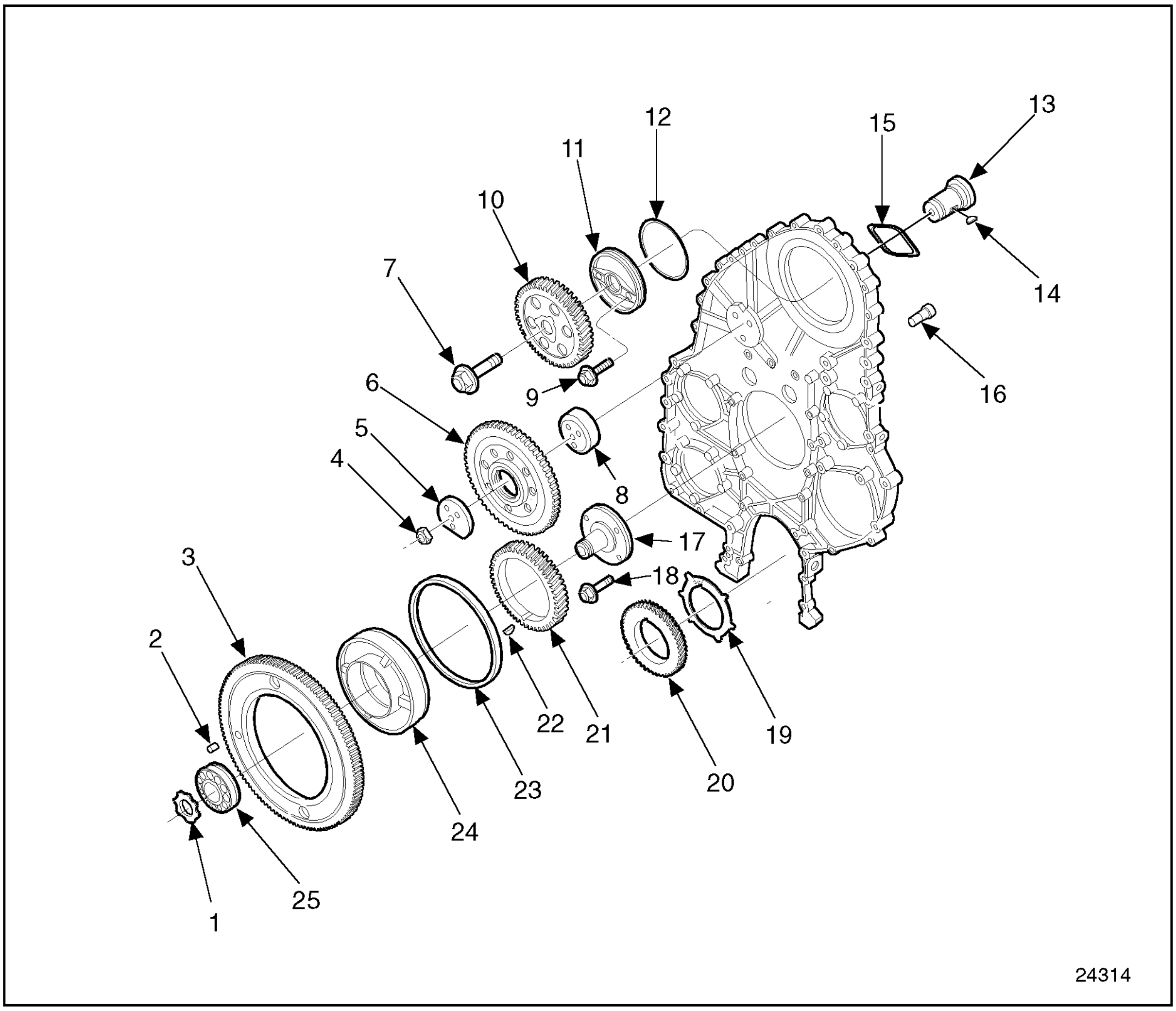


Figure 1-268 Engine Gear Train

The crankshaft timing gear, pressed onto the front end of the crankshaft, directly drives the bull gear and oil pump drive gear, and indirectly (through the bull gear), drives the fuel pump drive gear, air compressor and power steering pump drive gear, accessory pulley drive gear and water pump drive gear.

The camshaft idler gear is mounted to the rear of the bull gear on the same carrier, and rotates along with the bull gear at the same speed. This camshaft idler gear drives the adjustable idler gear, which in turn, drives the camshaft drive gear. See Figure 1-269.



1. Bull Gear Retaining Nut
2. Timing Pin
3. Bull Gear
4. Adjustable Idler Gear Locknut (3)
5. Adjustable Idler Gear Plate
6. Adjustable Idler Gear
7. Camshaft Retaining Bolt
8. Adjustable Idler Gear Hub
9. Thrust Plate Retaining (2) Bolt
10. Camshaft Drive Gear
14. Camshaft Drive Gear Hub Key
15. Camshaft Thrust Plate Seal
16. Adjustable Idler Gear Hub Retaining Stud
17. Bull Gear/Idler Gear Hub
18. Bull Gear Hub Retaining (4) Bolt
19. Crankshaft Timing Ring
20. Crankshaft Timing Gear
21. Camshaft Idler Gear
22. Bull Gear/Idler Gear Key
23. Spacer

11. Camshaft Thrust Plate
12. Camshaft Thrust Plate Seal O-ring
13. Camshaft Drive Gear Hub
24. Bull Gear/Idler Gear Carrier
25. Bull Gear/Idler Gear Bearings

Figure 1-269 Gear Train and Related Parts

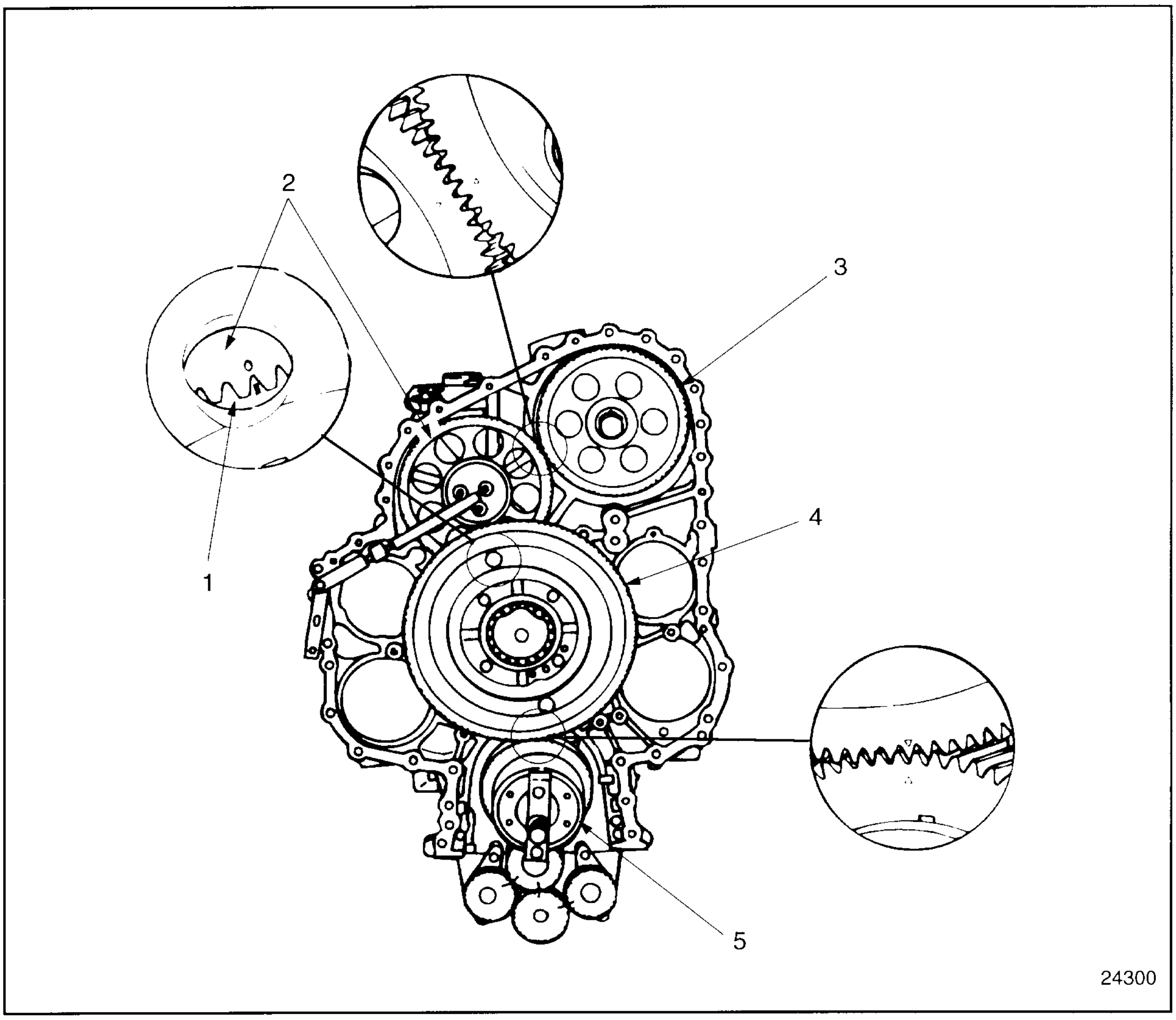
The bull gear and camshaft idler gear are a press-fit to the bull gear and camshaft idler gear carrier. Both gears are keyed to the carrier by the same key. The carrier is supported by two tapered roller bearings, which ride on a hub bolted to the engine block by four bolts. The bull gear and camshaft idler gear assembly is retained to the hub by a **left-hand threaded nut**.

The camshaft idler gear drives the camshaft drive gear through an adjustable idler gear. The adjustable idler gear is supported by a bushing and is mounted on an adjustable hub secured by three studs pressed into the gear case from the rear.

The balance shaft idler gear drives the right balance shaft gear and oil pump gear. The oil pump gear drives the left hand balance shaft, causing the balance shafts to counter-rotate.

The camshaft must be in time with the crankshaft timing gear. Since there are three gears between them, timing marks have been stamped or etched on the face of the gears to facilitate correct gear train timing. See Figure 1-270.

The balance shafts must be in time with the crankshaft. Timing marks are stamped on the balance shaft idler gear, balance shaft gears, and oil pump gear.



1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

Figure 1-270 Engine Gear Train and Timing Marks

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, work from the crankshaft timing gear to the camshaft drive gear and line up the appropriate symbols on the gears as each gear assembly is installed on the engine.

There are no timing marks on the drive gears for the fuel pump, air compressor and power steering pump, water pump or accessory drive pulley. Therefore, it is not necessary to align these gears in any particular position during their installation.

Alignment of the symbols on the balance shaft idler gear, balance shaft drive gears, and oil pump gear is done with balance shaft counter weights in the bottom, 6 o'clock, position and cylinder number one at TDC.

The backlash between the various mating gears in the gear train should be 0.051-0.229 mm (0.002-0.009 in.), and should not exceed 0.305 mm (0.012 in.) backlash between worn gears.

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth or excessive bearing wear. Therefore, when noise develops in a gear train, the gear case should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

The gear train is lubricated by oil splash. The bull gear and camshaft idler gear are pressure-fed lubricating oil through two holes in the bull gear recess area of the engine block. See Figure 1-271.

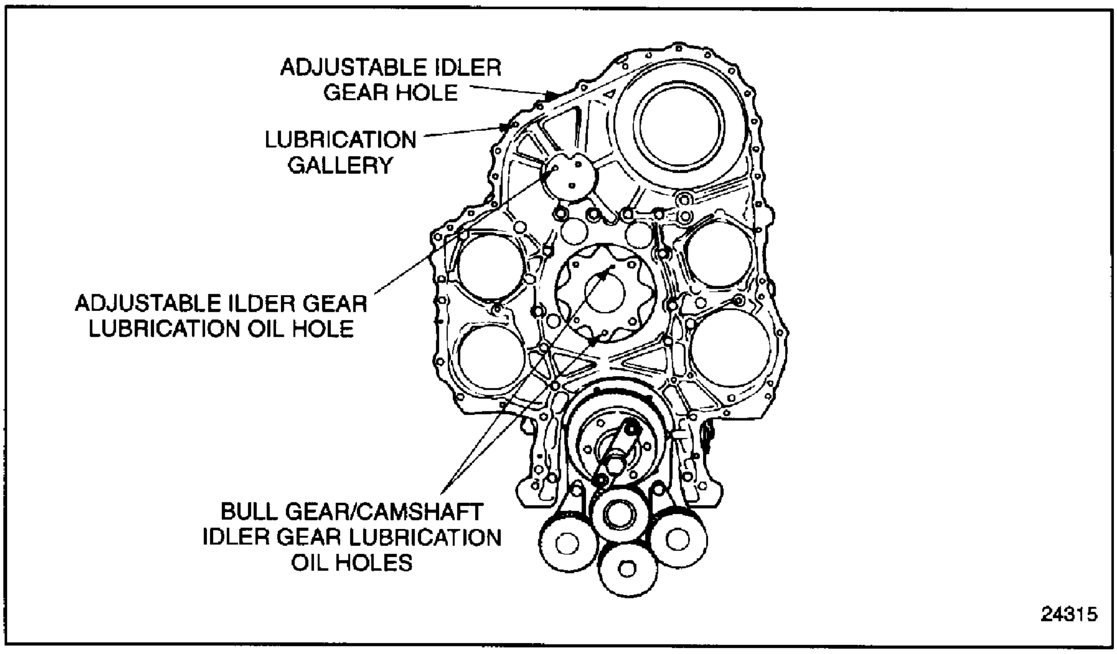


Figure 1-271 Gear Train Lubricating Oil Hole Locations

These two holes are connected to the main oil gallery. The adjustable idler gear assembly is pressure-fed by an oil gallery in the gear case that indexes with a hole in the engine block. The hole in the engine block is connected to the main oil gallery.

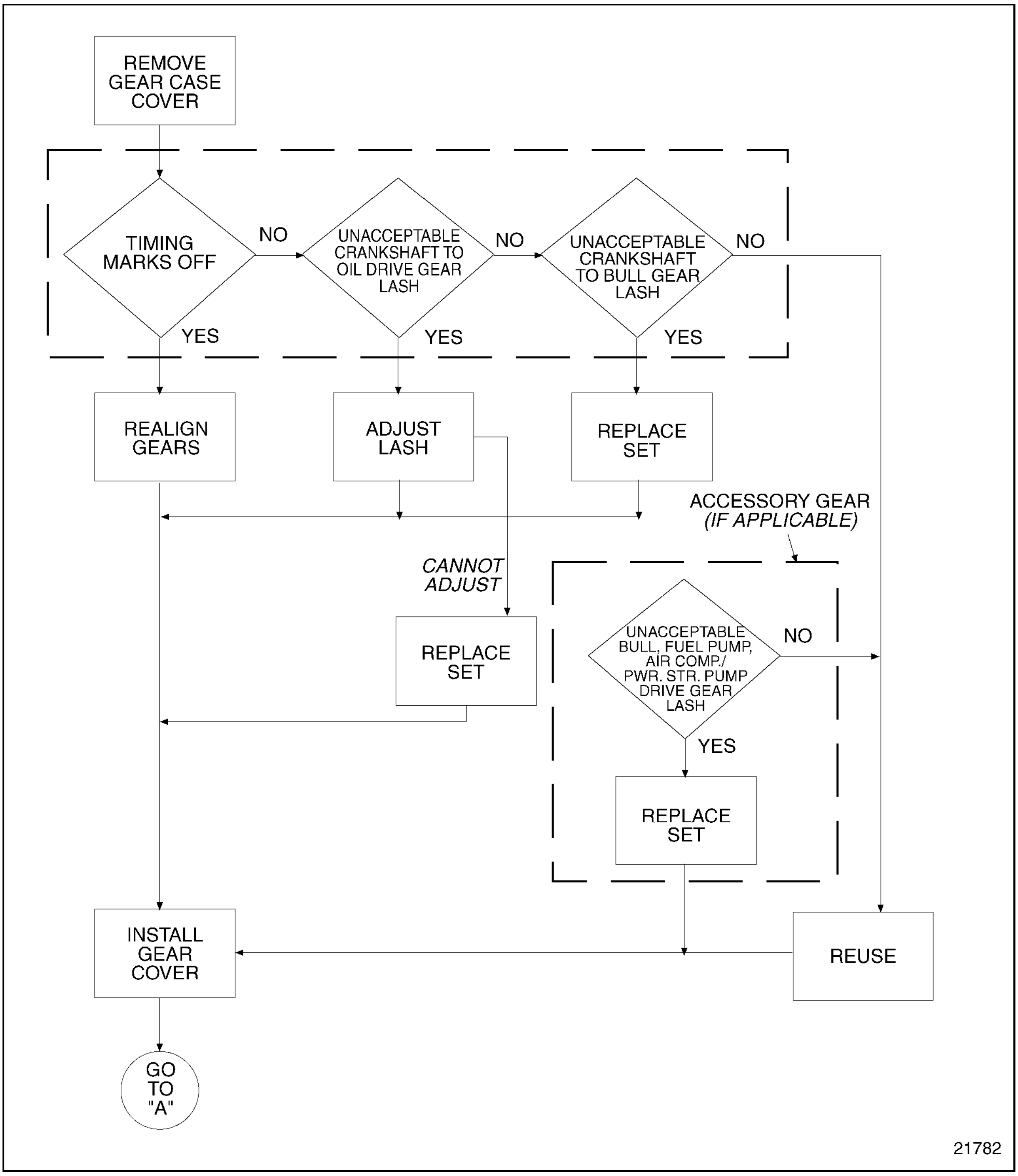
The correct relationship between the crankshaft and the camshaft must be maintained to properly control the opening and closing of the intake and exhaust valves, and the operation of the fuel injectors and to help maintain engine balance.

The crankshaft and camshaft gears can only be mounted in one position as they are both keyed to their mating parts. Therefore, when the engine is properly timed, the timing marks on the various gears will match. See Figure 1-270.

An "out of time" engine may result in valve-to-piston dome contact, a no-start condition or loss of power.

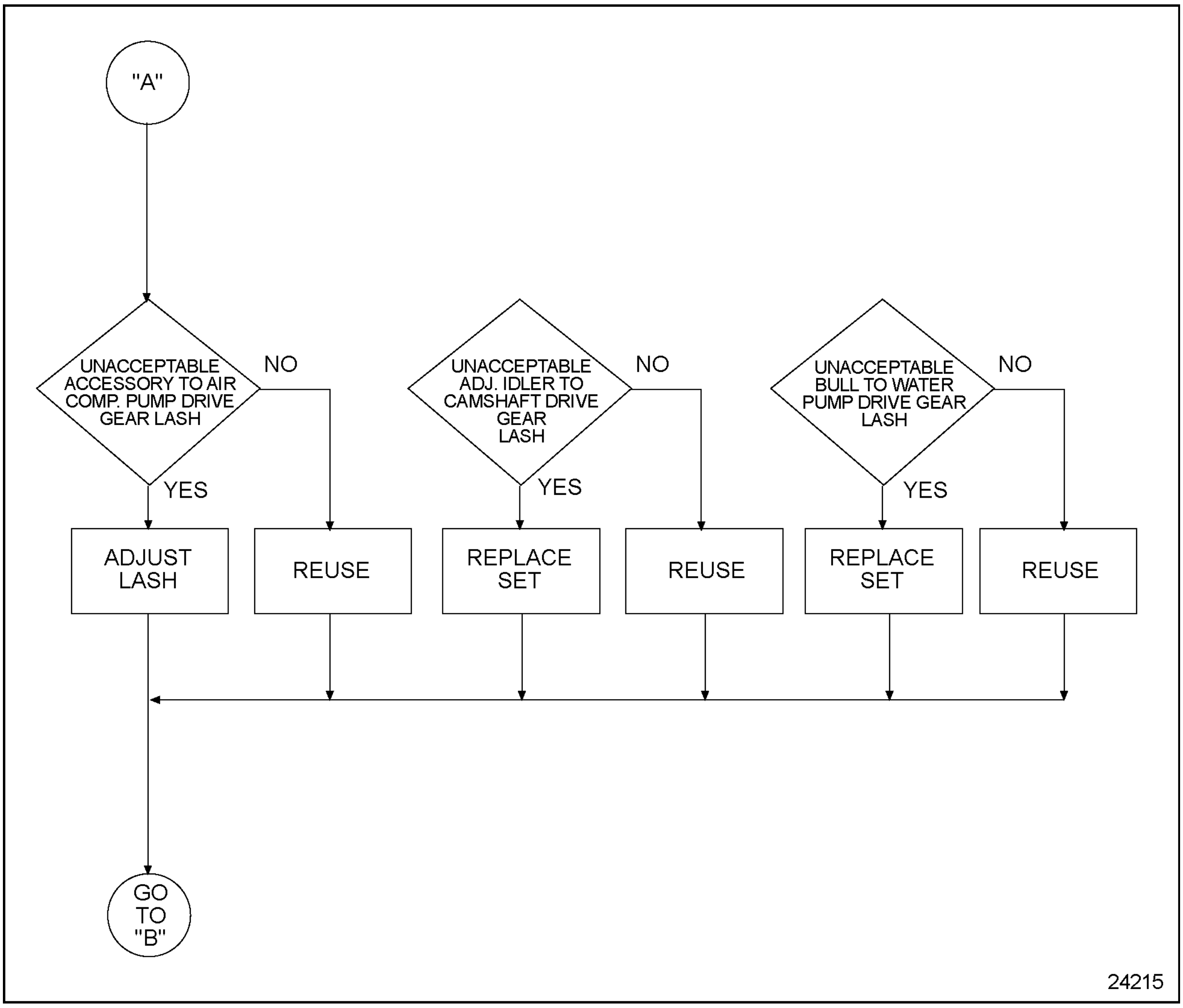
1.21.1 Repair or Replacement of Gear Train and Engine Timing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-272.



To go to " A", see Figure 1-273

Figure 1-272 Flowchart for Repair or Replacement of Gear Train and Engine Timing - Part 1 of 3



To go to " B", see Figure 1-274

Figure 1-273 Flowchart for Repair or Replacement of Gear Train and Engine Timing - Part 2 of 3

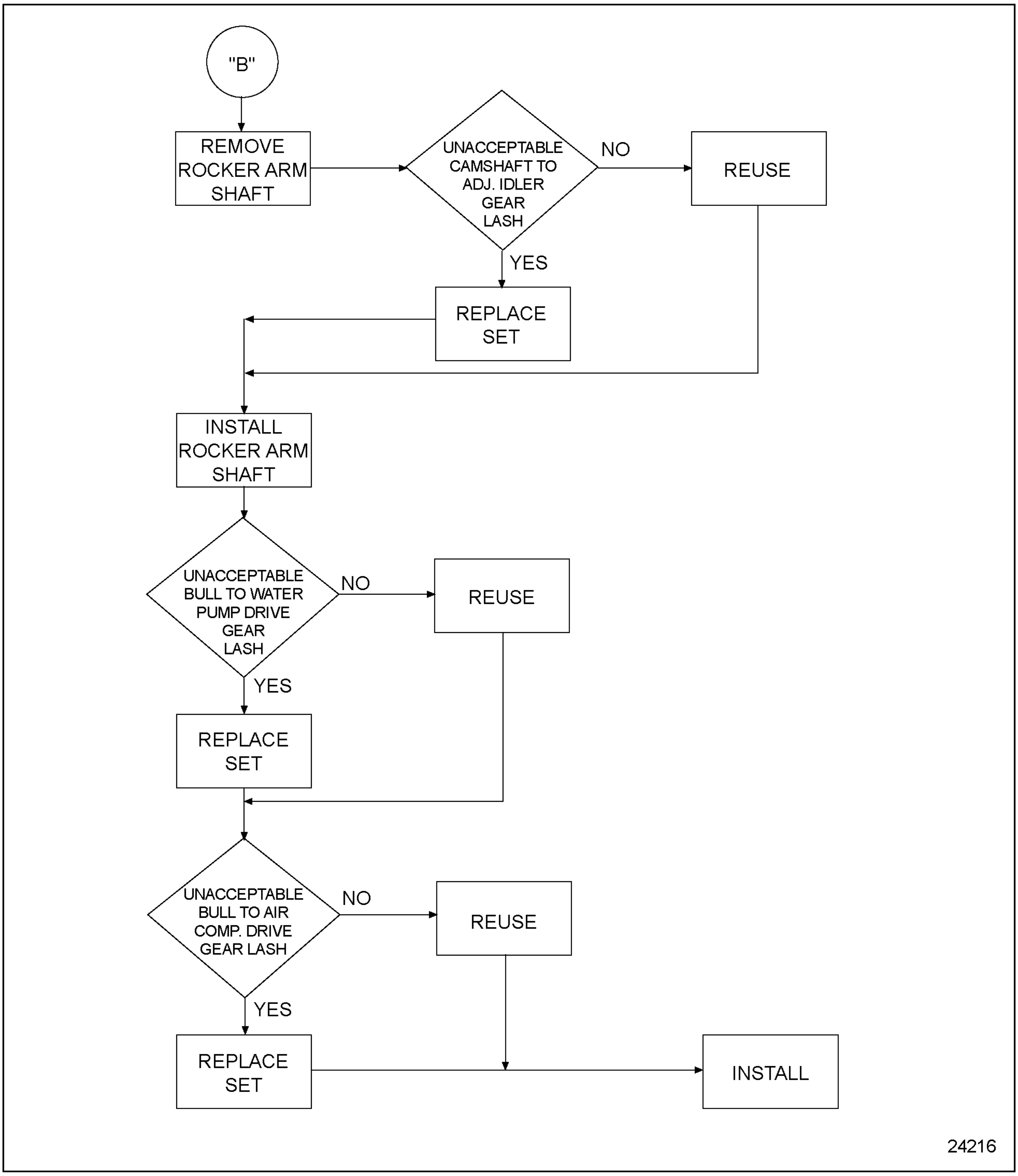


Figure 1-274 Flowchart for Repair or Replacement of Gear Train and Engine Timing - Part 3 of 3

1.21.2 Cleaning and Removal of Gear Train and Engine Timing

When an engine is out of time, the camshaft timing can be checked by following the camshaft timing check procedure. Refer to Section 1.22.6.1. If the engine is out of time, a visual inspection of the gear train is required.

Refer to Section 1.10.2 and perform all of the steps under "Removal of Gear Case Cover".

1.21.2.1 Check Engine Timing

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth, or excessive bearing wear. Therefore, when noise develops in a gear train, the gear case cover should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash. A whining noise indicates too little gear lash.

1. Check engine timing as follows:
   [a] Examine all timing marks to ensure they are aligned. See Figure 1-270.

NOTE:
The gear ratio between the adjustable idler gear and the camshaft drive gear causes a "hunting-tooth" situation. Therefore, the bull gear and rocker arm assemblies should be removed to align the timing marks. See Figure 1-270.

   [b] It may be necessary to remove the gears to align the timing marks. Refer to Section 1.26.2.

   [c] If any gears are removed or installed, or if lash between any two gears is out of specification, check the lash between the mating gears.

2. Check the crankshaft timing gear-to-oil pump idler gear lash measurement as follows:

[a] Fasten a dial indicator and magnetic base to the cylinder block so that the stem of the dial indicator rests on a tooth of the balance shaft idler gear. See Figure 1-275.

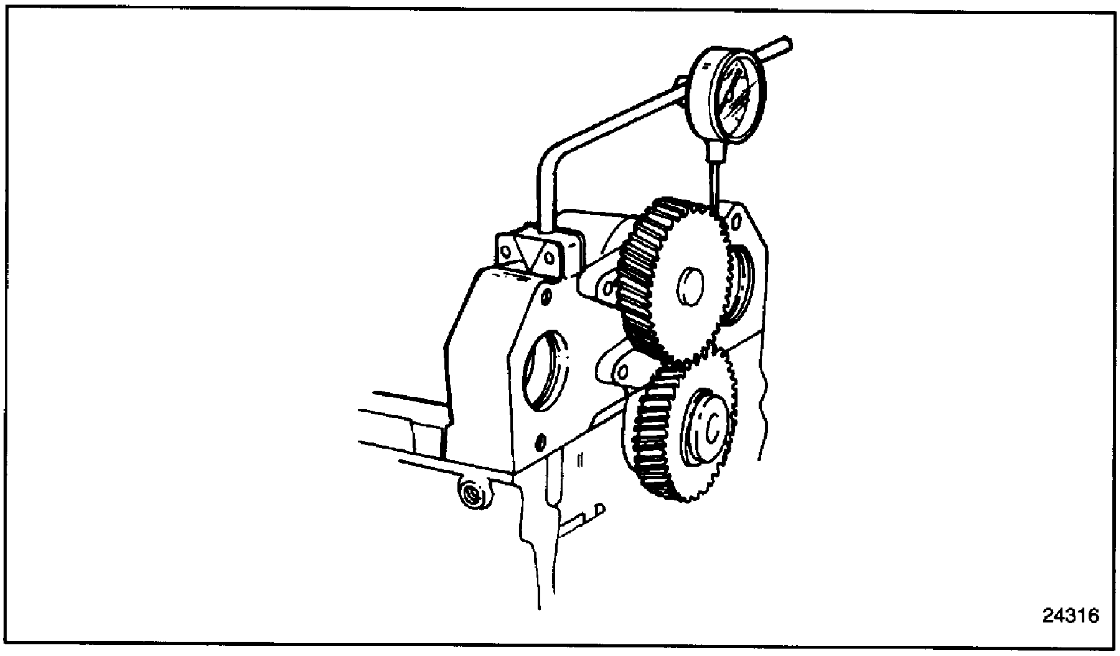


Figure 1-275 Crankshaft Timing Gear-to-Oil Drive Gear Lash Measurement

NOTE:
The lash between the crankshaft timing gear and oil pump idler gear must be measured with the engine in a running position. See Figure 1-270.

[b] Hold the crankshaft timing gear stationary, and rotate the balance shaft idler gear in one direction, as far as it will go, without moving the crankshaft timing gear.

[c] Zero the dial indicator.

[d] Move the balance shaft idler gear in the opposite direction, as far as it will go, without moving the crankshaft timing gear.

[e] Read and record the total gear lash.

NOTE:
The gear lash must be checked in four positions 90° apart.

Proper lash between the crankshaft timing gear and balance shaft idler gear is 0.051-0.229 mm (0.002-0.009 in.) for new parts, with a maximum of 0.305 mm (0.012 in.) for used parts.

The gear lash between the crankshaft timing gear and the balance shaft idler gear can be adjusted utilizing shims inserted between the balance shaft assembly and the cylinder block. See Figure 1-276.

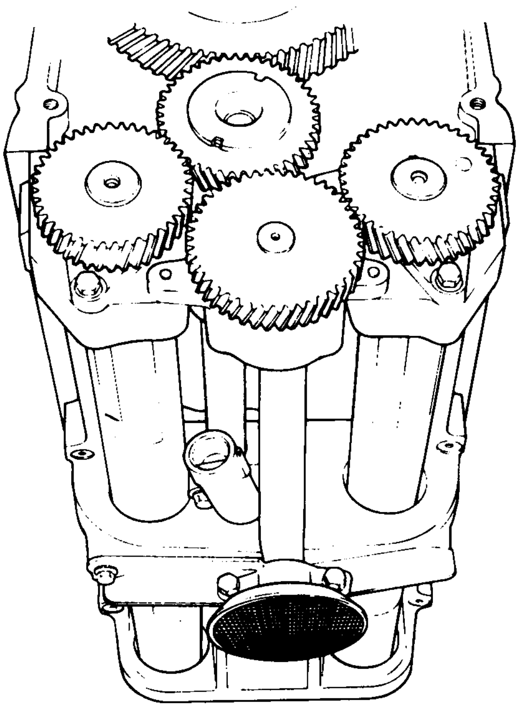


Figure 1-276 Lubricating Oil Pump Shim Installation

[f] Remove or install shims as necessary to obtain the proper gear lash clearance.

[g] If the use of shims cannot bring gear lash within acceptable limits, the gear or gears for that gear set must be replaced.

3. Check the crankshaft timing gear-to-bull gear lash measurement as follows:

[a] Install a dial indicator and magnetic base. See Figure 1-277.

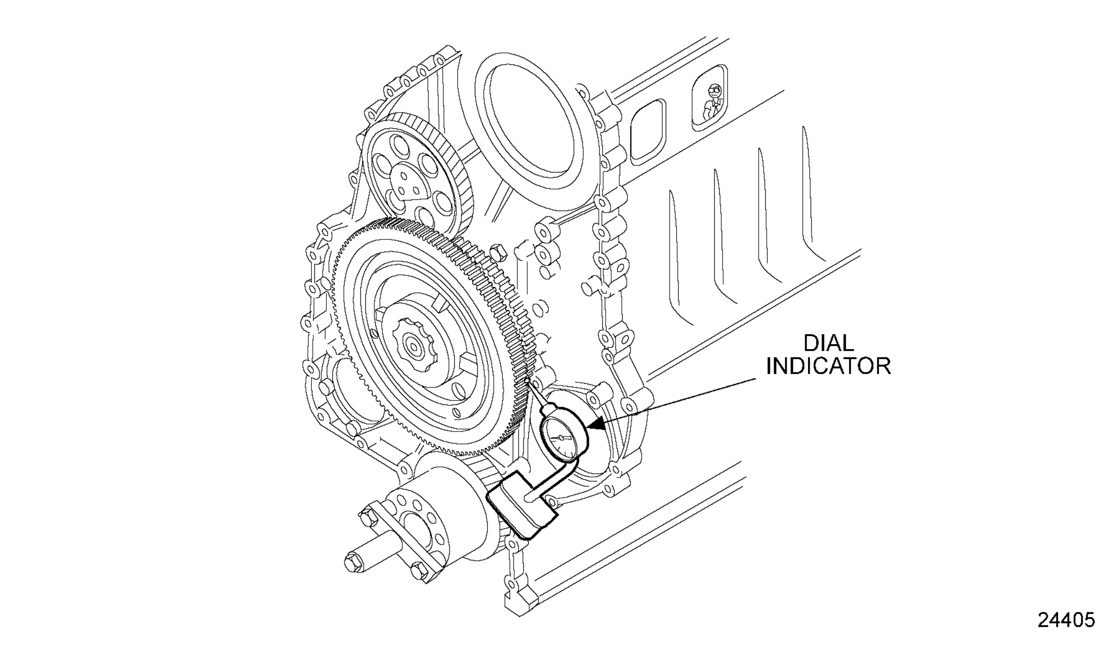


Figure 1-277 Crankshaft Timing Gear-to-Bull Gear Lash Measurement

[b] Adjust the stem of the dial indicator to rest on the center of a tooth on the bull gear.

[c] Preload the bull gear.

[d] Zero the dial indicator pointer.

[e] Hold the crankshaft timing gear stationary with one hand. Rotate the bull gear and check the total gear lash in four positions of crank gear, approximately 90° apart.

[f] Although gear lash for the remaining gear sets is not adjustable, the lash must still be measured. Lash specification is 0.051-1.229 mm (0.002-0.009 in.) for new parts and a maximum of 0.305 mm (0.012 in.) for used parts.

[g] If lash measurement is exceeded, replace gear with a new part.

4. The procedure for measuring the lash between the bull gear and the fuel pump drive gear (if applicable) and the air compressor and power steering pump drive gear is similar to the steps just mentioned. Refer to step 3[a], as the first step and refer to step 3[g], as the final step.
5. Gear case cover must be installed to continue or checking the engine timing. Refer to Section 1.8.5 and perform all of the steps under gear case cover installation.

6. The procedure for measuring the lash between the accessory drive gear and air compressor pump drive gear (on vehicle without power steering) is similar to the steps just mentioned. Refer to step 3, as the first step and refer to step 9, as the final step.

NOTE:
Lash can be measured with the gear case cover installed. Access covers are provided for checking the lash between these gears and the bull gear. For engines with no access cover for accessory drive, gear lash is to be measured off the accessory drive pulley.

7. The procedure for measuring the lash between the adjustable idler gear and camshaft drive gear is similar to the steps just mentioned. Refer to step 3, as the first step and refer to step 9, as the final step.

NOTE:
These gears are measured and adjusted with the gear case cover installed.

8. The procedure for measuring the lash between the bull gear and the water pump drive gear is similar to the steps just mentioned. Refer to step 3, as the first step and refer to step 9, as the final step.

NOTE:
These gears can be measured with the pump installed.

Refer to Section 1.3.2 and perform all of the steps under "Removal of Rocker Arm Assembly," in order to continue checking the engine timing.

9. When measuring or adjusting the gear lash between the adjustable idler gear and the camshaft drive gear, the valve and injector spring pressures must be removed from the camshaft lobes. Use the following procedure for this adjustment:

NOTE:
The front and rear rocker arm shafts look identical, but must not be interchanged due to different oil passage patterns. The outboard ends of the rocker arm shafts are marked for

identification with the DDC logo. See Figure 1-278. Use care to ensure that the rocker arm shaft assemblies are replaced exactly as removed.

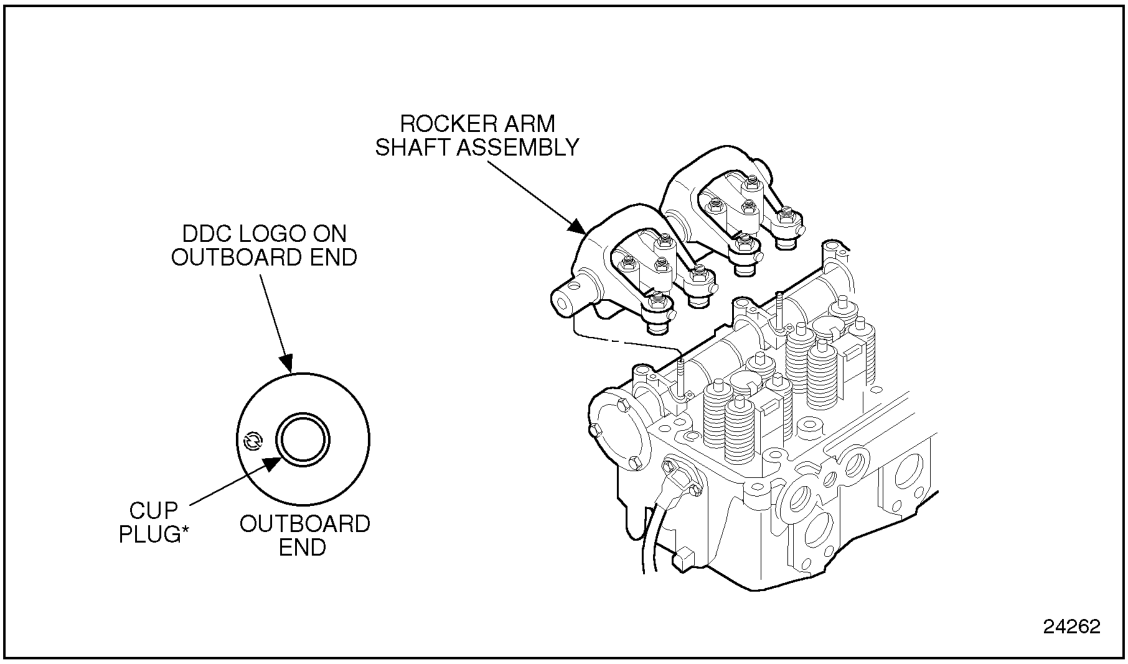


Figure 1-278 Rocker Arm Shaft Identification Mark

[a] Install the gear lash pedestal, J 35596-15 part of J 35596, into the threaded hole of the camshaft drive gear. Bar the engine over until the tool is at the three o'clock position. See Figure 1-279.

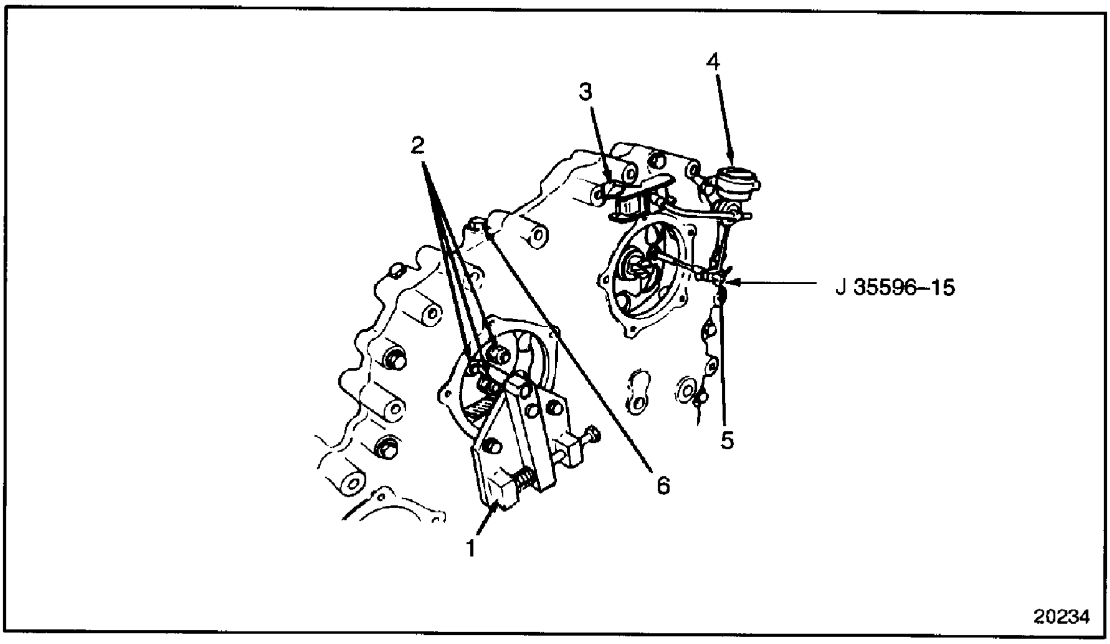


Figure 1-279 Camshaft Drive Gear-to-Adjustable Idler Gear Lash Measurement

NOTE:
Since the teeth of the camshaft drive gear are not accessible with the gear case cover installed, the lash is measured on the pedestal installed in the threaded hole, which is located exactly half-way between the center and edge of the camshaft drive gear. For this reason, the reading obtained will be exactly 1/2 of the actual gear lash.

[b] Mount a dial indicator adaptor and dial indicator. See Figure 1-279.

[c] Adjust the stem of the dial indicator to rest on the flat of the pedestal.

[d] If the adjustable idler gear has been removed, torque the three flanged nuts that retain the adjustable idler gear hub to the gear case to 57-67 N·m (42-49 lb·ft) to seat the assembly before proceeding.

[e] Loosen the three locknuts that retain the adjustable idler gear hub to the gear case until they are hand tight.

[f] Insert the dowel portion of the gear lash adjusting tool, J 35596, through the hole in the adjustable idler gear retaining plate and into the adjustable idler gear hub, using the bottom two adjustable idler gear cover bolt holes. See Figure 1-279.

[g] Turn the adjusting screw of the tool in a clockwise direction to force the adjustable idler gear against the camshaft drive gear, until there is zero lash between the two gears. See Figure 1-280.

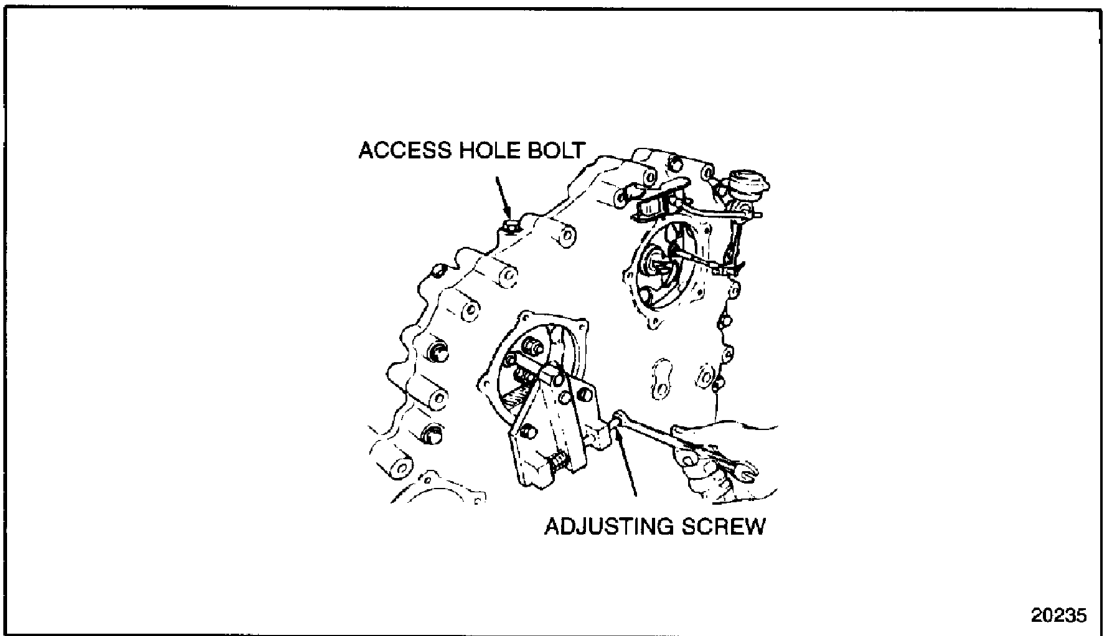


Figure 1-280 Adjustable Idler Gear-to-Camshaft Drive Gear Lash Adjustment

[h] Zero the dial indicator.

[i] Hold the adjustable idler gear by inserting a screwdriver through the hole provided in the gear case. Engage one of the adjustable idler gear teeth and apply pressure on the screwdriver to move the gear in a counterclockwise direction. This will prevent the gear from moving.

[j] Attempt to turn the camshaft drive gear, and watch the dial indicator pointer.

NOTE:
If there is zero lash between the two gears, the dial indicator pointer will not move from zero.

[k] Turn the adjusting screw of the tool approximately 1-1/2 turns or until the proper gear lash is obtained.

[l] When checking gear lash, hold the adjustable idler gear stationary. Refer to step 9[i] as the first step and refer to step 9[j]as the final step, and rotate the camshaft drive gear with your right hand. See Figure 1-281.

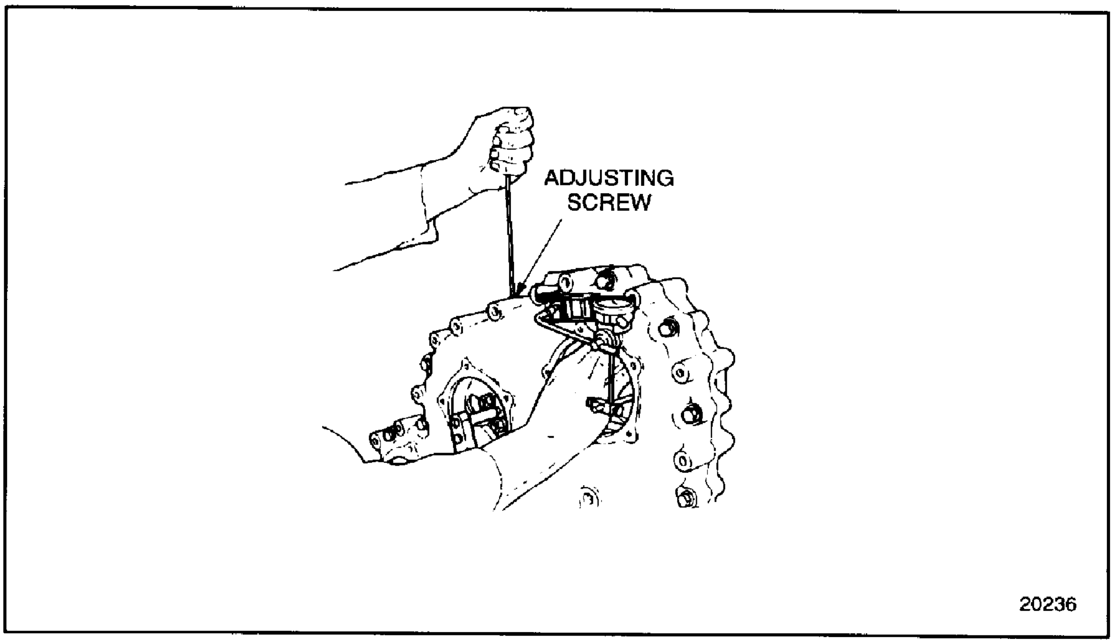


Figure 1-281 Checking Adjustable Idler Gear-to-Camshaft Drive Gear Lash

NOTE:
Remember to multiply the reading obtained by two to get the actual lash measurement. The specification of gear lash is 0.051-0.229 mm (0.002-0.009 in.) with a maximum of 0.305 mm (0.012 in.) for used parts.

[m] Check the gear lash with the pedestal at the 3,6,9 and 12 o'clock positions, exactly as previously performed.

[n] When the proper readings of 0.025-0.114 mm (0.001-0.0045 in.) are obtained at all four (4) positions, hold the idler gear. Refer to step 9[i]as the first step and refer to step 9[j] as the final step, and torque the top two adjustable idler gear flanged nuts to 57-67 N·m (42-49 lb·ft).

[o] Check the gear lash again as outlined above, with the flanged nuts torqued, to ensure that gear lash is still within limits.

[p] If proper lash measurement cannot be obtained, replace gear(s) with new part(s). Refer to Section 1.26.3.

[q] Remove the gear lash adjusting tool from the gear case.

[r] Torque the bottom adjustable idler gear flanged nut to 57-67 N·m (42-49 lb·ft).

[s] Remove the dial indicator and pedestal from the gear case.

[t] Before installing the rocker arm shaft assemblies, check the torque on the end studs to ensure they were not loosened at time of removal. The torque specification is 101-116 N·m (75-86 lb·ft).

[u] Install the front and rear rocker arm shaft assemblies to the cylinder head. Install the six rocker arm shaft thru-bolts and two nuts, finger tight.

[v] Install the rocker arms and torque the rocker arm shaft's thru-bolts and nuts to 101-116 N·m (75-86 lb·ft) using the sequence. See Figure 1-282.

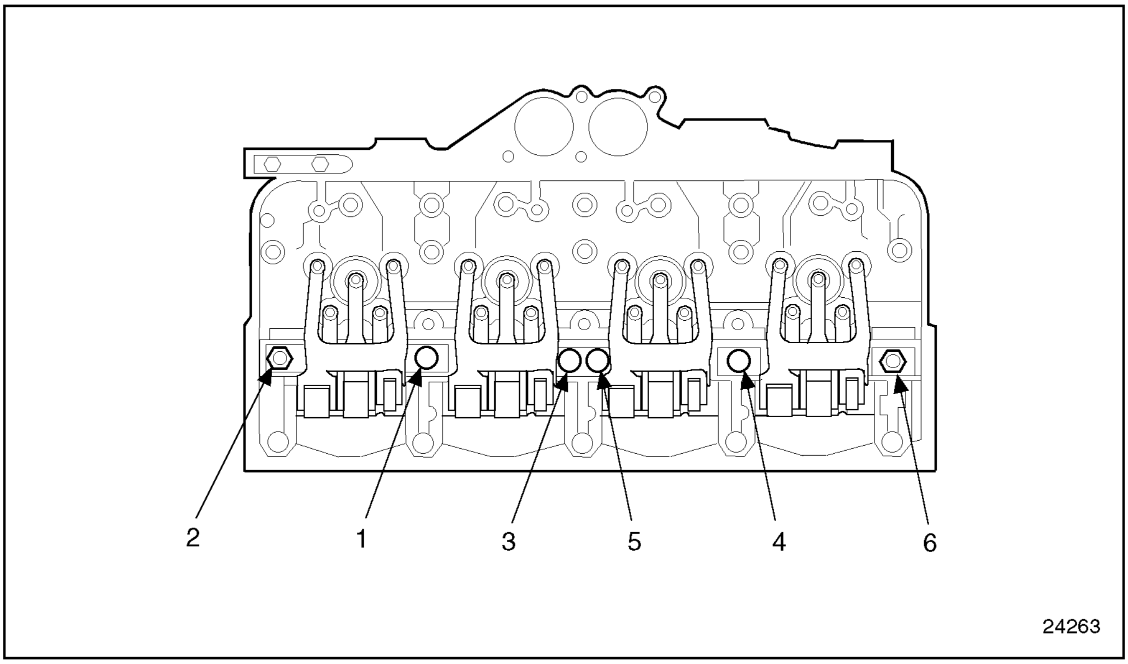


Figure 1-282 Rocker Arm Shaft Bolt and Nut Torque Sequence

[w] Refer to Section 12.2 and adjust the intake and exhaust valve clearances, and fuel injector heights.

[x] Install the rocker cover. Refer to Section 1.6.6.

[y] Insert a new gasket between the camshaft drive gear access cover and the gear case cover. Install the camshaft drive gear access cover to the gear case cover. Torque the bolts to 30-38 N·m (22-28 lb·ft) using the tightening sequence. See Figure 1-283.

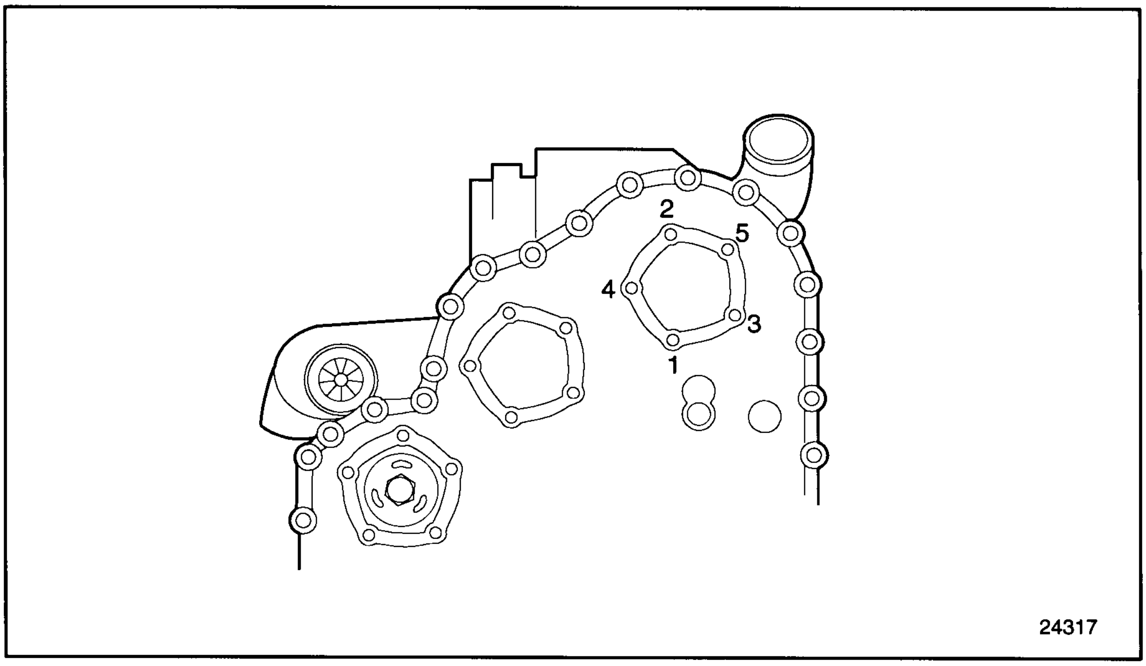


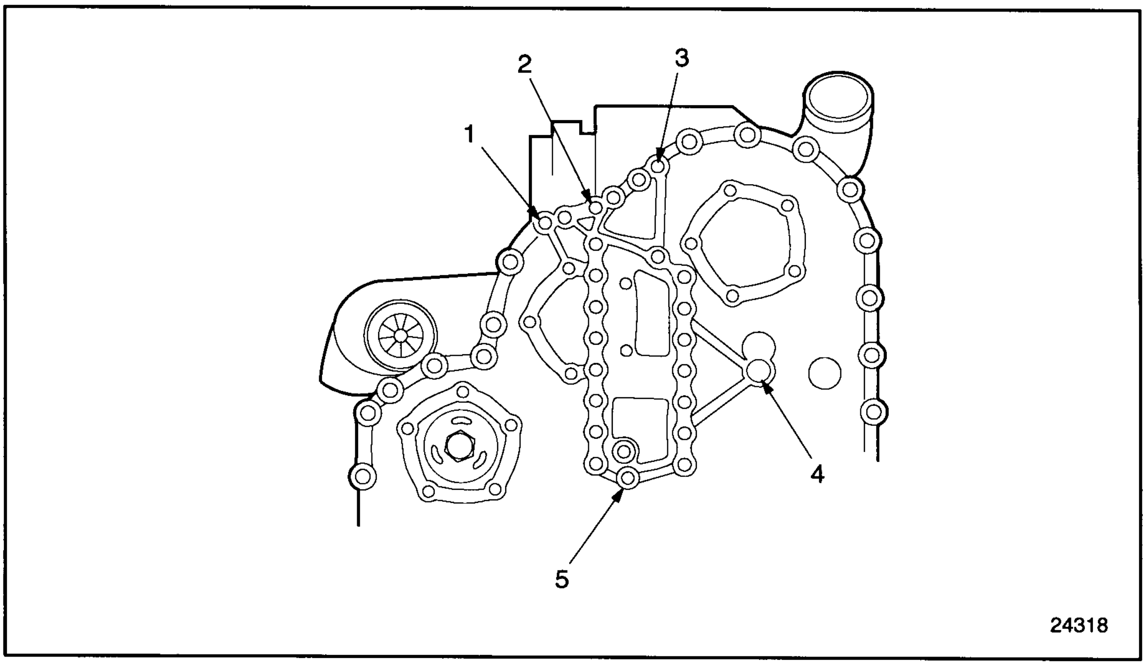
Figure 1-283 Camshaft Drive Gear Access Cover Bolt Torque Sequence

[z] Install the fan support bracket if required as follows:

Clean the mating surfaces of the fan support bracket and gear case of all old gasket eliminator. Gasket eliminator removal information may be found in the "General Information" section of this manual.

Apply a 1/16 in. bead of Gasket Eliminator PT-7276 (Loctite 51580), or equivalent, to the machined surface of the gear case cover surrounding the adjustable idler gear access.

Install the fan support bracket to the gear case cover using the torque values and tightening sequence. See Figure 1-284.



BOLT	TORQUE
1-3-5	58-73 N·m (43-45 lb·ft)
2-4	160-200 N·m (118-148 lb·ft)
6 to 10	30-38 N·m (22-28 lb·ft)

Figure 1-284 Fan Support Bracket Bolt Torque Sequence

10. Check the bull gear-to-accessory drive gear lash measurement as follows:

[a] Mount a magnetic dial indicator base and dial indicator to the gear case cover. See Figure 1-285.

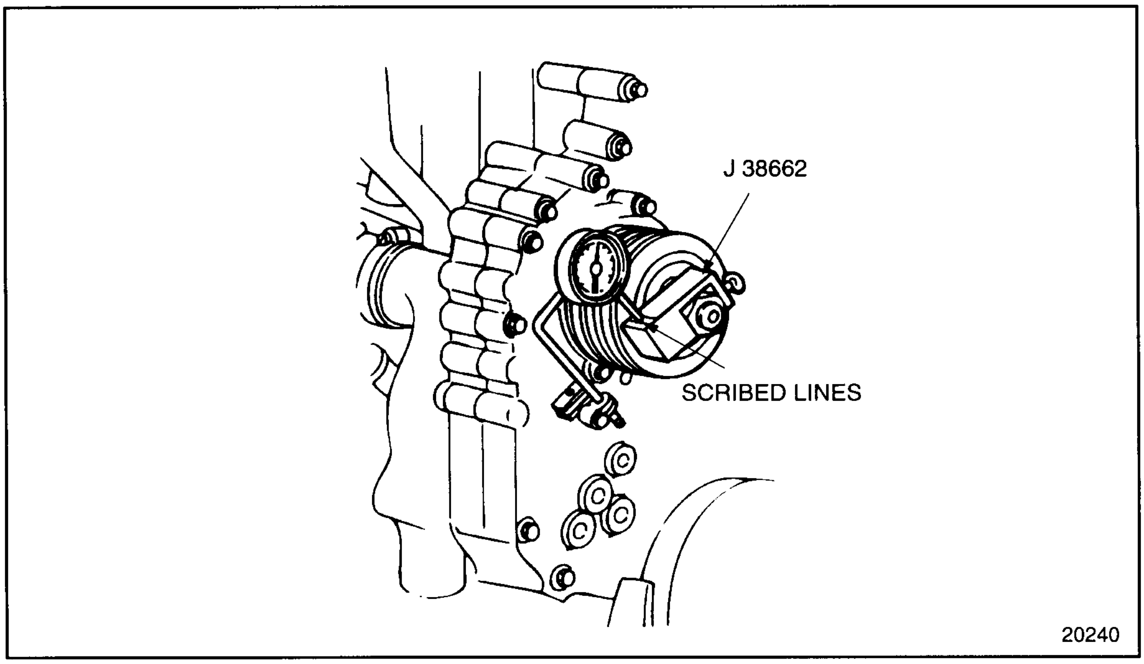


Figure 1-285 Accessory Drive Gear-to-Bull Gear Lash Measurement

[b] Install the gear lash tool J 38662. See Figure 1-285.

[c] Position the dial indicator to read between the scribed lines on the tool. See Figure 1-285.

[d] Rotate the accessory drive pulley, read and record the total gear lash.

[e] Lash should be 0.051-0.229 mm (0.002-0.009 in.) for new parts, with a maximum of 0.305 mm (0.012 in.) for used parts.

[f] If proper lash measurement cannot be obtained, replace gear with a new part. Refer to Section 1.26.2.

[g] Remove the dial indicator and gear lash tool.

11. Check the bull gear-to-water pump drive gear lash measurement with water pump impeller slip tester, J 35687 as follows:

NOTE:
The bull gear-to-water pump drive gear lash can be measured using the water pump impeller slip tester, J 35687, refer to step 11 Or by using the water pump gear lash tool, J 38977-A, refer to step 1.

CAUTION:

To avoid injury, wear a face shield or goggles.

[a] Remove the water pump cover snap ring with snap ring pliers. Remove water pump cover and seal ring.

[b] Install the water pump impeller slip tester, J 35687, to the water pump impeller with two 5/16-18 bolts, using the instructions supplied with the tool. See Figure 1-286.

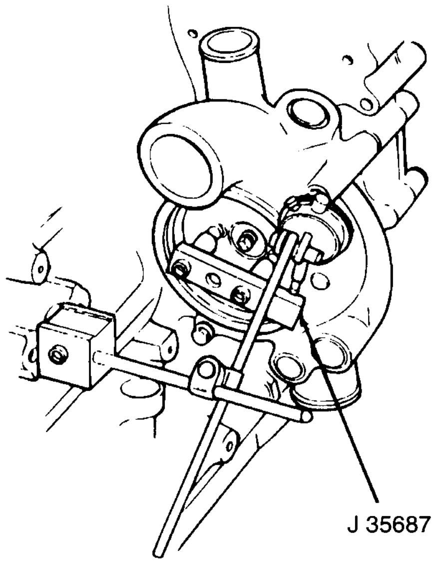


Figure 1-286 Water Pump Impeller Slip Tester Method

[c] One leg (the long one) of the tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051-0.229 mm (0.002-0.009 in.).

[d] If proper lash cannot be obtained, replace gear with a new part.

[e] Remove the dial indicator.

[f] Remove the tool from the water pump.

[g] Inspect the water pump cover seal for cracks or splitting. Refer to Section 4.2.3.1.

[h] Install a new seal, if necessary, between the water pump cover and the water pump housing.

[i] Using snap ring pliers, install the water pump snap ring in groove of water pump body.

[j] Tap around the inside rim of snap ring with a brass drift, and hammer to seat snap ring in groove fully.

12. Check the bull gear-to-water pump drive gear lash measurement with water pump gear lash tool, J 38977-A, as follows:
    [a] Remove the pipe plug in the gear case cover.
    [b] Install the water pump gear lash tool, J 38977-A, through the hole in the gear case and thread it into the special water pump drive gear retaining bolt. See Figure 1-287.

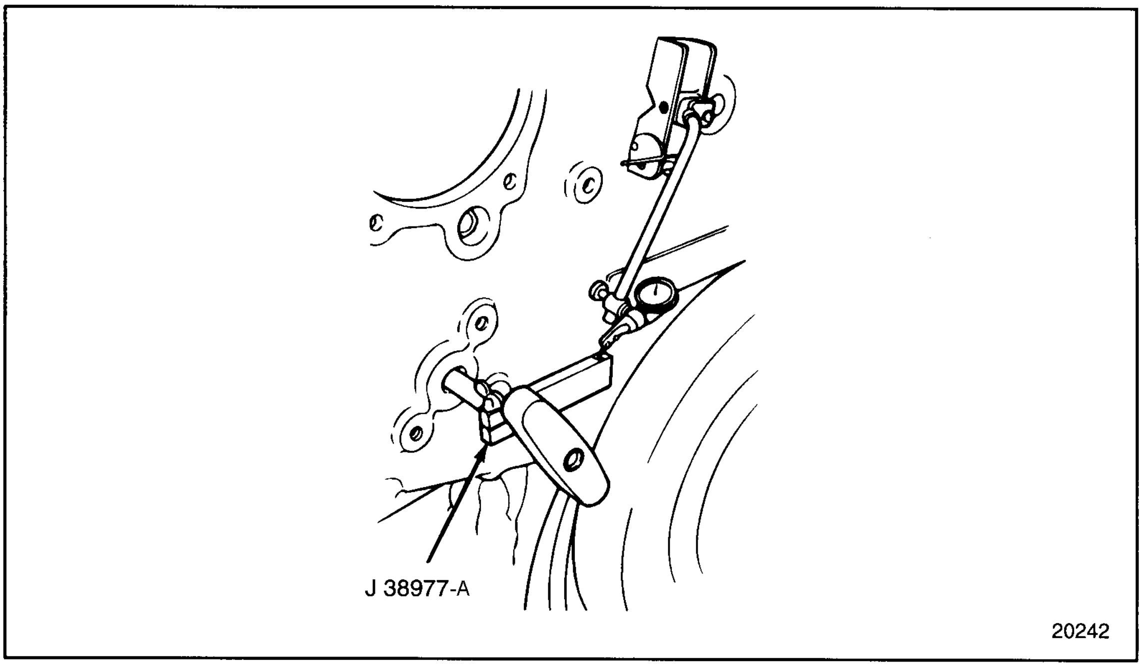


Figure 1-287 Water Pump Gear Lash Tool Method

    [c] The arm of this tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051-0.229 mm (0.002-0.009 in.).
    [d] If proper lash cannot be obtained, replace the gear with a new part.
    [e] Remove the dial indicator and the gear lash tool.
    [f] Install the pipe plug in the gear case cover. Torque to 24-31 N·m (18-23 lb·ft).
13. Check the bull gear-to-air compressor drive gear lash measurement as follows:
    [a] Mount a magnetic dial indicator base and dial indicator to the gear case cover so that the stem of the dial indicator may be positioned on a tooth of the air compressor drive gear.
    [b] Preload the drive gear in one direction.
    [c] Zero the dial indicator.
    [d] Rotate the air compressor drive gear, read and record the total gear lash. Lash should be 0.051-0.229 mm (0.002-0.009 in.) for new parts, with a maximum of 0.305 mm (0.012 in.) for used gears.

[e] If proper lash cannot be obtained, replace the gear with a new part.

[f] Remove the dial indicator and magnetic base.

[g] Install the power steering drive coupling to the air compressor drive gear (if equipped with power steering).

[h] Insert a new O-ring on the power steering pump (if so equipped).

[i] Install the power steering pump to the gear case cover, meshing the drive coupling properly

[j] Install and torque the power steering pump mounting bolts to 30-38 N·m (22-28 lb·ft). Tighten the five bolts alternately and evenly, in a star-shaped pattern, to progressively draw the power steering pump into the gear case cover

NOTE:
Do not force the bolts. If resistance is encountered, remove the power steering pump and re-engage the drive hub with the coupling.

[k] If the engine is not equipped with power steering, install the air compressor drive gear access cover using a new gasket.

[l] Install and torque the retaining bolts to 30-38 N·m (22-28 lb·ft), using a star-shaped pattern.

1.21.3 Installation of Gear Train and Engine Timing

After all of the gear lash measurements have been taken, assemble the engine components as follows:

1. Install the air conditioner compressor and brackets (if so equipped). Install the air conditioner drive belt.
2. Install the alternator and brackets. Refer to OEM guidelines. Install the alternator drive belts.
3. Install the alternator drive belts. Refer to OEM guidelines.
4. Install the fan and fan hub assembly. Refer to Section 4.5.5.
5. Adjust the alternator, fan and air conditioner compressor drive belts to the specifications. Refer to Section 13.5.7. Torque the accessory mounting bolts to specifications.
6. Install any other equipment such as hoses, brackets, lines or electrical looms that were removed to gain access to the engine gear case cover.
7. Install the engine oil pan. Refer to Section 3.9.3.
8. Fill the engine crankcase. Refer to Section 13.5.1.
9. Continue engine assembly.

1.22 CAMSHAFT AND CAMSHAFT BEARING

The Series 50 Engines camshaft is located on top of the cylinder head, just below the valve cover. The camshaft actuates the intake and exhaust valves and injector operating mechanism. See Figure 1-288.

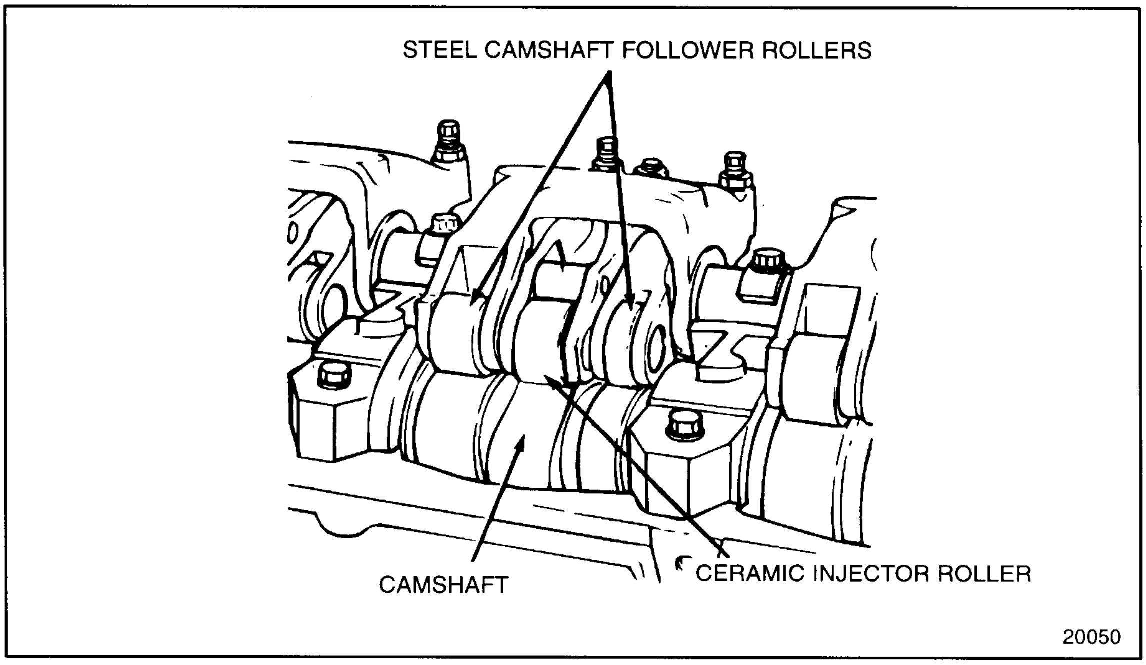
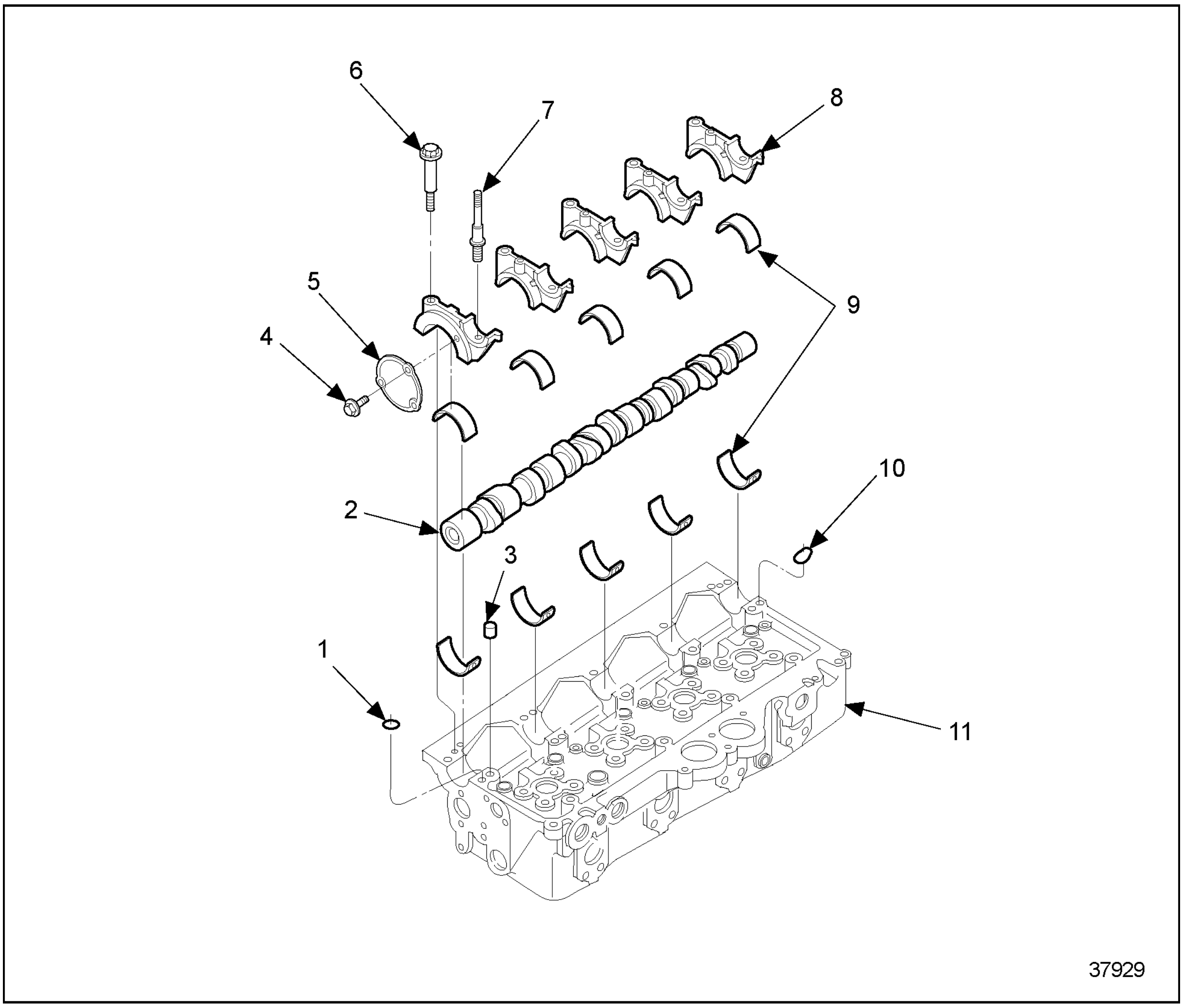


Figure 1-288 Camshaft and Related Parts

NOTE:
The S50G camshaft has no injector lobe on the cam.

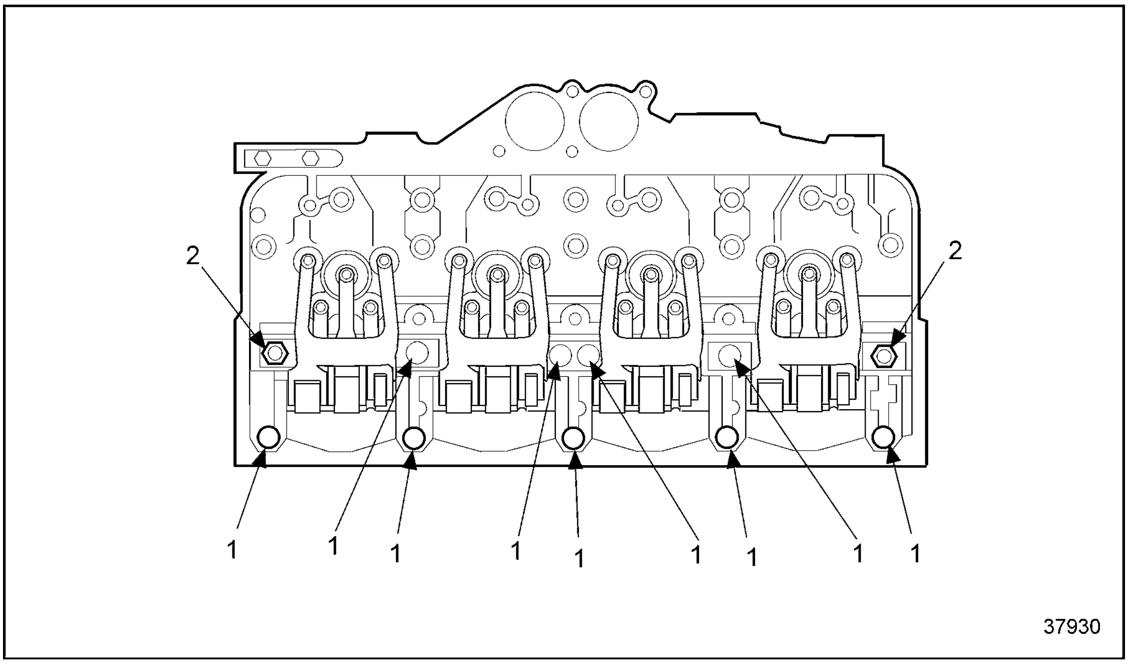
The camshaft is supported by five bearing assemblies, consisting of precision-type, replaceable bearing shell inserts that are split at their center lines. *Current non-tin-plated production bearing shells are identified by their shiny aluminum color. Current tin plated service bearing shells have dull gray sheen.* The lower bearing shell is positioned in a saddle that is integral with the cylinder head. The upper bearing shell is held in place by a machined camshaft cap. Upper and lower bearing shells are identical and have locating tangs and oil holes. Only the upper bearing shell oil holes index with oil supply holes in the camshaft caps. See Figure 1-289. These camshaft caps are precision line-bored after assembly to the cylinder head. Caps are NOT interchangeable once the head is finished. Caps are numbered and must NOT be interchanged with other caps of the same part number from stock or from a different cylinder head.



1. Cut Seal
2. Camshaft
3. Bushing
4. Bolt, Camshaft Cover
5. Camshaft Cover
6. Bolt, Camshaft Cap (9)
7. Stud, Camshaft Cap (2)
8. Camshaft Cap
9. Bearing Shells
10. Race Track Seal
11. Cylinder Head

Figure 1-289 Camshaft Bearings and Caps

The No. 3 camshaft cap is secured to the cylinder head with three bolts, with No. 2, and 4 caps utilize two bolts each. Caps one and five have a stud and one bolt each. The stud and nut arrangement on the end caps (1 and 5) allows rocker arm shaft removal without disturbing the gasket eliminator seal from the end camshaft caps to the cylinder head. There are four different camshaft cap configurations. Only the intermediate caps No. 2, and 4 are identical but must not be interchanged during re-assembly. See Figure 1-290.



1. Camshaft Cap Bolt (9)
2. Camshaft Cap Stud and Nut

Figure 1-290 Camshaft Caps Location

The camshaft is driven by a camshaft drive gear, located in the gear case at the front of the engine and is driven, through a series of intermediate gears, by the crankshaft timing gear. Refer to Section 1.21for gear train information and camshaft drive gear lash measurement and adjustment procedures. See Figure 1-291.

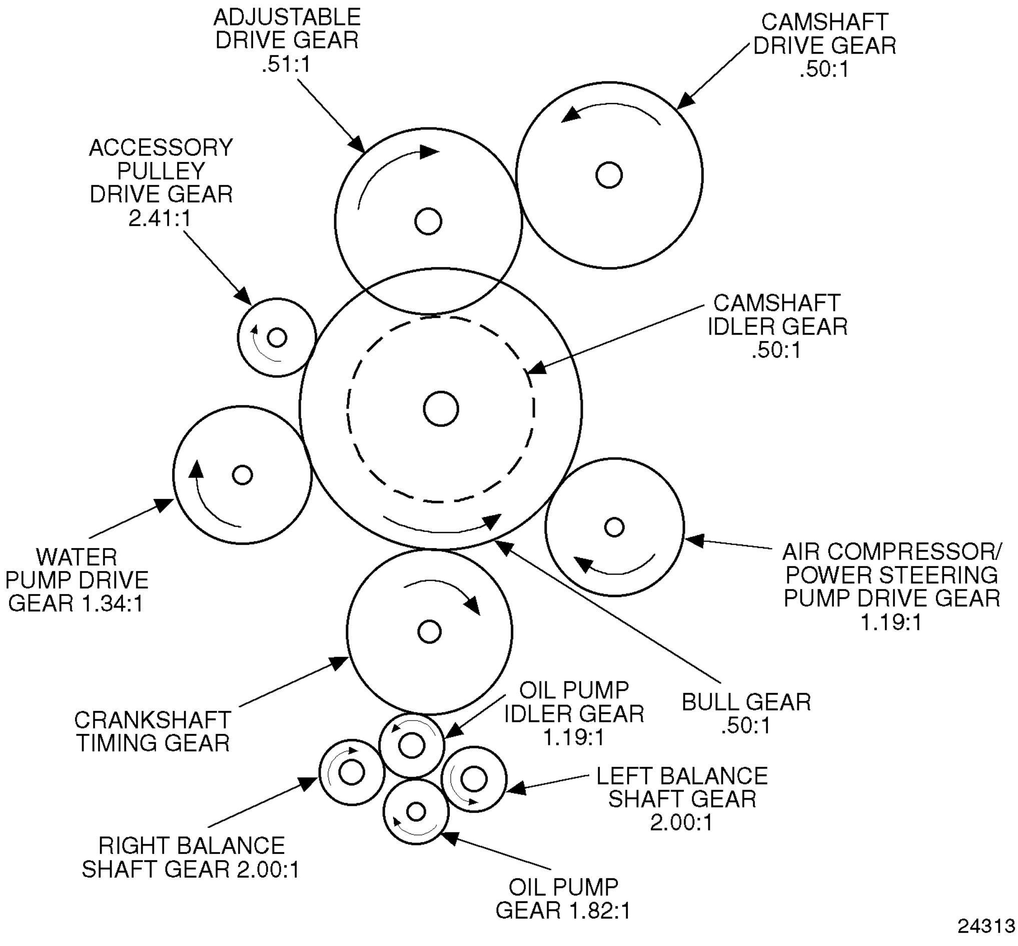
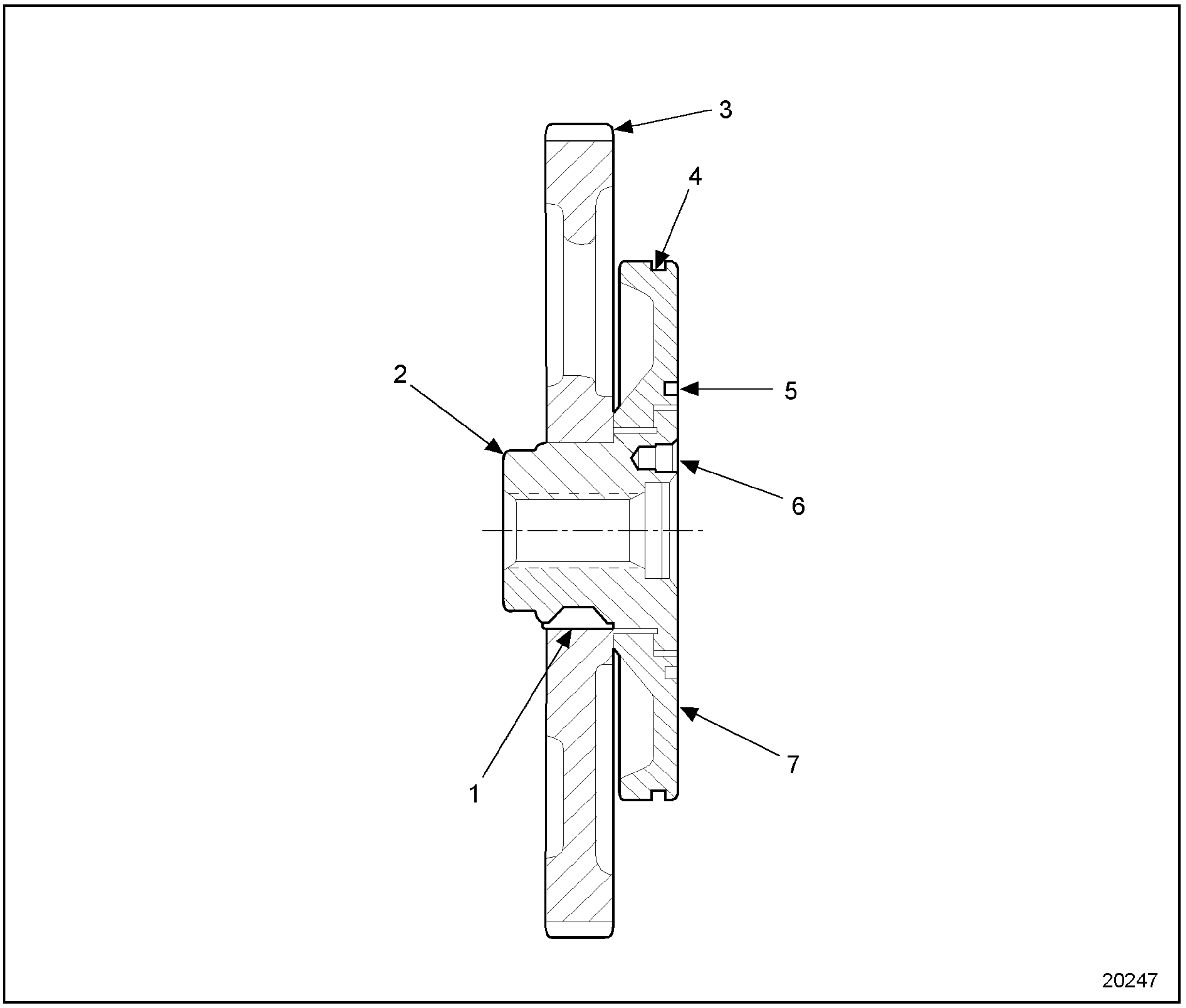


Figure 1-291 Engine Gear Train

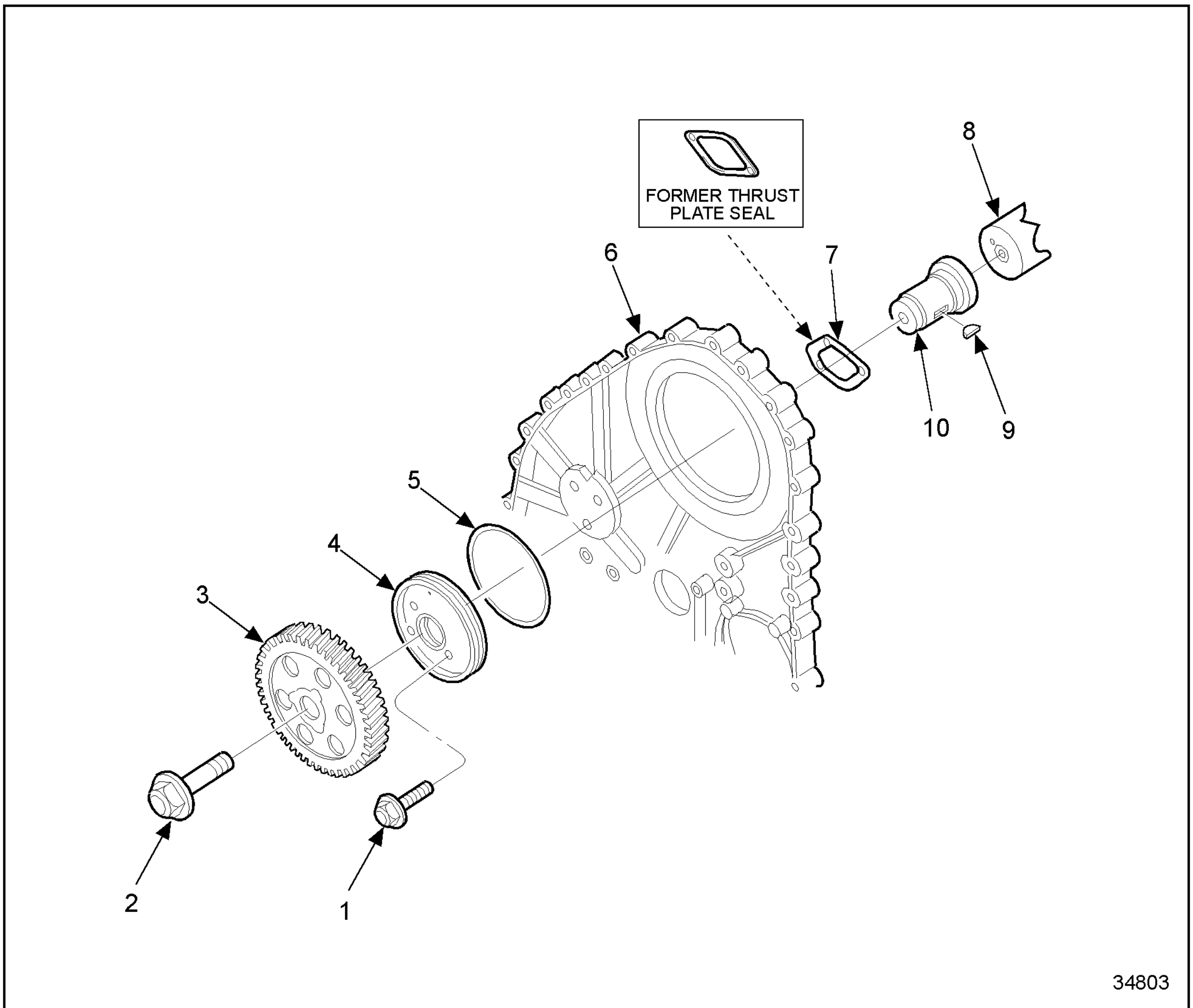
The camshaft drive gear is indexed to the camshaft drive gear hub by a Woodruff key and retained by a bolt which goes through the camshaft drive gear and hub and threads into the end of the camshaft. The camshaft has a dowel which indexes and fits into the mating hole in the camshaft hub. See Figure 1-292.



1. Woodruff Key
2. Camshaft Drive Gear Hub
3. Camshaft Drive Gear
4. O-ring Groove
5. Seal Groove
6. Camshaft Dowel Hole
7. Camshaft Thrust Plate

Figure 1-292 Cross Section of Camshaft Drive Gear and Related Parts

The camshaft hub is located in the camshaft thrust plate, which is positioned in an opening in the gear case housing. Refer to Section 1.24.2for camshaft drive gear, camshaft hub, or thrust plate removal. See Figure 1-293.



1. Bolt, Thrust Plate Retaining (2) or (3)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear, Camshaft
4. Thrust Plate, Camshaft
5. O-ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

Figure 1-293 Camshaft Thrust Plate and Related Parts

Access openings are provided in the gear case cover for camshaft drive gear lash adjustment and camshaft retaining bolt removal. See Figure 1-294.

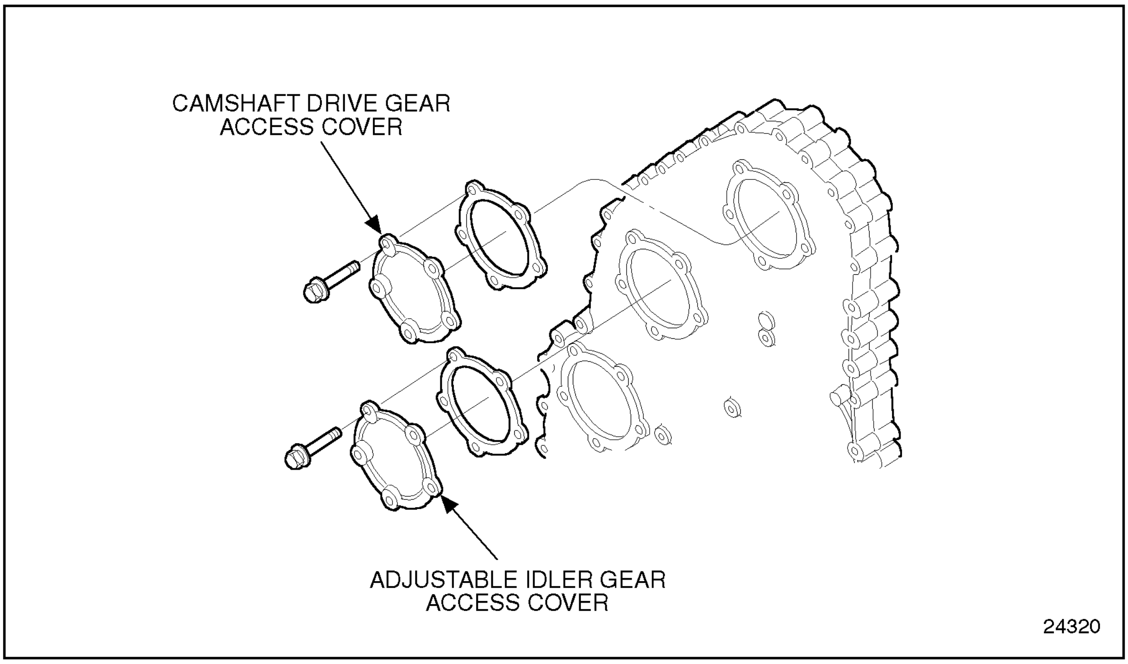


Figure 1-294 Camshaft Drive Gear and Adjustable Idler Gear Access Cover

A cover is provided at the rear end of the camshaft and is secured to the No. 5 camshaft bearing cap and the cylinder head by three bolts. See Figure 1-295.

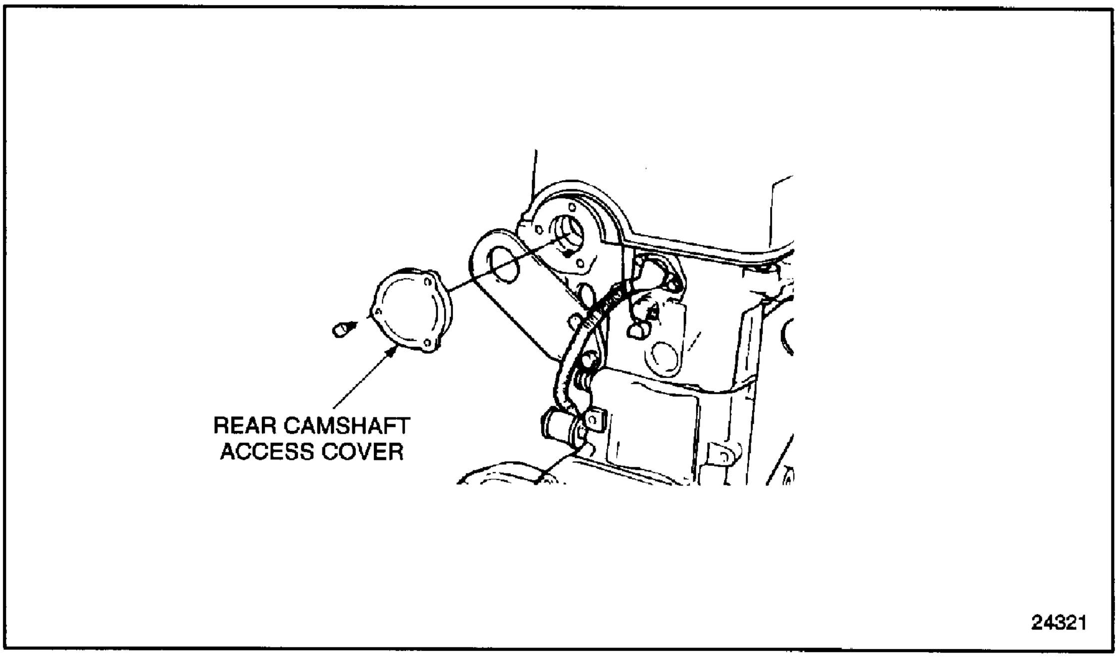
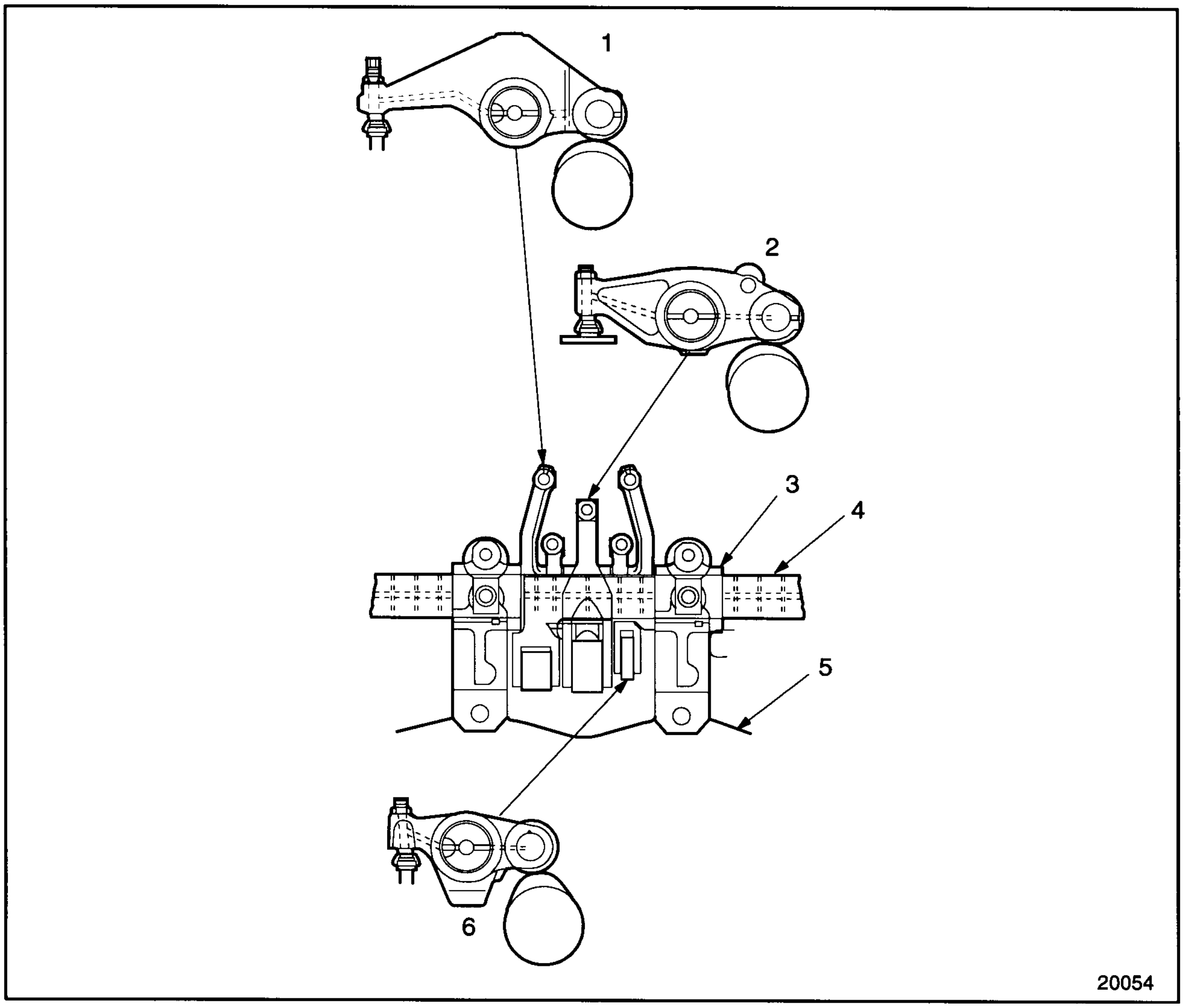


Figure 1-295 Rear Camshaft Access Cover

Vertical oil passages at the front and rear of the cylinder head deliver oil from the cylinder block front and rear oil galleries to the No. 1 and lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 5 upper bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each rocker arm shaft. The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushing passes through the oil hole in the bushing to the rocker arm. The rocker is drilled to supply oil to the camshaft follower, roller pin, and bushing. The rocker is also drilled to supply oil to the valve adjusting screw, valve button, retainer clip, intake, and exhaust valve stems and the fuel injector follower. The No. 3 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. See Figure 1-296.



1. Rocker Arm Exhaust Valve
2. Rocker Arm Fuel Injector
3. Camshaft Cap
4. Rocker Arm Shaft
5. Cylinder Head
6. Intake Valve Rocker Arm

Figure 1-296 Lubrication Schematic

1.22.1 Repair or Replacement of Camshaft and Camshaft Bearing

To determine if repair or replacement of the camshaft and camshaft bearings is necessary, perform the following procedure. See Figure 1-297.

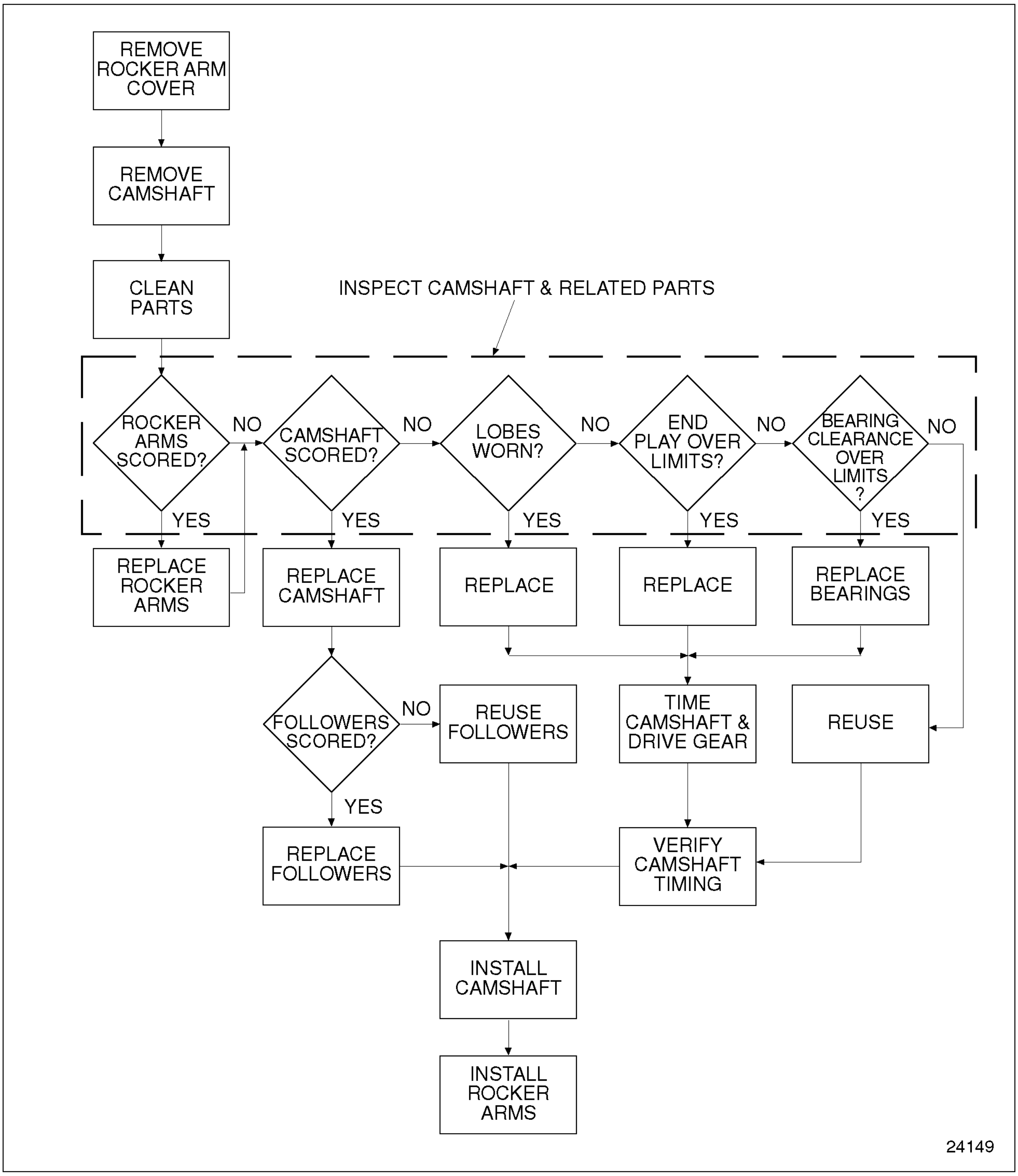


Figure 1-297 Flowchart for Repair or Replacement of Camshaft

1.22.2 Removal of Camshaft and Camshaft Bearing

Removal of camshaft and camshaft bearings as follows:

1. Remove the rocker cover. Refer to Section 1.6.2.

2. Remove the five bolts that secure the camshaft drive gear access cover to the gear case. See Figure 1-294.
3. Remove both rocker arm shaft assemblies. Refer to Section 1.3.2.

NOTICE:
Only special tool, J 35652-A part of J 35652, should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear-to-camshaft bolt. Other tools or devices can cause engine damage.

4. Insert the shoe of the camshaft drive gear torque holding tool, J 35652-A part of J 35652, through a lightening hole of the camshaft drive gear.
5. Using the 3/4 in. square hole in the center of the crankshaft pulley, bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover.
6. Install the camshaft drive gear torque holding tool, J 35652-A part of J 35652 to the gear case, engaging one of the lightening holes in the camshaft drive gear. Use two of the access cover bolts to secure the tool to the gear case. See Figure 1-298.
7. Use a long 3/4 in. drive breaker bar and a 27 mm impact socket to remove the camshaft drive gear-to-camshaft bolt. Discard the bolt.
8. Remove the camshaft drive gear torque holding tool from the gear case.

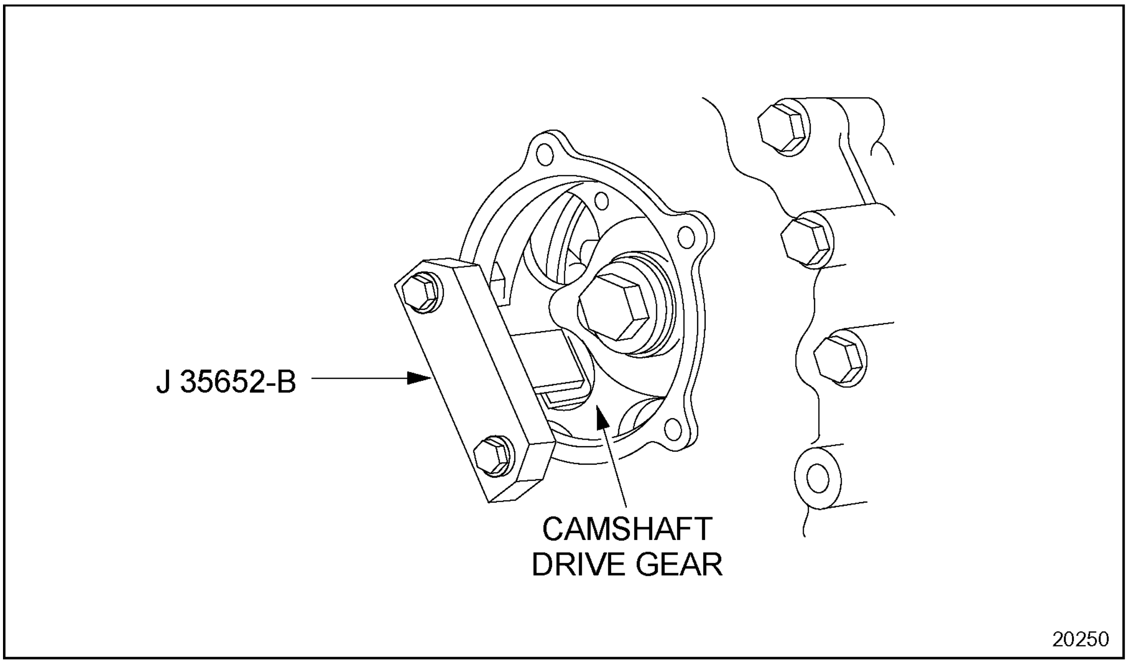
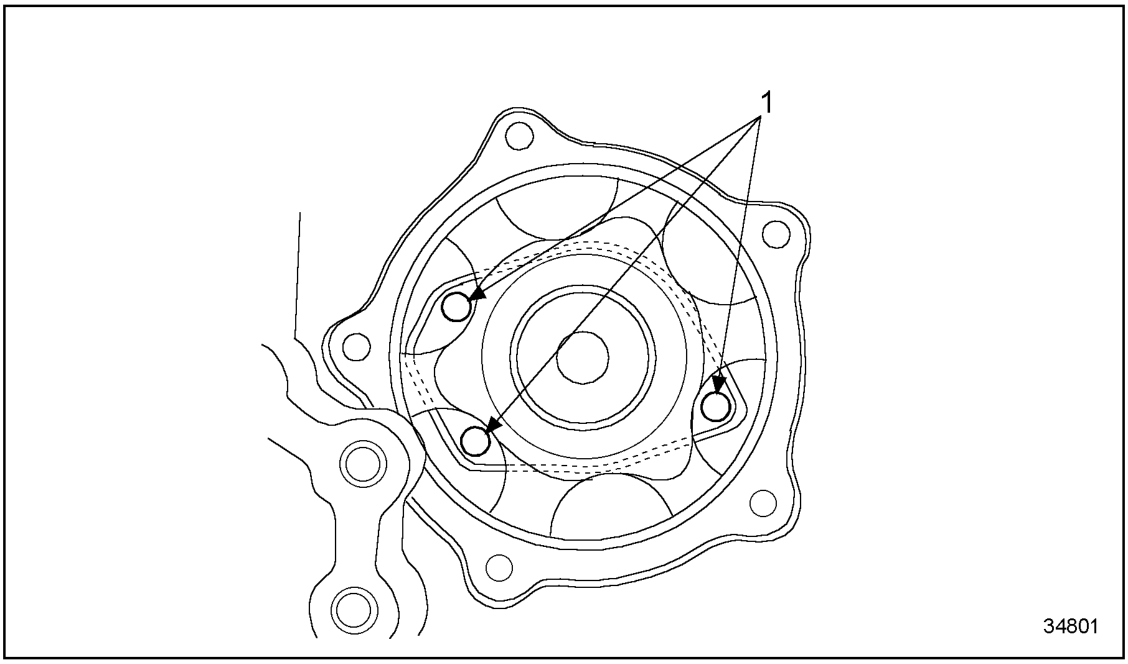


Figure 1-298 Camshaft Drive Gear Torque Holding Tool Installation

9. Rotate the crankshaft, using the square hole in the middle of the crankshaft pulley, to align the lightening holes in the camshaft drive gear to the camshaft thrust plate mounting bolts.
10. Remove the two camshaft thrust plate mounting bolts carefully, to avoid dropping them into the gear case. The current plate uses three bolts; the former plate requires two bolts. See Figure 1-299.

NOTE:
A clean shop towel may be inserted into the gear case opening to trap the bolts in case they are dropped. Do not allow the shop towel to drop into the gear case.



1. Camshaft Thrust Plate Mounting Bolt Locations

Figure 1-299 Camshaft Thrust Plate Bolt Locations

11. Install the camshaft gear pilot, J 35906–6, to the camshaft drive gear access opening, using three of the access cover bolt holes. Engage the puller screw (select proper size screw) in the threads of the camshaft drive gear hub, until the screw is tight. See Figure 1-300.

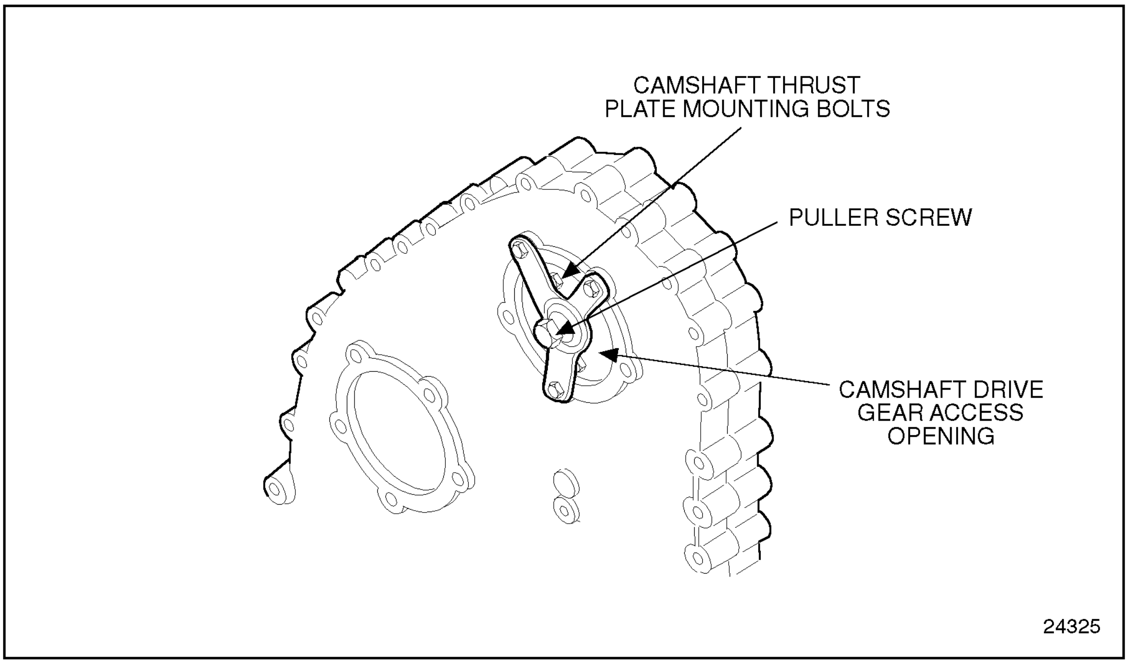


Figure 1-300 Camshaft Gear Pilot

12. Continue turning the puller screw to pull the camshaft drive gear hub and thrust plate forward approximately 6-7 mm (1/4 in.) until the thrust plate seal is clear of the camshaft front bearing cap and cylinder head. See Figure 1-301.

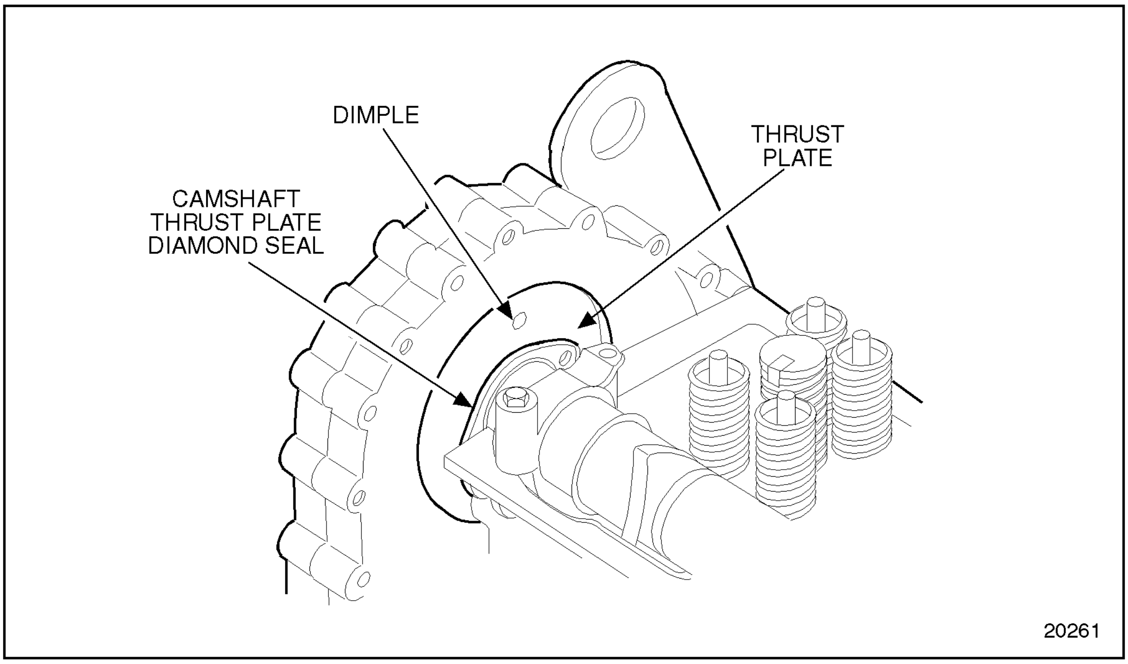


Figure 1-301 Camshaft Thrust Plate Clearance

13. Remove the three bolts that secure the rear camshaft cover to the engine and remove the cover.

14. Remove the remaining seven camshaft cap bolts. Remove the No. 1 and 5 studs using socket tool J 36003-A. See Figure 1-302.

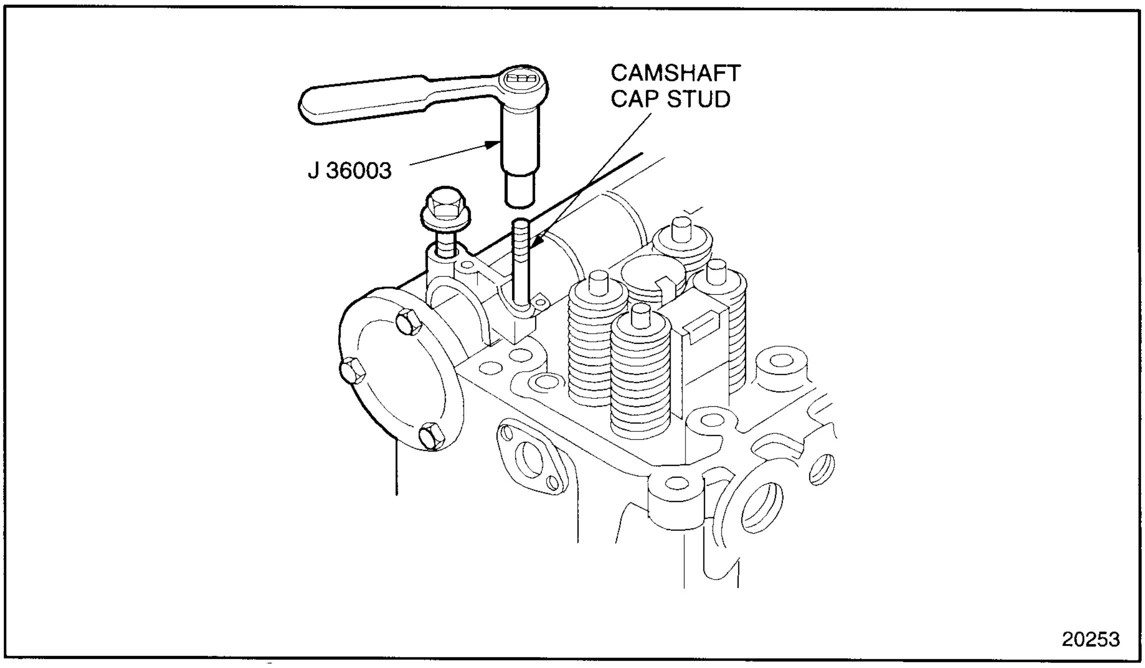


Figure 1-302 Camshaft Cap Stud Removal

15. Remove the five camshaft bearing caps and the upper bearing shells. Keep the caps and shells together for possible later installation. Tag the bearing cap location, as they must always be installed in the same location.
16. Remove the center screw from the camshaft gear pilot tool. The camshaft gear pilot tool will remain in place, holding the camshaft drive gear in contact with the adjustable idler gear, to prevent accidental disengagement. This arrangement makes it unnecessary to re-time the gear train.

NOTE:
The camshaft gear can go out of time if the pilot tool is removed.

17. Slide the camshaft rearward to completely disengage the dowel from the hub. Lift out the camshaft.
18. Remove the lower camshaft bearing shells, and group them with the upper shells and caps for possible reuse.

1.22.3 Disassembly of Camshaft and Camshaft Bearing

Refer to Section 1.24.2 for disassembly of camshaft drive gear, camshaft hub and thrust plate assembly.

NOTE:
Disassembly of camshaft and drive gear assembly is not required for inspection. Disassembly will require timing of the camshaft gear again.

1.22.3.1 Inspection of Camshaft and Camshaft Bearing

Inspect camshaft and camshaft bearings as follows:

1. Clean all of the removed parts in clean fuel oil.
2. Ensure all oil passages are clear.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Dry with compressed air.
4. Inspect the rocker arm valve springs for scoring. Refer to Section 1.4.5.3.
5. Replace damaged rocker arm components.
6. Inspect the camshaft lobes and journals for scoring, pitting, or flat spots.

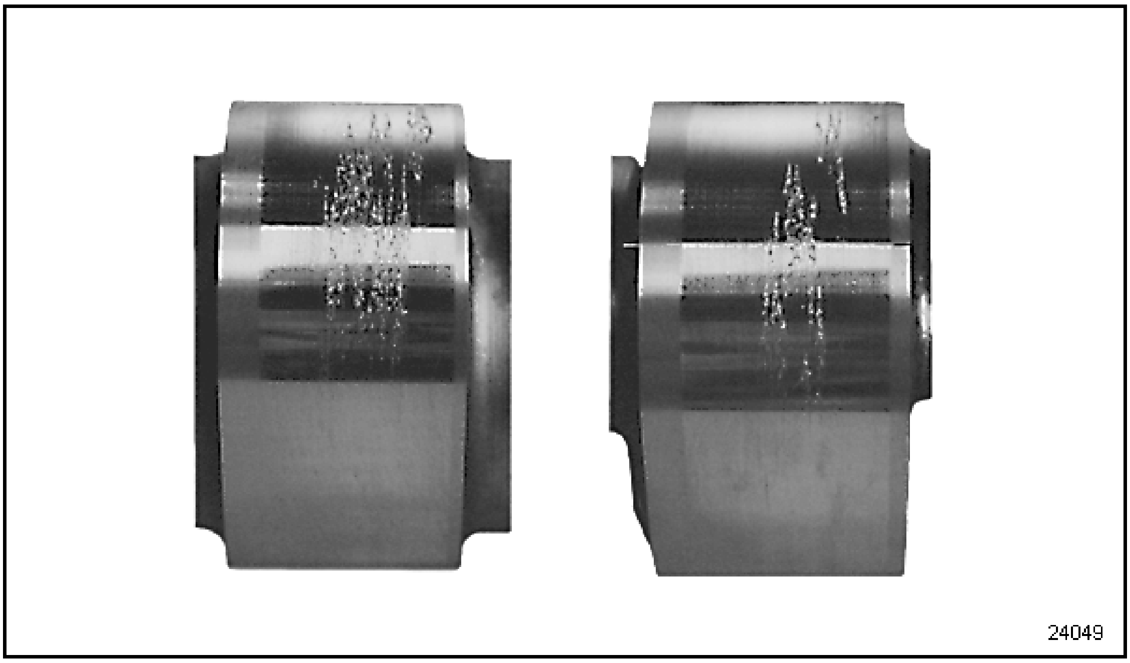


Figure 1-303 Camshafts Exhibiting Wear and Pitting

Figure 1-304 Camshafts Exhibiting Surface Pits on the Exhaust Lobes

NOTE:
Camshafts exhibiting extensive wear and pitting must be replaced. See Figure 1-303.

NOTE:
Camshafts may exhibit surface pits on the exhaust lobes. See Figure 1-304. Extensive durability and field testing has shown that surface pits on the exhaust lobes can occur early in the operation of the engine. These blemishes do not adversely affect engine performance or the durability of the camshaft and followers. Camshafts with this condition may be reused.

7. If the cam is scored, inspect the camshaft follower rollers.
8. Replace damaged camshaft followers.
9. If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of camshaft lobe wear as follows:

NOTE:
The camshaft can be in or out of the engine during this procedure.

[a] With a set of feeler gages, 0.038-0.254 mm (0.0015-0.010 in.) and a piece of square, hard material 3 x 10 x 25 mm (1/8 in. x 3/8 in. x 1 in.), measure the flat on the injector rise side of the camshaft lobes and nose of valve lobes. See Figure 1-305.

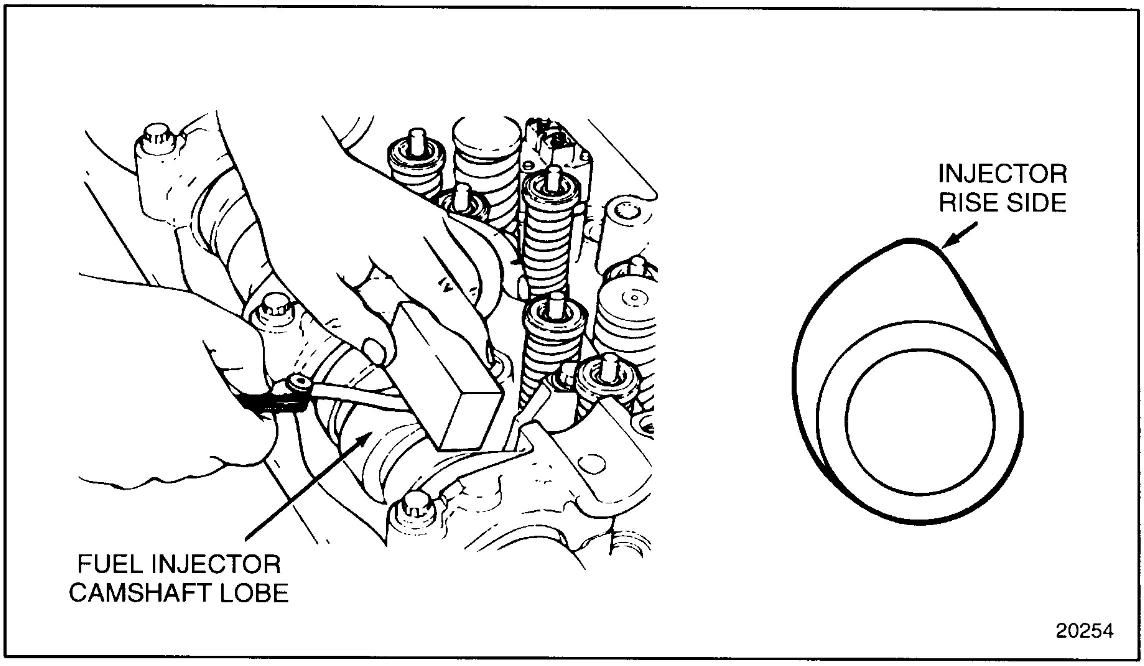


Figure 1-305 Checking Camshaft Lobe Wear

[b] If the flats measure greater than 0.076 mm (0.003 in.) in depth and there are no other camshaft defects, replace the camshaft.

[c] Inspect the camshaft bearings for signs of excessive wear, scoring or pitting.

[d] Replace camshaft bearings as necessary.

NOTE:
If one camshaft bearing needs to be replaced, replace all of the camshaft bearing shells.

[e] Check the camshaft bearing clearance using plastic gaging material under each upper shell. See Figure 1-306.

NOTE:
Check camshaft bearing clearance with bearing shells, camshaft, bearing caps and rocker arm shafts (without rocker assemblies in place) installed, and cap bolts, studs and nuts tightened to specification.

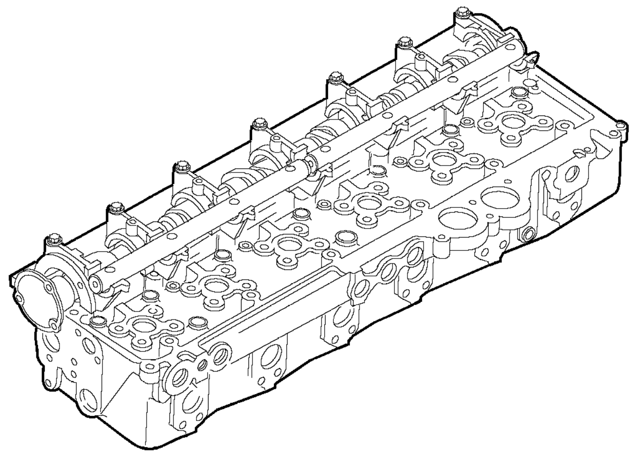


Figure 1-306 Camshaft Bearing Clearance Setup

[f] Allowable clearance is 0.09-0.166 mm (0.0035-0.0065 in.) or a maximum of 0.191 mm (0.0075 in.) with used parts.

[g] Replace excessively worn or scored parts.

[h] After completing the camshaft bearing clearance measurements, remove the rocker arm shafts, bearing caps, camshaft, and camshaft bearings. Keep the caps and shells together for possible reuse.

[i] Clean all of the plastic gaging material from the bearing shells and camshaft journals if used parts are to be reused.

[j] Remove all of the Gasket Eliminator from both the cylinder head and camshaft caps.

[k] Install the camshaft to its normal position in the bearing saddles. Install the No. 1 and 5 camshaft caps to the cylinder head.

[l] Install the Nos. 1 and 5 camshaft cap outboard bolts and inboard studs and torque both to 101-116 N·m (75-86 lb·ft). Use tool J 36003-Ato tighten the studs.

[m] Using a dial indicator with magnetic base, check the run-out of the camshaft at the No. 3 bearing journal. See Figure 1-307.

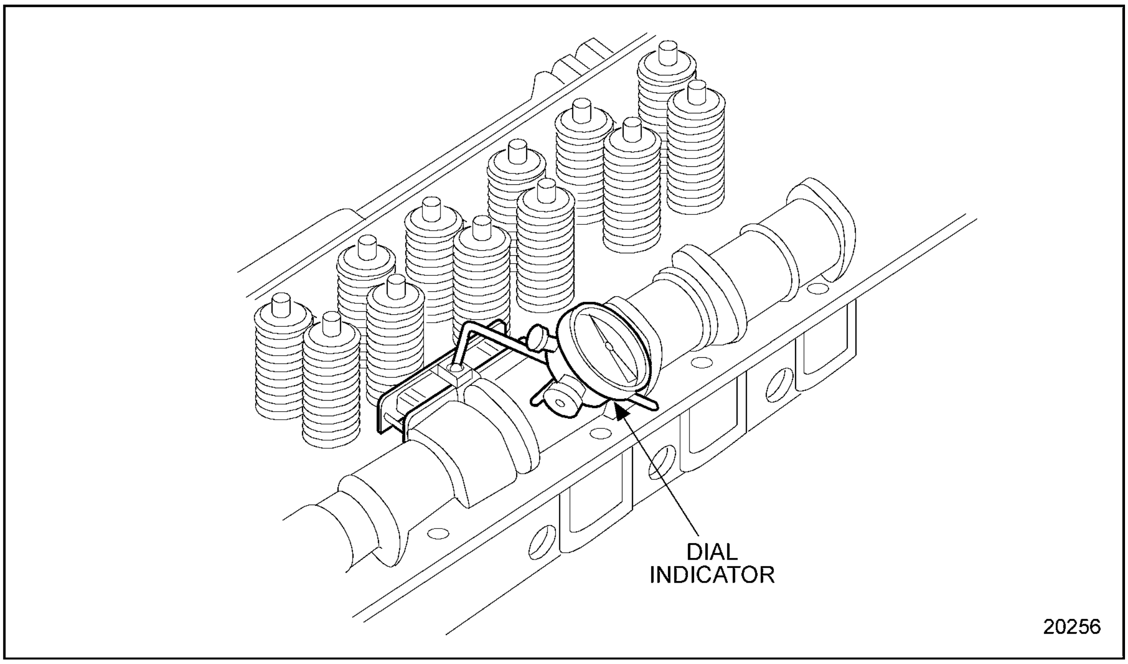


Figure 1-307 Camshaft Run-out

[n] If camshaft run-out exceeds 0.050 mm (0.002 in.), replace the camshaft.

1.22.4 Assembly of Camshaft and Camshaft Bearings

Refer to Section 1.24.3 for assembly of camshaft drive gear, camshaft hub and thrust plate assembly.

1.22.5 Installation of Camshaft and Camshaft Bearing

Install the camshaft and camshaft bearings as follows:

1. Coat the lower camshaft bearing shells with clean engine lubricating oil, and install them to their original positions. Note the position of oil holes and locating tangs.

NOTE:
If new bearings are to be installed, the upper and lower shells MUST be replaced as a set.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. When installing a new camshaft, steam clean it to remove the rust preventive and blow dry with compressed air.
3. Before installing the camshaft dowel into the camshaft hub, ensure that the dimple in the thrust plate is located at the 12 o'clock position to properly position bolt holes to cam cap and cylinder head. See Figure 1-308.

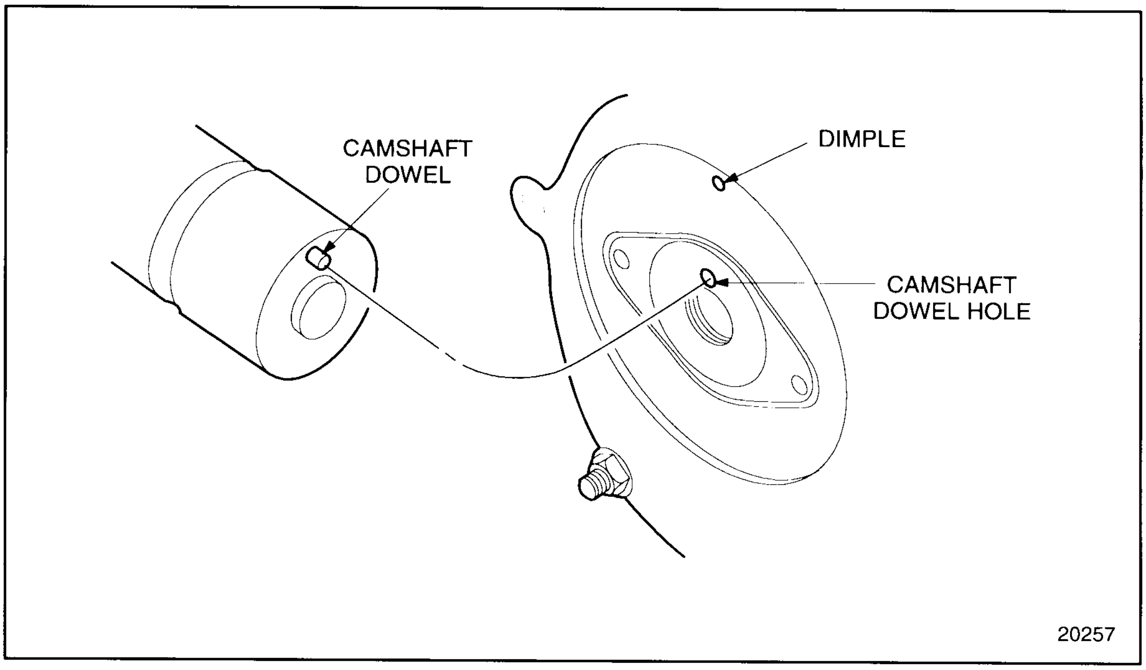


Figure 1-308 Indexing Camshaft Dowel

4. Coat the lobes and journals of the camshaft with clean engine lubricating oil. Index the dowel pin in the camshaft with the dowel hole in the camshaft hub.
5. Lower the camshaft into position and slide the camshaft forward, making certain that the camshaft dowel indexes with its mating hole in the camshaft thrust plate hub.
6. Install the upper bearing shells to the No. 1, 3 and 5 camshaft caps, noting the position of the oil holes and locating tangs.

NOTICE:
Do not apply oil to the No. 1 or No. 5 camshaft bearing shells. These shells *must* be clean and dry for proper sealant application. Applying oil to the No. 1 or No. 5 shells may result in oil leakage from the camshaft bearing caps.

NOTE:
The camshaft will still have adequate clearance from the No. 1 and No. 5 shells due to the oil film thickness on bearings 2 through 4.

7. Coat the No. 2 through No. 4 bearing shells with clean engine lubricating oil.
8. For engines built prior to S/N 4R0028789, install the two square cut seals to the counterbores in the cylinder head at the No. 1 and 5 camshaft cap locations. Before assembling the camshaft caps to the cylinder head, verify the two seals are in place on the cylinder head.

NOTICE:

For engines built prior to S/N 4R0028789, Gasket Eliminator P/N 23523064 must be kept from the bearing shell sets and bearing surfaces. Gasket Eliminator cures with the absence of air. The length of time between installation of the No. 1 and 5 camshaft caps and torquing the camshaft cap bolts and nuts should be kept to a minimum, or improper lubrication will result, causing engine damage.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

Always blow out the cam cap bolt holes in the cylinder head before applying sealant and installing the cam cap. Failure to observe this step may cause lubricating oil trapped in the holes to push the sealant away from the cap when bolts are installed, resulting in a leak path.

9. Install the two rubber O-rings to the counterbores in the cylinder head at the No. 1 and 5 camshaft cap locations. Before assembling the camshaft caps to the cylinder head, the two O-rings are in place on the cylinder head.

NOTICE:

Gasket Eliminator must be kept from the bearing shell sets and bearing surfaces. Gasket Eliminator cures with the absence of air. The length of time between installation of the No. 1 and 5 camshaft caps, and torquing the camshaft cap bolts and nuts should be kept to a minimum or improper lubrication will result causing engine damage.

10. Clean and dry the camshaft bearing cap joint face surfaces as well as the portions of the cylinder head face that the caps mate with. These areas *must* be clean and dry for proper sealant adhesion. Use LPS, Permatex, or an equivalent non-filming degreaser.
11. For engines built after 4R0028788, use P/N 23525918 or 23525919 in the diagonal groove cuts of the front bearing cap only.

12. For engines built prior to unit number 4R0028789 apply gasket eliminator P/N 23523064, or equivalent to the joint face surfaces of the No. 1 and 5 camshaft caps. See Figure 1-309.

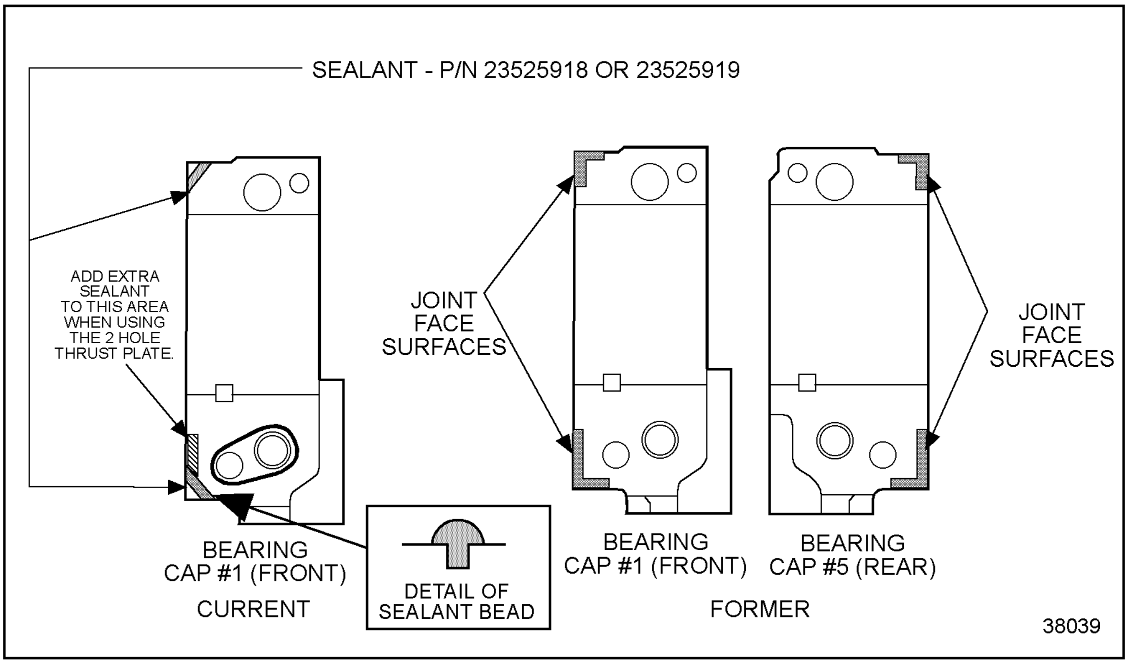


Figure 1-309 Gasket Eliminator Application (Camshaft Bearing Cap)

13. Install the No. 1, 3 and 5 camshaft caps, with bearing shells in place, to their respective locations.
14. Install and torque the two inboard studs and outboard bolts on bearing caps No. 1 and 5 to 126-146 N·m (93-108 lb·ft). Use tool J 36003-Ato tighten the bearing cap studs.
15. Install the No. three bearing cap outboard bolt and torque it to 126-146 N·m (93-108 lb·ft).
16. Remove the three bolts holding the camshaft gear pilot, J 35906–6, to the gear case. Remove the camshaft gear pilot.

NOTICE:
Use care to ensure that the camshaft dowel is not disengaged during this step or damage to engine may result.

17. Working through the camshaft drive gear access hole in the front of the gear case, tap the center of the camshaft drive gear with a fiber mallet or plastic hammer to move the camshaft thrust plate, hub and camshaft drive gear rearward in the gear case until the camshaft thrust plate bolts can be started in the cylinder head and No. 1 camshaft cap.

NOTICE:
Using care to prevent dropping thrust plate mounting bolts into the gear case. If not removed, fasteners dropped into the gear case can cause severe engine damage at start-up.

18. Install the thrust plate mounting bolts through the thrust plate and into the cylinder head and No. 1 camshaft cap. Using a 13 mm socket and ratchet, tighten the bolts alternately and progressively to draw the thrust plate straight into the gear case. Torque the bolts to 30-38 N·m (22-28 lb·ft).

NOTICE:
Always use new bolts when replacing the camshaft hub. Camshaft hub retaining bolts are considered single-use items and *cannot be reused,* regardless of apparent condition. Reusing these bolts may result in excessive bolt stretch, which could lead to loss of bolt torque, hub loosening, and severe engine damage.

NOTE:
Ensure any residual oil is removed from the dowel face of the camshaft and mating hub before installing the drive gear.

19. Coat the threads and underside of the head of the camshaft drive gear-to-camshaft bolt with International Compound #2®. Install the bolt to the camshaft, finger-tight.

NOTE:
The camshaft should be held in place while starting the camshaft drive gear-to-camshaft bolt, to prevent disengaging the camshaft dowel from the thrust plate hub and requiring disassembly and timing of camshaft.

20. Insert the shoe of the camshaft drive gear torque holding tool through a lightening hole of the camshaft drive gear.

NOTICE:
Only camshaft drive gear torque holding tool, J 35652-A part of J 35652, should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear-to-camshaft bolt to prevent component damage.

21. Bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover using the 3/4 in. square hole in the center of the crankshaft pulley to bar the engine over.
22. Install two of the access cover bolts to secure the tool to the gear case.

NOTICE:
Failure to tighten the camshaft hub retaining bolt to the required torque may result in bolt loosening during engine operation, which may lead to camshaft alignment pin damage, altered engine timing, and erratic engine operation.

23. Using a 27 mm impact socket and suitable torque wrench, torque the camshaft drive gear-to-camshaft bolt to 75 N·m (55 lb·ft). See Figure 1-310.

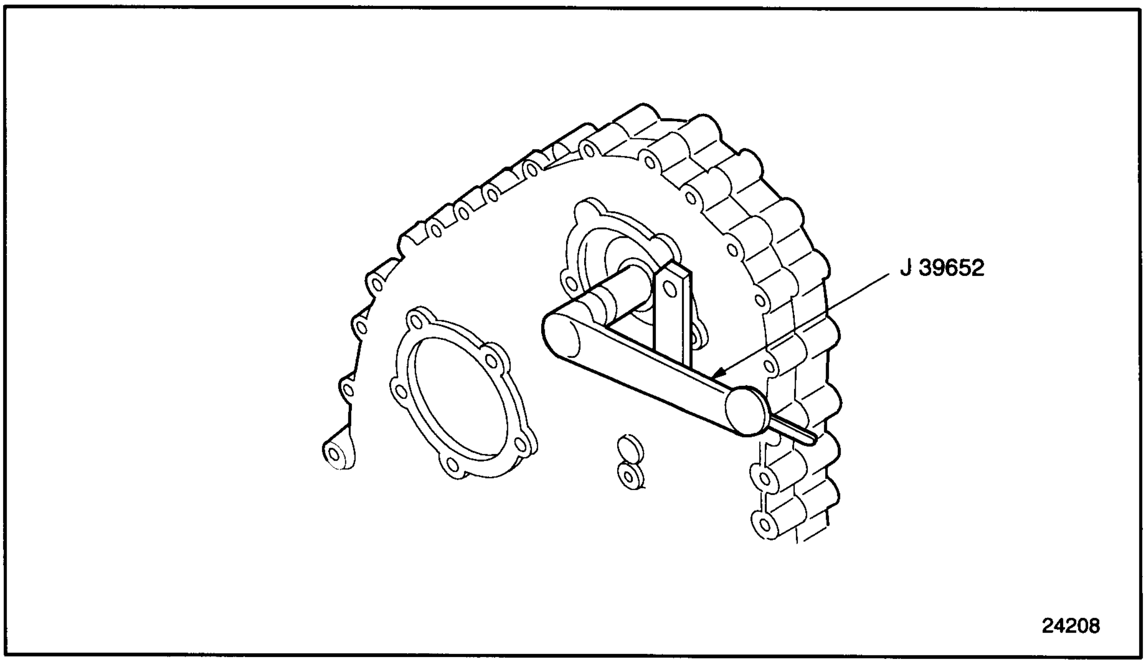


Figure 1-310 Camshaft Drive Gear-to-Camshaft Bolt Tightening

24. Turn the bolt an additional 120 degrees. See Figure 1-311.

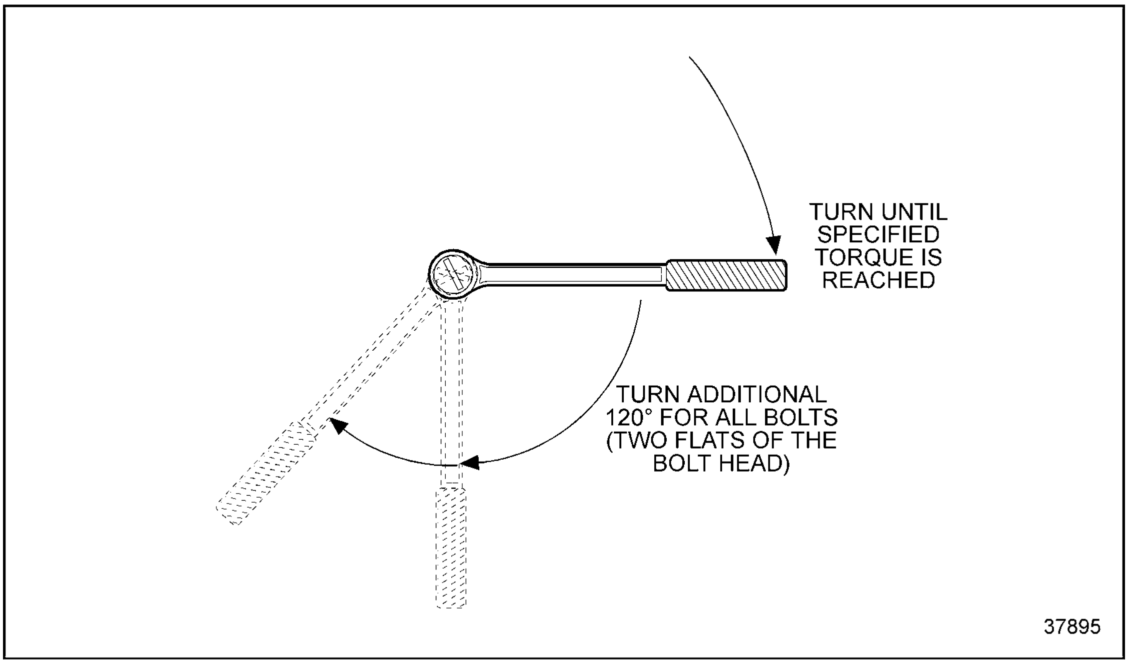


Figure 1-311 Torque Turn Limits — Camshaft Drive Gear-to-Camshaft Bolts

25. Remove the camshaft drive gear torque holding tool, J 35652-A part of J 35652.
26. Adjust the camshaft drive gear-to-adjustable idler gear lash. Refer to Section 1.21.2.1.

NOTE:
Correct camshaft drive gear lash adjustment depends on the bolt and stud for No. 1 and 5 camshaft caps, the outboard bolt on No. 3 camshaft cap, and the camshaft drive gear-to-camshaft retaining bolt being tightened to the specified torque. However, the valve and injector spring pressures will not allow correct camshaft rotation. Therefore, do NOT install the rocker arm shaft assemblies before the camshaft gear lash has been measured and adjusted.

1.22.5.1 Test of Camshaft End-play

Measure the camshaft end-play, using a dial indicator and magnetic base, as follows:

1. Install the dial indicator so that the pointer is in contact with either the camshaft drive gear-to-camshaft retaining bolt, or at the rear end of the engine, in contact with the end of the camshaft. See Figure 1-312.

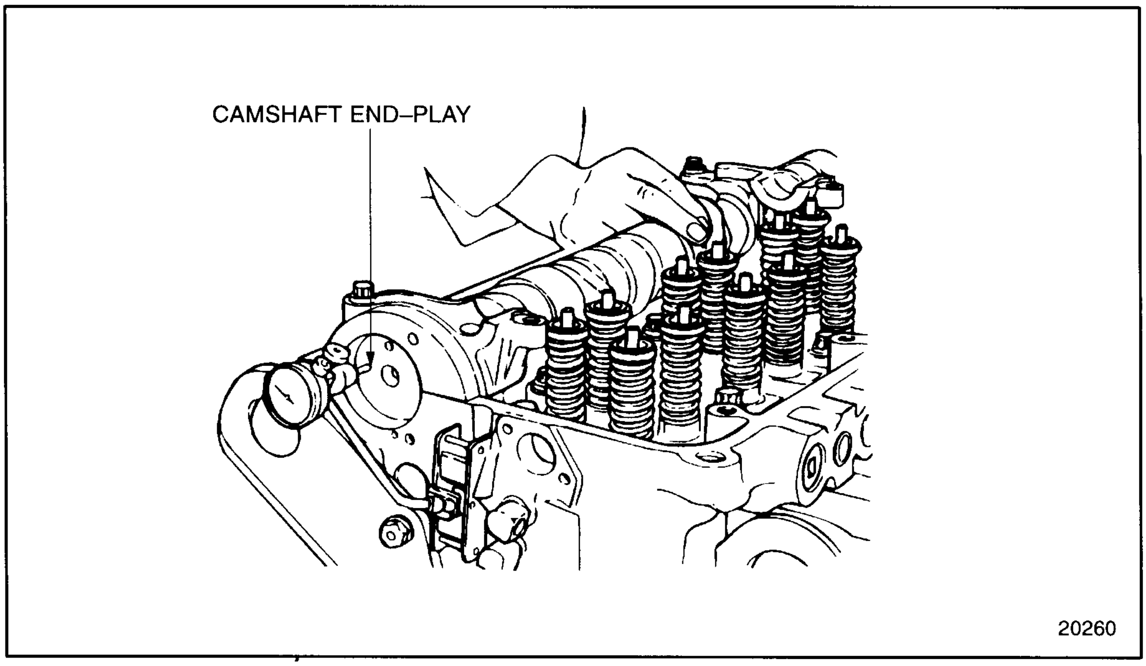


Figure 1-312 Camshaft End Play

2. Grasp the camshaft between the numbers one and three camshaft caps, and move the cam as far forward as possible. Zero the dial indicator.
3. Move the camshaft as far as possible, to the rear. Read and record the total amount of end-play as indicated.
4. Allowable camshaft end-play is 0.076-0.381 mm (0.003-0.015 in.).
5. If the end-play is beyond the maximum limit, loosen and retorque the camshaft drive gear-to-camshaft retaining bolt, and the camshaft thrust plate retaining bolts, to ensure that the camshaft thrust plate is seated properly in the gear case.
6. If the end-play is still beyond the maximum limit, remove and replace the camshaft thrust plate. Refer to Section 1.24.2and refer to Section 1.24.3.

1.22.6 Installation of Camshaft and Camshaft Bearing

Continue installing camshaft and camshaft bearings as follows:

1. Install the bearing shells to the remaining No. 2 and 4 camshaft caps, noting the oil holes and locating tangs.
2. Coat the bearing shells with clean engine lubricating oil.

3. Install the remaining camshaft caps to their saddles on the cylinder head. Install the four outboard camshaft cap bolts for caps No. 2 and No. 4 finger tight.
4. If they were removed, install the adjusting screws, valve buttons and clips to the rocker arms.
5. Install the rocker arms to the rocker arm shafts in their original positions. Use the rocker arm identification marks to ensure correct component installation. See Figure 1-313.

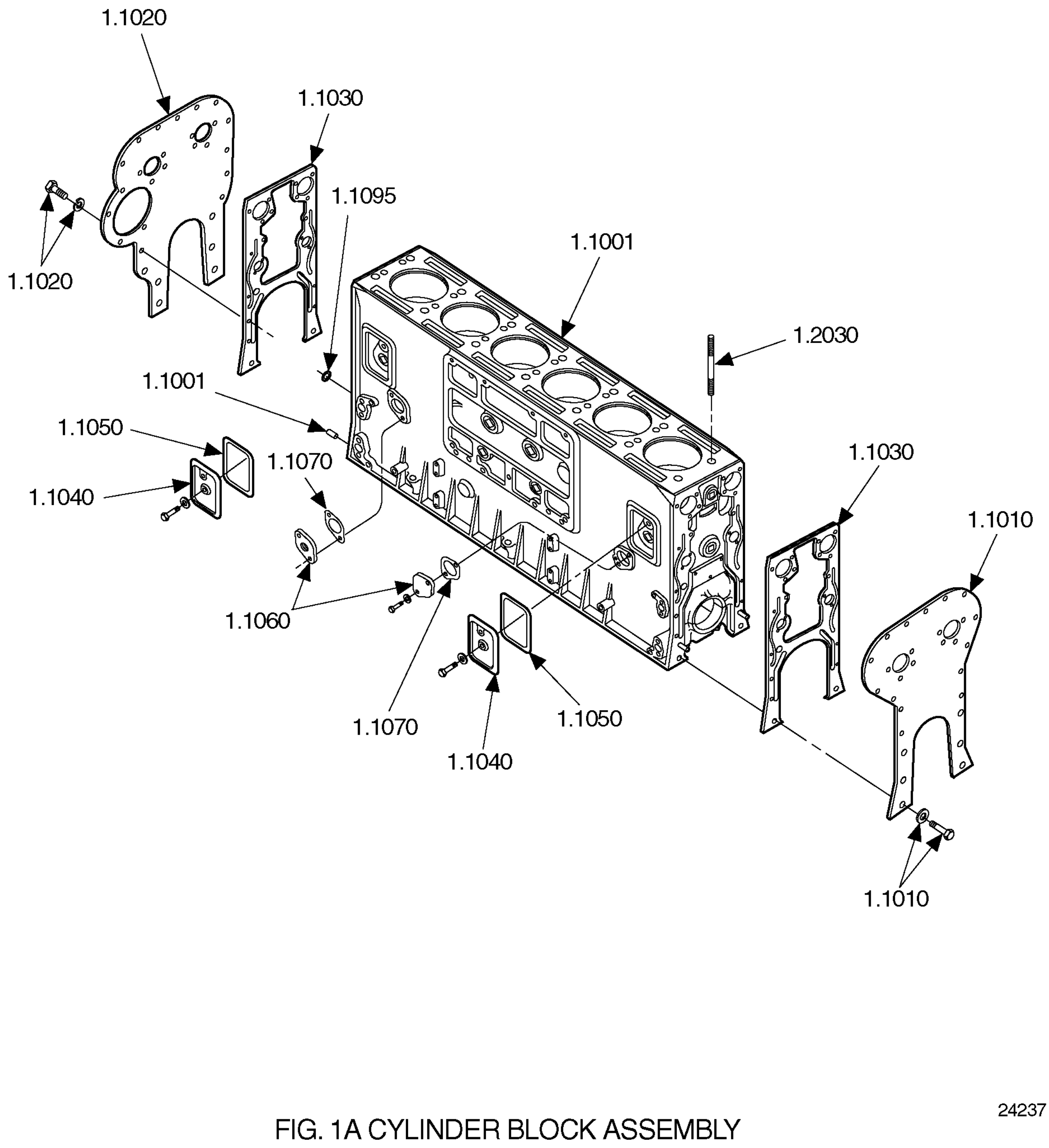


FIG. 1A CYLINDER BLOCK ASSEMBLY

FIG. 1A OF 1.0000

Figure 1-313 Rocker Arm Installation

6. Coat the rocker arm assemblies and camshaft liberally with clean engine lubricating oil.
7. Install the rocker arm shaft assemblies to the cylinder head. See Figure 1-313. Use care to locate the valve buttons to their respective valve stem and injector followers.
8. Install the remaining inboard camshaft cap bolts and spacers through the rocker arm shafts and into No. 2, 3, and 4 camshaft caps. Install the two nuts and spacers to the studs at No. 1 and No. 5 camshaft caps. Torque bolts to 101-116 N·m (75-85 lb·ft).
9. Torque the 9 camshaft cap bolts and two nuts to 101-116 N·m (75-85 lb·ft) using the sequence. See Figure 1-314.

NOTE:
It is not necessary to tighten bolts 7 and 10, if a Jake Brake is to be installed.

NOTE:
Jake Brakes are not on a natural gas engine.

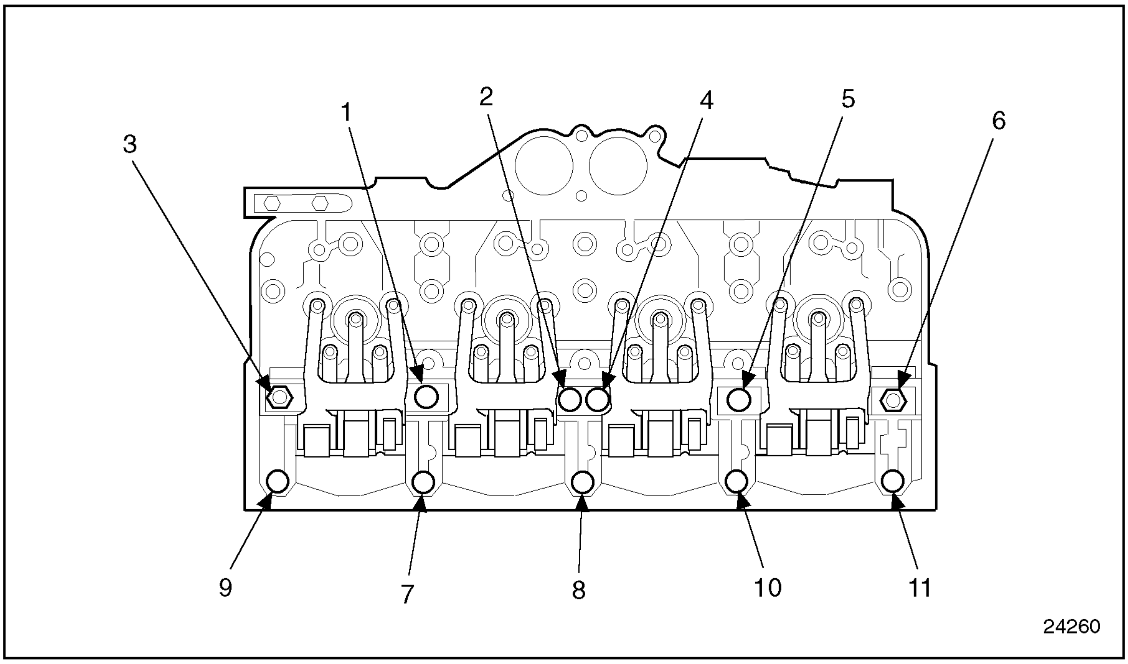


Figure 1-314 Camshaft Cap and Rocker Arm Shaft Bolt and Nut Torque Sequence

10. Clean all old gasket material from the mating surfaces of the rear camshaft cover and the cylinder head.
11. Apply a thin 1.5 mm (1/16 in.) bead of Gasket Eliminator, PT 7276 (Loctite 51580) or equivalent to the mating surface of the cover.
12. Install the cover and torque the three bolts to 30-38 N·m (22-28 lb·ft).
13. Clean all old gasket material from the mating faces of the camshaft drive gear access cover and the gear case cover.

14. Insert a new gasket between the camshaft drive gear access cover and the gear case.
15. Torque the bolts to 30-38 N·m (22-28 lb·ft) using the tightening sequence. See Figure 1-315.

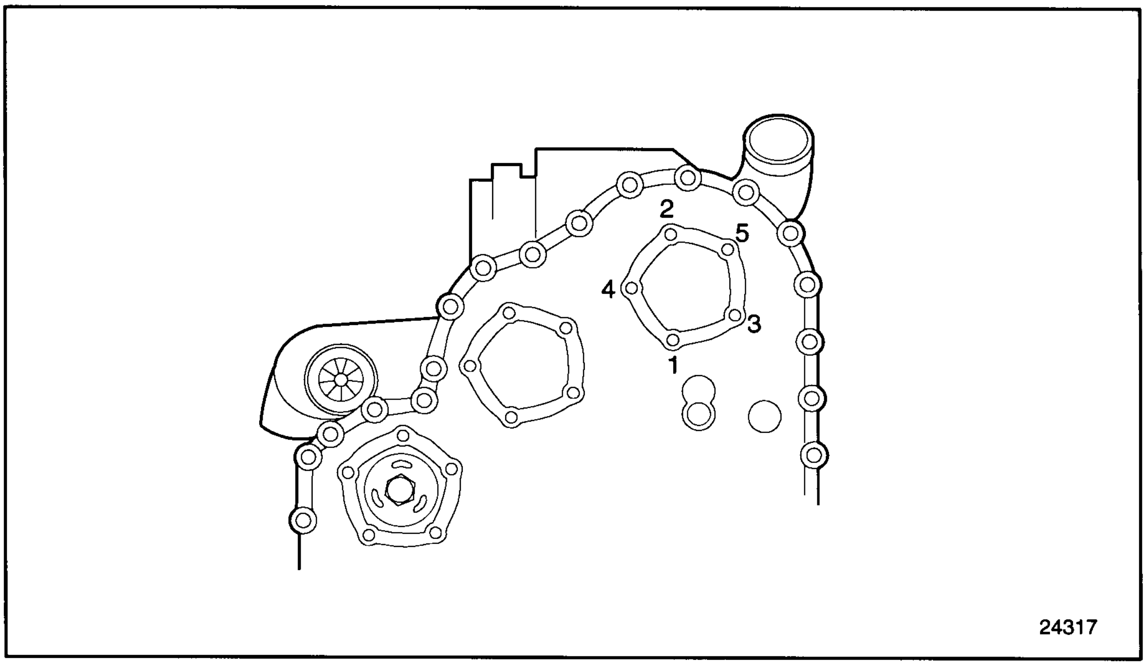


Figure 1-315 Camshaft Drive Gear Access Cover

16. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to Section 12.2.
17. Install the rocker cover. Refer to Section 1.6.6.
18. Install the fan hub, refer to Section 4.5.5, fan and drive belts. Refer to Section 13.5.7.
19. Install any other components that were removed for this procedure.

1.22.6.1 Test of Camshaft Timing on Diesel Engines

Check the camshaft timing as follows:

NOTICE:
The camshaft must be in time with the crankshaft. An engine which is " out of time" may result in pre-ignition, uneven running or a loss of power.

1. Remove the rocker cover. Refer to Section 1.6.2.
2. Select any cylinder for the timing check.
3. Remove the rocker arm assembly for the cylinder selected. Refer to Section 1.3.2.

4. Remove the injector for that cylinder. Refer to Section 2.3.2.
5. Carefully slide a rod, approximately 30 mm (12 in.) long, through the injector tube hole until the end of the rod rests on top of the piston.
6. Turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel.

NOTE:
The cylinder selected must be on the compression stroke when performing this check.

7. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
8. Select a dial indicator with 0.01 mm (0.001 in.) graduations and a spindle movement of at least 25 mm (1 in.). 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.
9. Install a magnetic dial indicator base in a suitable place on the cylinder head and position the dial indicator over the injector hole tube.
10. Attach a suitable pointer to the gear case cover. The outer end of the pointer should extend over the vibration damper.
11. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
12. Reset the dial to zero.
13. Turn the crankshaft until the indicator reading is 0.25 mm (0.010 in.).
14. Scribe a line on the vibration damper in line with the end of the pointer.
15. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
16. Reset the dial to zero.
17. Then turn the crankshaft in the same direction until the indicator reading is 0.25 mm (0.010 in.).
18. Scribe a second line on the vibration damper in line with the end of the pointer.
19. Scribe a third line half way between the first two lines. This is top dead center for the cylinder selected when the pointer is lined up with it.
20. Remove the dial indicator and base from the engine.
21. Install the injector that was removed. Refer to Section 2.3.5.
22. Install the rocker arm shaft assembly assembly. Refer to Section 1.3.4.
23. Turn the crankshaft opposite the direction of engine rotation while watching the injector rocker arm cam follower for the cylinder selected. Turn the crankshaft until the cam follower is on the base circle of the injector lobe of the cam.

24. Install a magnetic dial indicator base on the cylinder head. Install a dial indicator so that the spindle rests directly on the injector cam follower roller for the cylinder selected.

NOTE:
The spindle should be on the center line of the injector cam follower roller pin in order to get an accurate measurement of cam lift.

25. Turn the crankshaft slowly, in the direction of engine rotation, until the center mark on the vibration damper lines up with the pointer.
26. The correct indicator reading is 4.39 mm (0.173 in.) to 5.46 mm (0.215 in.) for diesel engines.
27. If the cam lift is incorrect, retime the engine. Refer to Section 1.21.2.1.

1.22.6.2 Test of Camshaft Timing on Natural Gas Engines

Check the camshaft timing as follows:

NOTICE:
The camshaft must be in time with the crankshaft. An engine which is " out of time" may result in pre-ignition, uneven running or a loss of power.

1. Remove the rocker cover. Refer to Section 1.6.2.
2. Select any cylinder for the timing check.
3. Remove the rocker arm assembly for the cylinder selected. Refer to Section 1.3.2.
4. Remove the spark plug for that cylinder.

NOTE:
The S50G does not contain an injector lobe like the diesel does, remove the spark plug.

5. Carefully slide a rod, approximately 30 mm (12 in.) long, through the spark plug hole until the end of the rod rests on top of the piston.
6. Turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel.

NOTE:
The cylinder selected must be on the compression stroke when performing this check.

7. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
8. Select a dial indicator with 0.01 mm (0.001 in.) graduations and a spindle movement of at least 25 mm (1 in.). 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.

9. Install a magnetic dial indicator base in a suitable place on the cylinder head and position the dial indicator over spark plug hole tube.
10. Attach a suitable pointer to the gear case cover. The outer end of the pointer should extend over the vibration damper.
11. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
12. Reset the dial to zero.
13. Turn the crankshaft until the indicator reading is 0.25 mm (0.010 in.).
14. Scribe a line on the vibration damper in line with the end of the pointer.
15. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
16. Reset the dial to zero.
17. Then turn the crankshaft in the same direction until the indicator reading is 0.25 mm (0.010 in.).
18. Scribe a second line on the vibration damper in line with the end of the pointer.
19. Scribe a third line half way between the first two lines. This is top dead center for the cylinder selected when the pointer is lined up with it.
20. Remove the dial indicator and base from the engine.
21. Install the spark plug that was removed.
22. Install the rocker arm shaft assembly assembly. Refer to Section 1.3.4.
23. Turn the crankshaft opposite the direction of engine rotation while watching the intake rocker arm cam follower for the cylinder selected. Turn the crankshaft until the cam follower is on the base circle of that intake lobe of the cam.
24. Install a magnetic dial indicator base on the cylinder head. Install a dial indicator so that the spindle rests directly on the intake cam follower roller for the cylinder selected.

NOTE:
The spindle should be on the center line of the intake cam follower roller pin in order to get an accurate measurement of cam lift.

25. Turn the crankshaft slowly, in the direction of engine rotation, until the center mark on the vibration damper lines up with the pointer.

26. Check the dial indicator reading and compare the reading with the values listed in Table 1-6to determine the correct indicator reading.

ENGINE	DDEC VERSION	MODEL	CAMSHAFT PART NO.	MODEL YEAR	LOW INJECTOR CAM ROLLER LIFT AT TDC	HIGH INJECTOR CAM ROLLER LIFT AT TDC
8.5 L	IV	TK	23522197	1998	5.54 mm (0.218 in.)	6.60 mm (0.260 in.)
8.5 L	II OR III	GU, GK	23511364	1993-1997	5.21 mm (0.205 in.)	6.27 mm (0.247 in.)
8.5 L	IV	MK, MKE	23524916	1999-2002	4.92 mm (0.194 in.)	5.99 mm (0.236 in.)
8.5 L	IV	MK, MKE	23527029	1999-2002	5.02 mm (0.198 in.)	6.09 mm (0.240 in.)

Table 1-6 Camshaft Timing Setting Dimensions

27. If the cam lift is not within the figureslisted in Table 1-6, retime the engine. Refer to Section 1.21.2.1.

1.23 THRUST PLATE PERIMETER SEAL

The camshaft thrust plate perimeter seal forms a seal between the camshaft thrust plate and the gear case cover. If the seal should require replacement due to leakage, the seal can be replaced without removing the cylinder head. The following procedure should be used if the perimeter seal requires replacement.

1.23.1 Repair or Replacement of Thrust Plate Perimeter Seal

To determine if repair or replacement of the thrust plate perimeter seal is necessary, perform the following procedure. See Figure 1-316.

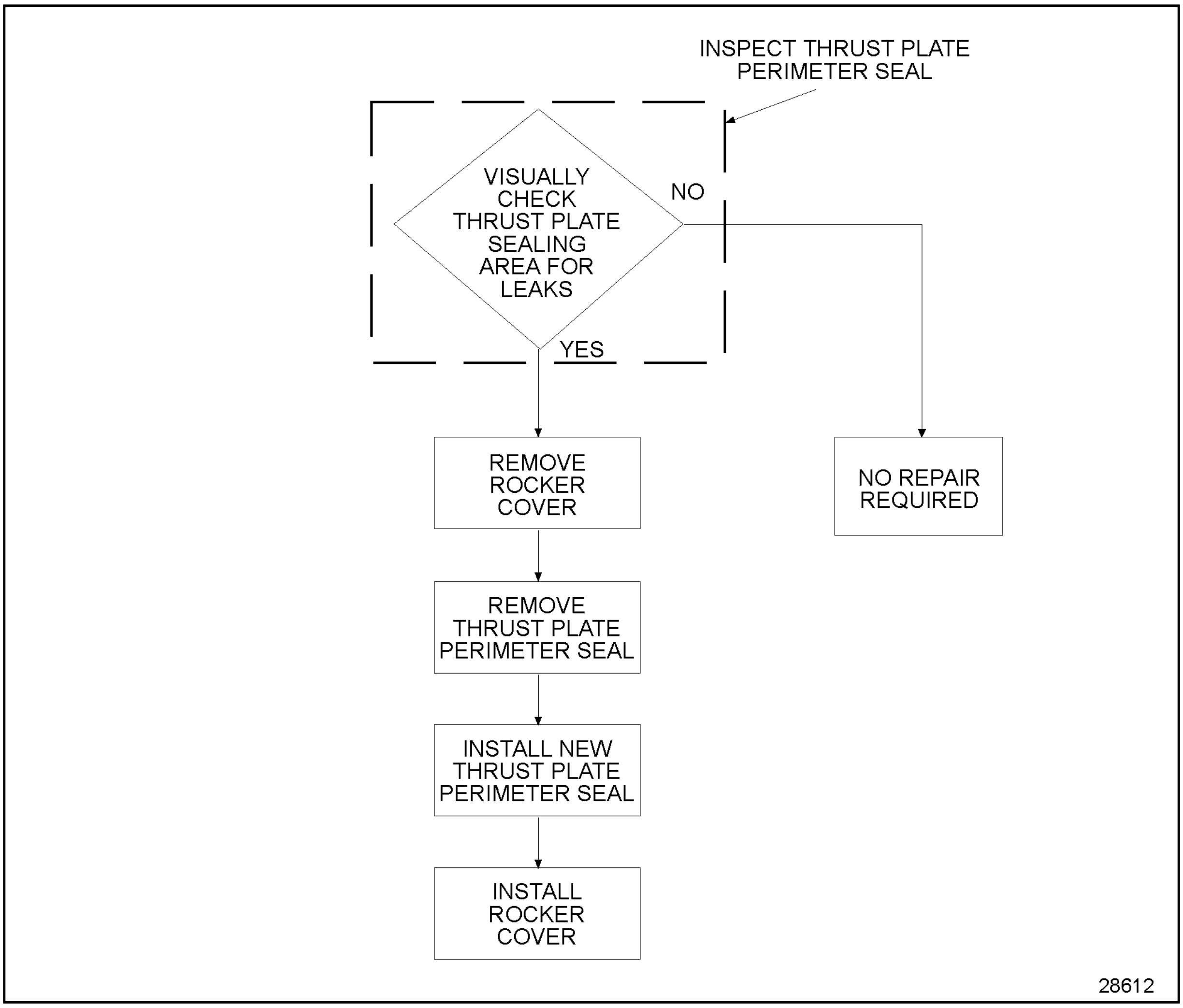


Figure 1-316 Flowchart for Repair or Replacement of Camshaft Thrust Plate Perimeter Seal

1.23.2 Removal of Thrust Plate Perimeter Seal

Remove the thrust plate perimeter seal as follows:

1. Remove the air cleaner and charge air cooler ducting from the turbocharger and air intake manifold. Refer to Section 6.2.2.
2. If the upper radiator hose prevents removal of the valve rocker cover, drain coolant into a suitable container until it is below the level of the thermostat housing outlet. Then disconnect the hose from the thermostat housing. Refer to Section 4.4.2.
3. Remove the valve rocker cover. Refer to Section 1.6.1.
4. Remove the five bolts that secure the camshaft drive gear access cover to the gear case cover. See Figure 1-317.

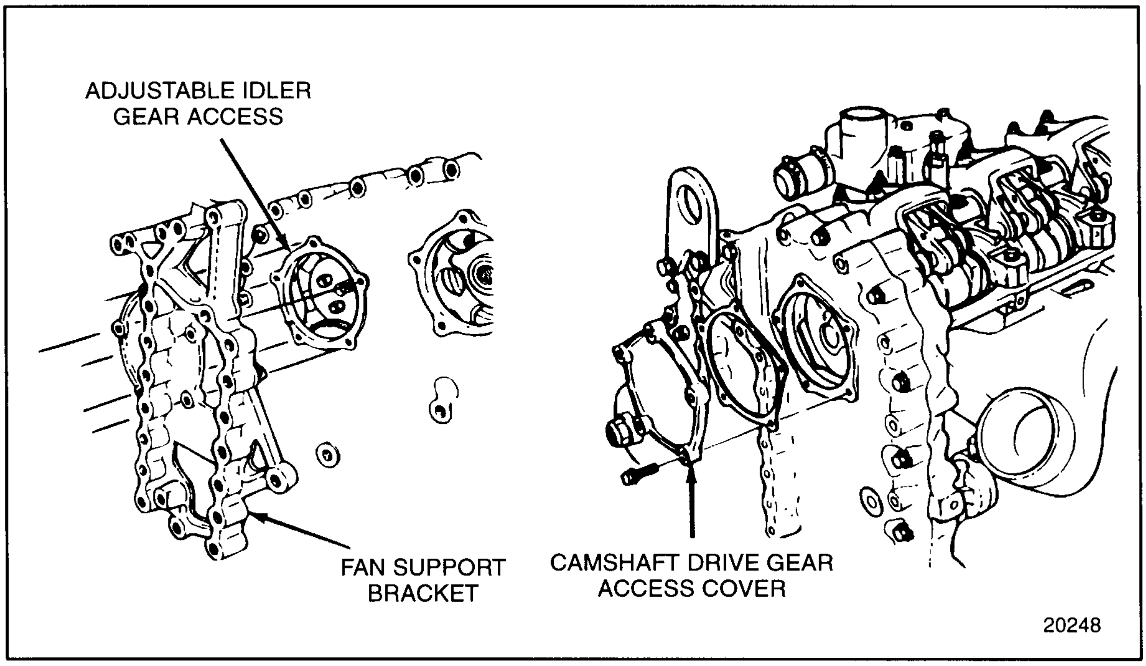


Figure 1-317 Camshaft Drive Gear Access Cover and Adjustable Idler Gear Access

5. Remove Jake Brakes®, if equipped. Refer to Section 1.30.
6. Remove the rocker and rocker shaft assemblies. Refer to Section 1.3.2.
7. Using LPS Contact Cleaner or equivalent residue-free solvent, clean the gear case back/thrust plate area to improve visual access to the seal area. Wipe the area dry with paper towels.

8. Using an appropriate marker, scribe a vertical locator line across the gear case and the back face of the camshaft thrust plate. This will ensure proper positioning of the thrust plate during reassembly. See Figure 1-318.

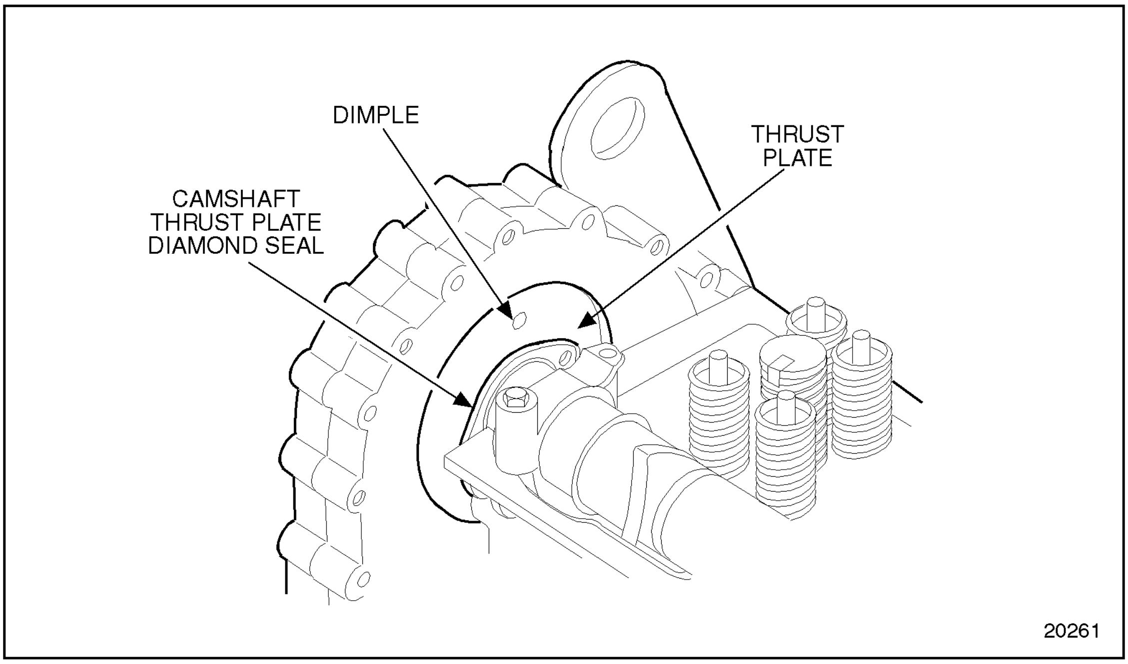


Figure 1-318 Camshaft Thrust Plate Clearance

9. Using the square hole in the middle of the crankshaft pulley, rotate the crankshaft to align the lightening holes in the camshaft drive gear with the camshaft thrust plate mounting bolts, providing access to the bolts.
10. Using an appropriate marker such as a grease pencil, mark the gear teeth. This will ensure proper cam timing during reassembly.

11. Insert the shoe of the camshaft drive gear torque holding tool, J 35652, through a lightening hole of the camshaft drive gear. See Figure 1-319.

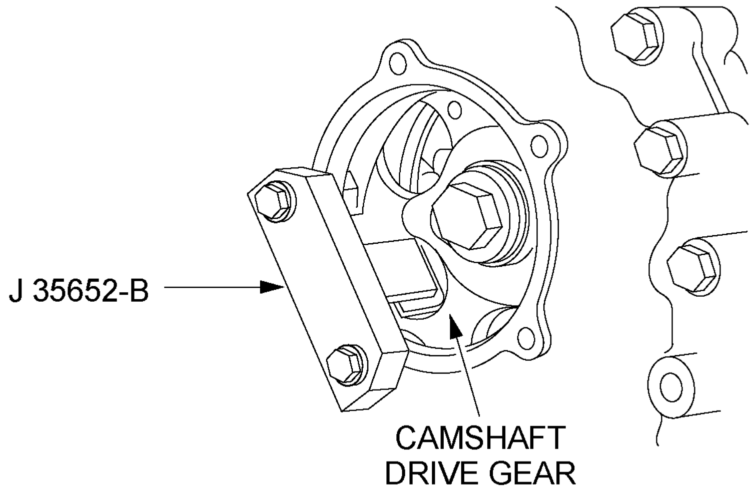


Figure 1-319 Installation of Camshaft Drive Gear Torque Holding Tool

12. Using the 3/4 in. square hole in the center of the crankshaft pulley, bar the engine over slightly so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover.
13. Install the camshaft drive gear torque holding tool, J 35652, to the gear case, engaging one of the lightening holes in the camshaft drive gear. Use two of the access cover bolts to secure the tool to the gear case cover.
14. Using a long 3/4 in. drive breaker bar and a 27 mm impact socket, remove the camshaft drive gear mounting bolt.
15. Remove camshaft drive gear torque holding tool J 35652 from the gear case cover.
16. Insert a clean shop towel into the gear case opening to prevent removed bolts from falling into the gear case.

NOTICE:
Do not allow bolts or the shop towel to fall into the gear case. Failure to remove loose bolts or the shop towel from the gear case may result in severe gear train damage at engine startup.

17. Remove the three (current) or two (former) camshaft thrust plate mounting bolts carefully to avoid dropping them into the gear case.

18. Reverse camshaft gear pilot tool J 35906 by turning it 180 degrees and install it to the camshaft drive gear access opening using three of the access cover bolt holes. The J tool number should face away from the engine and the hub end of the tool should be inside the access hole. Tighten the three tool retaining bolts.
19. Engage the puller bolt in the threads of the camshaft drive gear hub until the bolt is tight. Turn the bolt clockwise, pulling the thrust plate towards the front of the engine approximately 6-7 mm (1/4 in.) until the camshaft hub contacts the J tool and the perimeter seal is clearly accessible. The gap between the end of the camshaft and the thrust plate should be wide enough to permit the perimeter seal to pass through.
20. Remove the number 1 camshaft bearing cap using socket tool J 36003. See Figure 1-320.

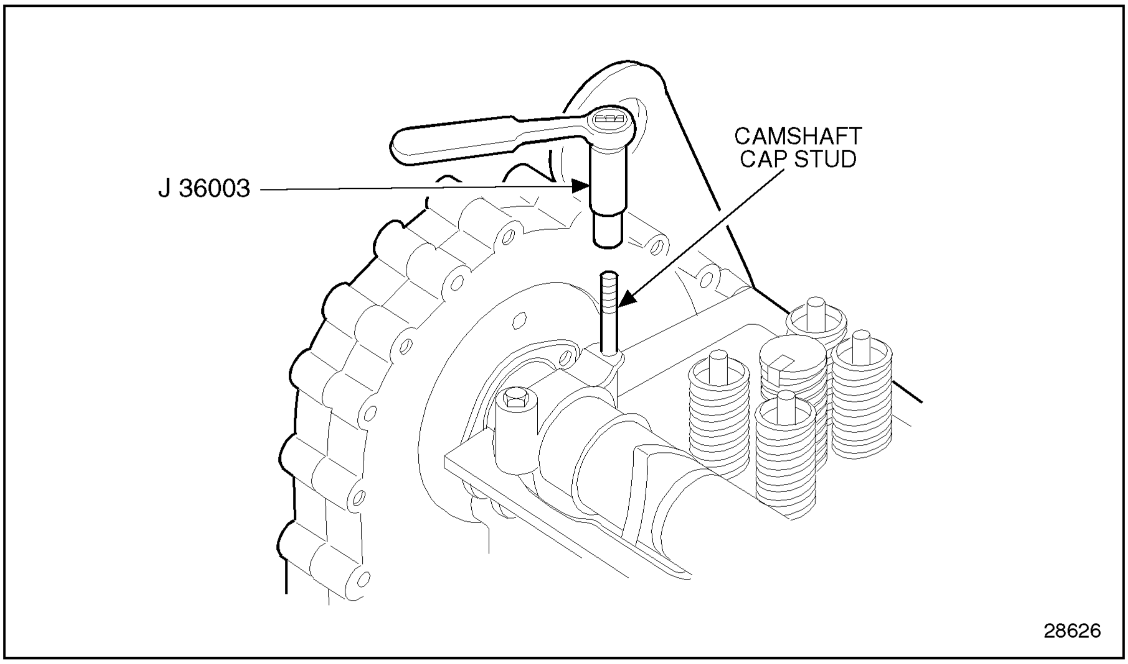


Figure 1-320 Removal of Camshaft Cap Stud

21. Using a flat-bladed screwdriver on the side of one of the camshaft lobes, lever the camshaft back and away from the thrust plate.
22. Using a hook-end pick, J 39227, reach into the thrust plate bore in the gear case, hook the perimeter seal, and pull it off of the thrust plate. Pass the seal between the thrust plate and camshaft and discard. Pull the diamond seal from the thrust plate groove and discard.

1.23.2.1 Inspection of Thrust Plate Perimeter Seal Groove

Inspect the thrust plate perimeter seal groove as follows:

1. Rotate the thrust plate by hand and visually inspect to make sure all seal material is completely out of the seal groove. If necessary, use a work light or flashlight to thoroughly inspect the groove.

2. Wipe the groove clean after inspection.

1.23.3 Installation of Thrust Plate Perimeter Seal

Install the thrust plate perimeter seal as follows:

NOTICE:
Failure to install seals properly, failure to install new, dry (no lubrication) bolts where required, or failure to tighten bolts to the required torque using an accurately calibrated hand torque wrench may result in bolt loosening and loss of clamping load, which may cause severe engine damage.

NOTICE:
Do not use RTV or any other type of sealant on the thrust plate perimeter seal. Application of sealant will prevent proper seal crush (flow), which may result in seal leakage.

1. After passing a new perimeter seal between the thrust plate and cylinder head, carefully install it in the thrust plate groove with the ribbed edges against the sides of the groove and the beveled edge facing out.

NOTE:
The former thrust plate perimeter seal was redesigned to provide greater reliability and less susceptibility to twisting during installation. See Figure 1-321 for design configuration.

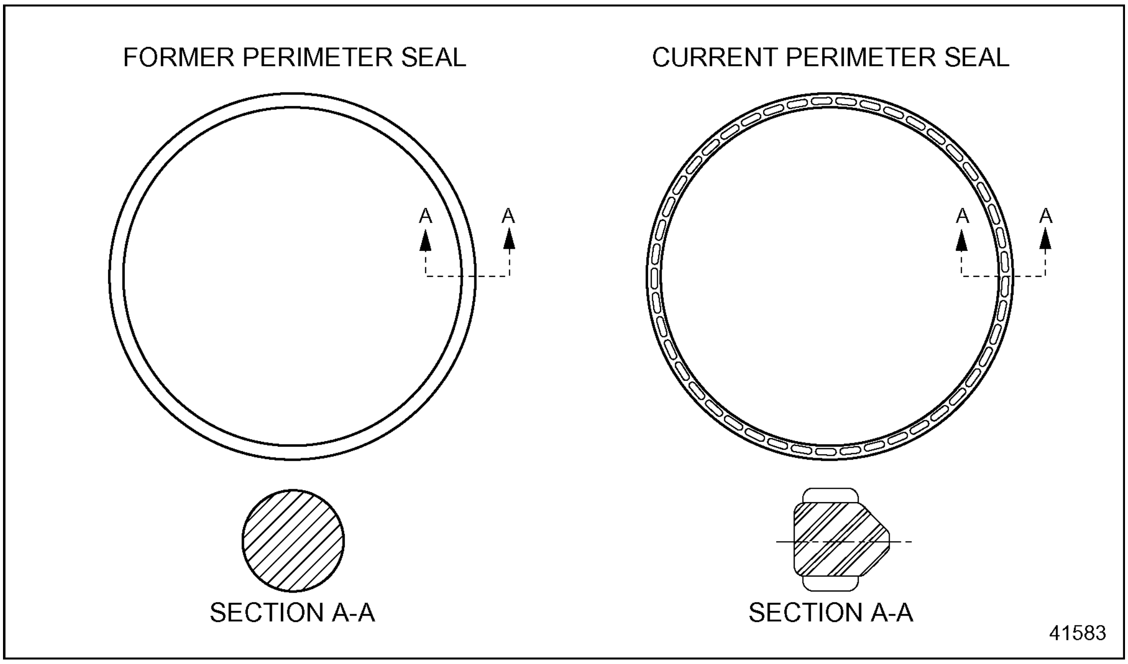


Figure 1-321 Thrust Plate Perimeter Seal

NOTICE:
Failure to properly seat the perimeter seal in the thrust plate groove will result in seal damage. If the seal twists at initial installation or when pushing in the thrust plate, the seal can be cut and damage will result. Any seal damage can result in seal leakage during engine operation.

2. Rotate the thrust plate by hand and feel the seal to ensure it is fully seated in the thrust plate groove. If any ribs are felt on the outside edge, the seal is twisted and must be adjusted. Apply Super Lube®, or an equivalent synthetic oil containing polytetrafluorethylene (PTFE), to the inside bore of the gear case housing and not the seal.

NOTE:
When pushing the thrust plate and seal into the gear case, the seal may appear to twist. Do not be concerned because it is only rolling a little. As long as the seal was not twisted when initially installed, the seal will straighten itself out because its profile is designed to resist rolling.

3. Inspect the thrust plate face seal groove to ensure all seal material is removed. Clean the face seal groove with LPS Contact Cleaner or equivalent residue-free cleaner. *Do not use mineral spirits, since this will leave a residue.* Wipe and dry the area thoroughly with clean paper towels.

4. Loctite 518 gasket eliminator, or equivalent, *must* be applied to the joint face surfaces of the number 1 camshaft bearing cap before installation. For proper adhesion of the anaerobic sealant at the cam cap/cylinder head joints, this area *must* be completely cleaned and all residue removed before new sealant is applied. Clean the cylinder head and bearing cap contact surfaces thoroughly with LPS Contact Cleaner or equivalent residue-free cleaner. Wipe dry with clean paper towels.

NOTICE:
Failure to clean surfaces completely and remove all residue may result in improper gasket eliminator application, which may cause oil seepage during engine operation.

NOTICE:
Do not use RTV or any other type of sealant or spray adhesive on the camshaft diamond seal. Application of sealant or adhesive will prevent proper seal crush (flow), which may result in seal leakage.

NOTE:
Camshaft thrust plate face seals are not reusable. When replacement of a perimeter seal or removal of the camshaft is required, a new camshaft face seal *must* be installed.

5. Install a new seal in the thrust plate, making sure it is securely seated in the thrust plate face seal groove.
6. Apply Loctite 518 gasket eliminator, or equivalent, to the joint surfaces of the number 1 camshaft bearing cap. See Figure 1-322. To help ensure proper adhesion of the gasket

eliminator to the bearing cap, do not apply oil to the number 1 cam bearing or journal before installation of the bearing cap.

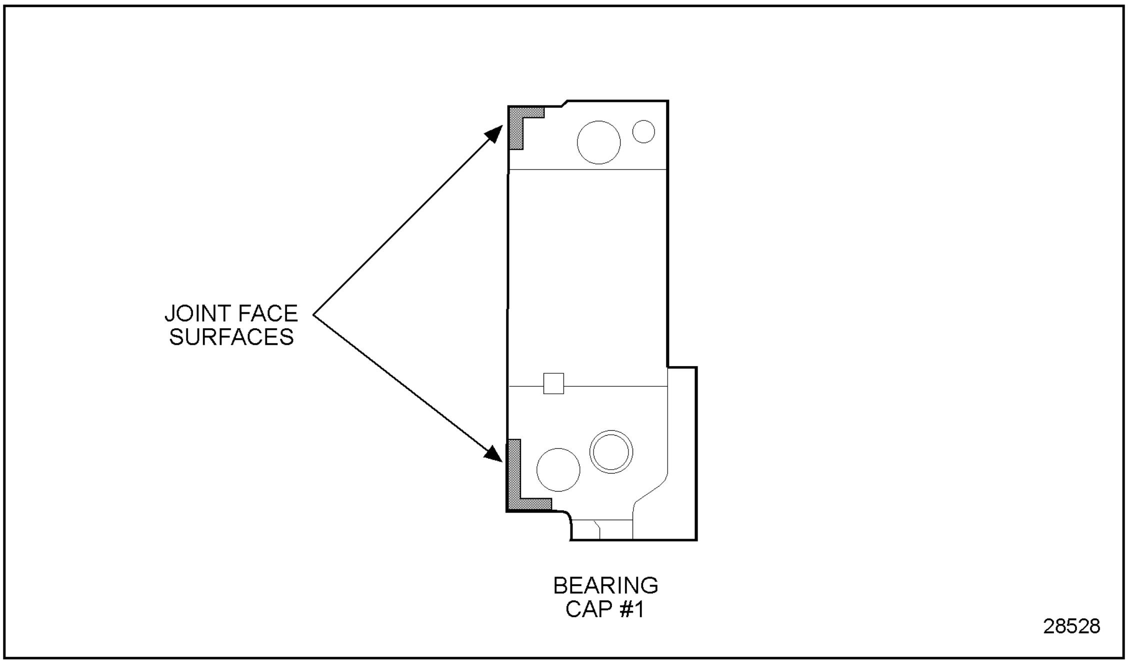
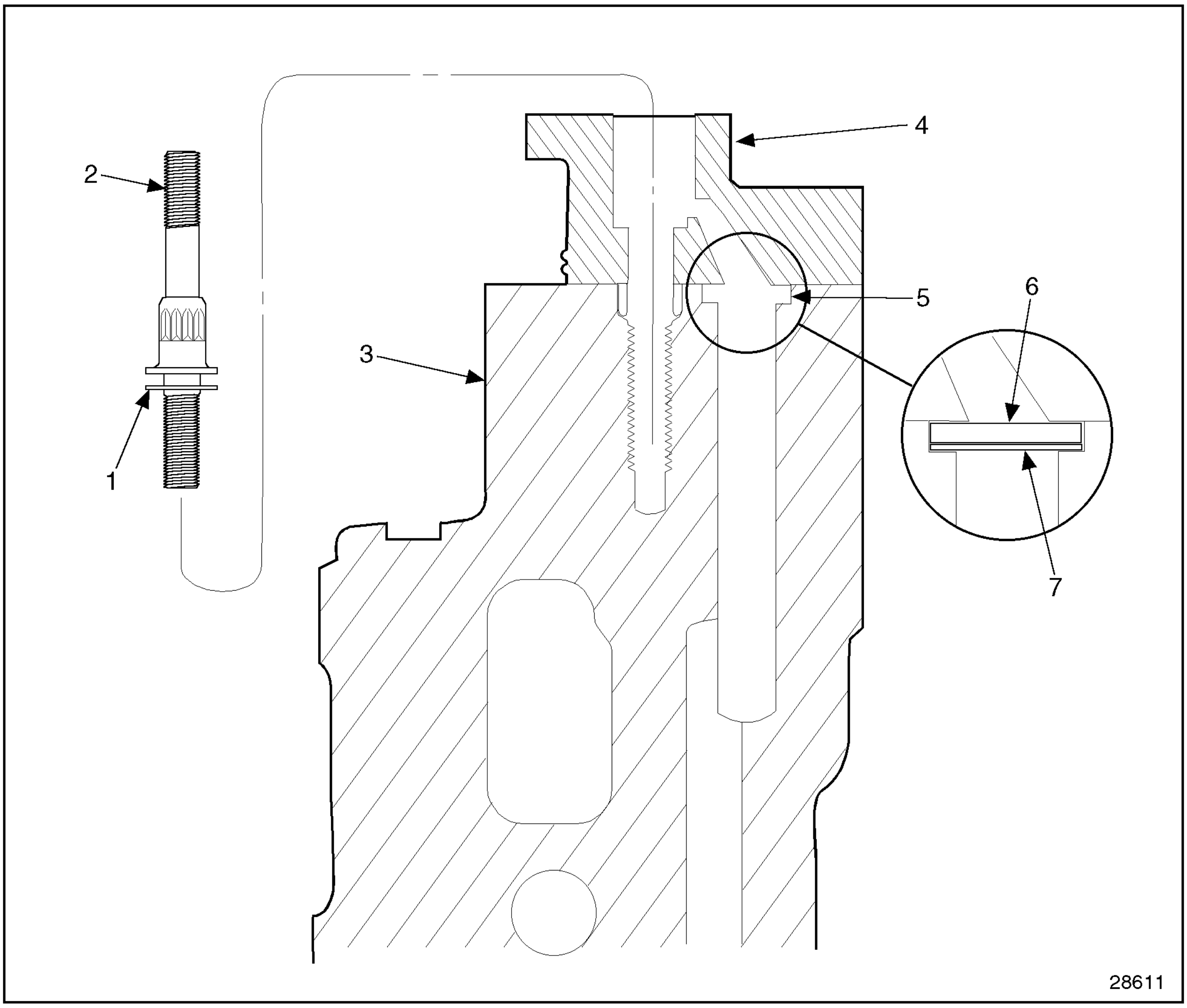


Figure 1-322 Gasket Eliminator Application

7. Install a new square cut seal ring in the cylinder head oil passage seal recess. Then replace the number 1 cam cap. Install a new cap stud seal (part number 23521111) onto the flange of the camshaft cap stud, then thread the stud and the camshaft cam bolt into the

cylinder head. See Figure 1-323. Alternating back and forth, torque cap stud and bolt progressively to 101 - 110 N·m (74.5 - 81 lb·ft).



1. Bearing Cap Stud Seal
2. Bearing Cap Stud
3. Cylinder Head
4. Camshaft Bearing Cap
5. Bearing Cap Oil Passage Seal Recess
6. Oil Passage Seal Ring
7. Shim (if required)

Figure 1-323 Cross-Sectional View of Series 50 Cylinder Head and Camshaft Bearing Cap

8. Loosen the large center bolt of tool J 35906 until it almost disengages from the camshaft hub.
9. Align the dowel on the camshaft with the cam hub. Push rearward on the tool J 35906 bolt while centering the thrust plate in the gear case bore and observing the alignment marks made previously on the thrust plate and gear case.

10. Install a metric bolt and washer in a gear case cover bolt hole next to the access hole.

NOTE:
To ensure proper camshaft-to thrust plate alignment, the scribe marks on the gear case and thrust plate *must* be aligned before the thrust plate is reinstalled in the gear case.

11. Carefully align the scribe marks on the thrust plate and gear case. Then, using a flat-bladed screwdriver or pry bar placed on the bolt washer and working from side to side, lever the thrust plate back toward the camshaft. With the thrust plate securely installed in the gear case, remove the metric bolt and washer carefully to avoid dropping them into the gear case.

NOTICE:
Improper installation of the camshaft thrust plate bolts may result in thrust plate bolt stretching or breakage. Bolt stretching may result in an inaccurate torque. Bolt breakage may cause severe gear train damage.

12. Remove tool J 35906. Carefully install new, dry (no lubrication) thrust plate mounting bolts through the thrust plate and into the cylinder head and No. 1 camshaft bearing cap. Using a 13 mm socket and an accurately calibrated hand torque wrench, torque the bolts alternately and progressively to 30 - 38 N·m (22 - 28 lb-ft). To avoid excessive tightening and possible bolt stretching, do not use an air wrench, since this may not provide an accurate torque.
13. Coat the threads and underside of the head of the camshaft drive gear-to-camshaft bolt with International Compound #2®. Check the marks previously made on the gear teeth to ensure proper cam gear timing. Install the bolt to the camshaft, finger tighten.

NOTICE:
Only tool J 35652 should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear-to-camshaft bolt to prevent component damage.

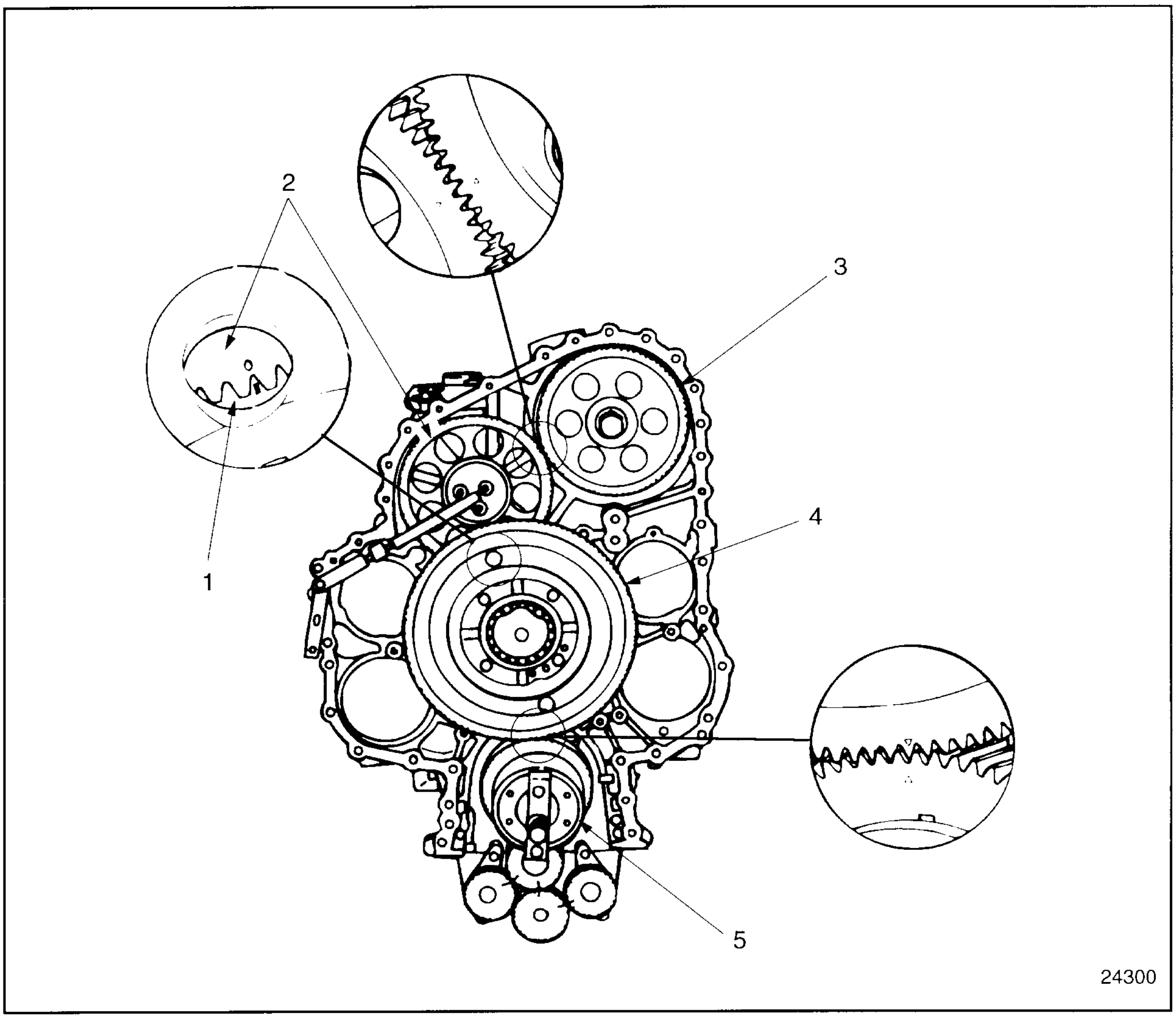
NOTE:
The camshaft should be held in place while starting the camshaft drive gear-to-camshaft bolt, to prevent disengaging the camshaft dowel from the thrust plate hub, requiring disassembly and timing of the camshaft.

14. Insert tool J 35652 through a lightening hole of the camshaft drive gear.
15. Using the 3/4 in. square hole in the center of the crankshaft pulley, bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover.
16. Install two of the access cover bolts to secure the tool to the gear case cover.

17. Using a 27 mm impact socket and suitable torque wrench, tighten the camshaft drive gear-to-camshaft bolt to 75 N·m (55 lb·ft) torque. Then turn the bolts clockwise 90 degrees to achieve the required torque.
18. Remove camshaft drive gear torque holding tool J 35652.
19. Install the access cover plate to the gear case cover. Refer to Section 1.10.3.
20. Install the rocker and rocker shaft assemblies. Refer to Section 1.3.3.
21. Install the Jake Brakes, if equipped. Refer to Section 1.30.5.
22. Install the valve rocker cover. Refer to Section 1.6.7 and refer to Section 1.6.8.
23. Install or reconnect any other components that were removed or disconnected for this procedure.

1.24 CAMSHAFT DRIVE GEAR

The camshaft drive gear, located at the front of the engine, under the gear case cover, is driven by the crankshaft through a series of intermediate gears. See Figure 1-324.



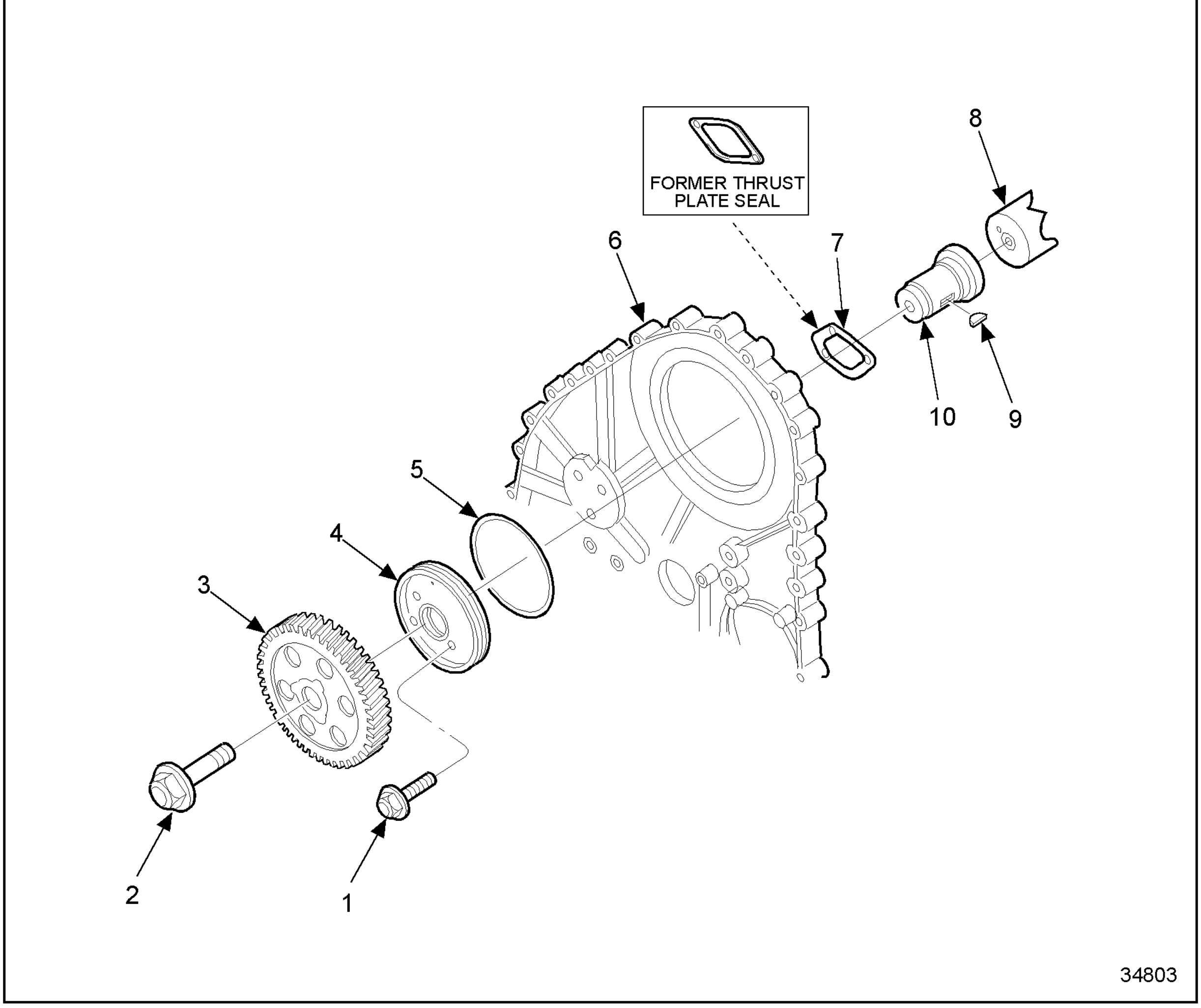
1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

Figure 1-324 Engine Gear Train and Timing Marks

The gear train for the crankshaft drive consists of a crankshaft timing gear, mounted to the end of the crankshaft, meshing with a bull gear. To the rear of the bull gear is the camshaft idler gear, which is mounted on the same hub and rotates at the same speed as the bull gear. The camshaft idler gear meshes with an adjustable idler gear, which is mounted on a separate hub. The adjustable idler gear in turn meshes with the camshaft drive gear, which is mounted on the camshaft drive gear hub. The gears are designed so that the camshaft is driven at half crankshaft speed.

Since the camshaft must be timed exactly to the crankshaft, a series of timing marks are stamped or etched on the gear faces of these gears so that they may be installed in correct relationship to each other. Refer to Section 1.21.2.1.

The camshaft drive gear is keyed and pressed onto a hub located in the thrust plate assembly at the end of the camshaft. The camshaft drive gear and hub are retained to the end of the camshaft by the camshaft drive gear retaining bolt which goes through the camshaft drive gear and the hub, and is threaded into the end of the camshaft. See Figure 1-325.



1. Bolt, Thrust Plate Retaining (2) or (3)	6. Gear Case
2. Bolt, Camshaft Hub Retaining	7. Seal, Thrust Plate
3. Drive Gear. Camshaft	8. Camshaft
4. Thrust Plate, Camshaft	9. Key
5. O-ring	10. Hub

Figure 1-325 Camshaft Drive Gear and Related Parts

The camshaft is indexed to the hub by a dowel. The camshaft drive gear hub rides in a camshaft thrust plate, which is retained by three (current) or two (former) bolts. One of these bolts screws into the cylinder head, while the other bolt screws into the No. one camshaft bearing cap.

The camshaft thrust plate is sealed to the gear case by an O-ring which fits into a groove machined in the outer diameter of the thrust plate. A diamond shaped rubber seal that fits into a groove machined in the rear camshaft thrust plate face, seals the camshaft thrust plate to the cylinder head and No. one camshaft cap. The dimple in the thrust plate must be installed at the 12 o'clock position to allow alignment of the thrust plate bolt holes with those in the cylinder head and No. 1 camshaft cap. See Figure 1-326.

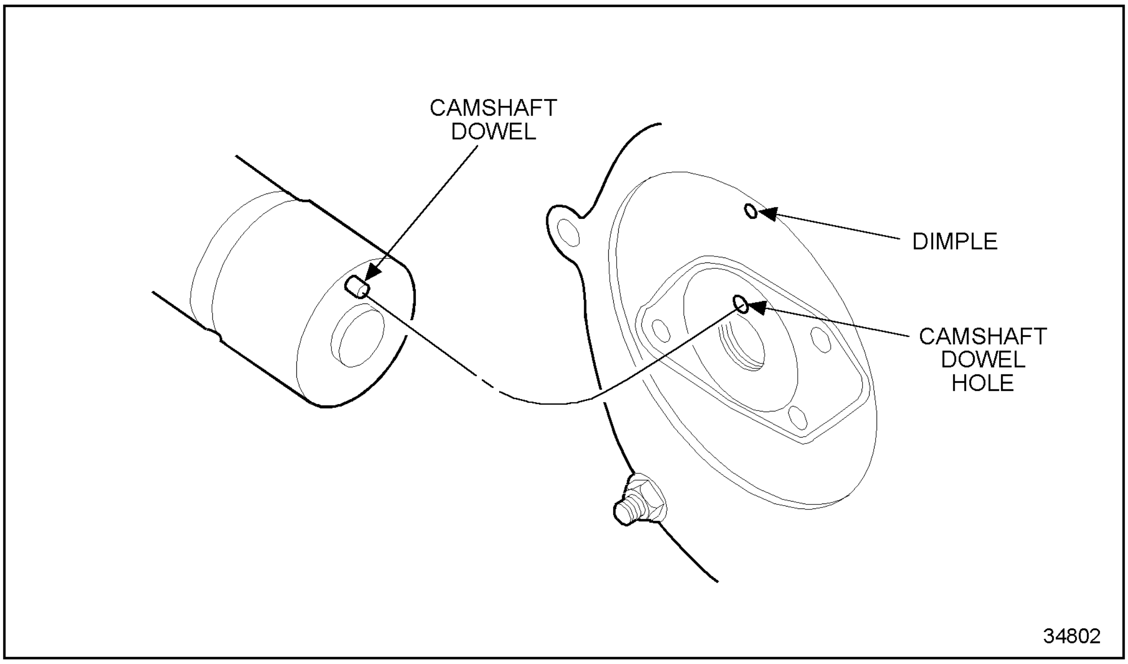


Figure 1-326 Camshaft Thrust Plate and Dowel Pin Location

The camshaft thrust plate can be moved horizontally in the gear case, to allow camshaft and cylinder head removal without damaging the thrust plate seal or removing the gear case cover. The camshaft drive gear will stay in mesh with its mating gear, and may be returned to its original position without retiming the gears.

1.24.1 Repair or Replacement of Camshaft Drive Gear

To determine if repair or replacement of the camshaft drive gear is necessary, preform the following procedure. See Figure 1-327.

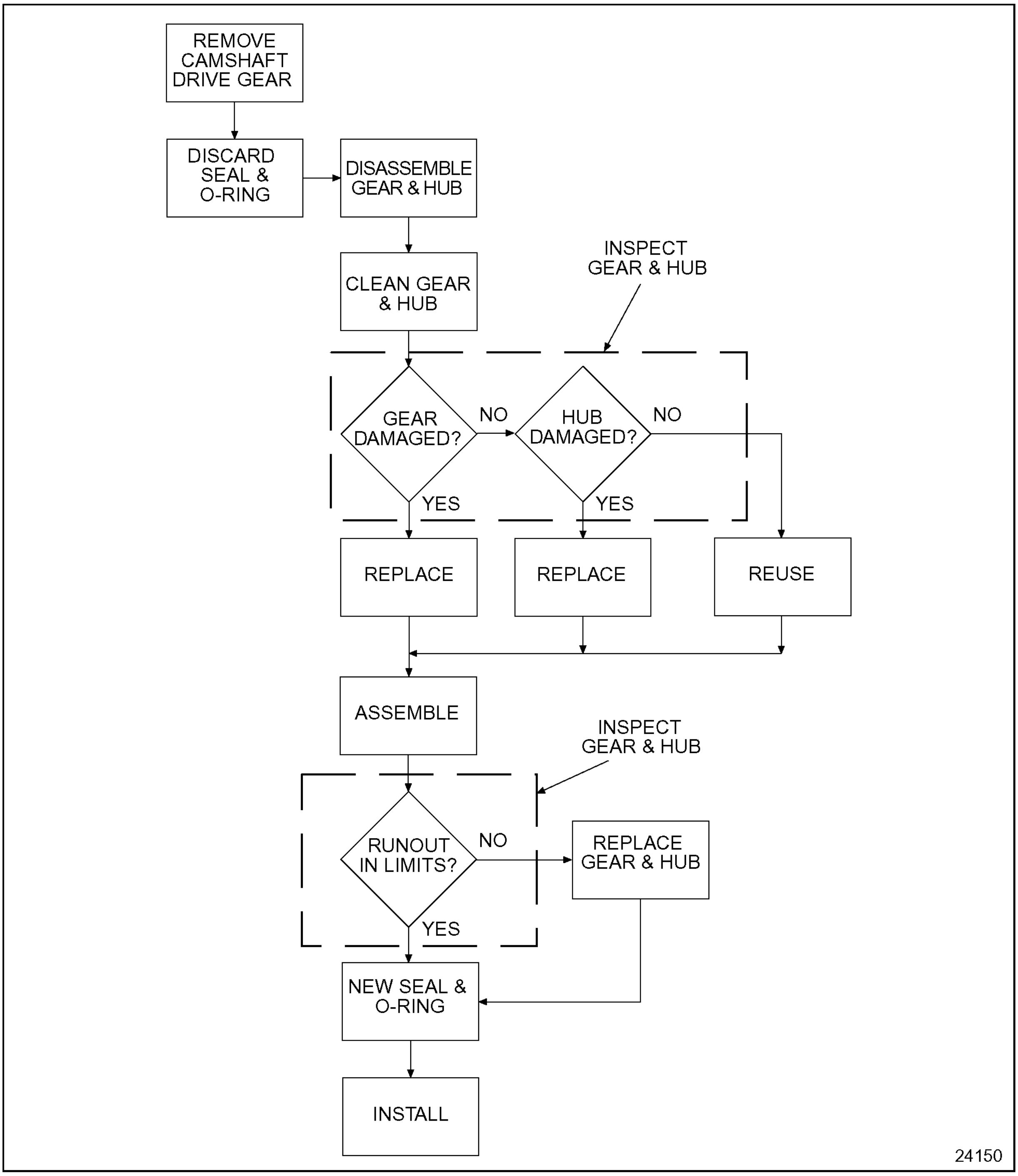


Figure 1-327 Flowchart for Repair or Replacement of Camshaft Drive Gear

1.24.2 Removal of Camshaft Drive Gear

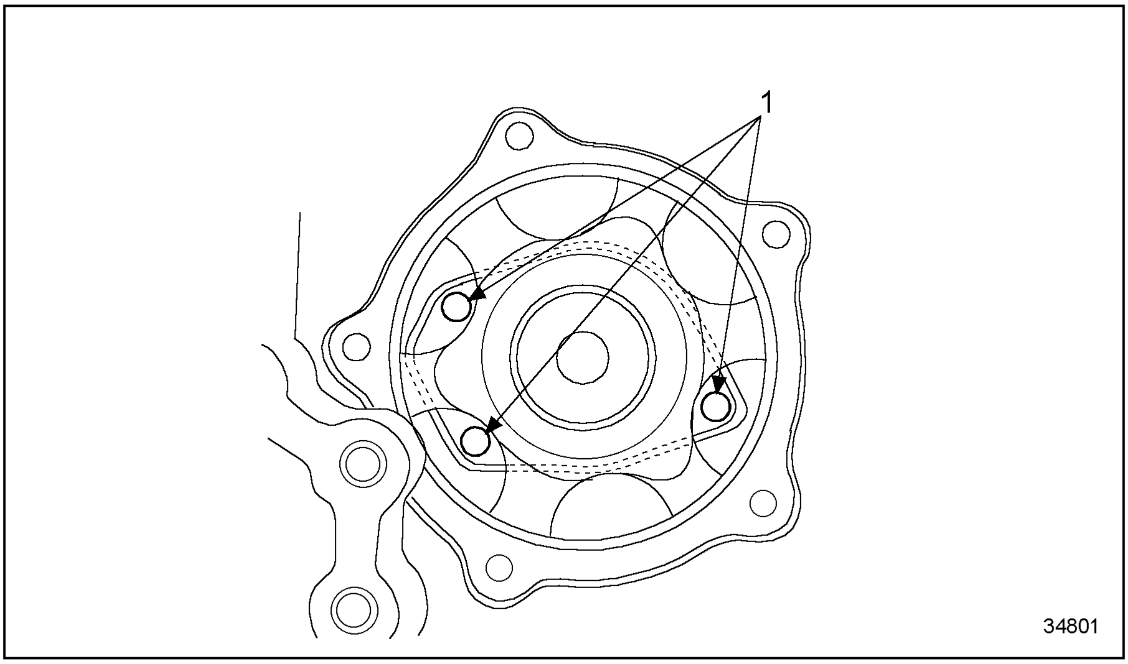
Remove the camshaft drive gear as follows:

1. Remove the engine rocker cover. Refer to Section 1.6.2.

2. Remove the camshaft drive gear access cover, fan bracket and camshaft retaining bolt. Refer to Section 1.22.2.

NOTICE:
Use care when removing the camshaft thrust plate retaining bolts to prevent their accidental dropping into the gear case and causing engine damage.

3. Working through the access holes in the camshaft drive gear, remove the three (current) or two (former) bolts that retain the camshaft thrust plate to the cylinder head and No. 1 camshaft bearing cap. See Figure 1-328.



1. Camshaft Thrust Plate Mounting Bolt Locations

Figure 1-328 Camshaft Thrust Plate Retaining Bolts

4. Using the Camshaft Gear Pilot Tool, J 35906, pull the cam gear thrust plate assembly forward as far as possible to separate the assembly from the camshaft.
5. Remove the gear case cover. Refer to Section 1.10.2.

6. Using a fiber mallet or plastic hammer, tap the rear face of the camshaft thrust plate forward until it is free of the gear case. See Figure 1-329.

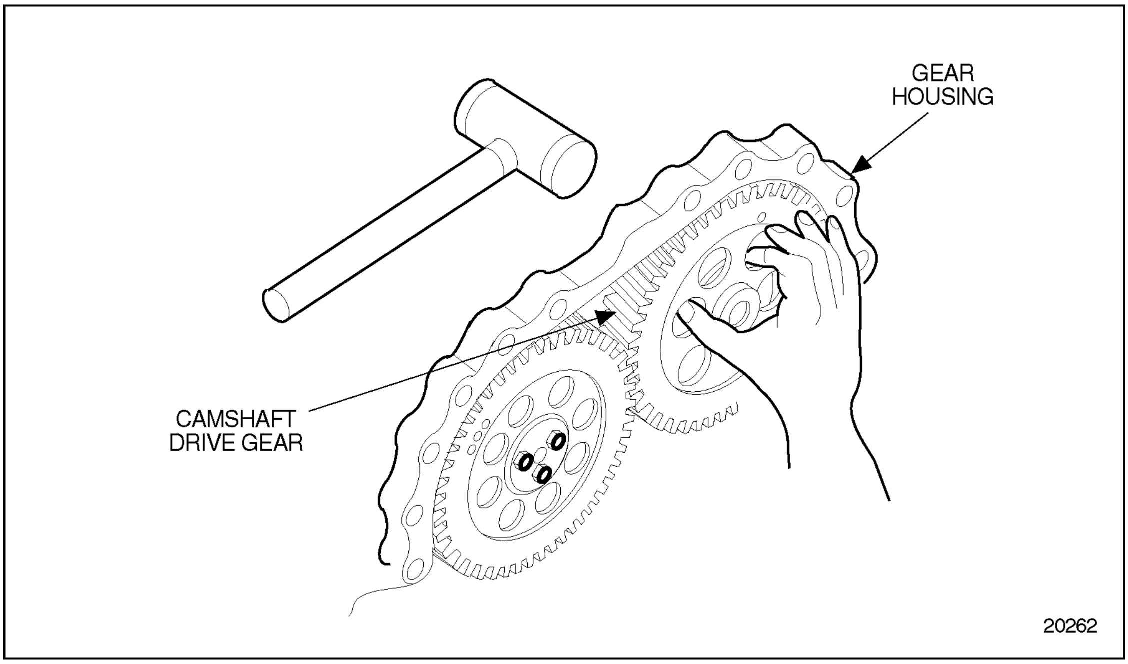


Figure 1-329 Removing Camshaft Thrust Plate Assembly

7. Remove the camshaft thrust plate, hub, and camshaft drive gear as an assembly. See Figure 1-330.

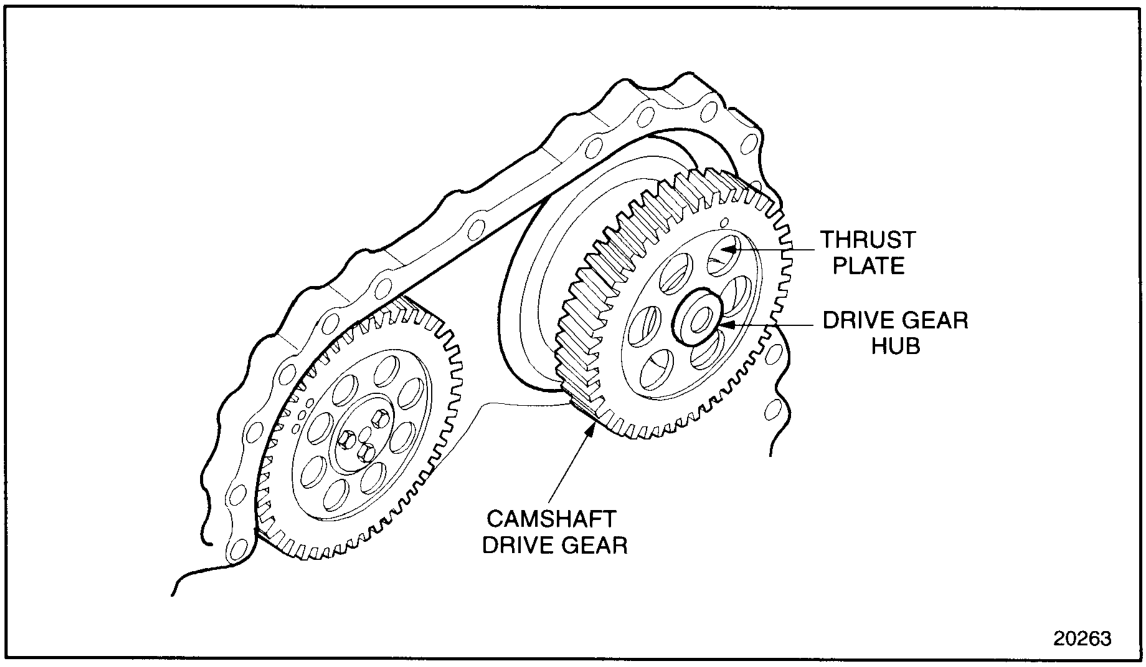


Figure 1-330 Camshaft Thrust Plate Assembly

8. Support the camshaft drive gear, with thrust plate facing down, on blocks.

9. Press the hub out of the camshaft drive gear until the hub separates from the camshaft thrust plate. See Figure 1-331.

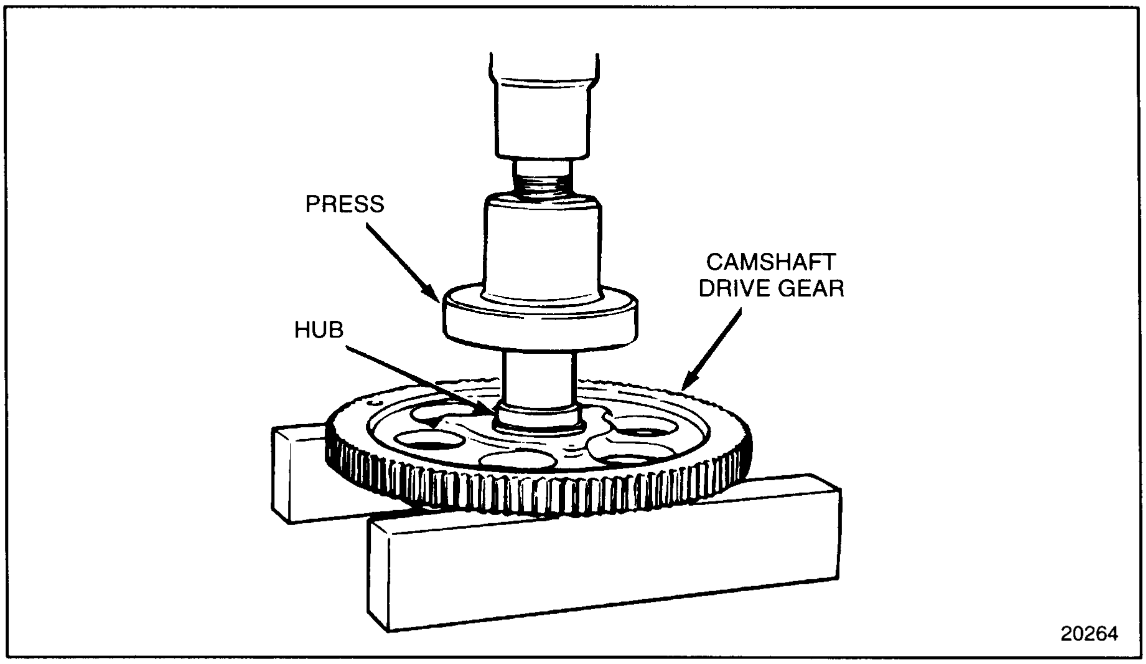


Figure 1-331 Camshaft Hub Removal

10. Remove the O-ring and seal from grooves in the camshaft thrust plate. Discard O-ring and seal.

1.24.2.1 Inspection of Camshaft Drive Gear

Inspect camshaft drive gear as follows:

1. Clean all parts with fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

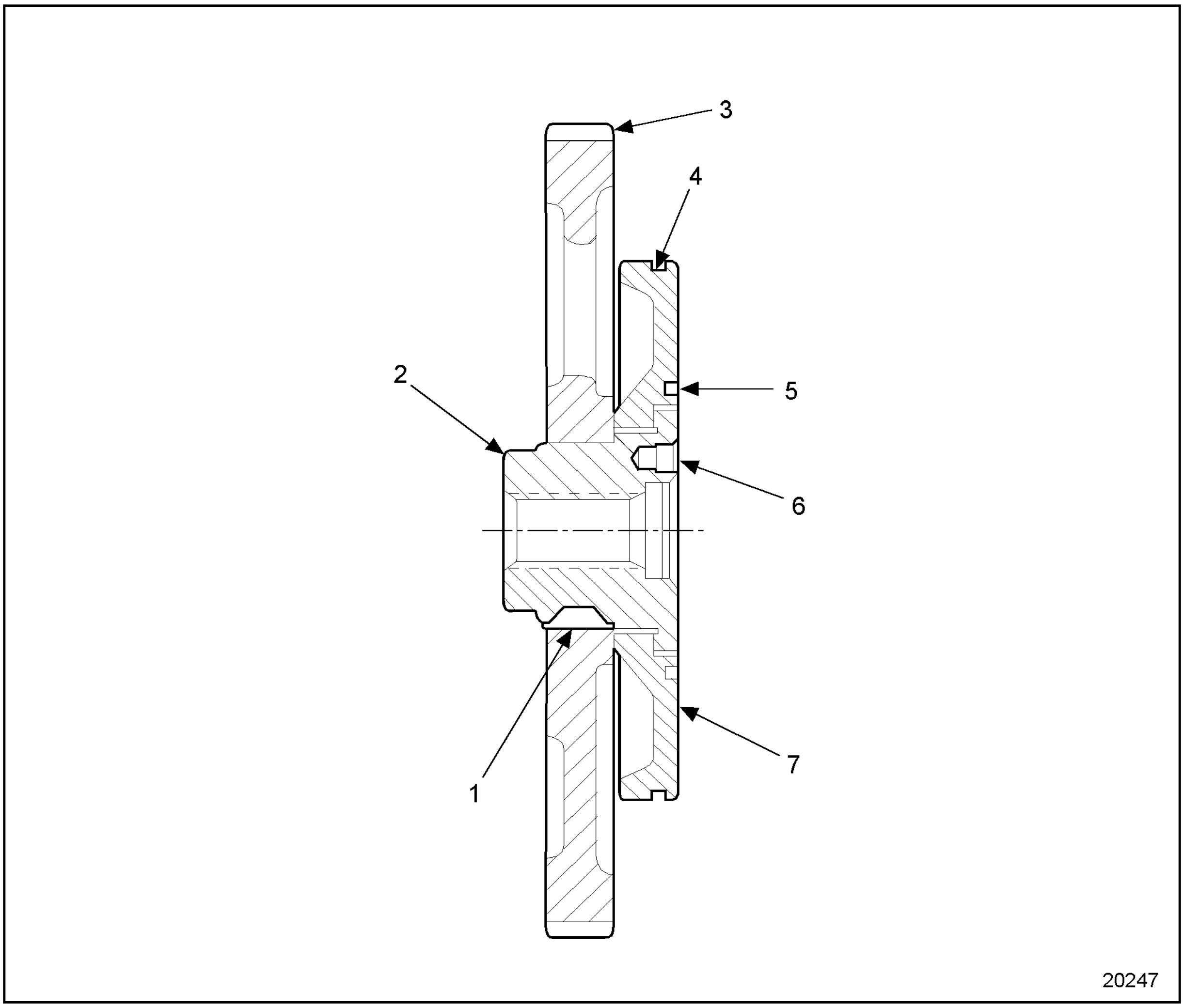
2. Dry them with compressed air.
3. Examine the camshaft drive gear teeth for scoring, pitting, excessive wear and cracking, peening of the Woodruff key slot.
4. If camshaft drive gear is damaged, replace drive gear.
5. Inspect the camshaft drive gear hub for scoring, pitting, galling or cracking, peening of the Woodruff key slot.

6. If damaged, replace drive gear hub.

1.24.3 Installation of Camshaft Drive Gear

Install the camshaft drive gear, hub and thrust plate as follows:

1. Coat the contact surfaces of the hub and camshaft thrust plate with clean engine oil. See Figure 1-332.



1. Woodruff Key
2. Hub, Camshaft Drive Gear
3. Drive Gear, Camshaft
4. Groove, O-ring
5. Groove, Seal
6. Dowel Hole, Camshaft
7. Thrust Plate, Camshaft

Figure 1-332 Cross Section of Camshaft Drive and Related Parts

2. Install the hub to the camshaft thrust plate.

3. Install the key into the keyway on the hub.
4. Apply a thin film of Lubriplate to the bore of the camshaft gear.
5. Support the hub from the engine side.

NOTICE:
A minimum force of 20 kN (4500 lb) must be obtained when pressing the gear on the hub which can distort camshaft gear if applied off center. Only apply force to the inner hub of the gear when pressing.

6. Align the keyway in the camshaft drive gear with the key in the hub and press the gear, timing markup, onto the hub until it is firmly seated against the shoulder.

1.24.3.1 Test of Camshaft Drive Gear Assembly Run-out

Measure the camshaft drive gear assembly run-out as follows:

1. While supporting the camshaft thrust plate on blocks, position the camshaft drive gear assembly with the engine side facing down.
2. Assemble a dial indicator and magnetic base with the indicator stem rests on the face of the camshaft drive gear, just inboard of the drive gear teeth. Zero the dial indicator.
3. Rotate the drive gear two full rotations while **reading the total indicated run-out**.

NOTE:
The total amount the dial indicator needle moves to the left and right of zero, added together, gives the total indicated run-out Total Indicator Reading (TIR).

[a] Maximum allowable TIR is 0.114 mm (0.0045 in.).

[b] If TIR exceeds limit, replace parts.

1.24.4 Installation of Camshaft Drive Gear

Continue installing camshaft drive gear assembly as follows:

NOTICE:
Failure to install seals properly, failure to install new, dry (no lubrication) bolts where required, or failure to tighten bolts to the required torque using an accurately calibrated hand torque wrench may result in bolt loosening and loss of clamping load, which may cause severe engine damage.

NOTICE:
Do not use RTV or any other type of sealant on the thrust plate perimeter seal. Application of sealant will prevent proper seal crush (flow), which may result in seal leakage.

1. Coat the camshaft thrust plate O-ring with clean engine oil.
2. Install it into its groove in the camshaft thrust plate.
3. Install diamond seal into its groove on the engine side of the thrust plate.The former two-bolt thrust plate oil seal design was redesigned to provide superior oil sealing characteristics. See Figure 1-333 for design configuration. The current thrust plate oil seal uses a three bolt design, as of serial number 4R21236.

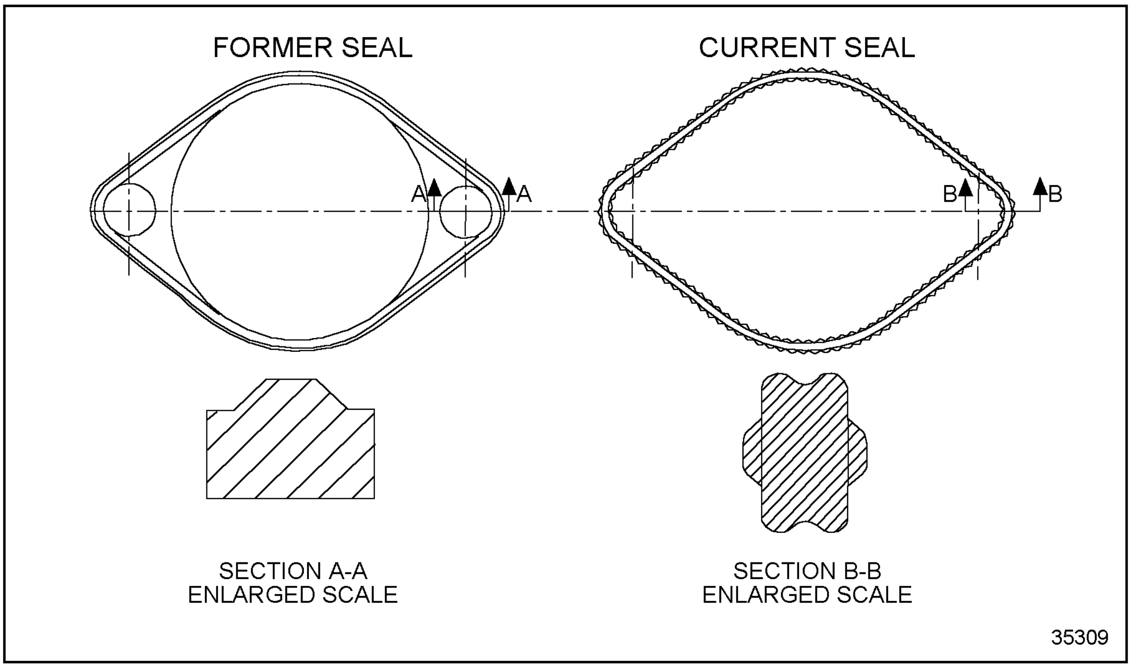


Figure 1-333 Camshaft Thrust Plate Oil Seal

4. Be sure the O-ring sealing surface of the gear case is clean and free of burrs.

5. Install the hub and camshaft thrust plate to the opening in the gear case. The depression in the rear face of the camshaft thrust plate must be positioned at 12 o'clock, see Figure 1-326, to align the retaining bolts in the thrust plate with those in the head and No. 1 cam cap.
6. Using a fiber mallet or plastic hammer, tap the camshaft drive gear at 90° intervals toward the engine, until the thrust plate bolts can be started in the cylinder head and No. 1 camshaft cap.

NOTICE:
Ensure camshaft dowel hole in camshaft drive hub is aligned with camshaft dowel prior to tightening thrust plate bolts. A misaligned hub can cause damage to the camshaft and thrust plate components

NOTICE:
Use care when installing the camshaft thrust plate retain bolts to prevent accidentally dropping them into the gear case and causing damage to gear train.

7. Using a 13 mm socket and ratchet, tighten the thrust plate bolts alternately and evenly to draw the thrust plate straight into the gear case. Torque the bolts to 30-38 N·m (22-28 lb·ft).
8. Install gear case cover. Refer to Section 1.10.3.

NOTICE:
Always hold the camshaft drive gear stationary using camshaft drive gear retaining tool, J 35652-A part of J 35652, to prevent component damage, while loosening or tightening the camshaft drive gear-to-camshaft bolt.

9. Once the gear case cover has been installed and secured, install the camshaft drive gear retaining tool, J 35652-A part of J 35652.

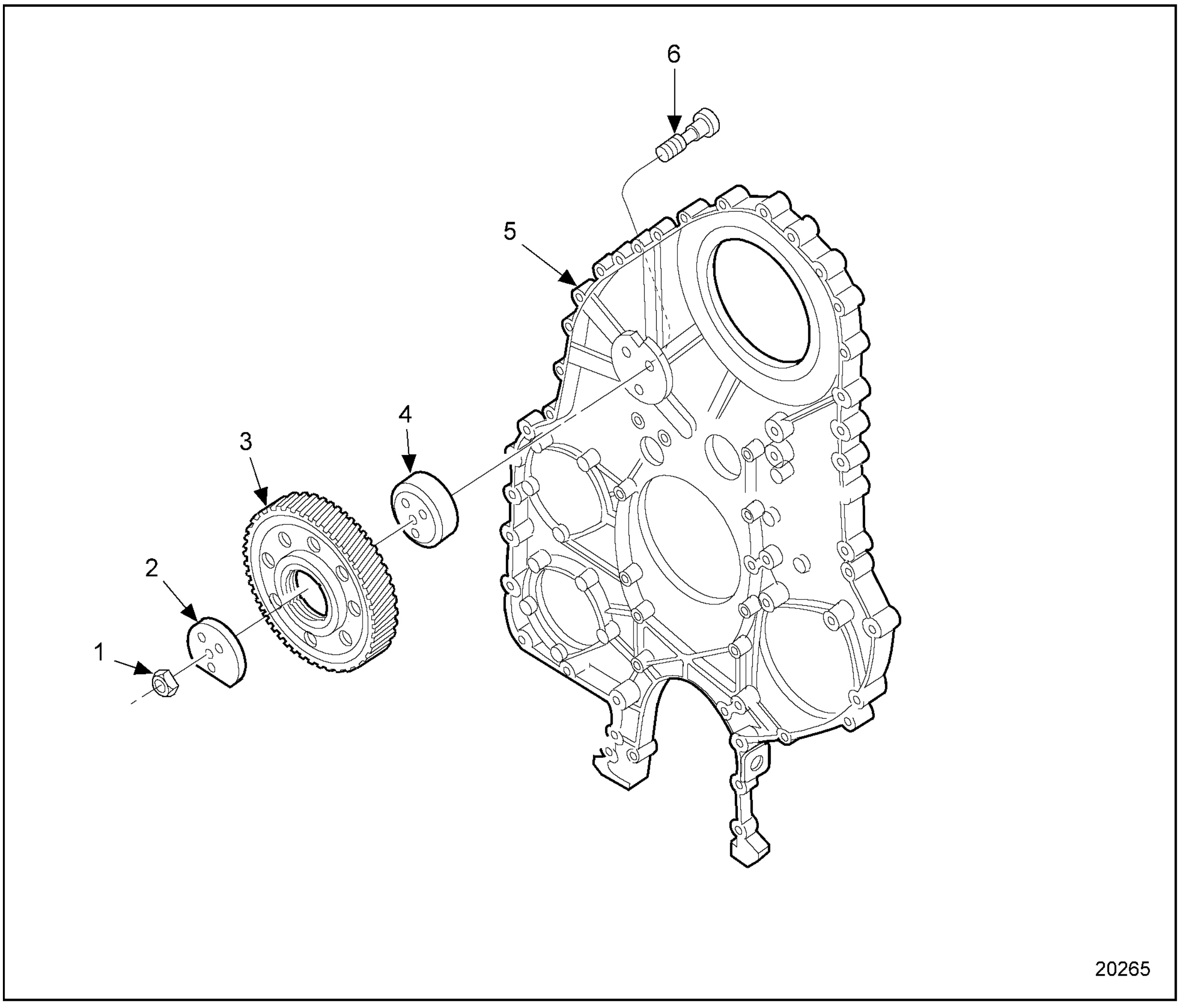
NOTE:
Before installing the fan support bracket and camshaft drive gear access cover, it will be necessary to install and tighten the camshaft drive gear retaining bolt, and to measure and adjust the adjustable gear-to-camshaft drive gear lash.

10. Install and torque the camshaft drive gear retaining bolt to 425 N·m (310 lb·ft).
11. Check the gear train timing and adjustable idler gear-to-camshaft drive gear lash. Refer to Section 1.21.2.1.
12. Install the camshaft drive gear access cover and fan bracket. Refer to Section 1.22.5.
13. Install any components that were removed for access to the gear case cover.
14. Check the lubricating oil. Refer to Section 13.5.1.

15. Check the coolant level. Refer to Section 13.5.4.

1.25 ADJUSTABLE IDLER GEAR ASSEMBLY

The adjustable idler gear is a straight-cut gear, mounted on a bushing pressed into the center of the gear, which in turn is supported on a stationary hub. The hub is secured to the gear case by a retaining plate, three studs, and locknuts. The studs are pressed into the gear case from the rear, and the flanged locknuts are installed after the gear, hub and hub retaining plate are installed. See Figure 1-334.



1. Locknut, Adjustable Idler Gear
2. Retaining Plate, Adjustable Idler Gear Hub
3. Gear Assembly, Adjustable Idler
4. Idler Hub, Adjustable
5. Gear Case
6. Stud, Adjustable Idler Gear (3)

Figure 1-334 Adjustable Idler Gear and Related Parts

The adjustable idler gear is pressure lubricated by engine oil fed to a gallery drilled into the gear case. This gallery indexes with the cylinder block oil gallery. See Figure 1-335.

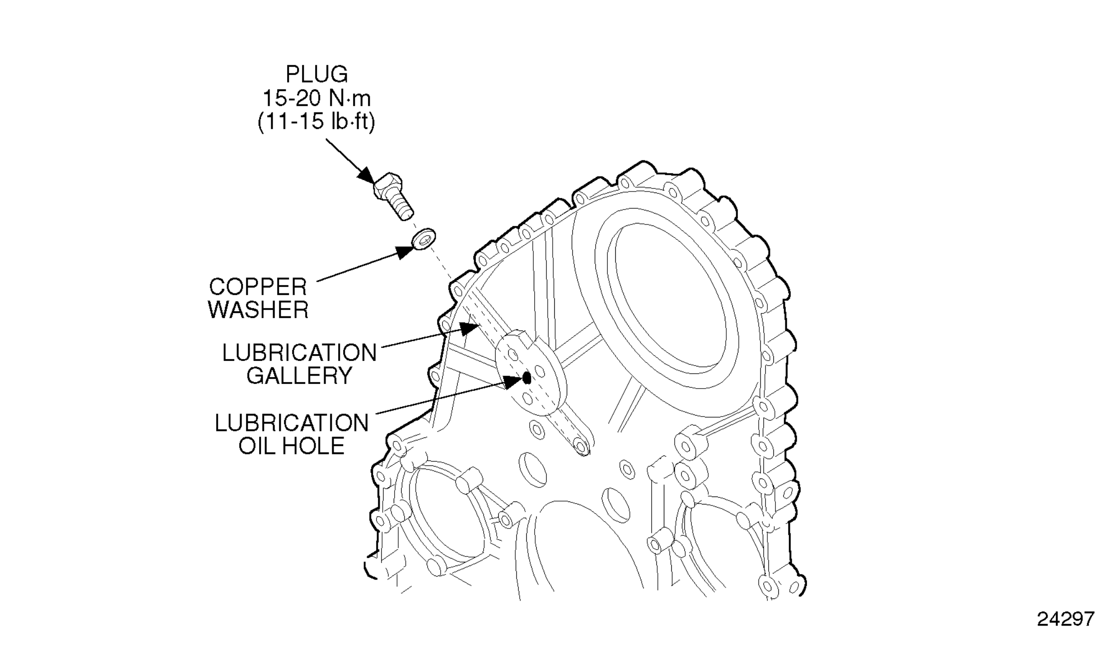


Figure 1-335 Adjustable Idler Gear Lubrication

The adjustable idler gear bushing has a series of machined grooves in the contact surface, for oil retention. The bushing is not serviced separately. If the bushing becomes worn or damaged, the gear and bushing must be replaced as an assembly.

There are three bolt holes in the hub where it is inserted over the studs. See Figure 1-336.

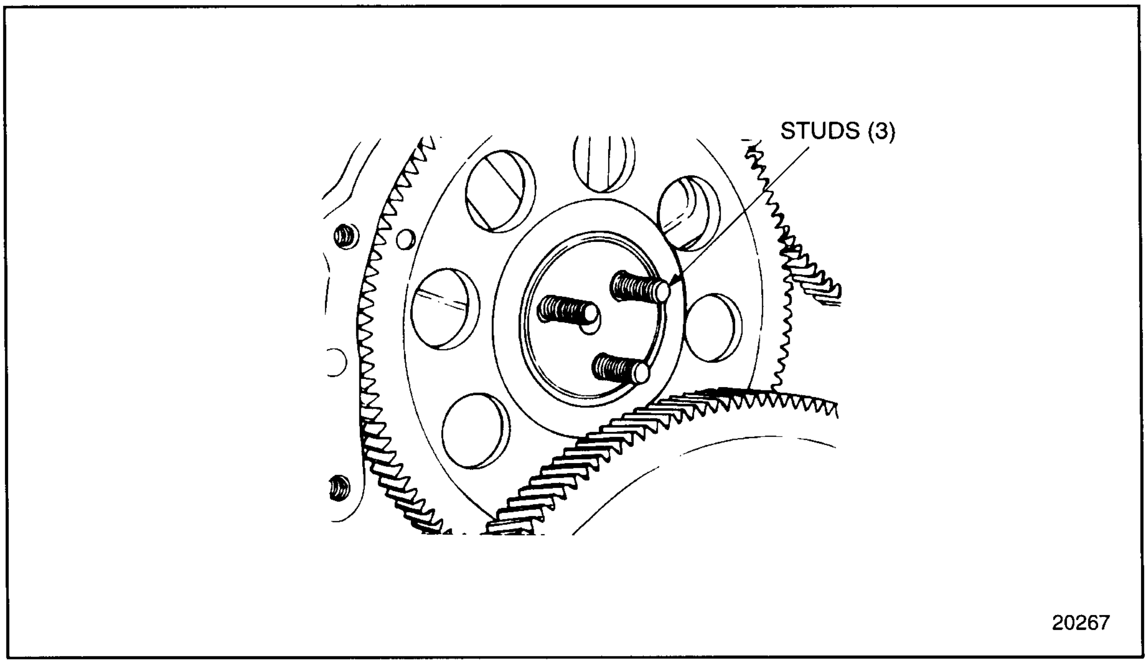


Figure 1-336 Adjustable Idler Gear and Hub Mounting

The top two holes are elongated, to allow the idler gear and hub assembly to be moved in relationship to the camshaft drive gear. The bottom stud hole is not elongated, and is a close fit to the stud. This allows the adjustable idler gear to pivot on the bottom stud, so the adjustable idler gear to camshaft drive gear lash can be adjusted without changing the clearance between the adjustable idler gear and camshaft idler gear. The adjustable idler gear retaining plate has a flat on the bottom to clear the bull gear for removal and installation. See Figure 1-337.

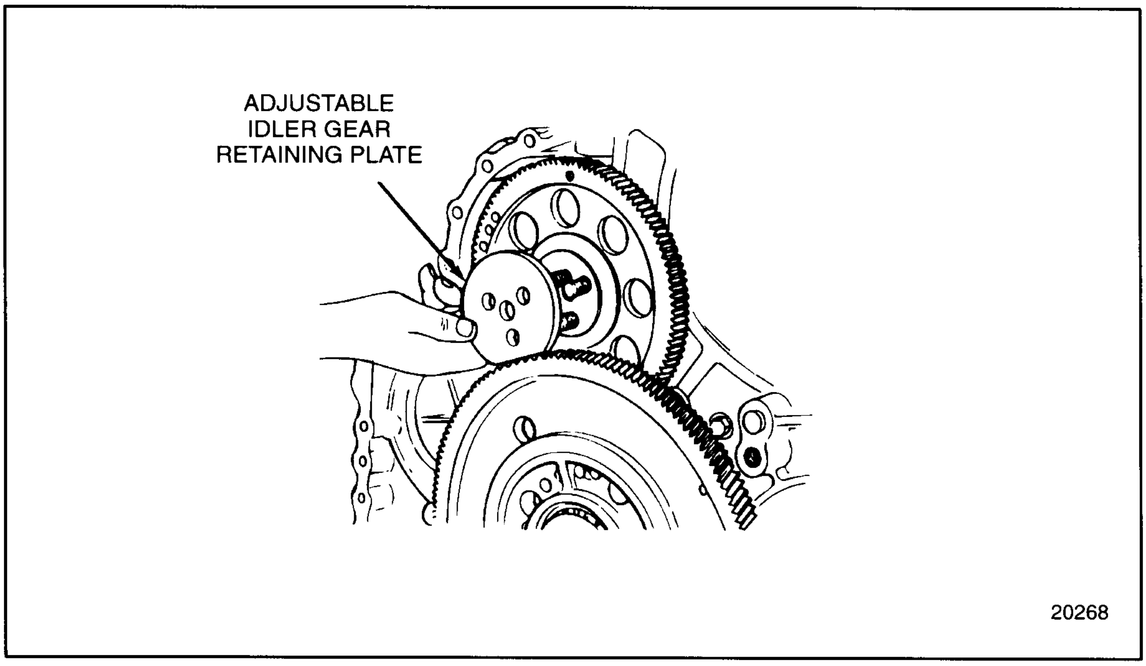


Figure 1-337 Adjustable Idler Gear Retaining Plate

1.25.1 Repair or Replacement of Adjustable Idler Gear Assembly

To determine if repair or replacement of the adjustable idler gear assembly is necessary, perform the following procedure. See Figure 1-338.

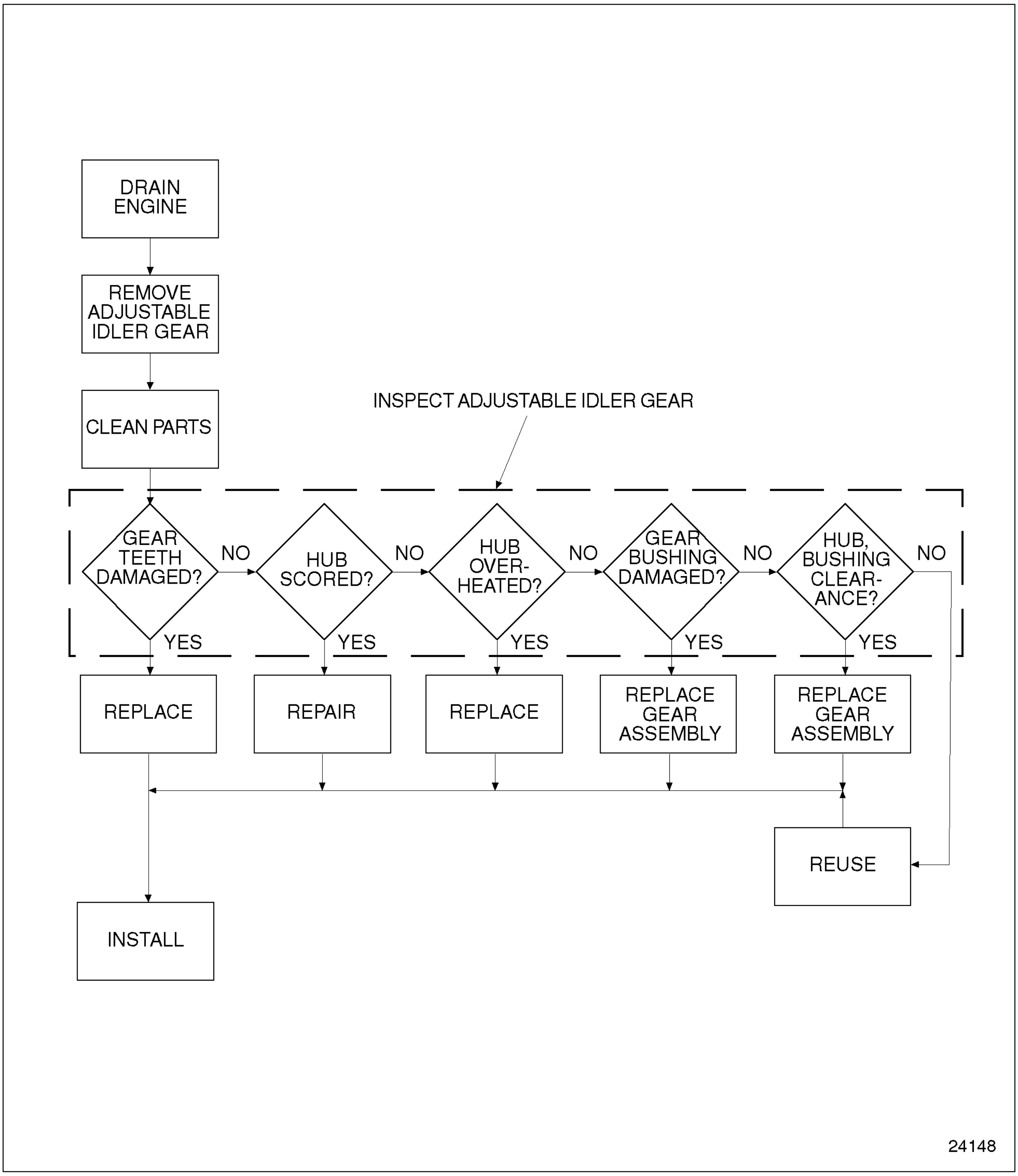
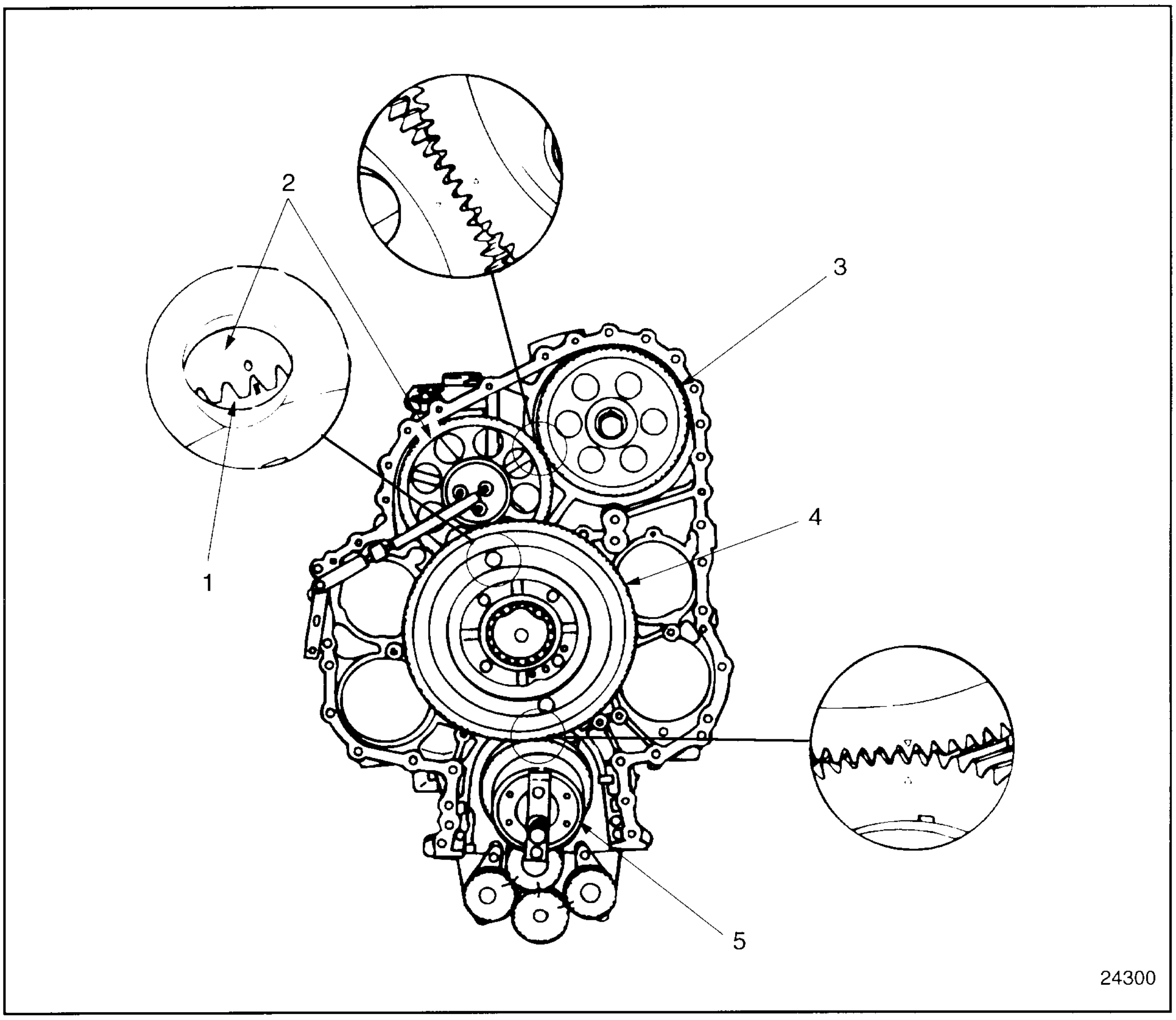


Figure 1-338 **Flowchart for Repair or Replacement of Adjustable Idler Gear Assembly**

1.25.2 Removal of Adjustable Idler Gear Assembly

Align gear train timing marks. Refer to Section 1.21.2.1before the removal of any gears. See Figure 1-339.

NOTE:
In order to maintain the proper timing between the crankshaft and the camshaft, a series of timing marks are stamped or etched on the gears in the gear train. With the timing marks aligned, the gears can be replaced exactly as removed.



1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

Figure 1-339 Engine Gear Train and Timing Marks

Drain the engine assembly as follows:

1. Drain the cooling system. Refer to Section 13.5.4.
2. Drain the engine lubricating oil. Refer to Section 13.5.1.

Remove the adjustable gear assembly as follows:

1. Remove the oil pan. Refer to Section 3.9.2.
2. Remove the gear case cover. Refer to Section 1.10.2.
3. Secure the engine barring tool, J 36237, to the front of the crankshaft. See Figure 1-340.

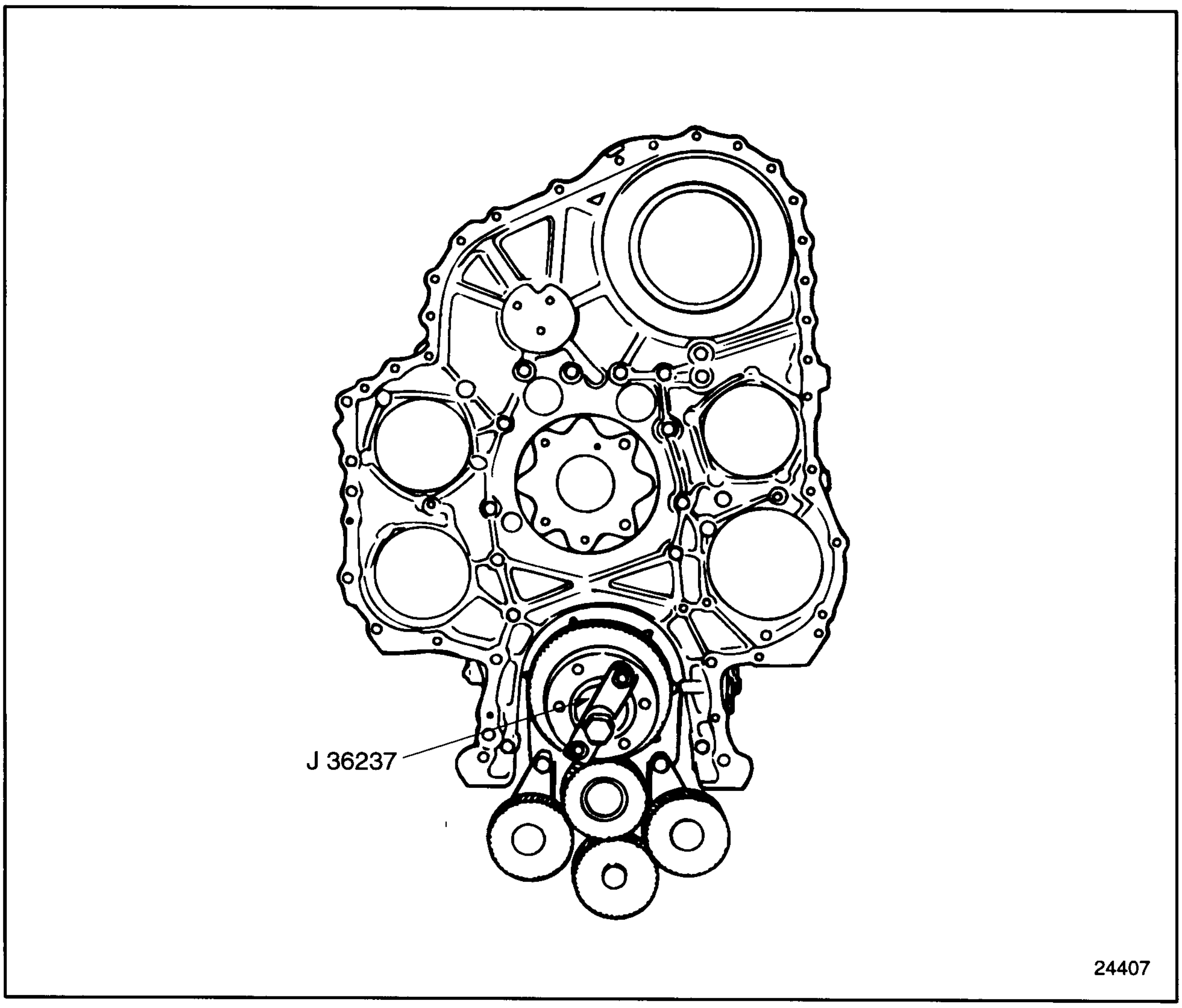


Figure 1-340 Barring Engine Over

4. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft.

NOTICE:
Always use Crankshaft Protector, J 35994, to guard against damage to the oil seal area of the crankshaft. When removing the bull gear or camshaft idler gear and hub assembly, do not come in contact with the oil seal contact surface of the crankshaft. If sealing surface is scratched, an oil leak may result.

5. Working through the four access holes in the bull gear and camshaft idler assembly, remove two of the four bolts that secure the bull gear and camshaft idler gear hub to the cylinder block. See Figure 1-341.

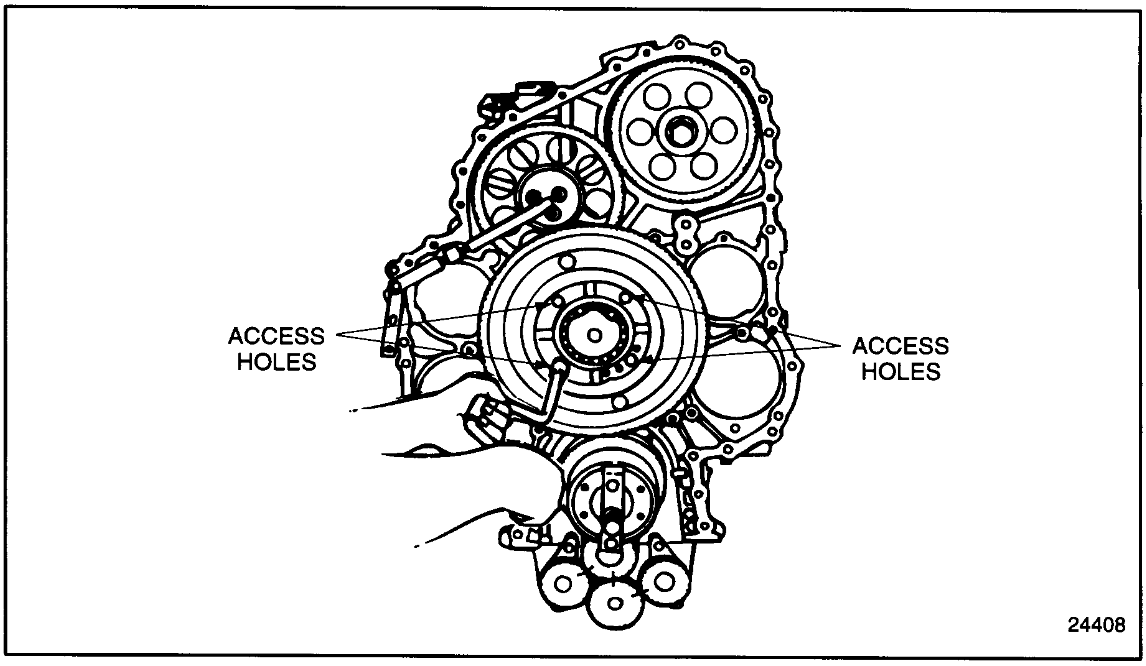


Figure 1-341 Removing Bull Gear and Camshaft Idler Gear and Hub

6. Install two bull gear guide studs, J 35785, to the holes from where the bolts were removed.
7. Remove the remaining two bull gear and camshaft idler gear hub bolts.
8. Grasp the bull gear and remove the bull gear and camshaft idler gear and hub assembly from its recess in the cylinder block.
9. Remove the three adjustable idler gear flanged locknuts.
10. Remove the adjustable idler gear hub retaining plate.
11. Remove the adjustable idler gear and hub.

1.25.2.1 Inspection of Adjustable Idler Gear Assembly

Inspect the adjustable idler gear assembly as follows:

1. Wash the adjustable idler gear, hub, and retaining plate thoroughly in clean fuel oil.

> **CAUTION:**
>
> **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Dry with compressed air.
3. Examine the gear teeth for evidence of scoring, pitting and wear.
4. If severely damaged or worn, replace the gear.

NOTE:
If gear teeth are damaged, also inspect the other gears in the gear train.

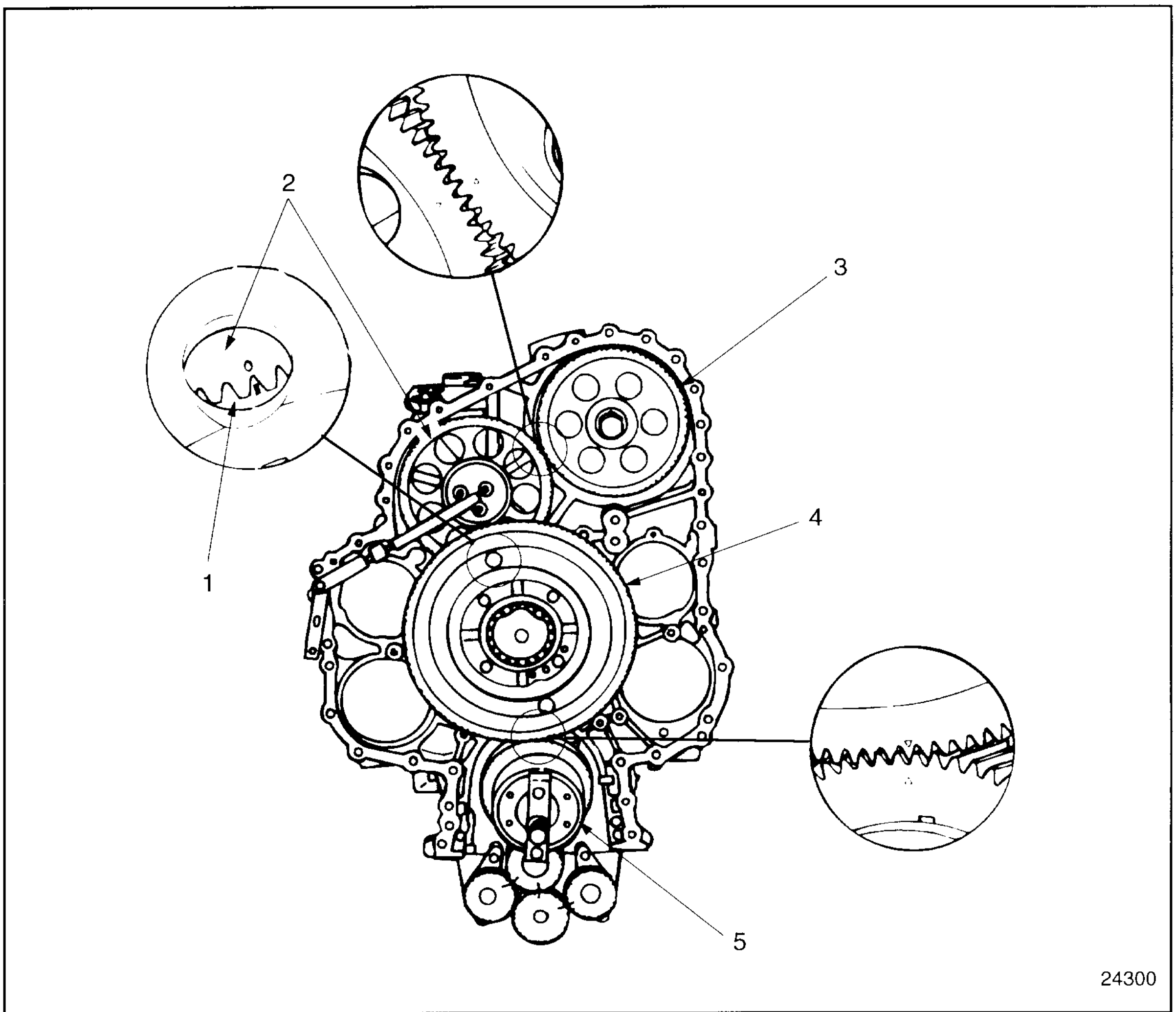
5. Inspect the contact surface of the hub for scoring or evidence of overheating (blue discoloration).
6. If hub has become overheated, replace the hub.
7. If slight irregularities are present, remove with a fine stone or emery cloth.
8. Check the lubrication hole and gallery in the gear case for blockage.
9. If blocked, clear the lubrication hole.
10. Inspect the bushing contact surface of gear and bushing assembly for signs of scoring, discoloration due to overheating, or excessive wear.
11. If the surface of the bushing is not acceptable, replace the gear and bushing as an assembly.
12. Measure the clearance between the bushing and hub.
13. If the clearance is more than 0.035-0.078 mm (0.0013-0.0030 in.), replace the gear and bushing as an assembly.

1.25.3 Installation of Adjustable Idler Gear Assembly

Install the adjustable idler gear and related parts as follows:

1. Coat the contact surfaces of the hub and idler gear bushing with clean engine oil.
2. Install the hub, with the word "OUT" facing outward, to the three studs in the gear case with the oil supply hole in the hub towards the gear case.

3. Align the timing marks on the face of the adjustable idler gear and camshaft drive gear and install the adjustable idler gear to its hub. See Figure 1-342.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1-342 Engine Gear Train and Timing Marks

4. Install thrust plate with the relief at the bottom.
5. Install the three flanged locknuts, finger-tight.
6. Install the bull gear guide studs, J 35785.
7. Install crankshaft protector, J 35994.
8. Coat the bearings and contact surfaces of the bull gear assembly with clean engine oil.

9. Looking through the inspection hole in the bull gear, align the timing marks on the camshaft idler gear (mounted to the rear of the bull gear) with the adjustable idler gear. Align the timing marks on the bull gear and crankshaft timing gear. Refer to Section 1.21. Install the bull gear hub assembly to the cylinder block. Refer to Section 1.26.3.
10. Install the gear case cover. Refer to Section 1.10.3.
11. Using the gear lash adjusting tool, J 35596, adjust the gear lash between the adjustable idler gear and camshaft drive gear. Refer to Section 1.25.3.
12. Install any other components that were removed for access to the gear case cover.

1.26 BULL GEAR AND CAMSHAFT IDLER GEAR ASSEMBLY

The bull gear and camshaft idler gear assembly is centrally located beneath the gear case cover. The larger bull gear is directly driven by the crankshaft timing gear. The bull gear directly drives all of the gear-driven engine accessories (except the oil pump and balance assembly), meshing with drive gears for the fuel pump drive, air compressor drive, power steering pump (if so equipped), water pump and accessory and alternator drive. See Figure 1-343.

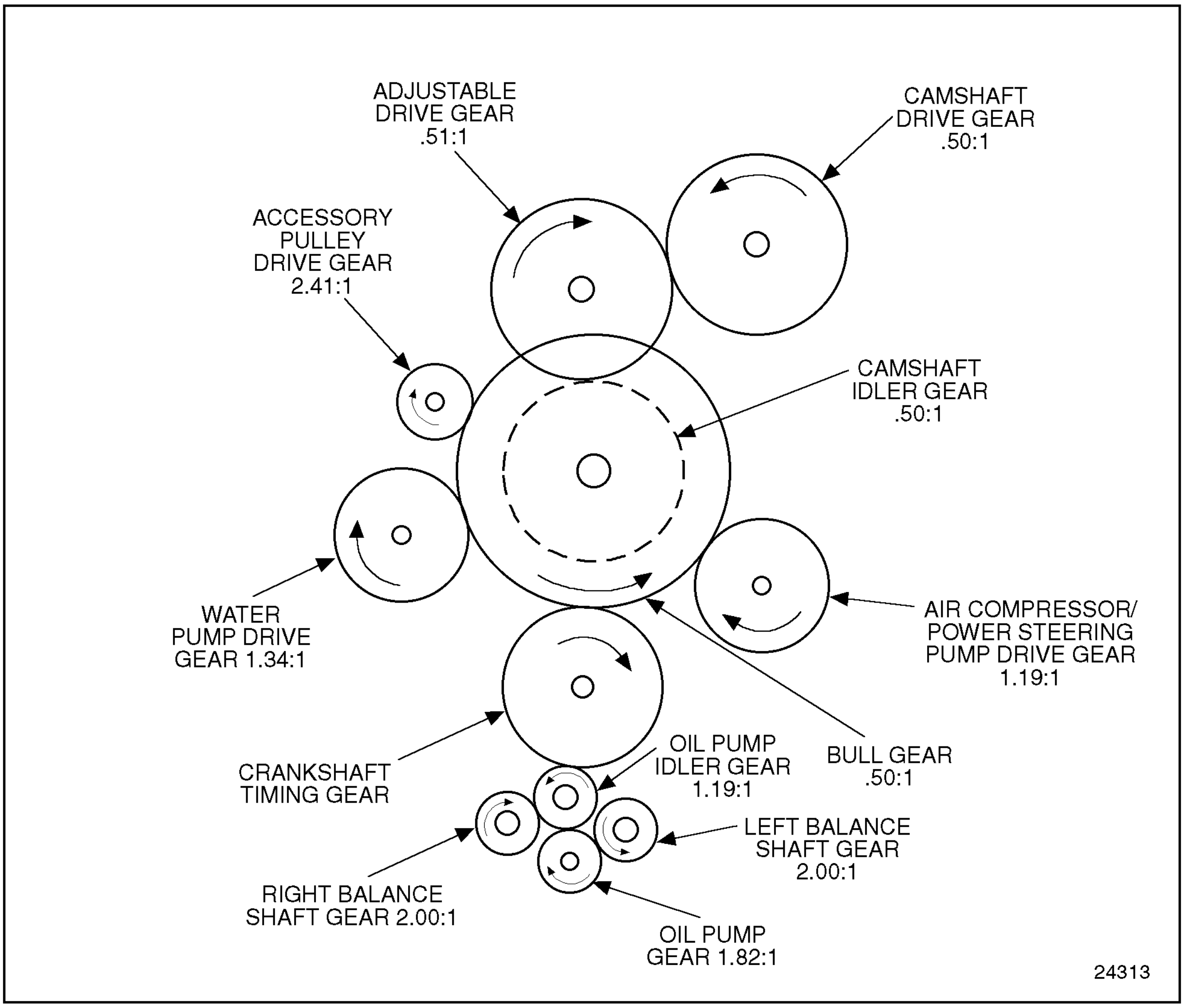
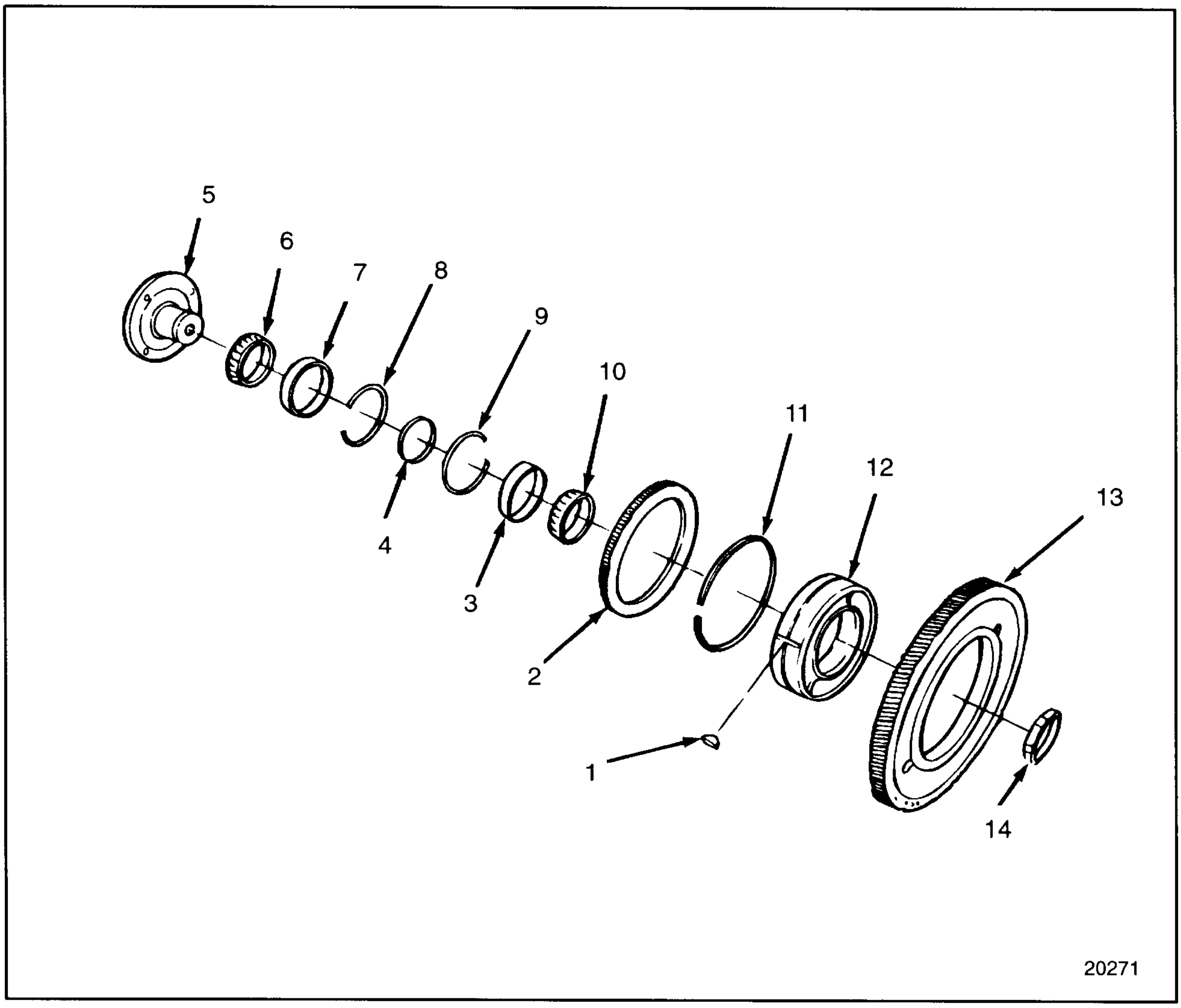


Figure 1-343 Engine Gear Train

The smaller camshaft idler gear is located behind the bull gear on the same carrier, and turns at the same speed as the bull gear. The camshaft idler gear drives an adjustable idler gear, mounted on a separate hub in the gear case. The adjustable idler gear drives the camshaft drive gear. The gear ratio of each gear in relationship to the crankshaft timing gear is shown directly below the gear title.

The bull gear and camshaft idler gear are a press-fit to the bull gear and camshaft idler gear carrier. See Figure 1-344.



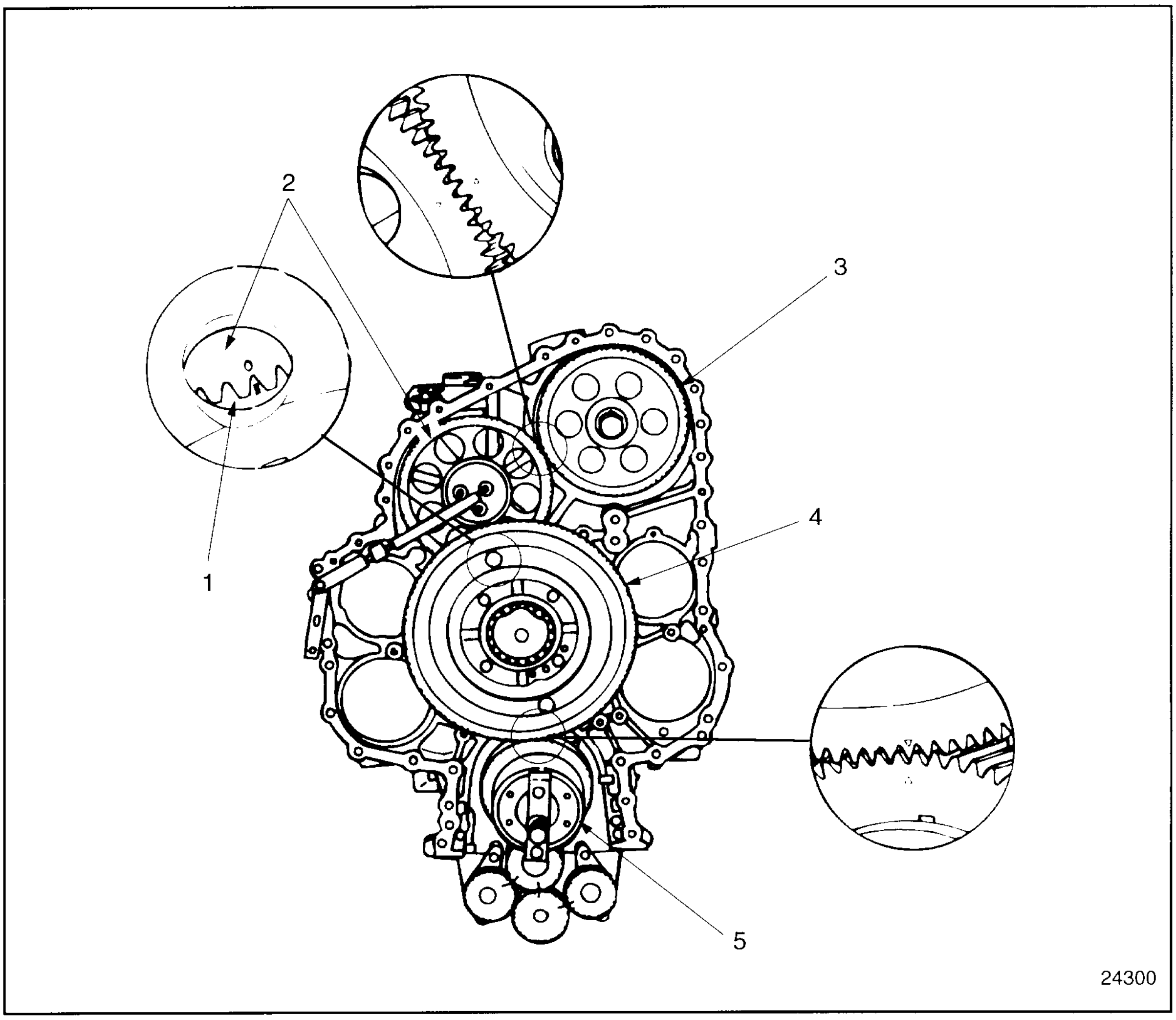
1. Woodruff Key
2. Camshaft Idler Gear
3. Bearing Race, Outer
4. Spacer Ring, Small
5. Hub
6. Bearing, Inner
7. Bearing Race, Inner
8. Snap Ring, Inner
9. Snap Ring, Outer
10. Bearing, Outer
11. Spacer Ring, Large
12. Carrier
13. Bull Gear
14. Thread Nut, Left Hand

Figure 1-344 Bull Gear and Related Parts

Both gears are keyed to the carrier by the same key. For earlier units, a spacer ring fits in a groove in the carrier between the bull gear and the camshaft idler gear. In later engines, this spacer was incorporated in the carrier. The carrier is supported by two tapered roller bearing assemblies that ride on a hub bolted to the engine block by four bolts. A selective-size spacer between the two bearing assemblies is used to obtain the correct bearing preload.

NOTE:
The bull gear and camshaft idler gear assembly is retained to the hub by a left-hand threaded nut.

The camshaft must be in time with the crankshaft timing gear. Since there are three gears between them, timing marks have been stamped or etched on the face of the gears to facilitate correct gear train timing. Refer to Section 1.21.2.1 for gear train timing procedures. See Figure 1-345.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1-345 Engine Gear Train and Timing Marks

The backlash between the various mating gears in the gear train should be 0.051-0.229 mm (0.002-0.009 in.), and should not exceed 0.305 mm (0.012 in.) backlash between worn gears. Refer to Section 1.21.2.1.

NOTE:
All gear lash measurements should be taken with engine in an upright position.

The bull gear and camshaft idler gear assembly is pressure-fed lubricating oil through two holes in the bull gear recess area of the engine block. See Figure 1-346.

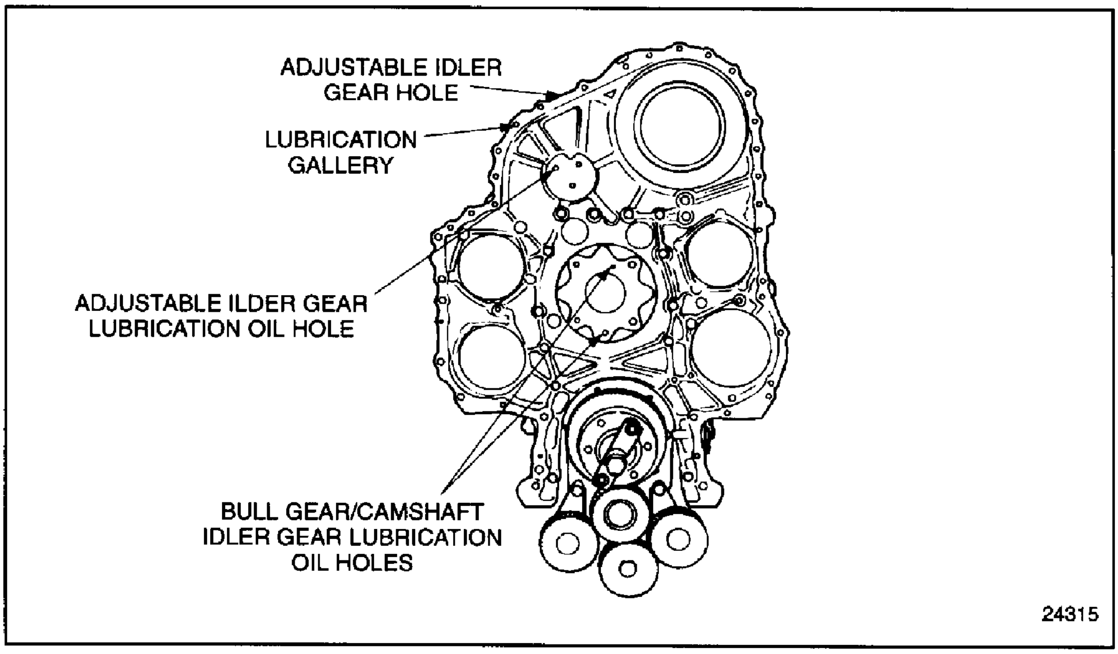


Figure 1-346 Bull Gear and Camshaft Idler Gear Lubricating Oil Hole Locations

These two holes are drilled into a main oil gallery. An internal oil passage, cast into the bull gear and camshaft idler gear hub relief at the rear of the hub indexes with these two oil holes to supply oil through a drilled passage to the two roller bearing assemblies.

1.26.1 Repair or Replacement of Bull Gear and Camshaft Idler Gear Assembly

To determine if repair or replacement of the bull gear and camshaft idler gear assembly is necessary, perform the following procedure. See Figure 1-347.

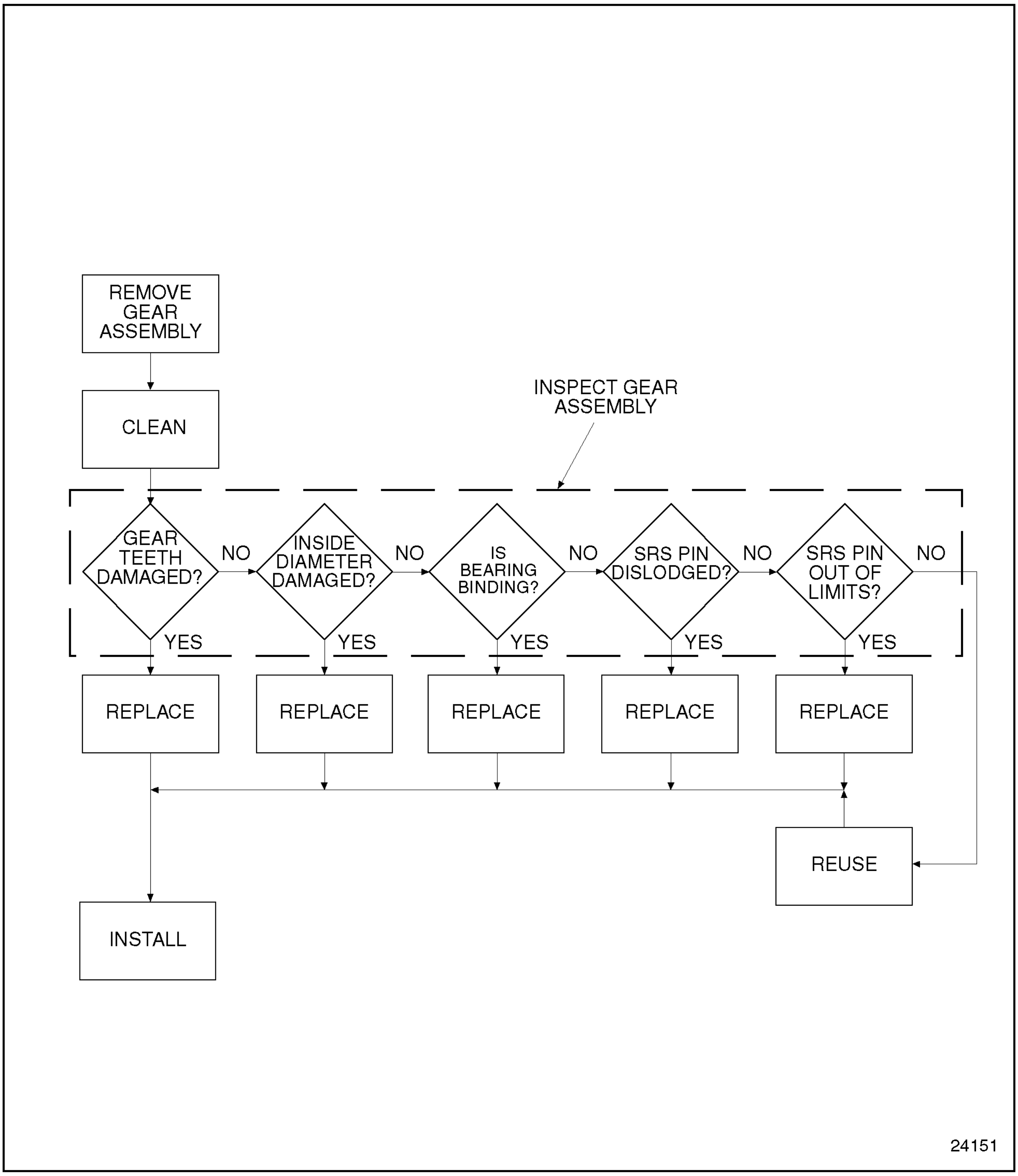


Figure 1-347 Flowchart for Repair or Replacement of Bull Gear and Camshaft Idler Gear Assembly

1.26.2 Removal of Bull Gear and Camshaft Idler Gear Assembly

Remove the bull gear and camshaft idler gear assembly as follows:

1. Remove the engine gear case cover. Refer to Section 1.10.2.
2. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft.

NOTICE:
Use care when removing the bull gear and camshaft idler gear assembly from the engine so that it does not come in contact with the oil seal contact surface of the crankshaft. If this sealing surface is scratched, an oil leak may result.

3. Working through the four access holes in the bull gear carrier, loosen and remove two of the four bolts that secure the bull gear assembly to the cylinder block. See Figure 1-348.

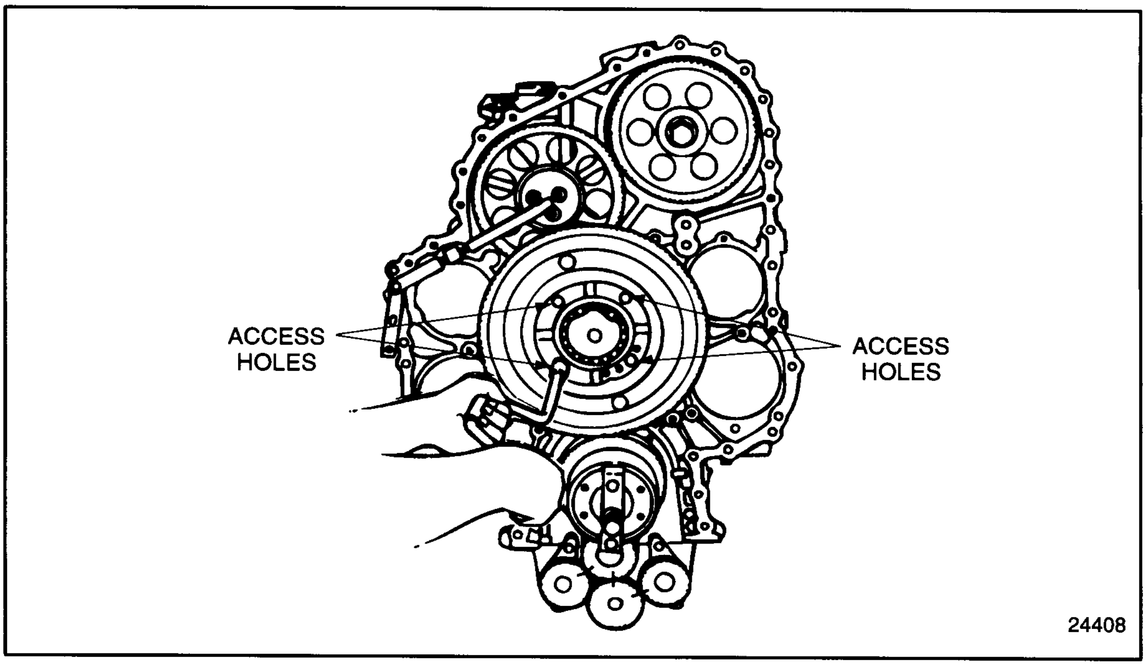


Figure 1-348 Removing Bull Gear Assembly Retaining Bolts

4. Install two bull gear guide studs, J 35785, into the holes the bolts from where they were removed.
5. Remove the two remaining bull gear retaining bolts.
6. Grasp the bull gear and pull the assembly straight out of the recess in the cylinder block.

1.26.2.1 Inspection of Bull Gear and Camshaft Idler Gear Assembly

Inspect the bull gear and camshaft idler gear assembly as follows:

1. Clean the bull gear and idler gear assembly in clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the bull gear and idler gear assembly with compressed air.
3. Examine the gear teeth on both the bull gear and idler gear for evidence of scoring, cracking, pitting, and wear.
4. If either gear is damaged, replace the bull gear and idler gear assembly.
5. Inspect the inner diameter of both gears, where they are pressed on the carrier for evidence of gear movement
6. If there is any evidence of gear movement, replace the bull gear and idler gear assembly.
7. Place the bull gear and idler gear assembly on a bench, resting on the hub. Inspect the bearings for signs of distress or overheating.
8. If there is any bearing distress, replace the bull gear and idler gear assembly.
9. Coat the bearings with clean engine oil.
10. Slowly rotate the gears on the hub looking for binding of the bearing.
11. If the gears do not rotate freely on the hub, replace the bull gear and idler gear assembly.

NOTICE:
Care should be taken not to damage or dislocate the pin. The pin is installed at a set dimension which is used by the Synchronous Reference Sensor (SRS). Damage to pin will cause loss of engine performance.

Inspect the SRS pin in the bull gear as follows. See Figure 1-349.

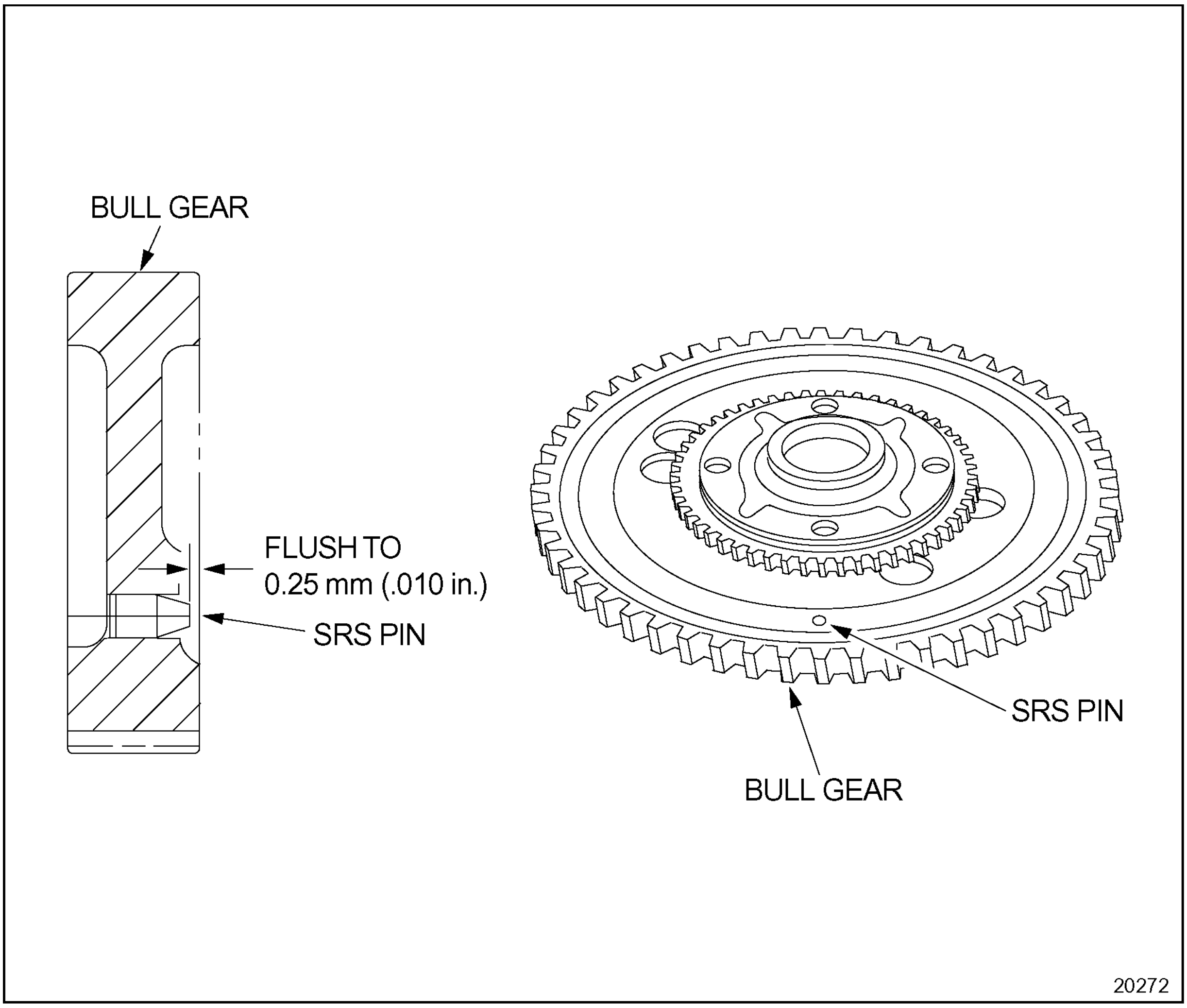


Figure 1-349 SRS Pin Location

1. Check the SRS pin for damage or looseness.
2. If the SRS pin is damaged or dislodged, replace the pin as follows:
   [a] Press the SRS pin from the bull gear. Discard pin.

NOTICE:
Do NOT reuse or readjust a pin once it has been installed. Damage to pin will cause loss of engine performance.

[b] Apply Loctite 609 (PT 7260) to pin.

[c] Press pin flush to 0.25 mm (0.010 in.) below bull gear surface.

3. Using straight edge and thickness gages, measure recess of SRS pin.
4. If pin is not flush to 0.25 mm (0.010 in.) below bull gear surface, repeat step 2.

1.26.3 Installation of Bull Gear and Camshaft Idler Gear Assembly

Install bull gear assembly and camshaft assembly as follows:

1. Inspect the bull gear and camshaft idler gear access opening in the gear case and remove any foreign material. Be sure the lubrication oil holes are clear and free.
2. Install two bull gear guide studs, J 35785, to the cylinder block. See Figure 1-350.

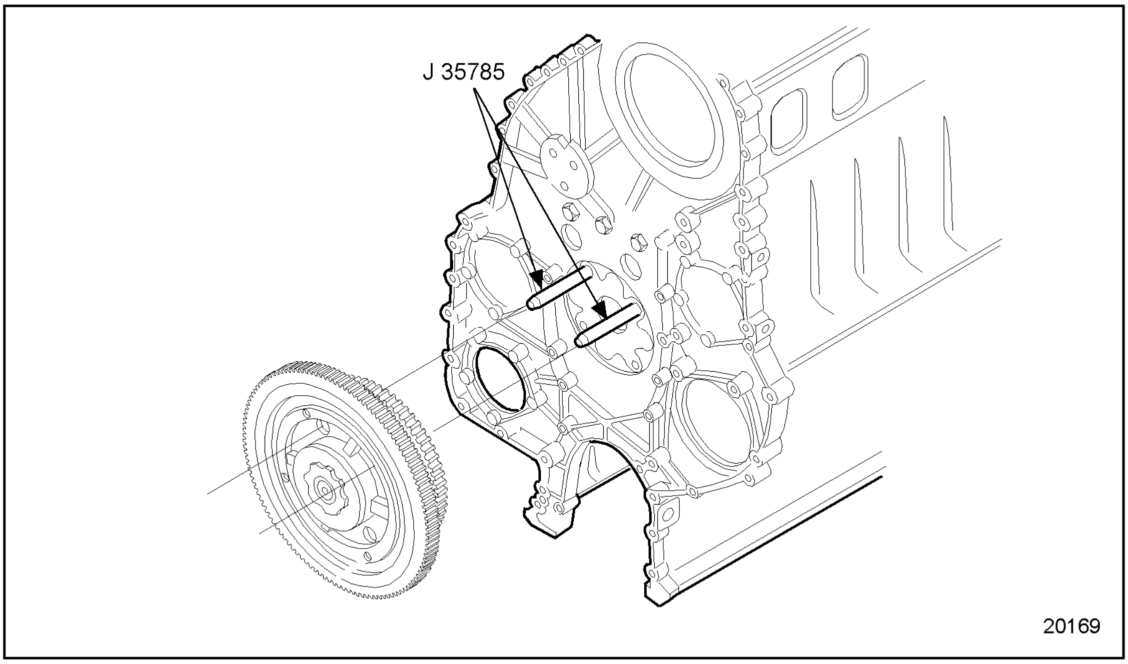
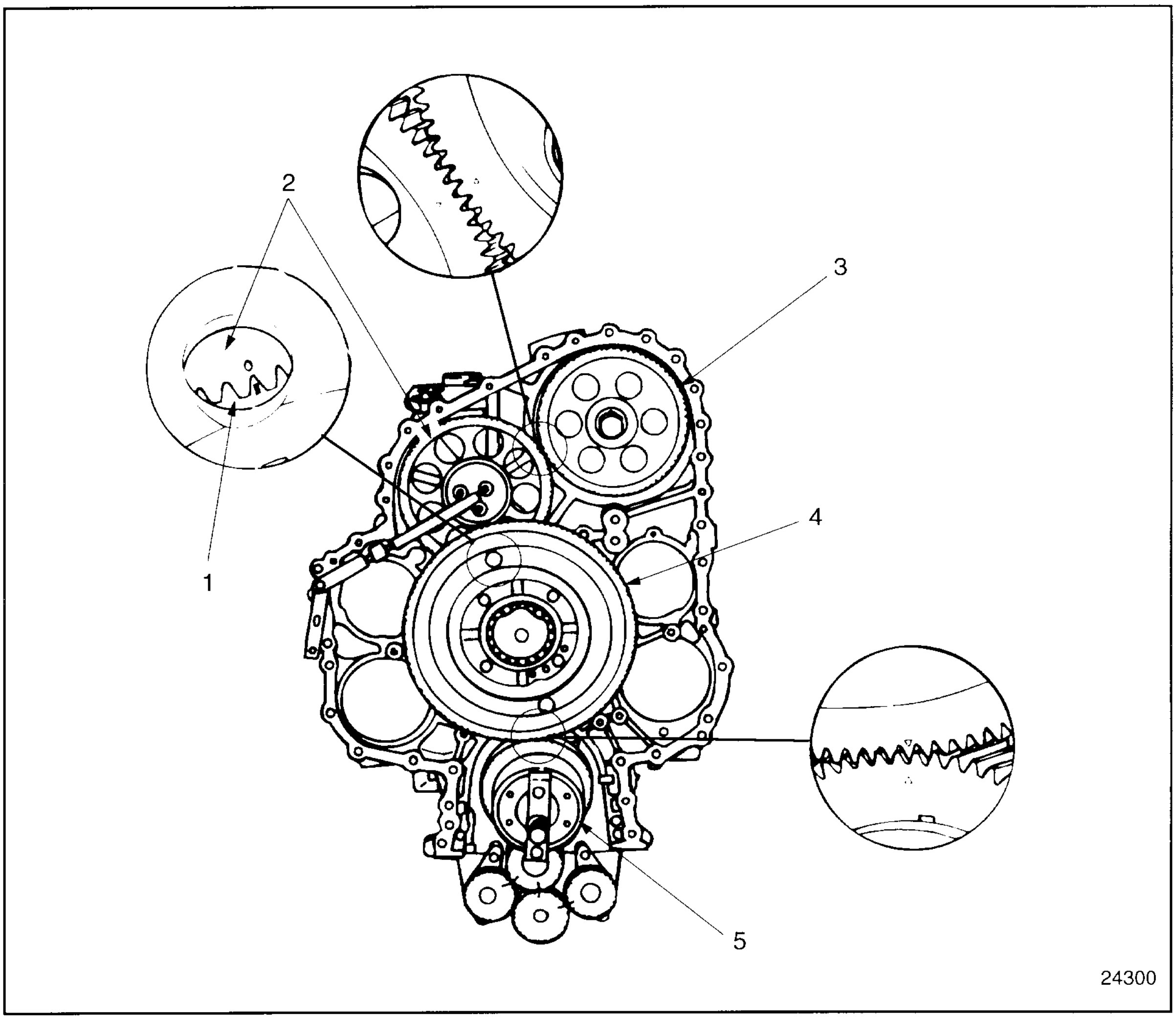


Figure 1-350 Bull Gear Stud Installation

3. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft.

NOTE:
The crankshaft protector, J 35994, will protect the crankshaft seal surface when installing the bull gear and camshaft idler gear assembly to the cylinder block.

4. Install the bull gear and camshaft idler gear assembly to the guide studs in the cylinder block.
5. Bar the engine over until the timing mark on the crankshaft timing gear is at the 12 o'clock position. See Figure 1-351.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1-351 Engine Gear Train and Timing Marks

6. Align the timing marks on the camshaft drive gear and the adjustable idler gear as shown. See Figure 1-351.
7. Slide the bull gear and camshaft idler gear assembly towards the engine, but do not engage any of the gears on the engine.

8. Looking through the access hole in the bull gear, align the timing marks on the adjustable idler gear and the camshaft idler gear as shown. See Figure 1-351.
9. Check the timing marks on the bull gear and crankshaft timing gear to ensure they will align when the bull bear assembly is seated in the cylinder block.

NOTE:
The injector and valve spring pressures will not allow easy rotation of the camshaft and adjustable idler gears. Therefore, it may be necessary to remove the rocker arm and shaft assemblies to facilitate aligning all three sets of timing marks. Refer to Section 1.3.2.

10. When all three sets of timing marks are aligned, slide the bull gear and camshaft idler gear towards the engine completely and seat it in the recess in the gear case and cylinder block.

NOTICE:
Use care when installing the bull gear and camshaft idler gear assembly to prevent damaging the crankshaft oil seal contact surface.

11. Working through the lightening holes in the bull gear, install two of the bull gear assembly mounting bolts through the hub and into the cylinder block. Tighten the bolts finger tight.
12. Remove the two bull gear guide studs.
13. Install the remaining two bull gear assembly mounting bolts. Torque all four mounting bolts to 101-116 N·m (75-86 lb·ft). Work in a clockwise direction.
14. Check the timing marks on the gears to ensure the gear train is properly timed. See Figure 1-351.
15. Check the gear lash for all of the gears that mate with the bull gear and camshaft idler gear. Refer to Section 1.21.
16. Install the gear case cover. Refer to Section 1.10.3
17. Check bull gear to accessory drive gear lash. Refer to Section 1.21.2.1.

1.27 CRANKSHAFT TIMING GEAR AND TIMING WHEEL

The crankshaft timing gear is a helical gear that is indexed to the crankshaft by a key and is pressed onto the end of the crankshaft. See Figure 1-352.

The Series 50 Engine crankshaft timing gear can be identified by a groove on the outside of the gear face.

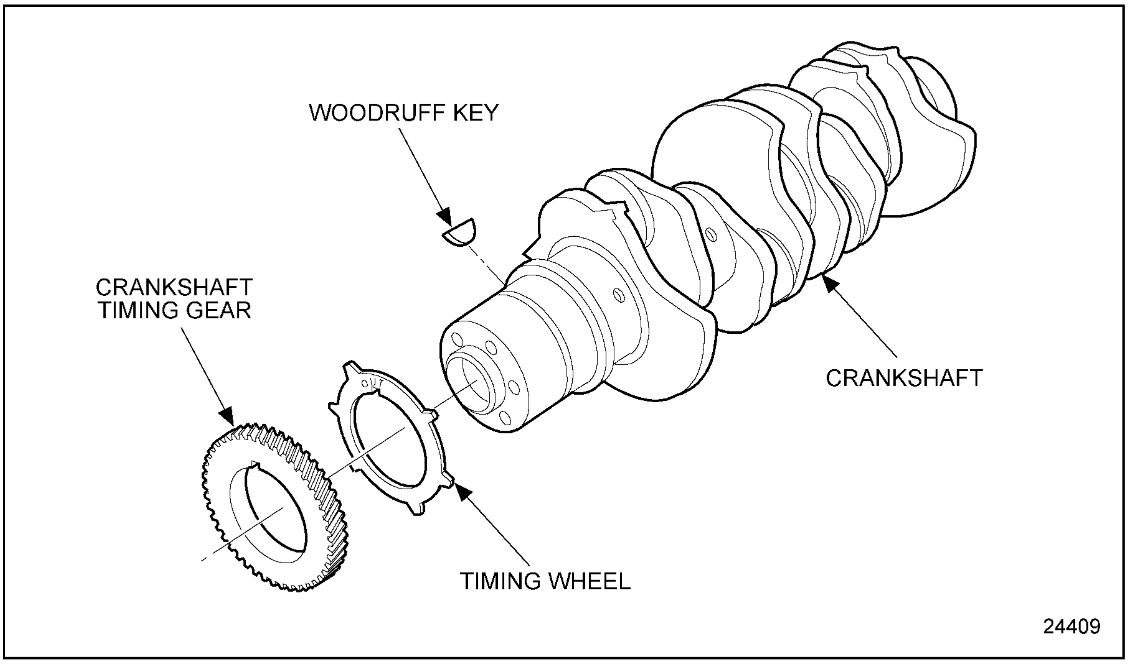


Figure 1-352 Crankshaft Timing Gear and Related Parts

The crankshaft timing gear directly drives the bull gear and oil pump drive gear. The bull gear drives the various accessories, and drives the camshaft through the idler gear. See Figure 1-353.

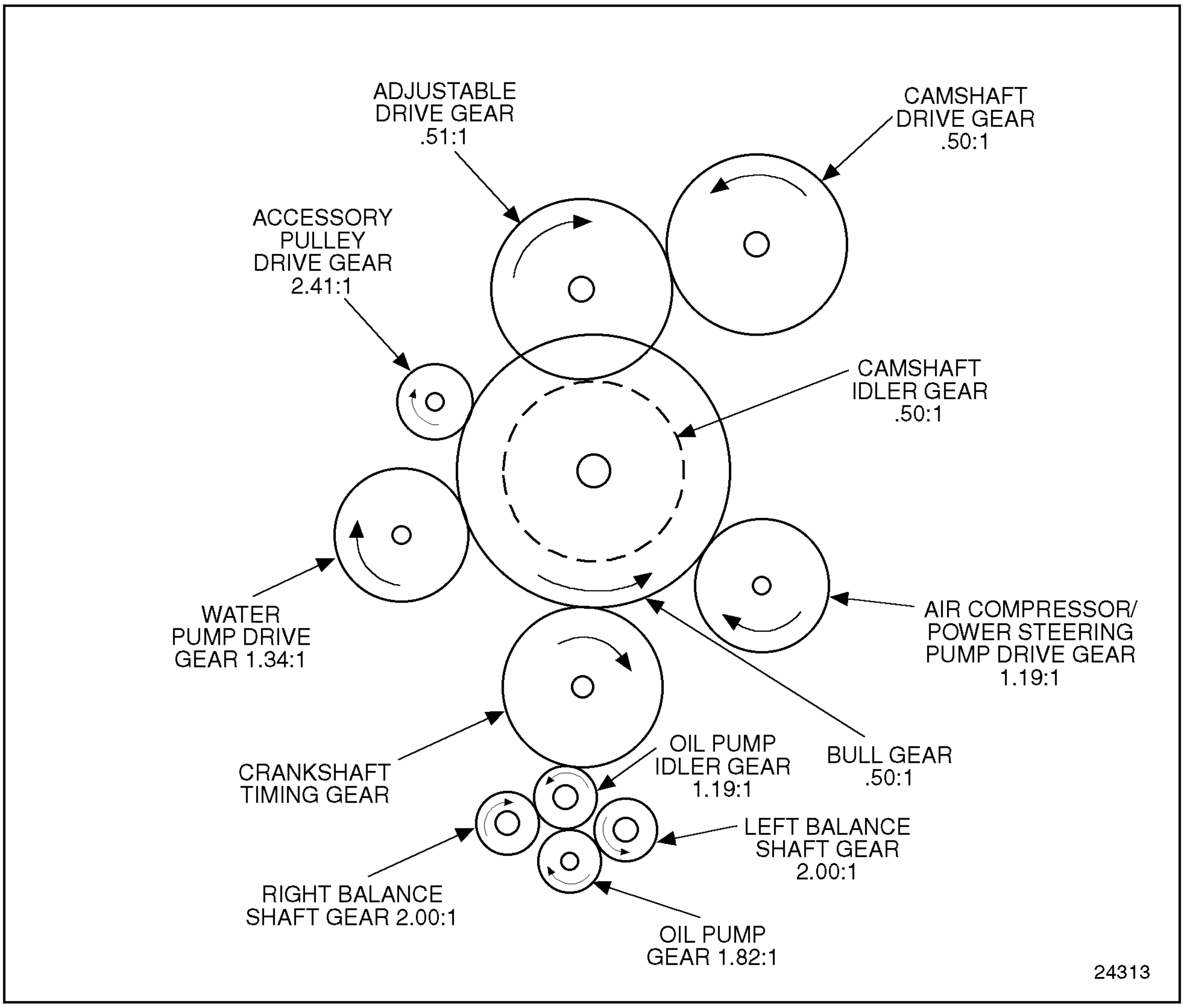


Figure 1-353 Engine Gear Train

A timing wheel is installed on the crankshaft directly behind the crankshaft timing gear. The timing wheel is indexed to the crankshaft by the same key as the crankshaft timing gear, and is retained to the crankshaft by the crankshaft timing gear. The timing wheel is marked with the word OUT on the outboard side, and should be installed with this mark facing you as you install the wheel. See Figure 1-354.

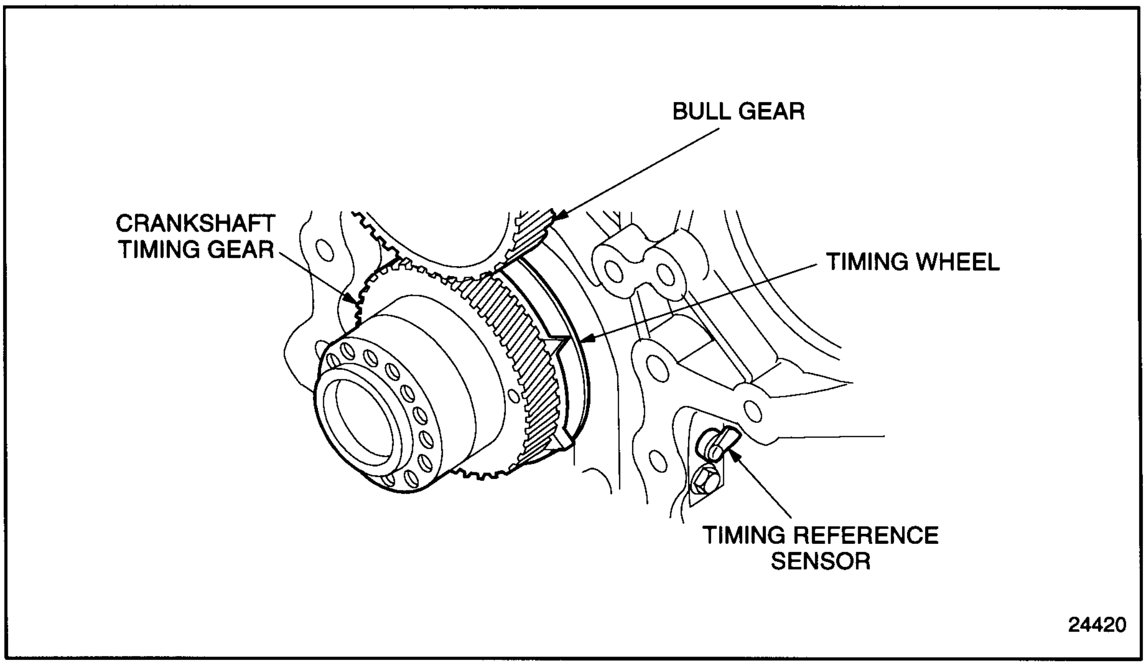


Figure 1-354 Crankshaft Timing Gear and Related Parts Location

The timing wheel induces a voltage signal in the Timing Reference Sensor (TRS), as the teeth of the pulse wheel passes by the TRS. This signal is sent to the Electronic Control Module (ECM) as each cylinder reaches 10° before top-dead-center.

Since the crankshaft and camshaft must be in time with each other, a series of timing marks are stamped or etched on the faces of the gears in the gear train. Refer to Section 1.21.2.1 for gear train timing information. The balance shafts and crankshaft must also be in time with each other.

The crankshaft timing gear is lubricated by splash from the engine oil pan, and excess oil returning to the oil pan from the other gears.

1.27.1 Repair or Replacement of Crankshaft Timing Gear and Timing Wheel

To determine if repair or replacement of the crankshaft timing gear and timing wheel are necessary, perform the following procedure. See Figure 1-355.

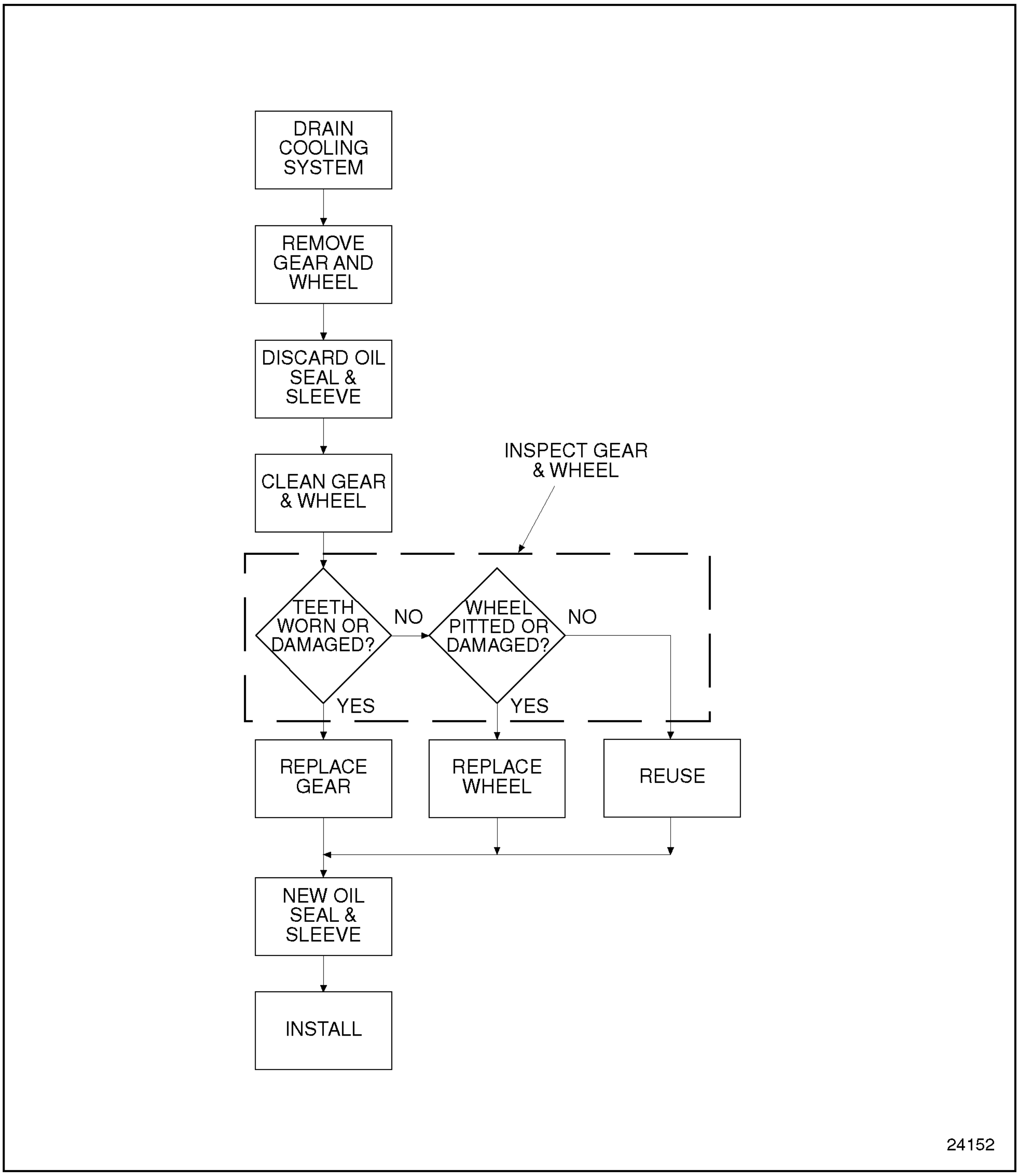


Figure 1-355 Flowchart for Repair or Replacement of Crankshaft Timing Gear and Timing Wheel

1.27.2 Removal of Crankshaft Timing Gear and Timing Wheel Removal

Remove the gear and the timing wheel as follows:

1. Drain the cooling system. Refer to Section 13.5.4.
2. Remove the radiator to engine coolant hoses.
3. Remove the timing reference sensor. Refer to Section 2.21.2.
4. Remove components as necessary to gain access to the gear case cover.
5. Remove the gear case cover. Refer to Section 1.10.2.
6. If an oversize crankshaft front oil seal sleeve is used, peen the outside diameter of the sleeve until it stretches sufficiently and slip the sleeve off of the crankshaft. Discard sleeve.
7. Remove the balance assembly. Refer to Section 1.28.2.

NOTICE:
Use care when removing the bull gear assembly. To prevent damaging the crankshaft oil seal contact surface, use Crankshaft Protector, J 35994 on end of crankshaft or oil leaks may result.

8. Remove the bull gear and camshaft idler gear assembly. Refer to Section 1.26.2.

9. Using two of the crankshaft pulley bolts, secure the base post, J 35642-1 part of J 35642 , part of tool kit J 35642, to the end of the crankshaft. Torque the bolts to 190-203 N·m (140-150 lb·ft). See Figure 1-356.

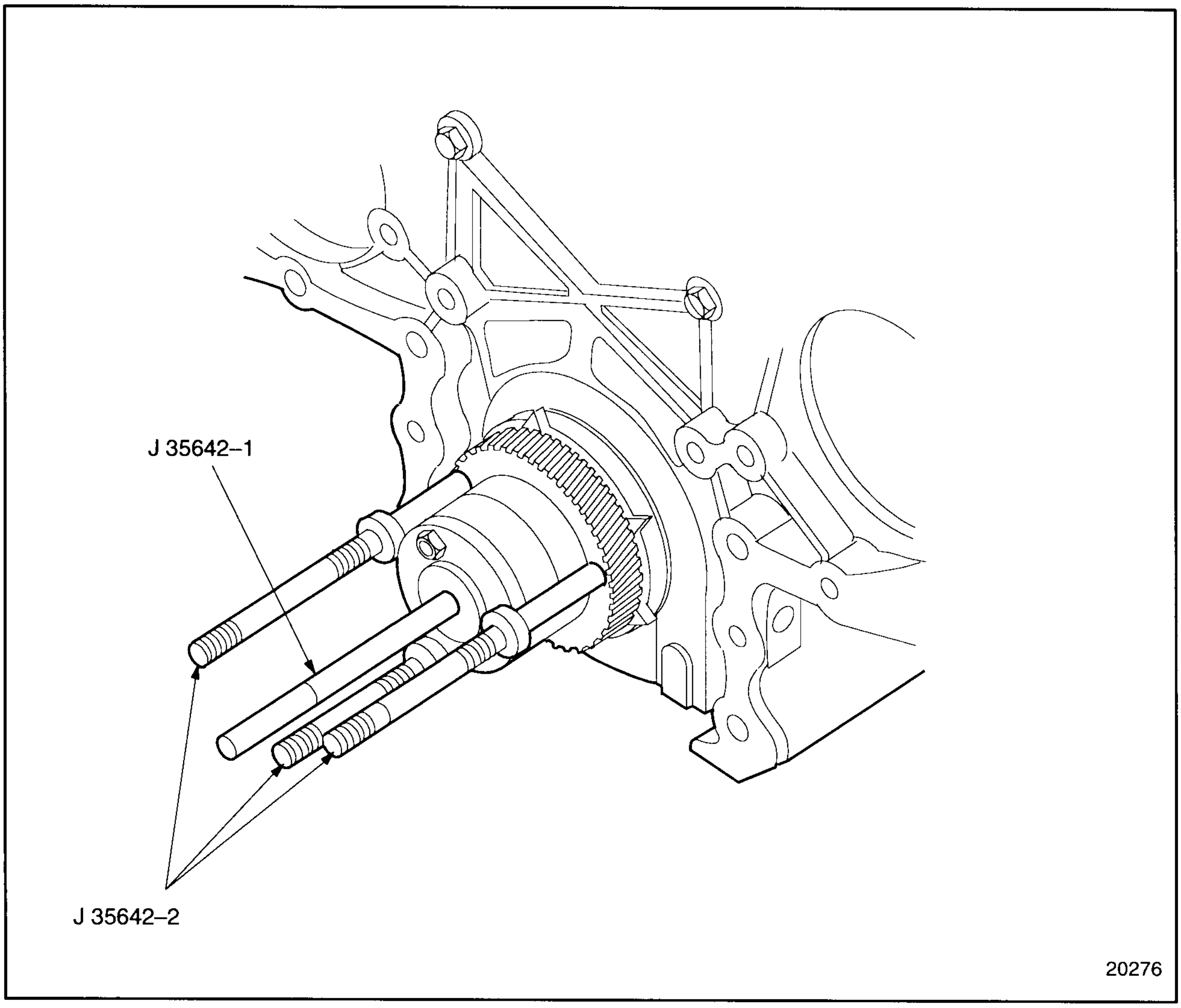


Figure 1-356 Installation of Crankshaft Timing Gear Removal Tools

NOTE:
The crankshaft removal values are shown with the crankshaft installed in the engine. The crankshaft timing gear may be removed with the crankshaft in or out of the engine.

10. Thread the three legs, J 35642-2 part of J 35642, part of tool kit J 35642, into the three threaded holes in the crankshaft timing gear. Tighten the legs so they are snug.

11. Slide the hydraulic ram of portable press, J 35951-175, over the center rod of base post, J 35642-1 part of J 35642 part of tool kit J 35642, and all the way to the base. See Figure 1-357.

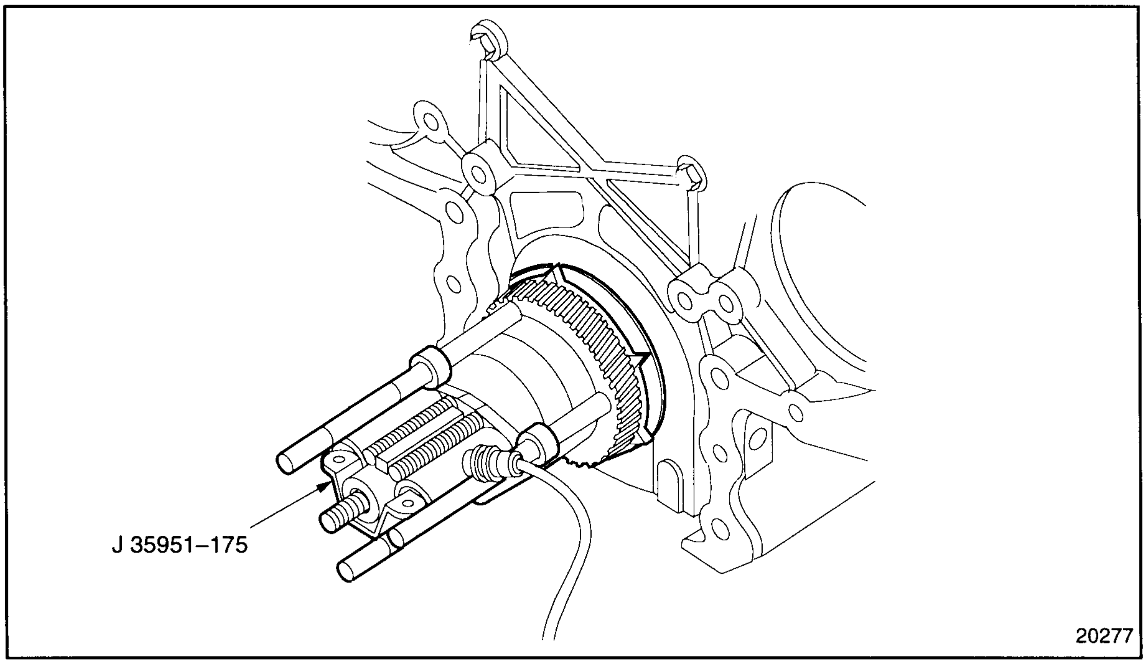


Figure 1-357 Hydraulic Ram Installation

12. Install the Pressure Plate, J 35642-4 part of J 35642, to the three legs, J 35642-2 part of J 35642, both part of tool kit J 35642. See Figure 1-358.

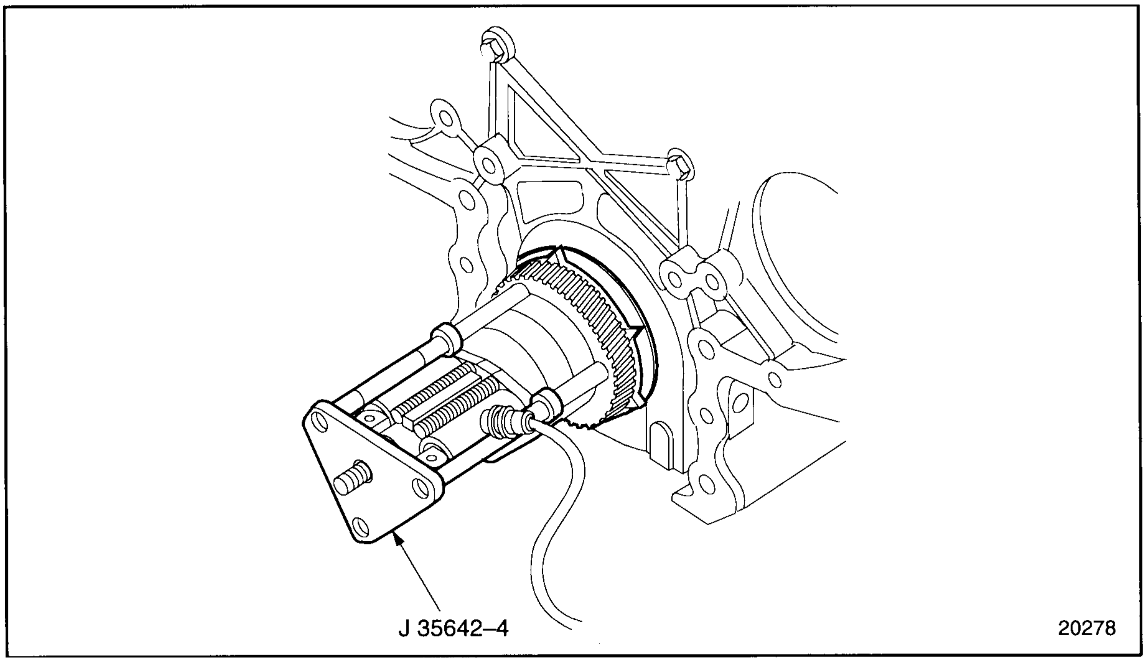


Figure 1-358 Pressure Plate Installation

13. Install the three retaining nuts to the legs. Tighten the nuts to the pressure plate. Tighten the nuts until they are snug. See Figure 1-359.

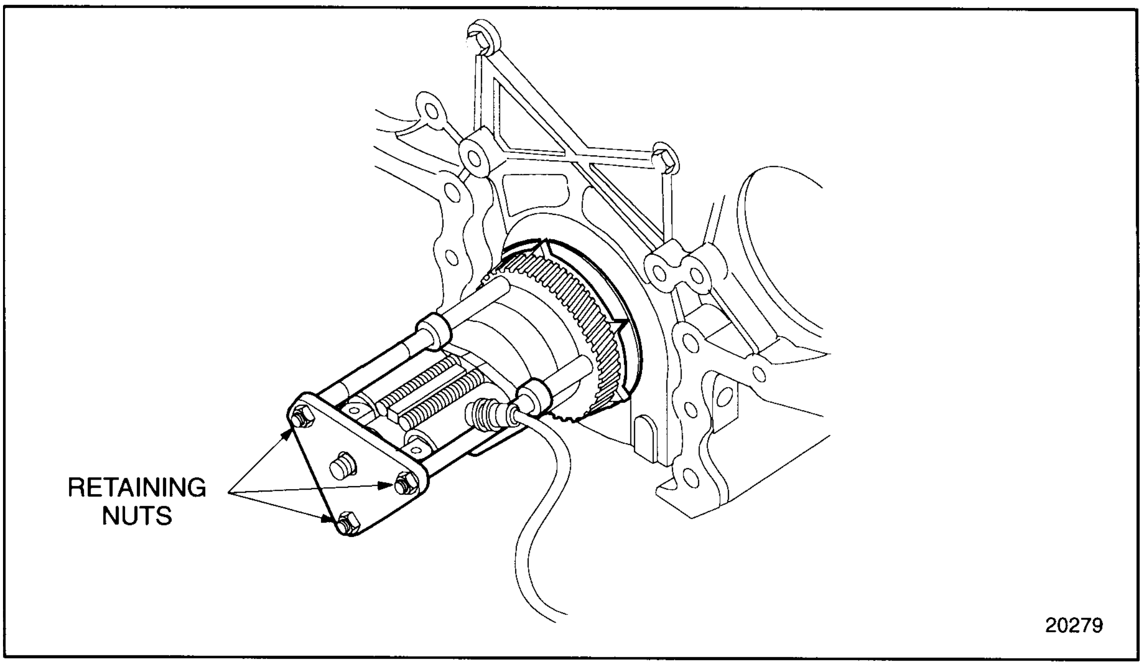


Figure 1-359 Retaining Nuts Installation

14. Close the valve on the hydraulic pump of portable press J 35951-175. Pump the lever to build pressure and remove the crankshaft timing gear. See Figure 1-360.

NOTE:
Considerable pressure is required to remove the crankshaft timing gear. Due to manufacturer's tolerances, it may take as much as 80 kN (9 tons) of force to remove the crankshaft timing gear.

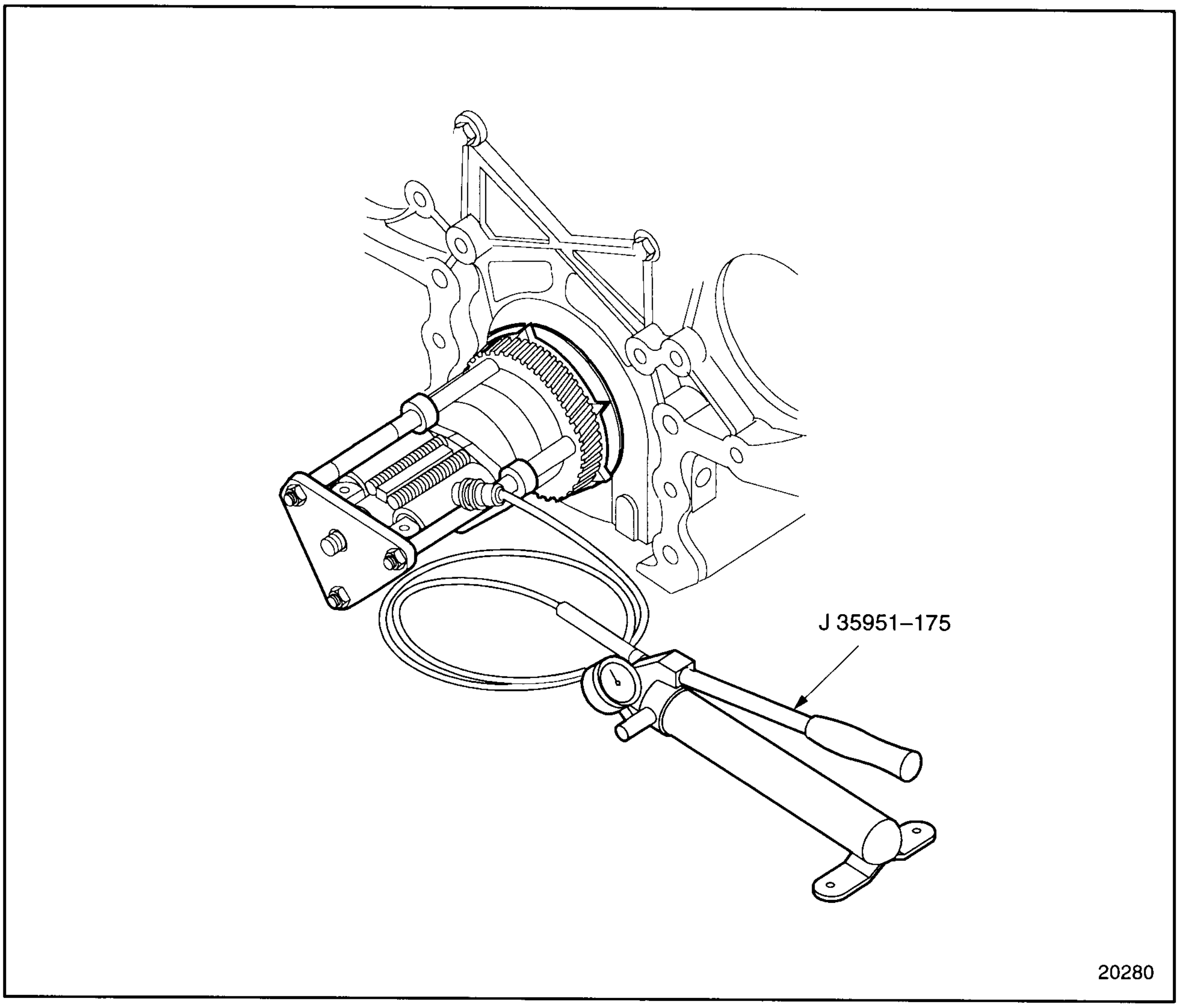


Figure 1-360 Crankshaft Timing Gear Removal

15. Remove the tools from the engine and timing gear as follows:
    - [a] Open the valve on the hydraulic pump of portable press, J 35951-175, to relieve the pressure.
    - [b] Loosen and remove the three retaining nuts on the legs, J 35642-2 part of J 35642 , part of tool kit J 35642, against the pressure plate.
    - [c] Remove the pressure plate, J 35642-2 part of J 35642, part of tool kit J 35642.

[d] Remove the hydraulic ram of portable press, J 35951-175.

[e] Loosen and remove the three legs, J 35642-2 part of J 35642, part of tool kit J 35642.

[f] Loosen and remove the two crankshaft pulley bolts and remove the base post, J 35642-1 part of J 35642, part of tool kit J 35642.

NOTICE:
Care should be exercised when removing the timing wheel. Do NOT use sharp tools to pry on the timing wheel. Damage to the crankshaft seal contact surface may cause oil leaks.

16. Slide the timing wheel off the end of the crankshaft.

NOTE:
The timing wheel is a slip fit to the crankshaft, and no special tools are required for removal. A three-jaw adjustable puller, however, may be necessary.

1.27.2.1 Inspection of Crankshaft Timing Gear and Timing Wheel

Inspect the crankshaft timing gear and timing wheel as follows:

1. Clean the crankshaft timing gear and timing wheel with clean fuel oil.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry all parts with compressed air.
3. Examine the gear teeth of the crankshaft timing gear for evidence of scoring, pitting, or excess wear.
4. If gear teeth are damaged or worn, install a new gear.

NOTE:
If gear teeth are damaged or severely worn, also check the other gears in the gear train. Refer to Section 1.21.

5. Examine the timing wheel for evidence of pitting and the gear teeth for bending or damage.
6. If wheel is pitted or gear teeth damaged, replace timing wheel.

1.27.3 Installation of Crankshaft Timing Gear and Timing Wheel

Install the crankshaft timing gear and timing wheel as follows:

1. Install the base post, J 35642-1 part of J 35642, part of tool kit J 35642, to the end of the crankshaft, using two crankshaft pulley retaining bolts. Torque the bolts to 190-203 N·m (140-150 lb·ft). See Figure 1-361.

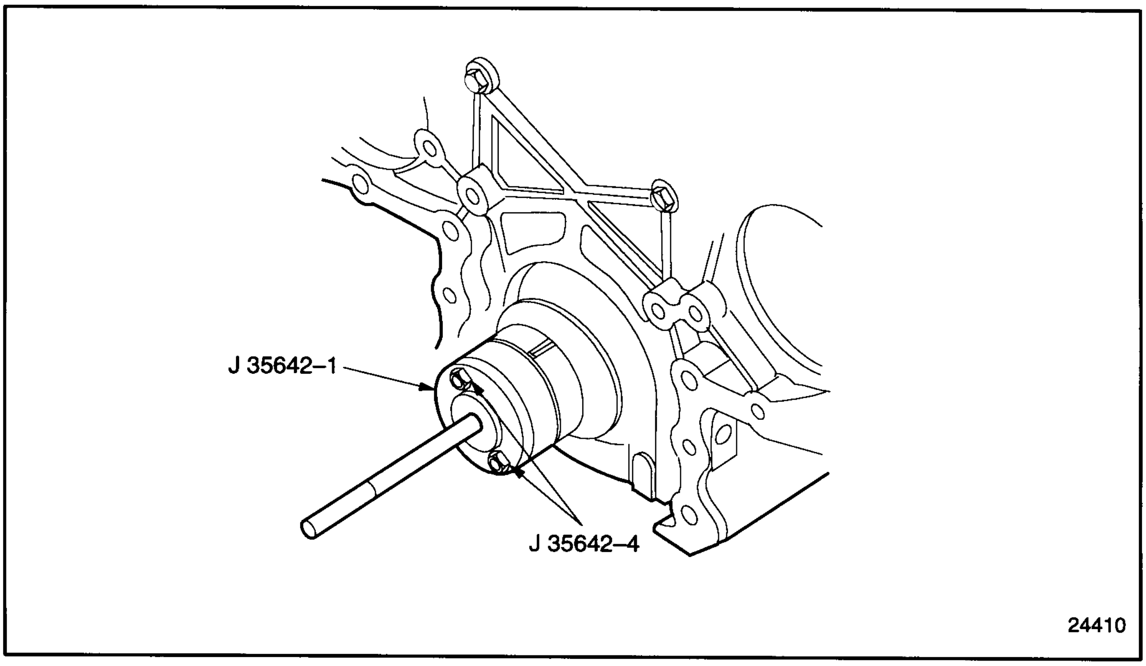


Figure 1-361 Base Post Installation

2. If removed, install the key to the keyway. Tap the key with a plastic mallet or brass hammer to seat. See Figure 1-362.

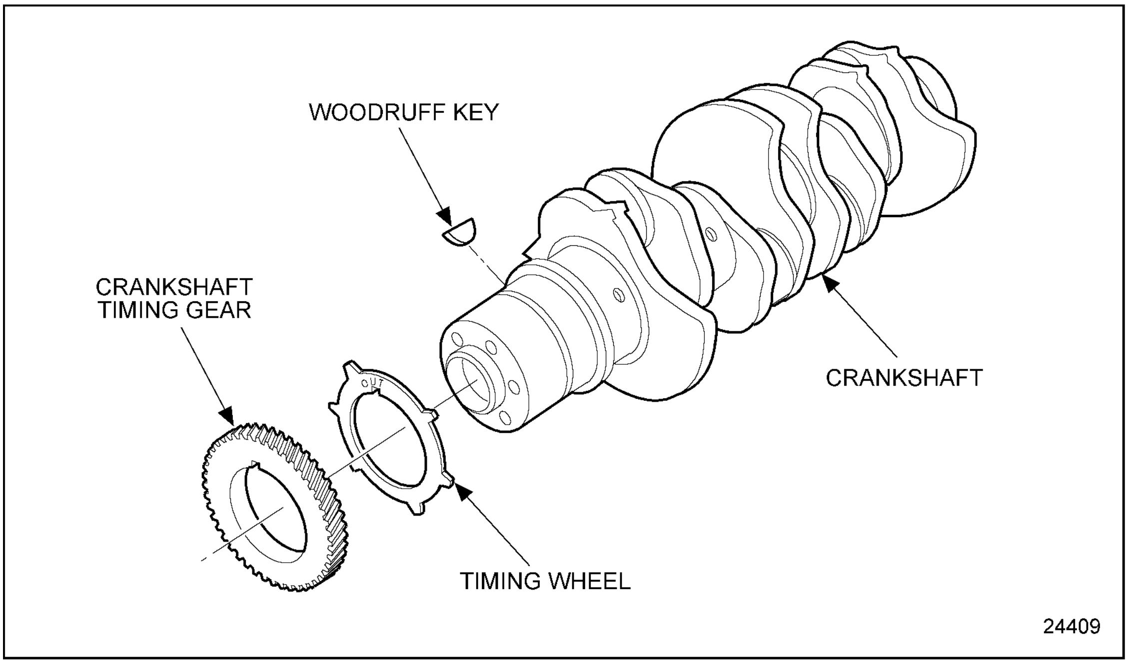


Figure 1-362 Non-Lock Key Installation

3. Index the keyway of the timing wheel with the key in the crankshaft. Slide the timing wheel onto the crankshaft, with the word OUT on the timing wheel facing you, as far as it will go without forcing it. See Figure 1-363.

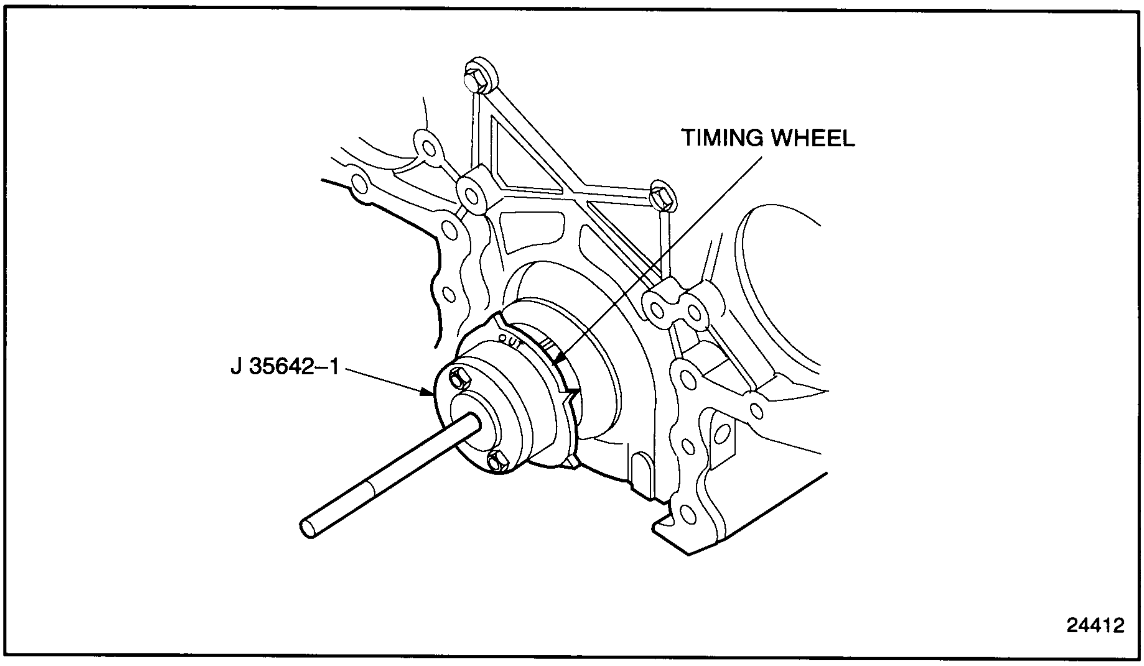


Figure 1-363 Timing Wheel Installation

4. Coat the bore of the crankshaft timing gear with a film of Lubriplate.

5. Index the keyway of the crankshaft timing gear with the Woodruff key in the crankshaft. Tap the gear with a plastic hammer or fiber mallet, to ensure that the key is started in the keyway. See Figure 1-364.

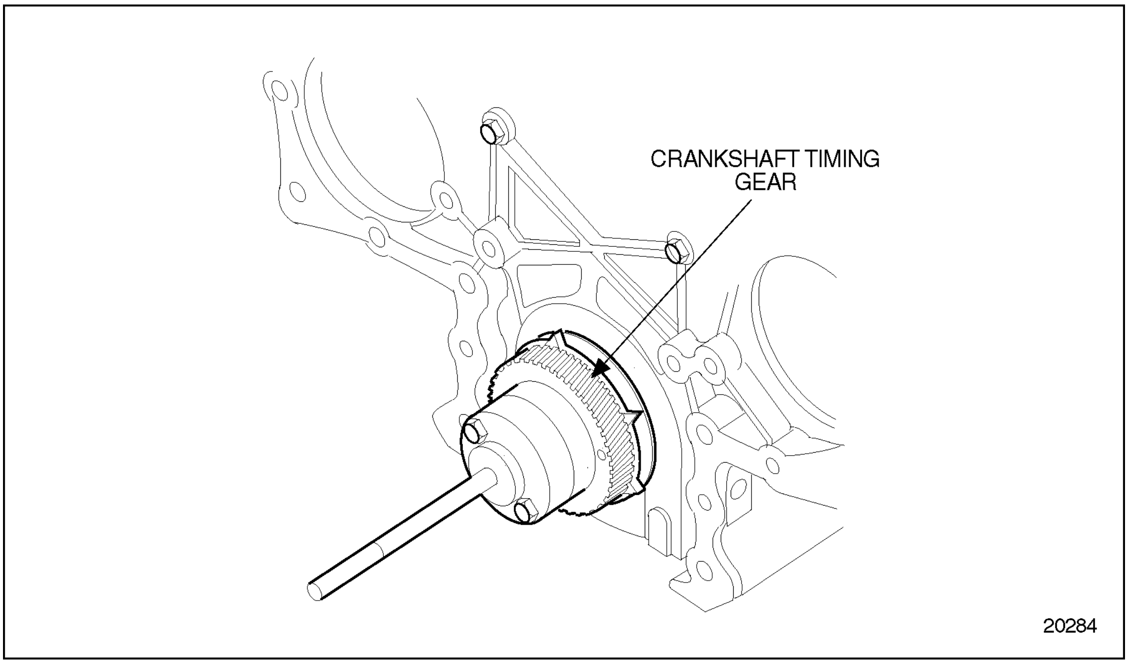


Figure 1-364 Crankshaft Timing Gear Indexing

6. Install the three legs of timing gear puller, J 35642-2 part of J 35642, part of tool kit J 35642, to the threaded holes in the crankshaft timing gear. Tighten the three legs, but do not torque. See Figure 1-365.

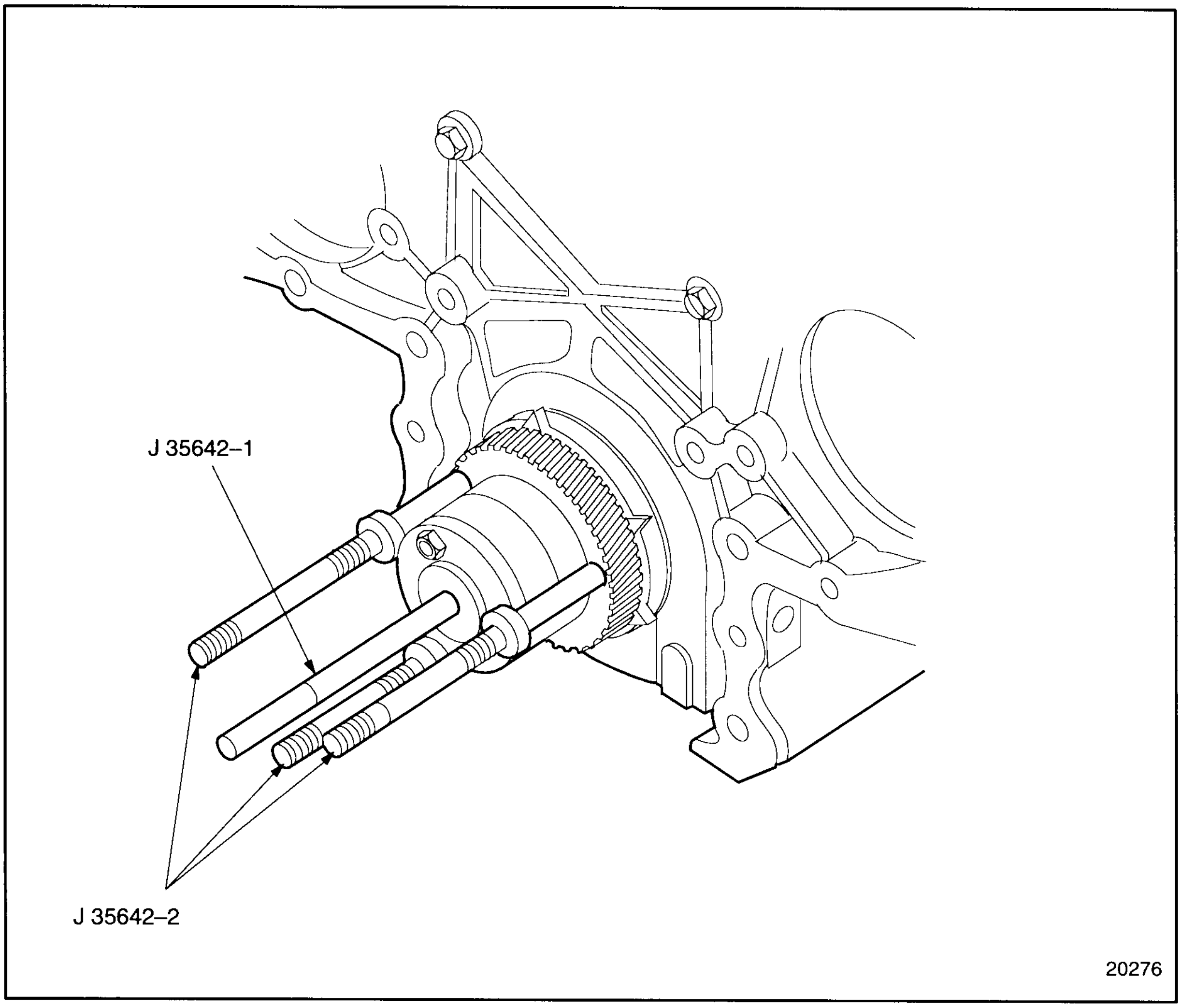


Figure 1-365 Puller Leg Installation

7. Install the pressure plate, J 35642-4 part of J 35642, part of tool kit J 35642, to the three pulley legs. Seat the pressure plate against the flanges on the puller legs. See Figure 1-366.

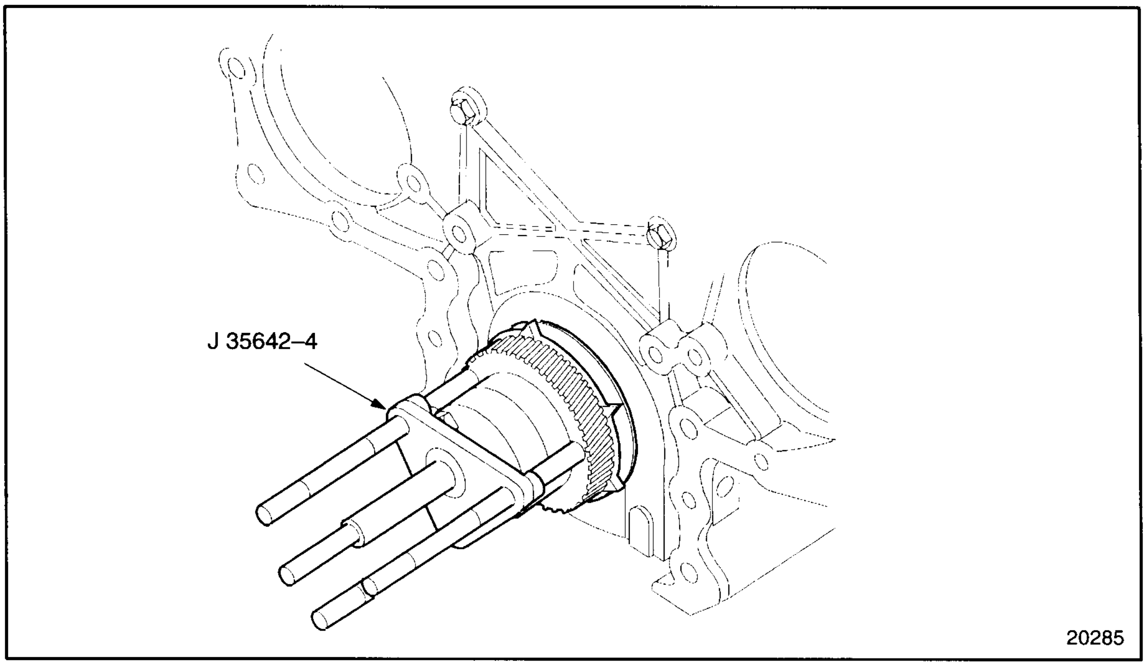


Figure 1-366 Pressure Plate Installation

8. Install the three retaining nuts to the puller legs. Thread the nuts past the first set of threads on the legs. Slide the nuts past the unthreaded portion of the shafts, and engage the second set of threads. Tighten but do not torque the retaining nuts. See Figure 1-367.

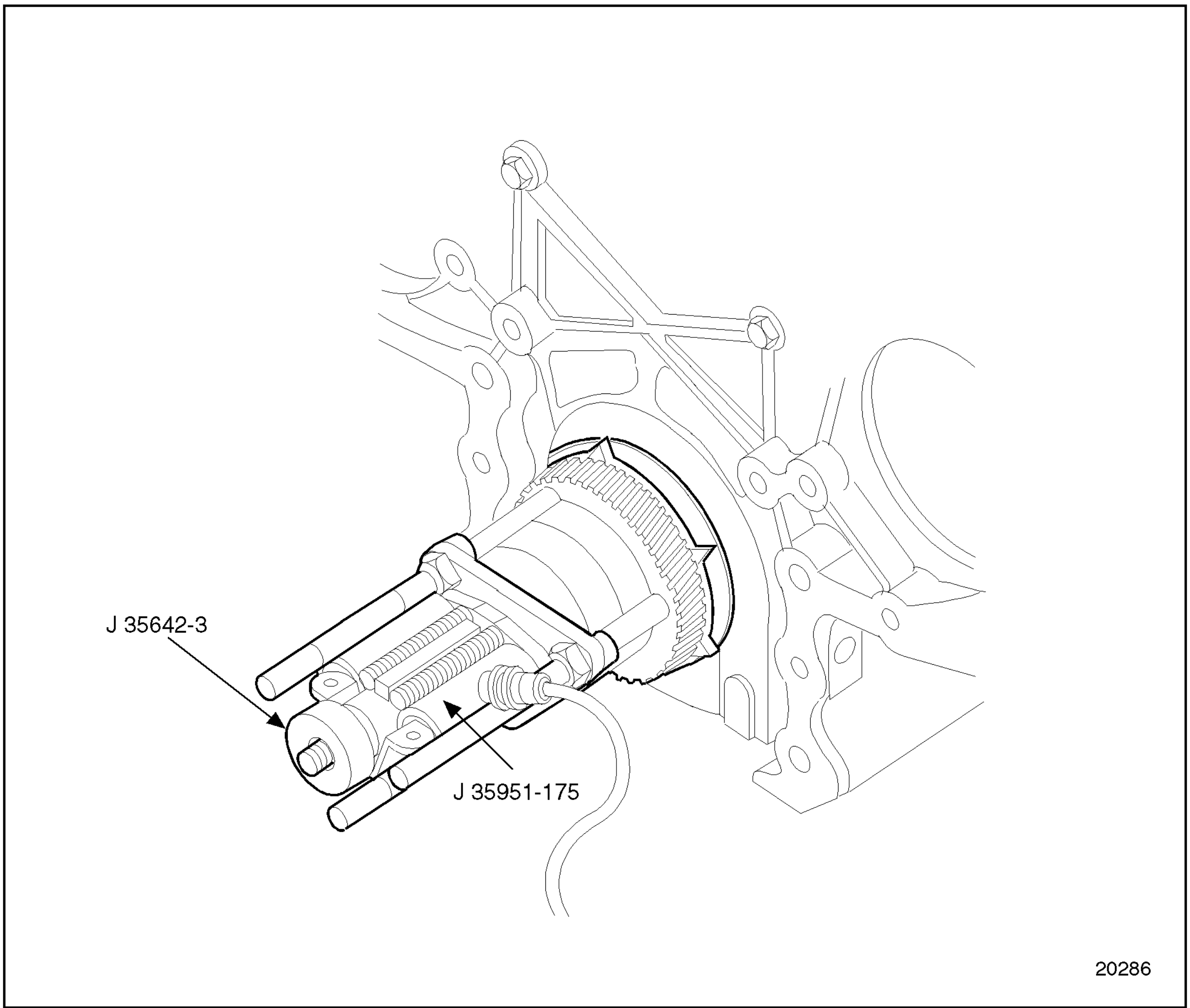


Figure 1-367 Crankshaft Timing Gear Installation Tools

9. Install the hydraulic ram to the base post rod. See Figure 1-367.
10. Install the stop nut, J 35642-3 part of J 35642, part of tool kit J 35642, to the end of the base post threaded rod. Tighten the stop nut.
11. Close the valve on the hydraulic pump, J 35951-175. Work the pump handle to supply hydraulic pressure to the ram. Make sure that the slot in the crankshaft timing gear indexes with the key in the crank. Pump until the crankshaft timing gear is seated firmly

against the timing wheel and the timing wheel is seated firmly against the crankshaft flange. See Figure 1-368.

NOTE:
A minimum force of 30 kN (3.37 tons) must be obtained when pressing the gear on the crankshaft.

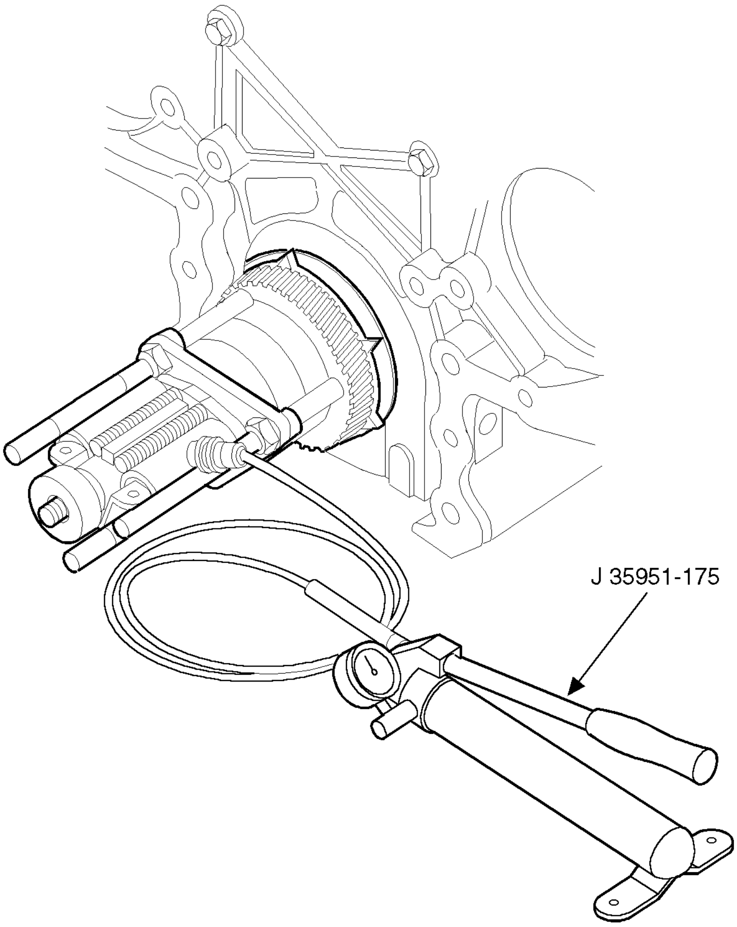


Figure 1-368 Crankshaft Timing Gear Installation

12. Remove the special tools as follows:
    [a] Open the valve on the hydraulic pump.
    [b] Remove the stop nut, J 35642-3 part of J 35642, part of tool kit J 35642, from the end of the base post threaded rod.
    [c] Remove the hydraulic ram from the base post rod.
    [d] Remove the three retaining nuts from the puller legs of timing gear puller, J 35642-2 part of J 35642, part of tool kit J 35642.

[e] Remove the pressure plate, J 35642-4 part of J 35642, part of tool kit J 35642, from the three pulley legs.

[f] Remove the three legs of timing gear puller, J 35642-2 part of J 35642, part of tool kit J 35642, from the threaded holes in the crankshaft timing gear.

[g] Remove the base post, J 35642-1 part of J 35642, part of tool kit J 35642, and two crankshaft pulley retaining bolts from the end of the crankshaft.

13. Install the bull gear and camshaft idler gear assembly to the gear case. Refer to Section 1.26.3.

NOTE:
Be sure to time the gears as instructed.

14. Install the balance assembly and outlet pipes. Refer to Section 1.28.3.
15. Measure the gear lash between the crankshaft timing gear and oil pump drive gear. Refer to Section 1.21.2.1.
16. Measure the lash between the crankshaft timing gear and the bull gear. Refer to Section 1.21.2.1.
17. Install the gear case cover. Refer to Section 1.10.3.
18. Install a new crankshaft seal and sleeve. Refer to Section 1.8.7.
19. Install the timing reference sensor (TRS). Refer to Section 2.21.3.
20. Install any components that were removed for access to the gear case cover.

1.28 BALANCE SHAFT AND OIL PUMP MECHANISM

The Series 50 Engines require a system to smooth the vibrations that are inherent in all four-stoke engines of inline, four cylinder configuration. Two counterweighted balance shafts rotate at twice the engine speed to cancel these forces. The balance mechanism is comprised of two gear driven balance shafts, the oil pump, oil suction and supply tubes, and the oil pressure relief and regulator valves. Engines built after S/N 4R-15542 use valve rocker arms without drilled oil passages to the valve adjusting screw. This supplies more oil to the balancer mechanism.

Engines used in transit bus applications require an oil analysis at each oil change. At 250,000 miles (400,000 km) an inspection of the balance shaft assembly is required.

1.28.1 Repair or Replacement of the Balance Shaft and Oil Pump Mechanism

To determine if repair or replacement of the balance shaft and oil pump mechanism is necessary, perform the following procedure. See Figure 1-369.

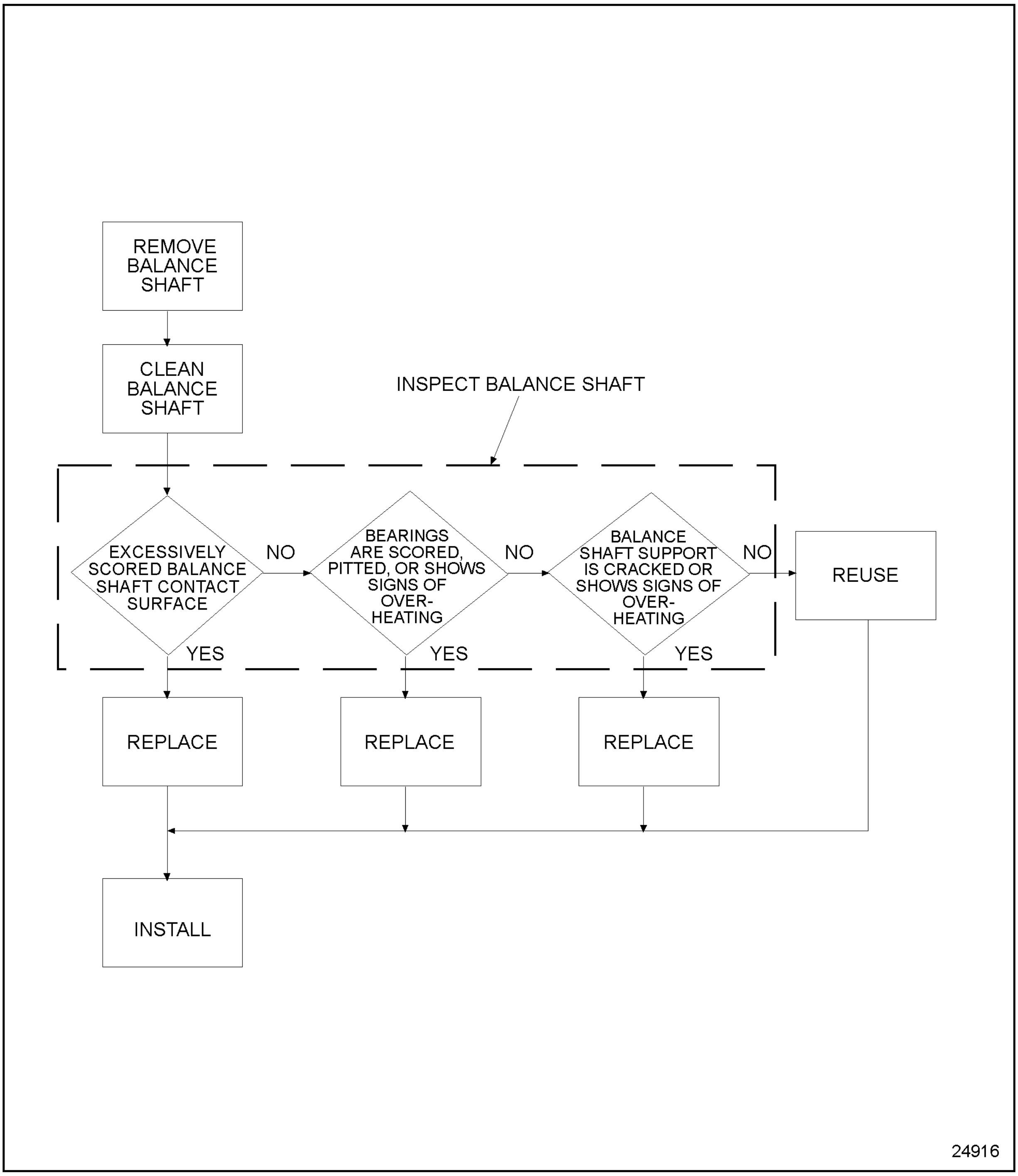


Figure 1-369 Flowchart for Repair or Replacement of the Balance Shaft and Oil Pump Mechanism

1.28.2 Cleaning and Removal of the Balance Shaft and Oil Pump Mechanism

Precleaning is not necessary.

Remove the balance shaft and oil pump mechanism as follows:

1. Set cylinder No. 1 at top-dead-center by barring the engine over until the piston reaches the top of the cylinder. The cylinder will then be at top-dead-center (TDC).
2. Drain the engine oil and remove the oil pan. Refer to Section 3.9.2.
3. Unfasten the two M10 capscrew that fasten the oil suction tube braces to the balance support.
4. Unfasten the two M8 capscrew that attach the suction tube flange to the oil pump body and remove the suction tube assembly.
5. Install oil pump gear holding tool, J 39816. See Figure 1-370.

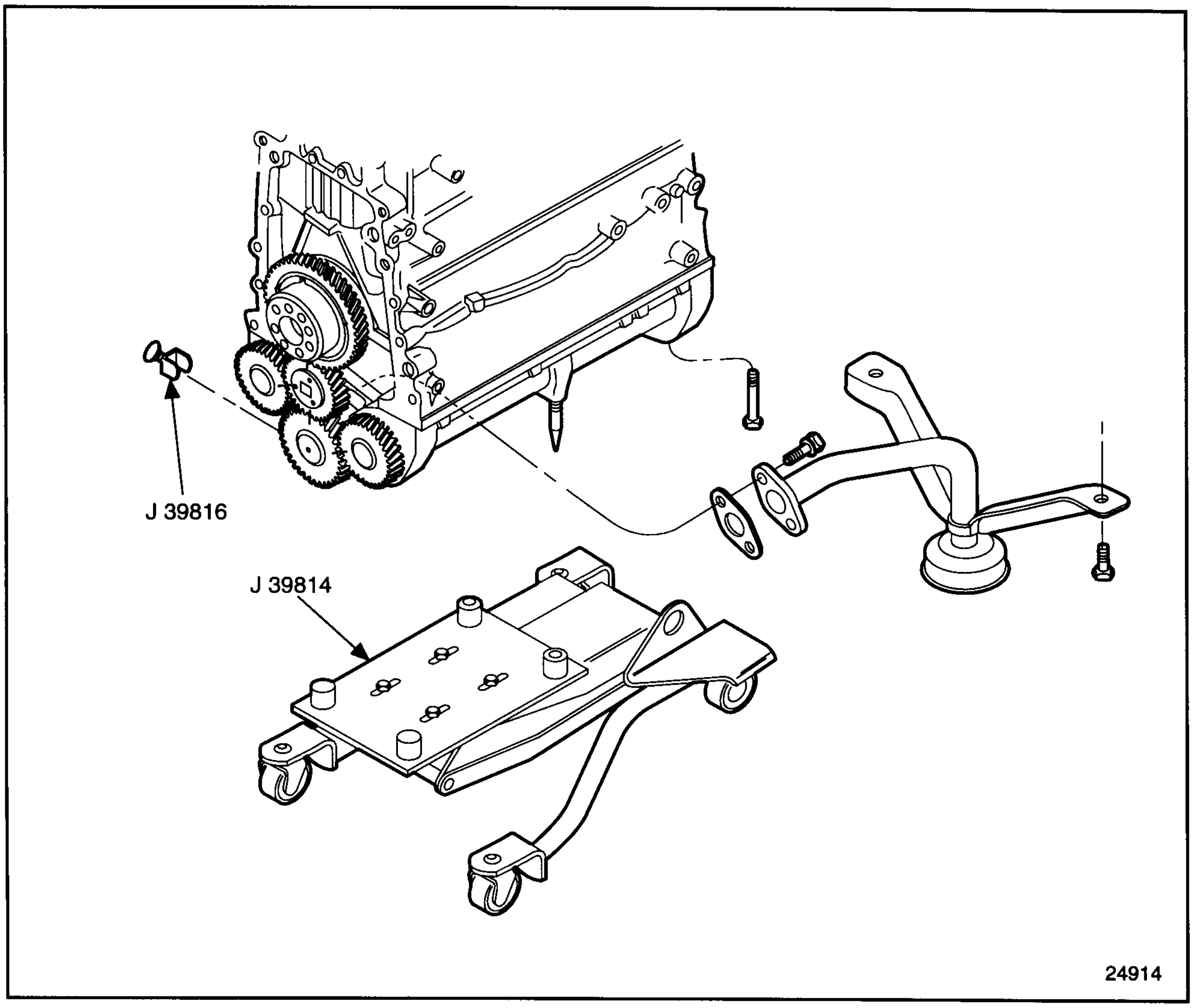
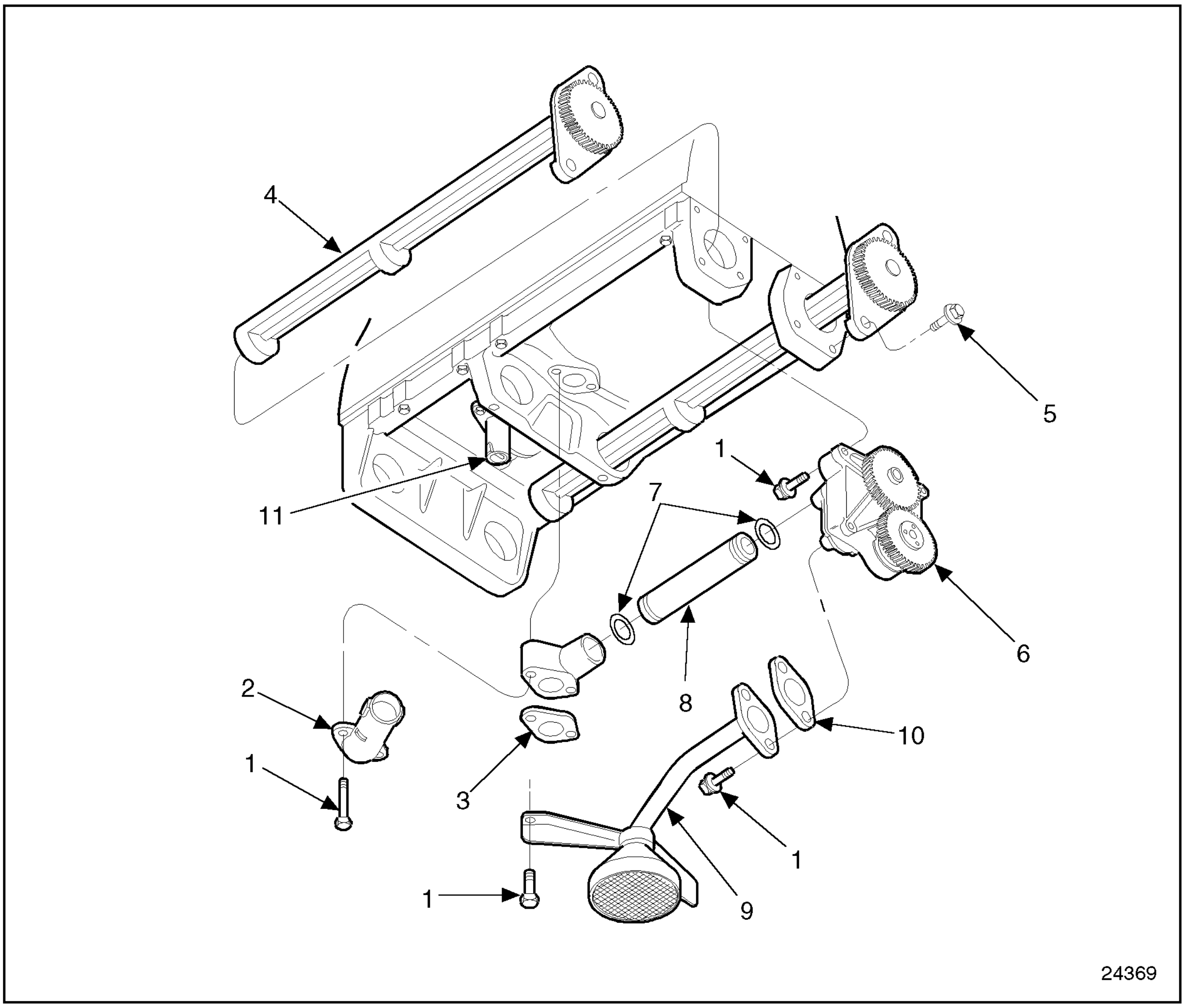


Figure 1-370 Oil Pump Gear Holding Tool

6. Support the balance assembly on the center and front bulkhead using tool, J 39814-A, and a transmission jack.

7. Remove the nine capscrews that fasten the balance assembly to the cylinder block and lower the assembly.
8. Lift the balance assembly from the transmission jack, turn it over and set it on a clean working surface using care not to damage the locating dowels.

Remove the oil pump as follows: See Figure 1-371.

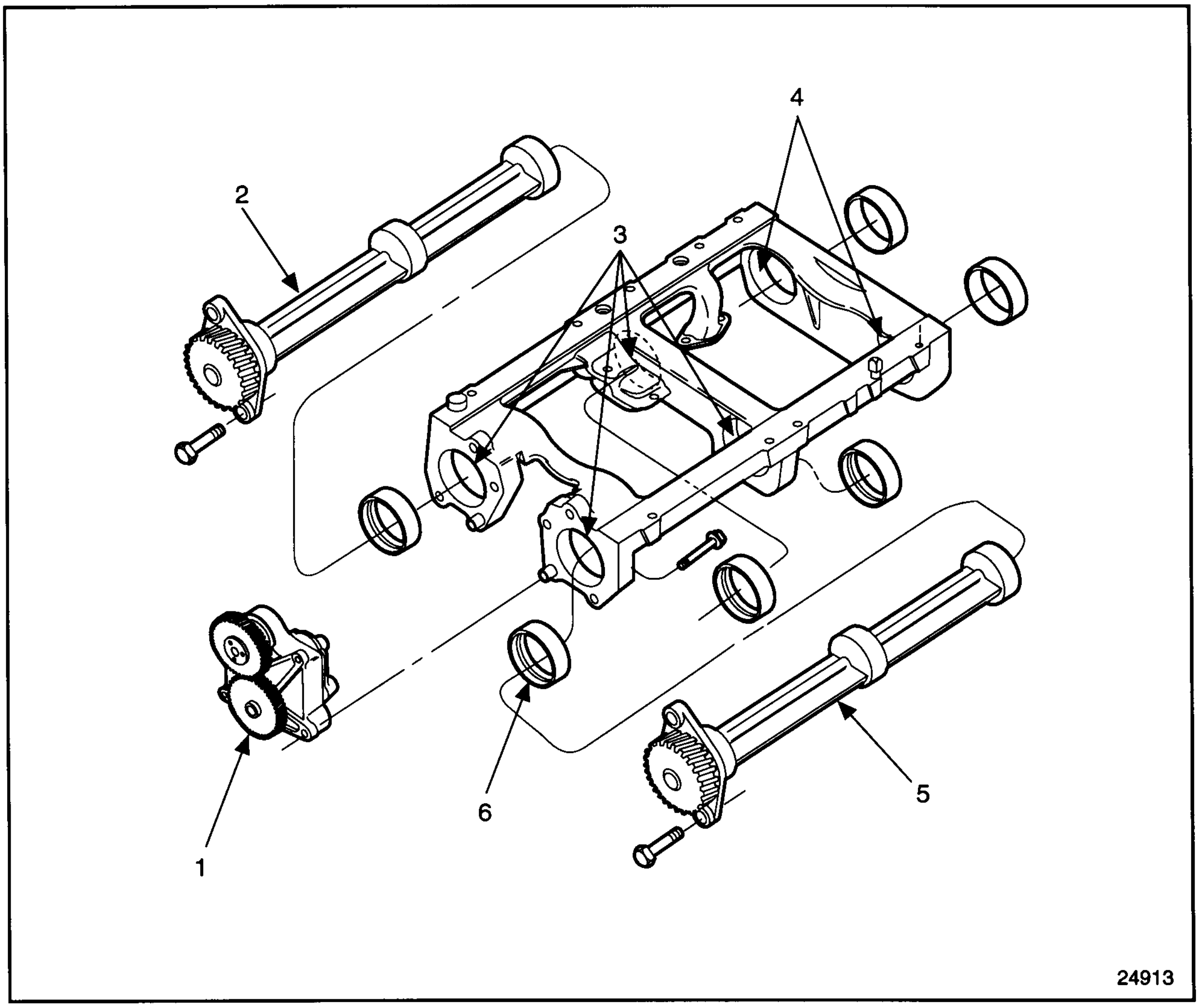


1. Bolt
2. Relief Valve
3. Gasket
4. Balance Shaft Assembly
5. Thrust Plate Bolt
6. Oil Pump Assembly
7. O-rings
8. Oil Feed Tube
9. Pick-up Tube and Bracket
10. Pick-up Tube Gasket
11. Regulator Valve

Figure 1-371 Oil Pump and Related Components Removal

1. Unfasten the four M8 capscrews that attach the oil pump to the balance support.
2. Loosen, but do not remove, the two M8 capscrews at each balance shaft thrust plate enough to allow the balance shaft to slide and create clearance for removal of the oil pump.
3. Remove the oil pump outlet tube and set it aside.

Remove the balance shaft as follows: See Figure 1-372.



1. Oil Pump
2. Balance Shaft
3. Wide Bushings
4. Narrow Bushings
5. Balance Shaft
6. Balance Shaft Bushing

Figure 1-372 Balance Assembly Disassembly

Remove the balance shaft bushings as follows:

1. Attach the balance shaft removal tool, J 39817, to the rearmost bearing journal face of the left side balance shaft. See Figure 1-373.

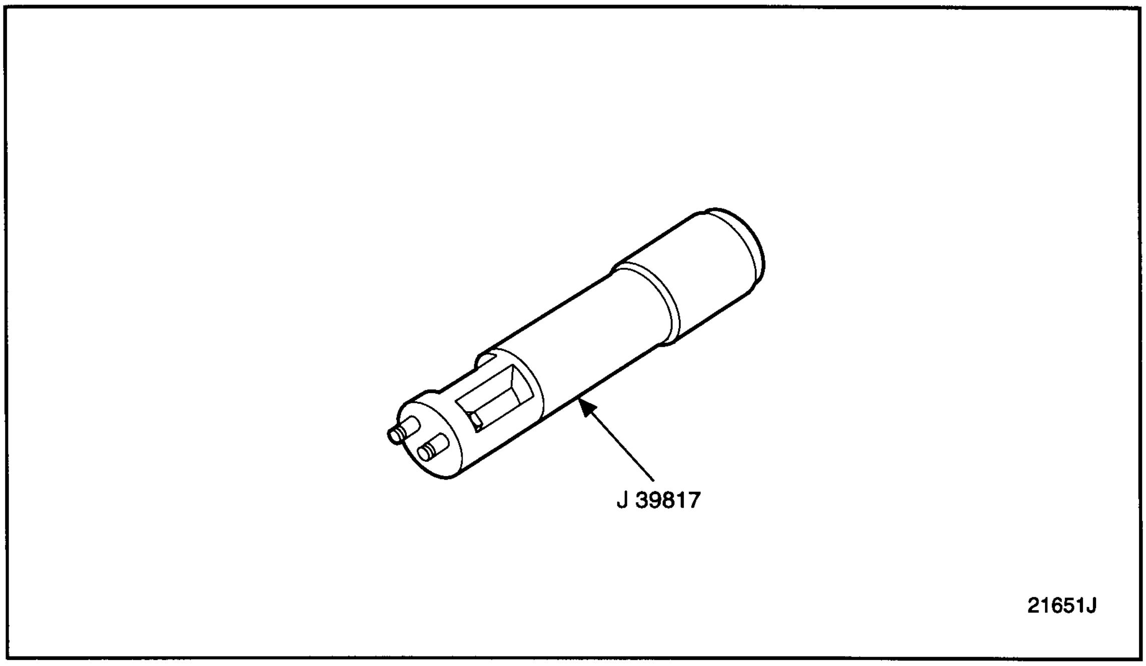


Figure 1-373 Balance Shaft Removal Tool

2. Remove the two M8 capscrews that attach the left side thrust plate to the balance support.
3. Slide the shaft out of the support, being careful to support the gear end and remainder of the shaft as it leaves the support.
4. Remove the balance shaft removal tool from the support and repeat the process for the right side shaft.

Using tool set J 39819, remove balance shaft rear bushings as follows:

1. Place bushing installer J 39819-1 and C-washer J 7593-4 onto the end of shaft 39819-5 and insert the shaft completely through the cradle from the front. See Figure 1-374.

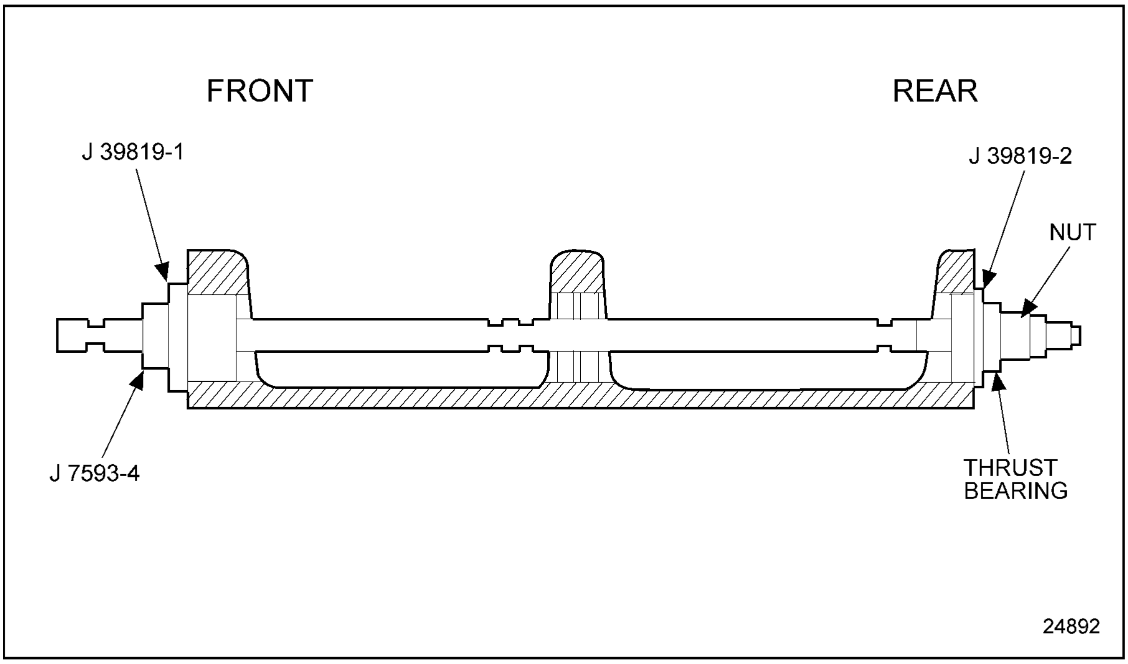


Figure 1-374 Remove Rear Bushings

2. Place bushing installer J 39819-2 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the rear bushing is removed.
4. Remove the tools and repeat this procedure to remove the remaining rear bushing.

Remove the balance shaft center bushings as follows:

1. Insert shaft J 39819-5 halfway through the front of the cradle, then place C-washer J 7593-4 and bushing installerJ 39819-2 over the threaded end. Pass the shaft through the center and rear bushing bore areas. See Figure 1-375.

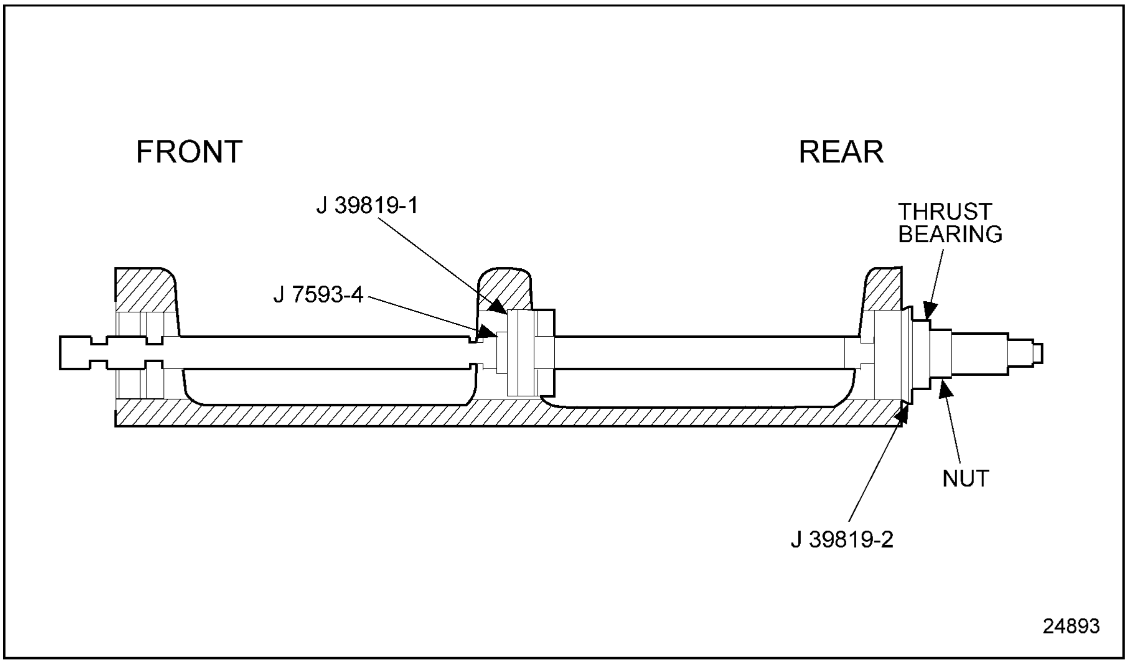


Figure 1-375 Remove Center Bushings

2. Place centering device J 39819-3 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the center bushing is removed.
4. Remove the tools and repeat this procedure to remove the remaining center bushing.

Remove balance shaft front bushings as follows:

1. Place C-washer J 7593 and bushing installer J 39819-2 onto the end of shaft J 39819-5 and insert the shaft completely through the cradle from the front. See Figure 1-376.

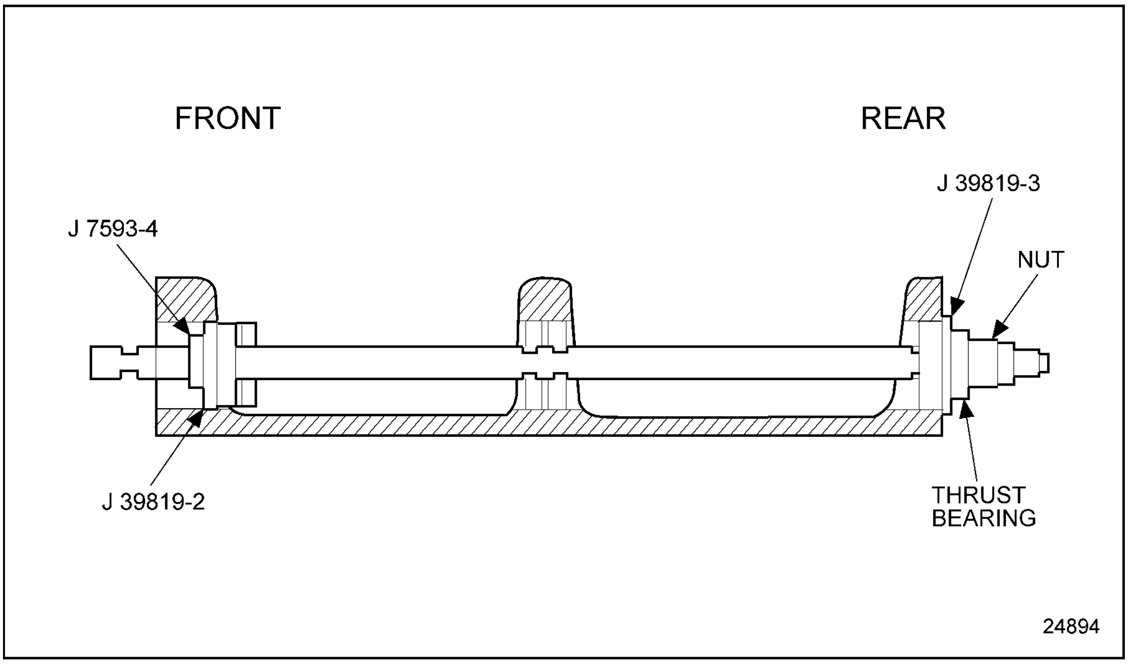


Figure 1-376 Remove Front Bushings

2. Place centering device J 39819-3 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the front bushing is removed.
4. Remove the tools and repeat this procedure to remove the remaining front bushing.

1.28.2.1 Inspection of the Balance Shaft

Inspect the balance shaft as follows:

1. Clean all removed parts in clean fuel oil.
2. Ensure all oil passages are clear.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Dry components with compressed air.
4. Inspect balance shaft contact surfaces for scoring, replace if excessively scored.
5. Inspect balance shaft bearings for scoring, pitting, flaking, etching, or signs of overheating. If any of these are evident the bearing must be replaced.
6. Inspect balance shaft support for cracks, signs of overheating, or other damage. Replace as necessary.

1.28.3 Installation of the Balance Shaft

Install balance shaft rear bushings as follows:

1. Place bushing installer J 39819-1 and C-washer J 7593-4 onto the end of shaft J 39819-5 and insert the shaft completely through the cradle from the front. See Figure 1-377.

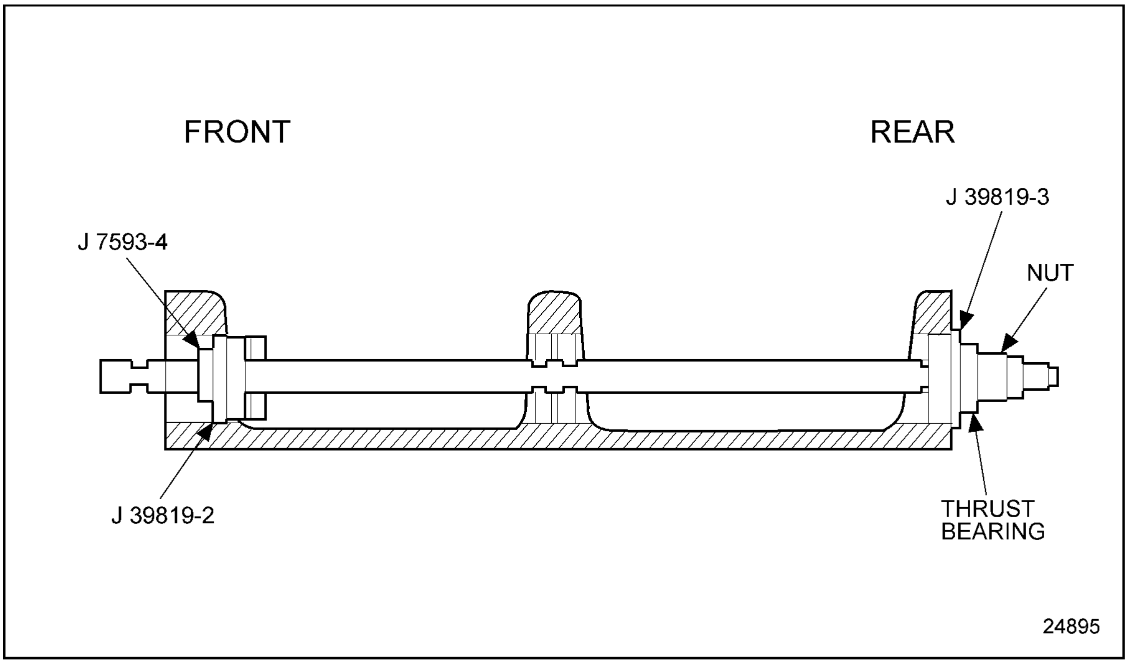


Figure 1-377 Install Rear Bushings

2. Place a new bushing on bushing installerJ 39819-2 and install over the threaded end of the shaft. Place the thrust bearing on the shaft and install the 1 7/16 in hex nut.

3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the rear bushing is installed.
4. Remove the tools and repeat this procedure to install the remaining rear bushing.

Install the balance shaft center bushings as follows:

1. Place bushing installer J 39819-1 and C-washer J 7593-4 onto the end of shaft J 39819-5 and insert the shaft half way through the cradle from the front. See Figure 1-378.

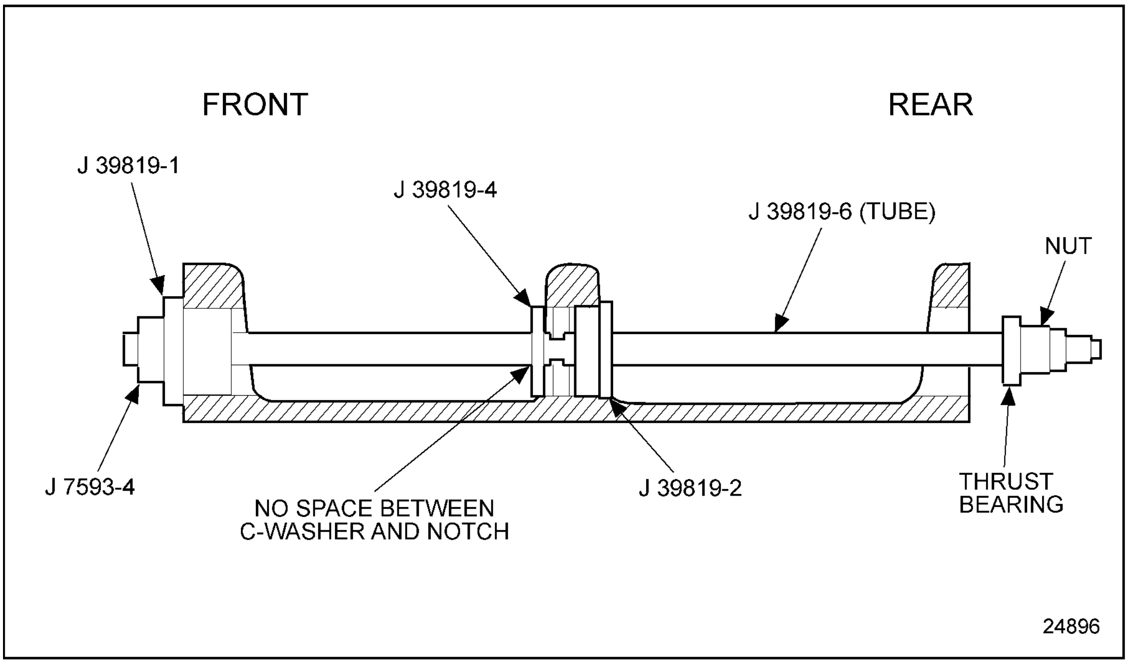


Figure 1-378 Install Center Bushings

2. Install C-washer J 39819-4 onto the shaft and pass the shaft through center bearing bore.
3. Position a new bushing on installerJ 39819-2, install onto the shaft, and pass the shaft completely through the rear bore. The bushing is located properly when the J 39819-4 C-washer is tight against the back of the notch in the shaft
4. Slip tube J 39819-6 over the shaft, then install the thrust bearing and nut onto the threaded end of the shaft.

NOTICE:
Before installing the bushing, align the hole in the bushing with the oil supply hole in the bearing bore. Failure to observe this step will result in inadequate flow of lube oil to the bearing, which may lead to bearing and shaft damage.

5. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the center bushing is installed.
6. Remove the tools and repeat this procedure to install the remaining center bushing.

Install the balance shaft front bushings as follows:

1. Place C-washer J 7593 and bushing installer J 39819-1 onto the end of shaft J 39819-5 and position a new bushing on the installer. Insert the shaft completely through the cradle from the front. See Figure 1-379.

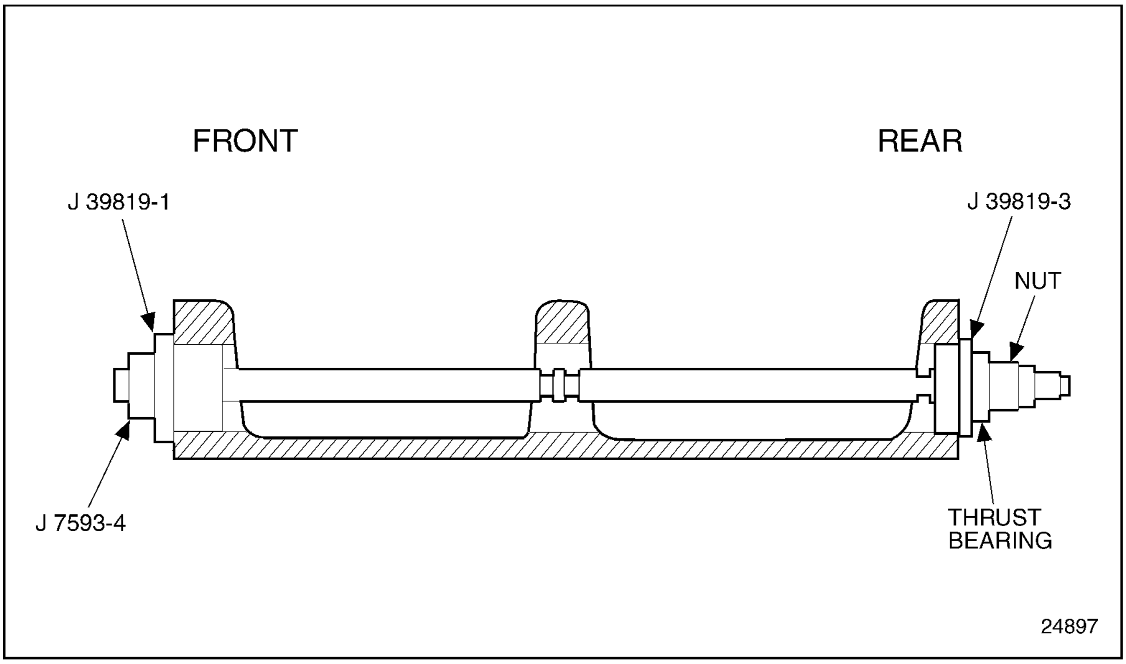


Figure 1-379 Install Front Bushings

2. Place centering device J 39819-3 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the front bushing is installed.
4. Remove the tools and repeat this procedure to install the remaining front bushing.

Install the balance shaft and assembly as follows:

1. Attach the balance shaft installation service tool, J 39817, to the right side shaft.

2. Lubricate the bushing in the support and the shaft journals with clean engine oil.
3. With balance shaft weights on top and supporting the gear end of the shaft assembly, slide the installation tool and shaft into the support.
4. To allow clearance for assembly of the oil pump, loosely install the two M8 capscrews that fasten the thrust plate to the support.
5. Repeat the previous steps for the left side shaft.
6. Proper timing of the balance mechanism is essential to proper engine operation. Using the oil pump gear holding tool J 39816, the balance shafts can be aligned and held in the position necessary to attain proper timing.

NOTE:
The counterweighted balance shafts will naturally want to rotate back into position unless held in place.

7. Before installation of the oil pump, rotate the drive gear so that the timing marks match the locating of those on the balance shaft gears. See Figure 1-380.

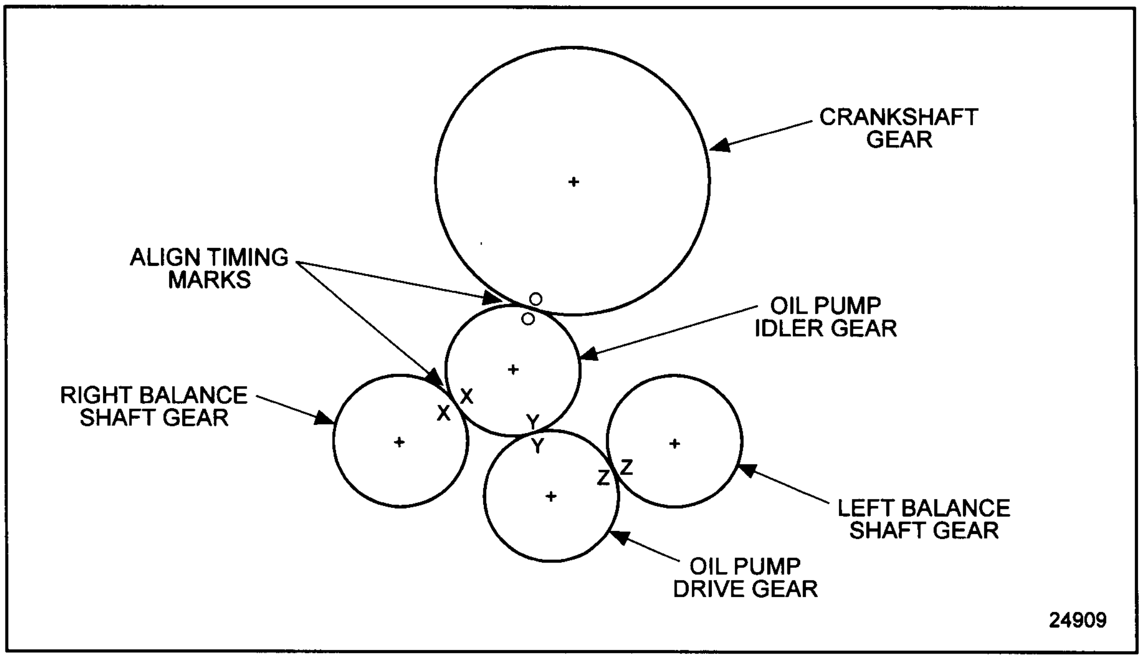


Figure 1-380 Balance Shaft Drive Gear Timing

Install the oil pump as follows:

1. Install the oil pump, taking care to match each of the letters stamped on the pump idler gear and pump drive gear with the same letter of the left and right side balance shafts.

2. When sure that all of the gears are properly aligned, tighten the M8 capscrews in each of the thrust plates, torque 34 N·m (25 ft·lb).

NOTE:
Bolts are installed from back side of pump.

NOTE:
Effective with engine serial number 4R25678 manufactured on September 18, 1998, an improved oil pump and balance shaft assembly is used. The improved oil pump is fastened to the balance support assembly with M10 bolts (torque to 66 N·m [49 ft·lb]). The former oil pump was fastened with M8 bolts (torqued to 34 N·m [25 ft·lb]). The bolts are installed from the back side of the oil pump. See Figure 1-381.

3. Install and tighten the four bolts that attach the oil pump to the balance support. See Figure 1-381.

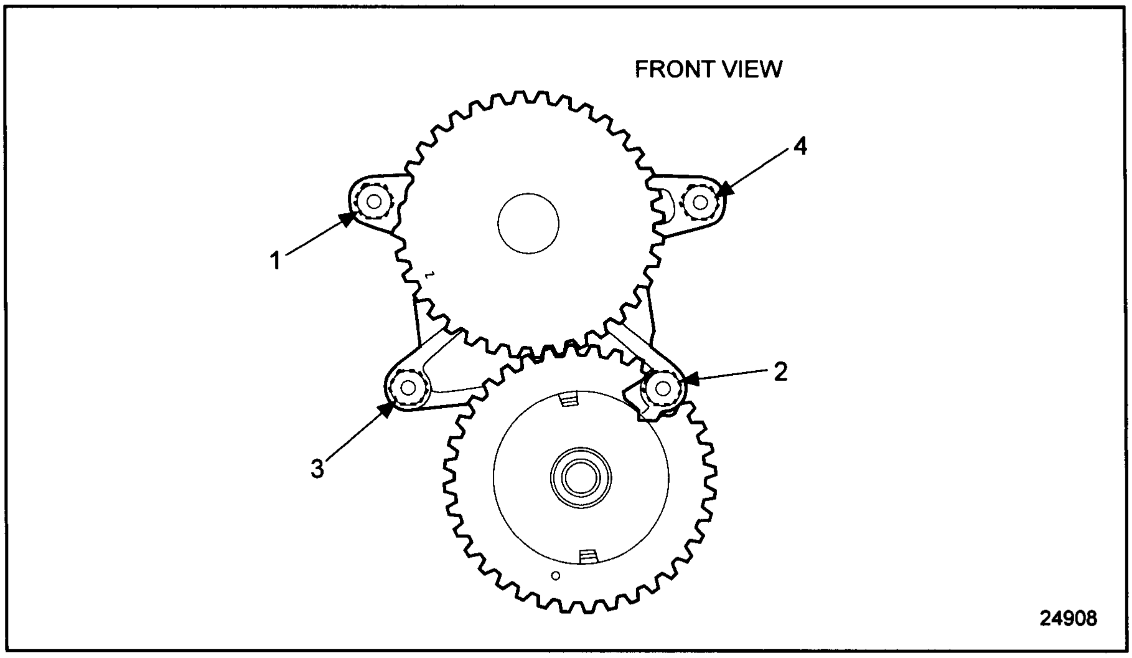


Figure 1-381 Oil Pump Bolt Torque Sequence

4. To aid balancer timing, leave the oil pump gear holding tool, J 39816, in place until the balance assembly is installed in the engine.
5. Install new O-ring seals on both ends of the oil pump outlet tube and lubricate them with clean engine oil.
6. Loosely assemble the left and right side oil inlet tube brackets to the inlet tube using the M10 nuts and bolts.
7. Install one end of the oil pump outlet tube into the inlet tee, the other into the pump body.

8. Install the inlet tee and attach the relief valve using two M8 capscrews torque 34 N·m (25 ft·lb).
9. Install the regulator valve using two M8 capscrews torque 34 N·m (25 ft·lb).
10. Install the two M10 capscrews that attach the left and right side oil inlet tube brackets to the support torque 48 N·m (35 ft·lb).
11. Tighten the M10 nuts and bolts that fasten the tube bracket to the inlet tube.
12. Attach the balancer assembly to the lifting jack service tool, J 39814-A.
13. Use guide studs in opposite center holes to properly align the balance shaft support.
14. Before the balance assembly is fastened to the cylinder block, make sure again that the timing marks on the balance gears are aligned with the oil pump idler and drive gears and that cylinder No. 1 at top dead center (on either the compression or exhaust stroke). With cylinder No. 1 at top dead center and all gear meshes properly aligned, the counter weights for both balance shafts should be in the bottom most, or 6 o'clock, position.
15. Raise the balance assembly to the cylinder block and attach it using the nine M12 capscrews torque 115 N·m (85 ft·lb).
16. Remove guide studs and stall remaining two bolts, torque to 115 N·m (85 ft·lb).
17. Remove the oil pump gear holding tool, J 39816, from the balance shafts.
18. Install the oil pan.

1.28.4 Installing a Balance Shaft and Oil Pump Mechanism (Which Has Not Been Disassembled)

If the balance shaft and oil pump mechanism is removed from the Series 50 engine and is not disassembled, it can be reinstalled on the engine and correctly timed without further disassembly of engine components. The procedure outlined below permits reinstallation of this mechanism with a minimum of engine downtime. Only this procedure should be used when replacing a balance shaft and oil pump mechanism which has not been disassembled.

To reinstall a balance shaft and oil pump mechanism which has not been disassembled, proceed as follows:

1. Remove two M8 bolts in each balance shaft thrust plate and slide the shafts forward, disengaging them from the lube oil pump/idler gear assembly.

2. Spin the pump/idler gears until the "Y" letters line up. See Figure 1-382. This may require up to 20 turns.

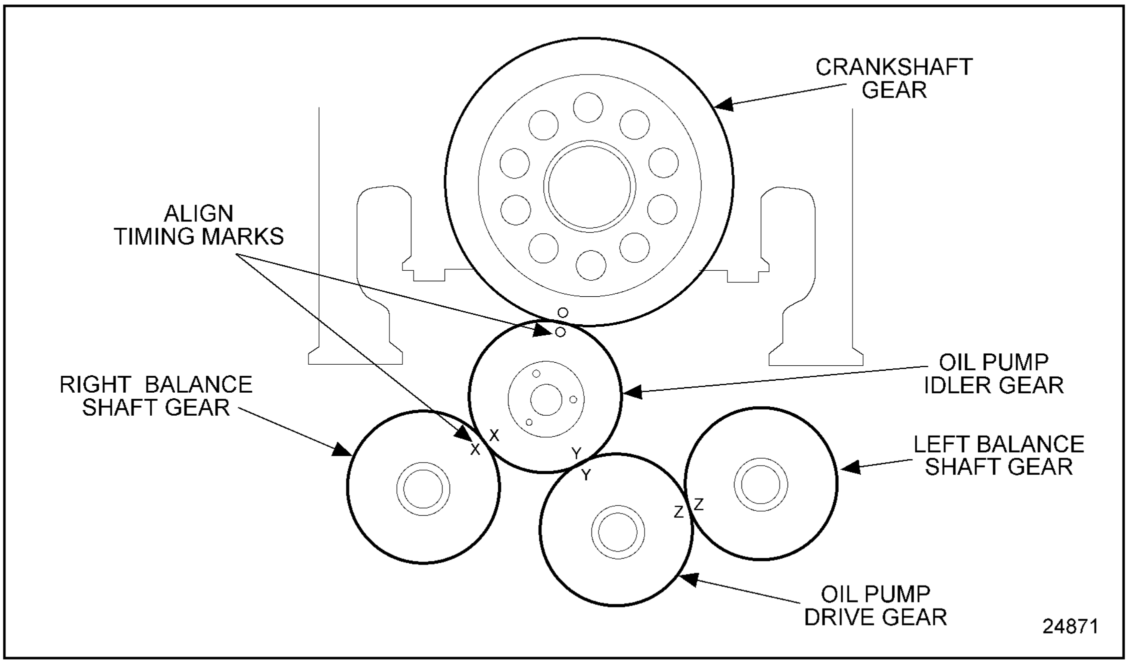


Figure 1-382 Balance Shaft Drive Gear Timing

3. With the "Y's" lined up on the pump gear and idler gear, install the left and right balance shafts with the timing marks lined up as shown. See Figure 1-382.

4. Lock the mechanism in this position with oil pump gear holding tool J 39816. See Figure 1-383.

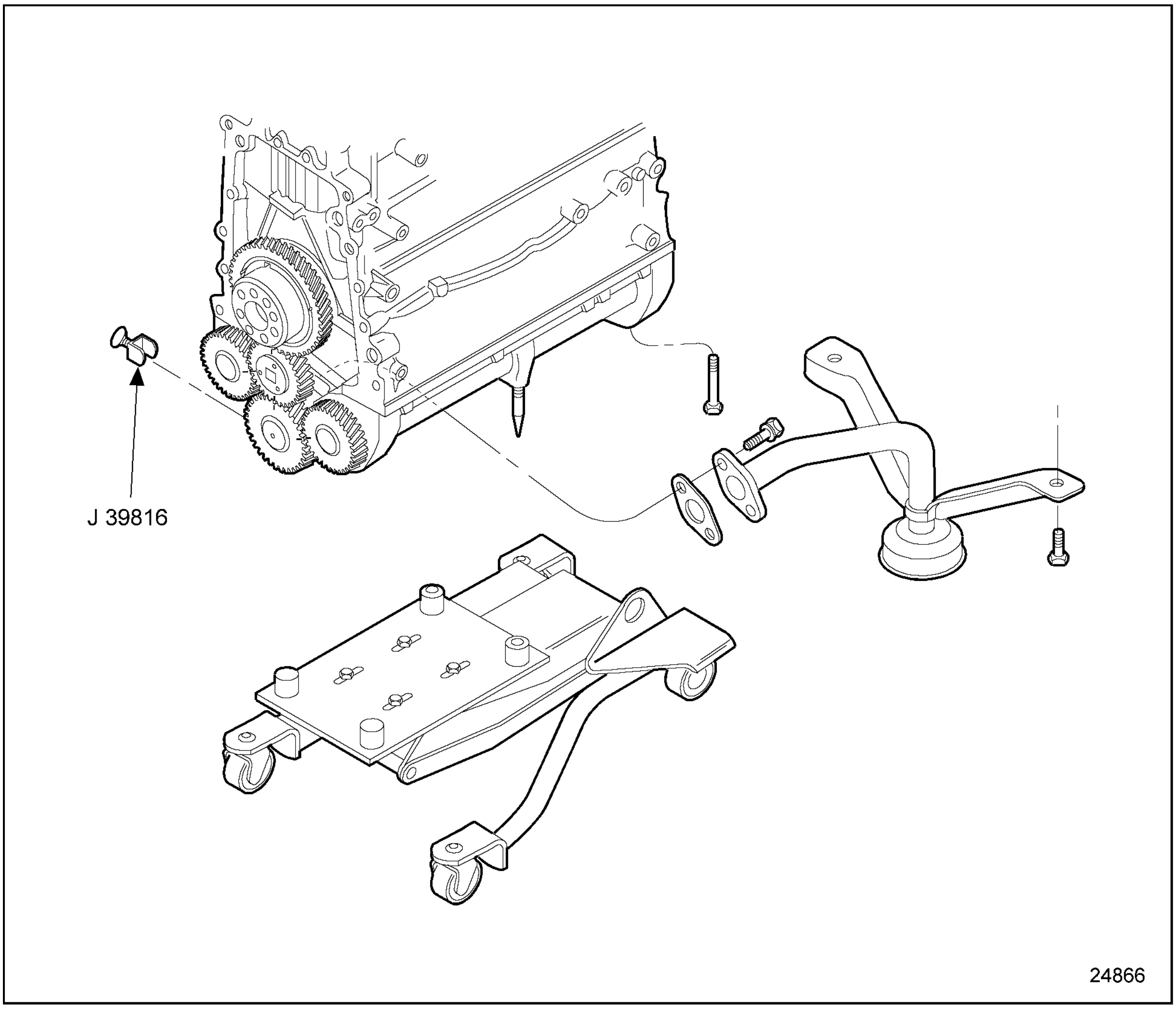


Figure 1-383 Balance Shaft and Oil Pump Mechanism Showing Tool J 39816

5. Reinstall the two M8 bolts in each balance shaft thrust plate and torque to 30 - 38 N·m (22 - 28 lb·ft). Recheck position of timing marks and realign, if required.
6. Bar the engine until the "O" on the crankshaft gear is in the *down* position.

NOTICE:
Failure to establish piston top dead center or to properly align timing marks on balance shaft and idler gears or to line up the " O" marks on the crank gear and oil pump idler gear before reinstalling the balance shaft and oil pump mechanism will result in an out-of-time condition. This will cause engine vibration, which may lead to serious engine damage after start-up.

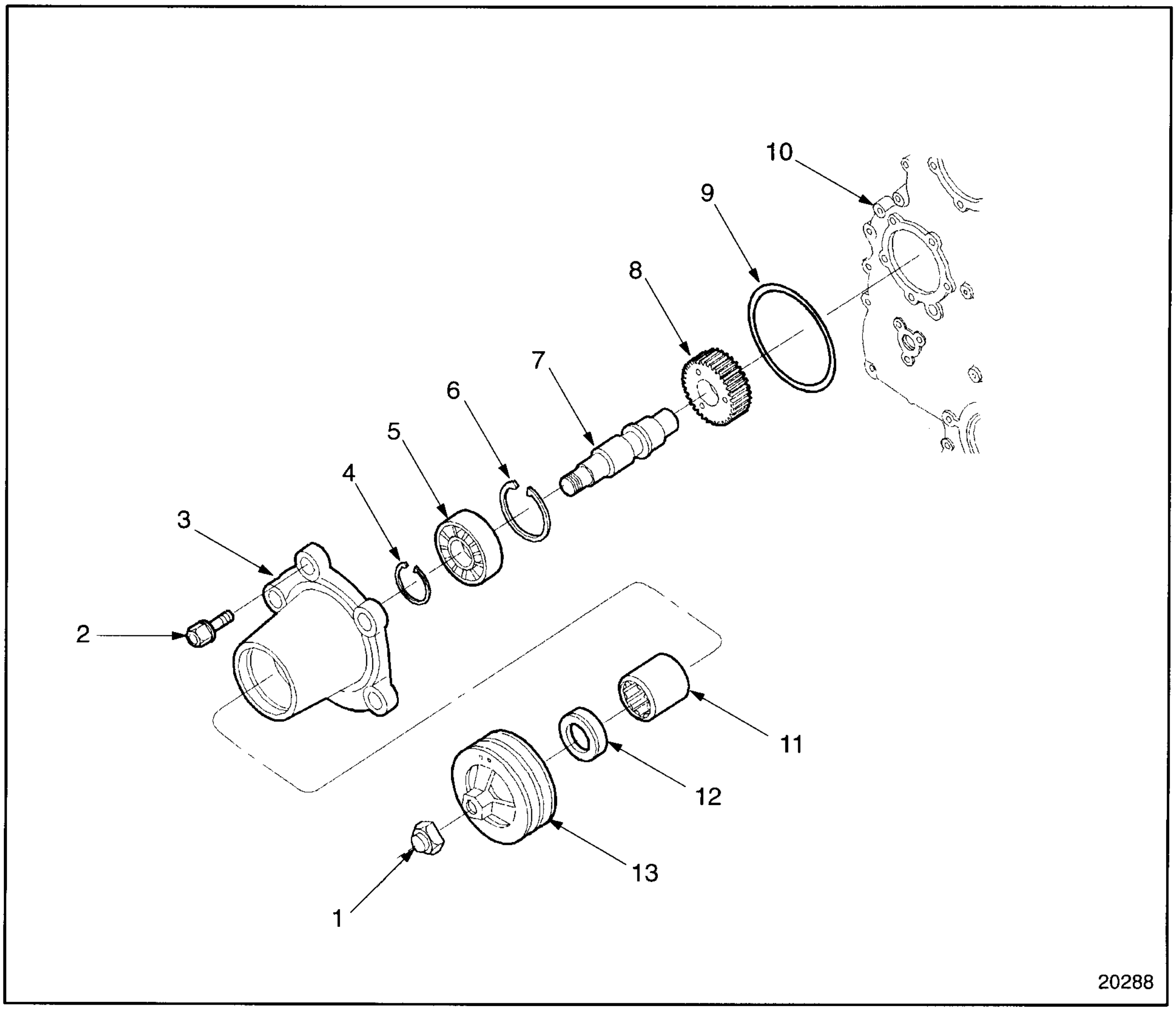
7. Attach the mechanism to lifting jack service tool J 39814. Make sure guide studs are installed in opposite center holes to properly align the mechanism support.
8. Using a transmission jack, carefully raise the mechanism to the cylinder block, lining up the "O" marks on the crank gear and oil pump idler gear. See Figure 1-383.
9. Secure the mechanism to the block with the nine M12 cap screws previously removed. Torque screws to 115 N·m (85 lb·ft).
10. Remove the guide studs from the mechanism and reinstall the two remaining M12 cap screws. Torque to 115 N·m (85 lb·ft).
11. Using the two M8 capscrews removed, attach the suction tube flange to the oil pump body.
12. Remove oil pump gear holding toolJ 39816.
13. Using the two M10 capscrews previously removed, fasten the oil suction tube brackets to the balance support.

NOTICE:
Failure to remove the oil pump gear holding tool before installing the oil pan may result in severe gear train damage at engine startup.

14. Install the oil pan.

1.29 ACCESSORY DRIVE

The accessory drive assembly is mounted to the front of the gear case cover and utilizes a two-groove pulley to drive the alternator. See Figure 1-384.



1. Locknut
2. Mounting Bolts (5)
3. Drive Housing
4. Snap Ring (Small)
5. Ball Bearing
6. Snap Ring (Large)
7. Driveshaft
8. Drive Gear
9. O-ring
10. Gear Case Cover
11. Needle Bearing
12. Oil Seal
13. Pulley

Figure 1-384 Accessory Drive Assembly Related Parts

The accessory drive assembly is splash fed oil through two holes in the casting of the accessory drive housing. The oil returns to the crankcase via the gear case.

The accessory drive is driven by a drive gear which is pressed onto the driveshaft. The drive gear meshes with the bull gear and is driven at 2.41 times engine speed.

The driveshaft is supported by a ball bearing at the drive end and a needle bearing at the pulley end.

NOTE:
A design change has been made to the accessory drive assembly. The needle bearing inner race is now incorporated into the driveshaft. See Figure 1-384.

An O-ring is used to seal the accessory drive housing to the gear case cover.

1.29.1 Repair and Replacement of the Accessory Drive

To determine if repair is possible or replacement is necessary, perform the following procedures. See Figure 1-385.

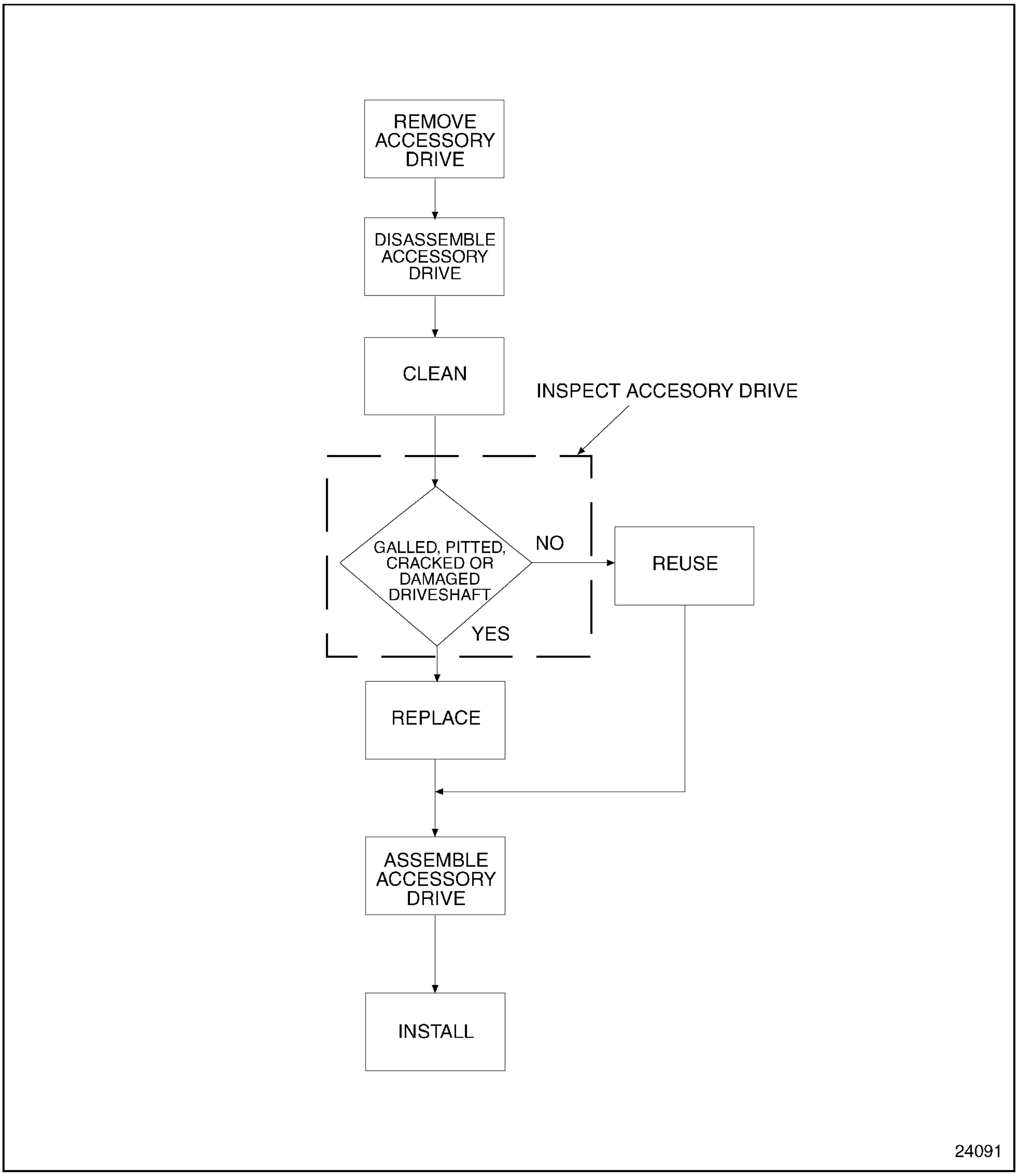


Figure 1-385 Flowchart for Repair or Replacement of Accessory Drive

1.29.2 Cleaning and Removal of the Accessory Drive

Precleaning is not necessary.

Remove the accessory drive as follows:

1. Loosen the alternator mounting bolts and the adjusting rod nuts to get slack in the alternator drive belts. Remove the alternator drive belts. See Figure 1-386.

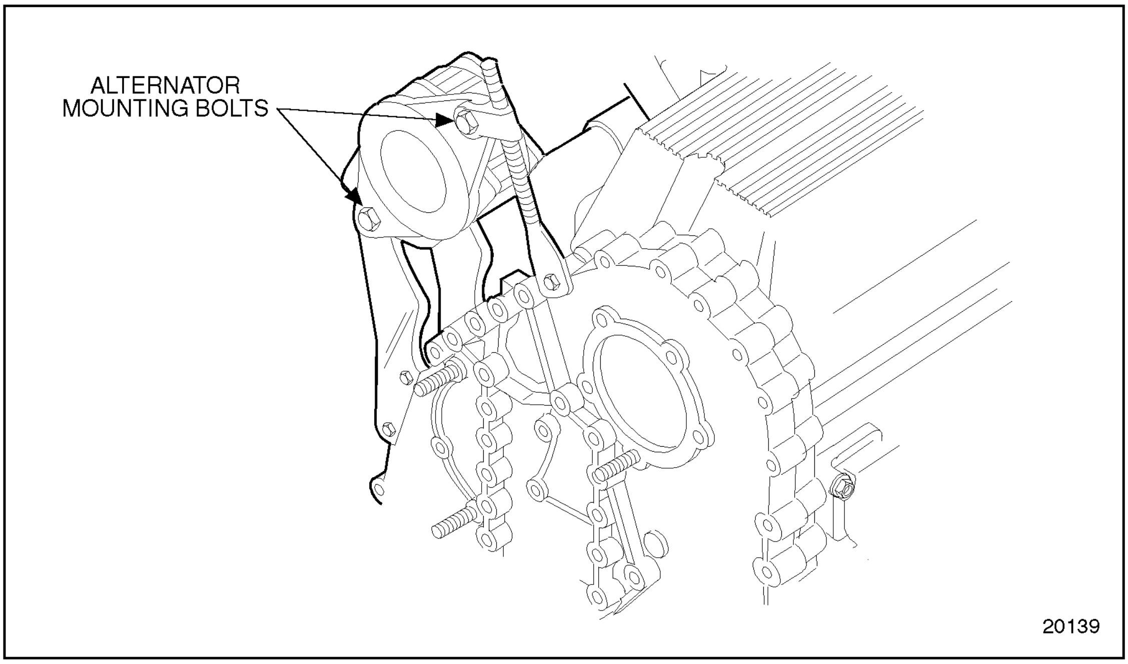


Figure 1-386 Alternator Mounting Bolts

2. Loosen and remove the five bolts that secure the accessory drive assembly to the gear case cover.

3. Remove the accessory drive assembly by pulling it straight out of the gear case cover to avoid damaging the rubber O-ring. See Figure 1-387.

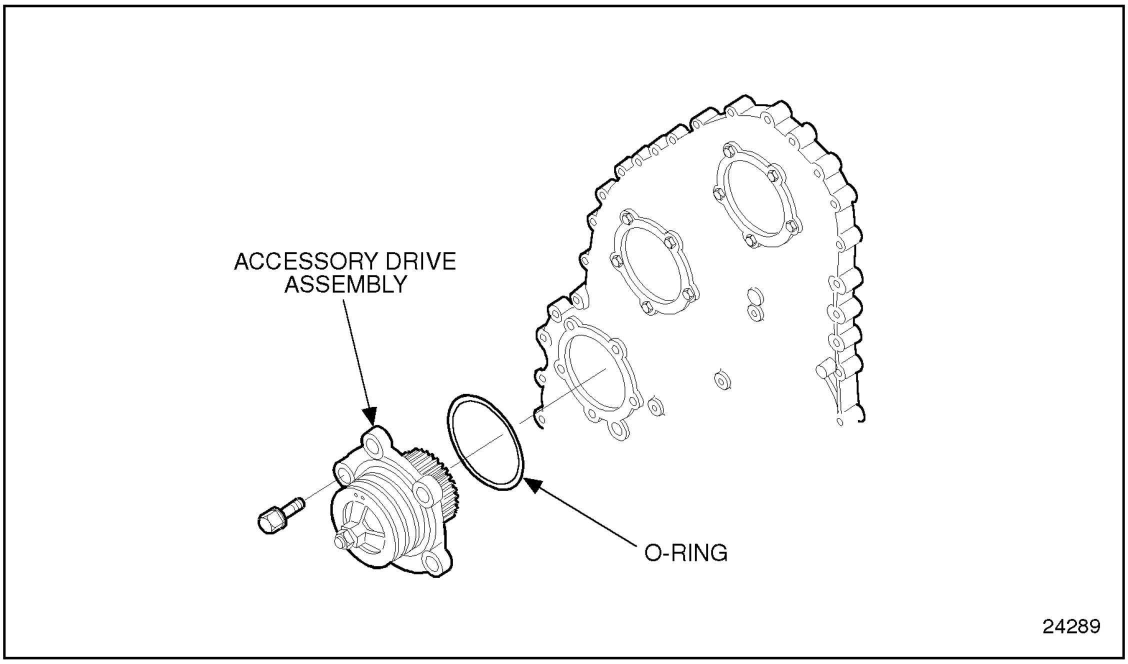


Figure 1-387 Accessory Drive Assembly Removal

1.29.3 Disassembly of the Accessory Drive

Disassemble the accessory drive as follows:

NOTE:
For disassembly and assembly of the accessory drive use toolset J 36024-D. See Figure 1-388

NOTE:
Engines built after December 2000, use the following tools for accessory drive seal removal and installation: J 45533 seal remover, J 45833 seal installer, and J 45877 seal

runout gauge adapter to verify proper installation of seal in accessory drive. These tools are part of toolset J 36024-D. See Figure 1-388.

NOTE:
The seal, pulley and pulley nut are the only serviceable parts of the accessory drive assembly with the unitized oil seal.

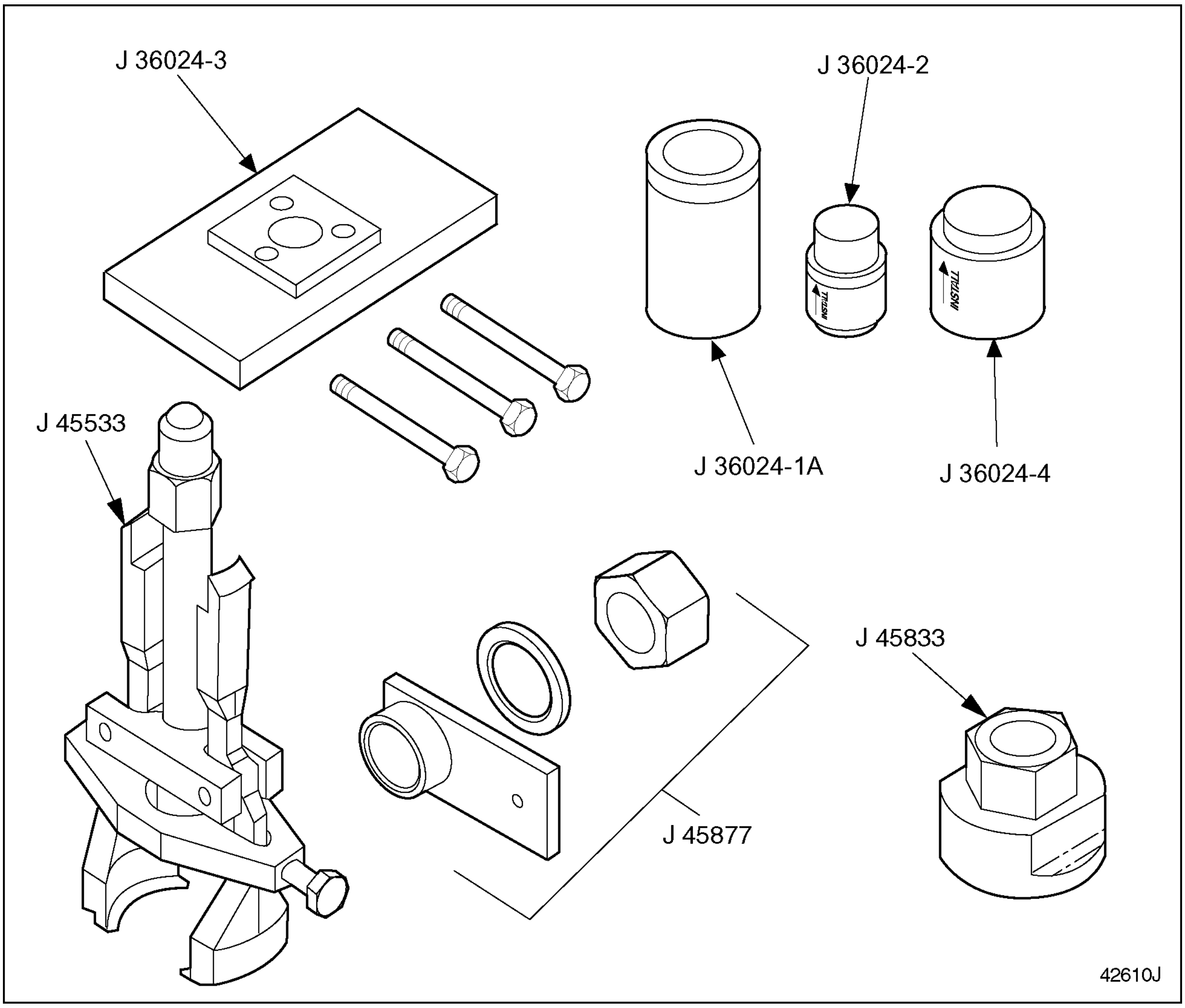


Figure 1-388 Accessory Drive Service Tool Set J 36024-D

1. Attach the accessory drive gear to the holding fixture, J 36024-3 part of J 36024–C, using the three bolts provided. See Figure 1-389.

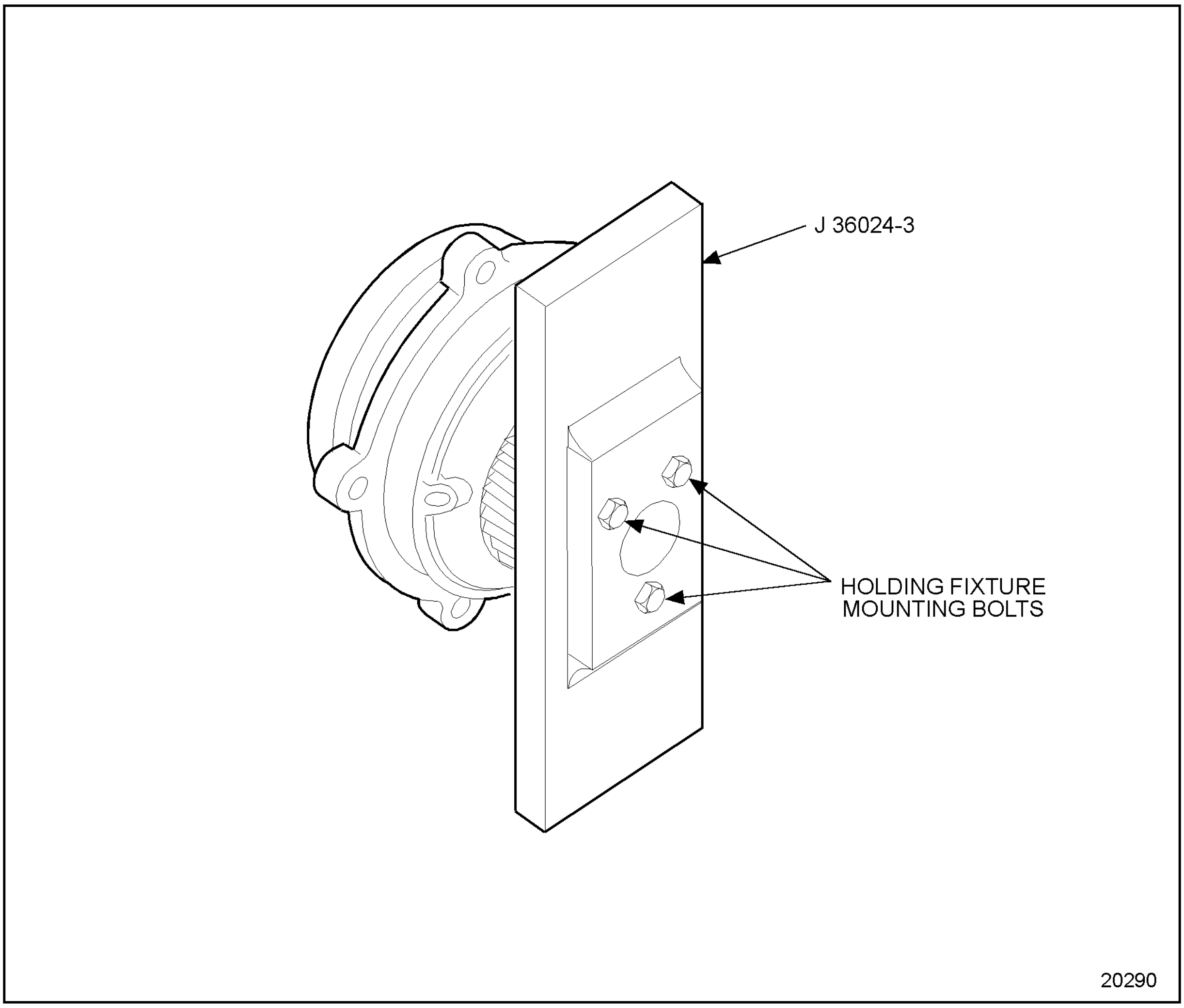


Figure 1-389 Holding Fixture

2. Place the accessory drive assembly holding fixture into a vise. See Figure 1-390.

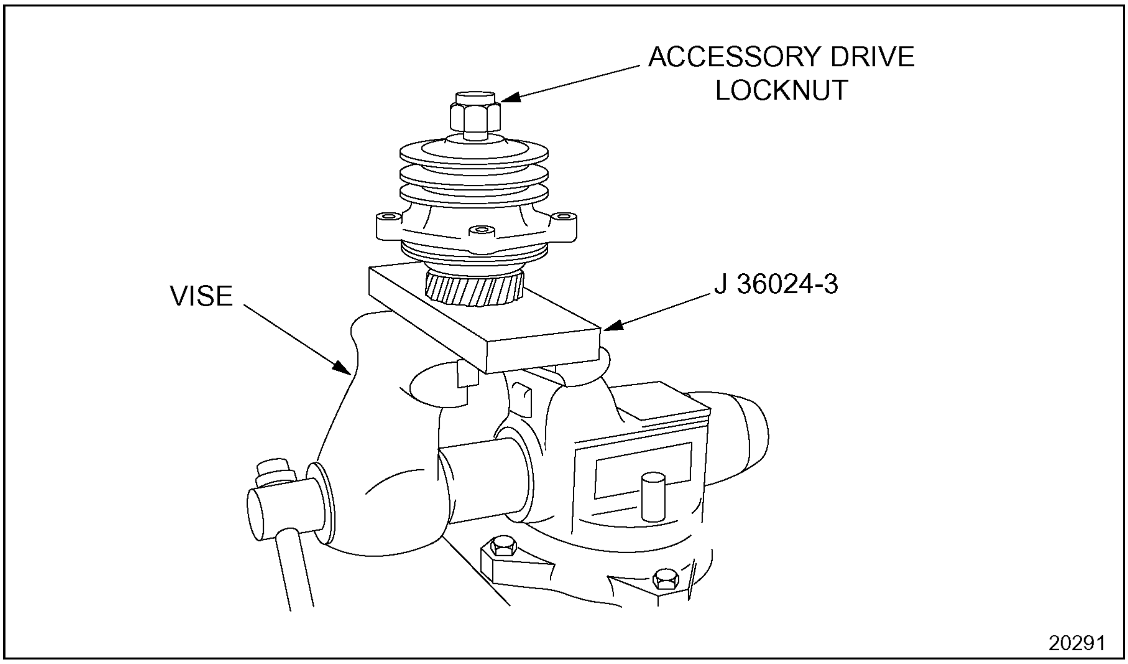
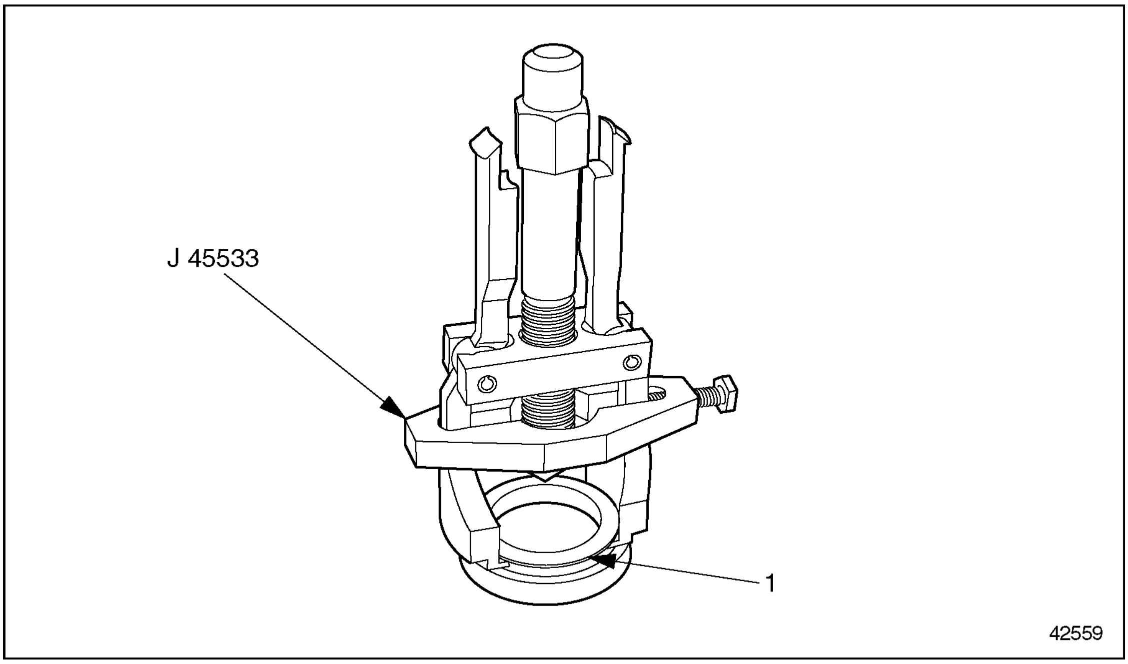


Figure 1-390 Accessory Drive Pulley Locknut Removal

3. Loosen and remove the accessory drive pulley locknut.

4. Remove the accessory drive pulley by tapping it with a rubber hammer or fiber mallet. If the pulley does not come off easily, use a puller to remove it. See Figure 1-390.



1. Seal Sleeve

Figure 1-391 J 45533 Accessory Drive Seal Remover

NOTE:
Perform steps 5, 6, and 7 unitzed seal removal procedure, for accessory drive assemblies on engines built after December 2000.

5. Using J 45533 (part of toolset J 36024-D), remove seal sleeve.
   [a] Ensure taper end of puller bolt is pointed toward inside jaws. See Figure 1-391.
   [b] Place inside jaws of tool over sleeve. See Figure 1-391.
   [c] Finger tighten hex bolt on side of tool.
   [d] Remove sleeve by tightening puller bolt.
6. Removal of seal.

[a] Invert puller bolt. See Figure 1-392

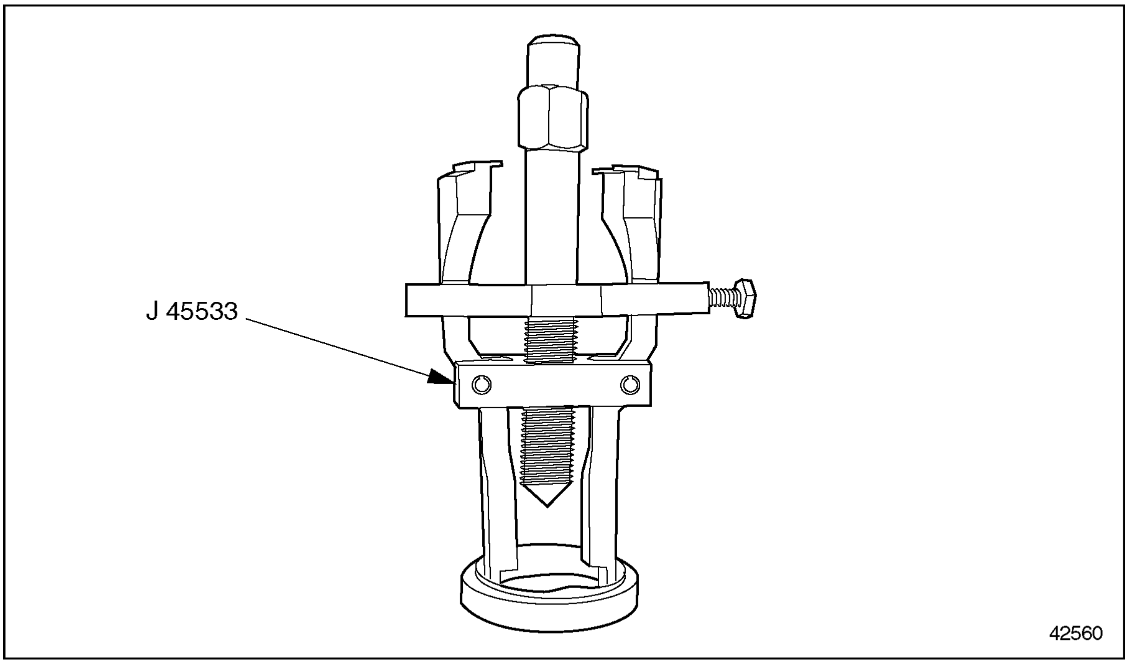


Figure 1-392 J 45533 Invert Puller Bolt

[b] Loosen hex bolt on side of tool.

[c] Using a rubber mallet, gently drive outside jaws between seal and shaft through the rubber membrane of seal until tool bottoms out.

[d] Finger tighten hex bolt on side of tool.

[e] Remove seal by tightening puller bolt.

7. Clean accessory drive housing at seal location.

8. Position the accessory drive assembly on a press bed with the holding fixture supported. See Figure 1-393.

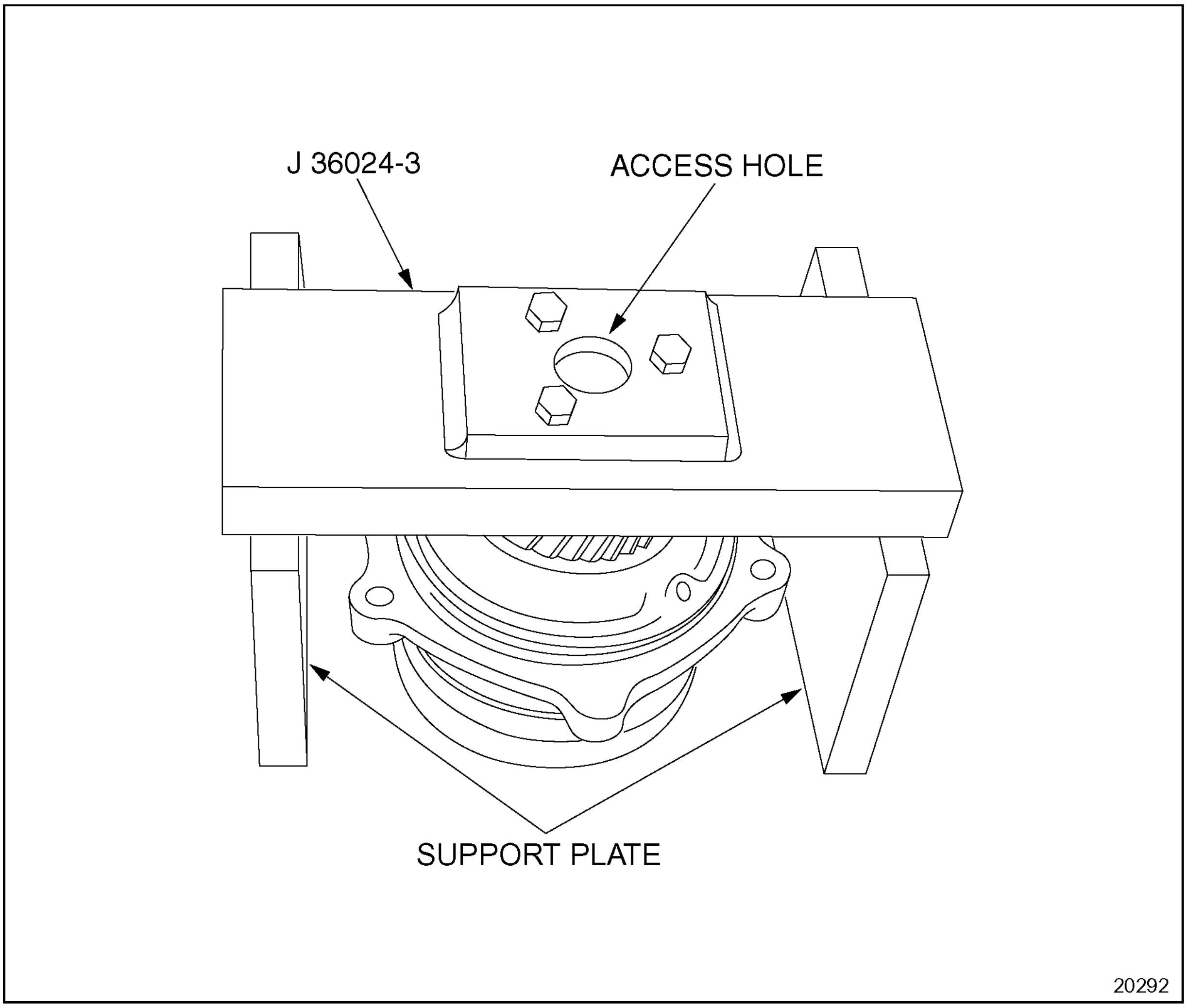


Figure 1-393 Accessory Drive Gear Removal

9. Using a press, apply pressure through the access hole in the holding fixture, J 36024-3 part of J 36024–C, and press the driveshaft out of the gear.

10. Remove the snap ring from the accessory drive housing. See Figure 1-394.

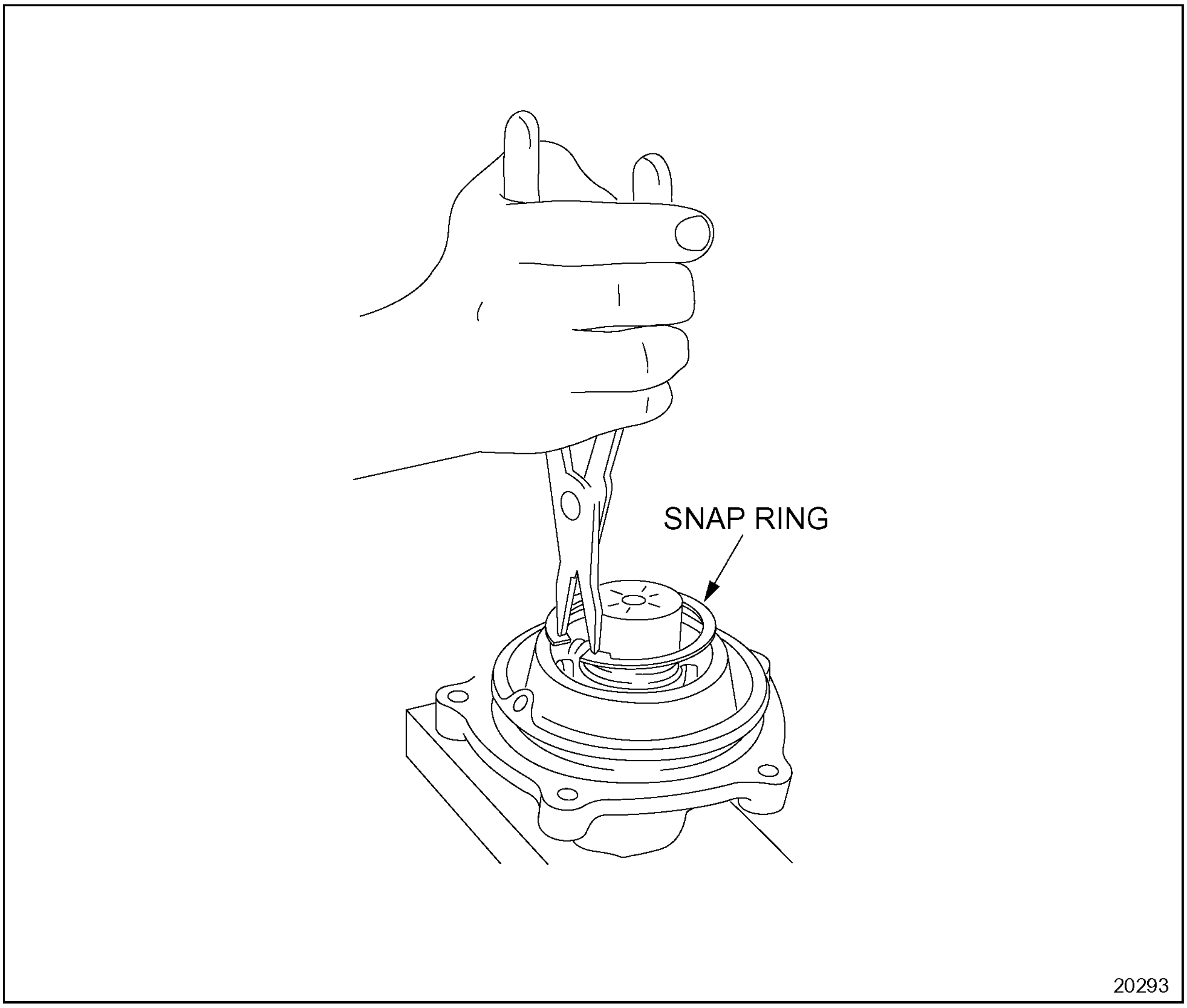


Figure 1-394 Snap Ring Removal

11. Turn the housing over and support the accessory drive housing on the machined surface using Vee-blocks.
12. Using a press, apply pressure to the pulley end of the shaft and remove the shaft and bearing assembly.
13. Turn the accessory drive housing over, and support it on the attaching bolt bosses using Vee-blocks.

NOTICE:
For assemblies with inner race for needle bearing, place the accessory driveshaft in a vise with soft jaws taking care not to damage the shaft surface.

14. Install needle bearing remover and installer, J 36024-2 part of J 36024–C. See Figure 1-395. Apply pressure to J 36024-2 part of J 36024–C, and remove the needle bearing.

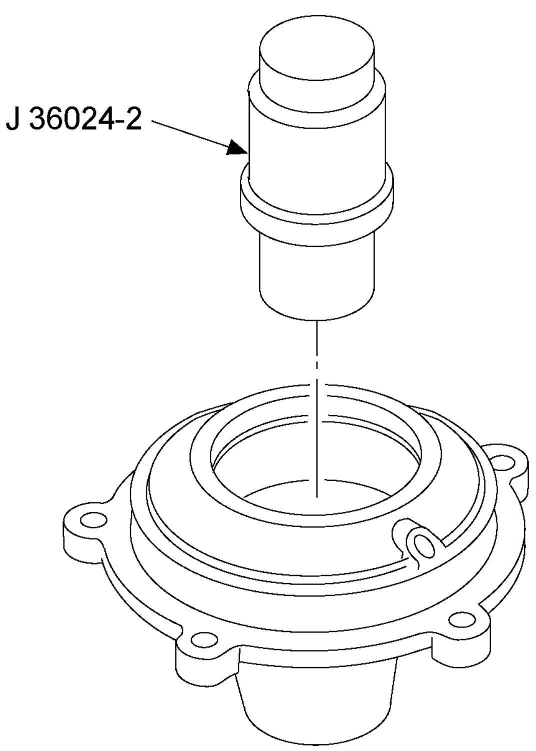


Figure 1-395 Needle Bearing Removal

15. Apply pressure to J 36024-2 part of J 36024–C and remove the needle bearing.

16. Remove the snap ring from the accessory driveshaft. See Figure 1-396.

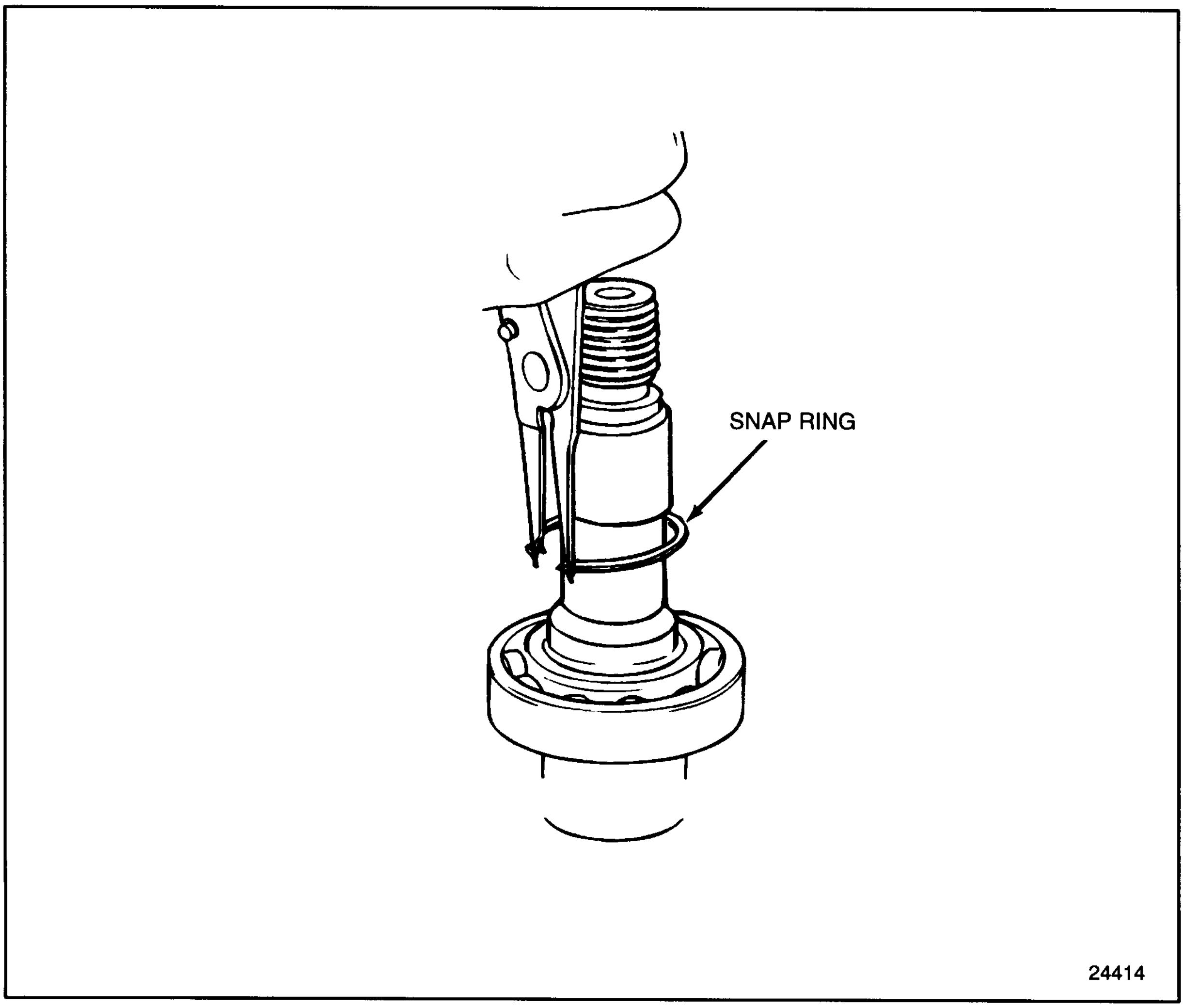


Figure 1-396 Snap Ring Removal

17. Position two steel press plates under the ball bearing outer race. See Figure 1-397.

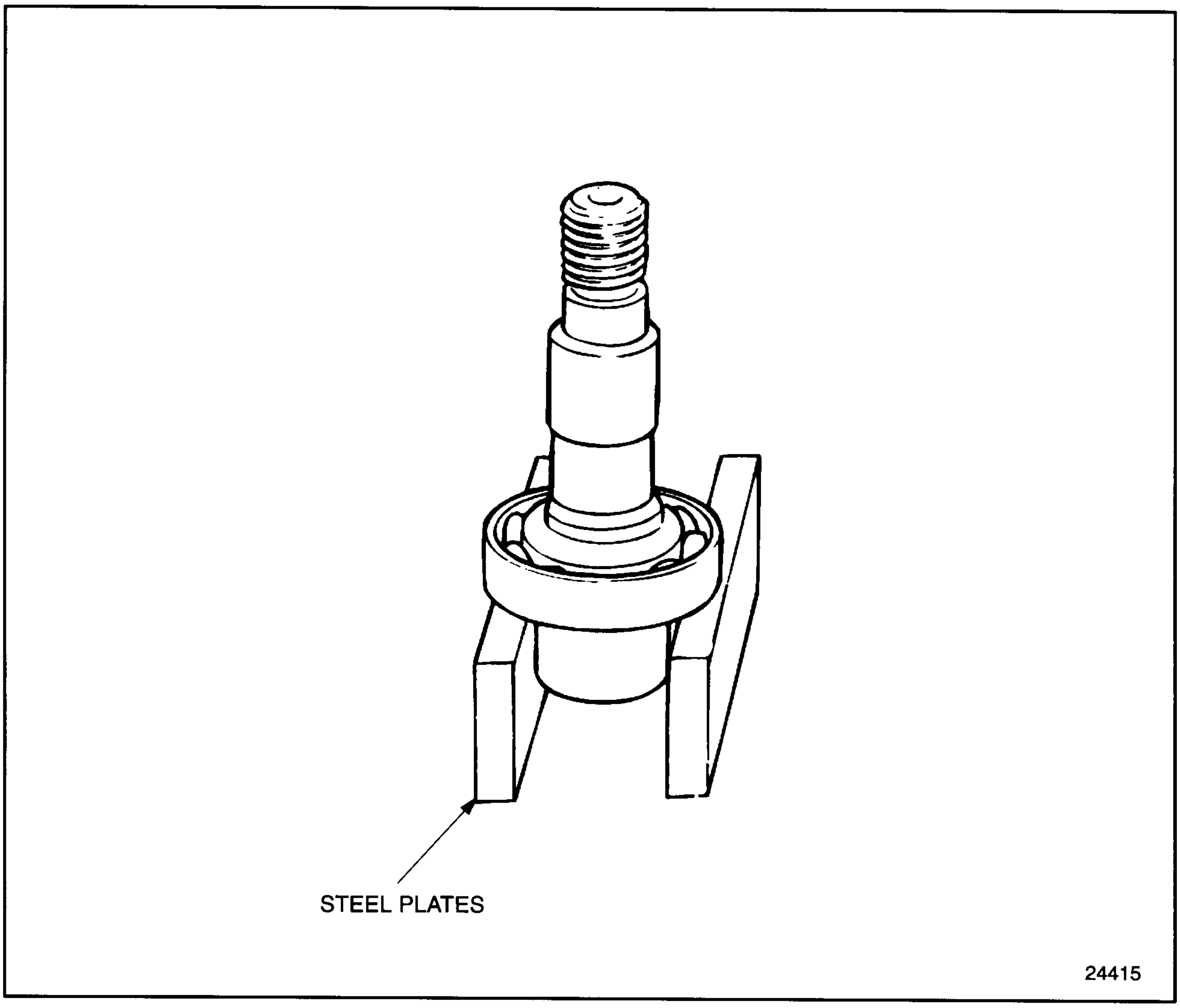


Figure 1-397 Ball Bearing Removal

NOTE:
Whenever the needle or ball bearing is removed from the shaft, they MUST be replaced with new bearing assemblies.

18. Use a press to apply pressure to the top of the shaft and remove the ball bearing from the shaft.

1.29.3.1 Inspection of the Accessory Drive

Clean the accessory drive prior to inspection as follows:

1. Clean all of the parts with clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry parts with compressed air.

Inspect the accessory drive as follows:

1. Inspect the driveshaft for damage.
   [a] Check the driveshaft for galling, pitting, cracks, or other damage.
   [b] If any damage is detected, replace with a new part.

1.29.4 Assembly of the Accessory Drive

Assemble the accessory drive as follows:

1. Place a new ball bearing on the accessory driveshaft. Use tool J 36024-1A part of J 36024–C and a press to install the bearing onto the shaft until it bottoms out against the shoulder of the driveshaft. See Figure 1-398.

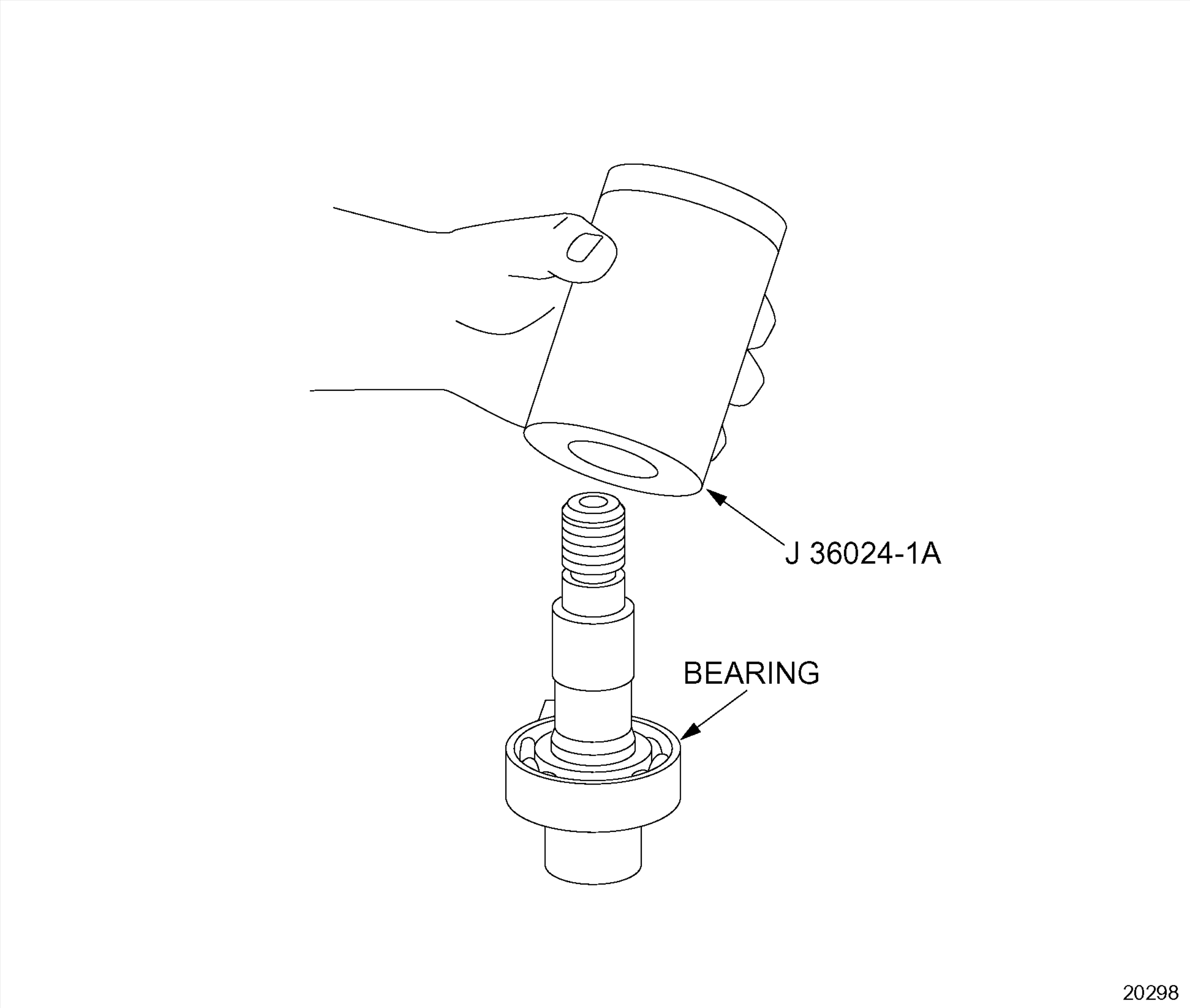


Figure 1-398 Bearing Installation

2. Install the snap ring to the accessory driveshaft making sure it is fully seated in the groove a full 360°. See Figure 1-399.

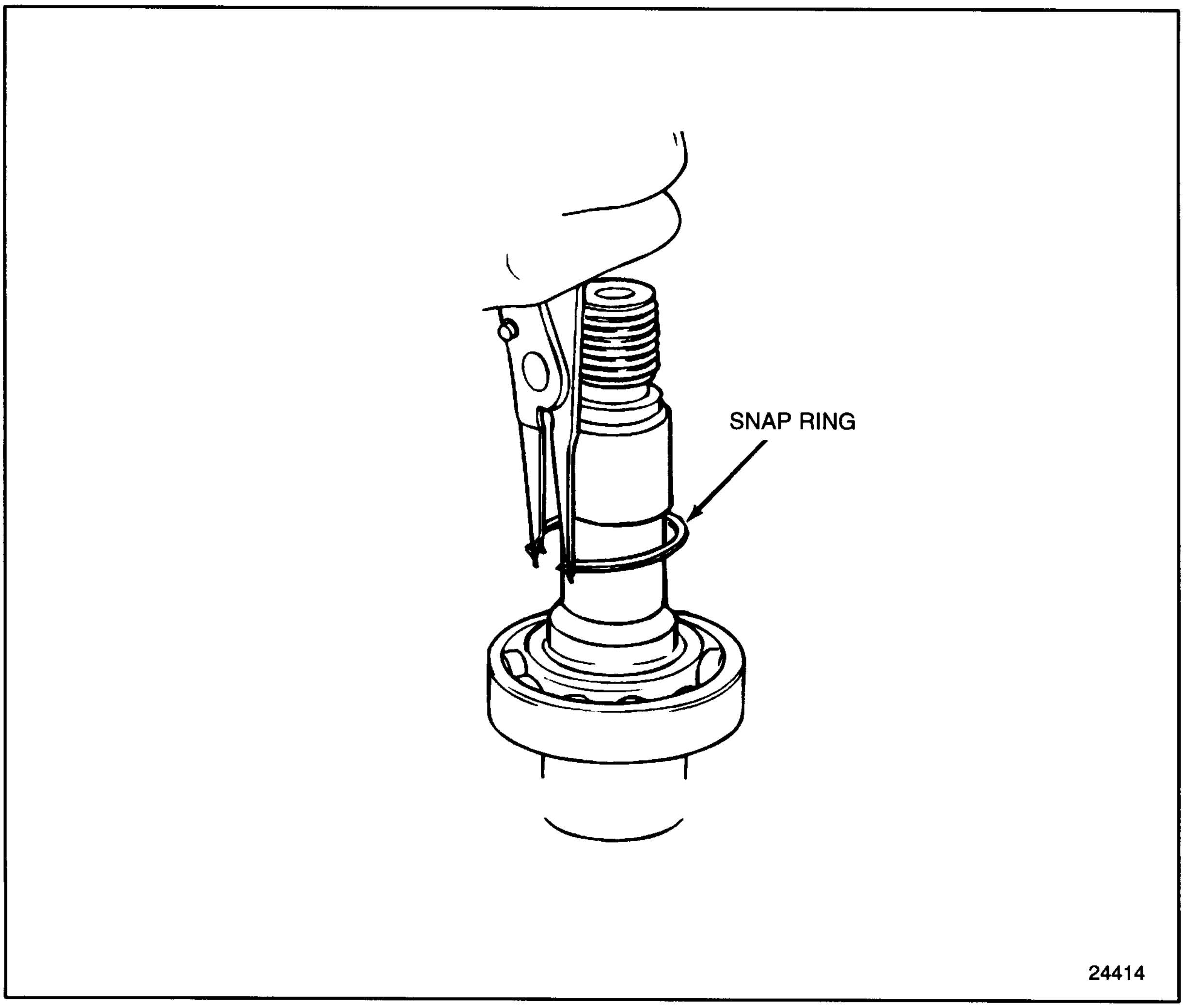


Figure 1-399 Snap Ring Installation

3. Place the needle bearing inner race on the accessory driveshaft. Use tool J 36024-1 part of J 36024–C and a press to install the bearing inner race to the shaft until it is tight against the shoulder. See Figure 1-400.

NOTE:
On current design accessory driveshaft, the needle bearing inner race is incorporated into the shaft.

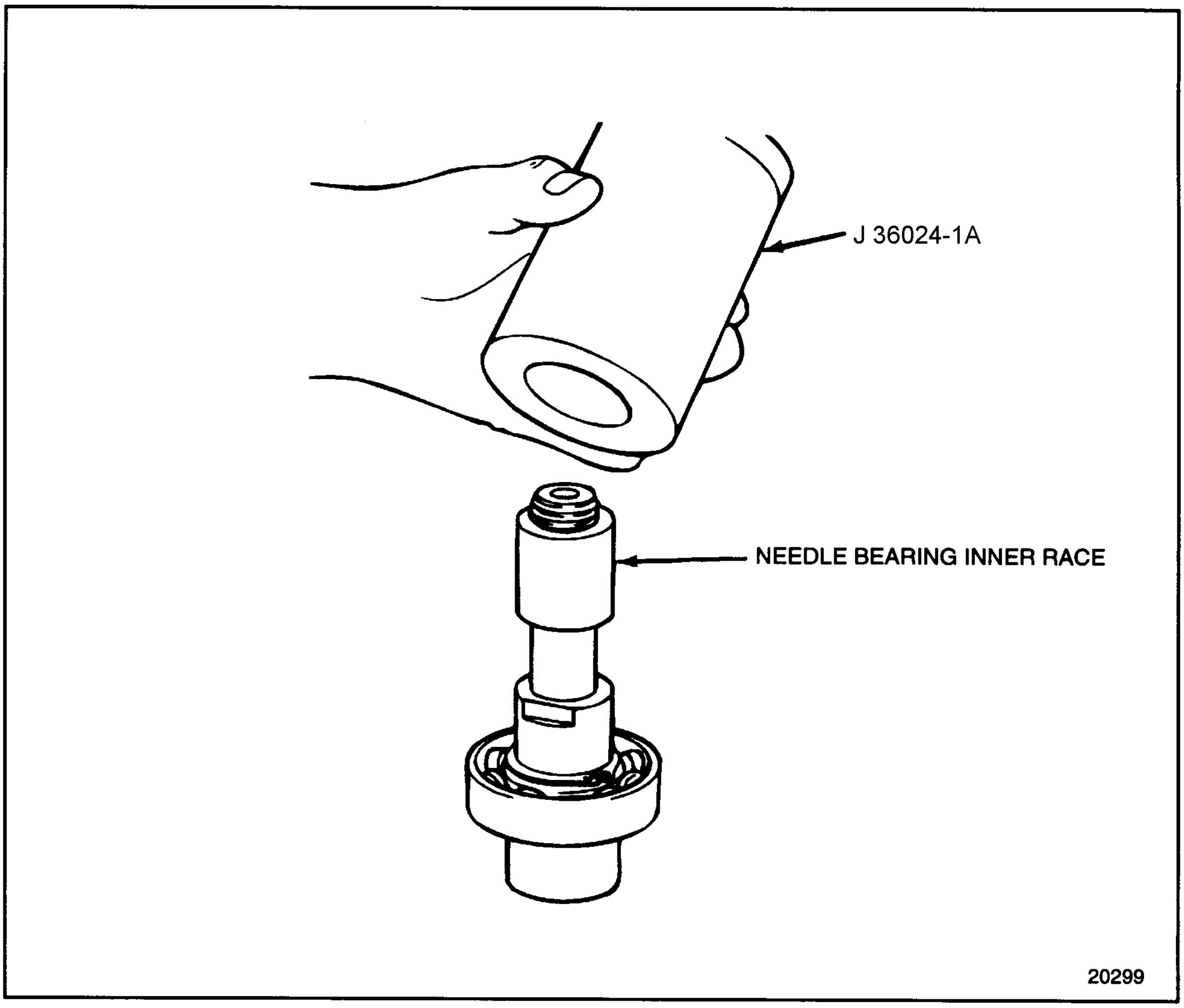


Figure 1-400 Bearing Inner Race Installation

4. Install the needle bearing to the accessory drive housing using tool J 36024-2 part of J 36024–C and a press. See Figure 1-401.

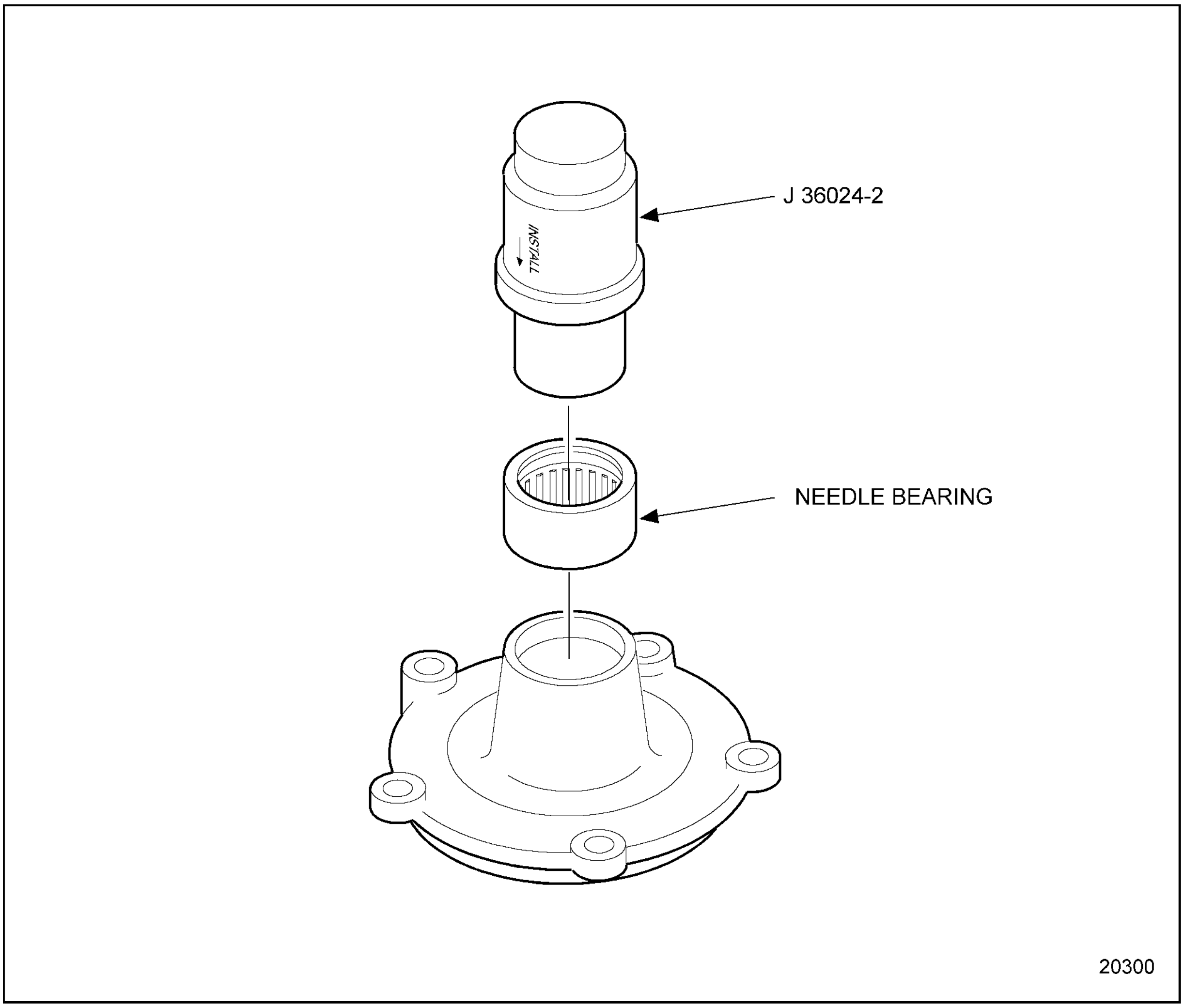


Figure 1-401 Needle Bearing Installation

NOTE:
The end of the bearing with the identification numbers must be against the installer.

NOTE:
The word INSTALL and an arrow are etched into the tool, J 36024-2 part of J 36024–C, to facilitate correct bearing installation.

5. Lubricate the oil seal contact area of the accessory drive housing with a thin film of engine oil.

6. Install the accessory drive oil seal to the accessory drive housing using the seal installer, J 36024-4 part of J 36024–C, and a plastic hammer or fiber mallet. The oil seal must be installed flush to 0.25 mm (0.010 in.) below the face of the housing. See Figure 1-402.

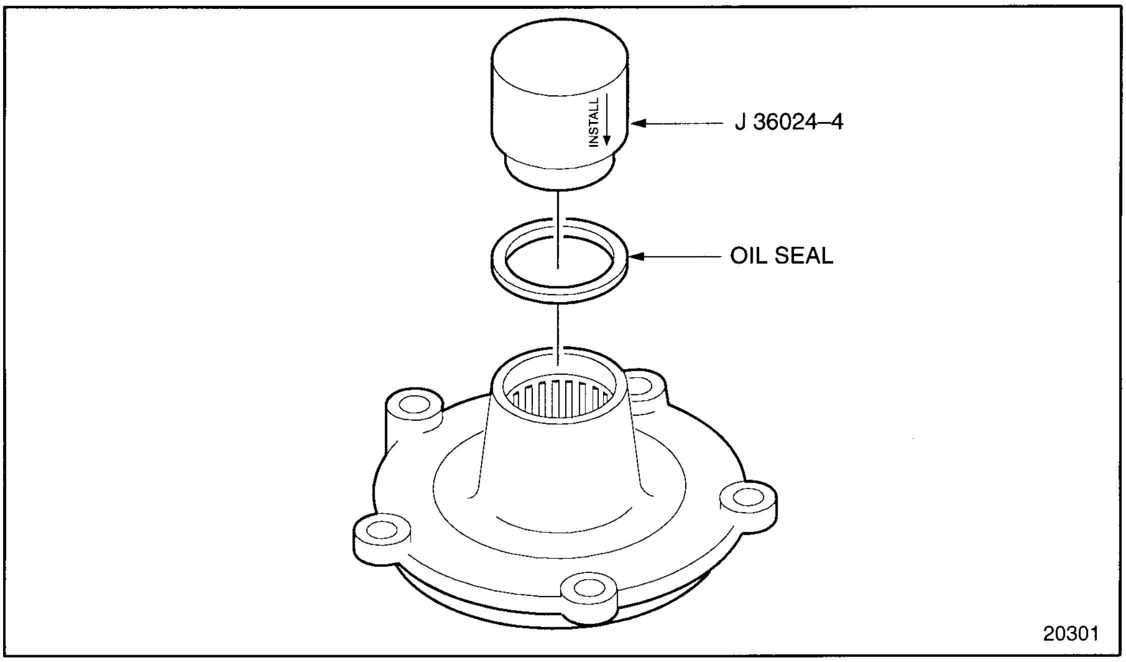


Figure 1-402 Accessory Drive Oil Seal Installation

7. Lubricate the oil seal with a thin film of engine oil.
8. Support the holding fixture, J 36024-3 part of J 36024–C on two steel plates and position the accessory drive housing into the hole in the fixture.

9. Install the driveshaft to the housing. See Figure 1-403.

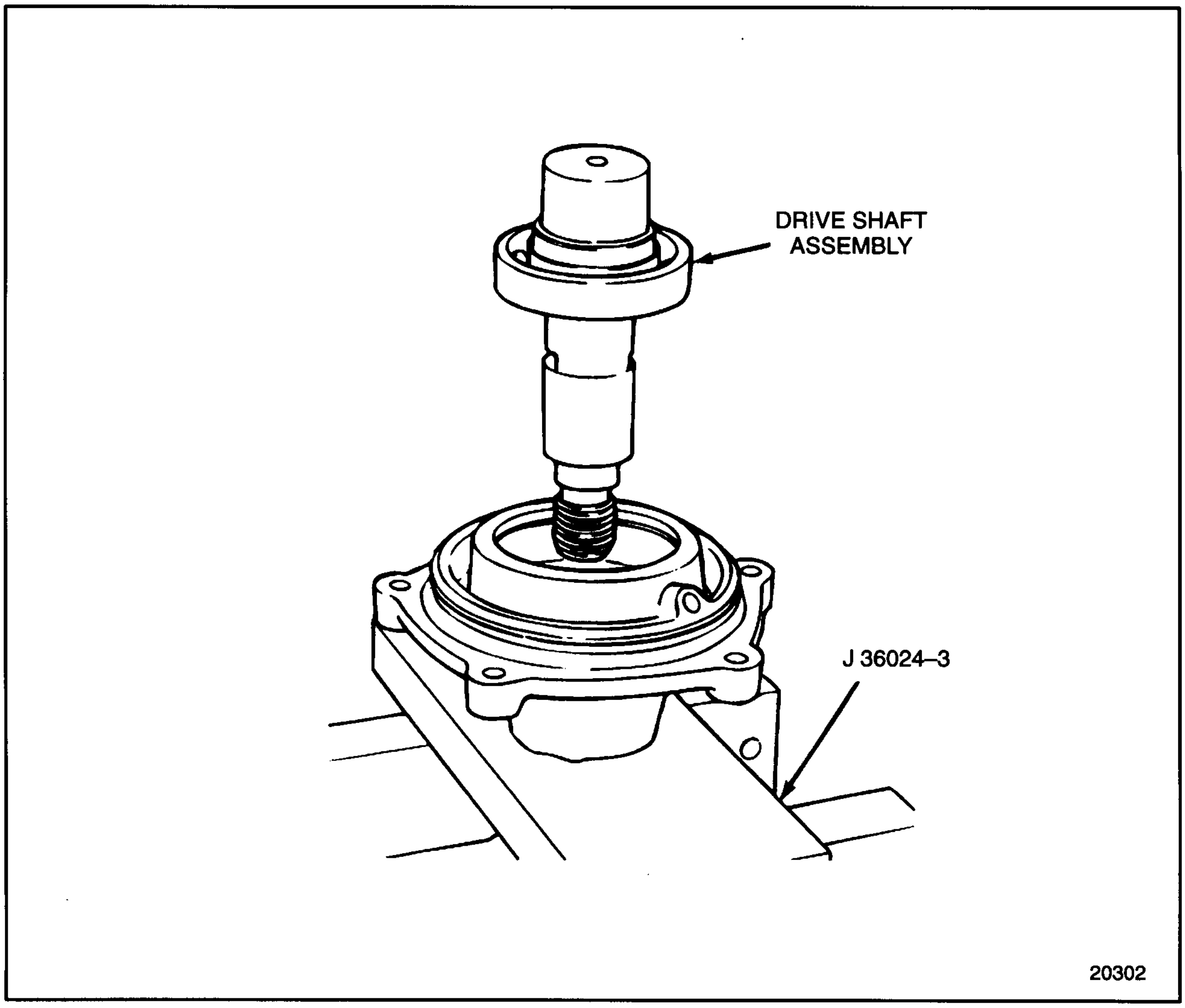


Figure 1-403 Accessory Driveshaft Preparation

10. Press the driveshaft into the housing by placing tool, J 36024-1A part of J 36024–C, on the bearing outer race.

11. Press the bearing into the housing until the bearing is seated against the shoulder of the housing. See Figure 1-404.

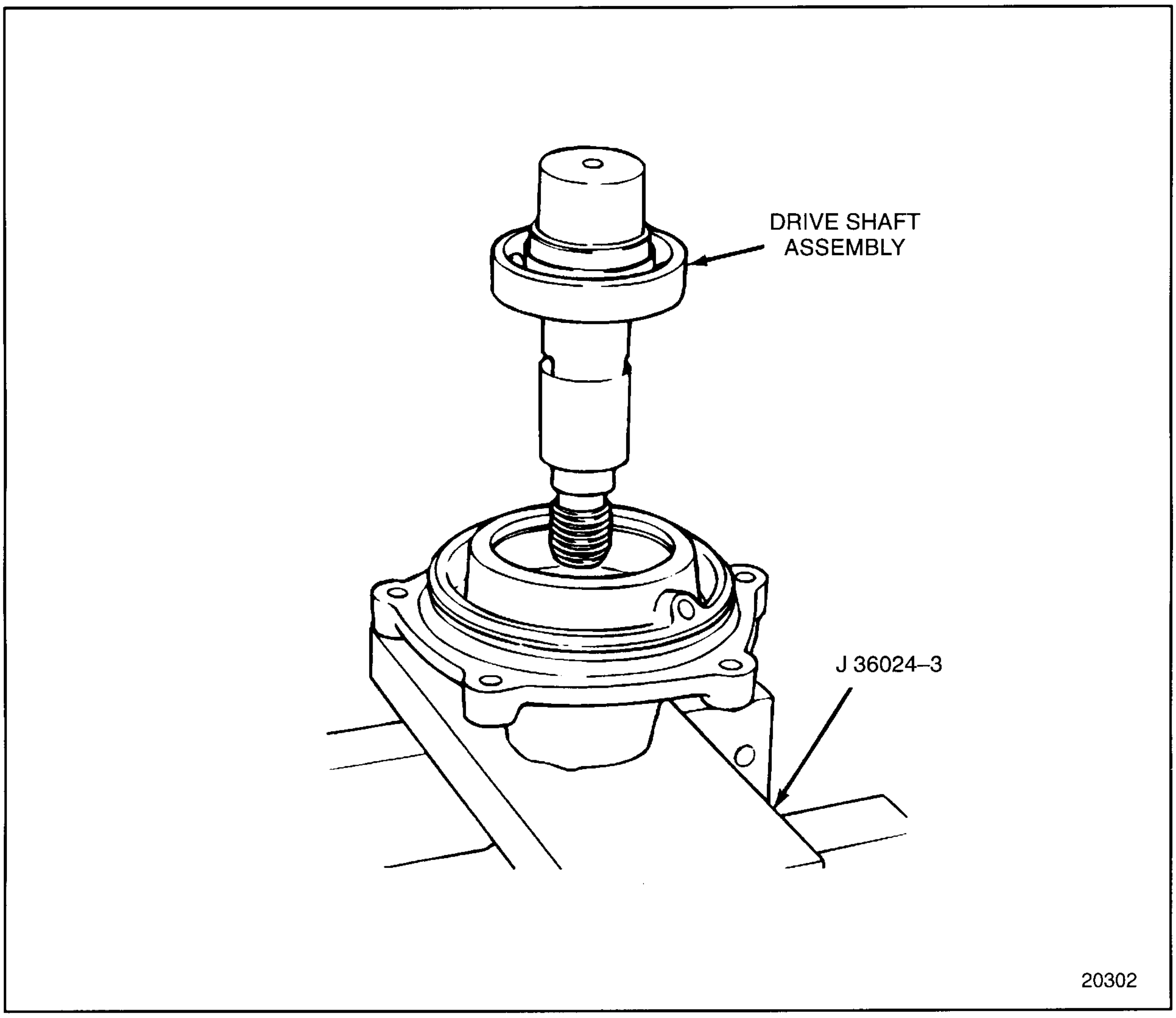


Figure 1-404 Accessory Driveshaft Installation

12. Install the snap ring to the accessory drive housing making sure the snap ring is fully seated in the groove a full 360°. See Figure 1-405.

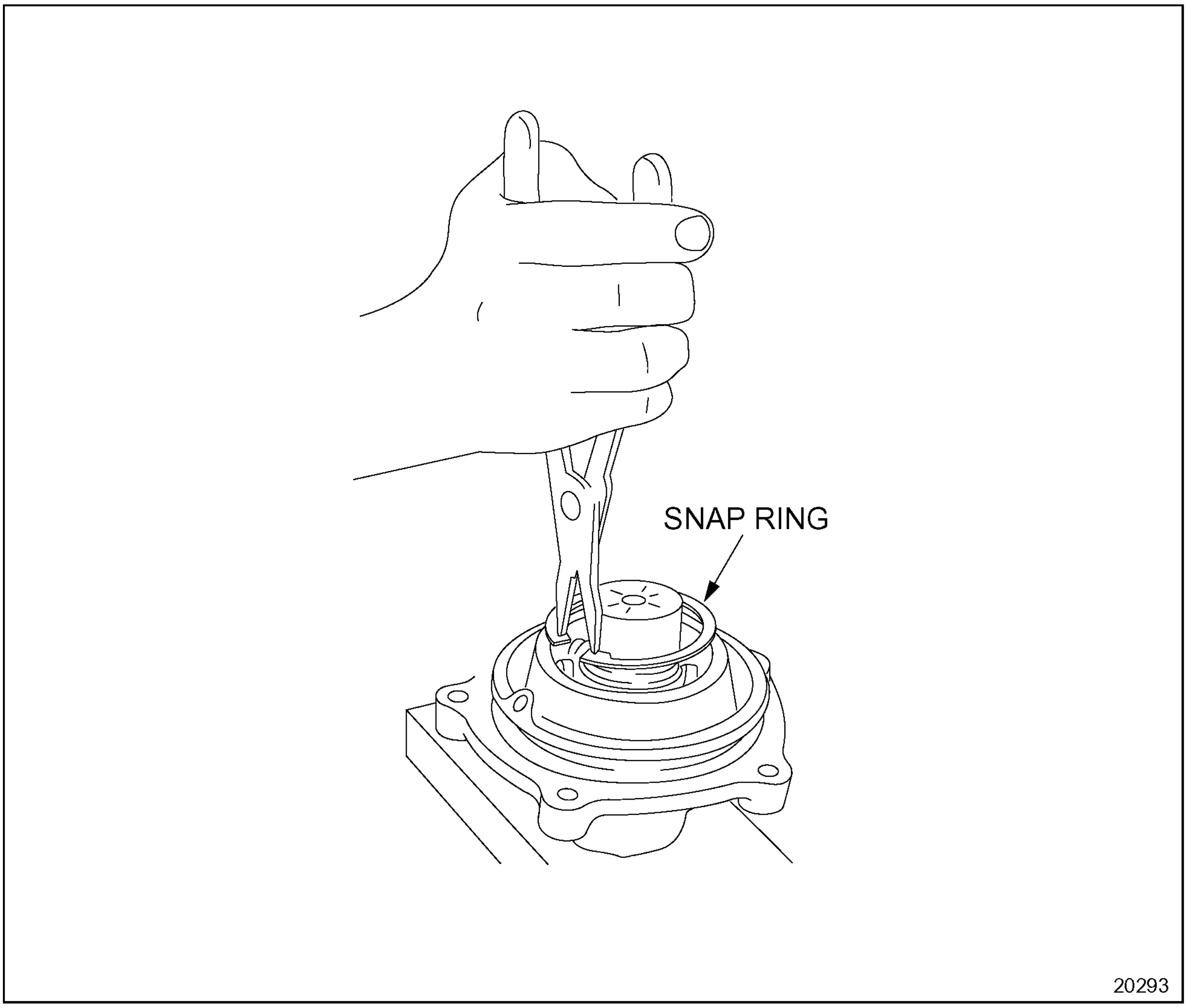


Figure 1-405 Snap Ring Installation

13. Lubricate the contact surfaces of the bearing with clean engine lubricating oil.

14. A film of lubriplate must be applied to the drive gear end of the accessory driveshaft. See Figure 1-406.

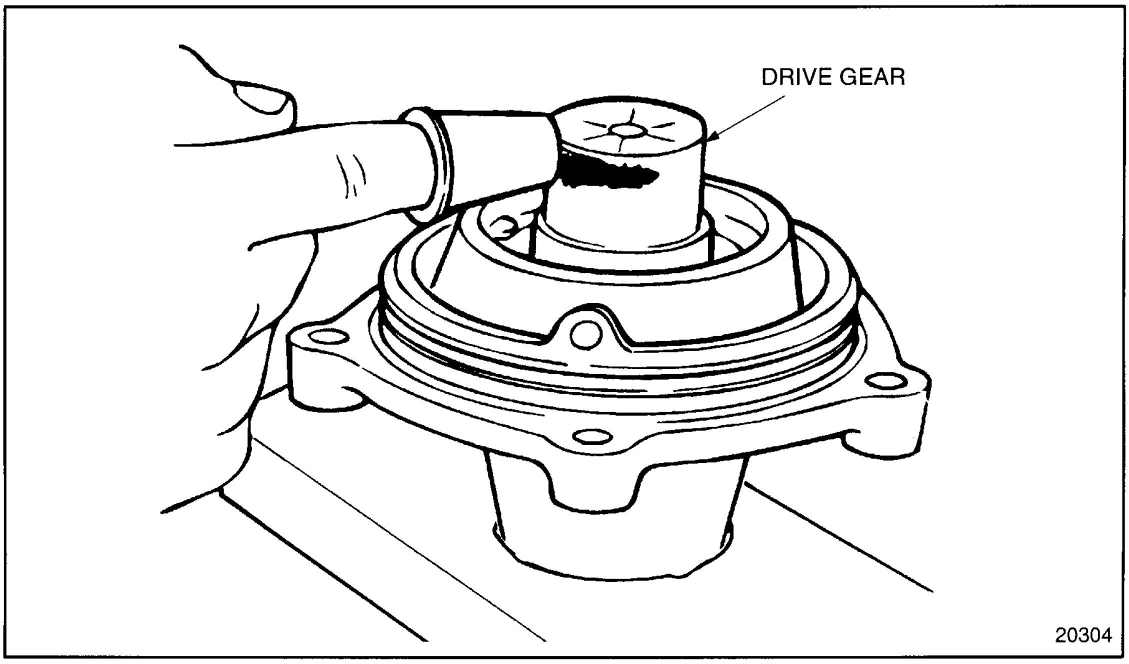


Figure 1-406 Drive Gear Installation Preparation

15. Use a press to install the drive gear on the accessory driveshaft until it is flush with the driveshaft end. Make sure the three threaded holes are facing up. See Figure 1-407.

NOTE:
Support the opposite end of the driveshaft on the press bed when pressing the gear on the shaft. A minimum press load of 17.8 kN (4000 lb) must be obtained when pressing the gear on the shaft.

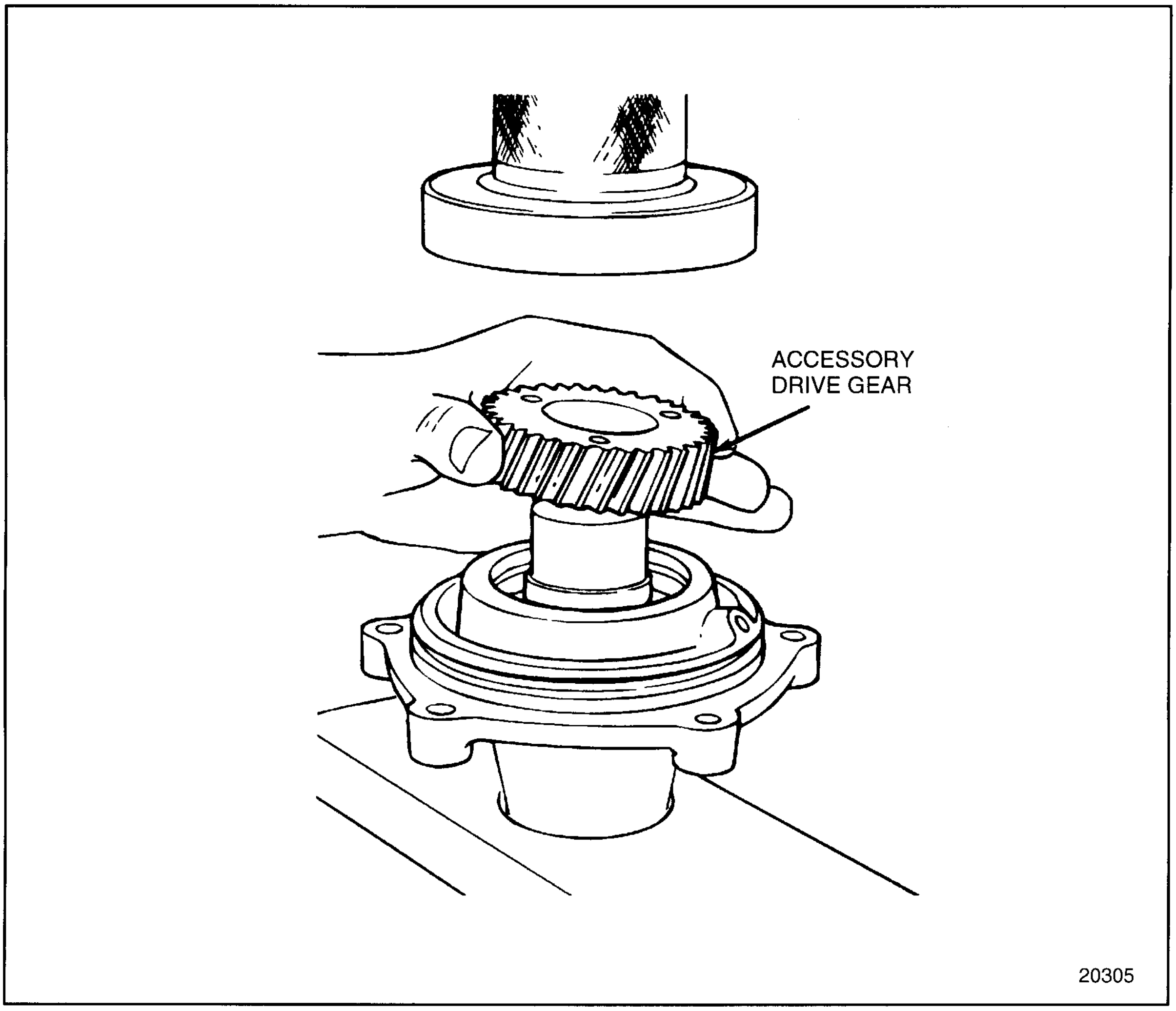
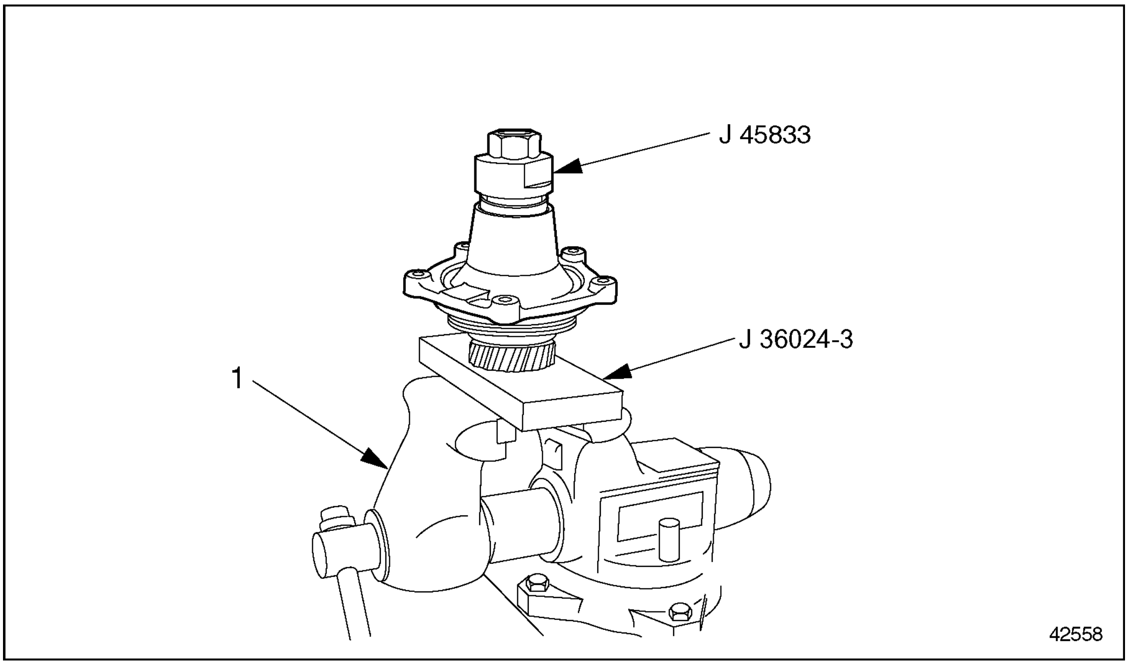


Figure 1-407 Accessory Drive Gear Installation

NOTE:
For accessory drive assemblies with unitized seals, effective with engines built after December 2000 perform the procedures in steps 16 and 17.

16. Install seal using J 45833 (part of toolset J 36024-D) by tightening installer nut until a positive stop is obtained. See Figure 1-408.

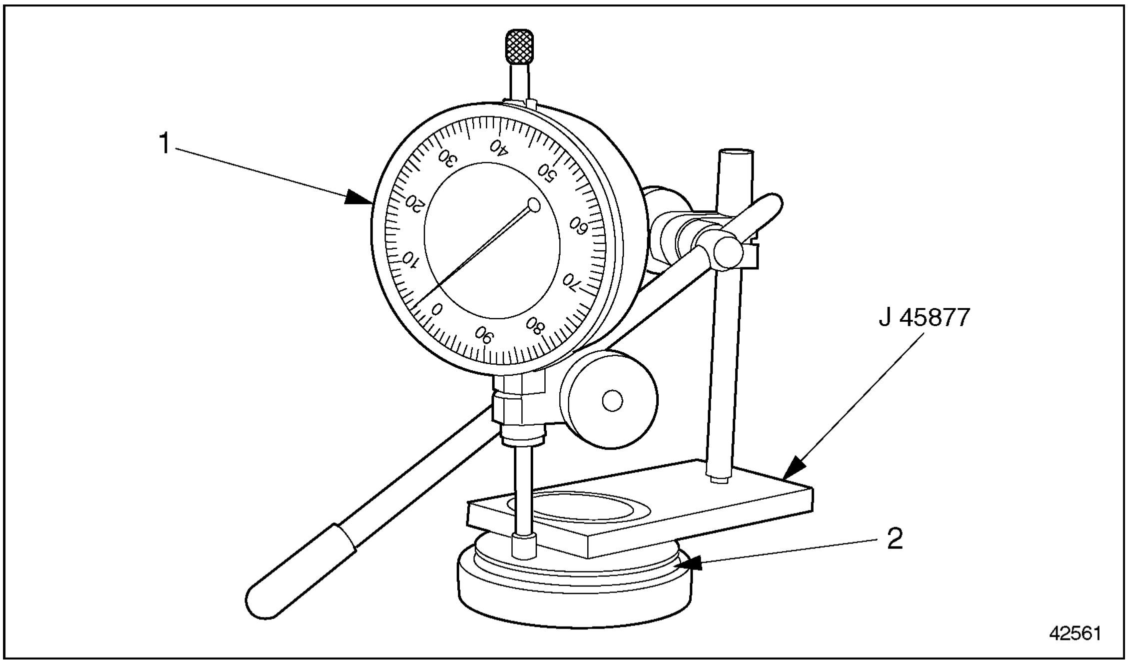


1. Vise

Figure 1-408 J 45833 Accessory Drive Seal Installer

17. Measure sleeve and run out using J 45877 (part of toolset J 36024-D) and a dial indicator. Total indicator deflection should not exceed 0.0762 mm (0.003 in.) for the sleeve and

0.1778 mm (0.007 in.) for the seal. If the run out is greater for either measurement, install a new seal. See Figure 1-409.



1. Dial Indicator
2. Seal Sleeve

Figure 1-409 J 45877 Seal Run Out Gauge Adaptor

18. Install the accessory drive pulley to the shaft.

NOTE:
If necessary, use tool J 36024-1A part of J 36024–C, to seat the pulley on the shaft. If pressing is necessary, the opposite (gear) end of the shaft must be supported during the pressing operation.

19. Attach the accessory drive holding fixture, J 36024-3 part of J 36024–C, to the drive gear. See Figure 1-389.
20. Place the accessory drive assembly holding fixture into a vise.

21. Install and torque the accessory drive pulley locknut to 360-400 N·m (266-295 lb·ft). See Figure 1-410.

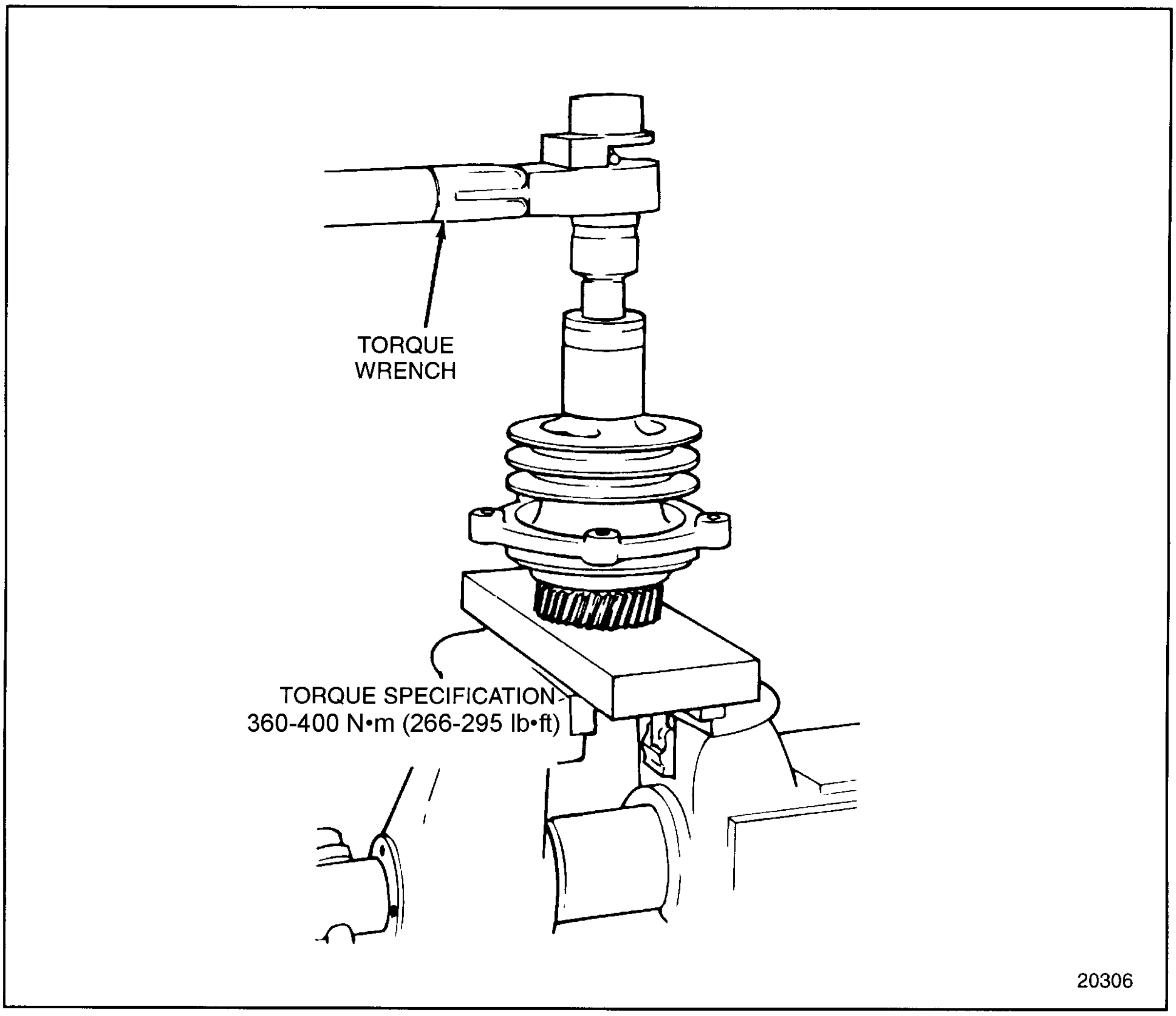


Figure 1-410 Accessory Drive Pulley Locknut Tightening

22. Support the accessory drive assembly. See Figure 1-411.

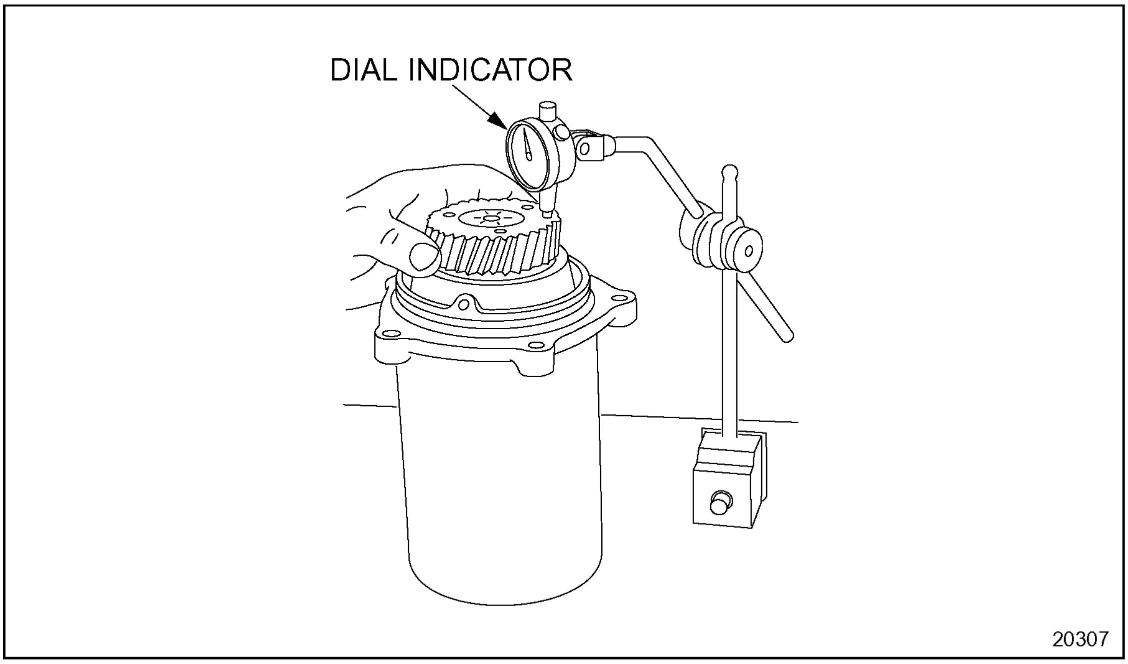


Figure 1-411 Accessory Drive Gear TIR Measurement

23. Assemble a dial indicator and magnetic base, so that the indicator stem rests on the face of the accessory drive gear just inboard of the drive gear teeth. See Figure 1-411.
24. Zero the dial indicator.
25. Rotate the drive gear two full rotations. See Figure 1-411. As the gear is rotated, the dial indicator needle may register both to the left and right of zero.
26. The total amount the dial indicator needle moves to the left and right of zero, added together, gives the total indicated run-out (TIR). Allowable TIR is 0.04 mm (0.0015 in.).

1.29.5 Installation of the Accessory Drive

Install the accessory drive as follows:

1. Install the O-ring seal in the groove on the drive housing.
2. Lubricate the O-ring with petroleum jelly.
3. Install the accessory drive housing to its original position in the gear case cover.

NOTE:
The word "UP" is cast into the drive housing.

4. Install the bolts that secure the accessory drive housing to the gear case cover and torque to 30-38 N·m (22-28 lb·ft) using the pattern. See Figure 1-412.

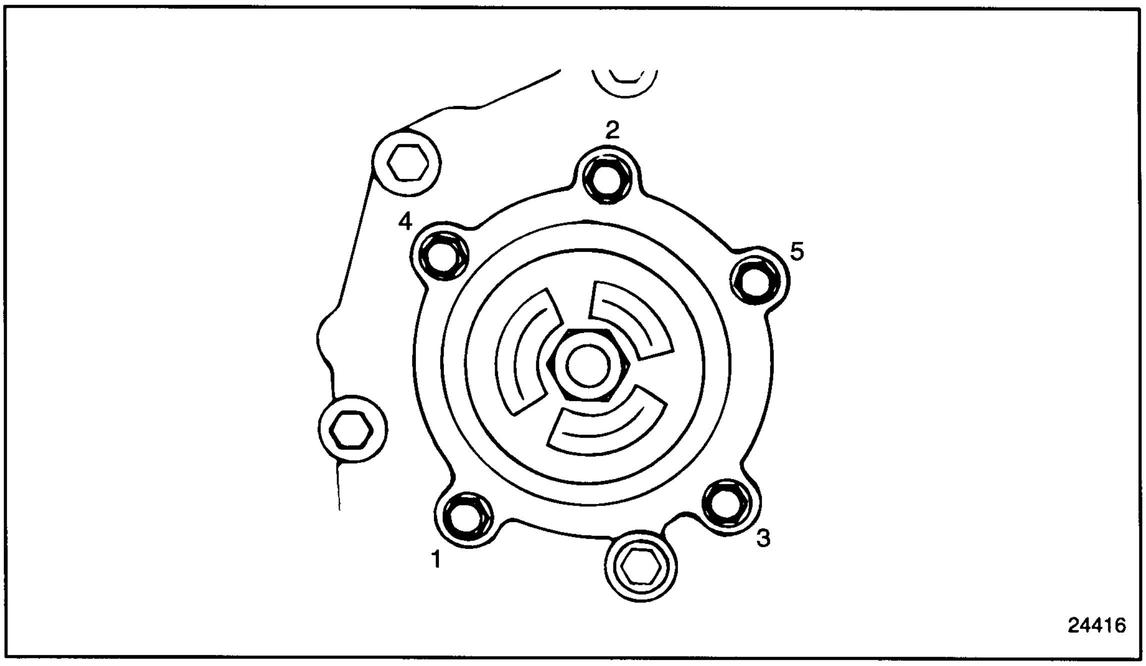


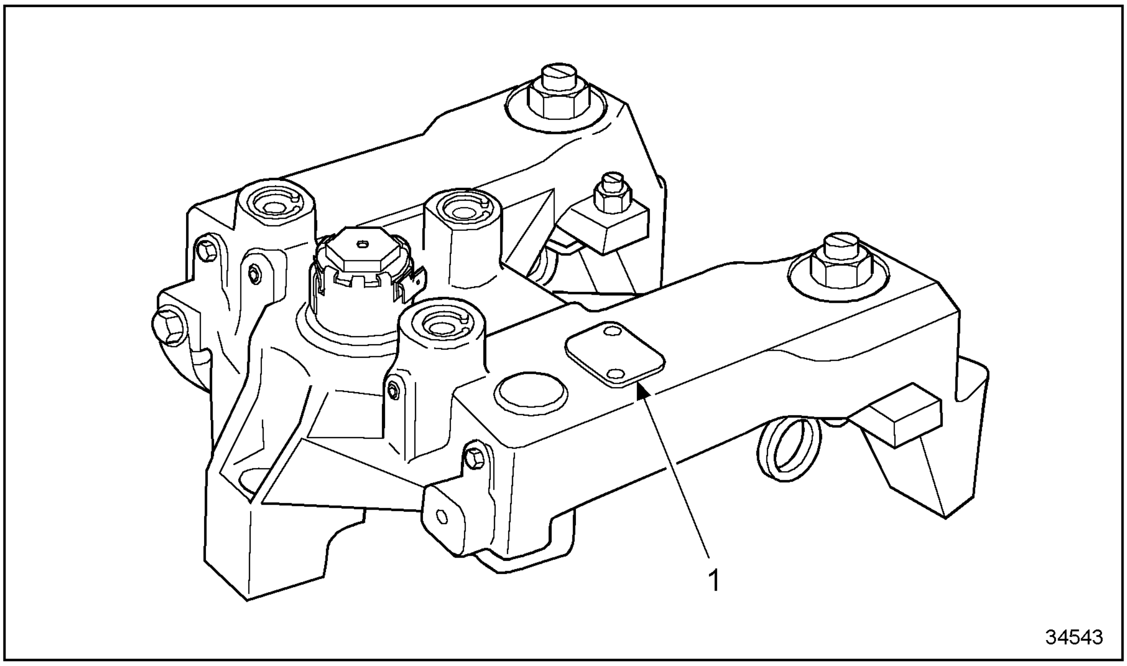
Figure 1-412 Accessory Drive Housing Bolt Torque Sequence

5. Check the bull gear-to-accessory drive gear backlash. Refer to Section 1.21.2.1.
6. Adjust the alternator belts. Refer to Section 13.5.7. Tighten the alternator mounting bolts.
7. Install any other components removed for this procedure.

1.30 JAKE BRAKE

The engine brake has been designed to fit on the Series 50 engine with no additional valve cover spacers. There are three styles of valve covers for the Series 50 engine. On engines equipped with a two-piece aluminum valve cover, it is NOT necessary to remove the lower valve cover to install the engine brake. However, one style of upper valve cover may require modification at the breather housing location (inside) for engine brake clearance.

The model, part number and serial number are located on the nameplates at the top of each housing. See Figure 1-413.



1. Identification Plate

Figure 1-413 Nameplate Location on Housing

NOTICE:
Only the specific brake model can be used with the engine model it was designed for. Also, the correct slave piston adjustment specification must be used. Failure to follow these instructions may result in serious engine or engine brake damage.

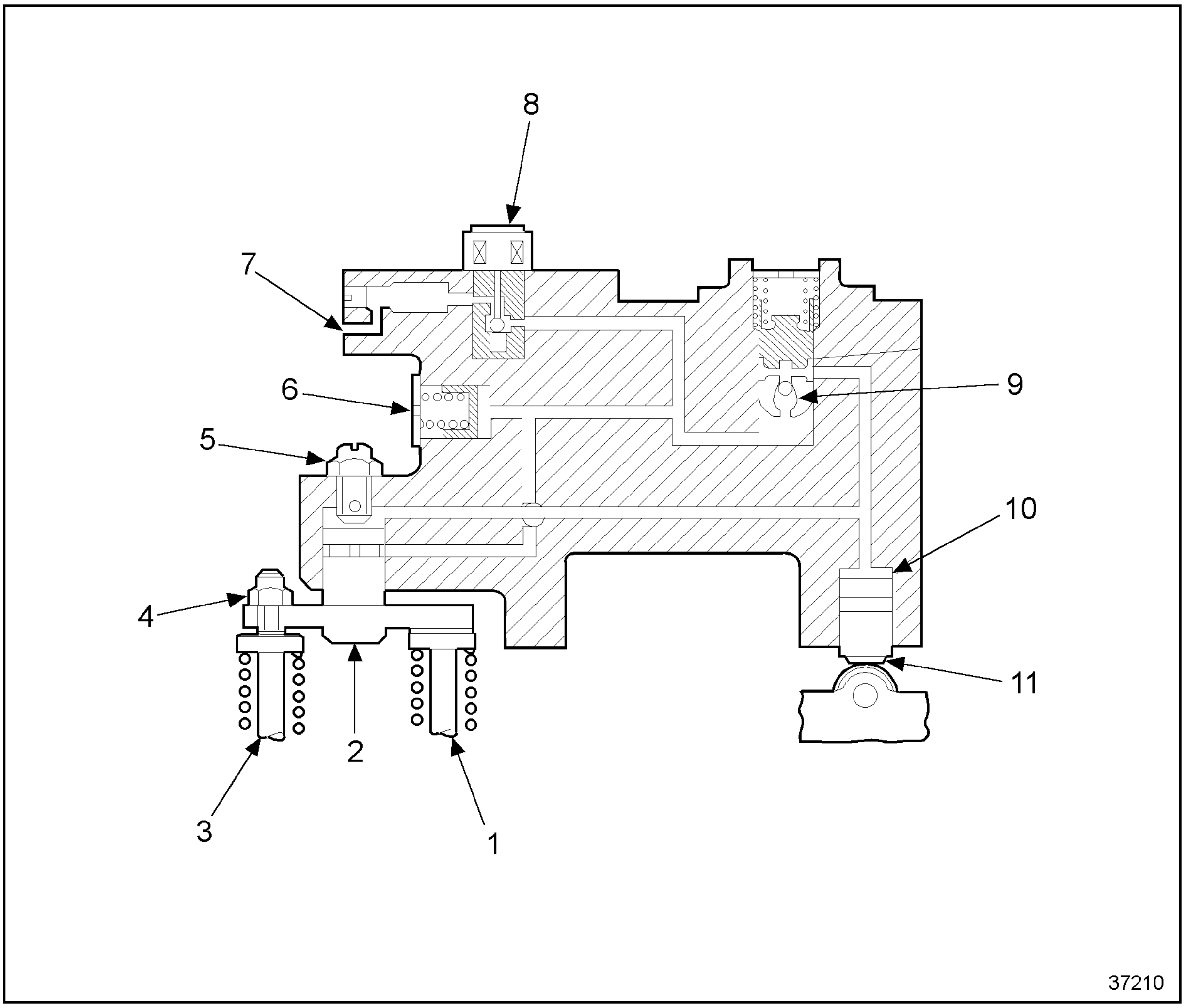
Listed in Table 1-7are the different Jake Brake models used and the slave piston adjustment specification.

Model Number	Engine Displacement	Engine Brake	Slave Piston Adjustment
6047GU28	8.5 L	750	0.660 mm (0.026 in.)
6047GU60	8.5 L	750	0.660 mm (0.026 in.)
6047GK28	8.5 L	750	0.660 mm (0.026 in.)
6047GK60	8.5 L	750	0.660 mm (0.026 in.)
6047TK60	8.5 L	750A	0.584 mm (0.023 in.)
6047TK45	8.5 L	750A	0.584 mm (0.023 in.)
6047TK28	8.5 L	750A	0.584 mm (0.023 in.)
6047MK60	8.5 L	750B	0.584 mm (0.023 in.)
6047MK50	8.5 L	750B	0.584 mm (0.023 in.)
6047MK45	8.5 L	750B	0.584 mm (0.023 in.)
6047MK57	8.5 L	750B	0.584 mm (0.023 in.)
6047MK28	8.5 L	750B	0.584 mm (0.023 in.)

All slave piston adjustments shown here are current as of the date of this manual and supersede all previous adjustments.

Table 1-7 Jake Brake Model Information

Current Jake Brake production models for the Series 50 engine are the 750, 750A and 750B.



1. Exhaust Valve
2. Slave Piston Assembly
3. Exhaust Valve
4. Leveling Screw
5. Slave Piston Adjusting Screw
6. Accumulator
7. Oil In
8. Solenoid Valve
9. Control Valve
10. Master Piston
11. Injector Pin and Roller

Figure 1-414 Jake Brake Schematic

The blowdown of compressed air to atmospheric pressure prevents the return of energy to the engine piston on the expansion stroke, the effect being a net energy loss, since the work done in compressing the cylinder charge is not returned during the expansion process.

Exhaust blowdown occurs as the energized solenoid valve permits engine lube oil to flow under pressure through the control valve to both the master piston and the slave piston.

See Figure 1-414.

Oil pressure causes the master piston to move down, coming to rest on the injector rocker

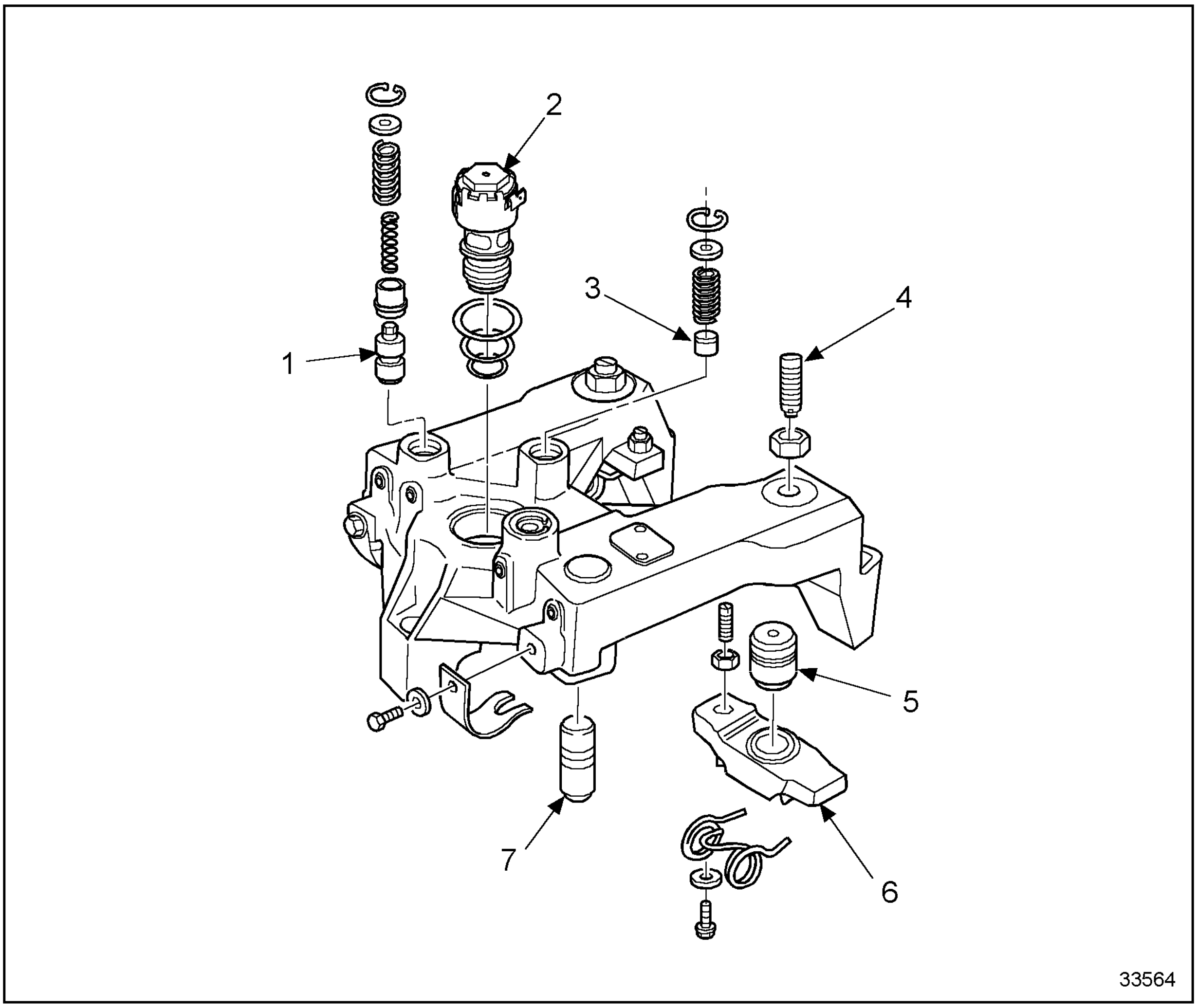
arm roller.

The injector rocker arm begins its travel as in the normal injection cycle, moving the master piston upward and directing high-pressure oil to the slave piston. The ball check valve in the control valve traps high-pressure oil in the master-slave piston system.

High pressure oil causes the slave piston to move down, momentarily opening the exhaust valves, while the engine piston is near its top-dead-center position, releasing compressed cylinder air to the exhaust manifold.

At the bottom of its stroke, the slave piston separates from the valve in the slave piston adjusting screw, allowing high pressure oil to flow into the accumulator. This reduces the pressure in the high pressure circuit, permitting the slave piston to retract and the exhaust valves to close in preparation for the normal exhaust valve cycle. The oil pressure reserved in the accumulator insures that the hydraulic circuit is fully charged for the next cycle. Compressed air escapes to the atmosphere, completing a compression braking cycle.

The Jake Brake is electronically controlled. Jake Brake control system wiring will vary depending on the vehicle manufacturer. For a general overview of the Jake Brake, see Figure 1-415.



1. Control Valve
2. Solenoid Valve
3. Accumulator Piston
4. Slave Piston Adjusting Screw
5. Slave Piston
6. Bridge
7. Master Piston

Figure 1-415 Typical Jake Brake Assembly

1.30.1 Repair or Replacement of Jake Brake

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-416.

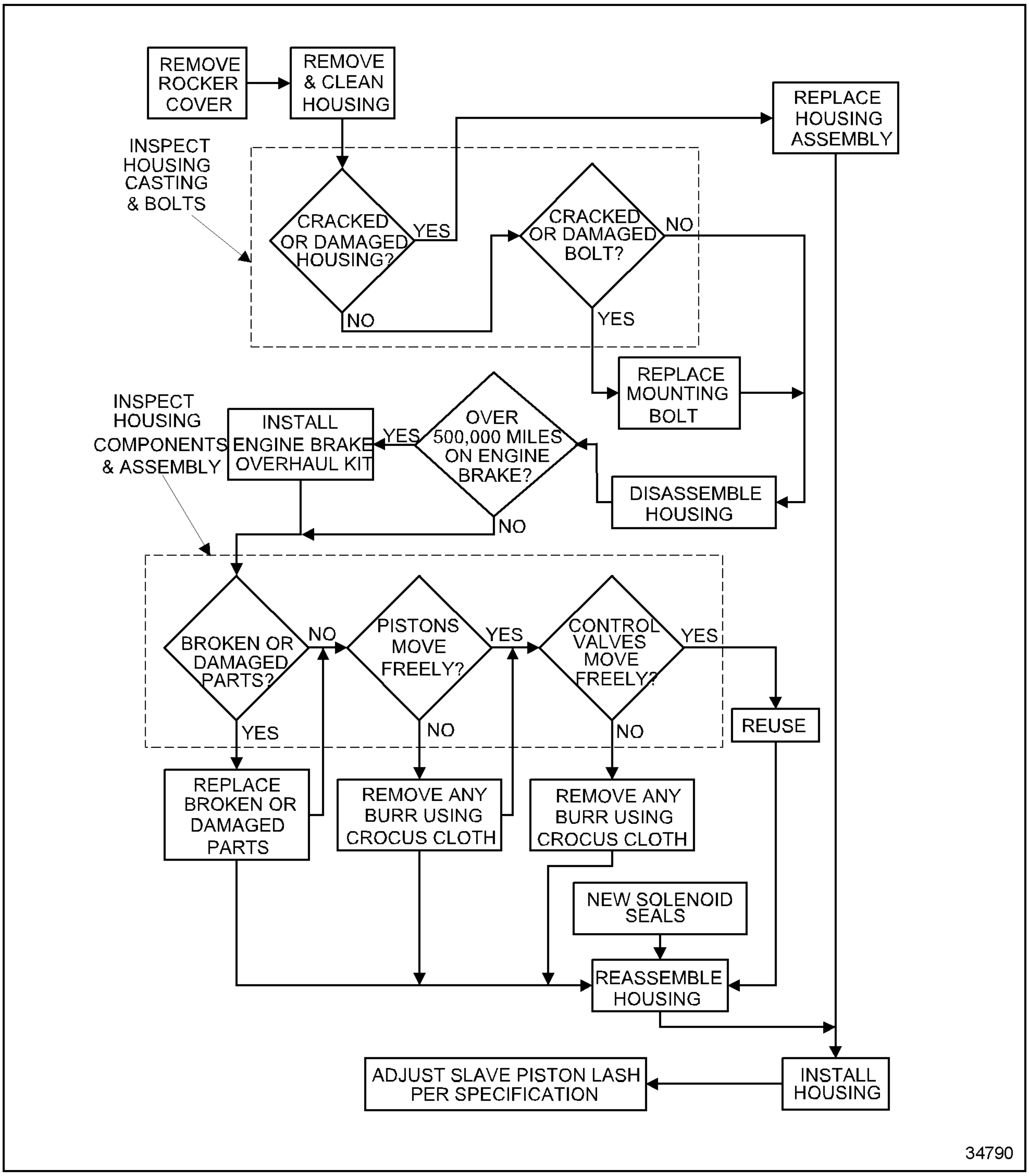


Figure 1-416 Jake Brake Repair or Replacement Flowchart

1.30.2 Removal of Jake Brake

Remove the Jake Brake as follows:

CAUTION:

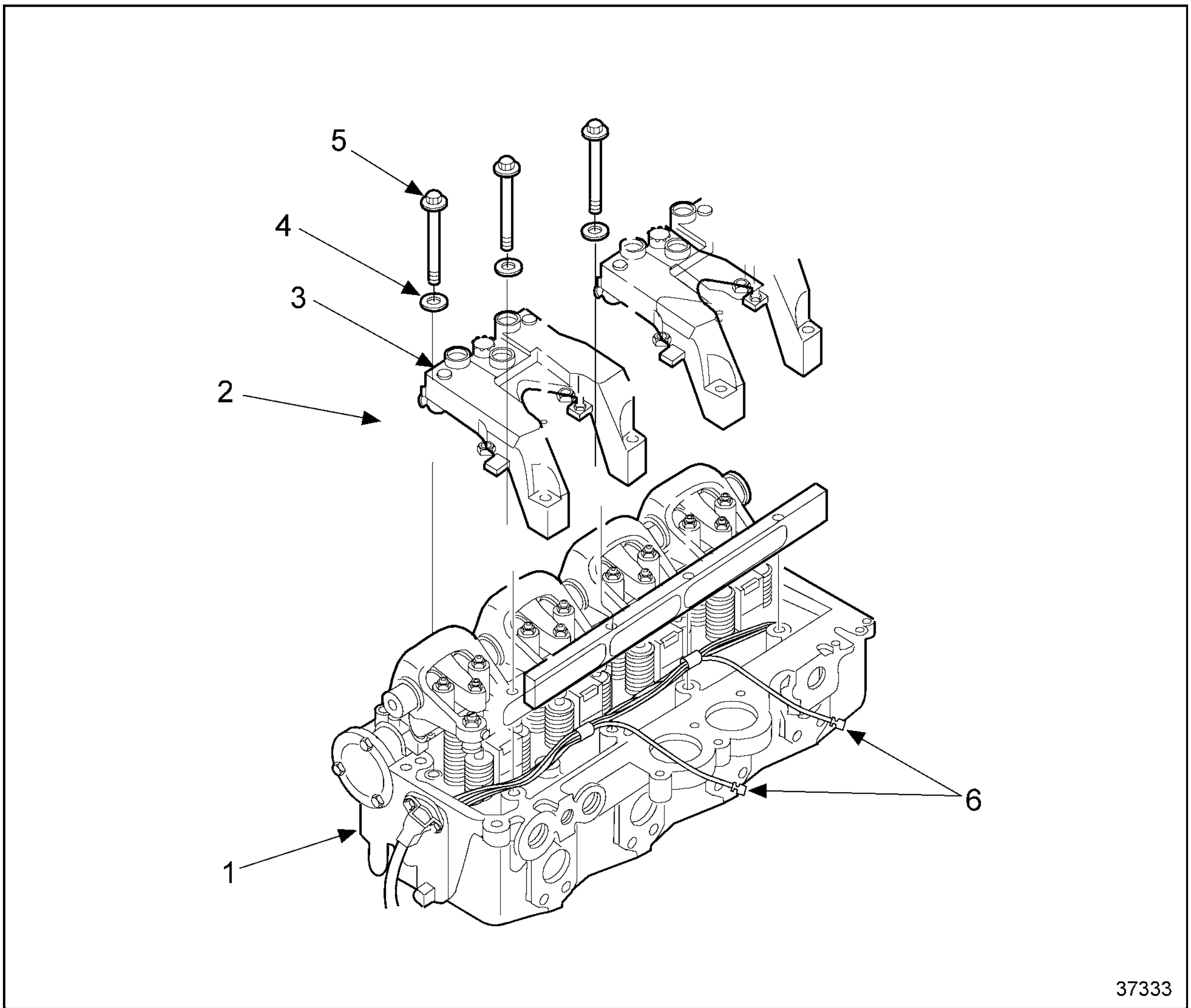
To avoid injury, never remove any engine brake component with engine running.

1. Disconnect starting power for engine. Refer to OEM guidelines.
2. Remove the engine rocker cover. Refer to Section 1.6.2.

NOTE:
If the engine is equipped with an aluminum two-piece valve cover, remove only the upper valve cover when installing the engine brake.

3. Note the location of the rocker arm shaft, the exhaust valve rocker arm, the fuel injector rocker arm, and the intake valve rocker arm.

4. Disconnect the solenoid wiring harness connectors from the engine brake solenoids. See Figure 1-417.



1. Cylinder Head
2. Jake Brake Assembly
3. Solenoid
4. Washers (3 Each)
5. Bolts (3 Each)
6. Engine Brake Harness

Figure 1-417 Jake Brake Assembly

5. Remove the six (6) mounting bolts and washers that secure the engine brake assemblies to the cylinder head. See Figure 1-417.
6. Remove the engine brake assemblies and the spacer bar.

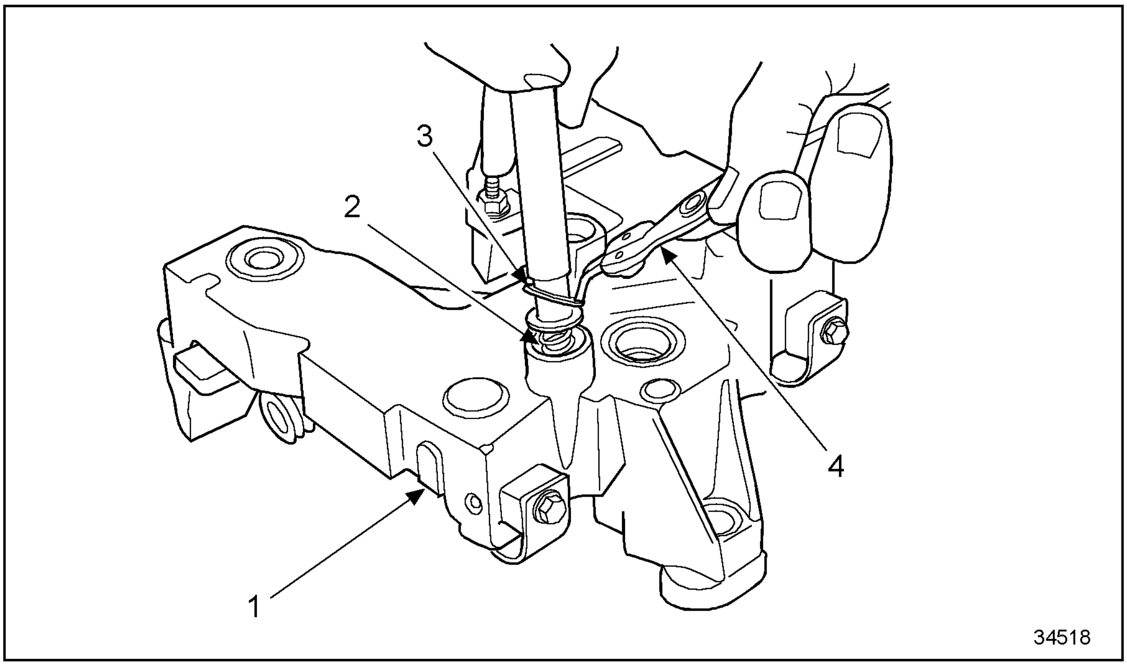
1.30.3 Disassembly of Jake Brake

Remove the control valve as follows:

CAUTION:

To avoid injury, wear a face shield or goggles.

1. Press down on control valve washer using an appropriate diameter rod to relieve spring pressure. See Figure 1-418.

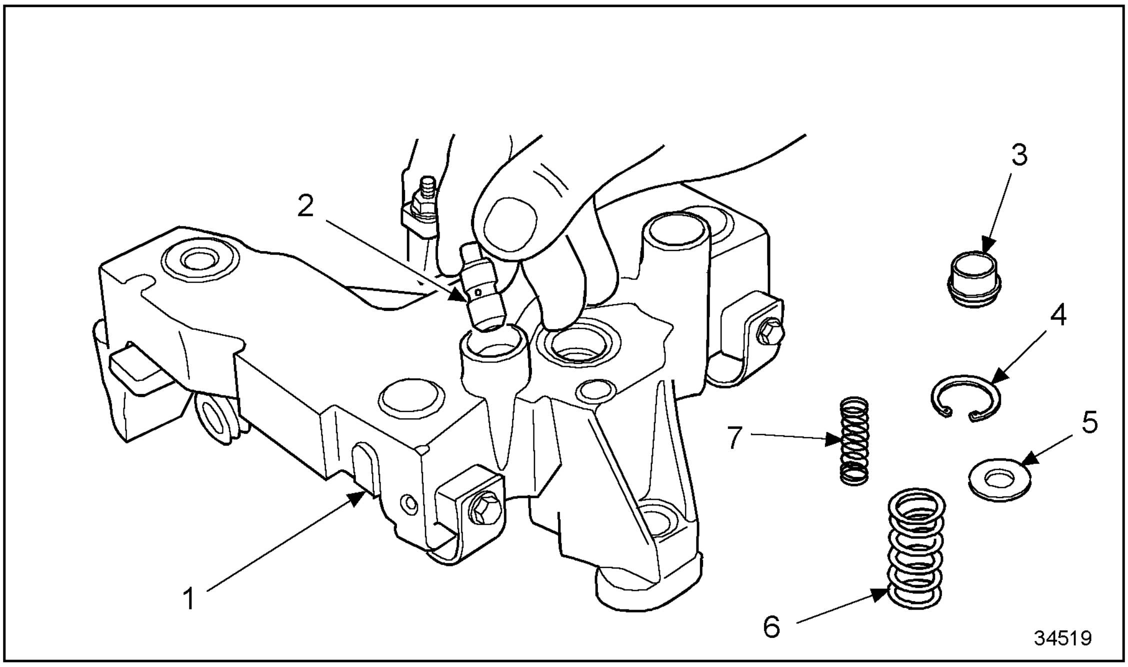


1. Jake Brake Assembly
2. Spring
3. Snap Ring Retainer
4. Snap Ring Pliers

Figure 1-418 Relieving Spring Pressure

2. Using retaining ring pliers, remove retaining ring.

3. Slowly remove cover until spring pressure ceases, then remove the two control valve springs and collar. See Figure 1-419.



1. Jake Brake Assembly
2. Control Valve
3. Collar
4. Snap Ring Retainer
5. Washer
6. Collar Spring
7. Control Valve Spring

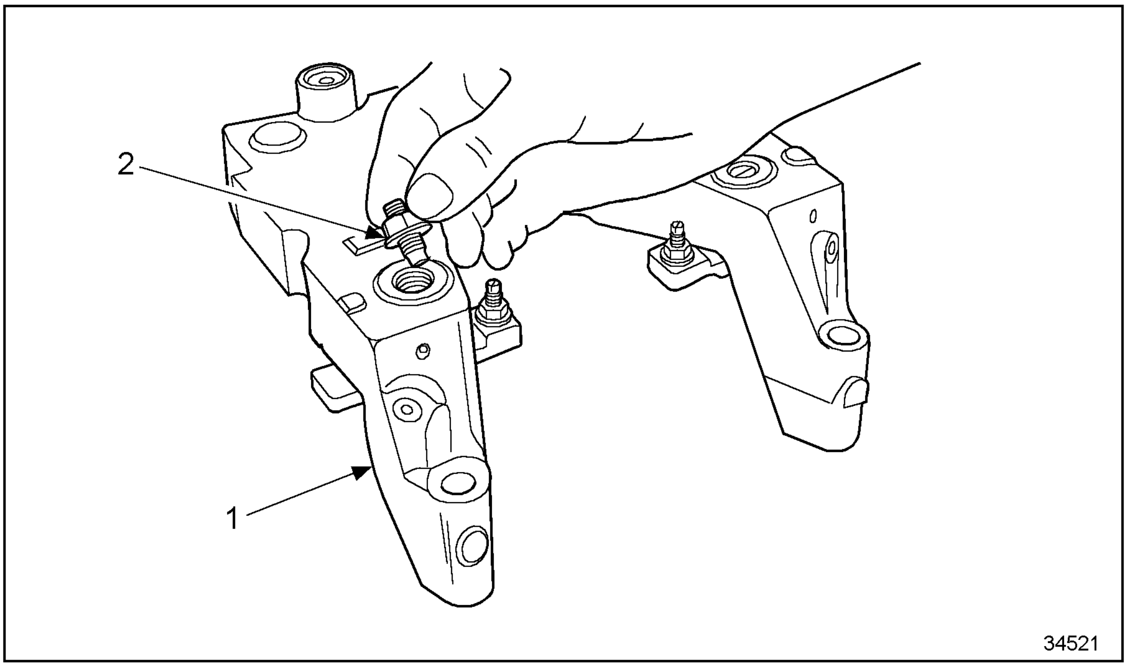
Figure 1-419 Removing Control Valve Springs and Collar

4. Using needle-nose pliers, reach into the bore and grasp the stem of the control valve. Remove control valve.

Remove the slave piston adjusting screw as follows:

1. Loosen slave piston adjusting screw locknut.

2. Remove adjusting screw from housing. See Figure 1-420.



1. Jake Brake Assembly
2. Slave Piston Adjusting Screw

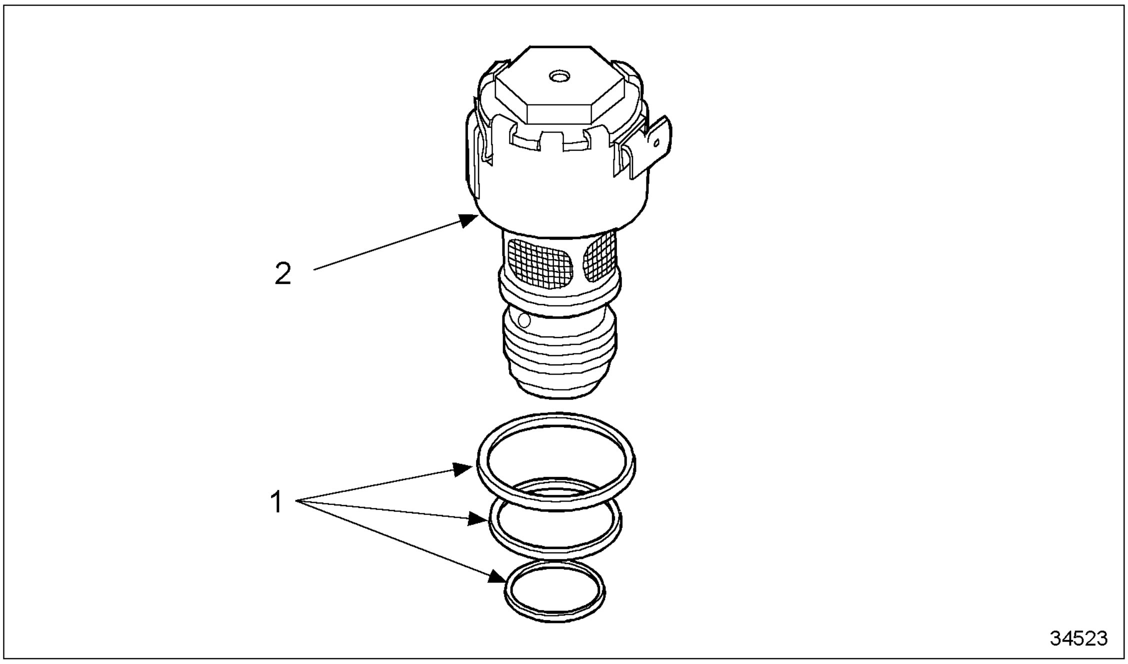
Figure 1-420 Removing Slave Piston Adjusting Screw

Remove the solenoid valve as follows:

NOTICE:
To avoid possible engine damage, do not disassemble or tamper with the solenoid valve.

1. Disconnect solenoid valve harness.
2. Using a 7/8 in. socket and extension for former solenoids or a 3/4 in., 6 point socket and extension for current solenoids, unscrew solenoid valve.

3. Remove and discard the three rubber seal rings. See Figure 1-421.



1. Seal Rings (3)
2. Solenoid

Figure 1-421 Removing Rubber Seal Rings

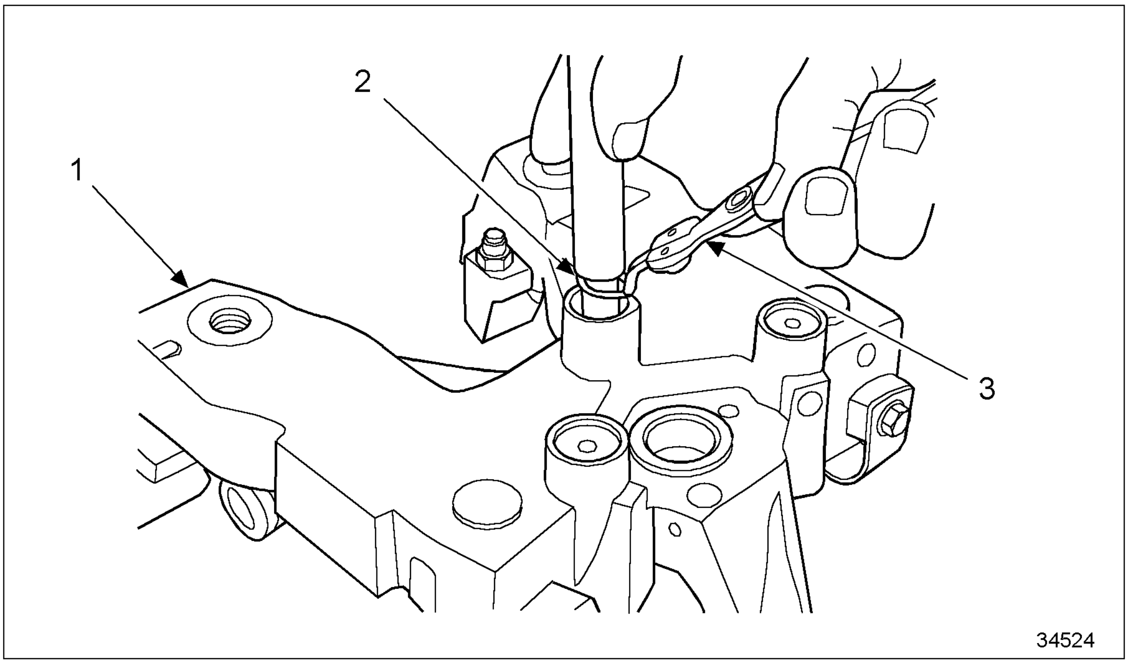
4. If the lower ring stays in the bottom of the housing bore, remove with a piece of wire.

Remove the accumulator as follows:

CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

1. Push down on the accumulator cover using the appropriate diameter rod, and remove the retaining ring. See Figure 1-422.

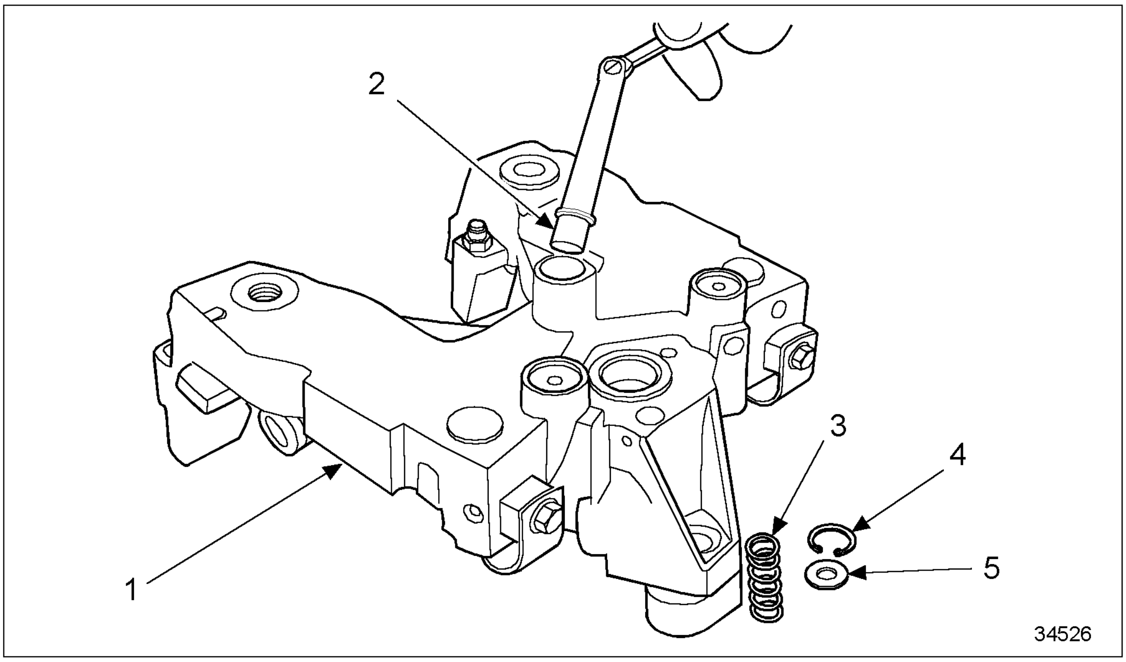


1. Jake Brake Assembly
2. Retaining Ring
3. Retaining Ring Pliers

Figure 1-422 Removing Retaining Ring

2. Relieve pressure on the accumulator cover.
3. Remove the cover and spring.

4. Use a magnet to remove the piston from the accumulator bore. See Figure 1-423.



1. Jake Brake Assembly
2. Piston
3. Spring
4. Retaining Ring
5. Washer

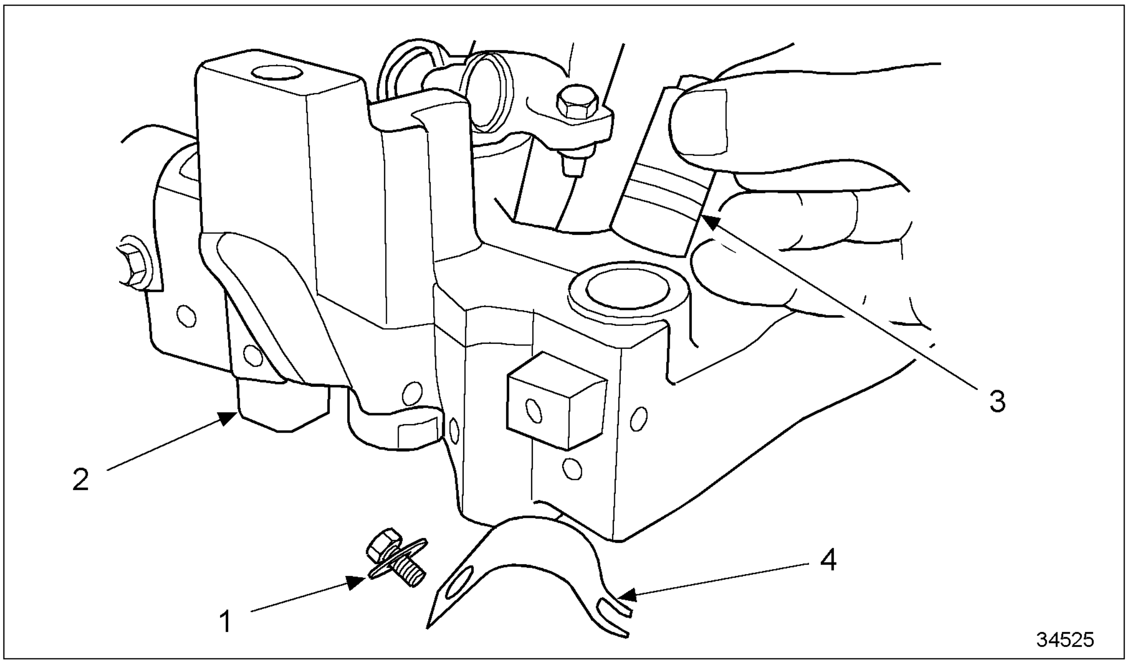
Figure 1-423 Removing Piston from Accumulator Bore with Magnet

Remove the master piston as follows:

1. Remove the screw, washer, and master piston spring from the housing.

2. Remove the master piston. See Figure 1-424.

NOTE:
Use needle-nose pliers, if necessary.



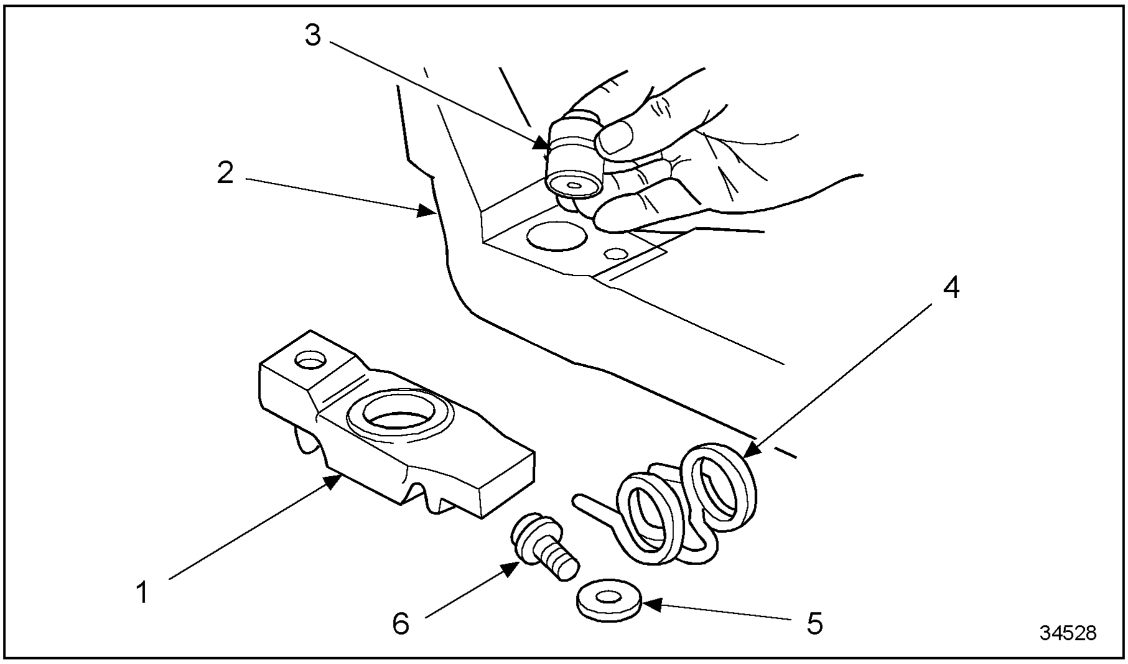
1. Washer and Screw Assembly
2. Jake Brake Assembly
3. Master Piston
4. Master Piston Spring

Figure 1-424 Removing the Master Piston

Remove the slave piston as follows:

1. Remove the screw and washer that retains the slave piston return spring.

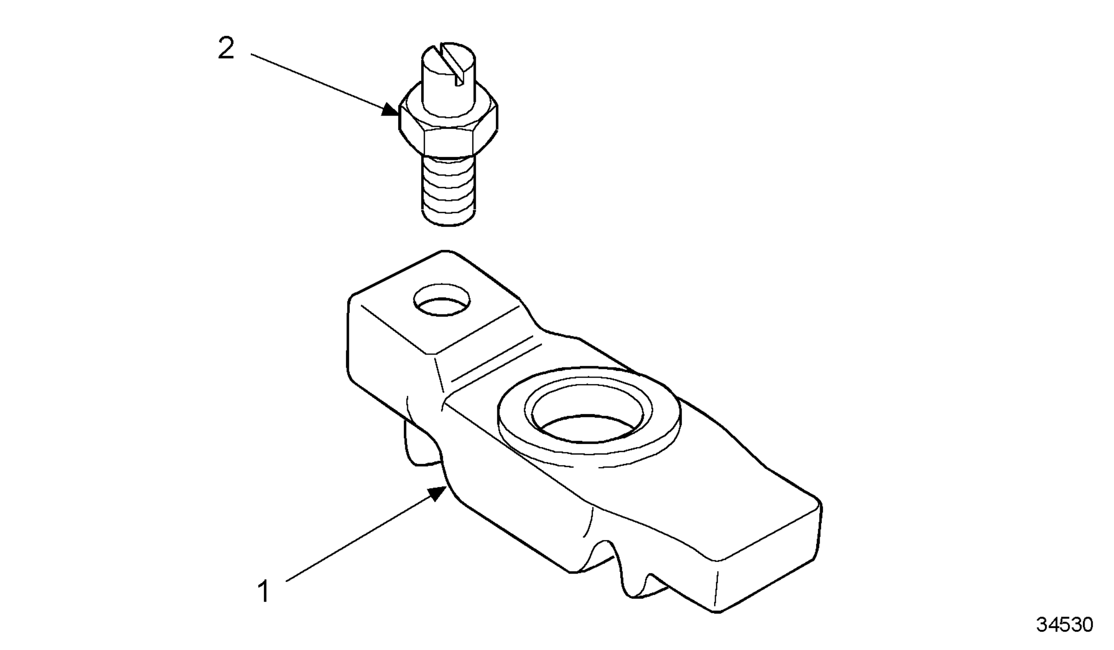
2. Remove the bridge and the slave piston. See Figure 1-425.



1. Slave Piston Bridge
2. Jake Brake Housing
3. Slave Piston
4. Return Spring
5. Washer
6. Screw

Figure 1-425 Removing Bridge and Slave Piston

3. Loosen the leveling screw locknut and remove the leveling screw from the bridge. See Figure 1-426.



1. Slave Piston Bridge
2. Slave Piston Leveling Screw

Figure 1-426 Removing the Leveling Screw from the Bridge

1.30.3.1 Cleaning of Jake Brake

Clean the Jake Brake as follows:

NOTE:
Use an OSHA-approved cleaning solvent when washing parts. Be sure to coat parts with clean engine oil when reinstalling them.

1. Wash the control valves with approved cleaning solvent.
2. Push a wire through the hole in the base of the valve to the distance required to ensure that the ball check is free.

NOTE:
The ball should lift with light pressure on the wire.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Dry the valve with compressed air, and wipe clean with a paper towel.
4. Thoroughly clean the control valve bore in the housing using clean paper towels.
5. Clean slave piston adjusting screw in an approved cleaning solvent.

NOTICE:

Use clean paper towels to clean the solenoid valve bore. Never use rags, as they may leave lint and residue which can plug the oil passageways, causing Jake Brake malfunction.

6. Clean out the solenoid valve bore in the housing.
7. Use a brush to clean the oil screen.
8. Rinse the solenoid valve in cleaning solvent.
9. Clean the master piston in approved cleaning solvent.

1.30.3.2 Inspection of the Jake Brake

The Jacobs engine brake is typically a trouble-free device. However, inspections are necessary and some maintenance is required. Use the following procedures to keep the engine brake in top condition.

Inspect the Jake Brake as follows:

1. Inspect slave piston adjusting screw for protrusion, spring pressure and freedom of movement.

NOTE:
The plunger should protrude from the bottom of the screw, have light spring pressure apparent when depressed, and move freely.

   [a] If the plunger does not protrude, the spring does not have light pressure or does not move freely, replace the entire screw assembly. Refer to Section 1.30.4.

   [b] If the slave piston adjusting screw meets specifications, continue with inspection.

2. Inspect the accumulator for wear or damage.

   [a] If worn or damaged, replace the accumulator. Refer to Section 1.30.4.

   [b] If accumulator is not worn or damaged, continue with inspection.

3. Inspect the master piston bore for wear or damage.

NOTE:
Some wear marks are permissible.

[a] If worn or damaged, replace the master piston. Refer to Section 1.30.4.

[b] If not worn or damaged, continue with inspection.

4. Apply clean lube oil to the piston, and insert into bore.

NOTE:
Master piston should move in and out freely with no binding.

[a] If binding occurs, replace master piston and/or housing. Refer to Section 1.30.4.

[b] If no binding occurs, continue with inspection.

5. Inspect master piston spring for relaxation.

NOTE:
The spring should hold the master piston completely in the housing.

[a] If relaxed, replace the spring. Refer to Section 1.30.4.

[b] If spring holds tightly, continue with inspection.

6. Inspect slave piston components for excessive wear or damage.

[a] If worn or damaged, replace slave piston component.

[b] If not worn or damaged, proceed with inspection.

1.30.3.3 Inspection of Control Valve

Inspect the control valve as follows:

1. Dip the control valves in clean lube oil.
2. Holding the control valve by the stem, let it drop into the bore.

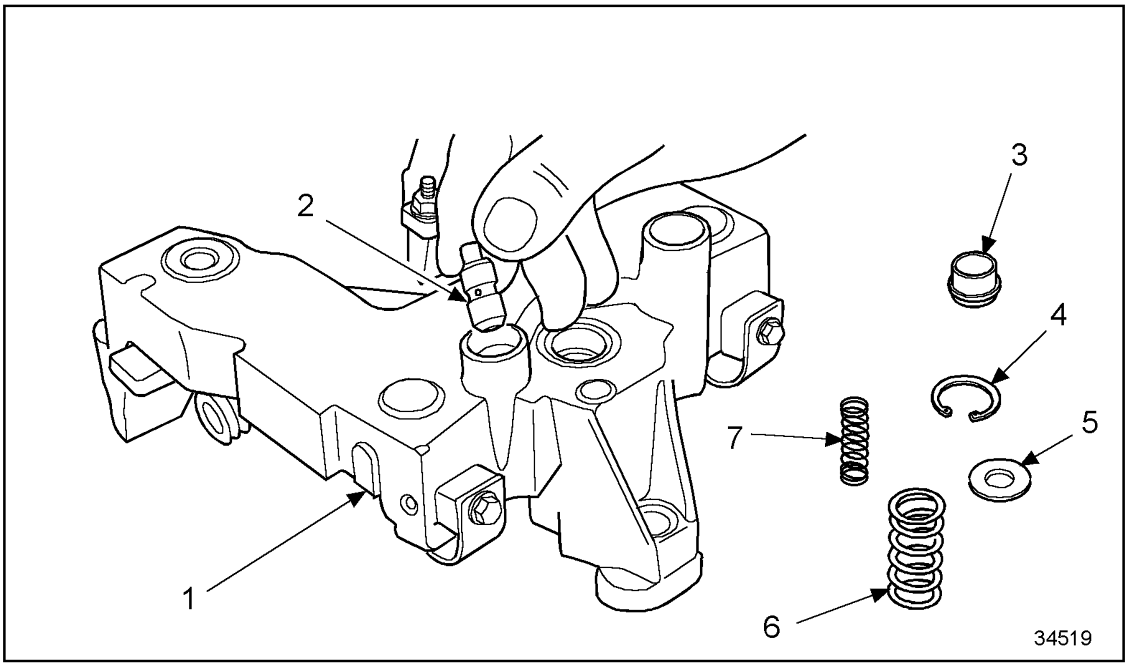
[a] If binding occurs or if the ball sticks in the valve, replace the control valve. Refer to Section 1.30.4.

[b] If no binding occurs and the ball does not stick in the control valve, assemble the Jake Brake. Refer to Section 1.30.4.

1.30.4 Assembly of Jake Brake

Install the control valve as follows:

1. Slip the control valve into the bore. See Figure 1-427.



1. Jake Brake Assembly
2. Control Valve
3. Collar
4. Snap Ring Retainer
5. Washer
6. Collar Spring
7. Control Valve Spring

Figure 1-427 Installing the Control Valve

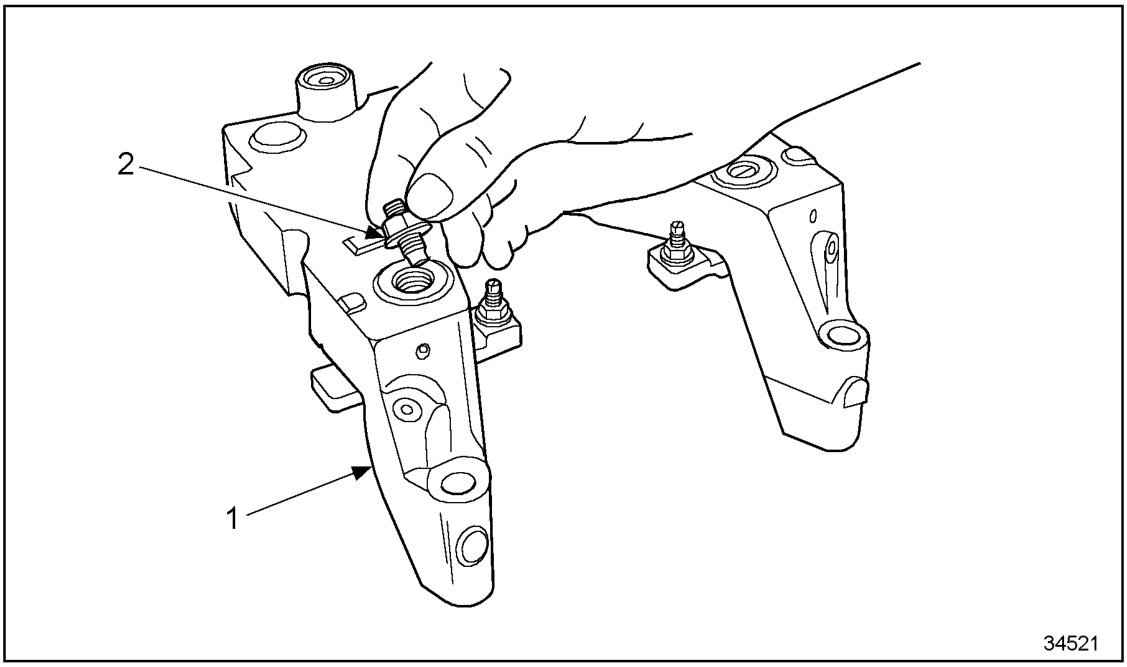
2. Install the control valve collar and two springs.

NOTE:
Ensure the collar is installed with the longer sleeve area facing up. If the collar is installed upside down, the engine brake cylinder will not operate.

3. Press the cover (washer) into place.
4. While holding the cover tightly in place, install the retaining ring.
5. Rotate retaining ring ears 90° to assure ring is seated in groove.

Install the slave piston adjusting screw as follows:

1. Place the screw in the housing. See Figure 1-428.



1. Jake Brake Assembly
2. Slave Piston Adjusting Screw

Figure 1-428 Installing the Slave Piston Adjusting Screw

2. Do not torque the slave piston adjusting screw locknut at this time.

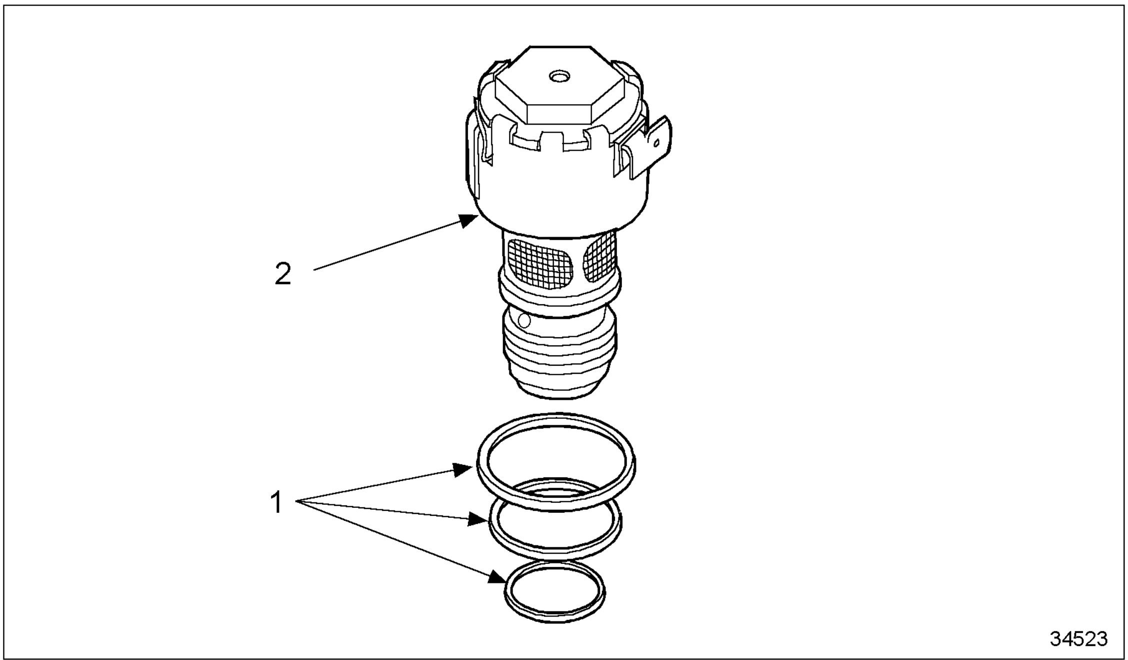
Install the solenoid valve as follows:

NOTE:
As of October 19, 1997, former solenoids have been replaced with the current improved solenoids. The current solenoids have an increased installation torque and improved durability. The current solenoid is interchangeable with the former.

1. Coat new solenoid valve seal rings with clean lube oil.

NOTE:
Use current upper seals when installing current solenoids. New seals are identified with yellow stripes.

2. Install the upper and center seal rings on the solenoid valve body and the lower seal ring into the bottom of the bore in the housing. See Figure 1-429.



1. Seal Rings (3)
2. Solenoid

Figure 1-429 Installation of Solenoid Valve Seal Rings

3. Make sure the seals are seated properly.
4. Using a 7/8 in. socket and extension for former solenoids or a 3/4 in., 6 point socket and extension for current solenoids, carefully screw the solenoid valve into the housing without unseating the seals.
5. Torque the former solenoid to 12.4 N·m (9 lb·ft). Torque the current solenoid to 20 N·m (15 lb·ft).

NOTE:
Be careful not to twist the seals while installing.

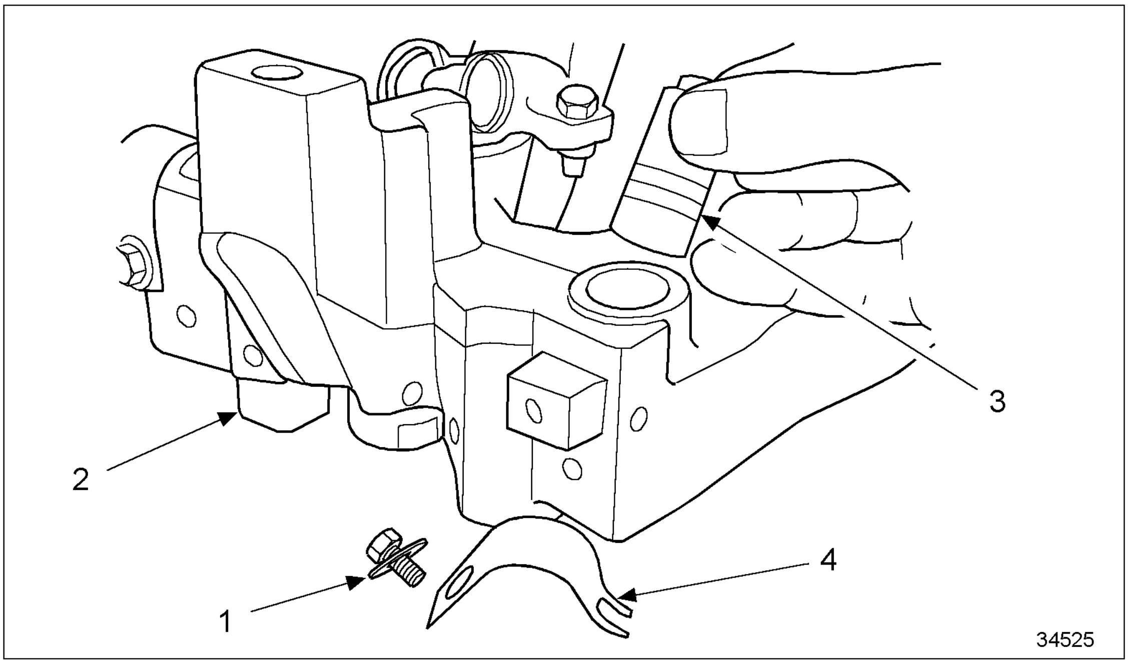
Install the accumulator as follows:

1. Place the piston into the accumulator bore.
2. Insert the spring, and install the cover.
3. Push down the accumulator cover, and insert retaining ring.

Install the master piston as follows:

1. Apply clean lube oil to the piston.

2. Insert master piston into bore. See Figure 1-430.



1. Washer and Screw Assembly
2. Jake Brake Assembly
3. Master Piston
4. Master Piston Spring

Figure 1-430 Inserting Master Piston into Bore

3. Install spring, washer, and screw.

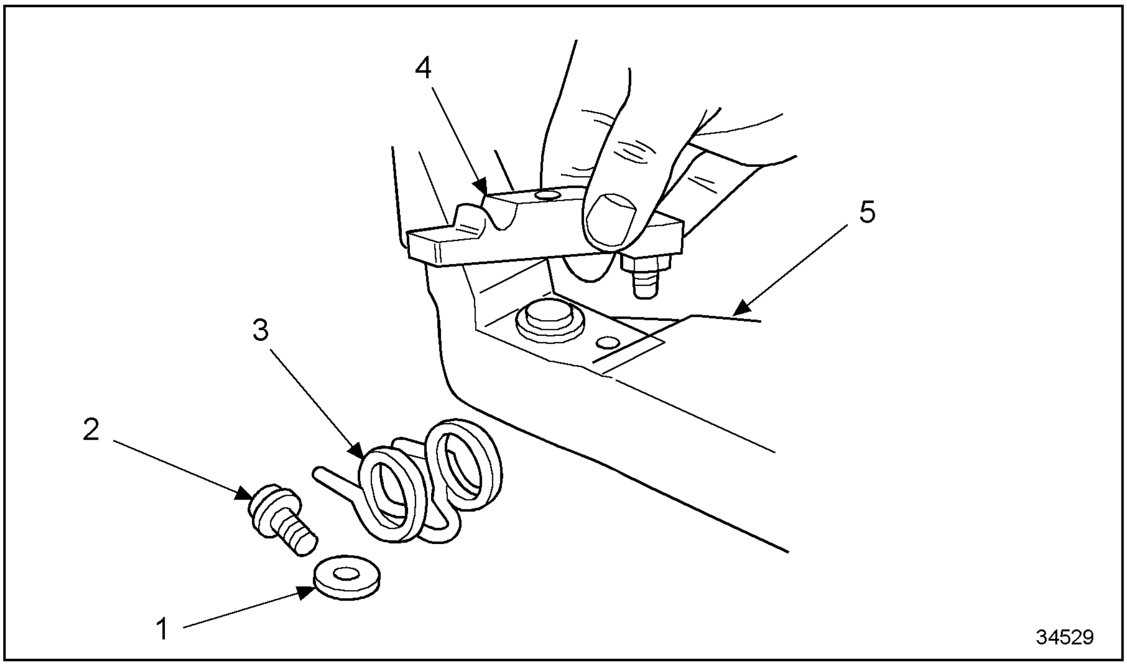
NOTE:
Make sure spring legs are centered around master piston boss.

4. Torque screw to 10 N·m (7.4 lb·ft).

Install the slave piston as follows:

1. Install the screw from the slave piston side of the bridge.
2. Install the leveling screw locknut.

3. Install the bridge with the leveling screw toward the center of the housing. See Figure 1-431.



1. Washer
2. Screw
3. Torsion Spring
4. Bridge Assembly
5. Jake Brake Housing

Figure 1-431 Installing Bridge with Leveling Screw Toward Center of Housing

4. Install the slave piston assembly torsion spring with the ends over the bridge. See Figure 1-432.

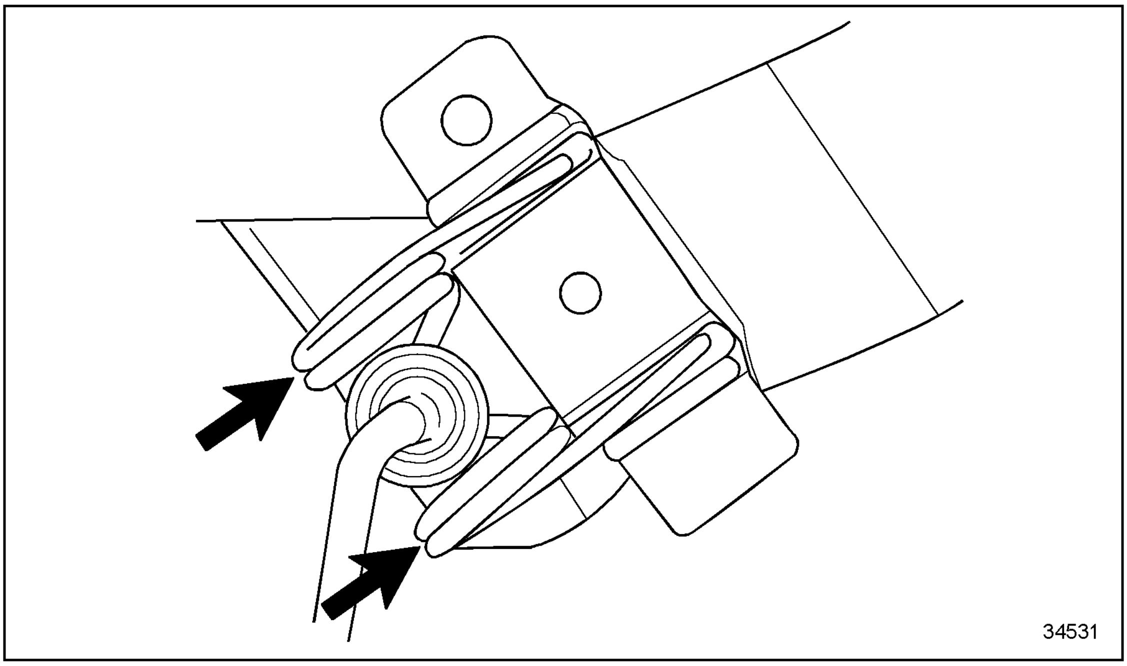


Figure 1-432 Installing the Slave Piston Assembly Torsion Spring

5. Install the screw over the center part of the spring.

NOTICE:
While tightening the screw on the torsion spring, push the spring toward the slave piston assembly. Failure to do so may result in contact between the intake valve adjusting screw and torsion spring. Serious engine damage may result.

6. Torque the screw to 20 N·m (15 lb·ft.).

1.30.5 Installation of the Jake Brake

Install the Jake Brake as follows:

1. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to Section 1.12.2.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Attach the length of tubing to a blow gun nozzle, and blow out the oil from the bolt holes.
3. Cover the holes with hand towels to minimize oil spray.

NOTE:
Removing the oil from the bolt holes prevents the cylinder head from cracking when tightening the bolts.

4. Place the spacer bar on the exhaust manifold side of the cylinder head with the center notch facing the exhaust manifold. See Figure 1-433.

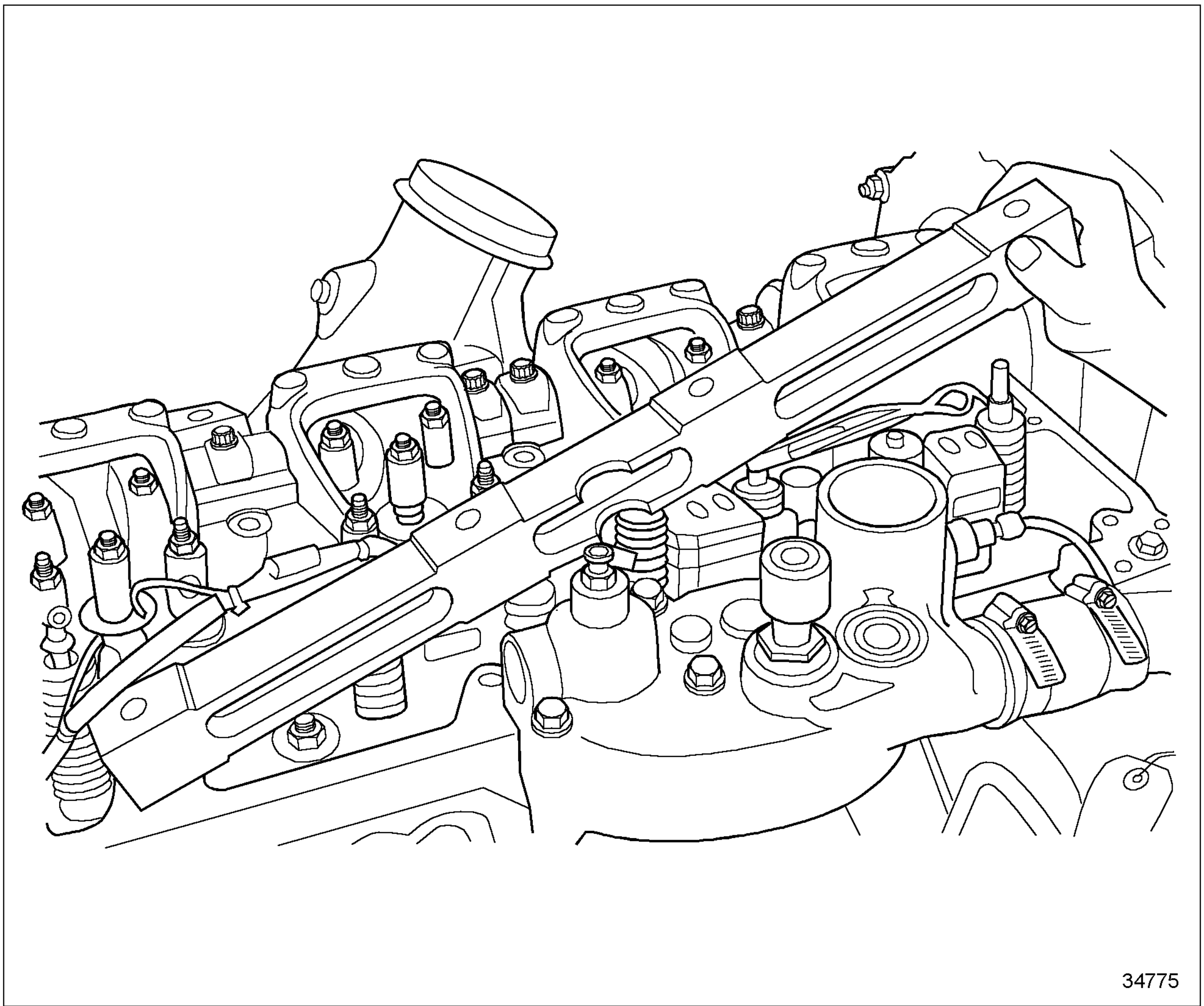


Figure 1-433 Location of Spacer Bar

5. Place the two engine brake housings over the rocker shafts with the solenoid valves toward the camshaft side of the engine.

NOTE:
Be sure housings do not interfere with wiring harness.

NOTICE:
Do not mix the rocker arm shaft bolts and the Jake Brake mounting bolts. If the rocker arm shaft bolt is mistakenly used to mount the Jake Brake housing, the longer shoulder on the bolt will block the oil supply to the Jake Brake on the camshaft side of the housing. The brake will not retard the engine as designed. This condition could cause loss of vehicle braking control on downgrades, which may create a risk of personal injury to the vehicle operator or other persons and damage to the vehicle or property of others.

NOTE:
The rocker arm shaft mounting bolt and Jake Brake mounting bolt, part of the Jake Brake assembly, are similar in appearance. Both are M12 x 110 mm (4.33 in.) long and have 12 point heads.

NOTE:
In the event of a housing hold down bolt failure on a Jacobs engine brake housing, replace all bolts on that particular housing.

NOTICE:
Use bolts that have the Jacobs logo, circled "J". Installation of bolts that do not have the circled "J" may result in damage to the engine, engine brake or both.

[a] The Jake Brake bolt has the Jacobs logo (circled "J") and the letters "EF" marked on the head. The bolt length is no longer marked atop the bolt head.

[b] The DDC rocker arm shaft bolt has the DDC logo (spinning arrows) and the vendor I.D. (F-C) on its head.

NOTE:
Be sure that only Jake Brake bolts, see Figure 1-434, are installed in the Jake Brake housing.

[c] [c] The DDC bolt shoulder is much longer, 17.0 mm (0.669 in.) versus 4 mm (0.157 in.) than the Jake Brake bolt. See Figure 1-434.

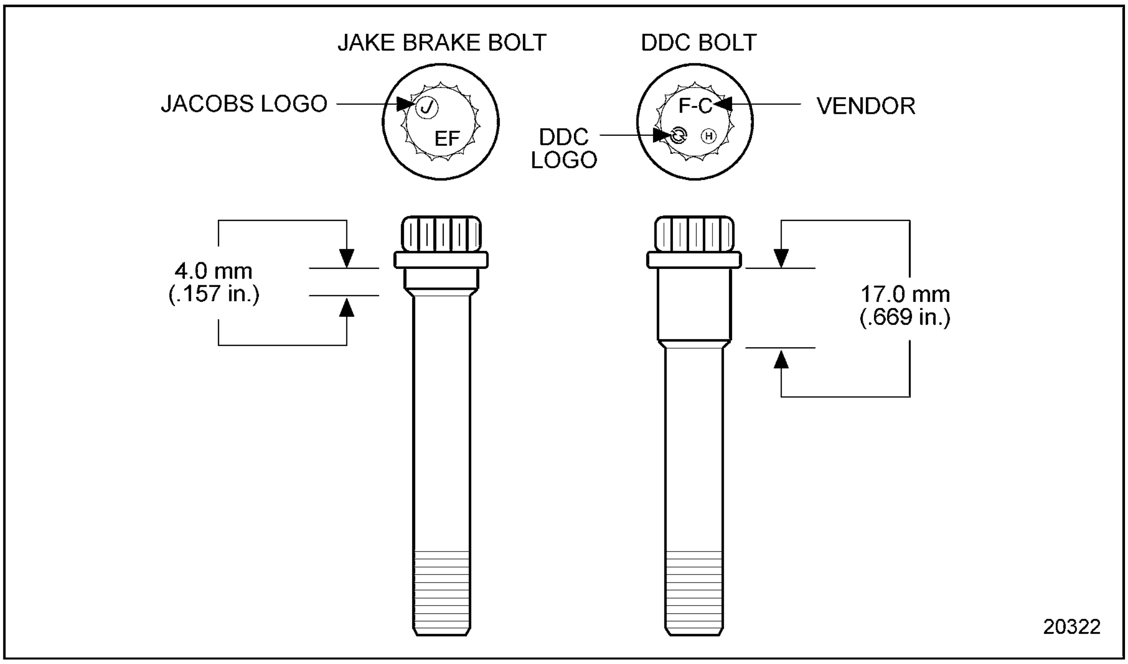


Figure 1-434 Jake Brake and DDC Bolt Identification

NOTE:
All the housing mounting bolts for models 750, 750A and 750B are the same length.

6. Install a washer on each bolt, and install into housings (three bolts per housing).

7. Move the housing from side to side. For models 750 and 750B locate the housing in the center position of the movement. For model 750A locate the housing as far towards the camshaft side of the engine as possible. See Figure 1-435.

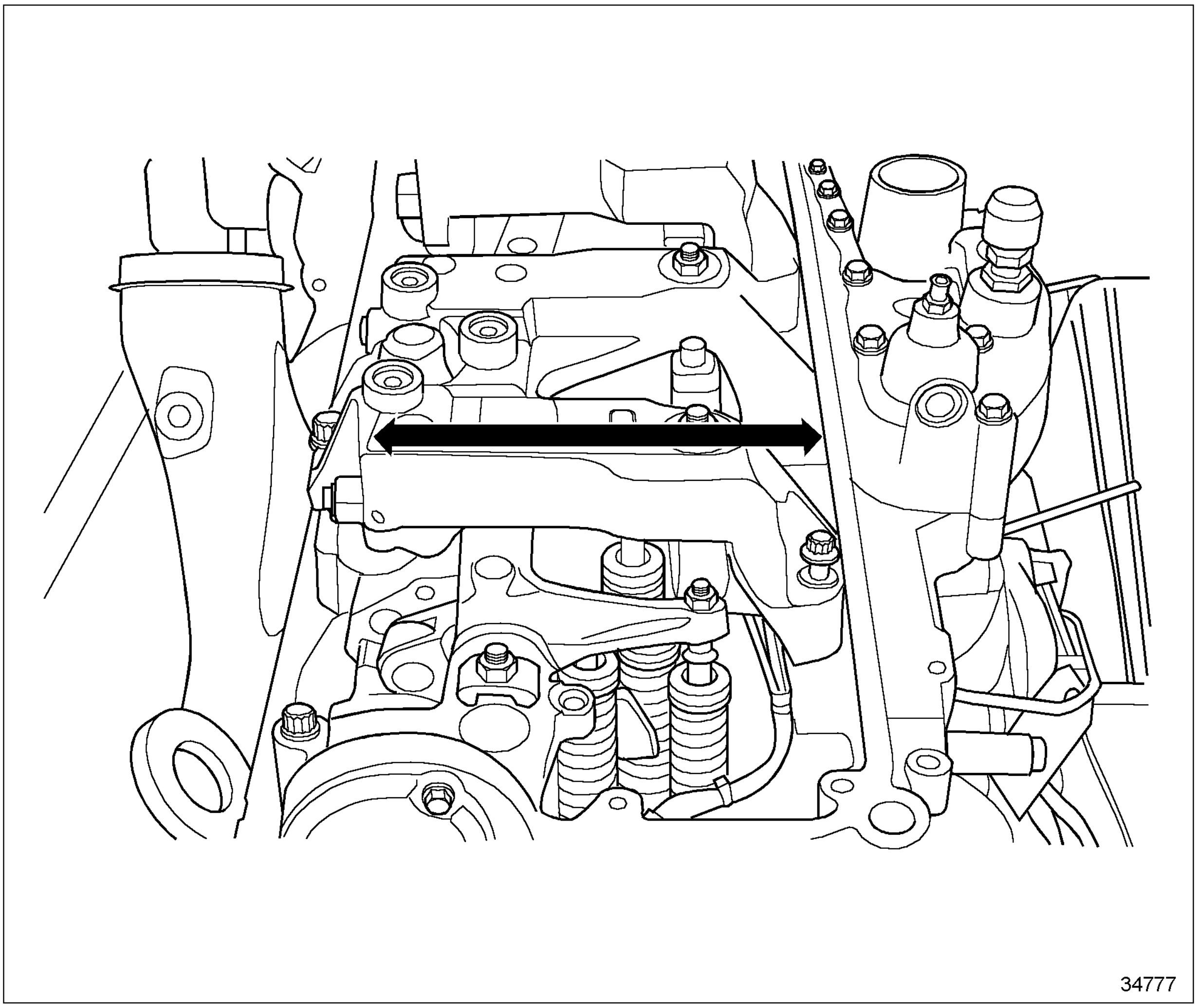


Figure 1-435 Locating Center Position of Housing

8. Torque the engine brake mounting bolts using the following sequence:
   [a] Torque the two bolts on the camshaft side of the engine to 55 N·m (40 lb·ft).
   [b] Torque the four bolts on the exhaust manifold side of the engine to 55 N·m (40 lb·ft).
   [c] Repeat the tightening sequence and re-torque all bolts to 136 N·m (100 lb·ft).
   [d] Check the torque to 136 N·m (100 lb·ft).
9. Secure wire harness to spacer bars with plastic ties.
10. Connect wiring harness solenoid connectors to solenoids.

1.30.5.1 Adjustment of Slave Piston

Make the following adjustment with the engine stopped and cold, and the oil temperature at 60°C (140°F) or below. The exhaust valves on the cylinder *must* be in the closed position (rocker arm roller on the base circle of the camshaft). When setting the engine brake lash, the exhaust valves must be in the closed position.

Adjust the slave piston on all models as follows:

NOTICE:
This application and adjustment information must be strictly followed. Failure to follow these instructions may result in serious engine or engine brake damage.

NOTE:
Model 750B Jacobs engine brake requires a special procedure for adjusting the slave piston. The procedure is clearly indicated in the following adjustment steps.

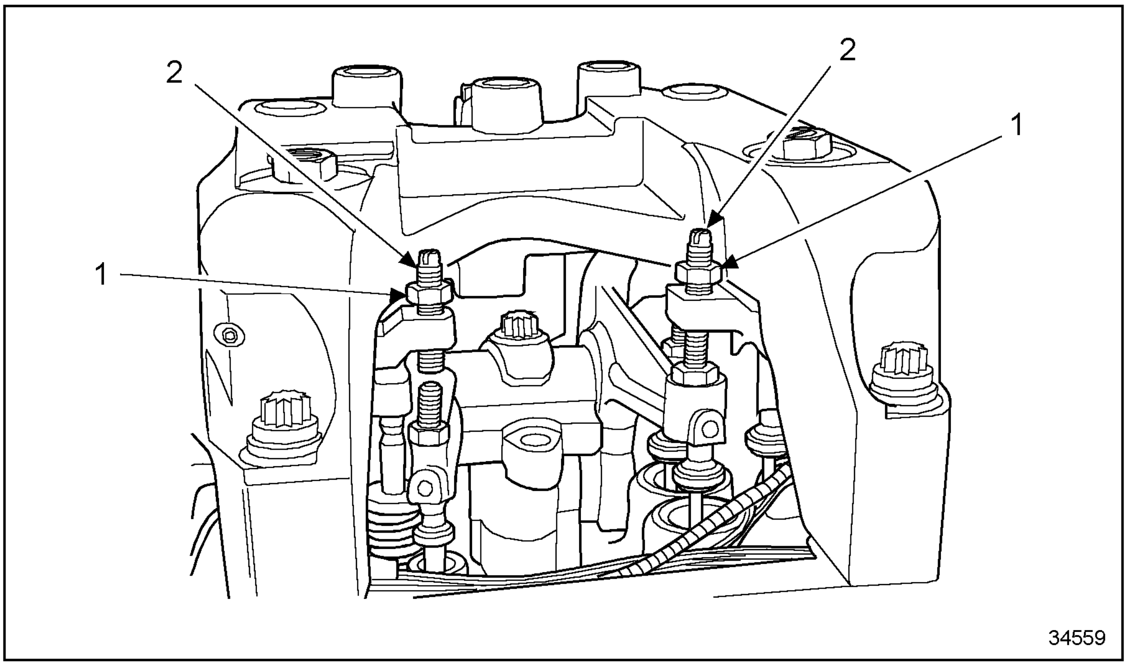
NOTICE:
Improper slave piston adjustment can result in engine or brake housing damage.

NOTICE:
Strictly follow the slave piston adjustment procedure. Failure to use the proper adjustment procedure will result in poor engine brake performance and/or serious engine damage.

1. Refer to Section1.30 for proper slave piston clearance setting.

2. Back out the leveling screw in the slave piston assembly until the end of the screw is beneath the surface of the bridge in the slave piston assembly. See Figure 1-436.

NOTE:
The leveling screw is located in the bridge member of the slave piston assembly.

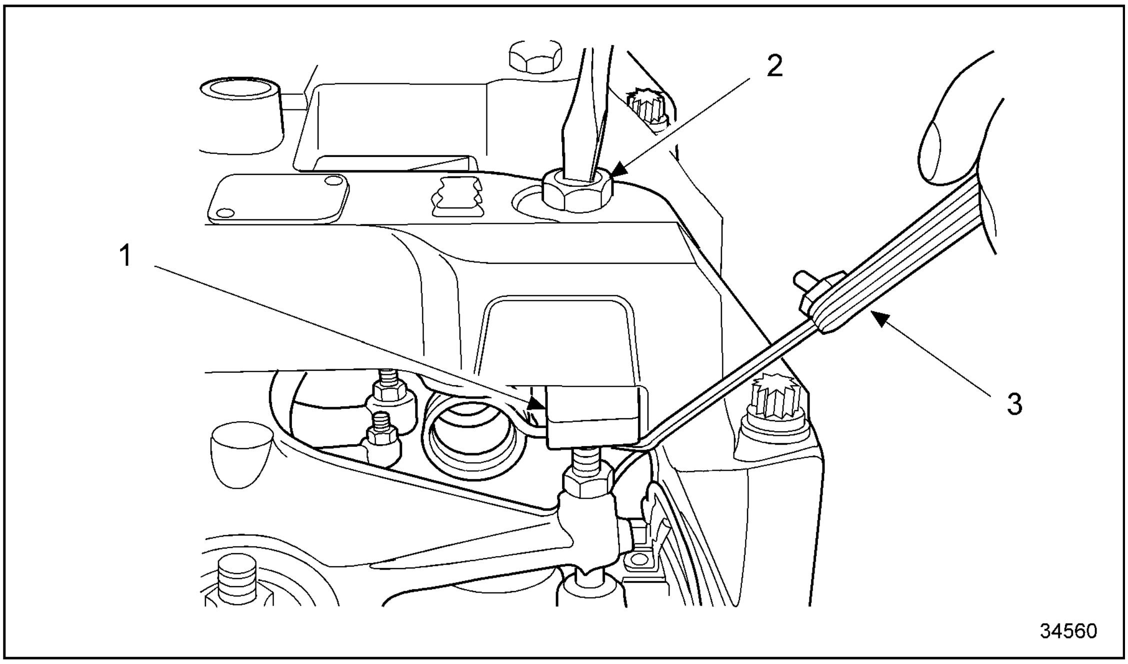


1. Locknut
2. Leveling Screw

Figure 1-436 Location of Leveling Screw

3. Place the correct size feeler gage between the solid side of the slave piston (the side without the leveling screw) and the exhaust rocker arm adjusting screw. Refer to Section 1.30 for proper feeler gage sizes.

4. Turn the slave piston adjusting screw clockwise until a slight drag is felt on the feeler gage. See Figure 1-437.



1. Slave Piston Bridge
2. Slave Piston Adjusting Screw
3. Feeler Gage

Figure 1-437 Turn Slave Piston Adjusting Screw Clockwise

5. Perform the following additional steps on model 750B:

   [a] Turn in the J-Lash® adjusting screw until the solid side of the slave piston bridge assembly contacts the exhaust valve and the valve springs begin to compress. Turn in one additional turn.

NOTICE:
All oil must be purged from the J-Lash adjusting screw. Oil remaining in the J-Lash screw will cause inaccurate clearance adjustment, resulting in possible engine or engine brake damage. If oil is below room temperature (below 60°F), wait at least two minutes for oil to be purged from the J-Lash adjusting screw.

NOTE:
Wait at least 30 seconds for oil to be purged from the J-Lash adjusting screw.

   [b] Back out the adjusting screw **only**until the correct size feeler gage can be inserted between the solid side of the slave piston bridge assembly and the exhaust valve.

[c] Adjust the J-Lash so that a light drag is felt on the feeler gage.

NOTE:
Do not back out the J-Lash more than required to obtain a light drag on the feeler gage.

[d] Use a screwdriver to hold the J-Lash in place, and torque the lock nut to 34 N·m (25 lb·ft).

NOTE:
If the J-Lash screw is backed out until it no longer compresses the slave piston spring, oil will enter the screw and the adjustment will be incorrect. If this occurs, repeat the J-Lash adjustment procedure.

[e] Recheck the lash settings. If clearance setting is incorrect, repeat the J-Lash adjustment procedure.

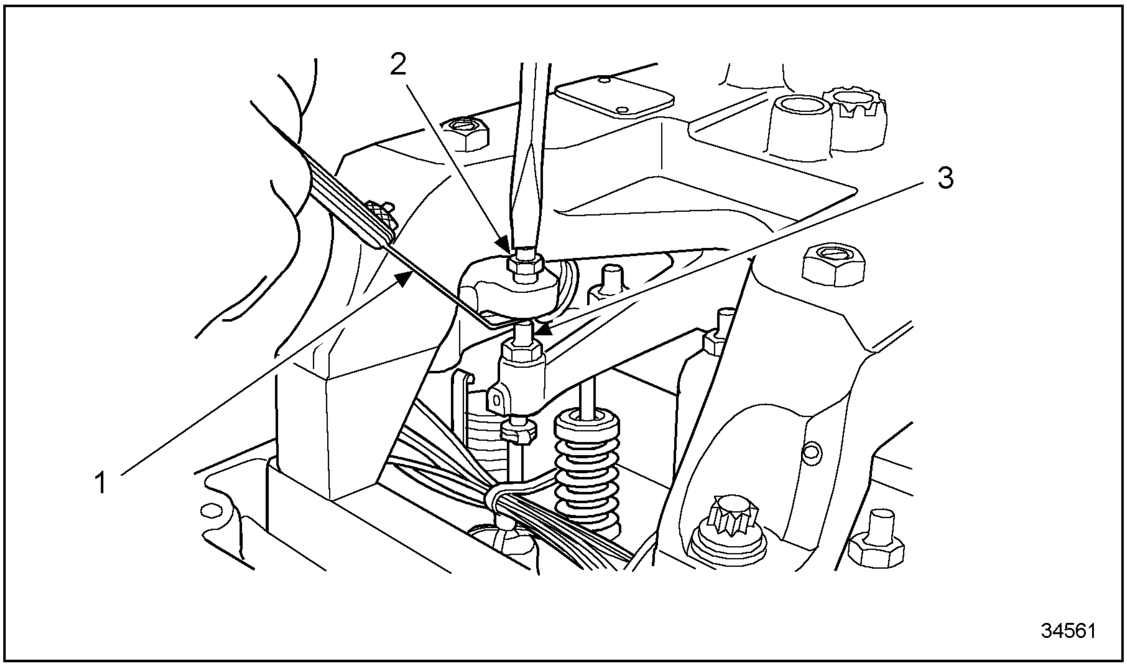
NOTE:
Once the engine brake has been run, oil enters the J-Lash screw making the engine brake adjustment unreadable. If unsure of the adjustment, repeat the J-Lash adjustment procedure.

6. Hold the screw in position, and torque the locknut to 35 N·m (26 lb·ft).
7. Check the adjustment, and repeat if necessary.

NOTE:
Do not disassemble the slave piston adjusting screws.

8. Place the correct feeler gage between the leveling screw and the rocker arm adjusting screw.

9. Turn the leveling screw clockwise until a slight drag is felt on the feeler gage. See Figure 1-438.



1. Feeler Gage
2. Slave Piston Leveling Screw
3. Rocker Arm Adjusting Screw

Figure 1-438 Setting Clearance on Leveling Screw and Rocker Arm

10. Hold the leveling screw in position, and torque the locknut to 47 N·m (35 lb·ft).
11. Check adjustment, and repeat if necessary.
12. Repeat the adjustment procedures for the remaining cylinders. Refer to step 2.

CAUTION:

To avoid injury when working near or on an operating engine, remove loose items of clothing, jewelry, tie back or contain long hair that could be caught in any moving part causing injury.

NOTE:
Bar over the engine when necessary to place the exhaust valves in the closed position for slave piston adjustment.

13. Install the engine rocker cover. Refer to Section 1-100.
14. Install all remaining components that were removed for this procedure.

15. Connect starting power for the engine.
16. Verify proper Jake Brake installation by driving the vehicle, then checking engine brake performance.

1.A ADDITIONAL INFORMATION

Description **Page**

SHOP NOTES

Shop notes contains information on checking bearing clearances, the crankshaft remanufacturing procedures and a glossary.

Cylinder Block Liner Boring

Further information will be printed as it is developed.

Checking Bearing Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of 0.0254-0.0762 mm (0.001-0.003 in.). Type PR-1 (red) has a range of 0.0508-0.1524 mm (0.002-0.006 in.). Type PB-1 (blue) has a range of 0.1016-0.2286 mm (0.004-0.009 in.).

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 to be checked.

NOTE:
Check the main bearing clearances with the weight of the crankshaft supported by a jack under the counterweight adjoining the bearing being checked. If the engine is positioned with the main bearing caps supporting the crankshaft and flywheel, an erroneous reading could result.

2. Place a piece of plastic strip the full width of the bearing shell, about 1/4 inch off center. See Figure 1-439.

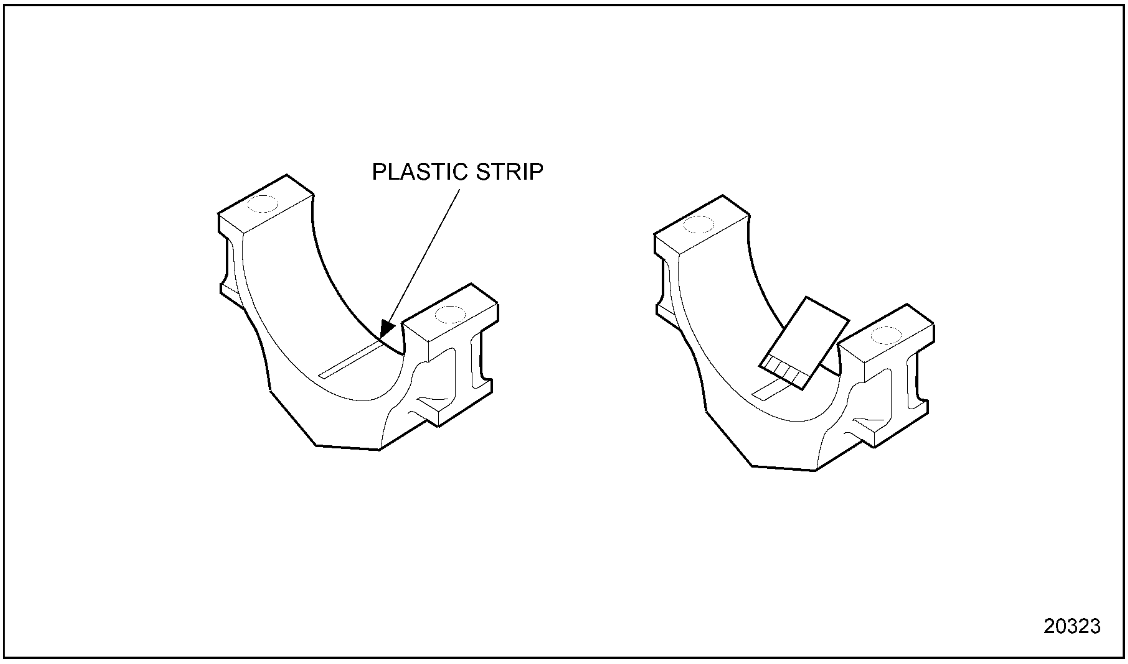


Figure 1-439 Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

3. Install the bearing cap. Torque the bolts to 470-530 N·m (347-391 lb·ft).
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. See Figure 1-439. The value within the graduation on the envelope indicates the bearing clearance in thousands of an inch. To obtain metric specifications:

[a] Multiply the reading obtained (in thousandths) by 25.4. Taper may be indicated when one end of the flattened plastic strip is wider than the other.

[b] Measure each end of the plastic strip. The difference between the two readings is the approximate amount of taper.

CRANKSHAFT REMANUFACTURING PROCEDURES

This section describes the procedures used to remanufacture crankshafts.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, 0.25 mm, 0.50 mm and 0.75 mm (approx. 0.010 in., 0.020 in., and 0.030 in.), undersize bearings listed in Table 1-8are available.

Crankshafts which exhibit surface irregularities may be reground to utilize these bearings. Listed in Table 1-8, are guidelines to determine if the crankshaft is suitable for regrinding:

Bearing Size	Connecting Rod Journal Diameter	Main Bearing Journal Diameter
Standard	85.000-84.975 mm (3.346-3.345 in.)	125.000-124.975 mm (4.921-4.920 in.)
0.250 mm (0.010 in.) Undersize	*84.750-84.775 mm (3.336-3.337 in.)	*124.750-124.725 mm (4.911.-4.910 in.)
0.500 mm (0.020 in.) Undersize	*84.500-84.475 mm (3.327-3.326 in.)	*124.500-124.475 mm (4.902-4.901 in.)
0.750 mm (0.030 in.) Undersize	*84.250-84.225 mm (3.317-3.316 in.)	*124.250-124.225 mm (4.892-4.891 in.)

* Dimension of reground crankshaft.

Table 1-8 Crankshaft Journal Specifications

Inspection

Perform the following steps for part inspection:

1. Determine if the crankshaft is from a Series 50 Engine models as listed in Table 1-9.

Model	Forging Part Number	Year Released	Fillet Finishing
8.5L Liter	23511363	1993	Induction Hardened
8.5L Liter	23515595	1994	Induction Hardened

Table 1-9 Crankshaft Part Number History

2. Inspect connecting rod and main bearing journals for discoloration due to excessive overheating from bearing failure.

NOTE:
Crankshafts with discoloration are not acceptable for rework.

3. Inspect keyway conditions using width gages and micrometers. Compare with the specifications. See Figure 1-440.

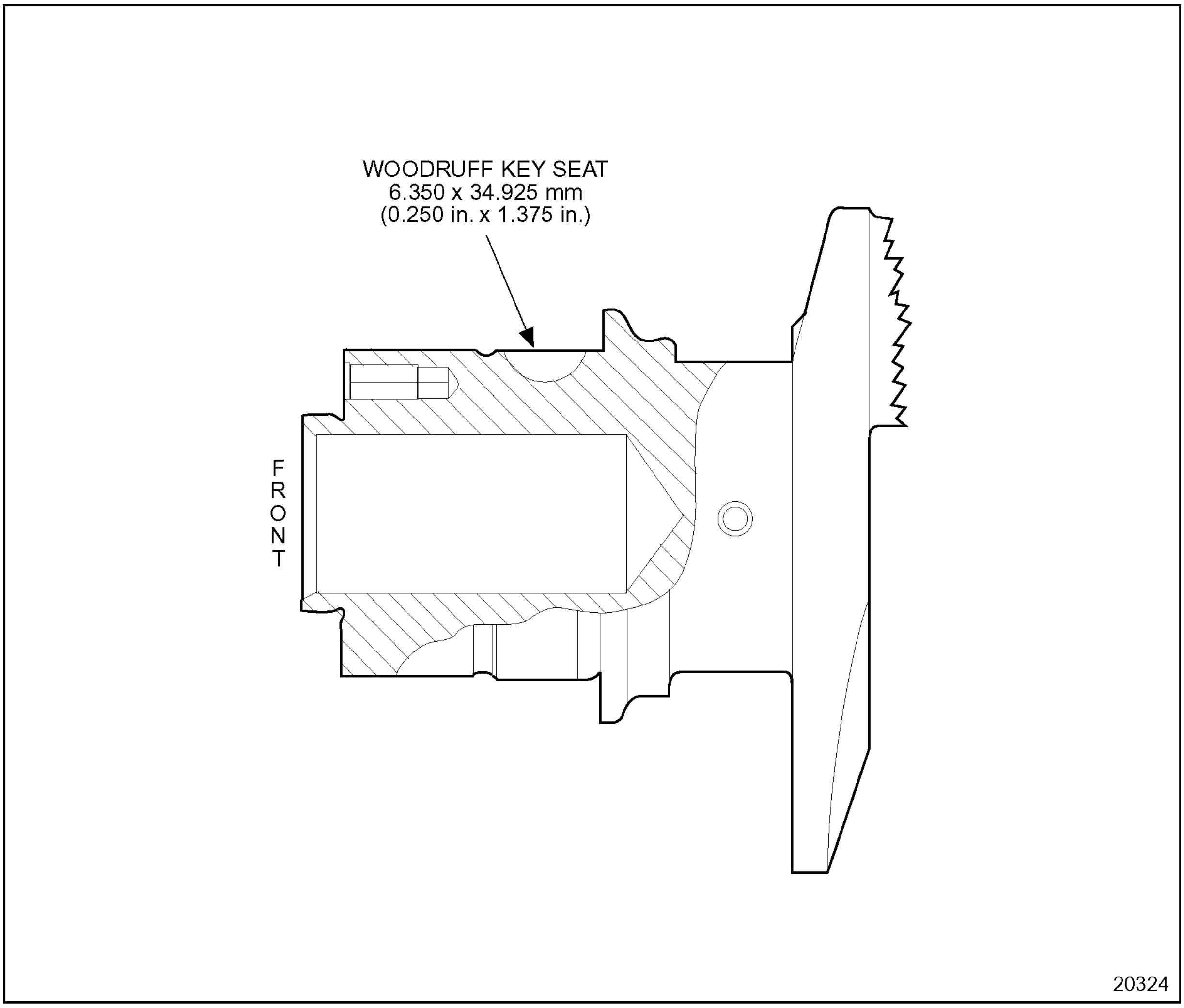
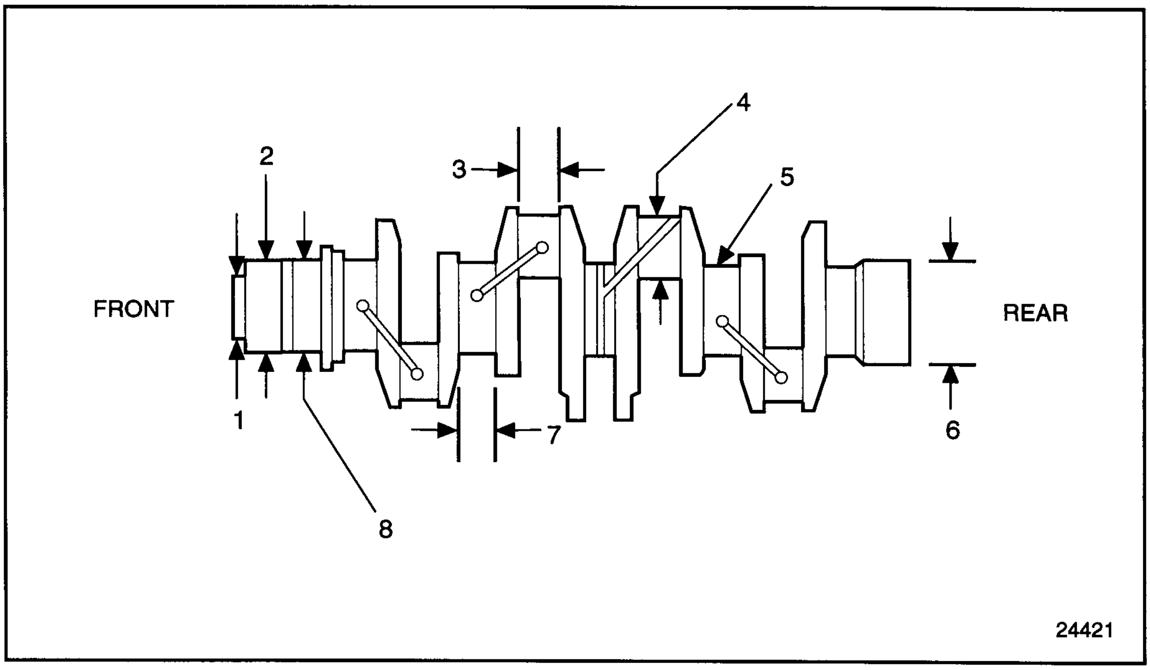


Figure 1-440 Standard Crankshaft Keyway Dimensions

4. Inspect flange bolt holes visually and determine if any necessary repairs can be made by chasing threads or installing Heli-coil(s).

5. Regardless of seal area wear condition, a new sleeve and seal must be installed. See Figure 1-441.



1. 80.19-80.22 mm (3.157-3.158 in.)
2. 131.72-131.78 mm (5.186-5.188 in.)
3. 55.77-55.87 mm (2.196-2.200 in.)
4. 84.975-85.00 mm (3.345-3.346 in.)
5. 49.45-49.55 mm (1.947-1.950 in.)
6. 131.72-131.78 mm (5.186-5.188 in.)
7. 49.35-49.65 mm (1.943-1.955 in.)
8. Crankshaft Timing Gear Contact Surface Diameter

Figure 1-441 Standard Crankshaft Dimensions

6. Read and record all "bearing" total indicator reading (TIR) measurements with the crankshaft mounted in vee-blocks. Listed in Table 1-10 are TIR limits.

NOTE:
run-out tolerance listed in Table 1-10are given for guidance when regrinding crankshaft. When the run-out on adjacent journals is in the opposite direction, the sum must not exceed 0.075 mm (0.003 in.) total indicator reading. When the run-out on adjacent

journals is in the same direction, the difference must not exceed 0.075 mm (0.003 in.) total indicator reading.

Journals Supported on	Journals Measured	Maximum Run-Out (Total Indicator Reading)
No. 1 and No. 5	No. 2 and No. 4	0.050 mm (0.002 in.)
No. 1 and No. 5	No. 3	0.075 mm (0.003 in.)

Table 1-10 Bearing Total Indicator Reading (TIR) Specifications

7. Whether run-out on adjacent journals is in the same or opposite directions, the sum shall not exceed 0.075 mm (0.003 in.) TIR.
8. When high spots of run-out adjacent journals are at right angles to each other, the sum shall not exceed 0.10 mm (0.004 in.) TIR or 0.05 mm (0.002 in.) on each journal.
9. In the event of bearing seizure, bearing overlay must be removed. Check the width of journals to determine whether the sidewalls can be reground. See Figure 1-441.
10. Visually inspect the entire crankshaft for any serious deviations from normal wear patterns, cracks, nicks or other damage.
11. If the crankshaft has been ground undersize prior to present receiving inspection, check fillets, thrust, and all widths to determine whether or not enough stock remains to warrant regrinding. Listed in Table 1-11 are crankshaft specifications.

Crankshaft Specifications	Minimum	Maximum	Tolerance
Journal Diameter-Main Bearing	124.975 mm (4.920 in.)	125.000 mm (4.921 in.)	0.025 mm (0.001 in.)
Journal Diameter-Connecting Rod Bearing	84.975 mm (3.345 in.)	85.000 mm (3.346 in.)	0.025 mm (0.001 in.)
Journal Out-of-Round-Main Bearing	-	0.012 mm (0.0005 in.)	0.012 mm (0.0005 in.)
Journal Out-of-Round-Connecting Rod Bearing	-	0.008 mm (0.0003 in.)	0.008 mm (0.0003 in.)
Journal Taper * - Main Bearing	-	0.012 mm (0.0005 in.)	0.012 mm (0.005 in.)
Journal Taper *-Connecting Rod-Full Length	-	0.008 mm (0.0003 in.)	0.008 mm (0.0003 in.)
Journal Taper * Connecting Rod Half-Length	-	0.004 mm (0.00016 in.)	0.004 mm (0.00016 in.)
Gear Fit run-out TIR (Total Indicated Reading)	-	0.038 mm (0.0015 in.)	0.038 mm (0.0015 in.)
Journal Alignment-Main and Connecting Rod-Per Length of Pin	-	0.012 mm (0.0005 in.)	0.012 mm (0.0005 in.)

Crankshaft Specifications	Minimum	Maximum	Tolerance
Axial Profile Slope-Main - Full Length	-	0.008 mm (0.0003 in.)	0.008 mm (0.0003 in.)
Axial Profile Slope-Mains Per 5.0 mm (0.197 in.) of Length	-	0.006 mm (0.00024 in.)	0.006 mm (0.00024 in.)
Axial Profile Slope-Connecting Rod Journals-Full Length	-	0.006 mm (0.00024 in.)	-
Axial Profile Slope-Connecting Rod Journals-Per 50 mm (0.197 in.) of Length	-	0.003 mm (0.0001 in.)	-
Main Fillet Radius	3.5 mm (0.1378 in.)	4.0 mm (0.1574 in.)	-
Connecting Rod Fillet Radius (23511363)	5.5 mm (0.2165 in.)	6.0 mm (0.2362 in.)	-
Connecting Rod Fillet Radius (23515595)	3.5 mm (0.130 in.)	4.0 mm (0.150 in.)	-
Surface Finish-Main and Connecting Rod Journals	-	0.3 µ m12AA	0.3 µ m12AA
Surface Finish-Thrust Wall	-	0.4 µ m16AA	0.4 µ m16AA
Surface Finish-Oil Seal Area	0.25 µ m10AA	0.63 µ m20AA	0.25 µ m10AA
Journal Hardness (Rockwell "C")	47 Rc	55 Rc	8 Rc
Crankshaft Dynamic Balance-(Ounce-Inch)	-	1.5	1.5
Main and Connecting Rod Journal Alignment Per Length of Pin	-	0.012 mm (0.0005 in.)	-
Convex Crankshaft Butt Face Convex	-	0.013 mm (0.0005 in.)	0.043 mm (0.0017 in.)
Convex Crankshaft Butt Face Concave		0.03 mm (0.0011 in.)	0.043 mm (0.0017 in.)

* As Measured on Radial Basis

Table 1-11 Crankshaft Specifications

12. Journal O.D. score marks must be:
    [a] Circumferential-not axial.
    [b] Maximum of 0.254 mm (0.010 in.) wide.
    [c] At least 3.175 mm (0.125 in.) from fillet tangent point.
    [d] Smooth, no proud metal.

[e] Maximum of one mark per journal.

13. No journal dimpling permitted for removal of defects.
14. Nicks, dents or pits in journal O.D. must be 3.175 mm (0.125 in.) maximum diameter, no proud metal, maximum (3) per journal.
15. Pins and bearing journals which exhibit discoloration due to excessive overheating from bearing failure are not acceptable for rework.
16. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.
17. Inspect the hardness of all journals. Crankshafts to be 47-55 Rc.
18. Clean the crankshaft as follows:

[a] Clean all oil passages with a brush. Power probing is recommended.

[b] Remove all copper, brass and lead, etc., from journal surfaces. Scrub the crankshaft until clean in a detergent bath.

[c] Extremely rusted shafts can be soaked in hot rust stripper.

[d] Scrub all webs and counterweights with a wire brush to remove all blackened residue. Use industrial detergent at proper ratios or regular hot degreaser.

NOTICE:
A crack in any vital area of the crankshaft cannot be repaired or removed. That is why magnetic particle inspection of the entire crankshaft before regrinding is mandatory. Crankshafts that are cracked MUST BE SCRAPPED.

19. After a visual inspection, the crankshaft should be magnetically inspected using one of the two following methods:

[a] **Magnetic Particle Method: Refer to Section** 1.7.2.6.

[b] **Fluorescent Magnetic Particle Method: Refer to Section** 1.7.2.7.

MACHINING OPERATIONS

The following topics cover machining operations:

- ☐ Main And Connecting Rod Journals
- ☐ Grinding Connecting Rod Journals (Pins)
- ☐ Grinding Main Bearing Journals

Main and Connecting Rod Journals

To machine main and connecting rod journals, perform the following:

1. Connecting rod and main bearing journal grinding should be performed with crankshaft rotation opposite to actual engine rotation. See Figure 1-442.

NOTE:
Crankshaft and main journal grinding should be performed with crankshaft rotation opposite to actual engine rotation. While polishing should be performed with the crankshaft rotation in the same direction as engine rotation.

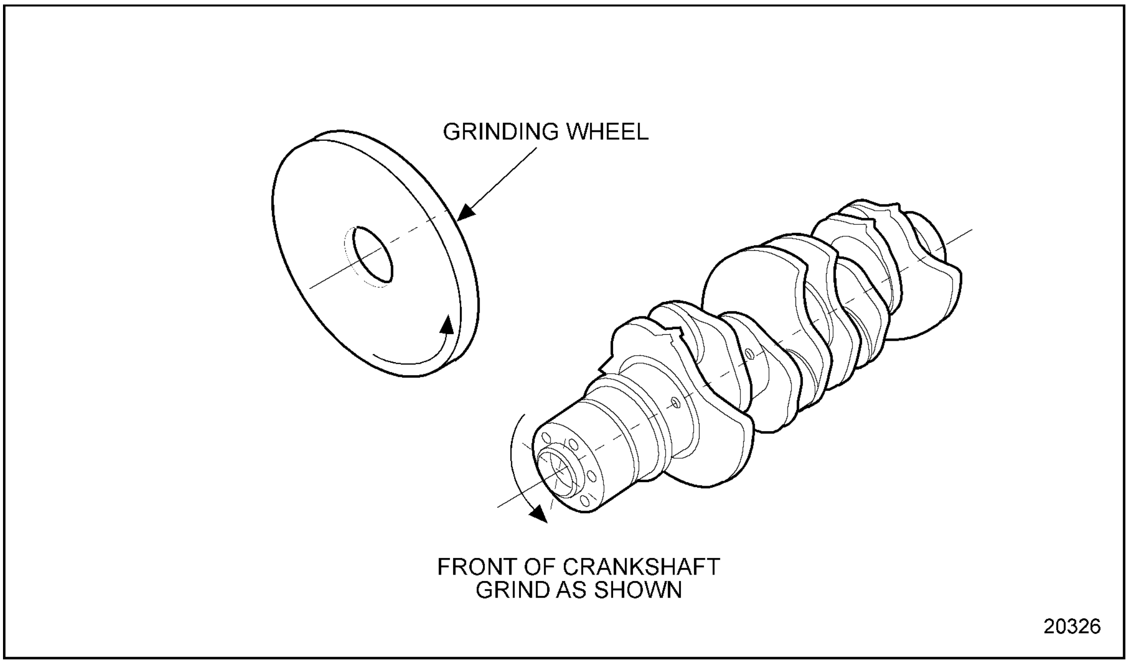


Figure 1-442 Crankshaft Grinding Rotation

2. Crankshaft polishing should be performed with the crankshaft rotation in the same direction as engine rotation.
3. All connecting rod journal fillets must have a 5.75 mm (0.226 in.) for 23511363 crank, and 3.75 mm (0.148 in.) for crank 23515595 radius between the crank cheek and the journal.
4. All main journal fillets must have a 3.75 mm (0.148 in.) radius between the crank cheek and the journal.
5. No journal may have any sharp grind marks. The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches.

6. The radius may be checked with a fillet gage. See Figure 1-443.

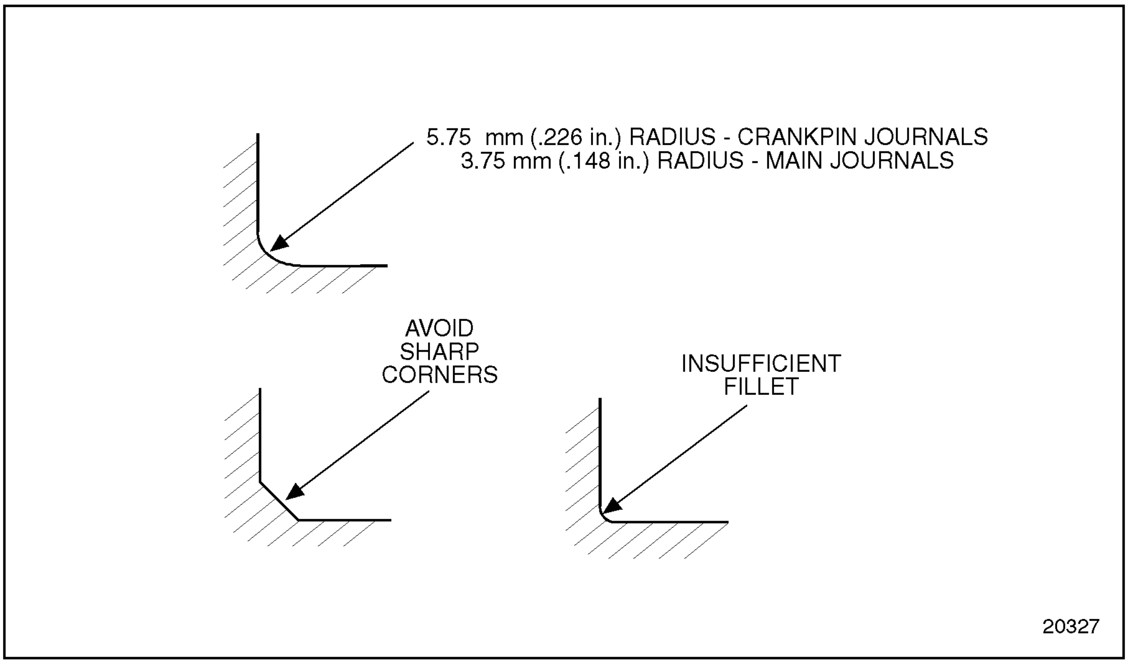


Figure 1-443 Crankshaft Journal Fillets

7. Lobing and Chatter: The No. of lobes around the journal circumference, times the average peak to valley lobe height in micrometers, shall not exceed 42 micrometers. Peak to valley excursions exceeding 1.0 micrometers shall be considered lobing or chatter.
8. Excursions can be measured on a circular chart of the circumferential profile.

Grinding Connecting Rod Journals (Pins)

Perform the following steps for grinding connecting rod journals:

1. Grind the pin O.D. surface to the specified undersize. The undersize conditions are 0.250 mm, 0.500 mm or 0.750 mm (approximately 0.010 in., 0.020 in. or 0.030 in.) undersize.
2. ALL connecting rod journals must be ground to the same undersize condition.
3. Journal taper on a radial basis shall not exceed 0.008 mm (0.0003 in.) overall, or exceed 0.004 mm (0.00016 in.) on half-length.

NOTE:
Avoid localized heating, which often produces grinding cracks. Cool the crankshaft generously with coolant while grinding. Do not crowd the grinding wheel into the work.

4. Grind sidewalls wide enough to clean up the basic face surface, not to exceed pin width allowable. See Figure 1-441.
5. If there are deep interruptions, gouges or nicks that do not extend into fillets, smooth the edges with 120 grit emery cloth.

Grinding Main Bearing Journals

Perform the following steps for grinding main bearing journals:

1. Grind the main bearing O.D. surface to the specified undersize. The undersize conditions are 0.250, 0.500 or 0.750 mm (approximately 0.010, 0.020, or 0.030 in.) undersize.

NOTE:
Avoid localized heating, which often produces grinding cracks. Cool the crankshaft generously with coolant while grinding. Do not crowd the grinding wheel into the work.

2. ALL main bearing journals must be ground to the same undersize conditions.
3. Journal taper on a radial basis shall not exceed 0.012 (0.0005 in.) overall or exceed 0.006 mm (0.00024 in.) on half-length.

Other Machining Operations:

Perform the following steps for other machining operations:

1. Examine the thrust wall (No. 4 Main Bearing):
   - [a] If the thrust wall surface is scored, scratched or groove worn, the thrust wall must be "bump ground."
   - [b] The maximum run out of the thrust wall is 0.038 mm (0.0015 in.) TIR.
   - [c] If wear is 0.0508 mm (0.002 in.) or more, regrind to restore flatness to the thrust wall. See Figure 1-444.

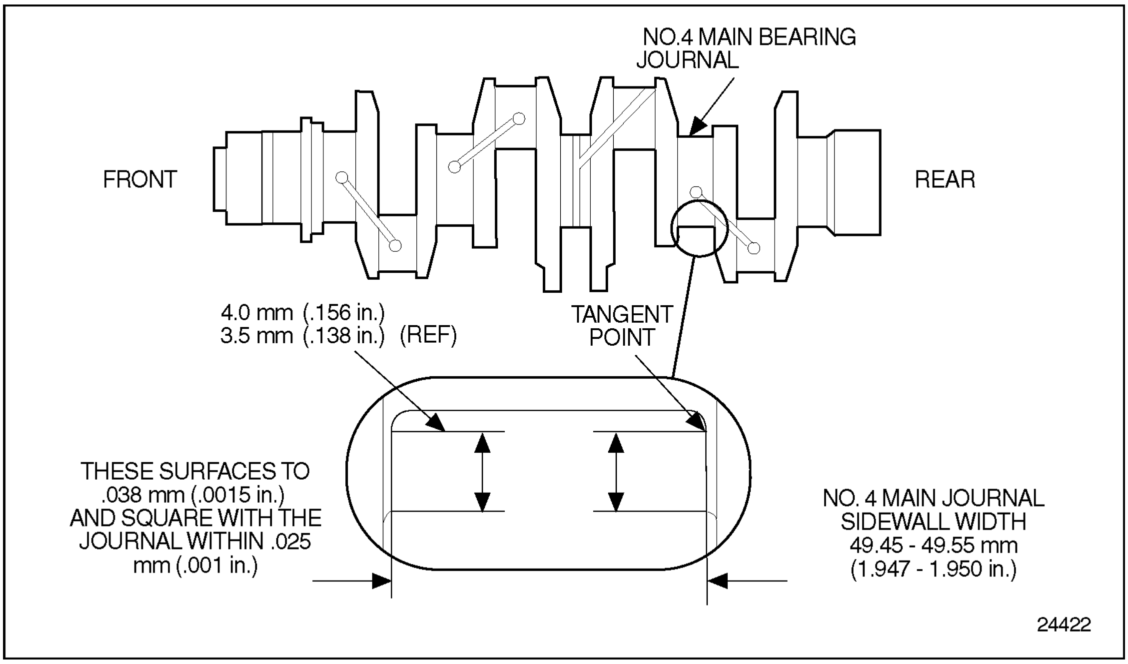


Figure 1-444 No. 4 Main Journal Thrust Wall Dimensions

[d] An oversize thrust wall is to be "bump ground" in multiples of 0.127 mm (0.005 in.), with a maximum of 0.250 mm (0.010 in.) to be removed from each side. Record oversize for installations.

NOTE:
Avoid localized heating, which often produces grinding cracks. Cool the crankshaft generously with coolant while grinding. Do not crowd the grinding wheel into the work.

2. Chamfer all oil holes to remove grinding burrs to the limit shown on illustrations. See Figure 1-445. See Figure 1-446. See Figure 1-447.

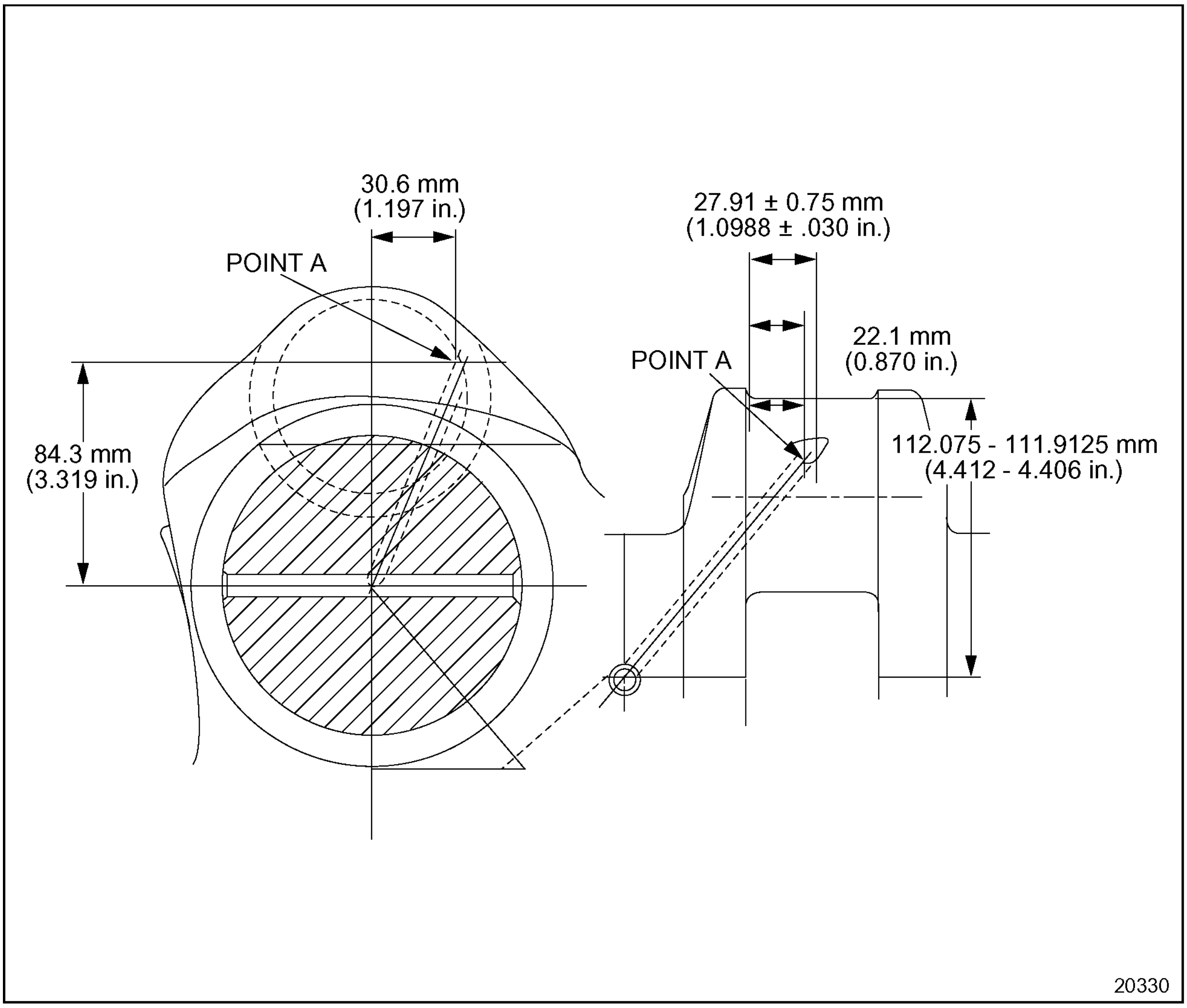


Figure 1-445 Oil Hole Specifications - Connecting Rod Journals - Crankshaft (160 mm stroke)

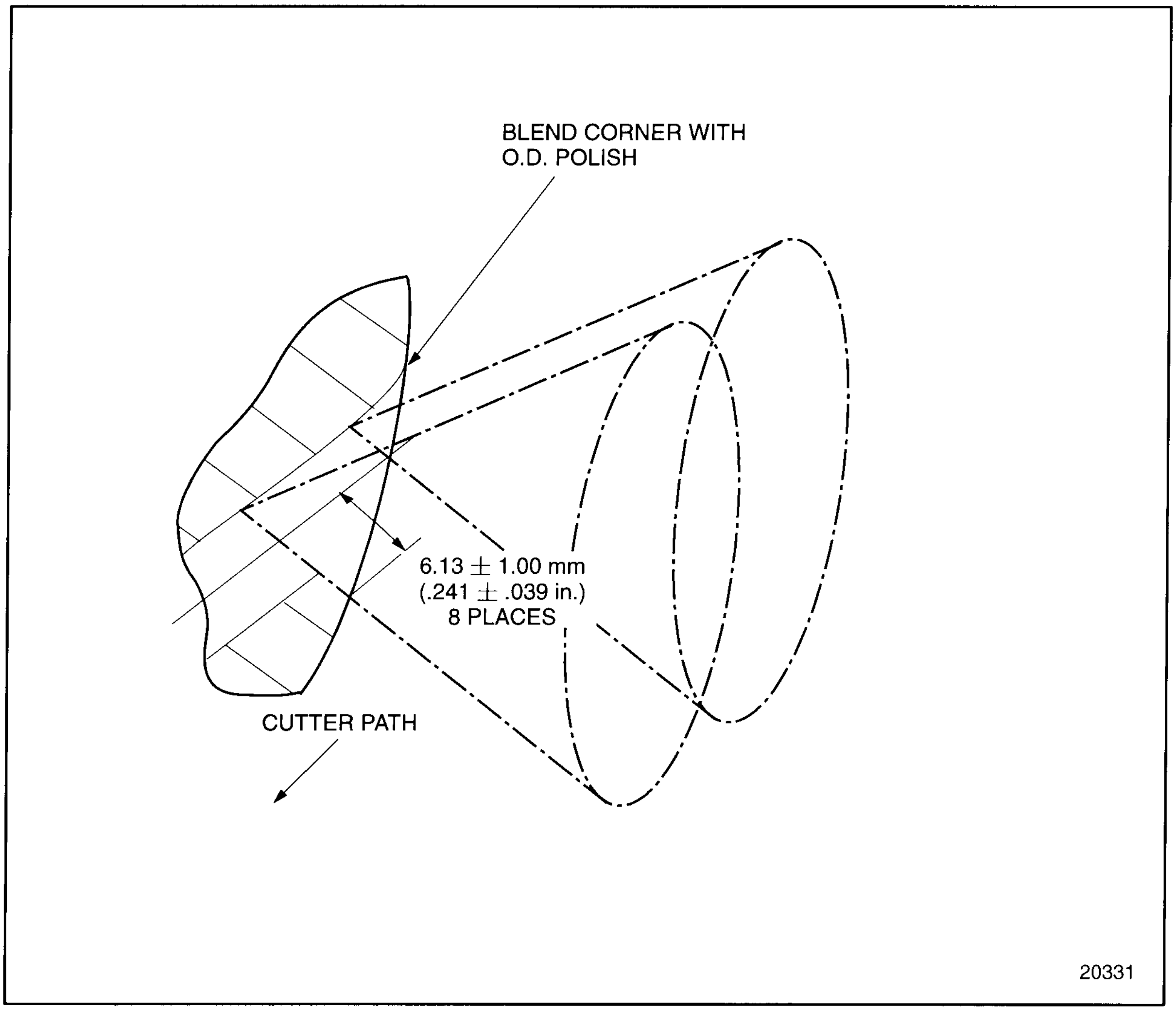


Figure 1-446 Connecting Rod Journal Oil Hole Chamfer Limits

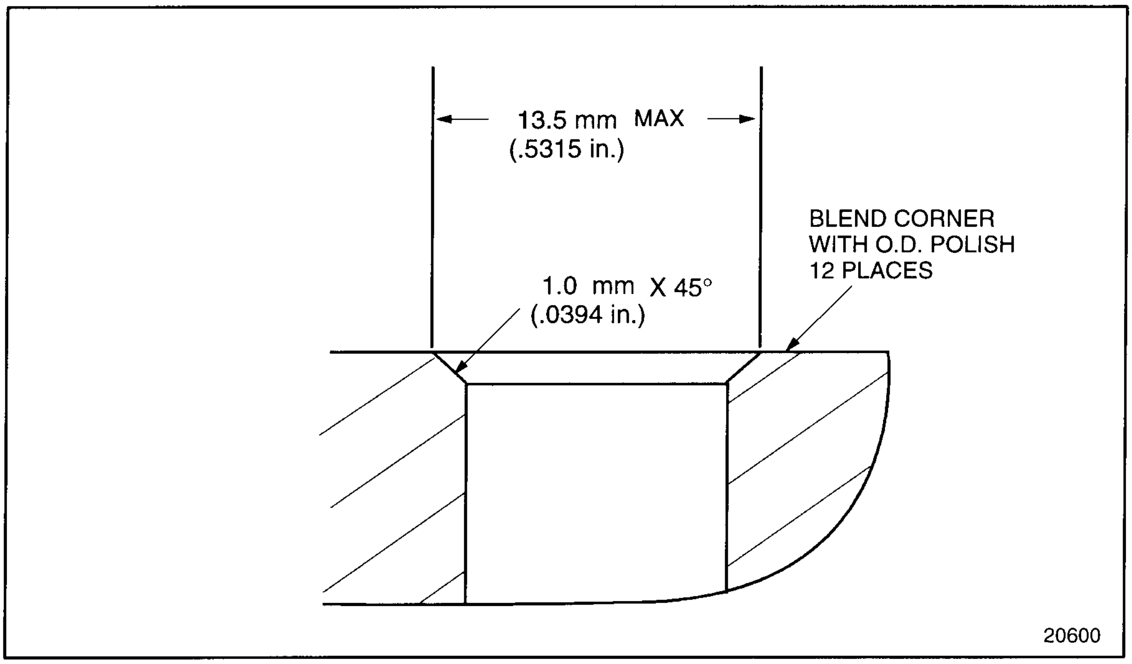


Figure 1-447 Main Journal Oil Hole Chamfer Limits

3. Repair the flywheel and pulley contact faces of the crankshaft to clean up the surface of any nicks, gouges or raised metal. The crankshaft face must be 0.013 mm (0.0005 in.) convex to 0.030 mm (0.001 in.) concave.

After-grinding Inspection

Perform the following steps for after grinding:

1. Inspect the crankshaft by the magnetic particle method after grinding has been completed to determine whether the grinding operation has produced cracks.
2. Retap and check all internal threads with plug gages to determine acceptability. If necessary, Heli-coil pulley and flywheel flange bolt holes with the following restrictions: Heli-coil 2 holes max. per crankshaft end (front or rear). Heli-coil of two adjacent holes at rear (forward end) is not permitted.
3. Demagnetize the crankshaft.
4. Clean the crankshaft and oil passages thoroughly with clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

5. Dry the crankshaft with compressed air.

GLOSSARY

The following glossary terms support the Series 50 Engines.

Glossary Terms

AA - ARITHMETICAL AVERAGE: The average total sum of the heights and depths of the ridges and valleys above and below the mean reference line. Limits for journal surfaces are 0.3 µ N (12 AA).

AXIAL PROFILE: The deviation of the journal surface from a reference line. Total peak to valley variation per full length of journal.

AXIAL PROFILE SLOPE: The amount of variation tolerable from the mean reference line of the journal in a particular distance (example: 0.0025 mm [0.0001 in.] deviation/2.54 mm [0.100 in.] length maximum). This specification indicates that any deviation in excess of 0.0025 mm 0.0001 in.) inside a 2.54 mm (0.100 in.) length is not acceptable.

GOULD 1200: Surfanalyzer 1200 surface texture measuring system is used to determine surface parameters such as profile, roundness and waviness. A diamond stylus having a radius of 0.0025-0.013 mm (0.0001-0.0005 in.) is moved at a constant speed over the surface. Vertical displacements of this stylus are converted into a voltage signal through a linear variable differential transformer.

OIL HOLE WASHOUT: The localized removal of material below the reference surface of an idealized round and straight journal at the trailing edge of the oil hole. This condition is the result of excessive polishing with a soft black apparatus (nut cracker, soft show, rawhide) with lapping paper or cloth in an attempt to improve the surface finish.

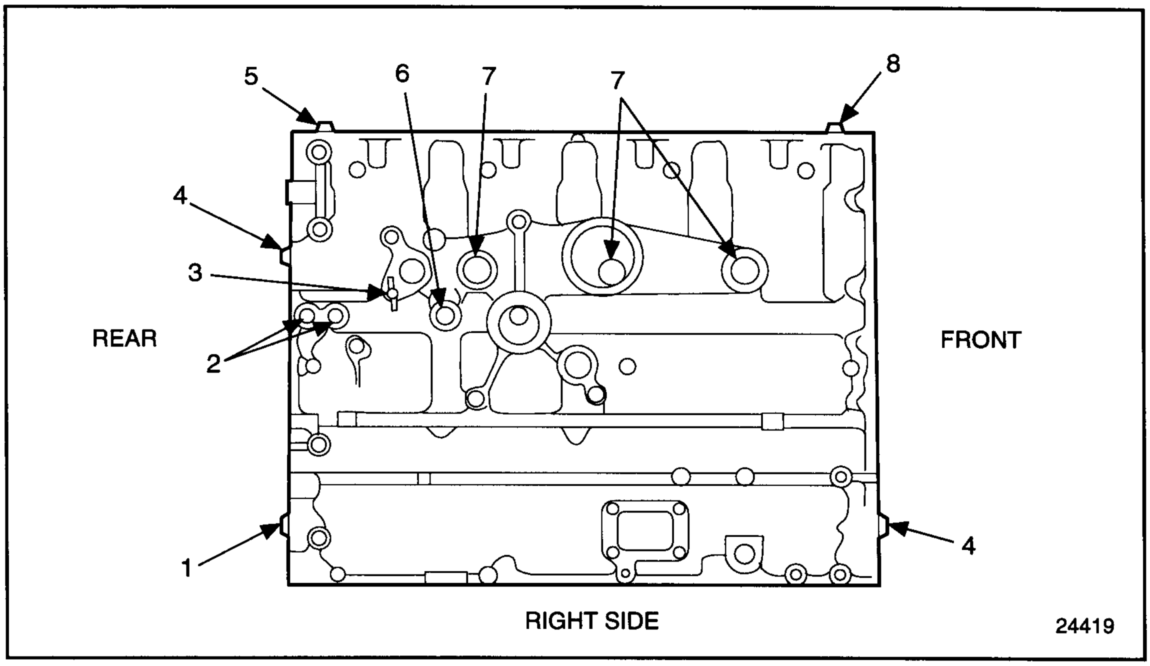
A depression (washout) extending beyond the oil hole blend out ellipse reduces the effective bearing area appreciably. This type of polishing is not recommended.

PIN and CRANKPIN: The cylindrical piece to which the connecting rod is attached.

RADIAL CHATTER: This term relates to surface irregularities which are of greater magnitude or spacing than those indicated by the term roughness. Chatter might be the result of vibration or deflection of a cutting tool, of some part of the machine, or the work itself.

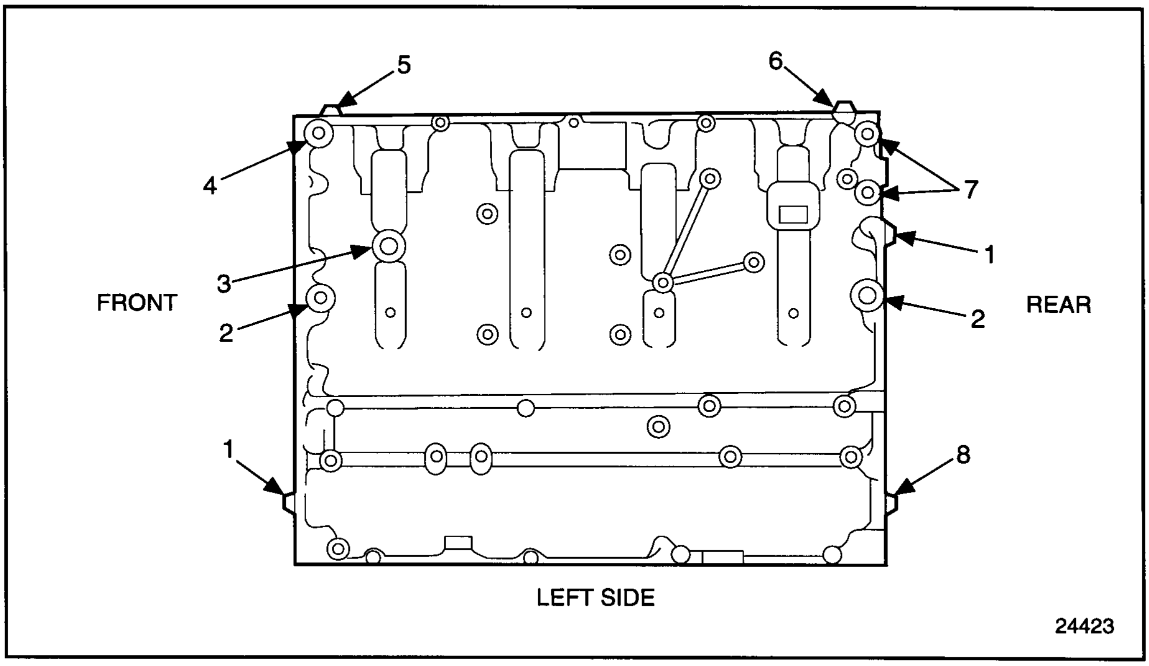
ENGINE PLUG AND DOWEL CHARTS

The following graphics, see Figure 1-448, see Figure 1-449, see Figure 1-450, see Figure 1-451, see Figure 1-452, see Figure 1-453, see Figure 1-454, and see Figure 1-455, support the Series 50 Engines plugs and dowels configurations.



1. 8929015 Dowel (Round)
2. 8922327 1/4 in. Pipe Plug (4 places). Torque to 19-24 N·m (14 -18 lb·ft).
3. 8924140 Draincock
4. 8929022 Dowel (Diamond) (2 Places)
5. 8929153 Dowel (Diamond)
6. 8929594 3/8 in. Pipe Plug (2 places). Torque to 24-31 N·m (18 - 23 lb·ft).
7. 5139991Cup Plug (3 places)
8. 8929152 Dowel (Round)

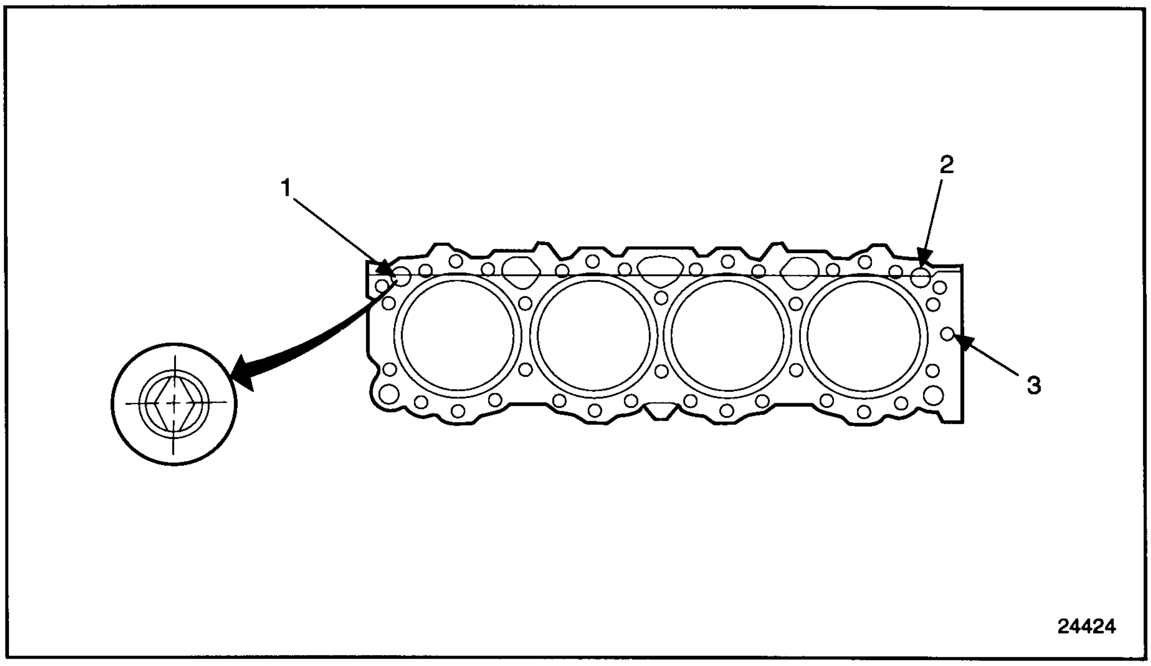
Figure 1-448 Right Side View



1. 8929022 Dowel (Diamond) (2 places)
2. 8923916 3/8 in. Pipe Plug (2 places). Torque to 24-31 N·m (18-23 lb·ft).
3. 8923916 1/2 in. Pipe Plug (1 place) torque to 31-39 N·m (23-29 lb·ft).
4. 8922327 1/4 in. Pipe Plug (4 places). Torque to 19-24 N·m (14-18 lb·ft).
5. 8929152 Dowel (Round)
6 .8929153 Dowel (Diamond)
7. 8922327 1/4 in. Pipe Plug (2 places).*
8. 8929015 Dowel (Round)

*Required for pressure testing only.

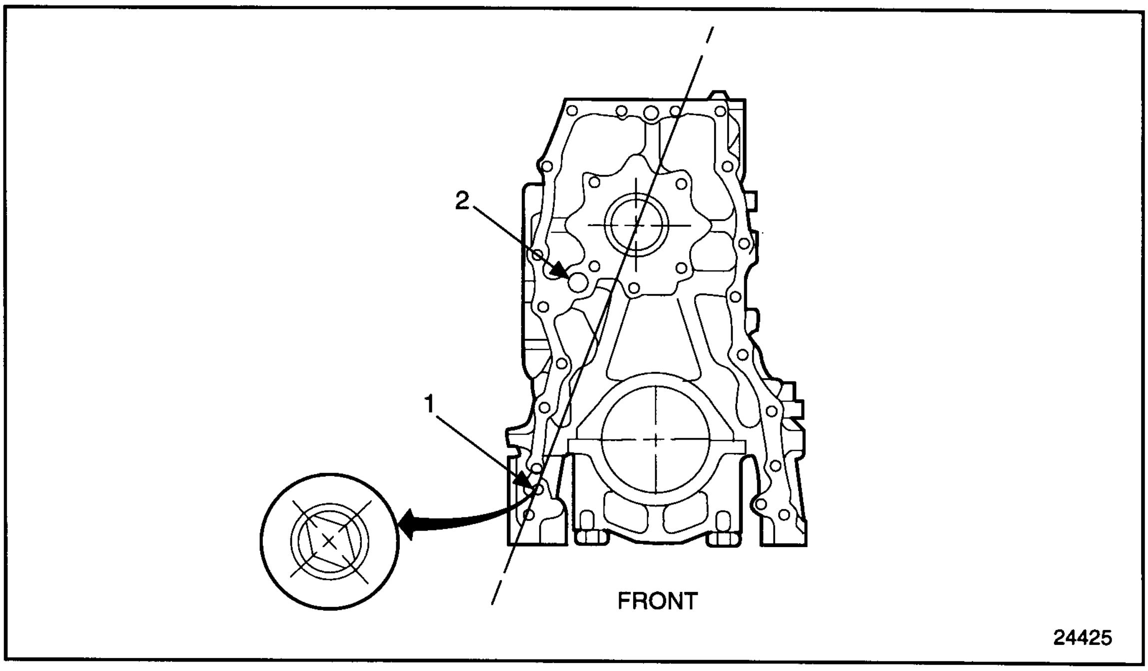
Figure 1-449 Left Side View



1. 8929153 Dowel (Diamond)
2. 8929152 Dowel (Round)
3. 5151272 Plug*

* Install flush to 1.0 mm (0.040 in.) below surface.

Figure 1-450 Cylinder Head Deck



1. 8929022 Dowel (Diamond)
2. 5139988 Cup Plug

Figure 1-451 Front View

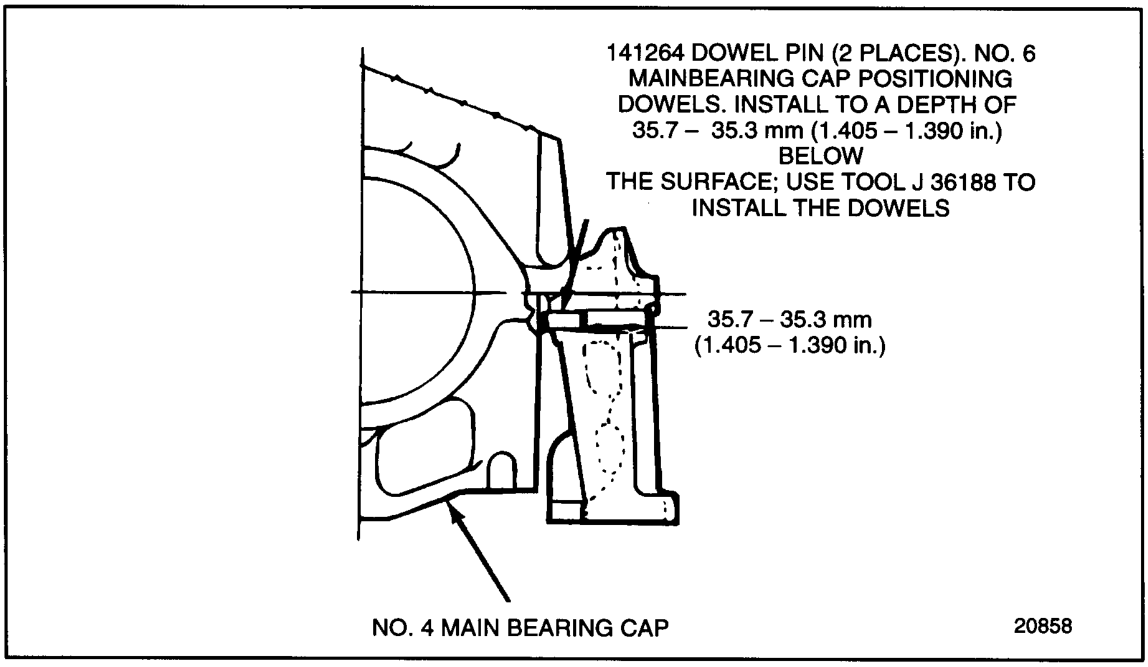
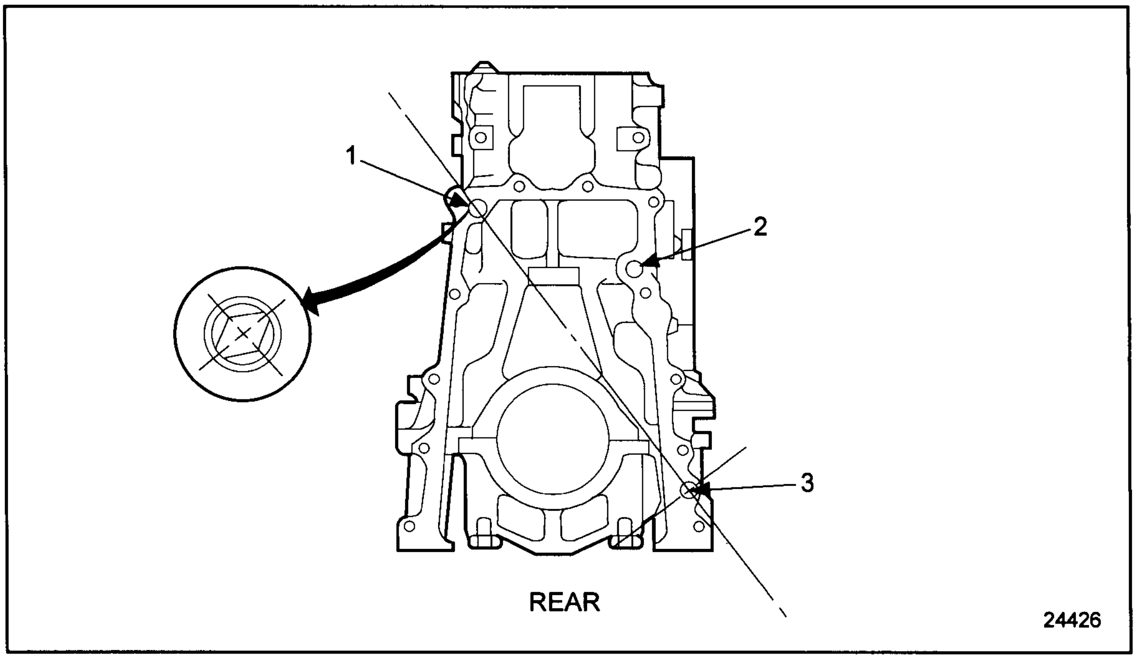
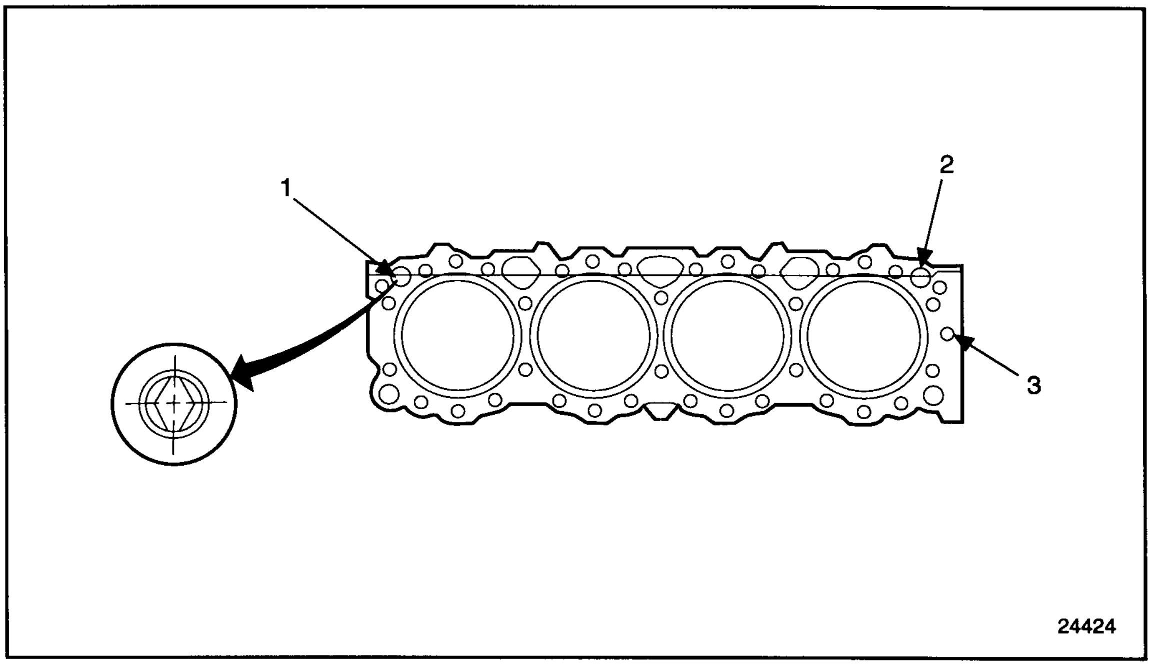


Figure 1-452 No. 4 Main Bearing Cap



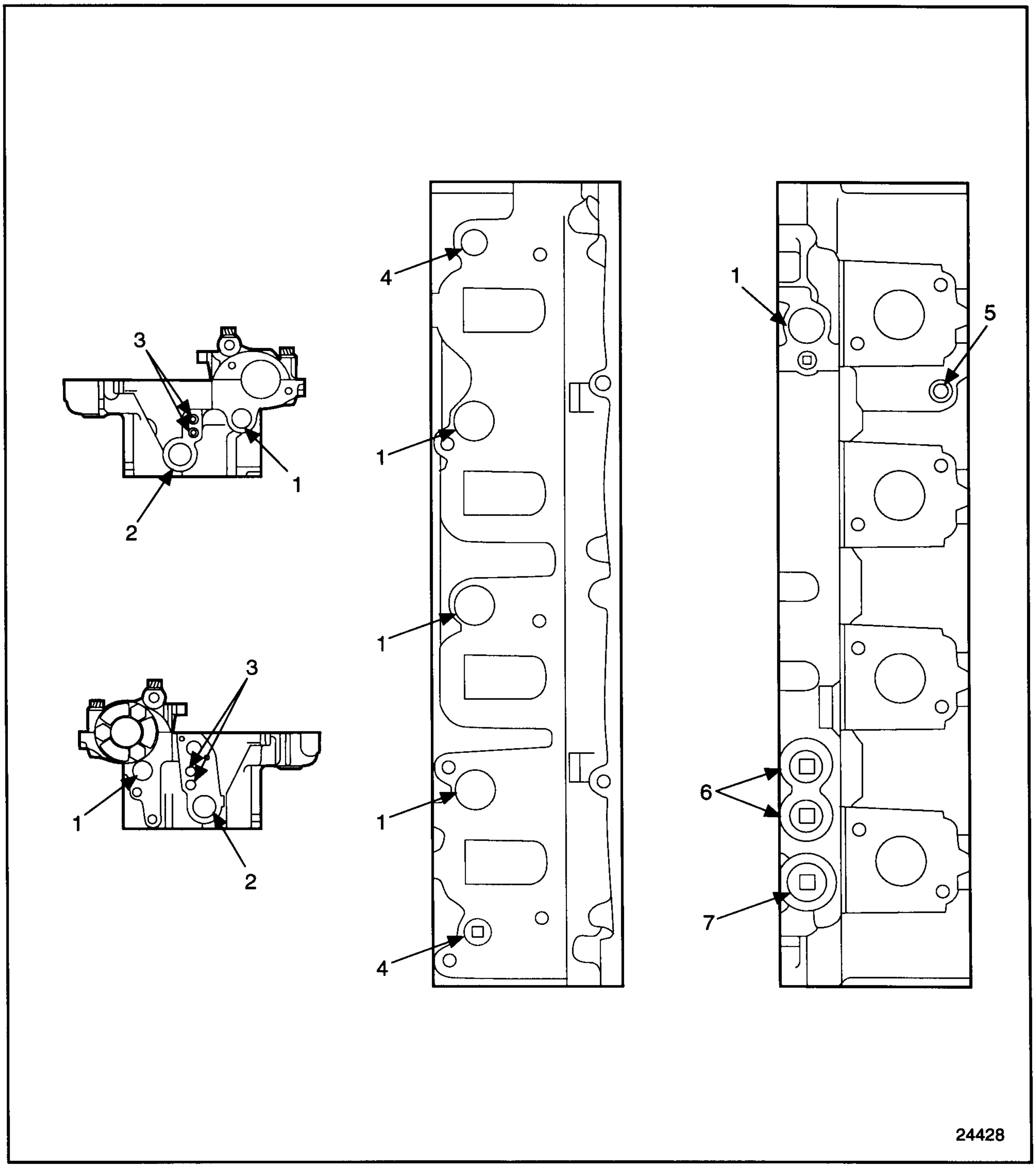
1. 8929022 Dowel (Diamond)
2. 5139988 Cup Plug (2 places)
3. 8929015 Dowel (Round)

Figure 1-453 Rear View



1. 5138638 Dowel (Hollow) (5 places). Install to a height of 5.0 mm ± 0.5 mm (0.199 in. ± 0.010 in.). Bearing Cap.
2. 5143033 Dowel (Diamond) (3 places). Install to a height of 6.1 mm ± 0.5 mm (0.240 in. ± 0.010 in.).

Figure 1-454 Cylinder Head Dowel Chart



1. 5109157 Cup Plug (6 places)
2. 5139991 Cup Plug (2 places).
5. 89269991 Fuse Plug. Torque to 19-24 N·m (14-18 lb·ft).
6. 23511573 3/4 in. Pipe Plug (2 places). Torque to 45-56 N·m (33-41 lb·ft).

3. 23513197 Square Head Pipe Plug. Front and Rear.

4. 23511572 1/2 in. Pipe Plug (2 places). Torque to 31-39 N·m (23-29 lb·ft).

7. 23511574 1 in. Pipe Plug (1 place). Torque to 19-24 N·m (14-18 lb·ft).

Figure 1-455 Cylinder Head Cup and Pipe Plug and Dowel Chart

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 the following tables, lists the amount of wear or increase of clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the values given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

Table of Specifications, New Clearances, and Wear Limits

These limits also apply to oversize and undersize parts.

Refer to the following tables to obtain specifications, new clearances, and wear limits for the Series 50 Engines:

1. Cylinder block is listed in Table 1-12.
2. Cylinder liner is listed in Table 1-13.
3. Cross-head piston and piston rings are listed in Table 1-14.
4. Piston pin is listed in Table 1-15.
5. Crankshaft is listed in Table 1-16.
6. Connecting rod bearing is listed in Table 1-17.
7. Main bearing is listed in Table 1-18.
8. Camshaft is listed in Table 1-19.
9. Camshaft bearing is listed in Table 1-20.
10. Camshaft drive gear is listed in Table 1-21.
11. Idler gear is listed in Table 1-22.
12. Crankshaft timing gear is listed in Table 1-23.
13. Bull gear is listed in Table 1-24.
14. Cylinder head is listed in Table 1-25.
15. Intake valve seat insert is listed in Table 1-26.
16. Exhaust valve seat insert is listed in Table 1-27.
17. Intake valves is listed in Table 1-28.

18. Exhaust valves is listed in Table 1-29.
19. Valve guides is listed in Table 1-30.
20. Rocker arms and shaft is listed in Table 1-31.
21. Cam follower roller is listed in Table 1-32.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Cylinder Block	-	-	-
Block Bore: Diameter-15.0 mm (0.60 in.) form top of block	149.050 mm (5.868 in.)	149.120 mm (5.871 in.)	0.070 mm (0.003 in.)
Diameter-235.0 mm (9.25 in.) from top of block	146.050 mm (5.750 in.)	146.120 mm (5.753 in.)	0.070 mm (0.003 in.)
Diameter-270.0 mm (10.63 in.) from top of block	146.050 mm (5.750 in.)	146.120 mm (5.753 in.)	0.070 mm (0.003 in.)
Out-of-round	-	-	0.0254 mm (0.001 in.)
Taper (lower bore)	-	-	0.0254 mm (0.001 in.)
Cylinder Liner Counterbore:	-	-	-
Diameter	157.15 mm (6.186 in.)	157.25 mm (6.191 in.)	-
Depth *	8.9246 mm (0.3514 in.)	8.9746 mm (0.3533 in.)	-
Main Bearing Bore:	-	-	-
Inside diameter (vertical axis)	133.00 mm (5.236 in.)	133.025 mm (5.237 in.)	-
Top Surface of Block:	-	-	-
Center of main bearing bore to top of block	436.50 mm (17.1850 in.)	436.62 mm (17.1897 in.)	-
Flatness (transverse)	-	-	0.076 mm (0.003 in.)
Flatness (longitudinal)	-	-	0.120 mm (0.005 in.)

* The bottom of the counterbore must not vary in depth more than 0.04 mm (0.0015 in.). No two adjacent counterbores can vary in depth more than 0.025 mm (0.001 in.) when gaged longitudinally.

Table 1-12 Cylinder Block

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter (below flange)	148.95 mm (5.864 in.)	149.00 mm (5.866 in.)	-
Outside Diameter (below crevice seal groove)	145.985 mm (5.747 in.)	146.035 mm (5.749 in.)	-
Outside Diameter (between "D" ring grooves)	145.985 mm (5.747 in.)	146.035 mm (5.749 in.)	-
Flange Thickness	8.960 mm (0.3527 in.)	9.00 mm (0.3543 in.)	-
Inside Diameter	130.00 mm (5.118 in.)	130.05 mm (5.120 in.)	-
Out-of-Round (inside diameter)	-	-	0.025 mm (0.001 in.)
Taper	-	-	0.025 mm (0.001 in.)
Height of Flange ABOVE Block	-0.0127 mm (-0.0005 in.)	0.0762 mm (0.003 in.)	-
Variation in Height between Adjacent Liners	-	-	0.05 mm (0.002 in.)

Table 1-13 Cylinder Liner

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
At top (above firing ring)	128.64 mm (5.064 in.)	128.84 mm (5.072 in.)	-
Below (2nd) compression ring	129.775 mm (5.1093 in.)	129.825 mm (5.112 in.)	-
Compression Rings	-	-	-
Gap (2.5 mm chrome fire ring)	0.40 mm (0.016 in.)	0.87 mm (0.034 in.)	-
Gap (3.5 mm plasma fire ring) (High sulfur fuel export engines)	0.51 mm (0.020 in.)	0.87 mm (0.034 in.)	-
Gap (No. 2 compression ring)	0.80 mm (0.031 in.)	1.31 mm (0.051 in.)	-
Clearance ring-to-groove:	-	-	-
Top (keystone fire ring)	must be checked with Piston Ring Land Gage J 35884-A	-	-
No. 2 (keystone compression ring)	must be checked with Piston Ring Land Gage J 38689-A	-	-
Oil Control Rings	-	-	-
Gap	0.40 mm (0.016 in.)	0.81 mm (0.032 in.)	-
Clearance	0.03 mm (0.001 in.)	0.11 mm (0.004 in.)	-
Piston Pin Bore in Dome (3-piece bushing) *	51.000 mm (2.0078 in.)	51.025 mm (2.0088 in.)	-
Piston Skirt to Liner Clearance (thrust faces)	0.047 mm (0.0020 in.)	0.184 mm (0.0072 in.)	-
			-

*

Table 1-14 Cross-head Piston and Piston Rings

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Piston Pin Diameter	44.99 mm (1.7712 in.)	45.00 mm (1.7716 in.)	44.96 mm (1.770 in.)

Table 1-15 Piston Pin

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Journal Diameter (main bearing)	124.975 mm (4.920 in.)	125.000 mm (4.921 in.)	-
Journal Diameter (connecting rod bearing)	84.975 mm (3.345 in.)	85.000 mm (3.346 in.)	-
Journal Out-of-Round (ROD)	-	-	0.008 mm (0.0003 in.)
Journal Out-of-Round (MAIN)	-	-	0.0127 mm (0.0005 in.)
Journal Taper: Main Bearing	-	-	0.0127 mm (0.0005 in.)
Connecting Rod (full length)	-	-	0.008 mm (0.0003 in.)
Connecting Rod (half length)	-	-	0.004 mm (0.00016 in.)
Run-out on Journals-Total Indicator Reading (mounted on numbers 1 and 7 Journals): At Journals No. 2 and 6 *	-	-	0.075 mm (0.003 in.)
At Journals No. 3 and 5	-	-	0.130 mm (0.005 in.)
At Journal No. 3	-	-	0.152 mm (0.006 in.)
No. 4 Main Bearing Journal Thrust Width	49.45 mm (1.947 in.)	49.55 mm (1.950 in.)	-
Thrust washer Thickness	3.48 mm (0.137 in.)	3.56 mm (0.140 in.)	-
End Play (end thrust clearance)	0.097 mm (0.0039 in.)	0.419 mm (0.0165 in.)	-

* Run-out tolerance given for guidance when regrinding crankshaft. When the run-out on adjacent journals is in the opposite direction, the sum must not exceed 0.076 mm (0.003 in.) total indicator reading. When the run-out on adjacent journals is in the same direction, the difference must not exceed 0.076 (0.003 in.) total indicator reading.

Table 1-16 Crankshaft

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Bearing-to-Journal Clearance	0.040 mm (0.0016 in.)	0.116 mm (0.005 in.)	0.151 mm (0.006 in.)
Bearing Thickness 90° from Parting Line	3.111 mm (0.1224 in.)	3.125 mm (0.1230 in.)	3.086 mm (0.1215 in.)

Table 1-17 Connecting Rod Bearing

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Bearing-to-Journal Clearance	0.040 mm (0.0016 in.)	0.126 mm (0.005 in.)	0.151 mm (0.006 in.)
Bearing Thickness 90° from Parting Line	3.962 mm (0.1559 in.)	3.980 mm (0.1566 in.)	3.937 mm (0.1550 in.)

Table 1-18 Main Bearing

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Diameter (bearing journals)	64.974 mm (2.558 in.)	65.000 mm (2.5559 in.)	-
Run-out at Center Bearing (when mounted on end bearings should not exceed)	-	-	0.050 mm (0.002 in.)
End Thrust	0.076 mm (0.003 in.)	0.381 mm (0.015 in.)	-

Table 1-19 Camshaft

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Bearing-to-Journal Clearance	0.090 mm (0.0035 in.)	0.166 mm (0.0065 in.)	0.191 mm (0.0075 in.)
Bearing Thickness (90° from Parting Line)	1.942 mm (0.0764 in.)	1.955 mm (0.0769 in.)	-

Table 1-20 Camshaft Bearing

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter:	-	-	-
Camshaft Drive Gear	52.00 mm (2.0472 in.)	52.0 mm (2.0484 in.)	-
Outside Diameter:	-	-	-
Camshaft Hub	52.10 mm (2.0511 in.)	52.03 mm (2.0523 in.)	-
* Interference (gear-to-hub)	0.07 mm (0.0027 in.)	0.13 mm (0.0051 in.)	-
Backlash (cam gear-to-adjustable idler)	0.051 mm (0.002 in.)	0.229 mm (0.009 in.)	0.305 mm (0.012 in.)

* A minimum force of 20.0 kN (4500 lb) must be obtained when pressing the camshaft drive gear to the drive gear hub.

Table 1-21 Camshaft Drive Gear

Engine Part (standard Size, New)	Minimum	Maximum	Limits
Backlash (adjacent idler-to-cam idler	0.051 mm (0.002 in.)	0.229 mm (0.009 in.)	0.305 mm (0.012 in.)

Table 1-22 Idler Gear

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter:	-	-	-
8.5 Liter Engine	133.562 mm (5.2583 in.)	133.600 mm (5.2598 in.)	-
* Interference (gear-to-crankshaft)	0.100 mm (0.003 in.)	0.108 mm (press) (0.004 in.) (press)	-
Backlash:	-	-	-
Crank Gear-to-Bull Gear	0.051 mm (0.002 in.)	0.229 mm (0.009 in.)	0.305 mm (0.012 in.)
Crankshaft Gear-to-Oil Pump Drive Gear	0.051 mm (0.002 in.)	0.229 mm (0.009 in.)	0.035 mm (0.012 in.)

* A minimum force of 30 kN (6750 lb) must be obtained when pressing the crankshaft timing gear on the crankshaft.

Table 1-23 Crankshaft Timing Gear

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Backlash (Bull Gear-to-Water Pump, Accessory, Fuel Pump or Air Compressor Drive Gears)	0.051 mm (0.002 in.)	0.229 mm (0.009 in.)	0.3050 mm (0.012 in.)

Table 1-24 Bull Gear

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Flatness (transverse)	-	-	0.076 mm (0.003 in.)
Flatness (longitudinal)	-	-	0.120 mm (0.005 in.)
Distance between Rail and firedeck (new)	164.85 mm (6.490 in.)	165.15 mm (6.501 in.)	-
Distance between Rail and firedeck (resurfaced)	164.08 mm (6.460 in.)	-	0.762 mm (0.030 in.)
Valve Insert Counterbore:	-	-	-
Intake Valve:	-	-	-
Diameter	46.12 mm (1.8157 in.)	46.15 mm (1.8169 in.)	-
Depth	11.46 mm (0.4511 in.)	11.76 mm (0.4629 in.)	-
Valve Insert Counterbore:	-	-	-
Exhaust Valve:	-	-	-
Diameter	41.26 mm (1.6244 in.)	41.29 mm (1.6255 in.)	-
Depth	10.70 mm (0.4212 in.)	11.00 mm (0.4330 in.)	-

Table 1-25 Cylinder Head

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter	46.20 mm (1.8188 in.)	46.22 mm (1.8196 in.)	-
Seat Width	0.48 mm (0.019 in.)	2.14 mm (0.084 in.)	-
Valve Seat run-out	-	-	0.05 mm (0.002 in.)
Standard Seat Thickness	7.155 mm (0.2187 in.)	7.256 mm (0.2857 in.)	-

Table 1-26 Intake Valve Seat Inserts

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter	41.34 mm (1.627 in.)	41.36 mm (1.628 in.)	-
Seat Width	0.67 mm (0.026 in.)	2.66 mm (0.105 in.)	-
Valve Seat run-out	-	-	0.05 mm (0.002 in.)
Standard Valve Seat Thickness	6.261 mm (0.2465 in.)	6.362 mm (0.2505 in.)	-

Table 1-27 Exhaust Valve Seat Inserts

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	P/N 8929589 8.679 mm (0.3417 in.) P/N 23518745 8.725 mm (0.3435 in.) P/N 23529004 8.701 mm (0.3426 in.)	P/N 8929589 8.699 mm (0.3425 in.) P/N 23518745 8.745 mm (0.3443 in.) P/N 23529004 8.721 mm (0.3433 in.)	-
Valve Head-to-Cylinder Head 30° (recess)	P/N 8929589 1.4 mm (0.055 in.) P/N 23518745 0.8 mm (0.031 in.) P/N 23529004 1.4 mm (0.055 in.)	P/N 8929589 1.8 mm (0.071 in.) P/N 23518745 1.2 mm (0.047 in.) P/N 23529004 1.8 mm (0.071 in.)	-

Table 1-28 Intake Valves

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	P/N 23506350 8.679 mm (0.3417 in.) P/N 23524521 8.701 mm (0.3426 in.) P/N 23519093 8.712 mm (0.3430 in.) P/N 23529596 8.701 mm (0.3426 in.)	P/N 23506350 8.699 mm (0.3425 in.) P/N 23524521 8.721 mm (0.3433 in.) P/N 23519093 8.732 mm (0.3438 in.) P/N 23529596 8.721 mm (0.3433 in.)	-
Valve Head-to-Cylinder Head 30° (recess)	P/N 23506350 1.4 mm (0.055 in.) P/N 23524521 1.4 mm (0.055 in.) P/N 23519093 0.92 mm (0.036 in.) P/N 23529596 1.4 mm (0.055 in.)	P/N 23506350 1.8 mm (0.071 in.) P/N 23524521 1.8 mm (0.071 in.) P/N 23519093 1.3 mm (0.051 in.) P/N 23529596 1.8 mm (0.071 in.)	-

Table 1-29 Exhaust Valves

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Height Above Cylinder Head	37.5 mm (1.476 in.)	38.0 mm (1.496 in.)	-
Diameter (inside)	8.759 mm (0.3448 in.)	8.785 mm (0.3459 in.)	-
Clearance (valve-to-guide, maximum)	-	Intake Valve P/N 8929589 0.106 mm (0.004 in.) Intake Valve P/N 23518745 0.060 mm (0.002 in.) Intake Valve P/N 23529004 0.084 mm (0.0033 in.) Exhaust Valve P/N 23506350 0.106 mm (0.004 in.) Exhaust Valve P/N 23524521 0.084 mm (0.0033 in.) Exhaust Valve P/N 23519093 0.073 mm (0.0029 in.) Exhaust Valve P/N 23529596 0.084 mm (0.0033 in.)	Intake Valve P/N 8929590 0.152 mm (0.006 in.) Exhaust Valve P/N 23506350 0.152 mm (0.006 in.) Exhaust Valve P/N 23524521 0.101 mm (0.004 in.)

Table 1-30 Valve Guides

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Rocker Shaft Diameter	35.993 mm (1.417 in.)	36.007 mm (1.418 in.)	35.943 mm (1.415 in.)
Steel Rocker Arm Bushing Diameter (inside)	36.025 mm (1.418 in.)	36.110 mm (1.422 in.)	36.200 mm (1.425 in.)
Clearance (shaft to bushing) (maximum): Bronze Bushing	-	-	0.057 mm (0.0020 in.)
Steel Bushing	-	-	0.257 mm (0.010 in.)

Table 1-31 Rocker Arms and Shafts

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Diameter	37.95 mm (1.494 in.)	38.05 mm (1.498 in.)	-
Rollers and Pins:	-	-	-
Clearance (pin-to-bushing) (maximum) (horizontal)	-	-	0.08 mm (0.003 in.)
Side Clearance (roller-to-follower) (maximum)	-	-	0.40 mm (0.015 in.)

Table 1-32 Cam Follower Roller

2 FUEL SYSTEM

2.1 FUEL SYSTEM OVERVIEW

For a schematic diagram of a typical fuel system, see Figure 2-1.

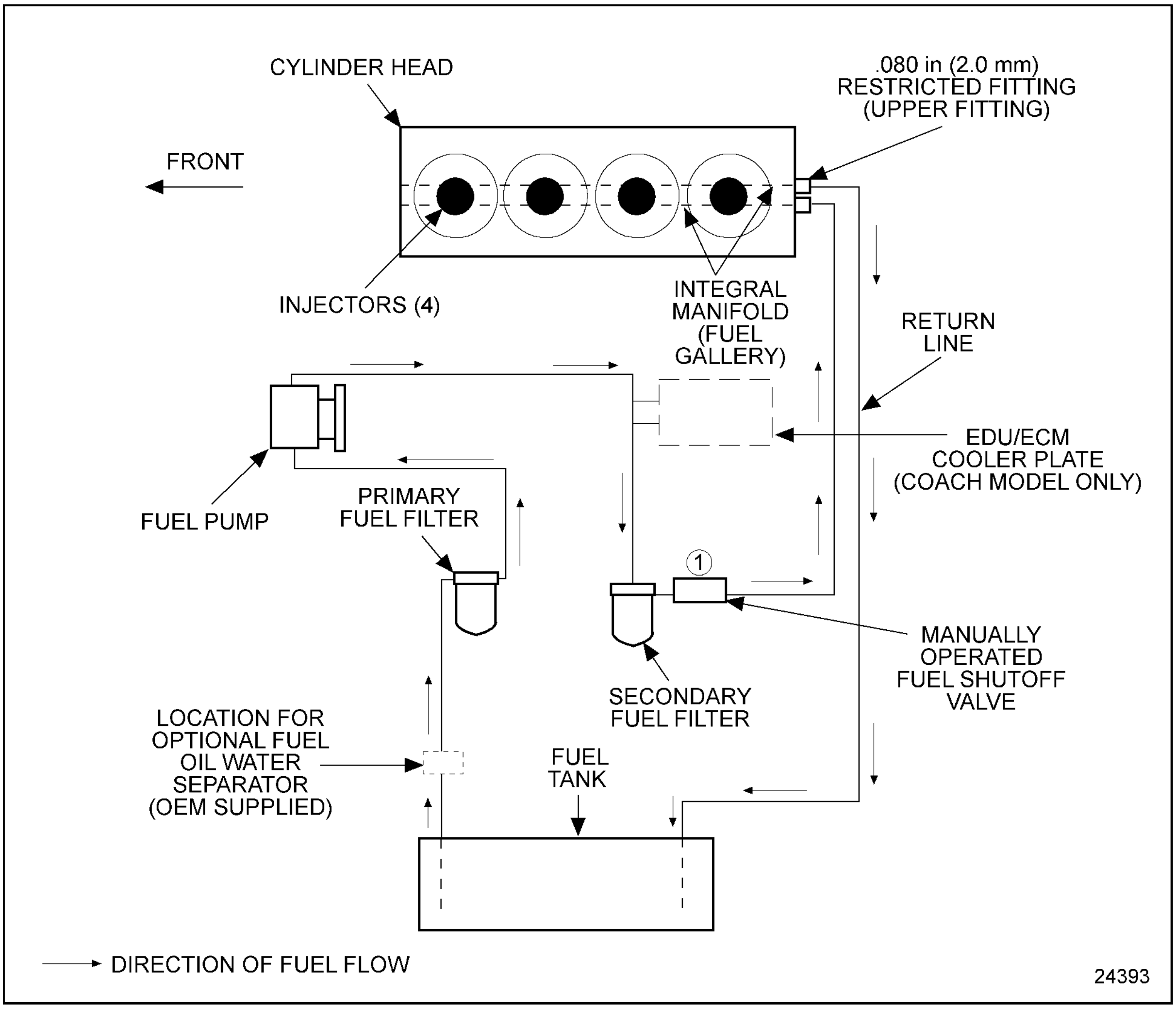


Figure 2-1 Schematic Diagram of the Fuel System

The fuel system includes injectors, integral fuel manifold in the cylinder head, fuel pump, a cooling plate for the Electronic Control Module (ECM), a primary fuel filter, a secondary fuel filter, and a fuel shutoff valve if equipped. An 2.0 mm (0.080 in.) restrictive orifice is located in the fuel return fitting at the rear of the cylinder head to maintain the pressure in the fuel system.

CAUTION:

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

CAUTION:

To avoid injury when working on or near an operating engine, wear protective clothing, eye protection, and hearing protection.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

CAUTION:

To avoid injury from fire, keep all potential ignition sources away from diesel fuel, open flames, sparks, and electrical resistance heating elements. Do not smoke when refueling.

Fuel is drawn from the fuel tank through an optional fuel water separator, into the primary fuel filter and enters the pump. After leaving the fuel pump under pressure, the fuel flows through the ECM cooler plates (if equipped) through the secondary fuel filter to the cylinder head.

An optional PRO-CHEK ® check valve that removes air from the fuel supply line may be installed between the secondary filter and the cylinder head. The fuel flows to the injectors in the cylinder head through passages integral with the head. Surplus fuel exits at the rear of the head just above the inlet, through a restrictive return fitting which maintains fuel pressure in the system and returns back to the fuel tank.

2.2 VEHICLE SAFETY FOR THE NATURAL GAS ENGINE

Today, a wide variety of vehicles from passenger cars to pickup trucks to school buses operate on one of the most plentiful fuels available, compressed natural gas. There are some very good reasons for this.

Natural gas is one of the most environmentally friendly fuels available. When burned, it produces far fewer air pollutants than conventional gasoline - up to 90 percent less carbon monoxide and up to 85 percent less reactive hydrocarbons - and contains no particulates. Further, it produces far less carbon dioxide (a "greenhouse gas") than conventional fuels. This makes natural gas an ideally friendly fuel for the environment.

2.2.1 Natural Gas Vehicles - The Safe Alternative

Safety is probably among your chief concerns as you approach adding NGVs to your fleet. Although gasoline and diesel seem safer because they've been around for a very long time, natural gas has many characteristics that actually make it safer than these more familiar fuels.

First of all, natural gas is lighter than air, so it won't pool on or near the ground. When accidentally released in an unconfined space, it quickly disperses in the atmosphere, away from the scene of an accident.

Natural gas also has a high ignition temperature, igniting at around 1,350°F, compared to between 400°F and 900°F for gasoline and diesel. What's more, natural gas has a narrower flammability range than other fuels including liquid petroleum gas (LPG). Natural gas is only flammable in concentrations above 5.3 percent in air. Gasoline, diesel and LPG, on the other hand, are flammable at much lower concentrations, above 0.5 percent to 2 percent.

Although the upper limit of natural gas' flammability range at about 15 percent is a bit higher than other fuels, because natural gas disperses quickly it's highly unlikely it will collect in a flammable concentration in the open air.

Natural gas is a safe fuel for other reasons as well. Unlike gasoline or diesel, it is nontoxic, noncaustic and poses no threat to land or water in the case of a spill. Also, several studies relating to the safety of operating NGVs in tunnels, in parking garages and on ferries have shown that natural gas poses no greater hazard than conventional fuels.

But what if natural gas is released in a confined space? Won't it float to the ceiling in a garage, for example? That is a concern. Experts recommend, and regulations in some cases require, that shops servicing NGVs install a methane detector and that they make sure there aren't areas in the service area where natural gas could collect in dangerous concentrations if released. Adequate ventilation is also important, but natural gas's lighter-than-air properties make it easier to ventilate than the heavier vapors of gasoline, diesel and LPG. Check with your gas company or contractor to be certain, but you shouldn't have to augment your existing air-handling system to service NGVs.

2.2.2 Safety Standards

Products manufactured for the NGV industry - from under-hood components to fuel-pump nozzles - are governed by a variety of standards to ensure safety. For example, onboard components including pressure regulators, valves, fueling nozzles and connectors, etc., must be certified by International Approval Services, jointly sponsored by American Gas Association Labs and Canadian Gas Association Labs. The National Fire Protection Association (NFPA) has created a safety standard (NFPA 52) for equipment installation and fueling infrastructure. The Uniform Fire Code (Article 52, Standard No. 52-1) also addresses NGV safety issues relating to fueling stations, including fueling indoors. And the Compressed Gas Association has numerous standards pertaining to cylinders.

Through several NGV Coalition committees, the industry has created a series of strict voluntary standards and continues to improve and add to these. Standards for fueling connectors and cylinders are already on the books (known as ANSI/NGV1 and ANSI/NGV2, respectively).

As a fleet operator, you needn't become a NGV standards expert, but you can rest assured the industry is working hard to address safety concerns and ensure NGVs perform as safe and safer than conventional vehicles. As you introduce NGVs to your fleet and need to know more about which safety standards apply to your operation, consult your gas company representative. Your gas company probably has several NGVs in its fleet and has worked with local officials on meeting codes. If your local fire marshal isn't familiar with NGVs, your gas company representative in many cases can put him or her in touch with someone who is.

2.2.3 Cylinder Safety

Fuel for NGVs is stored in cylinders under pressure, typically at 3,000 or 3,600 pounds per square inch (psi). To the uninitiated this sounds hazardous just by definition. As one industry report notes, "There is no doubt that carrying a highly pressurized fuel onboard a vehicle represents a ‘high perceived risk' which simply does not occur on conventionally fueled vehicles." The NGV industry, to its credit, has made addressing any risks, perceived or real, a top priority, and this is particularly evident in the area of storage container (cylinder) safety.

In recent years the industry has developed strict voluntary standards for cylinders in conjunction with governmental bodies such as the American National Standards Institute (ANSI). In 1994, the National Highway Traffic Safety Administration (NHTSA) adopted a set of regulations (known as DOT 304) governing cylinder durability, strength and pressure relief. The regulations also set testing criteria and generally follow the industry's existing ANSI/NGV2 standard. In the future NHTSA will codify additional standards, including cylinder resistance to chemical corrosion.

Cylinders undergo a variety of rigorous tests. In the bonfire test, as its name suggests, a pressurized cylinder is subjected to flames of around 1,200°F (649°C) to determine its resistance to bursting. To pass the test, the cylinder must remain intact long enough to safely release its contents. A pressure-relief device, required by NHTSA rules, vents the contents when the cylinder reaches about 210°F to 220°F (98°C to 104°C), and the cylinder typically remains intact for another 100 degrees beyond that. Cylinders must also pass a pressure test that subjects them to 18,000 cycles of pressurization and depressurization.

Manufacturers also test cylinders for resistance to rough handling and impact by dropping them from a certain height, hitting them with a heavy weight or gouging them. The cylinders are then cycled the equivalent of a million miles of operation. In the gunfire test, manufacturers test a cylinder's resistance to fragmentation by shooting it. Cylinders have also shown their durability in crash tests featured in informational videos produced by the NGV Coalition and others. In these tests, cylinders are mounted in a vehicle that is then dropped from several feet. The cylinders come through unscathed, even though the car is demolished.

Commenting on cylinder safety, one industry expert notes that the science of designing safe pressurized cylinders is by no means new, and the safety record is excellent. For example, some 1.4 million cylinders have been used by firemen for more than 15 years with only two catastrophic accidents, he notes, and those cylinders, pressurized to 4,500 lb/in.^{2}, aren't mounted in a vehicle but carried on a person's back.

2.2.4 Fueling Safety

When designing for safety, companies manufacturing fuel dispensers for compressed natural gas typically concentrate on two areas: hardware and what engineers call the "fill routine." For example, some dispenser valves are designed to shut off the flow of fuel if needed or vent the gas away from the dispenser in a closed-loop return system. Dispensers also have what's called "driveway protection." If someone drives away while fueling, a breakaway device on the dispenser ensures that the hose won't rupture or topple the dispenser. By the way, the breakaway force, according to code, for compressed natural gas dispensers is about 44 pounds vs. 250 pounds for gasoline pumps.

To guard against overfilling or any other kind of uncontrolled fill, dispensers are designed to monitor, either mechanically or electronically, whether the vehicle is receiving the amount of fuel it should. If the fill pressure rises beyond a predetermined level, the dispenser shuts off automatically. By the same token, if there's no pressure or a sudden loss in pressure - as in the case of an aborted fill or a hose being cut - it also shuts off.

Natural gas fuel dispensers are designed to be as easy to use and as similar to conventional fuel dispensers as possible, with safety and convenience in mind. With a minimum of training, anyone who can pump gasoline can safely dispense natural gas.

2.2.5 Safety Training

When is comes to dealing with any fuel, it's important that technicians and vehicle drivers learn about safety. Technicians working with liquid fuels have learned to keep them contained, keep them off their skin and keep them away from any source of ignition. They've learned, too, what to do in the event of a spill or leak.

In the same way, NGV technicians and drivers need to learn how to safely handle a gaseous fuel, natural gas. While working with a gaseous fuel that's under pressure may be no more inherently hazardous than working with a liquid fuel, it is different. To do their jobs safely, your technicians and drivers need to know what the differences are and how to work with them.

2.2.6 Fueling Vehicles

Unlike liquid fuels which are simply poured into a fuel tank, CNG fuel systems require a closed fuel dispensing system that allows the natural gas to flow into the fuel cylinder without leaking into the atmosphere. Such a system must use ANSI (American National Standards Institute) NGV1-standard fuel nozzles which will not allow the CNG to flow unless the nozzle is properly connected to the vehicle fuel inlet. Such a system will also comply with the NFPA (National Fire Protection Association) standards for fueling station construction and safety

The typical commercial natural gas dispenser looks a lot like a gasoline pump. It has a hose that connects easily to the vehicle fuel inlet with a snap-type coupling device and a meter that indicates how much fuel has been pumped. Once the cylinders are full, the pump shuts off automatically.

Most stations can fill fuel cylinders on a "quick fill basis" or on a "timed fill" basis. With a "quick fill" system cylinders can be filled in about five minutes. Stations with "timed fill" systems may take longer, depending on the number of vehicles being fueled and the size or capacity of the fueling unit. Many fleets operate their own timed fill stations because this allows them to fill their vehicles unattended at night.

Home dispensers for natural gas are also available. These are about the size of a window air conditioner and can be hooked up directly to the natural gas supply of the home. Home dispensers normally use the "timed fill" principle so a vehicle can be fueled overnight.

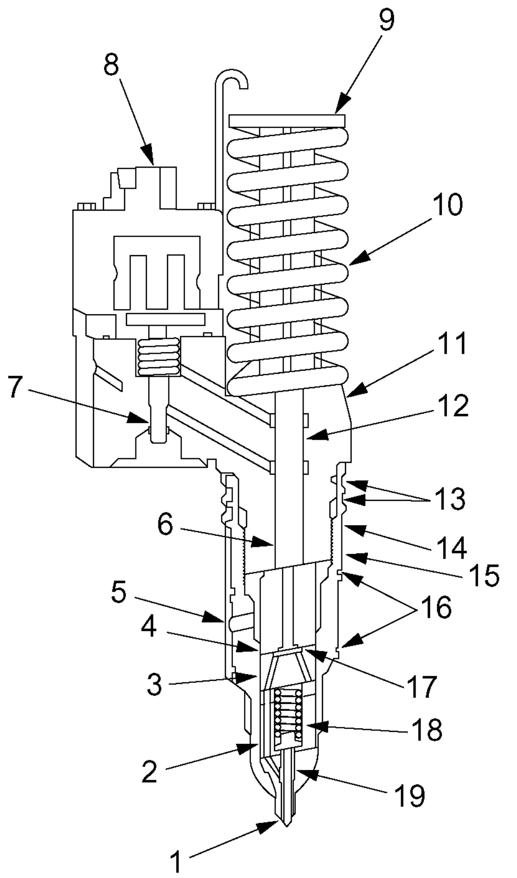
2.3 ELECTRONIC UNIT INJECTOR

The Electronic Unit Injector (EUI) is a lightweight, compact unit that injects diesel fuel directly into the combustion chamber. See Figure 2-2. The amount of fuel injected and the beginning of injection timing is determined by the 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.

NOTE:
Do not test new or reliabilt® remanufactured electronic unit injectors prior to installation in the engine. The Kent-Moore® POP stand should be only be used as a diagnostic tool on fuel injectors that have been *removed* from an engine.



1. Spray Tip
2. Spring Cage
3. Check Valve Cage
4. Spacer
5. Fuel Inlet Opening
6. Fuel Supply Chamber
7. Poppet Control Valve
8. Solenoid
9. Injector Follower
10. Injector Follower Spring
11. Injector Body
12. Plunger
13. Upper O-ring Grooves and Seals
14. Fuel Outlet Openings
15. Injector Nut
16. Lower O-rings Grooves and Seals
17. Flat Disk Check Valve
18. Injector Needle Valve Spring
19. Needle Valve

Figure 2-2 Electronic Unit Injector Cross Section

Fuel enters the injector through the two fuel inlet filter screens located around the injector body. See Figure 2-3. Filter screens are used at the fuel inlet openings to prevent relatively coarse foreign material from entering the injector.

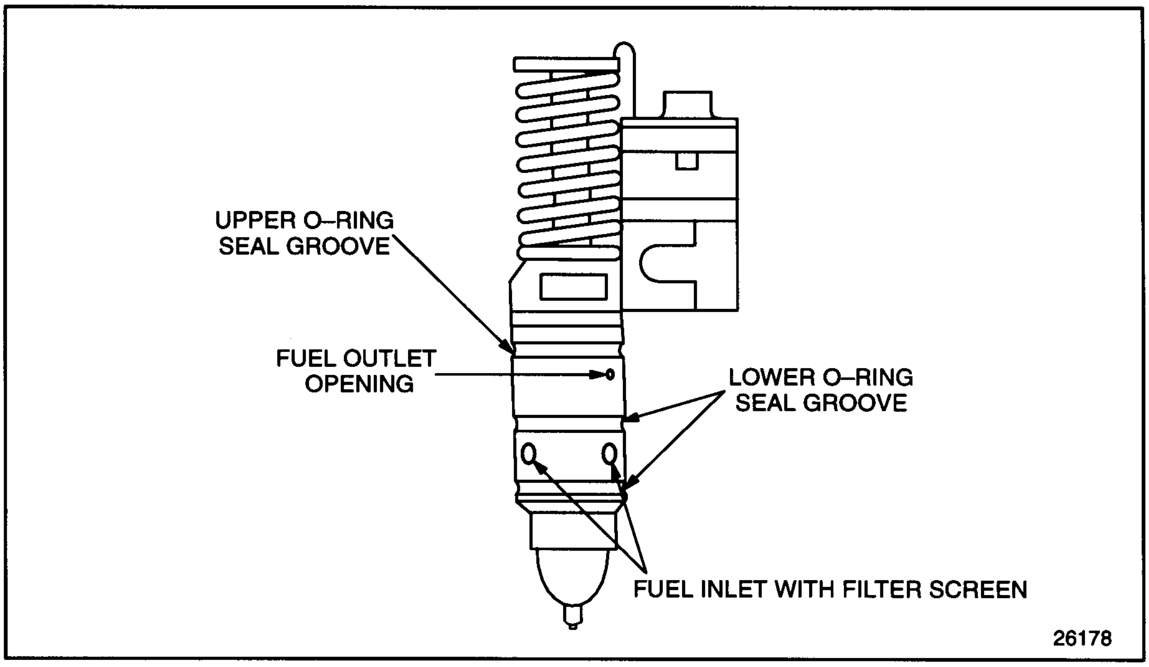


Figure 2-3 Electronic Fuel Injector

After entering the nut cavity, the fuel passes through a drilled passage into the poppet control valve and plunger area. See Figure 2-2.

Outlet openings, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, are located around the injector nut. See Figure 2-4.

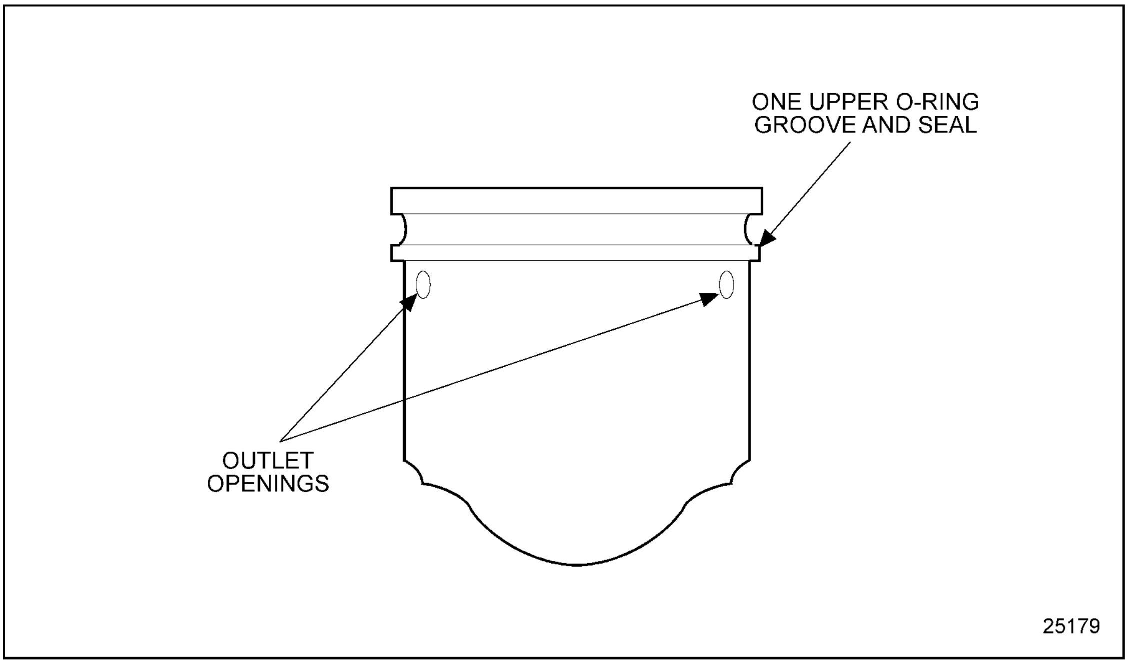


Figure 2-4 Fuel Outlet Openings in the Fuel Injector Body

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 lobe 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 electronic 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 if a particle of debris should become lodged between the needle and seat or the tip assembly fails.

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.

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.

2.3.1 Repair or Replacement of Electronic Unit Injector

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 2-5.

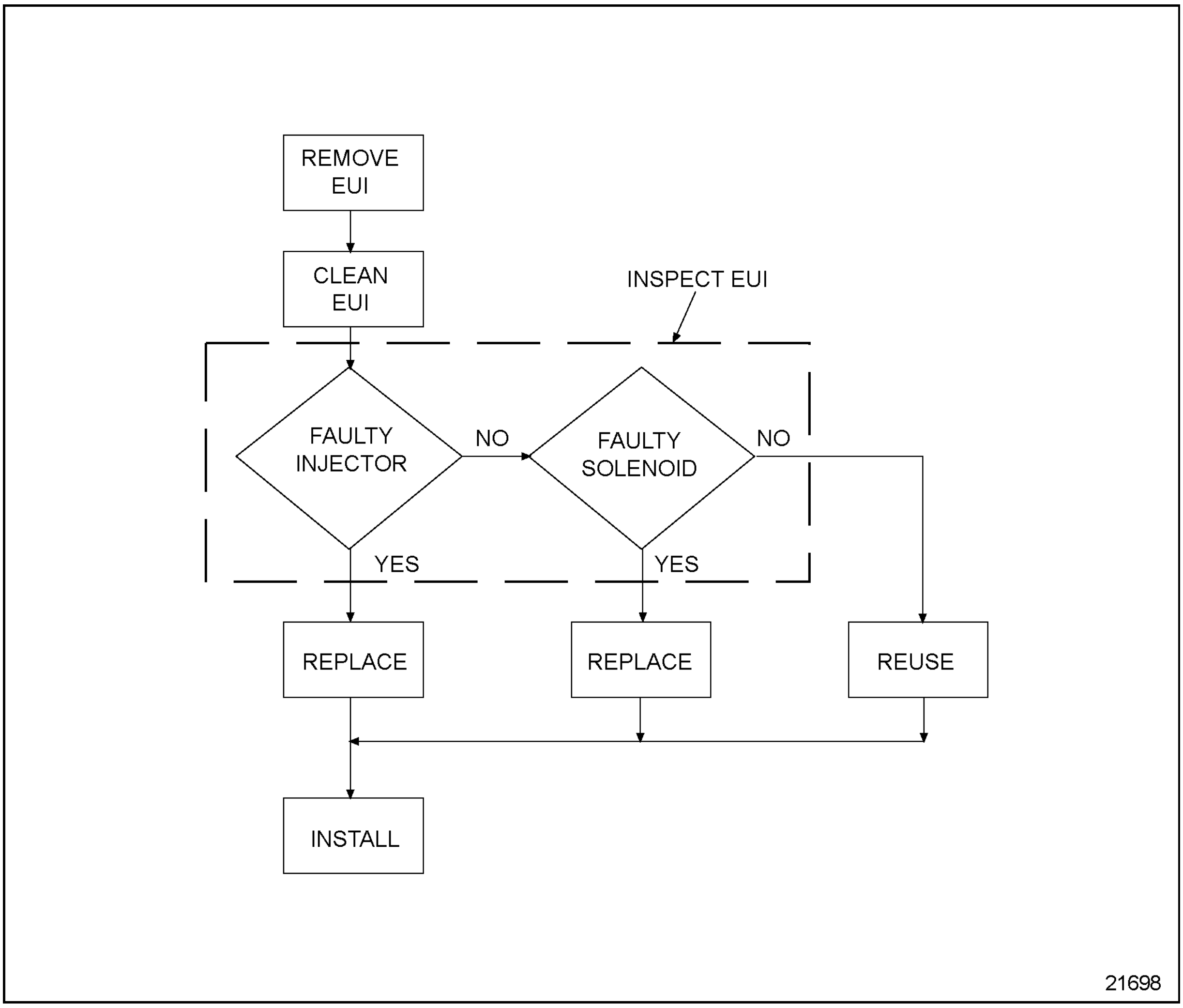


Figure 2-5 Flowchart for Repair or Replacement of EUI

2.3.2 Removal of Unit Injector

The following steps must be performed prior to removing an injector:

NOTE:
The solenoid can be replaced without removing the injector. Refer to Section 2.3.4.

1. Clean the valve rocker cover around its seat on the head, and in the attaching bolt recesses.
2. Remove the valve rocker cover. Refer to Section 1.6.2.

3. Drain the cylinder head fuel gallery by removing the fuel gallery plugs.

NOTE:
Loosening the fuel line at the inlet fitting will allow fuel to flow faster. Carefully collect the drained fuel in an appropriate container.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

All the fuel must be removed from the cylinder head before removing an injector to prevent the fuel from entering the cylinder and causing hydrostatic lock or washdown. If the head is not thoroughly purged of fuel before an injector is removed, fuel remaining in the fuel manifold will drain into the cylinder filling the piston dome recess. It cannot drain from the dome and, if not removed, can cause hydrostatic lock and bend the connecting rod.

4. Remove the inlet and outlet lines from the fittings at the rear of the cylinder head. Blow low pressure compressed air into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head. See Figure 2-6.

NOTE:
Front and rear rocker shaft assemblies look identical but are not interchangeable because of different bolt hole center distances. The outboard end of each rocker shaft

assembly is marked with the DDC logo for identification. Care should be taken to identify and return assemblies to the proper location if both overhead assemblies are removed.

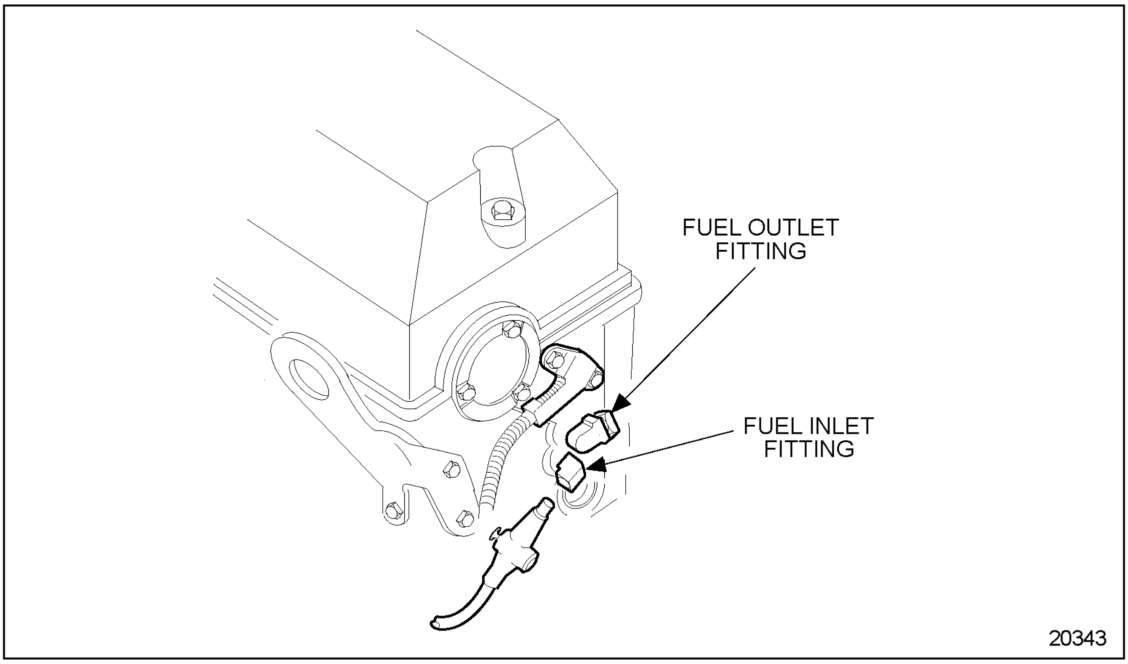


Figure 2-6 Cylinder Head Fuel Fitting Locations

5. Remove the two rocker shaft thru-bolts and one nut for each rocker shaft assembly, and lift the rocker shaft assembly off the engine as outlined in the first section of this manual. Refer to Section 1.3.2, step 3.

To remove the injector, complete the following steps:

NOTICE:
Do not remove the screws from the injector. The terminal wires have keyhole slots to fit over the screw head. Turning the screws will damage the threads in the solenoid housing.

1. Loosen the injector wire terminal screws two full turns and remove the terminal wires.
2. Remove injector hold down crab.

NOTICE:
Extreme care should be used when handling an EUI to avoid costly damage by dropping or otherwise mishandling the EUI.

NOTE:
When replacing an EUI, always replace the injector O-rings.

3. Lift the injector from its seat in the cylinder head by inserting a pry bar under the injector body. See Figure 2-7.

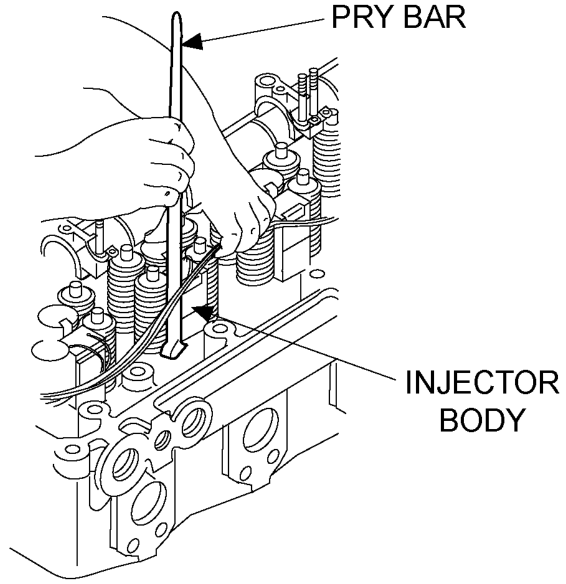


Figure 2-7 Removing EUI

NOTICE:
Avoid wire brushing the spray holes to prevent damage.

4. 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, J 7944.

2.3.3 Disassembly of Electronic Unit Injector

On a Series 50 EUI, only the injector solenoid and seal rings are serviceable. The injector must not be disassembled.

2.3.3.1 Inspection of Electronic Unit Injector

The solenoid can be tested either on or off of the injector.

To clean and inspect the injector, complete the following steps:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Clean the exterior of the injector with clean solvent and dry it with compressed air.

NOTE:
Do not test new or reliabilt® remanufactured electronic unit injectors prior to installation in the engine. The Kent-Moore® POP stand should be only be used as a diagnostic tool on fuel injectors that have been *removed* from an engine.

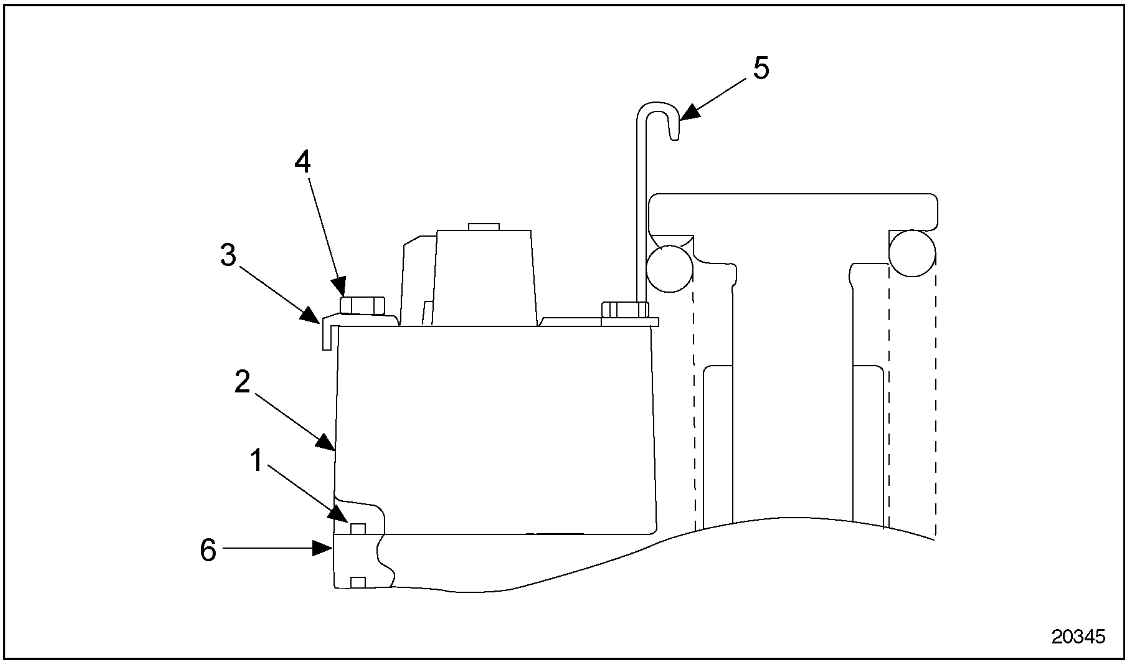
2. Test the EUI using J 34760 part of J 34760–147A injector pop-n-fixture. Follow procedures supplied with this tool. Reuse or replace injector or injector and solenoid as indicated. Discard O-rings and replace with new.
3. Inspect the fuel injector tubes at the injector seat. If required, replace the fuel injector tubes.

2.3.4 Replacement of Fuel Injector Solenoid and Seals

Perform the following steps for solenoid replacement:

1. Loosen the injector wire terminal screws two turns and remove terminal wires.

2. Loosen four hex head screws and remove old solenoid. See Figure 2-8.



1. Spacer Seals
2. Solenoid
3. Load Plate
4. Screw
5. Follower Retainer
6. Spacer

Figure 2-8 EUI Solenoid Assembly

3. This step is different depending on the DDEC unit used:
   [a] For DDEC II, discard the solenoid, load plate, follower retainer, and screws. Do not reuse old screws.
   [b] For DDEC III, discard the solenoid, follower retainer, and screws. Do not reuse old screws. The load plate must be reused.
4. Remove spacer and seals from injector body.

NOTICE:
The spacer is a matched component with the armature and must remain with its respective injector.

5. Discard seals, but do not discard spacer.
6. Install new seal in spacer groove and position spacer on body with seal facing down. See Figure 2-8. Seal may be retained in groove with small quantity of grease.
7. Install new seal in solenoid groove.
8. Install solenoid on spacer.

NOTICE:
The load plate on each DDEC III injector is unique and must remain with the injector. The DDEC III load plate carries the injector part number, it's injector serial number in bar code format, and the injector calibration code number.

9. Install new screws through load plate and follower retainer, solenoid, and spacer.
10. Thread screws into body and torque all screws until heads contact retainer and load plate with a slight force of 0.6 N·m (5 lb·in.). See Figure 2-9.

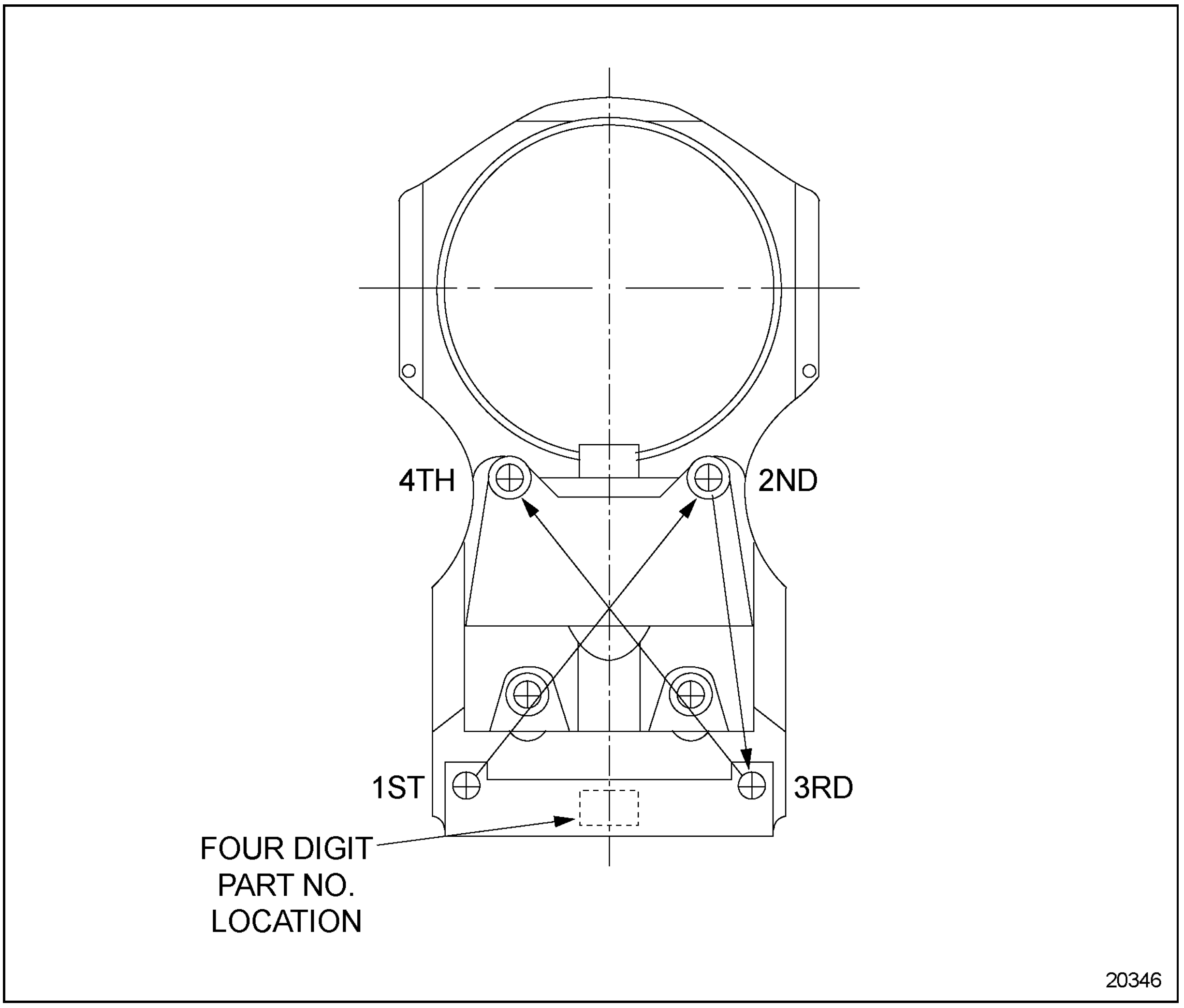


Figure 2-9 EUI Solenoid Torque Sequence

11. Torque screws to 2 N·m (19 lb· in.) in the sequence shown. See Figure 2-9.
12. On DDEC II injectors only, etch the last four digits of injector part number on the load plate. See Figure 2-9.

2.3.5 Installation of the Electronic Unit Injector

Perform the following steps to install the EUI:

1. If the fuel system is contaminated with coolant, perform the following:
   [a] Drain the fuel tanks and refill with clean fuel.
   [b] Replace both filters with new filters, and clean the fuel/water separator, if equipped.
2. If the coolant system is contaminated with fuel, flush and reverse flush the system. Refer to Section 13.5.4.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

Leftover fuel must be removed from the injector bore before injector installation. If fuel is trapped between the top of the injector hole tube and the lower injector O-ring seal, it may seep down to the injector hole tube seal ring, causing swelling and possible seal leakage.

3. Using clean compressed air, blow out any fuel remaining in the injector bore.

NOTE:
If the engine is equipped with an auxiliary injector tube seal, replace it with a new seal when the injector is removed.

NOTICE:

Do not use a metal dowel as this may damage the seal.

NOTICE:

Injector seals are considered one-use items and cannot be reused. Any time an injector is removed, all three injector nut O-ring seals must be replaced with new seals. Failure to replace seals can result in seal leakage.

4. Detroit Diesel encourages the use of an additional service seal (5104701) that is impervious to both coolant and fuel. This seal should be used in situations where injector tube seal leakage or deterioration is suspected or confirmed. Place the auxiliary seal in the injector hole and seat it against the top of the injector tube with a 41.3 mm (1-5/8 in.) diameter wood or plastic dowel.

5. Check to make sure the injector bore is thoroughly clean.
6. Apply a thin coat of clean ethylene glycol to the injector seal rings and install them in the injector nut ring grooves. Make sure seals are properly seated.
7. 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 EUI). 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.

NOTE:
Before installing injectors, the injector tube bore should be cleaned refer to Section 2.4.3 and inspected for any damage.

8. Install the hold down crab, hemispherical crab washer (flat surface up against bolt) and hold down bolt to the injector. See Figure 2-10. Be sure that the clamp does not interfere with the injector follower spring or valve springs.

NOTICE:
The hemispherical portion of the hold-down crab washers must be installed facing the crab (pointing down) in order to prevent damage to the washers. See Figure 2-10.

9. Torque the hold down bolt to 58-66 N·m (43-49 lb·ft).

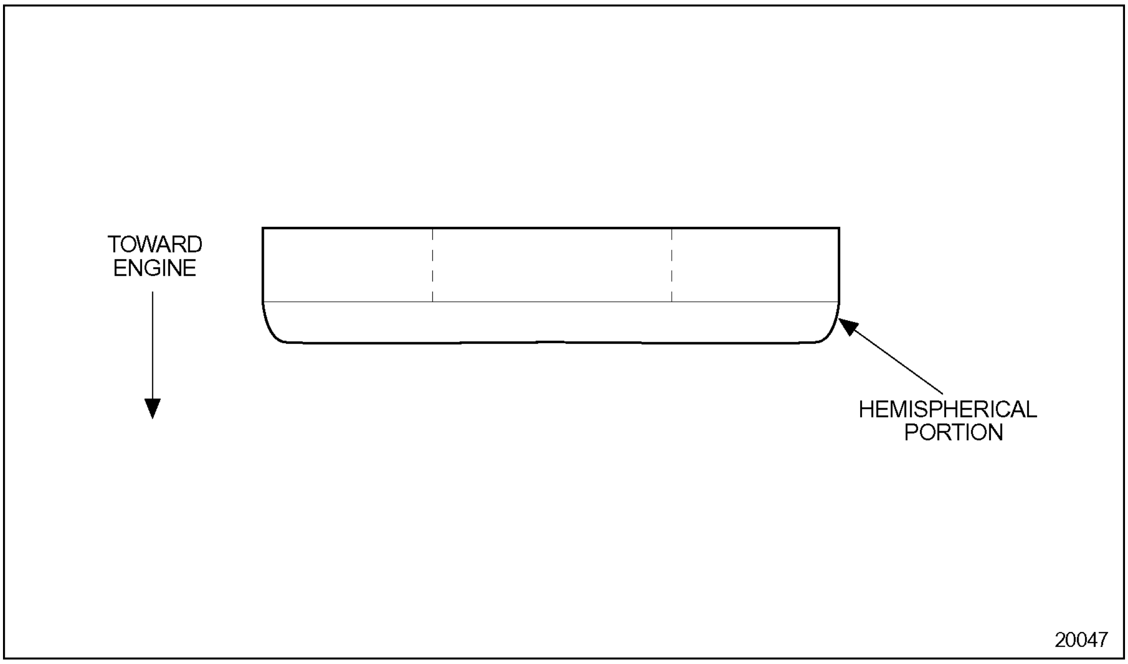


Figure 2-10 Hold-down Crab Washer Installation

Perform the following steps for installation of the injector hold-down crab:

10. Determine which type of hold-down crab needs to be installed by measuring the overall height between the crab and injector spring.

    [a] If the overall height is 54 mm (2.125 in.), proceed to step 11

    [b] If the overall height is 52 mm (2.047 in.), skip to step 12

11. Position a 0.762 mm (0.030 in.) feeler gage between the crab and injector spring on the side of the spring that faces the intake manifold.

NOTICE:
The hemispherical portion of the hold-down crab washers must be installed facing the crab (pointing down) in order to prevent damage to the washers. See Figure 2-11.

12. Install the hold-down crab, hemispherical crab washer (flat surface up against bolt) and hold-down bolt to the injector. See Figure 2-11. Be sure that the clamp does not interfere with the injector follower spring or valve springs.

13. Torque the hold down bolt to 58-66 N·m (43-49 lb·ft).

    [a] If a former crab was installed, remove the feeler gage after torquing the bolt.

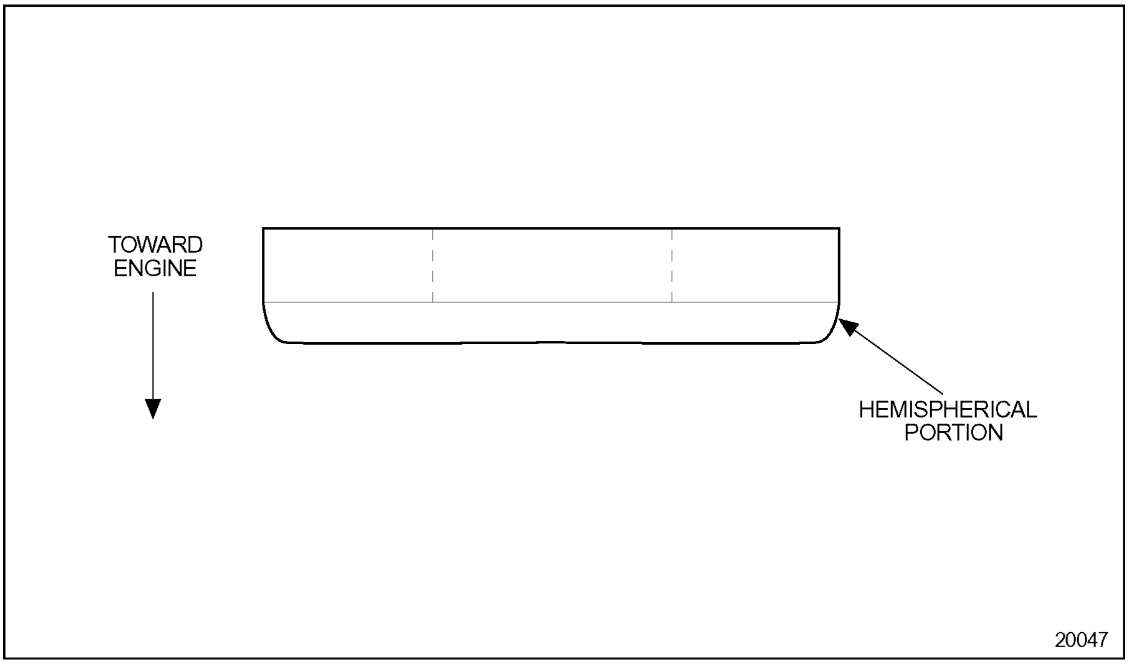


Figure 2-11 Hold-down Crab Washer Installation

Perform the following steps to complete the installation of the EUI:

1. 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. Torque the terminal screws to 108-1.13 N·m (9.5-10.0 lb· in.). Do not bend the terminals down after installation. See Figure 2-12.

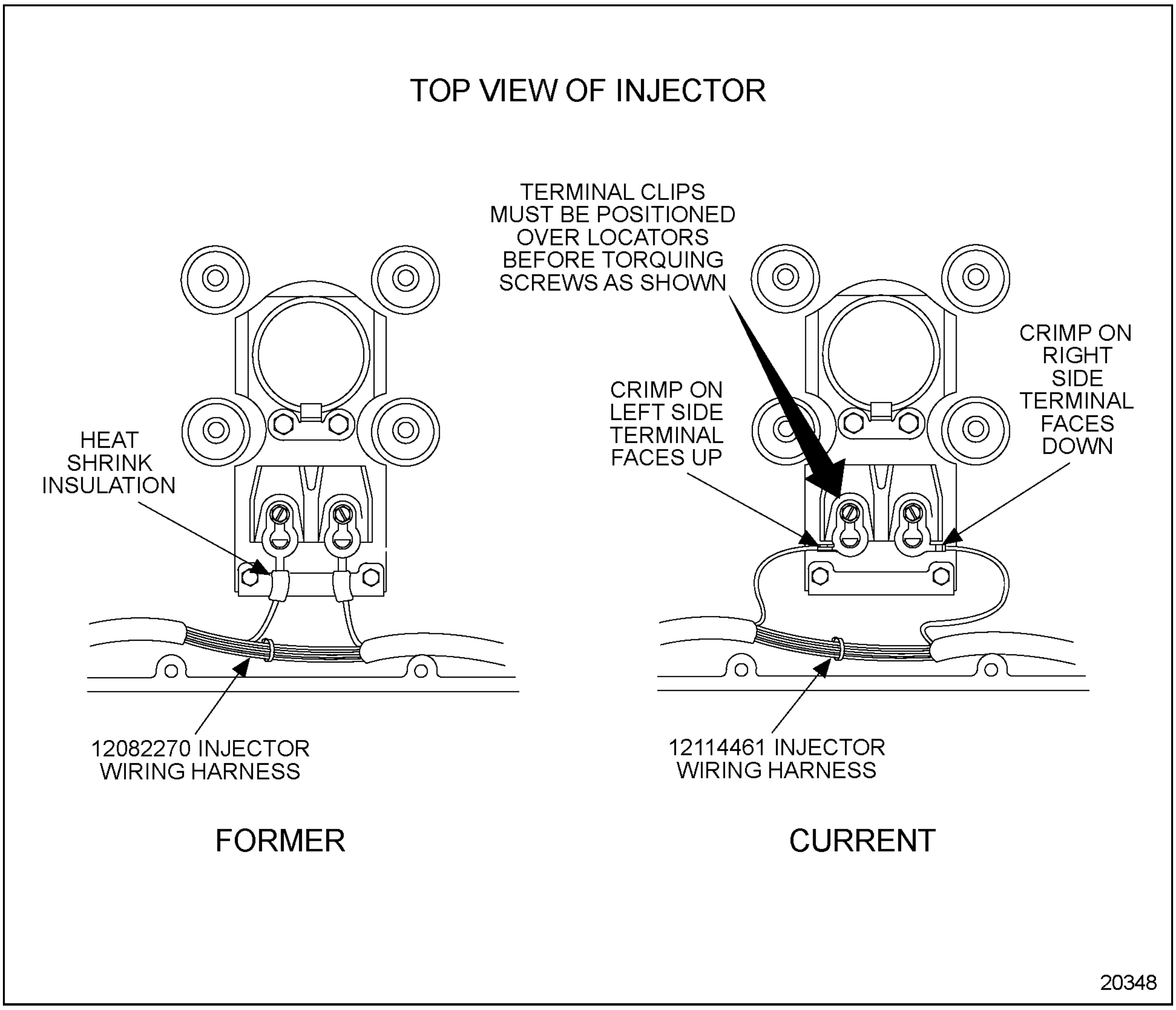


Figure 2-12 EUI Terminal Installation

NOTE:
Front and rear rocker shaft assemblies look identical but are *not interchangeable* due to different bolt hole center distances. The outboard end of each rocker shaft assembly is marked with the DDC logo for identification. Care should be taken to identify and return assemblies to the proper location if both overhead assemblies were removed.

2. Install the rocker arm shafts, with rocker arms in place. Refer to Section 1.3.4.
3. Adjust the intake and exhaust valve clearances and injector height. Refer to Section 12.2.
4. Install the inlet and outlet fuel lines to the fittings at the rear of the cylinder head.
5. On DDEC III engines, record the injector calibration code from the load plate with the proper cylinder location.

6. Install the valve rocker cover. Refer to Section 1.6.6.
7. Turn the ignition on. Plug in DDR to DDL connector, and select injector calibration. View injector calibration to ensure injector calibration is correct for each cylinder. If not correct, select update injector calibration and set correctly.

2.4 FUEL INJECTOR TUBE AND O-RING

The bore in the cylinder head for the EUI is directly through the cylinder head water jacket. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a copper tube is pressed into the injector bore. The tube has a ring seal at the top and is flared at the bottom, on the lower side of the cylinder head, to create water and gas tight joints at the top and bottom.

NOTE:
It is recommended that the injector tube be replaced with new parts at the time of engine overhaul.

2.4.1 Repair or Replacement of Fuel Injector Tube

To determine if repair or replacement of the fuel injector tube is necessary. See Figure 2-13.

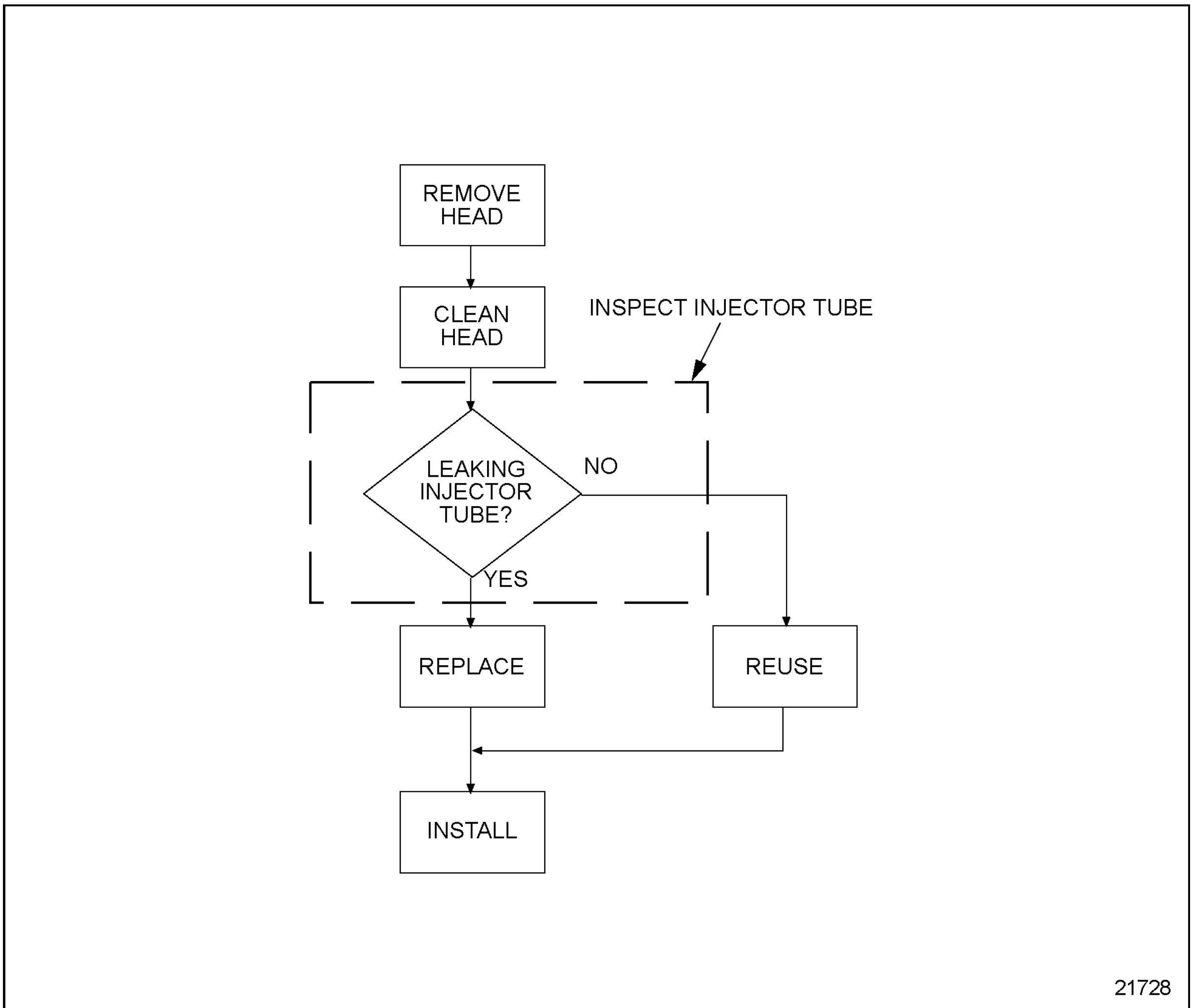


Figure 2-13 Flowchart for Repair or Replacement of Fuel Injector Tube

2.4.2 Removal of the Injector Tube and O-Ring

When removing an injector tube, use injector tube installation, removal and refinishing tool set, J 33880.

1. Remove, disassemble and clean the cylinder head. Refer to Section 1.2.2.
2. Place the injector tube installation/removal tool, J 33880-4 part of J 33880, in the injector tube. Insert the pilot, J 5286-5 part of J 33880, through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installation/removal tool. See Figure 2-14.

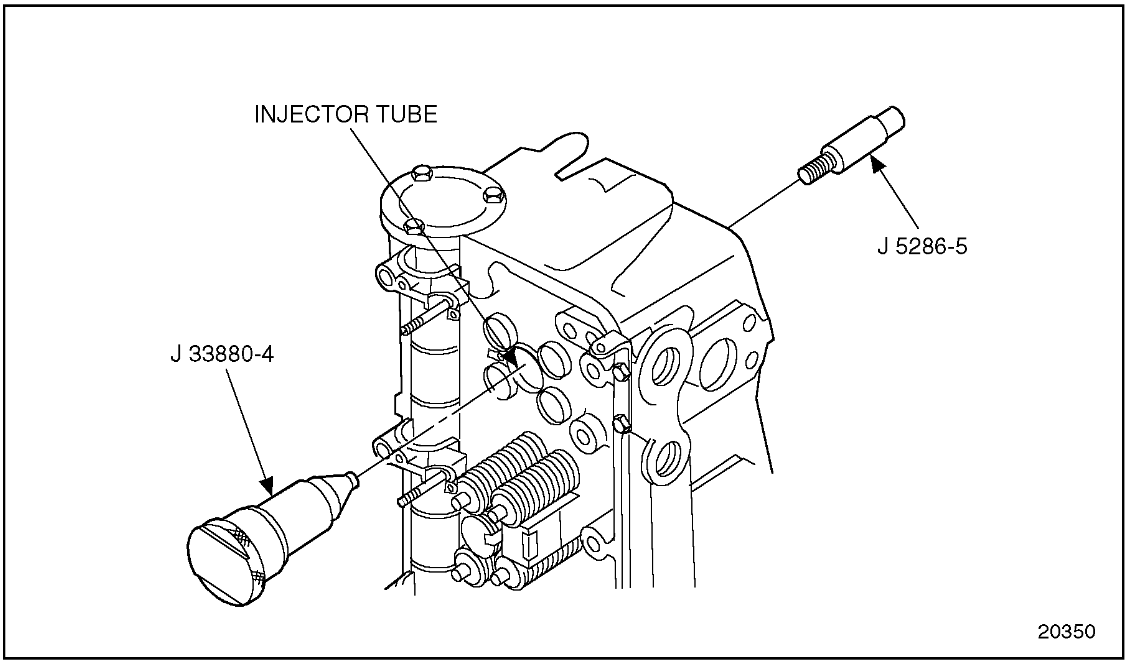


Figure 2-14 Removal of Injector Tube

3. Tap on the end of the pilot using a brass hammer or fiber mallet. Carefully drive and lift the injector tube, installation/removal tool and pilot from the cylinder head. If the injector tube O-ring is not removed with the injector tube, remove the O-ring from the cylinder head casting at the upper end of the injector tube bore.

2.4.3 Cleaning of Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove any dirt, burrs, or foreign material that may prevent the new tube from seating at the lower end or sealing at the upper end. Excess material in the form of a small copper ring may be left at the lower end of the injector tube counterbore after the injector tube has been removed. This copper ring will have to be removed using a suitable sharp pointed tool.

2.4.4 Installation of Auxiliary Injector Seal

Perform the following for installation of auxiliary injector seal.

NOTICE:
If a cylinder head has a damaged injector hole tube seal, coolant may seep past the seal after injector removal Drain down the injector tube hole, and fill the combustion chamber. If this condition goes undiscovered and the coolant is not removed from the cylinder before the injector is replaced, the engine may be damaged at startup. Always check cylinders for possible coolant seepage before replacing injectors and use care to prevent coolant or fuel from contaminating the engine lubricating oil.

NOTICE:
Do not use a metal dowel to install the auxiliary injector seal, as this may damage the seal.

1. Place the auxiliary seal in the injector hole.
2. Seat it against the top of the injector tube with a 1-5/8 in. diameter wood or plastic dowel. See Figure 2-15.

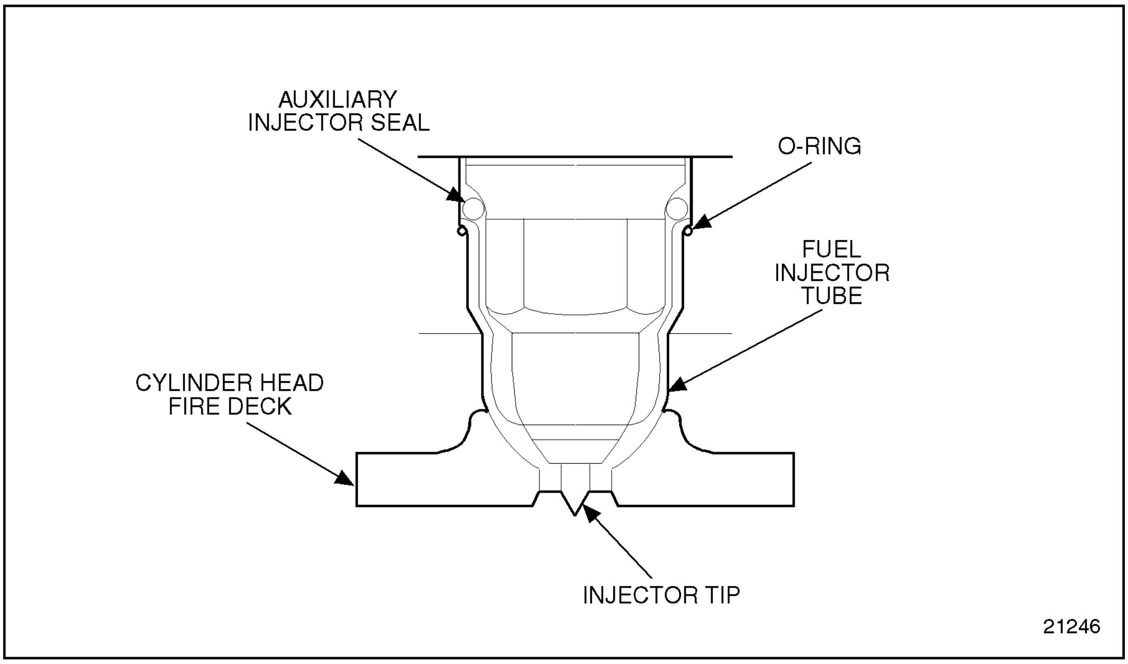


Figure 2-15 Auxiliary Injector Seal Location

2.4.5 Installation of Injector Tube and O-Ring

Perform the following steps for injector tube installation:

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 may cause the tube to turn during reaming or flaring operations possibly damaging the injector tube or reamers.

1. Lubricate the blended fluorocarbon injector tube sealing O-ring with liquid hand soap.

NOTE:
This ring was formerly made of fluoroelastomer and had a blue coating for identification. It is now made of a special blended fluorocarbon material with an orange Teflon coating for identification. Former and current-design seal rings are completely interchangeable, and only the current orange-coated seal ring will be serviced.

2. Place the O-ring over the injector tube, sliding it up to the lip.
3. Install the injector tube on the injector tube installation/removal tool, J 33880-4 part of J 33880. See Figure 2-16.

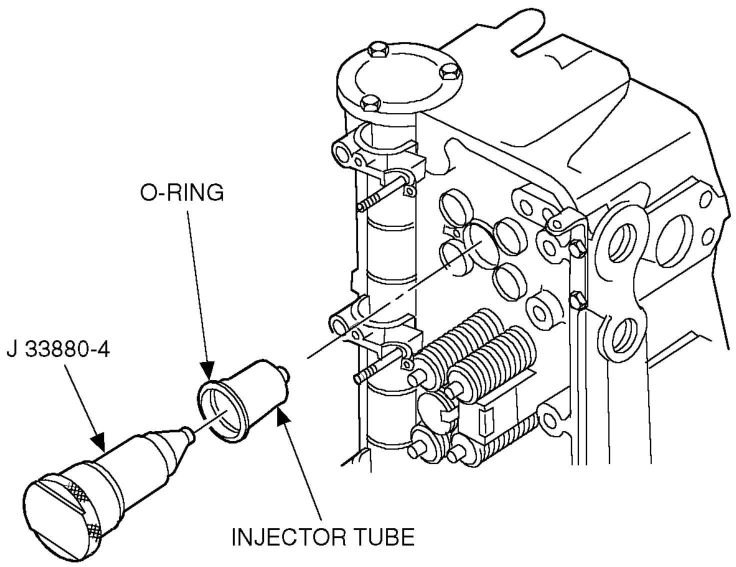


Figure 2-16 Installing Injector Tube

4. Install the injector tube installation/removal tool with tube in place, into the injector bore. Be sure the tip of the injector tube goes through the small hole in the fire deck. Tap lightly on the end of the tool, if necessary, to seat the tube.
5. Install the EUI hold-down clamp and bolt it in place over the installation/removal tool. See Figure 2-17.

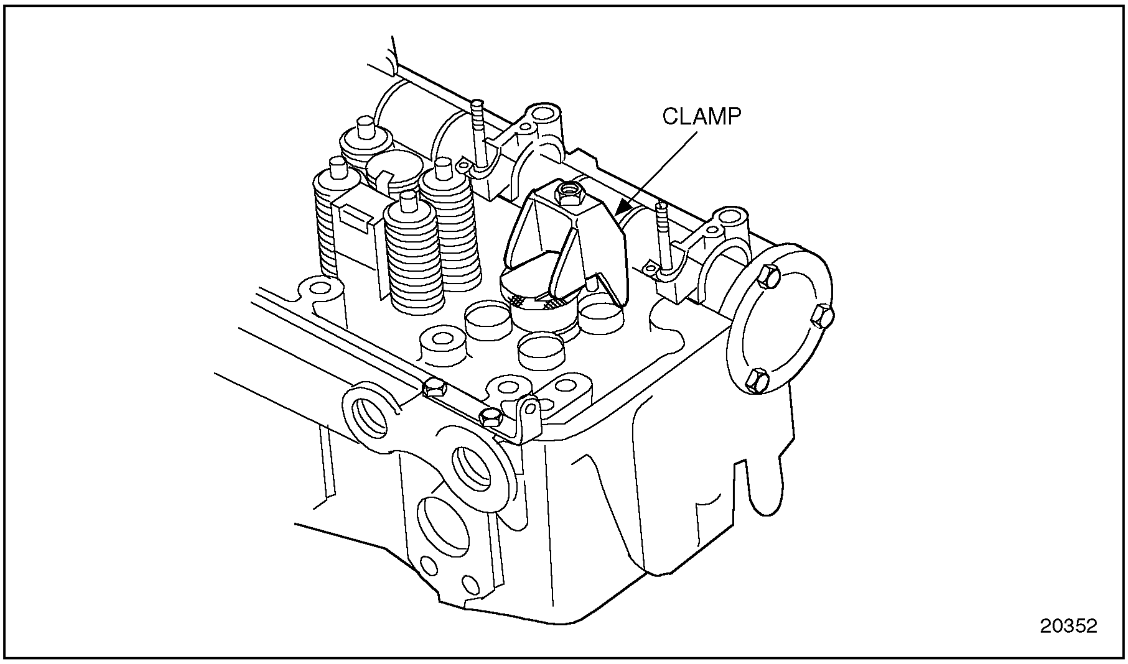


Figure 2-17 Installing Injector Hold-down Clamp

6. Torque the EUI hold-down clamp bolt 58-66 N·m (43-49 lb·ft). This will seat the injector tube at the desired depth.

After an injector tube has been installed in a cylinder head, it must be finished. For flaring injector tube, use injector tube installation, removal and refinishing tool set, J 33880. See Figure 2-18.

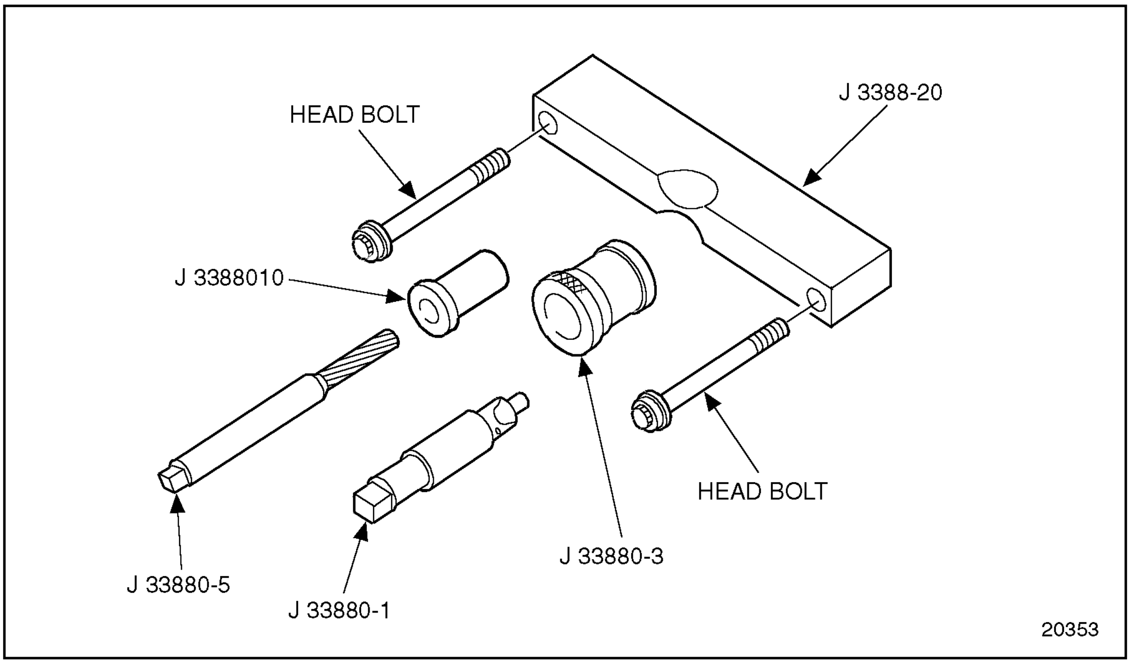


Figure 2-18 Injector Tube Installation Tool Set

Perform the following steps for a flaring injector tube:

1. Insert the injector tube flaring tool, J 5286-6 part of J 33880 through the small hole in the bottom of the tube, rotating to engage the threads in the installation/removal tool.

2. Using a torque wrench and 12-point, 29/32 in. socket, screw the flaring tool into the tube installation/removal tool until it begins to flare the tube. See Figure 2-19.

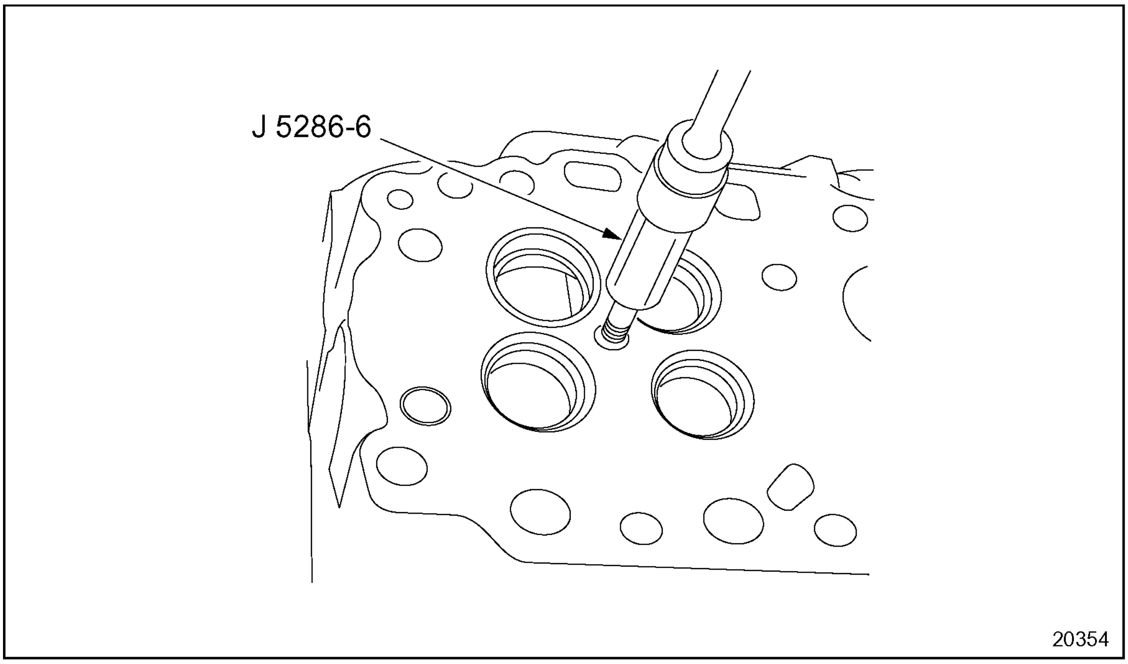


Figure 2-19 Flaring Injector Tube Tip

3. Continue to rotate the flaring tool and apply pressure to the flare end of the tube firmly against the cylinder head casting tube opening. Do not exceed 41 N·m (30 lb·ft) torque. See Figure 2-20.

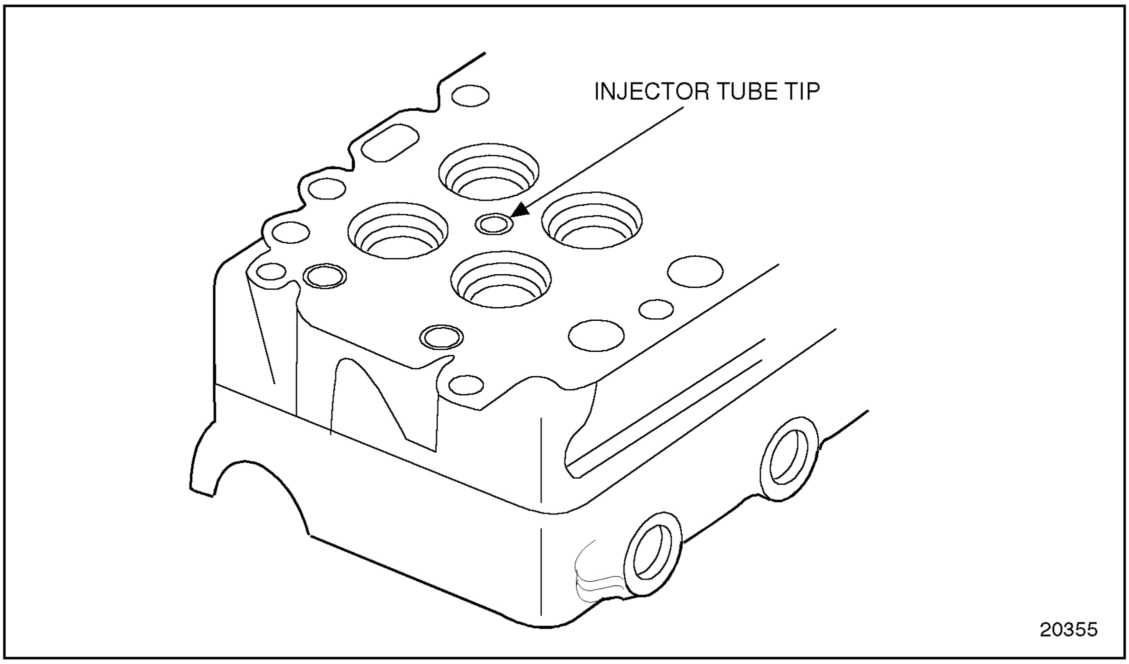


Figure 2-20 Properly Flared Injector Tube Tip

4. Remove the flaring and installation tools.

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 into the combustion chamber. To ream the injector tube, complete the following steps:

1. Install the seat reamer pilot tool, J 33880-3 part of J 33880, into the injector bore until it contacts the cylinder head.

NOTICE:
Turn the reamer in a clockwise direction only (both when inserting and withdrawing the reamer) because movement in the opposite direction will dull the cutting edges of the flutes.

2. Install the tip reamer pilot tool, J 33880-10 part of J 33880, into the seat reamer pilot until it bottoms.

3. Place a few drops of cutting oil on the cutting edges of the tube tip reamer tool, J 33880-5 part of J 33880, and install it in the pilot. See Figure 2-21.

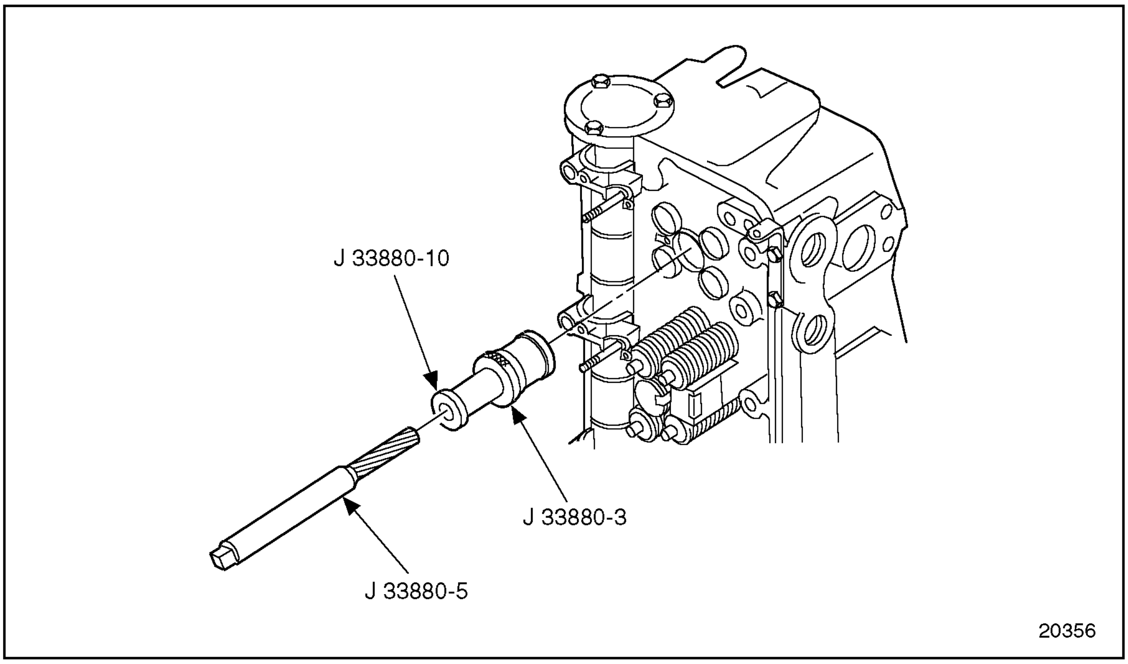


Figure 2-21 Reaming Injector Tube Tip

4. Using a speed handle with 7/16 in. socket attached, turn the tip reamer in a clockwise direction using light pressure until it goes completely through the end of the injector tube.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

5. Remove the reamer and pilot. Blow out the injector tube and tip with compressed air to remove all metal shavings.

6. Install the stop block tool, J 33880-20 part of J 33880, to the firedeck of the cylinder head using two existing head bolts. Tighten the head bolts, but do not torque. Position the cut out portion of the stop block beneath the injector tube. See Figure 2-22.

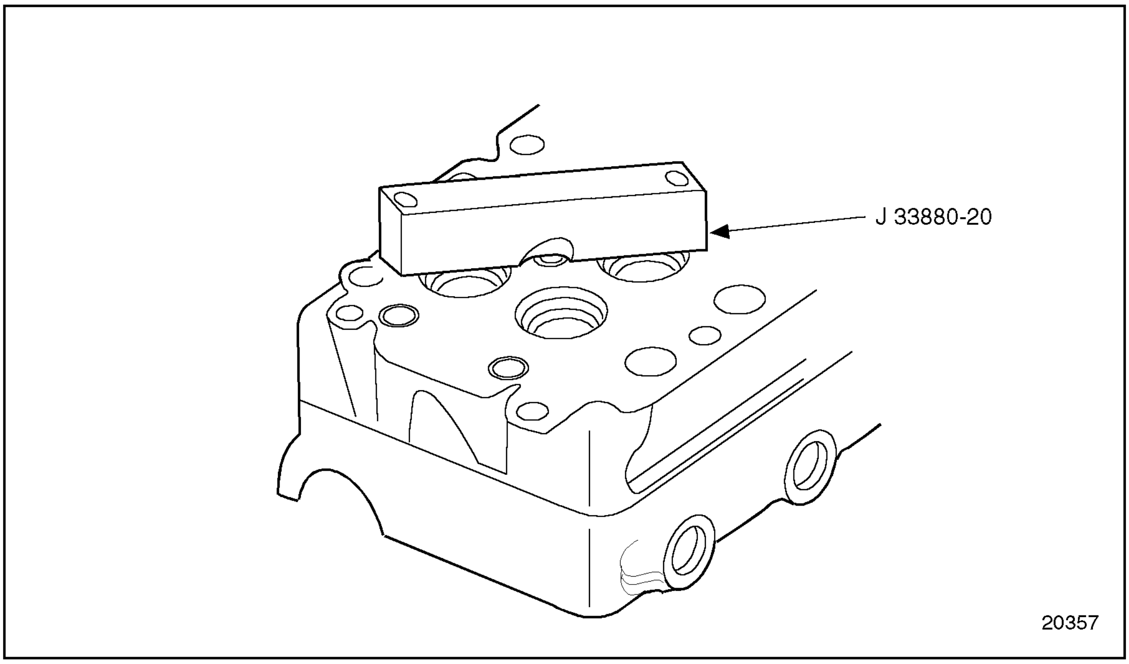


Figure 2-22 Stop Block Installed on Cylinder Head

7. Install the seat reamer pilot tool, J 33880-3 part of J 33880, into the injector tube bore until it contacts the cylinder head.

NOTICE:
If the seat reamer is dropped into the pilot, or is allowed to strike the injector tube, this may cause chatter marks in the seat. Use extreme care when inserting the seat reamer to prevent damaging the tube.

8. Place a few drops of cutting oil on the edges of the seat reamer tool, J 33880-1 part of J 33880, and gently place it in the pilot. See Figure 2-23.

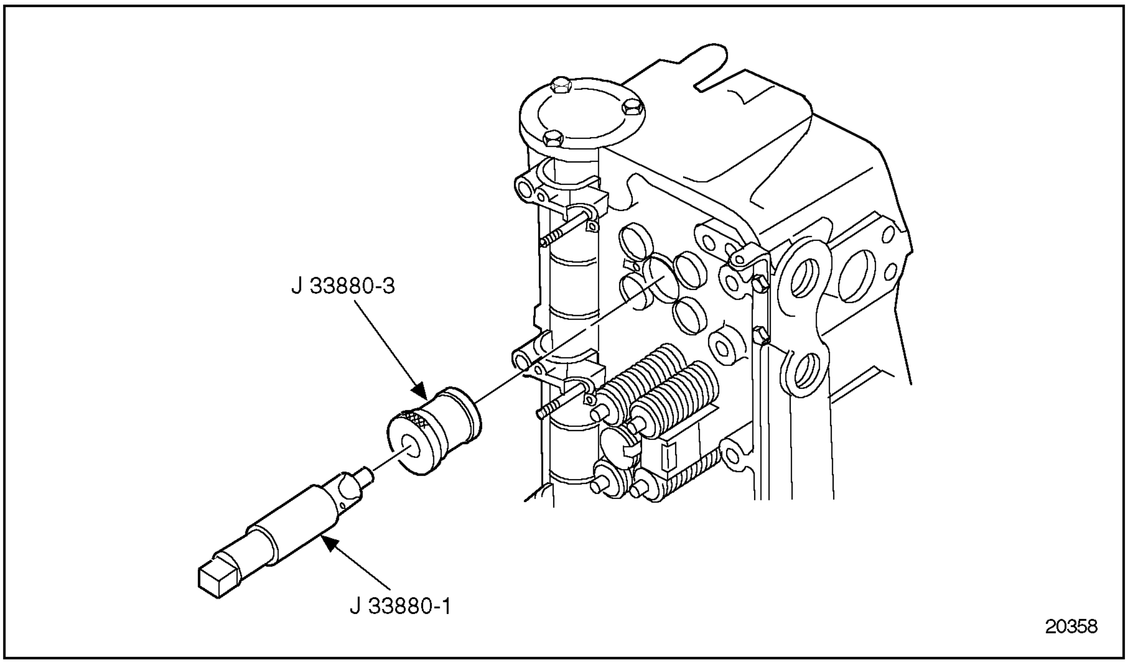


Figure 2-23 Reaming Injector Tube Seat

NOTICE:
Turn the reamer in a clockwise direction only, because movement in the opposite direction will dull the cutting edges of the flutes.

9. Using a speed handle with 15/16 in. socket attached, turn the seat reamer in a clockwise direction with light pressure. Continue until the reamer bottoms against the stop block.

10. Inspect the tube seating surface to ensure that there are no irregularities or chatter marks in the seating surface. If irregularities or chatter marks are found, remove and replace the injector tube. See Figure 2-24.

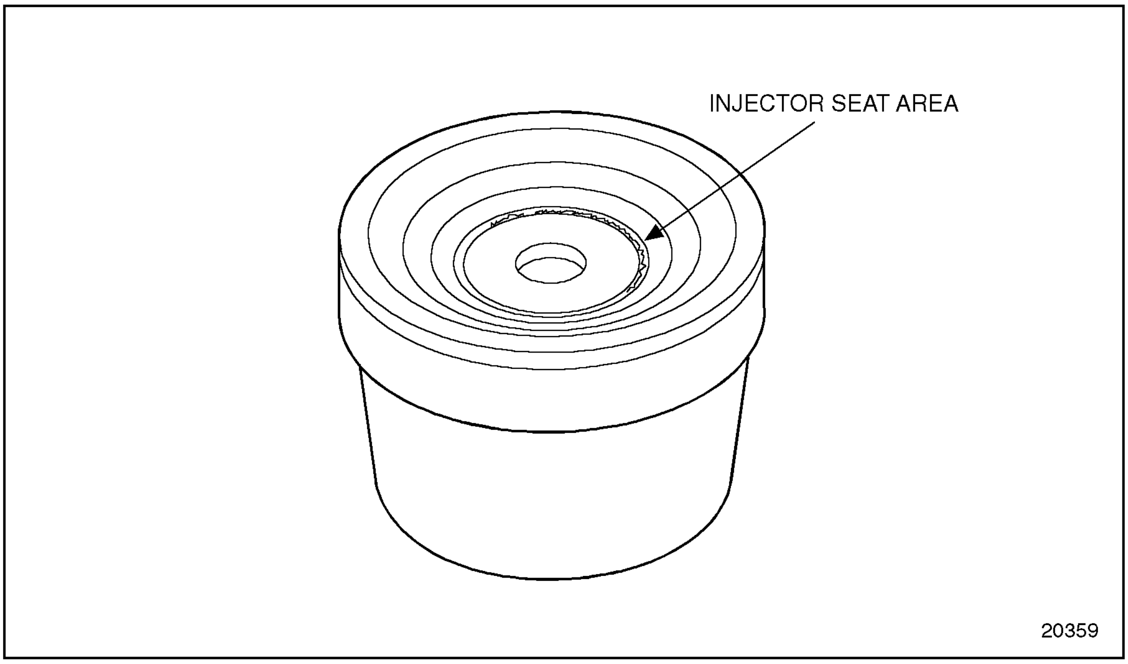


Figure 2-24 Injector Tube Seat Irregularities

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

11. Remove the reamer and pilot. Clean out the injector tube with compressed air.
12. Remove the two head bolts and stop block from the cylinder head.
13. Spot-face the injector tube as follows:

[a] With the cylinder head firedeck in a workable position, insert the tube tip refinisher tool, J 5286-8 part of J 33880, into the injector tube. See Figure 2-25.

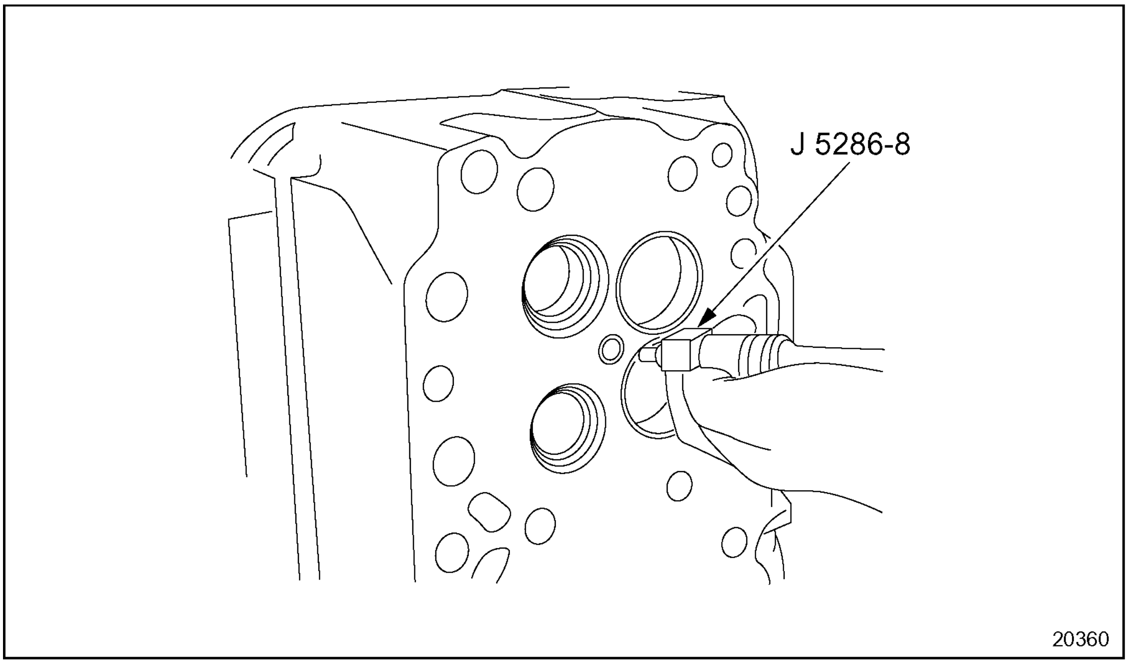


Figure 2-25 Refinishing Injector Tube Tip

[b] Using a 12-point socket and speed handle, turn the refinisher to remove excess stock so that the lower end of the injector tube is from flush to 0.76 mm (0.003 in.) below the firedeck surface of the cylinder head.

[c] Remove the chips from the injector tube.

2.4.5.1 Check Injector Tip Protrusion

To check the injector tip protrusion:

1. Insert the seat reamer pilot tool, J 33880-3 part of J 33880, into injector tube bore of cylinder head.

2. Insert protrusion gage tool, J 33880-7 part of J 33880, into pilot. See Figure 2-26.

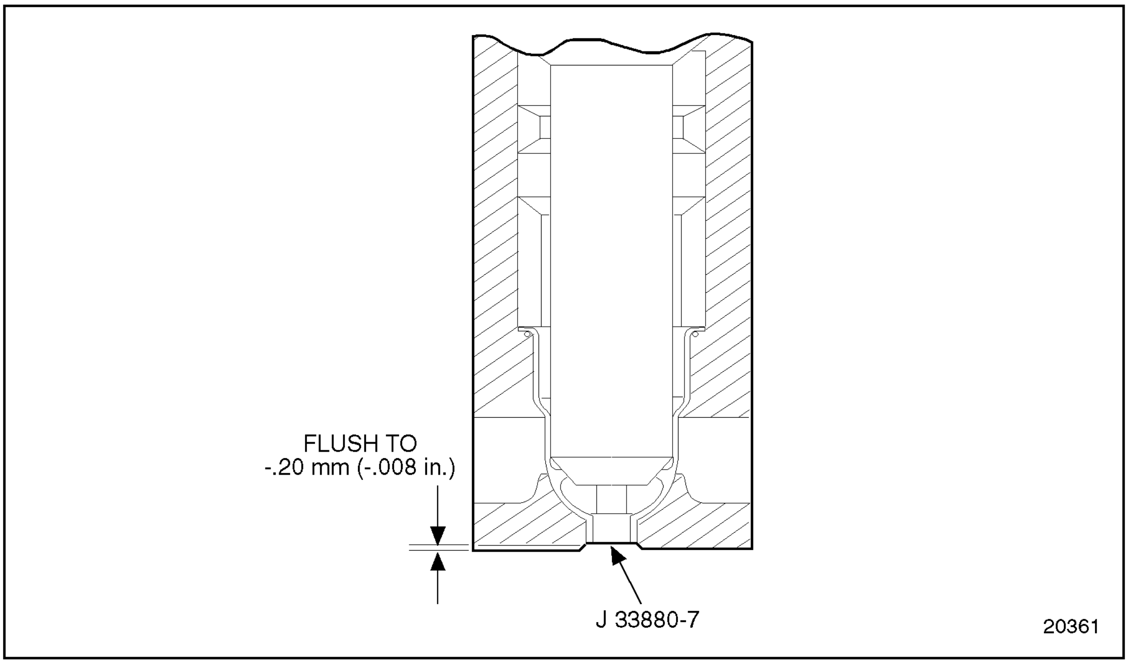


Figure 2-26 Checking Injector Tip Protrusion

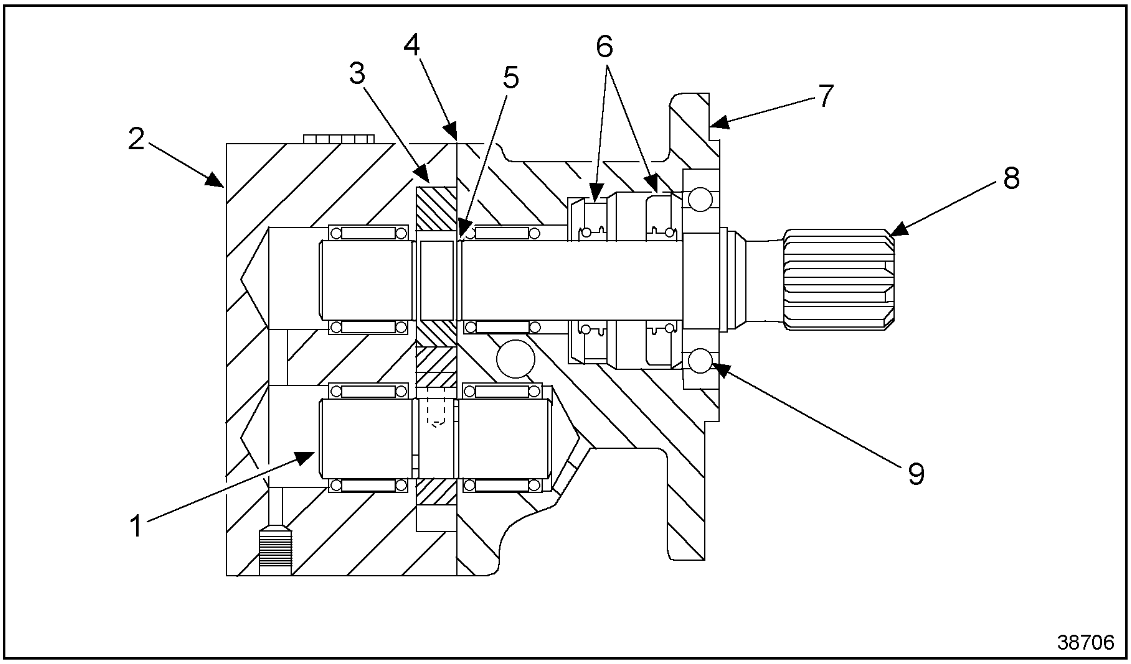
3. Check injector tip protrusion using sled gage tool, J 22273-01. Hold protrusion gage against pilot while measuring tip protrusion. This measurement should be flush to 0.2032 mm (0.008 in.) below the firedeck surface.

2.5 FUEL PUMP

The fuel pump system consists of the following components:

- ☐ Barnes positive displacement type fuel pump; separate drive shaft
- ☐ Air compressor drive coupling
- ☐ Gear train mounting adaptor

NOTE:
Effective with engine serial number 04R0030272 built on October 27, 1999, gear case-mounted fuel pumps have a splined drive shaft and splined gear coupling assembly. See Figure 2-27. The former and current fuel pump and drive assemblies are not interchangeable. Both current assemblies must be used together. Components of former and current pump assemblies and drive assemblies are not interchangeable.



1. Driven Shaft
2. Cover
3. Drive Gear
4. Gasket
5. Snap Ring
6. Oil Seal
7. Pump Body
8. Drive Shaft, Splined
9. Ball Bearing, Steel Cage

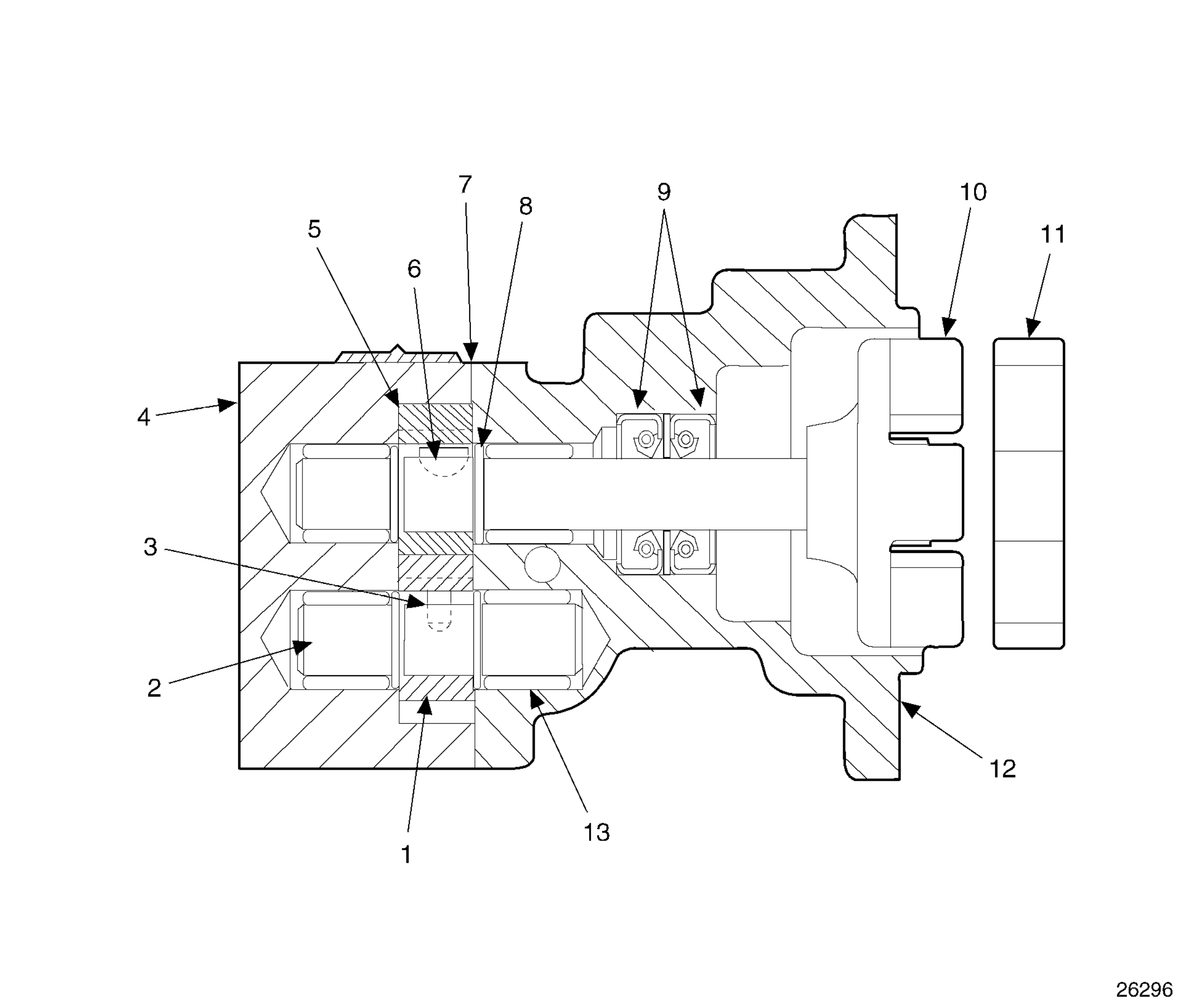
Figure 2-27 Current Gear Case-Mounted Fuel Pump Assembly

The compressor-mounted pump has been replaced, effective July 1995, with an improved fuel pump.

The pumps are similar, except the improved pump has a one-piece drive.

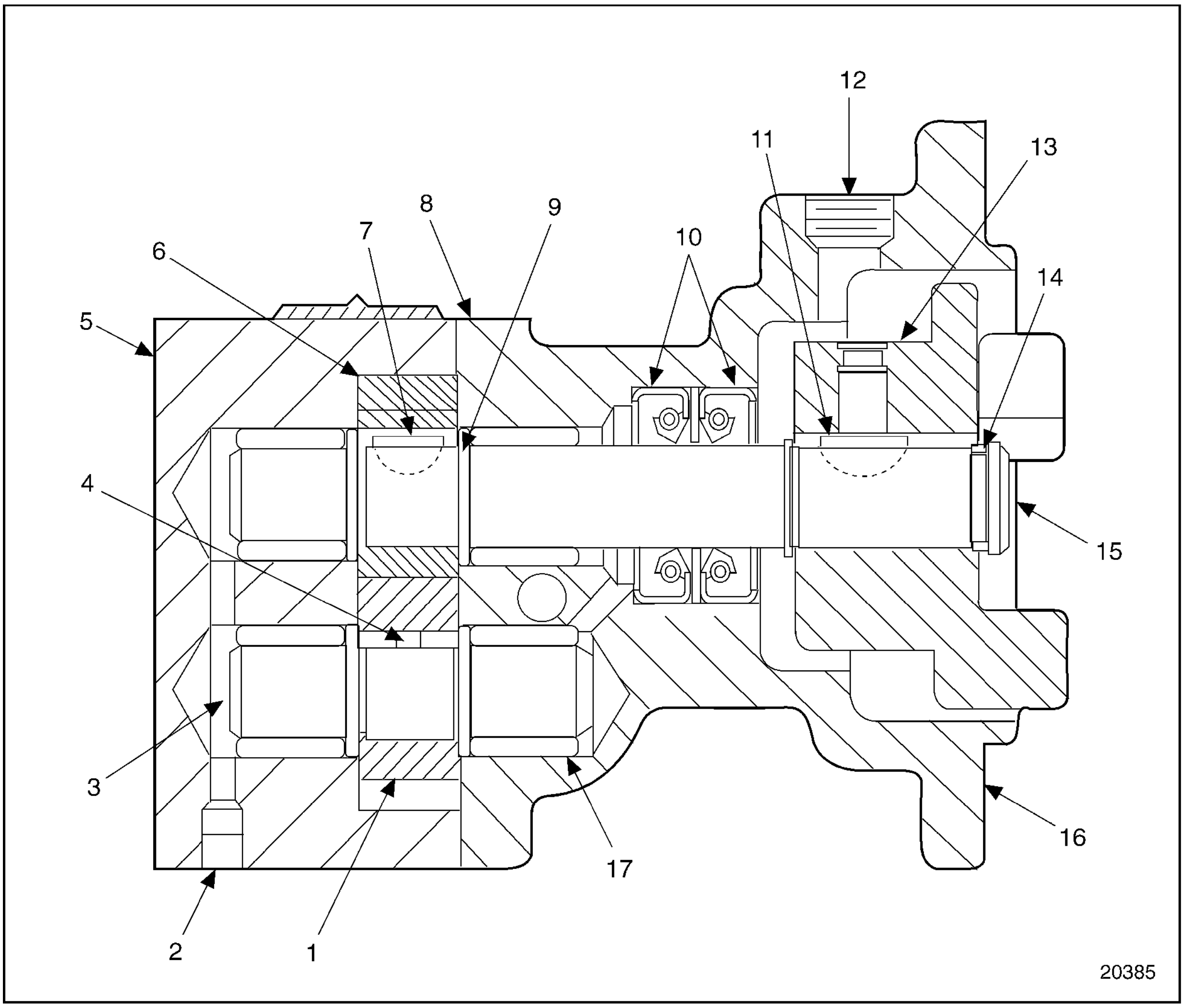
These pump assemblies are completely interchangeable. Components are not interchangeable.

The positive displacement gear-type fuel pump is seen in the next illustration. See Figure 2-28, for improved fuel pump or See Figure 2-29, for former fuel pump.



1. Driven Gear
2. Driven Shaft
3. Pin, Drive
4. Cover
5. Drive Gear
6. Key
7. Gasket
8. C-clip
9. Oil Seals
10. Drive Shaft and Hub Assembly
11. Coupling
12. Pump Body
13. Needle Bearing

Figure 2-28 Current Compressor-Mounted Fuel Pump Assembly with One-piece Drive Shaft and Hub Assembly



1. Driven Gear
2. Plug
3. Driven Shaft
4. Pin
5. Cover
6. Drive Gear
7. Key
8. Gasket
9. Snap Ring
10. Oil Seals
11. Key
12. Plug
13. Drive Hub
14. Snap Ring
15. Drive Shaft
16. Pump Body
17. Needle Bearing

Figure 2-29 Former Compressor-Mounted and Gear Case-Mounted Fuel Pump Assembly with Separate Drive Shaft and Hub Assembly

The fuel pump 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 line.

The fuel pump is attached to either a drive assembly mounted on the rear side of the gear case, or driven off of the rear of the air compressor. See Figure 2-30.

NOTE:
Effective with engine serial number 04R0030272 built on October 27, 1999, gear case-mounted fuel pumps have a splined drive shaft and splined gear coupling assembly. See Figure 2-27. The former and current fuel pump and drive assemblies are not interchangeable. Both current assemblies must be used together. Components of former and current pump assemblies and drive assemblies are not interchangeable.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining alignment between the body, cover and shafts. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. A gasket is used between the cover and body.

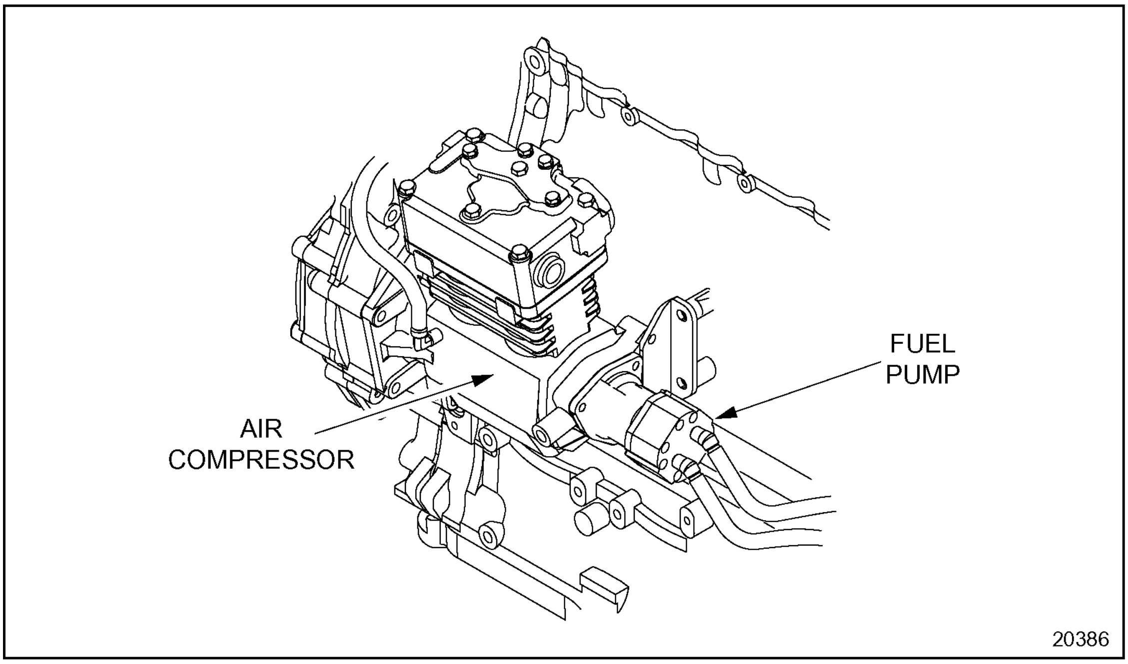
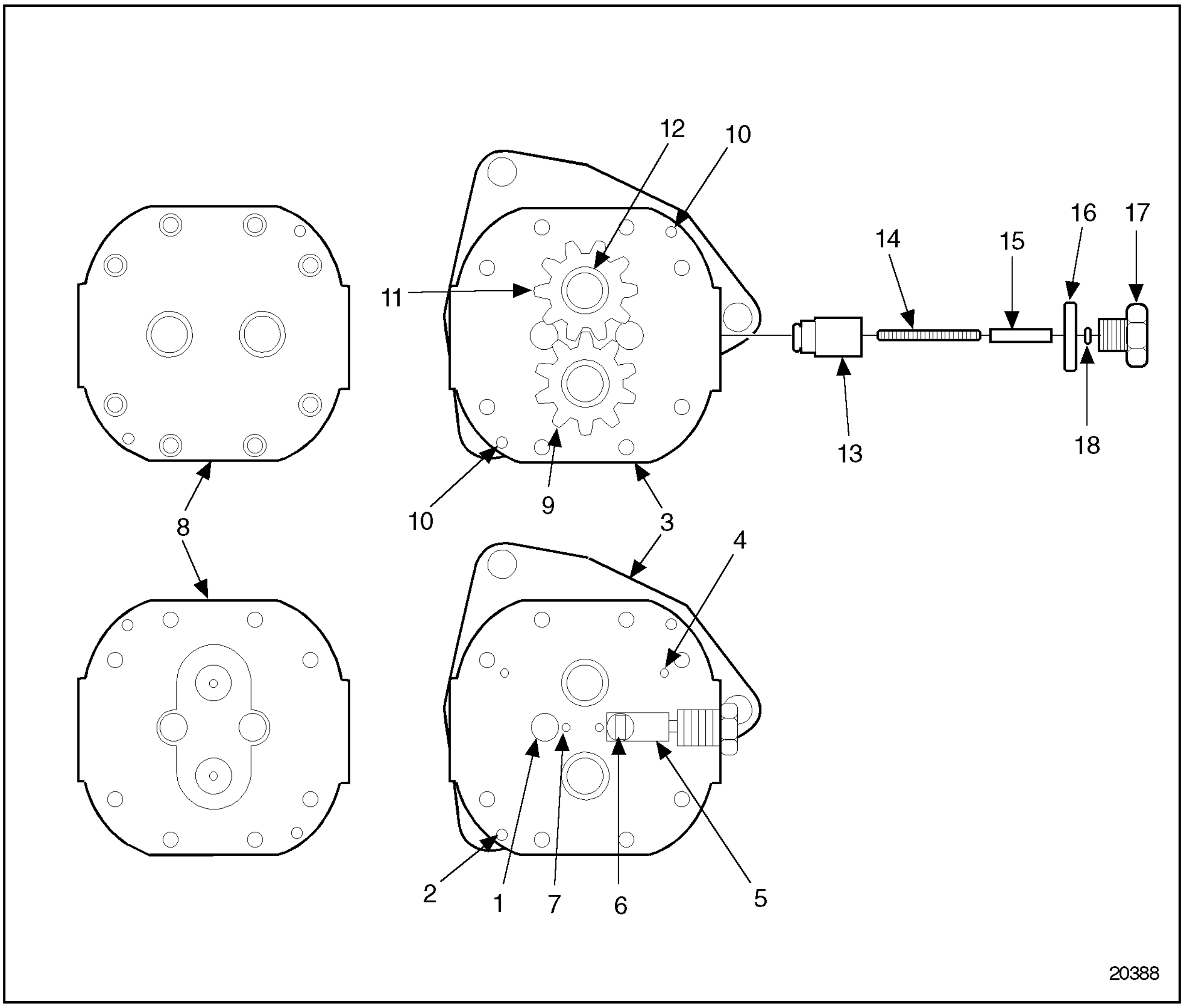


Figure 2-30 Fuel Pump Mounting

The fuel pump body is recessed to provide running space for the pump gears. Recesses are also provided at the inlet and outlet positions of the gears. The small relief valve vent (5) (see Figure 2-31) permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end. This eliminates the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through the passage to head of the relief valve (1) and provides for relief of excess discharge pressures.

Fuel re-enters the inlet side of the pump through the passage to head of the relief valve (6) 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 the passage to the head of the relief valve (6).

The gear teeth vent cavity (7) provides escape for the fuel oil that 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. See Figure 2-31.



1. Passage to Head of Relief Valve-Pressure Side
2. Dowel Hole
3. Body
4. Oil Seal Vent to Suction Side
5. Relief Valve Vent to Suction Side
6. Passage to Head of Relief Valve-Suction Side
7. Gear Teeth Vent Cavity
8. Cover
9. Drive Gear
10. Dowel
11. Drive Gear
12. Drive Shaft Gear
13. Relief Valve
14. Spring
15. Pin
16. O-ring
17. Plug
18. Spacer

Figure 2-31 Fuel Pump

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 fuel pump drive and gear case. The oil seal vent (4) (see Figure 2-31) serves as a vent passageway in the body between the inner oil seal and the suction side of the pump. This prevents building up any fuel oil pressure around the shaft ahead of the inner seal. The oil seals are installed with the lips of the seals, see Figure 2-32.

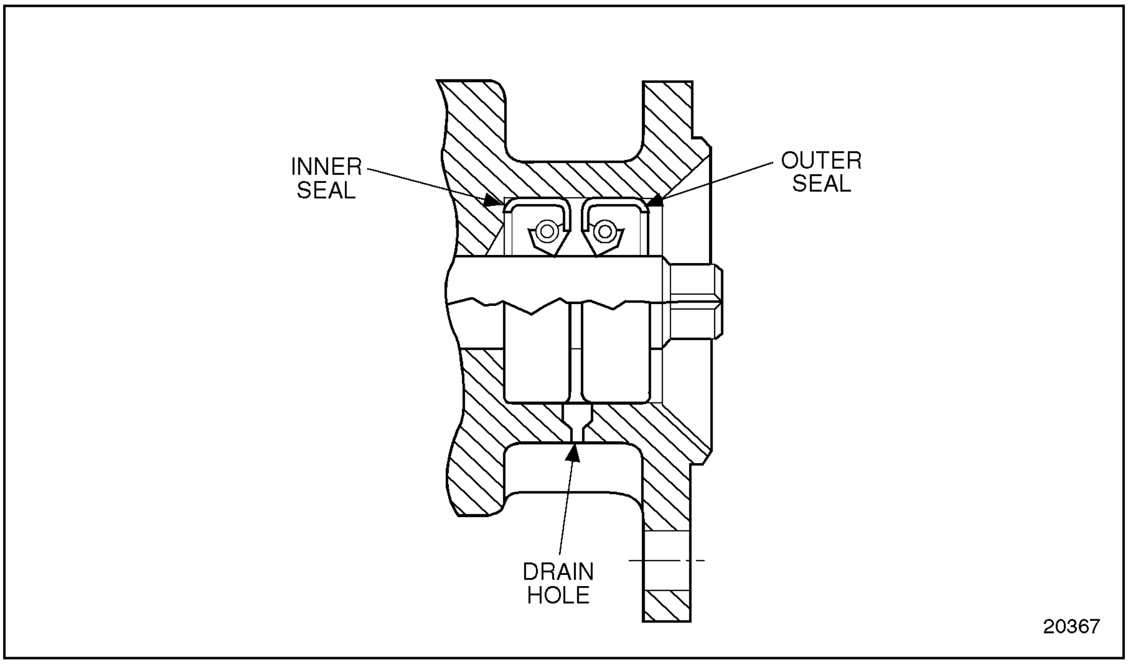


Figure 2-32 Fuel Pump Oil Seal Arrangement

Some fuel oil seepage by the fuel pump can be expected with a running the engine and immediately after an engine has been shut down. This is especially true with a new fuel pump, new pump seals, or both, as the seals have not yet conformed to the pump drive shaft. A drain hole in the pump body is 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.

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 448 kPa (65 lb/in.^{2}). The drain hole should be checked for plugging at normal scheduled maintenance.

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth that 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 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 448 to 517 kPa (65 to 75 lb/in.^{2}).

The fuel pump should maintain the fuel pressure listed in Table 11-2.

2.5.1 Repair or Replacement of Fuel Pump

To determine if repair or replacement of the fuel pump is necessary. See Figure 2-33.

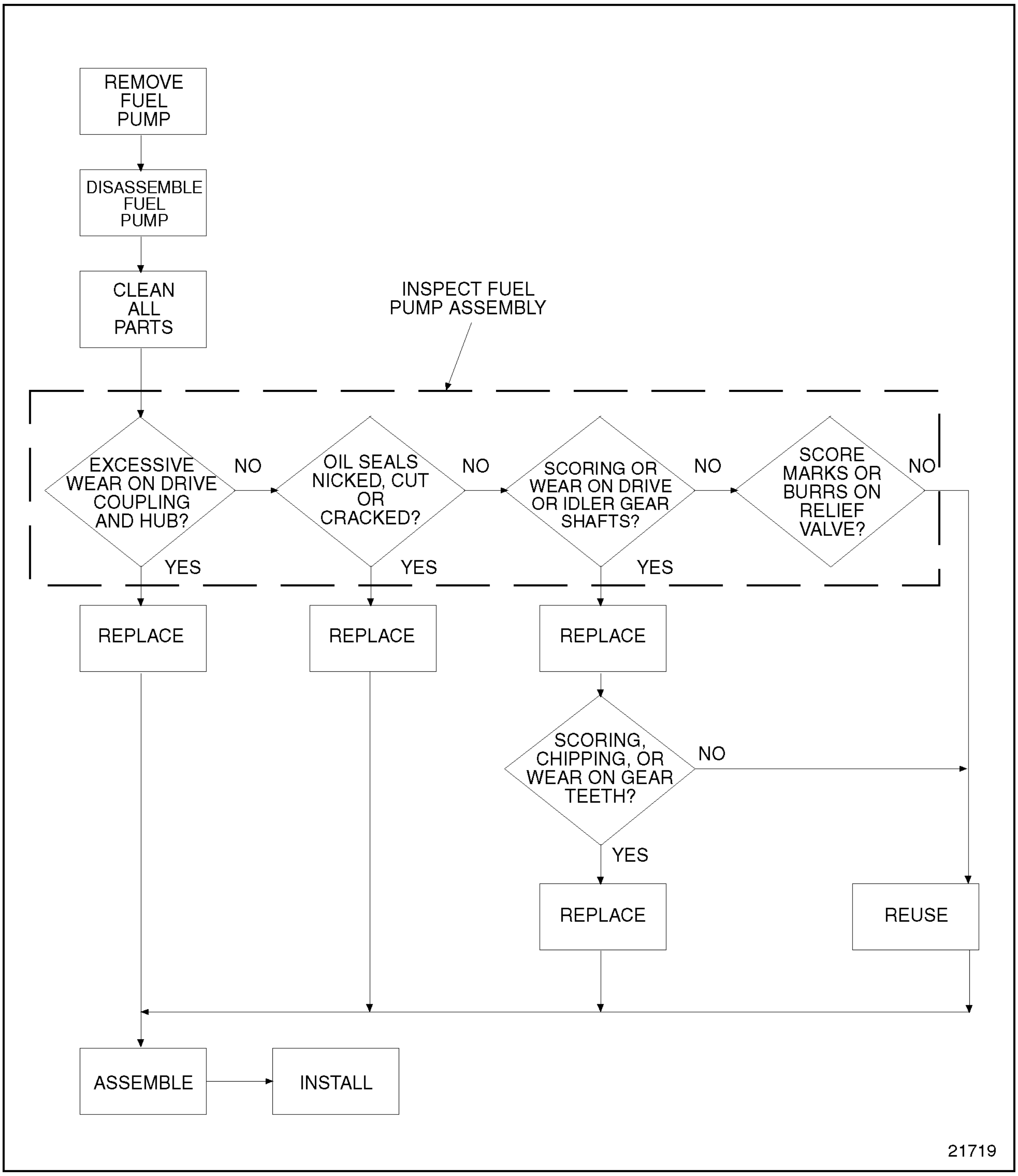


Figure 2-33 Flowchart for Repair or Replacement of Fuel Pump

2.5.2 Removal of Fuel Pump

Perform the following steps for fuel pump removal:

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
2. Remove the three fuel pump attaching bolts and withdraw the pump from the mounting adaptor on the gear case or air compressor.
3. Check the drive coupling and if broken or worn, replace it with a new coupling.

2.5.3 Disassembly Fuel Pump

Perform the following steps for fuel pump disassembly:

1. With the fuel pump removed from the engine, clamp the pump in a bench vise equipped with soft jaws.
2. Remove fuel inlet and outlet fittings from fuel pump cover.
3. Remove access hole plug.
4. Use snap ring pliers, J 4880 part of J 5586–A, and remove outer drive hub positioning snap ring.

NOTE:
It may be necessary to rotate the drive hub and shaft to align the set screw with access hole.

5. Working through access hole, loosen but do not remove set screw securing drive hub to drive key.
6. Slide drive hub off shaft and remove drive key from shaft.
7. Use snap ring pliers, J 4880 part of J 5586–A, and remove inner drive hub positioning snap ring.

8. Position pump on holding fixture, J 38767-1 part of J 38767–A, hub side down. See Figure 2-34.

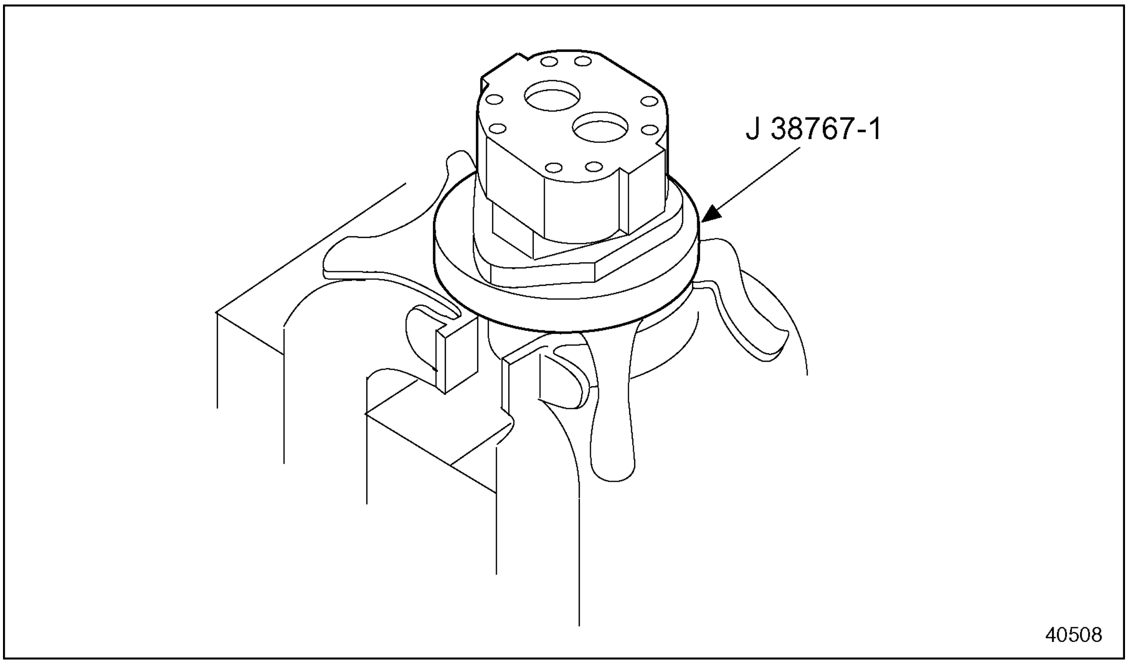


Figure 2-34 Fuel Pump Holding Fixture

9. Using a No. E-8 torx socket, J 25359-11 part of J 25359–C, remove eight bolts securing the pump cover to body.

NOTE:
Note the color of the foil gasket, gold or silver. If the pump is reassembled, the same color foil gasket must be used. The gaskets are of different thickness and establish correct internal clearance.

10. Separate the pump cover from the body by lifting it off the shafts and dowels. Remove and discard the foil gasket between the cover and body.

NOTE:
When the drive shaft is removed from the pump, the oil seals must be replaced.

11. Withdraw the driven shaft and drive shaft and gear assemblies from the pump body.
12. Remove the C-clips that retain the gears on the shafts taking care not to lose the drive pin from the drive shaft or the key from the drive shaft.

13. Remove the gears from the shafts.

NOTE:
When the drive shaft is removed, the drive shaft needle bearing assembly in the pump body must also be removed to allow installation of the oil seal protector used during reassembly.

14. Use needle bearing remover, J 33853, with slide hammer and remove the needle bearing assemblies from the pump body and cover. See Figure 2-35.

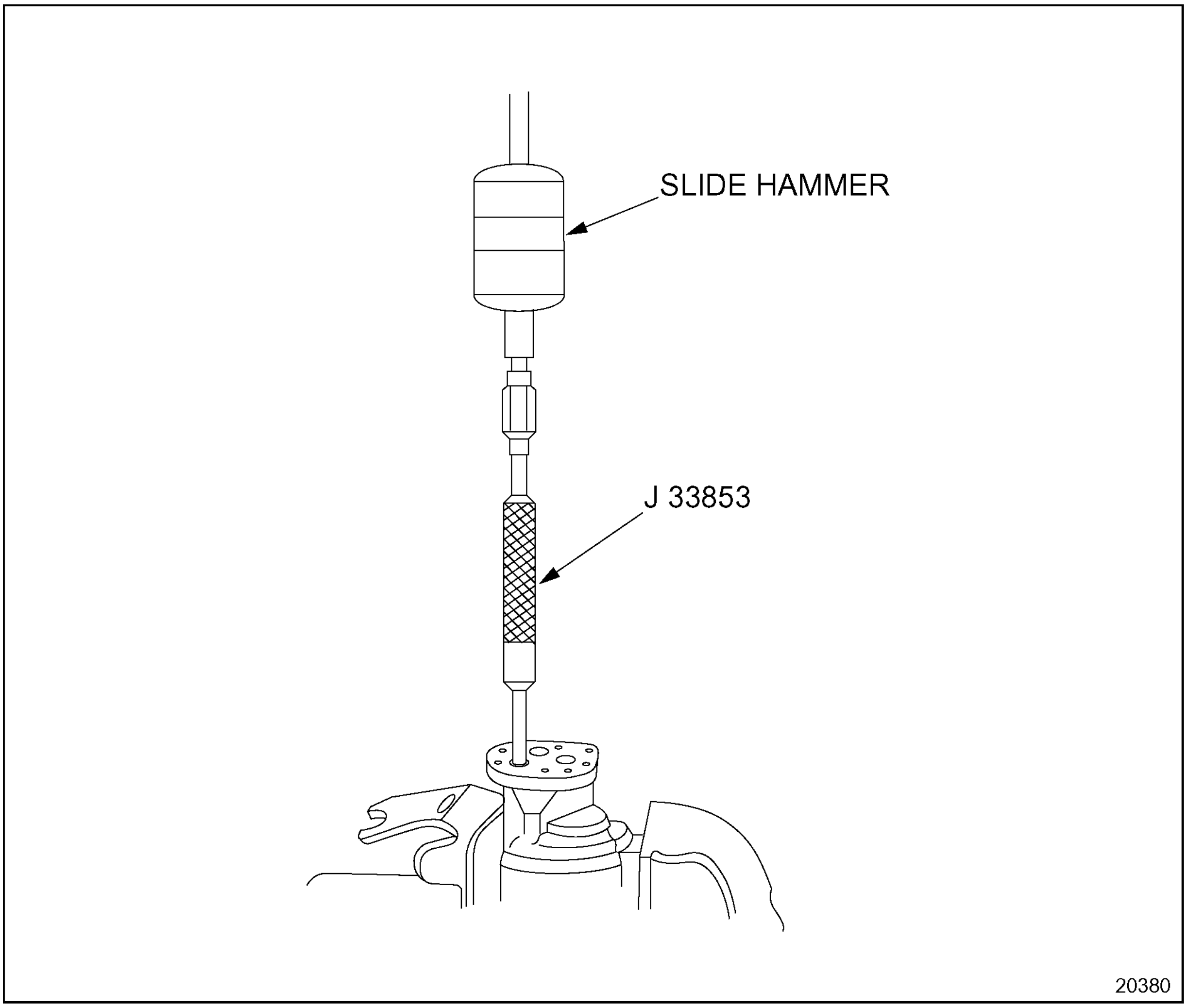


Figure 2-35 Needle Bearing Removal

15. Position pump on fixture, J 38767-1 part of J 38767, and insert lip of seal remover, J 1508-13, between the inner and outer oil seals. Tap the tool with a light hammer to drive the outer seal out of the pump body. See Figure 2-36. Discard the seal.

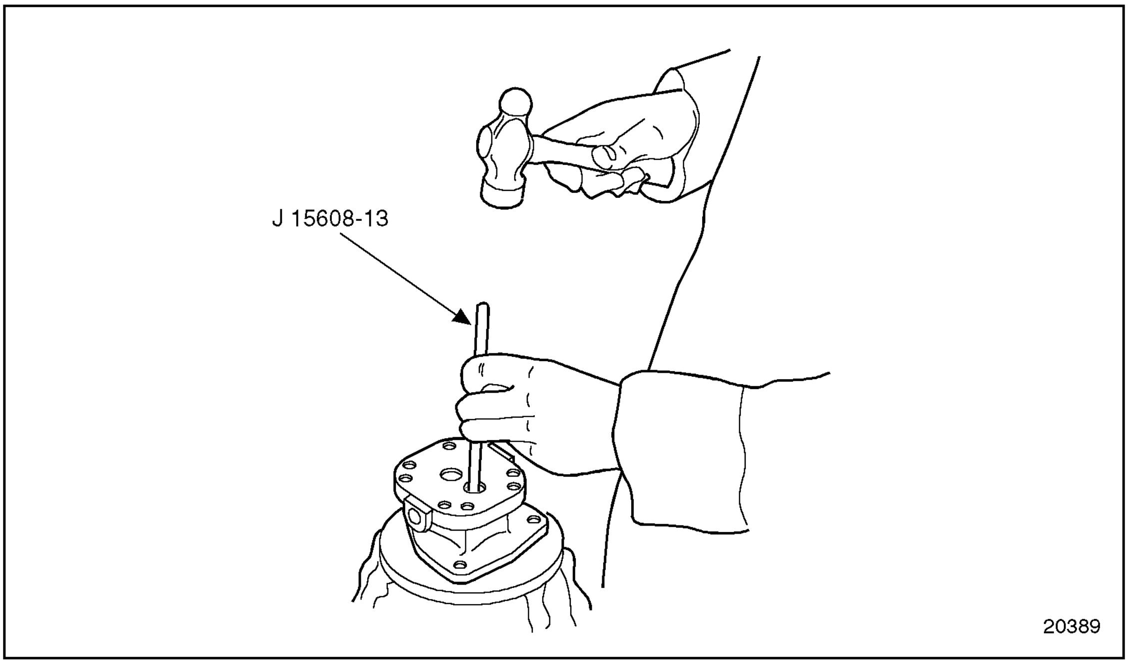


Figure 2-36 Oil Seal Removal

16. Repeat the process removing the inner seal by placing the tool lip against the inside of the seal case. Discard the seal.
17. Unscrew and remove the relief valve cover and remove the relief valve plunger, spring and pin from the bore.
18. Remove the spacer from the relief valve cover.
19. Remove and discard the O-ring seal under the head of the cover.

2.5.3.1 Cleaning and Inspection of Fuel Pump

All parts must be cleaned with clean fuel oil, before inspection as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Dry the parts with compressed air.
2. Inspect the splined shaft or drive coupling and hub for wear or damage. Replace as necessary.
3. Oil seals, once removed, must be discarded and replaced with new seals. Oil seals must be removed whenever the fuel pump drive shaft is withdrawn. Oil seals must be free of nicks, cuts, or cracks.
4. Inspect the drive and idler gear shafts for scoring or wear. Replace shafts as necessary. If drive shaft is grooved from contact with oil seals, replace the shaft.
5. Check the gear teeth for scoring, chipping or wear. If necessary, replace the gear.
6. The relief valve must be free of score marks and burrs. If the relief valve is scored and cannot be cleaned up with fine emery cloth, it must be replaced.

2.5.4 Assembly of Fuel Pump

Perform the following steps for fuel pump assembly:

1. Lubricate the lips of the oil seals and pilot of oil seal installer, J 1508-8, with a light film of clean engine oil.
2. Place oil seal adaptor, J 34158, on the pilot with the wide end of the adaptor against the installer handle.
3. Place oil seal on installer pilot with seal case against the adaptor. To insure proper assembly, seals must be installed in the proper location. See Figure 2-32.

4. Support the pump body on wood blocks, hub side up, and insert the pilot into the shaft bore positioning the seal on the bore. Use a light hammer and drive the seal into the bore until the adaptor is bottomed against the pump body. See Figure 2-37.

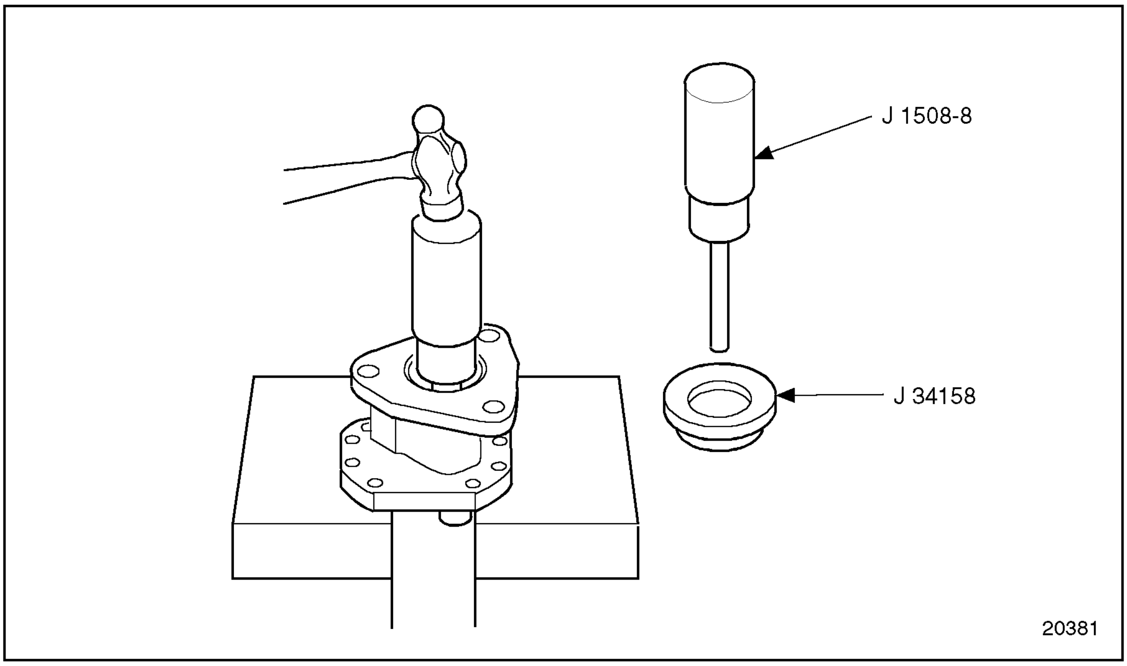


Figure 2-37 Installing Inner Oil Seal

5. Remove the installer and reverse the adaptor placing the narrow end against the installer handle. See Figure 2-38.

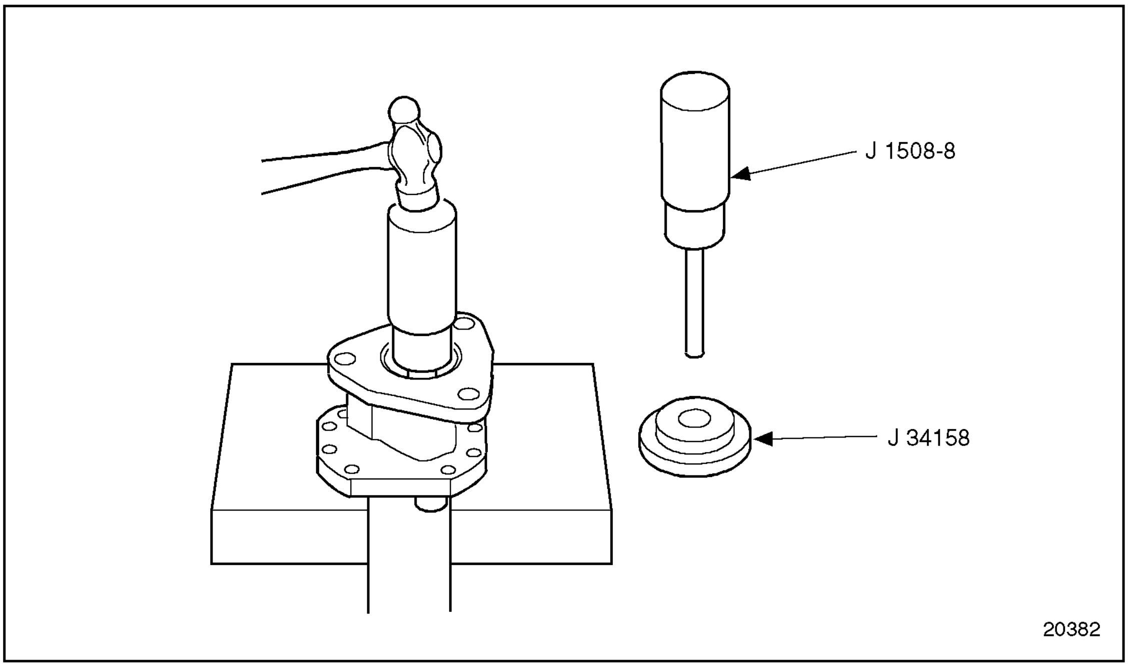


Figure 2-38 Installing Outer Oil Seal

6. Place a second seal on the installer pilot with the seal case faced away from the adaptor.
7. Carefully reinsert the installer pilot through the inner seal and position the second outer seal on the bore. Use a light hammer and drive the seal into the bore until the adaptor is bottomed against the pump body.
8. Press a fuel pump gear positioning C-clip directly into inner groove of fuel pump drive shaft opposite the drive hub end of the shaft.
9. Install drive key in slot on the drive shaft and slide the gear on the shaft indexing the keyway in the gear with the key.
10. Press a second C-clip directly into the groove behind the gear to retain it in position.
11. As the driven shaft is reversible, press a C-clip directly into either groove on the shaft.
12. Insert driven gear pin into its hole in the driven shaft with the square head of the pin parallel to the shaft. Slide the gear on the shaft indexing the keyway in the gear over the square head of the pin.
13. Press a second C-clip directly into the groove behind the gear to retain it in position.

NOTE:
The bearing numbers should always be against the tool during installation.

14. With the pump cover on a bench, inside face up, position a new roller bearing assembly on bearing installer, J 33854, with the bearing numbers against the installer. Position the

bearing carefully on a shaft bore in the cover and with a light hammer drive the bearing into the bore until the installer is flush against the cover surface. See Figure 2-39. Repeat the procedure, installing a new bearing assembly in the remaining shaft bore.

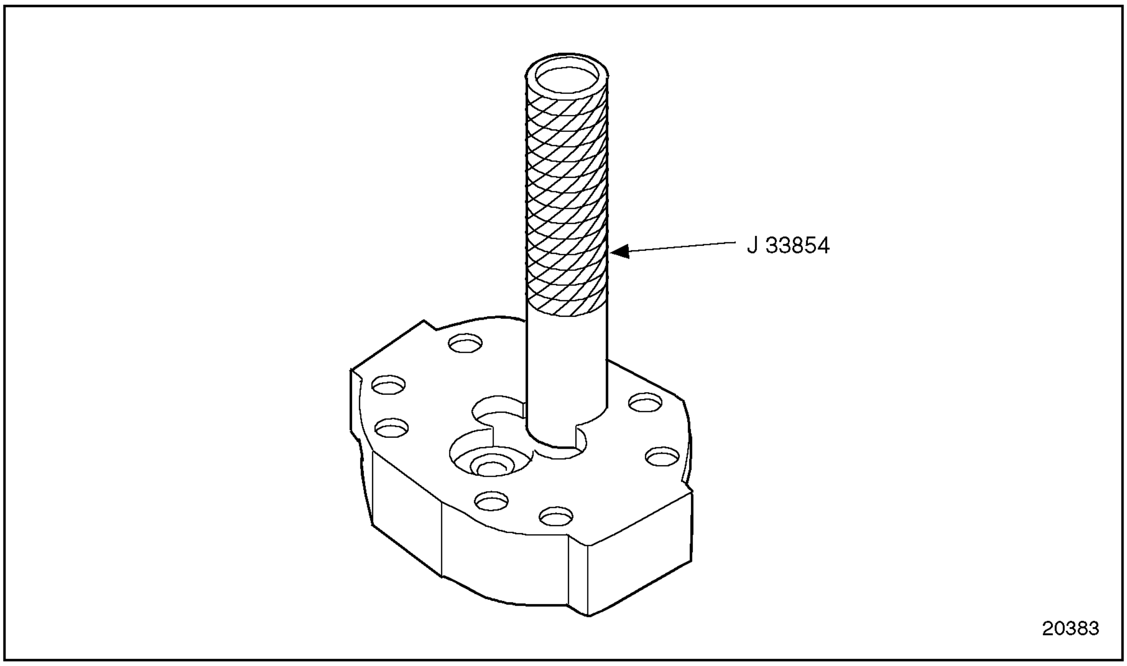


Figure 2-39 Bearing Assembly Installation

NOTE:
Do not install a needle bearing assembly in the drive shaft bore until all other needle bearings have been installed and the oil seal protector has been positioned in the seals.

15. Position the pump body on a bench, hub side down, and following the same bearing installation procedure, install a new needle bearing assembly in the driven shaft bore in the body.

NOTICE:
The seal protector must remain in place on both seals during installation of the needle bearing assembly in the drive shaft bore. If the protector is allowed to come out before the drive shaft is installed, the bearing must be removed and discarded and the protector reinstalled. The protector will be pushed out during drive shaft installation.

16. With the pump body on a bench, hub side down, lubricate the outside of seal protector, J 33021-A, with clean engine oil. Install the solid end of the protector down through both

seals until it contacts the bench. See Figure 2-40. Approximately 3 mm (1/8 in.) of the open end of the protector should remain above the inner seal.

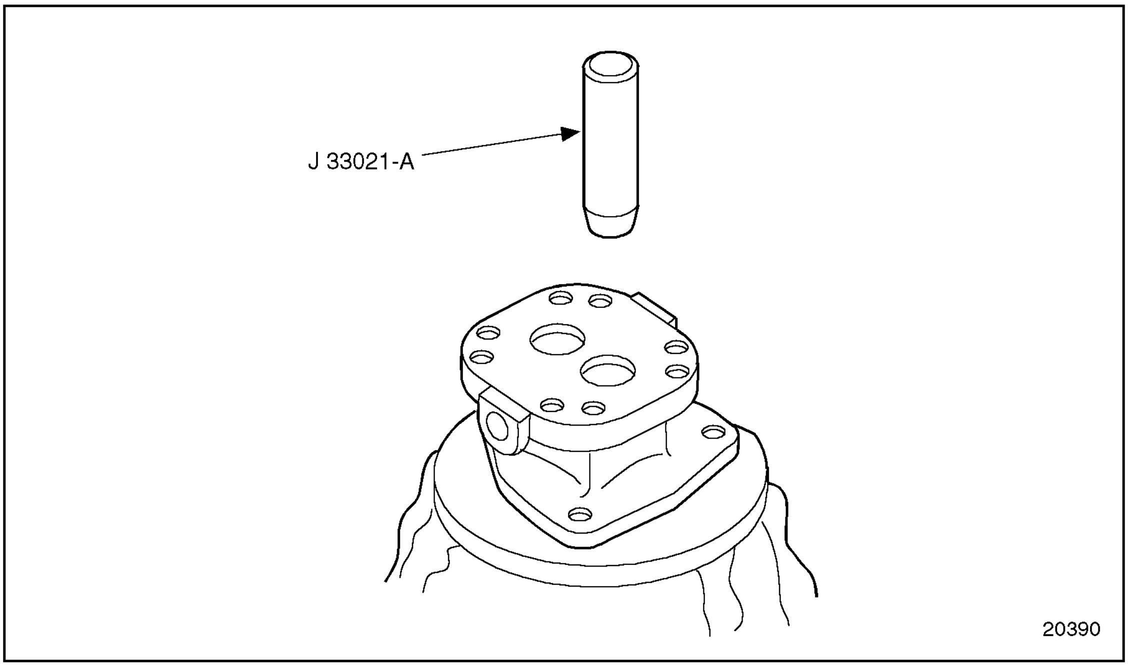


Figure 2-40 Seal Protector Installation

17. Install a new needle bearing assembly in the drive shaft bore. See Figure 2-41.

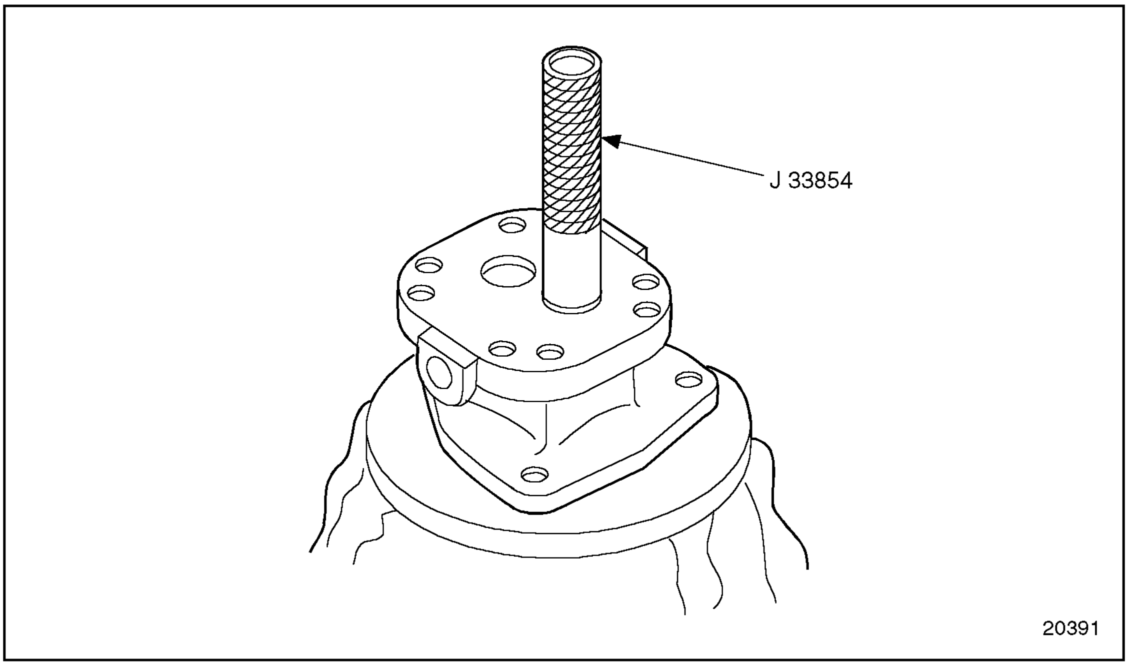


Figure 2-41 Drive Shaft Bearing Installation

18. Carefully insert the drive hub end of the drive shaft through the needle bearing assembly and into the seal protector. Ensure the shaft is fully seated in the seal protector.
19. Hold the shaft down in the seal protector and lift the pump body up against the gear. With the gear in contact with the pump body, lift the body and remove the seal protector from the drive shaft.

NOTE:
Hold the shaft in position with the gear against the pump body to ensure the drive hub snap ring grooves do not contact the oil seals.

20. Position the pump body on the holding fixture, J 38767-1 part of J 38767, hub side down.

NOTE:
When assembling pump, always use the same color foil gasket that was originally installed and is listed in Table 2-1. If the color is unknown, measure the depth of the gear cavity in the pump cover and install the required gasket.

Gear Cavity Depth	Color Gasket Used
0.24885 - 0.24905 in. (6.320-6.325 mm)	Blue
0.24906 - 0.24925 in. (6.326-6.331 mm)	Amber
0.24935 -0.24955 in. (6.333-6.338 mm)	Gold
0.24956 - 0.24975 in. (6.339-6.344 mm)	Silver

Table 2-1 Color vs. Gear Cavity Depth Chart

21. Place a new foil gasket on the face of the pump. With a finger tip, carefully smooth the gasket against the face to ensure there are no wrinkles, creases or bubbles. If present, and they cannot be removed with the finger, remove the gasket and repeat the procedure.
22. Carefully insert the driven shaft and gear assembly in the needle bearing in the pump body.

NOTE:
When positioning the cover, the fuel inlet (stamped on cover) must be on the side of the relief valve bore in the pump body.

23. Position the needle bearing assemblies in the pump cover on the ends of the driven and drive shafts and slide the cover against the pump body.

24. Install eight cover retaining bolts. Use Number E-8 torx socket, J 25359-11 part of J 25359–C , and torque bolts to 12-15 N·m (9-12 lb·ft).

NOTE:
As the outside of the pump body and cover are not machined and to prevent possible distortion, be sure that only the pump cover is gripped and that the vise jaws do not contact both body and cover.

NOTE:
Effective with engine serial number 04R0030272 built on October 27, 1999, gear case-mounted fuel pumps have a splined drive shaft and splined gear coupling assembly. See Figure 2-27. The former and current fuel pump and drive assemblies are not interchangeable. Both current assemblies must be used together. Components of former and current pump assemblies and drive assemblies are not interchangeable.

25. Clamp the fuel pump cover in a soft jawed vise with the relief valve bore in the pump body positioned up.
26. Lubricate the relief plunger with clean engine oil and insert the plunger into the bore with the hollow end up. Insert the relief spring inside the plunger and the pin inside the spring.
27. Install the spacer in the bottom of the spring seat in the cover and install a new O-ring seal under the head of the cover. Thread the cover into the pump body and torque to 8-14 N·m (6-10 lb·ft).
28. Place the pump assembly on a bench, hub side up. Coat the surface of the outer seal with a small amount of lithium base all purpose grease.
29. Use snap ring pliers, J 4880 part of J 5586–A, and install inner drive hub positioning snap ring in its groove in the shaft.
30. Remove the set screw from the drive hub and apply one drop of Loctite 242 (or equivalent) to the threads and reinstall the set screw two or three turns.
31. Install the hub drive key in the groove on the shaft and slide the hub on the shaft indexing the keyway in the hub with the key in the shaft.
32. Use snap ring pliers and install outer hub retaining snap ring in groove.
33. Rotate the drive shaft and hub to align the hub set screw with the access hole in the pump body. Torque the set screw to 3.8 N·m (2.8 lb·ft).
34. Install access hole plug.
35. Install fuel inlet and outlet fittings in the pump cover.

2.5.5 Installation of Gear Train-Driven Fuel Pump

Install the fuel pump as follows:

NOTE:
Effective with engine serial number 04R0030272 built on October 27, 1999, gear case-mounted fuel pumps have a splined drive shaft and splined gear coupling assembly.

See Figure 2-27. The former and current fuel pump and drive assemblies are not interchangeable. Both current assemblies must be used together. Components of former and current pump assemblies and drive assemblies are not interchangeable.

NOTICE:
It may be necessary to use a brass hammer or fiber mallet to seat the drive assembly. Be careful not to damage the O-ring on installation.

1. Install the drive assembly on the gear case.
2. Install the fuel pump drive bolts and torque to 30-34 N·m (22-25 lb·ft).
3. Install the fuel pump.
4. Install any other components that were removed for this procedure.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

5. Start the engine and check for leaks.

2.5.6 Installation of Air Compressor Driven Fuel Pump

Perform the following steps for fuel pump installation:

NOTE:
New fittings have sealant already applied. If reusing fittings, coat the threads lightly with Loctite Pipe Sealant, PT-7271 , or equivalent, before installing. To prevent sealant from entering fuel system, do not apply it to the first two threads of the fitting. Do not use Teflon tape or paste on the fittings.

1. If removed, install inlet and outlet fittings in the rear cover of the fuel pump.

2. Install drive coupling in drive hub of the fuel pump and affix a new gasket to the mounting flange of the pump.

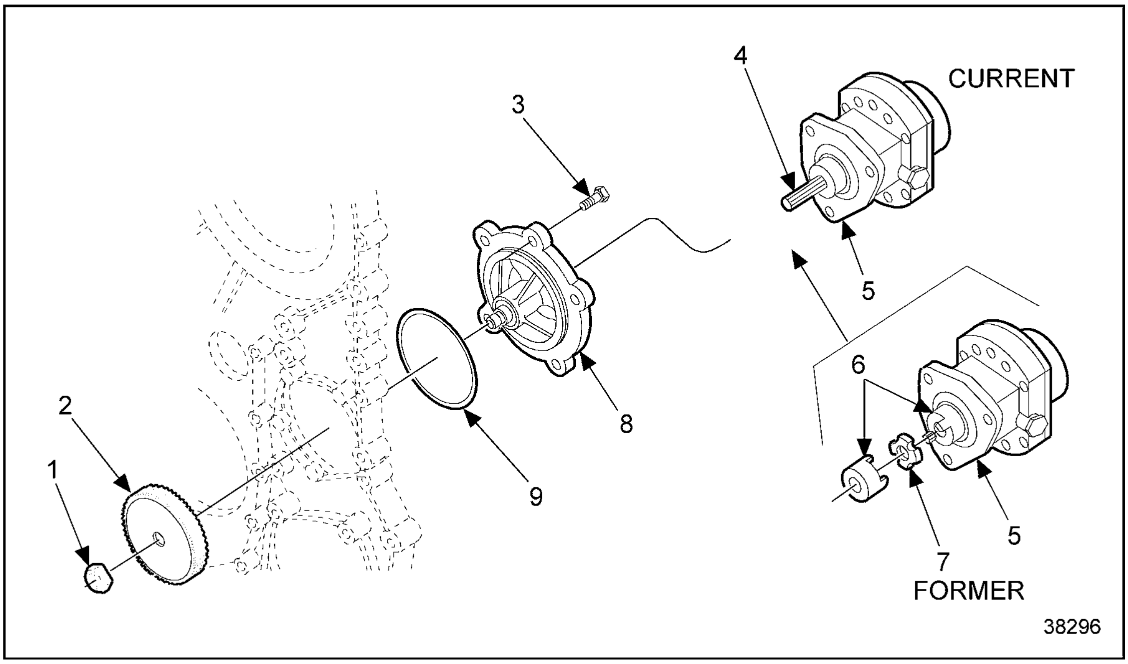
NOTE:
When correctly positioned, the outlet fitting on the pump should be in approximately 8 o'clock position when viewed from the rear, and the drain opening in the pump body facing down.

3. Index the drive coupling with the drive hub on the end of the air compressor crankshaft and align the pump mounting bolt holes with those in the air compressor rear cover.
4. Seat the fuel pump squarely against the air compressor piloting the flange on the pump body in the opening in the rear cover of the compressor. Install three fuel pump mounting bolts and torque them to 30-38 N·m (22-28 lb·ft).
5. Connect the fuel inlet and outlet lines to the fuel pump and tighten.
6. Prime engine fuel system before starting engine to ensure pump seal lubrication and prompt engine starting.

2.6 FUEL PUMP DRIVE

The fuel pump drive assembly consists of an aluminum housing, a helical gear driven off the bull gear, a drive shaft supported in the middle by a double-row ball bearing, and a forked hub which mates with a drive coupling. The fuel pump drive is supplied as an assembly, so components are not serviced. The drive gear and hub are pressed onto the drive shaft. A rubber O-ring located in a groove machined into the mounting surface of the drive is used to seal the fuel pump assembly to the gear case. An internal-type snap ring is fitted to a groove in the fuel pump drive housing to retain the bearing and shaft.

NOTE:
Effective with engine serial number 04R0030272 built on October 27, 1999, gear case-mounted fuel pumps have a splined drive shaft and splined gear drive assembly. See Figure 2-42. The former and current fuel pump and drive assemblies are not interchangeable. Both current assemblies must be used together. Components of former and current pump assemblies and drive assemblies are not interchangeable.



1. Nut
2. Gear, Fuel Pump Drive
3. Bolt, Fuel Pump Drive Retaining (5)
4. Spline Shaft
5. Fuel Pump Assembly
6. Hub
7. Coupling
8. Fuel Pump Drive Assembly
9. O-ring

Figure 2-42 Current and Former Gear Case-Mounted Fuel Pumps

The coupling between the fuel pump and fuel pump drive hubs is plastic, and acts as a shock absorber in the fuel pump drive line.

2.6.1 Lubrication of Fuel Pump Drive Bearing

The fuel pump drive bearing is lubricated by engine oil splash-fed by the gears rotating in the gear case. This oil feeds the bearing and drive shaft through a hole in the fuel pump drive housing.

2.6.2 Removal of Fuel Pump Drive Assembly

Remove the fuel pump drive assembly as follows:

1. Remove the bolts retaining the assembly to the gear case.

NOTICE:
Failure to remove the fuel pump drive assembly by pulling it straight out may damage the O-ring.

2. Remove the fuel pump drive assembly by pulling it straight out of the gear case.

2.6.2.1 Clean the Fuel Pump Drive Assembly

Clean the fuel pump drive assembly as follows:

1. Clean the mating surfaces of the fuel pump drive assembly and gear case with fuel oil.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the fuel pump drive assembly with compressed air.

2.6.2.2 Inspection of Fuel Pump Drive Assembly

Perform the following to inspect the fuel pump drive assembly:

1. The fuel pump drive assembly is nonserviceable if the bearing is worn or scored. Replace the fuel pump drive assembly.

2.6.3 Installation of Fuel Pump Drive Assembly

Perform the following steps to install the fuel pump drive assembly:

1. Replace the O-ring as necessary.
2. Lubricate the O-ring with a light coating of petroleum jelly.
3. Install the O-ring on the fuel pump drive housing.

4. Install the drive assembly on the gear case.

NOTE:
It may be necessary to use a brass hammer or fiber mallet to seat the drive assembly. Be careful not to damage the O-ring during installation.

5. Install the fuel drive bolts and torque to 30-34 N·m (22-25 lb·ft) using the torque pattern shown. See Figure 2-43.

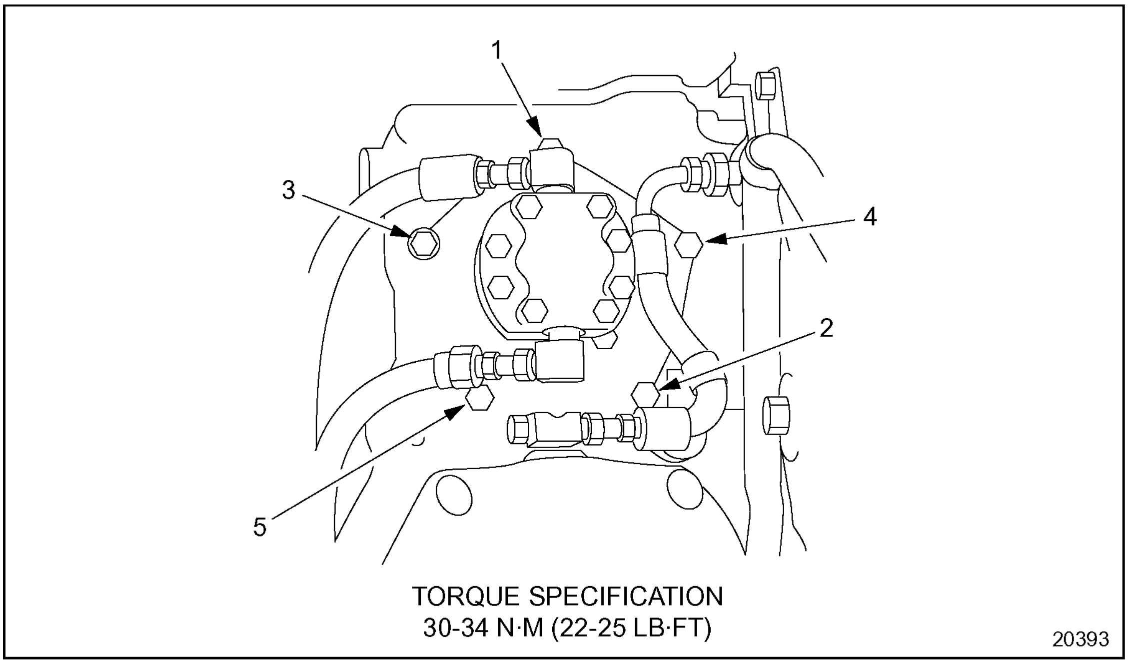


Figure 2-43 Fuel Drive Torque Sequence

6. Install the fuel pump. Refer to Section 2.5.5for gear train-driven fuel pump. Refer to Section 2.5.6 for air compressor-driven fuel pump.
7. Install any other components that were removed for this procedure.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

8. Start the engine and check for leaks. If leaks are found. Repair as necessary.
9. Shut down the engine upon completion of inspection.

2.7 FUEL FILTERS (SPIN-ON)

Two spin-on type filters are used on the Series 50 engine. The first in the fuel flow is a strainer, and the second is a filter. Although they are not marked as such, the threaded sleeves that accept the cartridges are different sizes to prevent mismatching. The primary filter has a 1 in. x 12 thread. The secondary filter has a 13/16 in. x 12 thread. The word "Primary" or "Secondary" is cast into the top of the respective adaptor. See Figure 2-44.

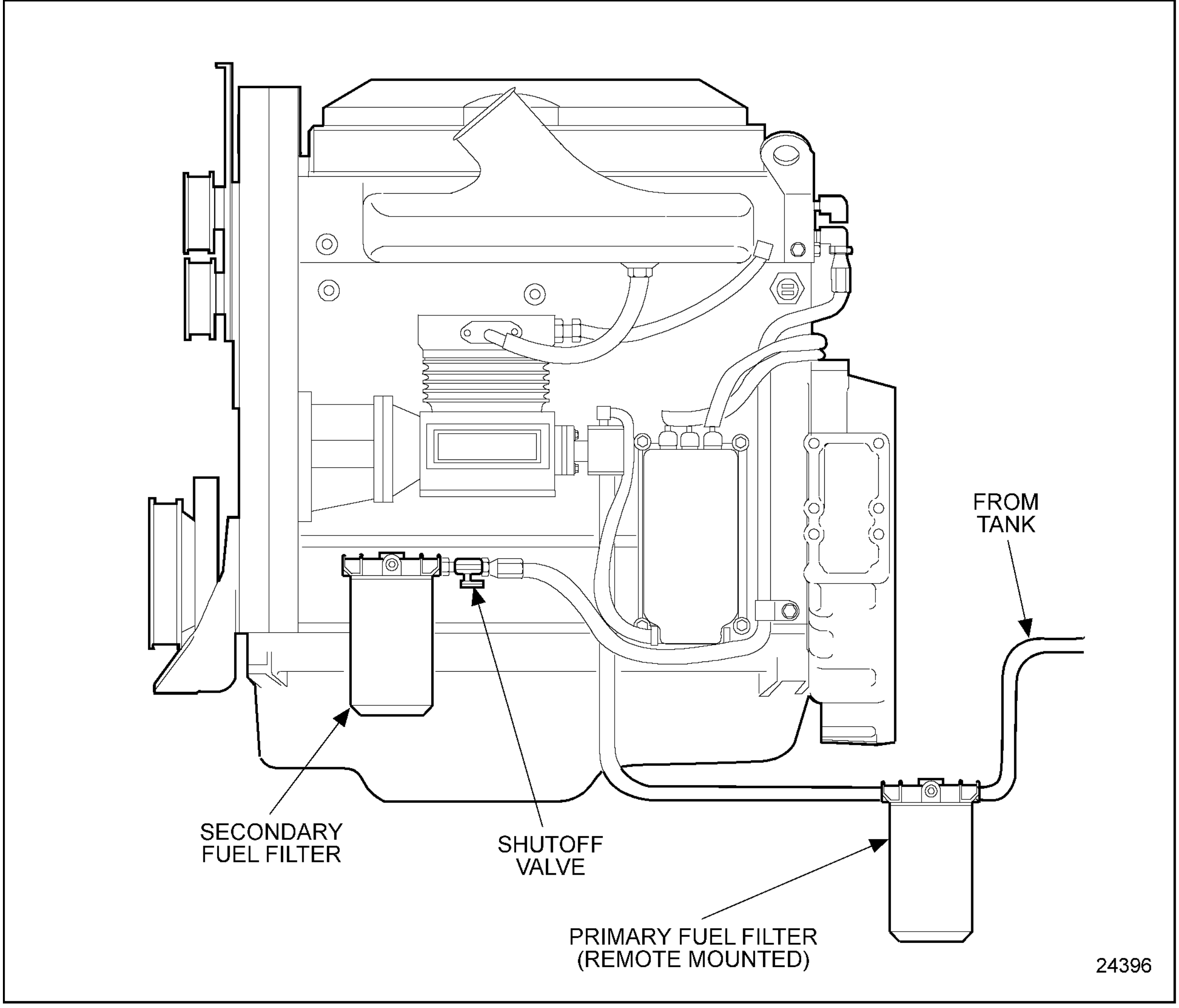


Figure 2-44 Fuel Filters

The spin-on filter cartridges consist of a shell, element, and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters. Effective with 1993 engine production, an optional fuel filter/water separator assembly may be installed in place of the strainer. A fuel shutoff valve or check valve may be installed on the outlet side of the secondary filter.

The fuel filter system consists of the following:

- ☐ Spin-on primary fuel filter
- ☐ Primary fuel filter adaptor
- ☐ Spin-on secondary fuel filter
- ☐ Secondary fuel filter adaptor
- ☐ Fuel shutoff valve or check valve

2.7.1 Replacement of Fuel Filter

As contaminants build up on the filter medium, a number of factors start to affect vehicle performance:

- ☐ The fuel delivery rate is reduced, making less fuel available for combustion.
- ☐ The fuel pump is forced to work harder to move the same volume of fuel. This subjects internal seals to abnormal conditions which may lead to seal leakage. In extreme cases air can be drawn into the fuel system.
- ☐ With the rate of flow slowed, fuel stays in the cylinder head for a longer period of time, allowing its temperature to rise above normal. Because fuel temperature has an affect on engine power, higher fuel temperatures normally result in reduced power.
- ☐ If the restriction is severe enough, fuel vaporization can occur, resulting in pockets of air that can further reduce fuel delivery.

All of these conditions can lead to power loss and subsequent operator complaints of "low power" and "reduced vehicle fuel economy" caused by the need to downshift more frequently on grades.

To determine if replacement of fuel filter element is necessary. See Figure 2-45.

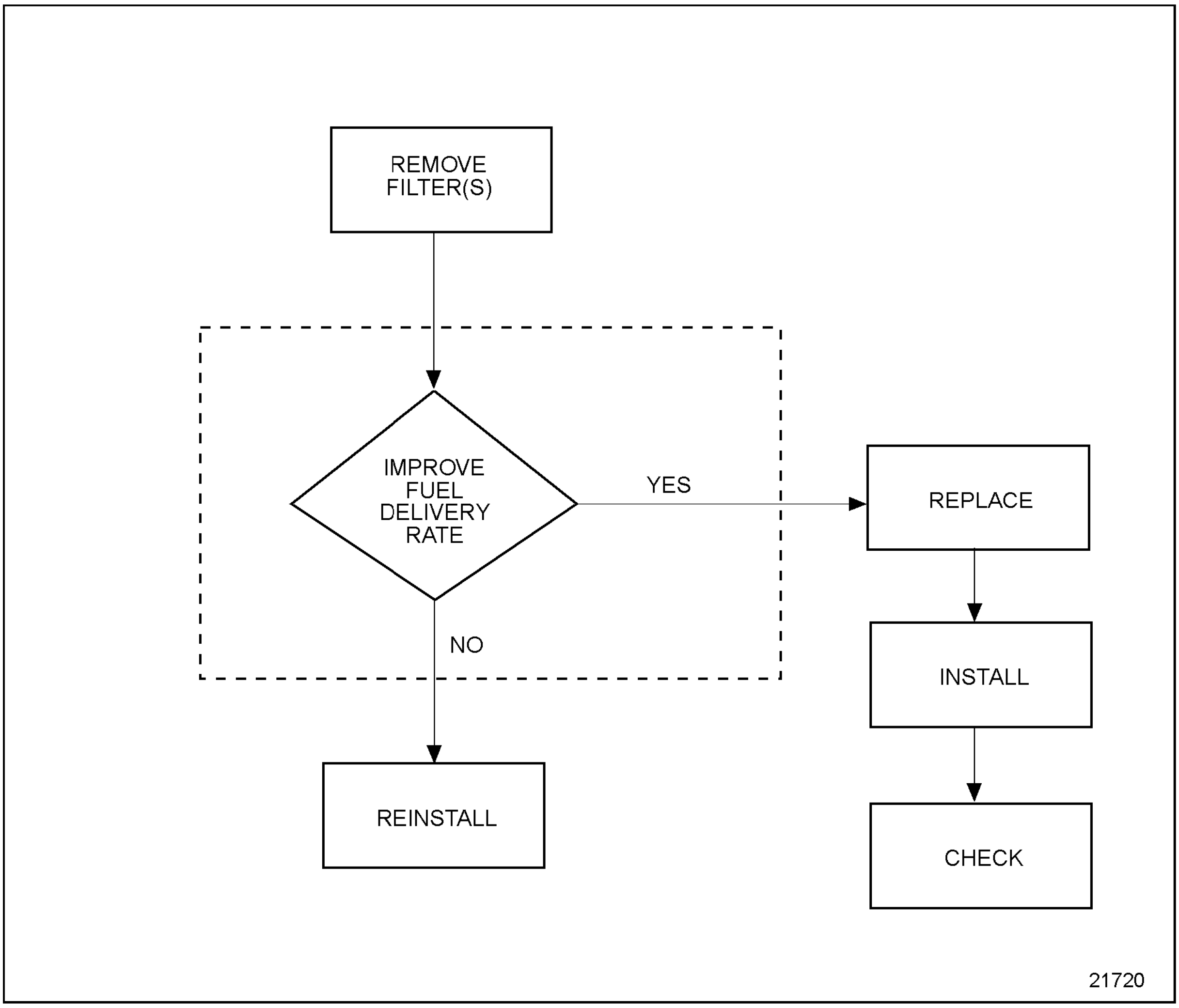


Figure 2-45 Flowchart for Replacement of Fuel Filter Element

To replace the filter, perform the following steps:

1. Use a suitable band wrench or filter wrench, such as J 22775, to remove the filter(s).
2. To install, fill the new filter replacement cartridges with clean fuel oil. Coat the gaskets slightly with clean fuel oil.

NOTICE:

Mechanical tightening of the fuel filters is not recommended, and may result in seal damage, cartridge damage, or both. Tighten the fuel filters by hand only.

3. Thread the new filters on the adaptor, turning them until they contact the gasket fully with no side movement of the filter evident; then turn an additional one-half turn by hand, or as indicated on the filter cartridge.

NOTICE:

Do not overtorque the external threaded end of the shutoff valve when installing it in the fuel filter adaptor. The connection must be tight enough to prevent leakage but not tightened to the point where the adaptor will crack.

NOTE:

There is a fuel system shutoff valve on the discharge side of the secondary fuel filter. This valve is designed to prevent loss of fuel prime at time of filter replacement.

CAUTION:

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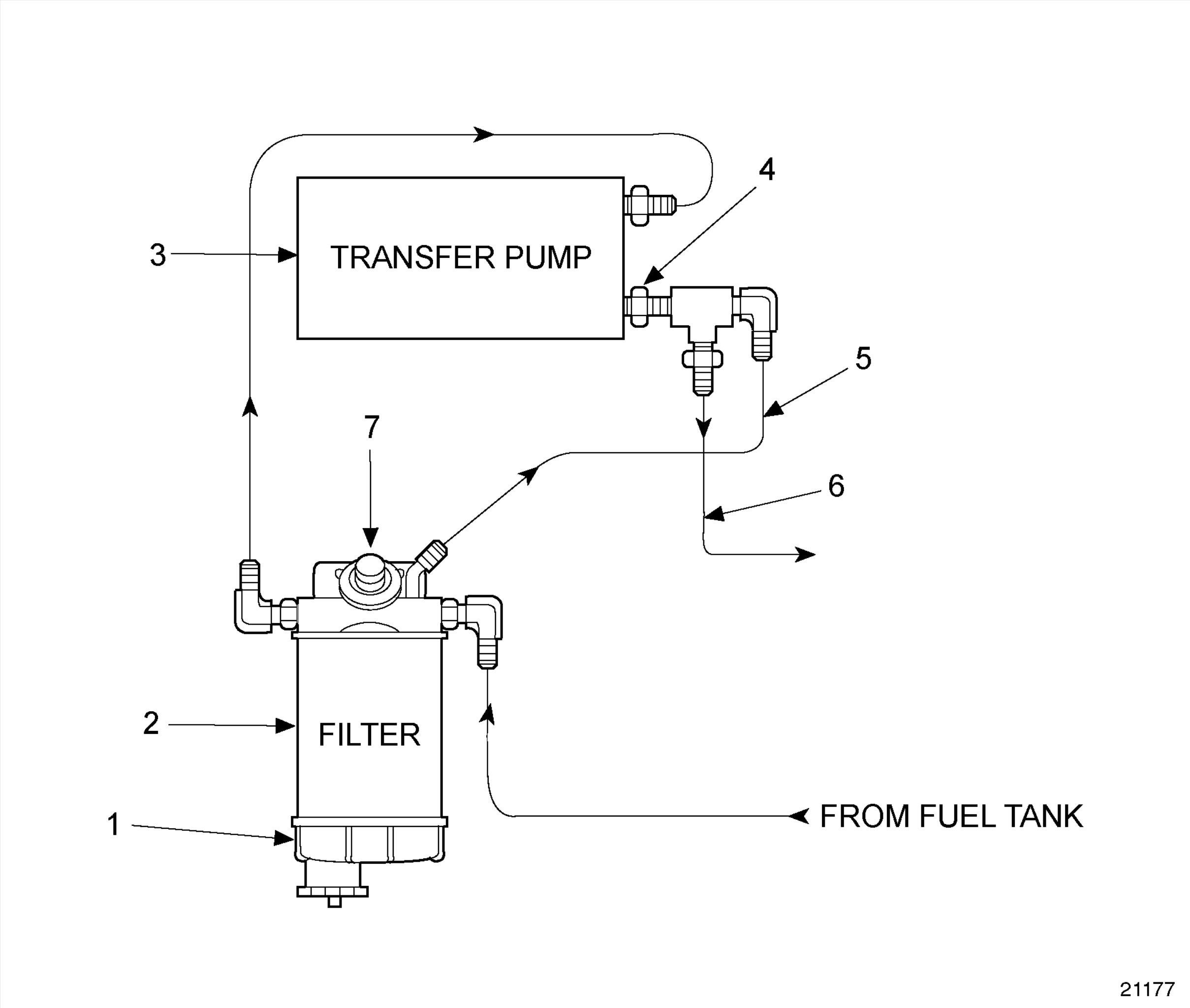
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Start the engine and check for leaks.

2.8 FUEL FILTER AND WATER SEPARATOR ASSEMBLY

The fuel filter and water separator assembly facilitates the settling of water in a collection bowl. See Figure 2-46.



1. Collection Bowl
2. Spin-on Element
3. Priming Pump
4. Reducer Bushing
5. Hose from Filter Head to Transfer Pump Discharge
6. Hose to Secondary Fuel Filter

Figure 2-46 Typical Fuel Filter/Water Separator Installation

2.8.1 Replacement of Fuel and Water Separator Element

Replace the fuel and water separator element as follows:

1. Drain off some fuel by opening the drain valve on the collection bowl. Close the valve.

2. Remove the element and bowl together, then remove the bowl from the element. Clean the bowl and the O-ring gland.
3. Apply a coating of clean fuel or grease to the new O-ring and element seal. Spin the bowl onto the new element and them spin the assembly onto the filter head by hand until snug. Do not use tools to tighten.
4. To eliminate air from the filter, operate the primer pump until the fuel purges at the filter assembly.

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- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

5. Start the engine and check for fuel leaks. Correct any leaks with the engine shut off.

2.8.2 Fuel Return System Check Valve

The purpose of the check valve is to reduce the risk of fuel prime loss and fuel siphoning from the head when the fuel filter is removed. See Figure 2-47.

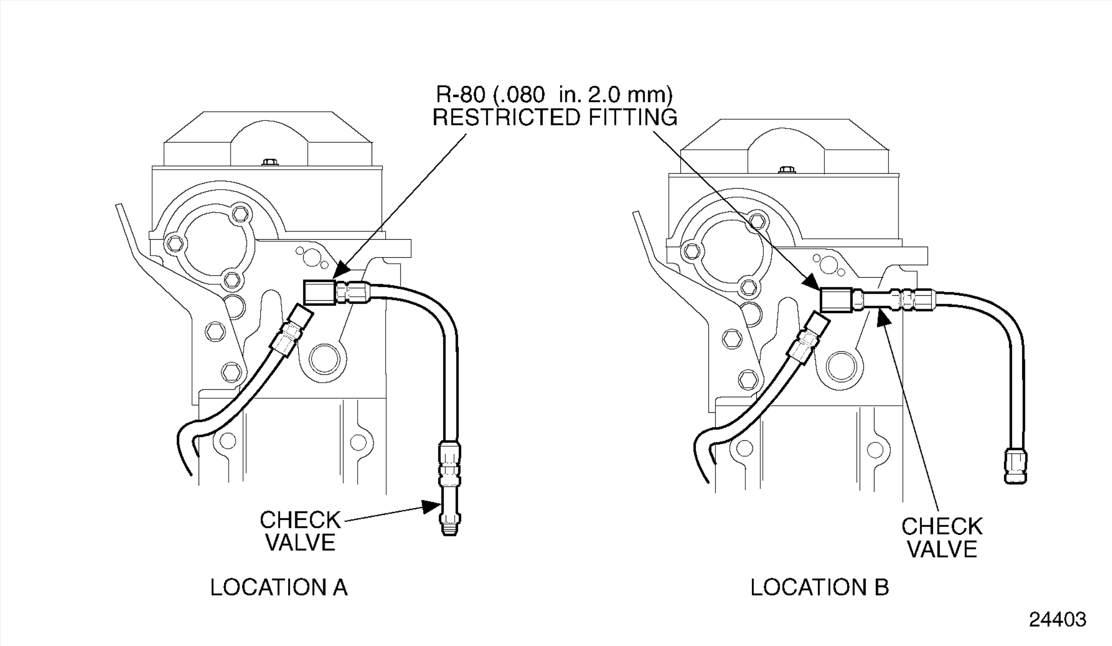


Figure 2-47 Typical Fuel Return Check Valve Locations

NOTICE:
The check valve must be included in the fuel system. If the check valve is removed for any reason or found to be defective, a new valve must be installed and the fuel system primed before start-up. The R-80 2.032 mm (0.080 in.) restricted fitting (elbow connector) which is ahead of the check valve must also be included in the fuel system.

NOTICE:
Do not increase the size of the orifice in restricted fittings. Increasing restricted fitting hole size can cause injector cavitation, resulting in reduced durability of injectors and other engine components, and increased engine emissions.

A check valve is connected to a hose in the fuel return line coming from the rear of the cylinder head or at the cylinder head restricted fitting, depending on individual installation requirements. See Figure 2-47.

2.8.3 Removal of PRO-CHEK ® Fuel System Check Valve

Remove the valve as follows:

NOTICE:
The PRO-CHEK ® fuel system check valve is installed after the secondary filter. Any dirt or debris entering the fuel system at this point may cause severe injector damage.

1. Clean the area around the PRO-CHEK ® valve thoroughly to remove loose dirt or debris.
2. Disconnect the fuel supply and return lines from the bottom of the valve and cap the hoses immediately to prevent the entrance of dirt.
3. Disconnect the air purge line from the top elbow on the valve and cap the line to prevent the entrance of dirt.
4. Remove the valve and bracket assembly from the engine as follows:
   [a] If rear mounted, remove the two 12 mm bolts securing the valve to the rear lifter bracket.
   [b] If side mounted, remove the two 10 mm bolts and spacers holding the valve to the cylinder head.

2.8.3.1 Inspection of the PRO-CHEK ® Fuel System Check Valve

Inspect the PRO-CHEK ® fuel system check valve as follows:

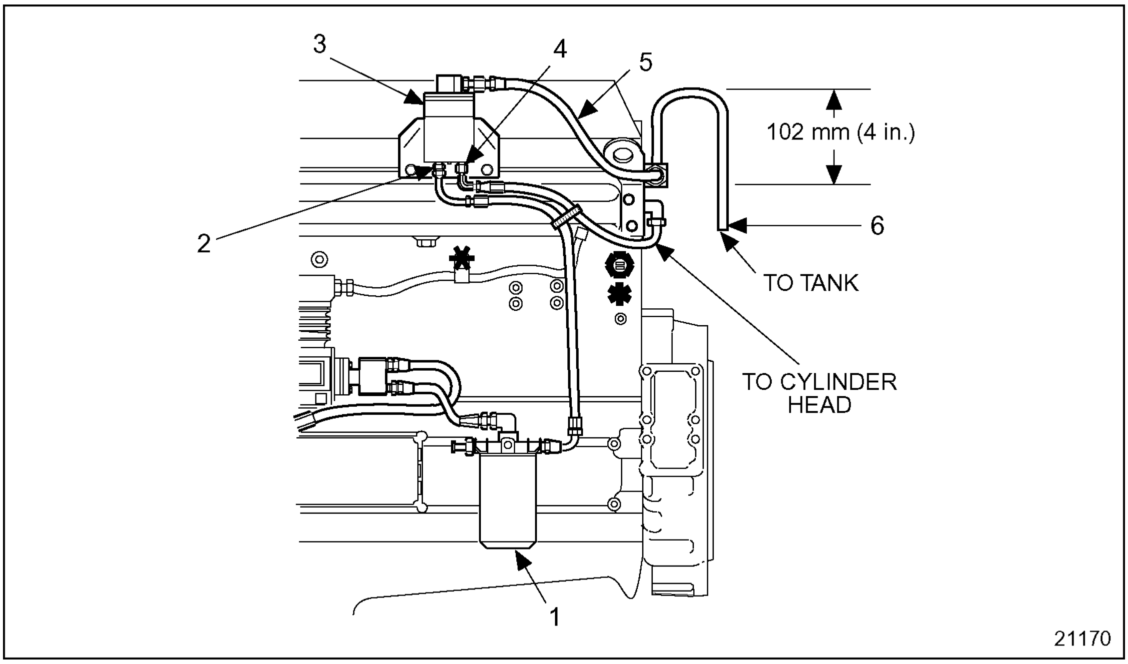
1. Visually inspect exterior casing of the PRO-CHEK® valve for cracks, leaks, or other signs of damage.
   [a] If the PRO-CHEK ® valve has no cracks, leaks, or other signs of damage, reuse the valve.
   [b] If the PRO-CHEK ® valve has cracks, leaks, or other signs of damage, replace the valve.

2.8.4 Installation of PRO-CHEK ® Fuel System Check Valve

Install the PRO-CHEK ® valve as follows:

1. Mount the PRO-CHEK ® valve on the side or rear of the Series 50 engine.

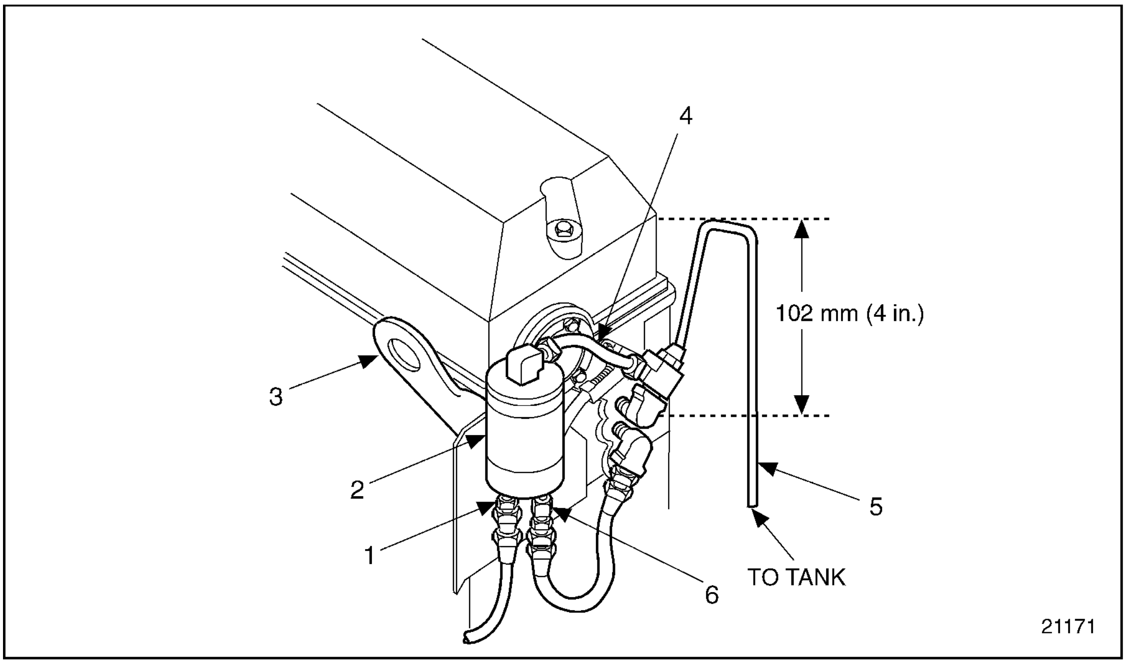
[a] If side-mounted, install with two 10 mm bolts and spacers. The location may be ahead of or behind the location shown. See Figure 2-48.



1. Secondary Fuel Filter
2. Fuel Inlet
3. PRO-CHEK ®
4. Air Purge Line
5. Fuel Outlet
6. Fuel Spill Line

Figure 2-48 Typical Side-mounted PRO-CHEK ® Installation

[b] If rear-mounted remove the two 12 mm bolts holding the rear lifter bracket and install the PRO-CHEK ® valve against the bracket with two 12 mm bolts that are 5 mm (approximately 0.20 in.) longer and two spacers. See Figure 2-49.



1. Fuel Inlet
2. PRO-CHEK ®
3. Engine Lifter Bracket
4. Air Purge Line
5. Fuel Spill Line
6. Fuel Outlet

Figure 2-49 Typical Rear-mounted PRO-CHEK ® Installation

2. Disconnect the fuel supply hose assembly at the rear of the engine and reconnect it to the PRO-CHEK ® 3/8 in. SAE flared bottom fitting marked with the words *Fuel In.*
3. Connect a separate fuel hose assembly to the 1/4 in. 18 NPTF PRO-CHEK ® female bottom fitting marked with the words *Fuel Out.* Install the other end in the fuel manifold inlet port at the rear of the engine.
4. An R80 2.032 mm (0.080 in.) restricted fitting is installed in the fuel spill (return) opening in the cylinder head. Install a tee fitting after the R80 spill fitting. The spill hose from this tee fitting must be routed at least 102 mm (4 in) above the fuel gallery. See Figure 2-48 and see Figure 2-49. Connect a 1/4 in. diameter fuel hose assembly to the elbow in the top port of the PRO-CHEK ®. Route this air purge hose to the spill tee fitting.
5. Tie-wrap the PRO-CHEK ® inlet and outlet fuel lines to prevent chafing and contact with metal parts.
6. Prime the fuel system.

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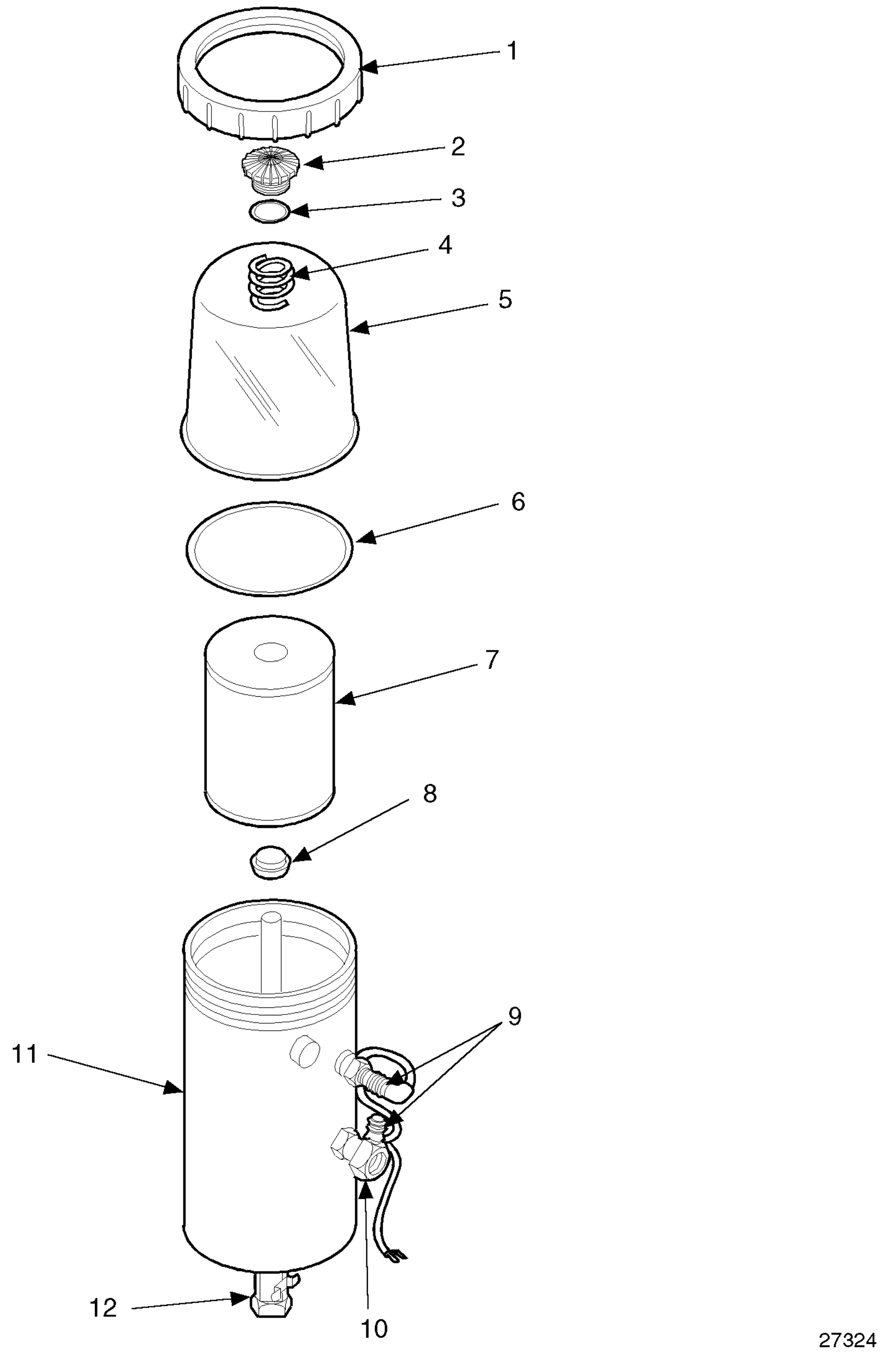
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

7. Start the engine and check for leaks.

2.9 FUEL PRO ® 380/380E FUEL FILTER SYSTEM

The Fuel Pro ® 380/380E diesel fuel filter system is used in place of separate spin-on primary and secondary fuel filters. See Figure 2-50. This system uses a high efficiency 5-micron fuel filter element which requires replacement when the fuel level in the see-through filter cover reaches the top of the element or after one year of service, whichever comes first.



1. Collar
2. Vent Cap
3. Vent Cap Seal
4. Spring
5. Cover
6. Cover Seal
7. Filter Element
8. Filter Seal Grommet
9. Wiring Harness (380E System Only)
10. Check Valve and Thermostat
11. Fuel Processor Assembly
12. Drain Valve

Figure 2-50 Fuel Pro ® 380E Fuel Processor Assembly

The Fuel Pro ® 380/380E diesel fuel filter system consists of the following:

- ☐ A permanently mounted fuel processor
- ☐ A replaceable 5-micron filter element and sealing grommet assembly
- ☐ A filter spring
- ☐ A see-thru filter cover and O-ring seal
- ☐ A cover locking collar
- ☐ A cover vent cap and seal

The Fuel Pro ® 380E system also includes the following:

- ☐ A fuel heater element
- ☐ A thermostat switch
- ☐ A wiring harness

2.9.1 Replacement of Fuel Pro ® 380E Fuel Filter Element

Replace the Fuel Pro ® as follows:

1. With the engine shut down and cool, place a suitable container under the fuel processor.
2. A fuel shutoff valve may be installed on the discharge side of the fuel filter. If installed, turn the handle on the shutoff valve to the closed position (perpendicular to the valve).
3. Open the drain valve at the base of the fuel processor, and drain the fuel until it is below the level of the filter. Close the drain valve.
4. Using filter collar wrench 23516731 or equivalent, remove the collar by turning counterclockwise. Remove the cover, filter spring, and cover seal ring by lifting straight up and over the filter element. Remove the element from the center stud (fuel outlet pipe) by pulling upward and twisting slightly.

NOTE:
Current filter elements include an integral sealing grommet. Former filter elements used a separate sealing grommet. If a former element is replaced, make sure the separate sealing grommet is removed from the center stud.

5. Dispose of the used filter element and grommet in an environmentally responsible manner, according to state and federal (EPA) recommendations.

Fuel Pro ® is a registered trademark of Davco Manufacturing Corporation, L.L.C.

2.9.2 Installation of Fuel Pro ® 380E Fuel Filter Element

Install the Fuel Pro ® as follows:

1. Ensure a sealing grommet is included in the base of the replacement element, then install the element onto the center stud.

NOTICE:
Do not use a wrench of any kind to tighten the collar, since this may lead to overtightening which can damage the collar and the cover.

2. Ensure the filter spring is installed at the top of the cover. If missing, the spring *must* be replaced to insure proper filter operation. Wipe the cover lip and cover seal clean. After ensuring the seal is properly positioned at the base of the cover, install the cover and collar onto the fuel processor. Tighten the collar *by hand* until secure.

NOTICE:
To avoid cover or vent plug damage, do not use tools to tighten the vent plug.

3. Remove the vent plug from the top of the cover by turning the plug counterclockwise. Fill the cover *full* of clean fuel. After ensuring the O-ring seal is installed on the vent plug, reinstall the plug and *tighten by hand only*.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Open the fuel shutoff valve (if installed) and start the engine. When the lubrication system reaches its normal operating pressure, increase engine speed to high idle for 2 to 3 minutes.
5. After the air is purged and with the engine still running, loosen the vent cap on the filter cover. The fuel level in the cover will start falling. When the fuel level falls to the top of the collar, tighten the vent cap quickly.

NOTICE:
Do not use a wrench of any kind to tighten the collar, since this may lead to overtightening which can damage the collar and the cover.

6. Shut down the engine and *hand-tighten* the collar again.

CAUTION:
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm. □ **Always start and operate an engine in a well ventilated area.** □ **If operating an engine in an enclosed area, vent the exhaust to the outside.** □ **Do not modify or tamper with the exhaust system or emission control system.**

7. Start the engine and check for leaks.

NOTE:
The clear filter cover will not fill completely during engine operation. It will gradually fill over time as the filter medium becomes clogged. The filter element does not require changing until the fuel level has risen to the top of the element, or after one year of service, whichever comes first.

2.10 ELECTRONIC ENGINE CONTROL

The Detroit Diesel Electronic Control System (DDEC) controls fuel injection timing and output by the electronic unit injectors (EUI) on the Series 50 Diesel engine. DDEC controls throttle and the ignition system on the Series 50G engine. 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 current engines have the third generation DDEC system, DDEC III. See Figure 2-54. Former Series 50 engines had DDEC II systems.

The replacement of DDEC components is based on indicated diagnostic codes leading to faulty components. Check the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497, for more complete information on diagnosis of components and system problems.

2.11 DDEC III

DDEC III provides an indication of engine and vehicle malfunctions. The ECM continually monitors the DDEC III system. See Figure 2-51 and see Figure 2-52.

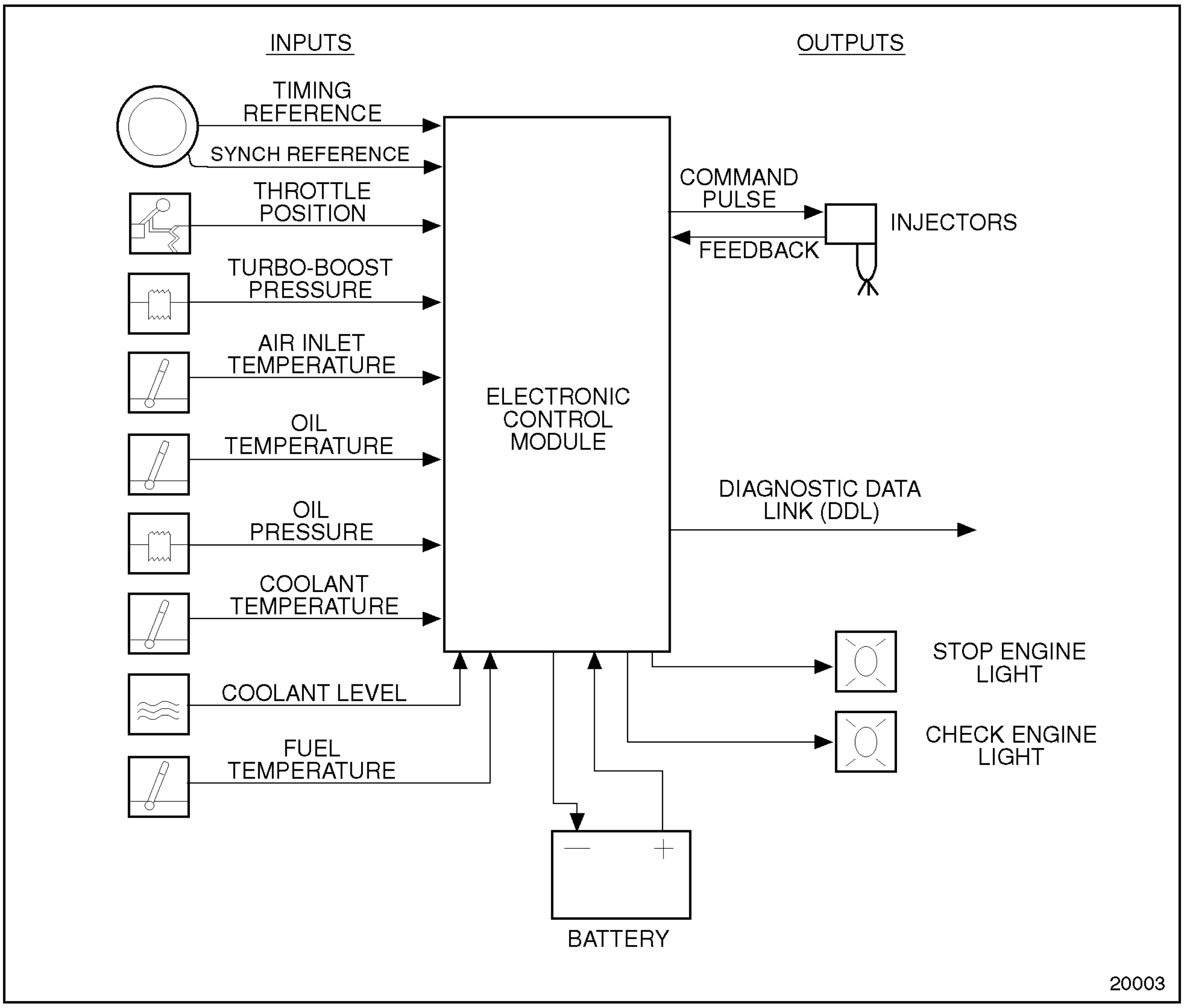


Figure 2-51 DDEC III System Series 50 Diesel

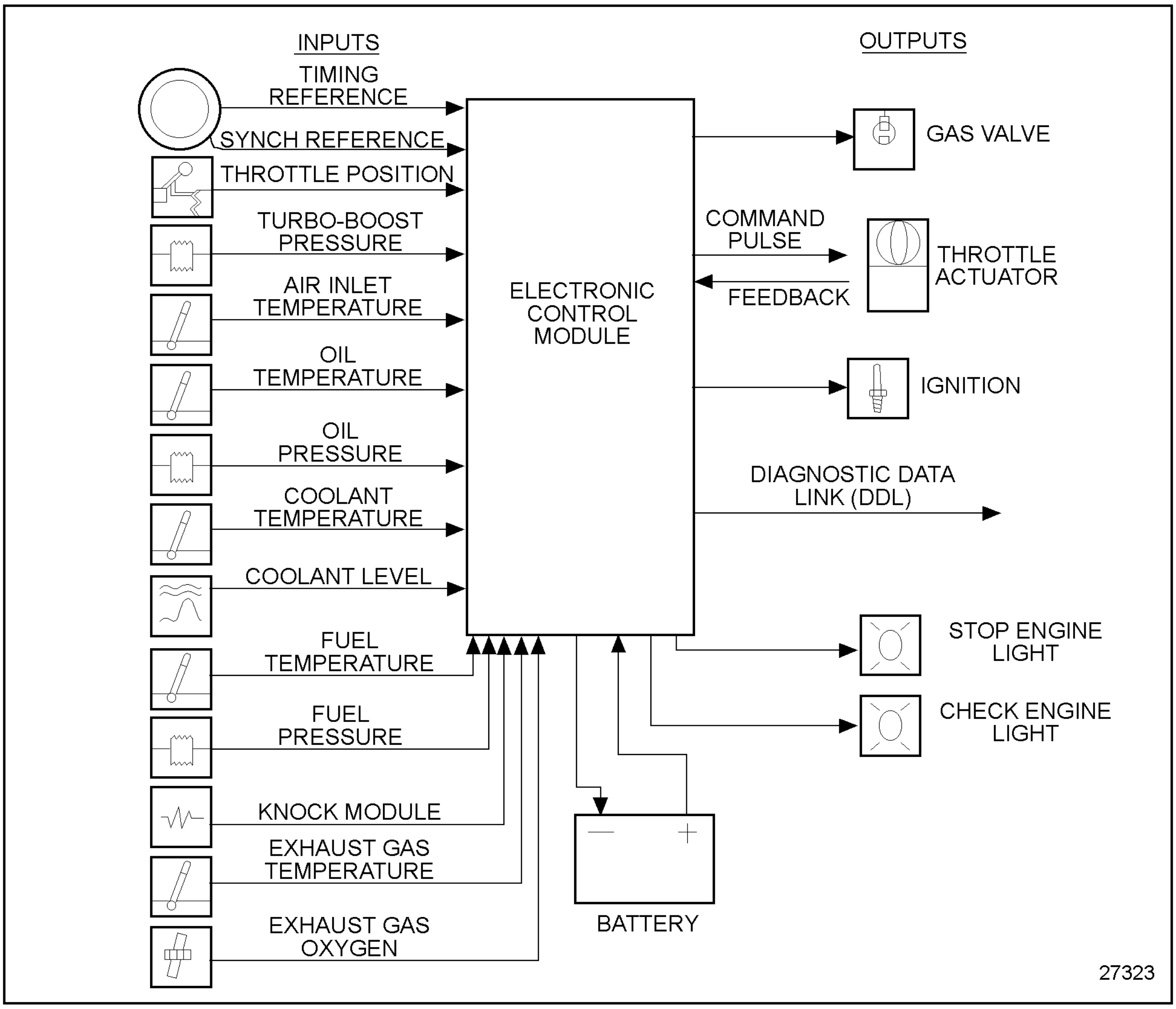


Figure 2-52 DDEC III System Series 50 Natural Gas

Any faults that occur are stored as codes in the ECM's memory. These codes can be accessed in any of three ways:

1. A DDR can be used to read the codes. See Figure 2-53.
2. A personal computer (PC) connected to the ECM through a translator device which converts J 1708 to RS232 protocol can be used.
3. The Check Engine Light (CEL) or the Stop Engine Light (SEL) is illuminated.
   - □ The CEL, (panel mounted yellow indicator light) illuminated, diagnose condition as soon as convenient.
   - □ The SEL, (panel mounted red indicator light) and CEL illuminated, a major fault occurred and immediate attention required to avoid engine damage.
   - □ Automatic engine shutdown or rampdown is available as an option. A shutdown override switch is required to allow the vehicle to be moved to a safe location during automatic shutdown or rampdown.

DDEC III features programmable with a Diagnostic Data Reader (DDR) are:

- ☐ Password
- ☐ Droop
- ☐ Active hop braking
- ☐ Cruise control
- ☐ Engine brake
- ☐ Cruise control
- ☐ Vehicle speed limiting
- ☐ Vehicle speed sensor
- ☐ Variable Speed Governor cruise switch
- ☐ Idle timer shutdown
- ☐ Idle timer between air temperatures
- ☐ Vehicle ID number (IN)
- ☐ Idle adjustment
- ☐ Progressive shifting
- ☐ Engine protection

The hand-held DDR is used on engines equipped with DDEC III to display engine description, diagnostic data, fault codes, and to program the ECM calibration. A printout of the information displayed on the DDR, can be obtained by attaching a printer. The diagnostic data reader kit, J 38500-1DD, includes a reader, cable, carrying case, DDEC cartridge, manual, and a 6-pin adaptor. See Figure 2-53.

NOTE:
S50G GFI controlled fuel systems that have been converted to DDEC III controlled close loop fuel system will not have an oil temperature sensor.

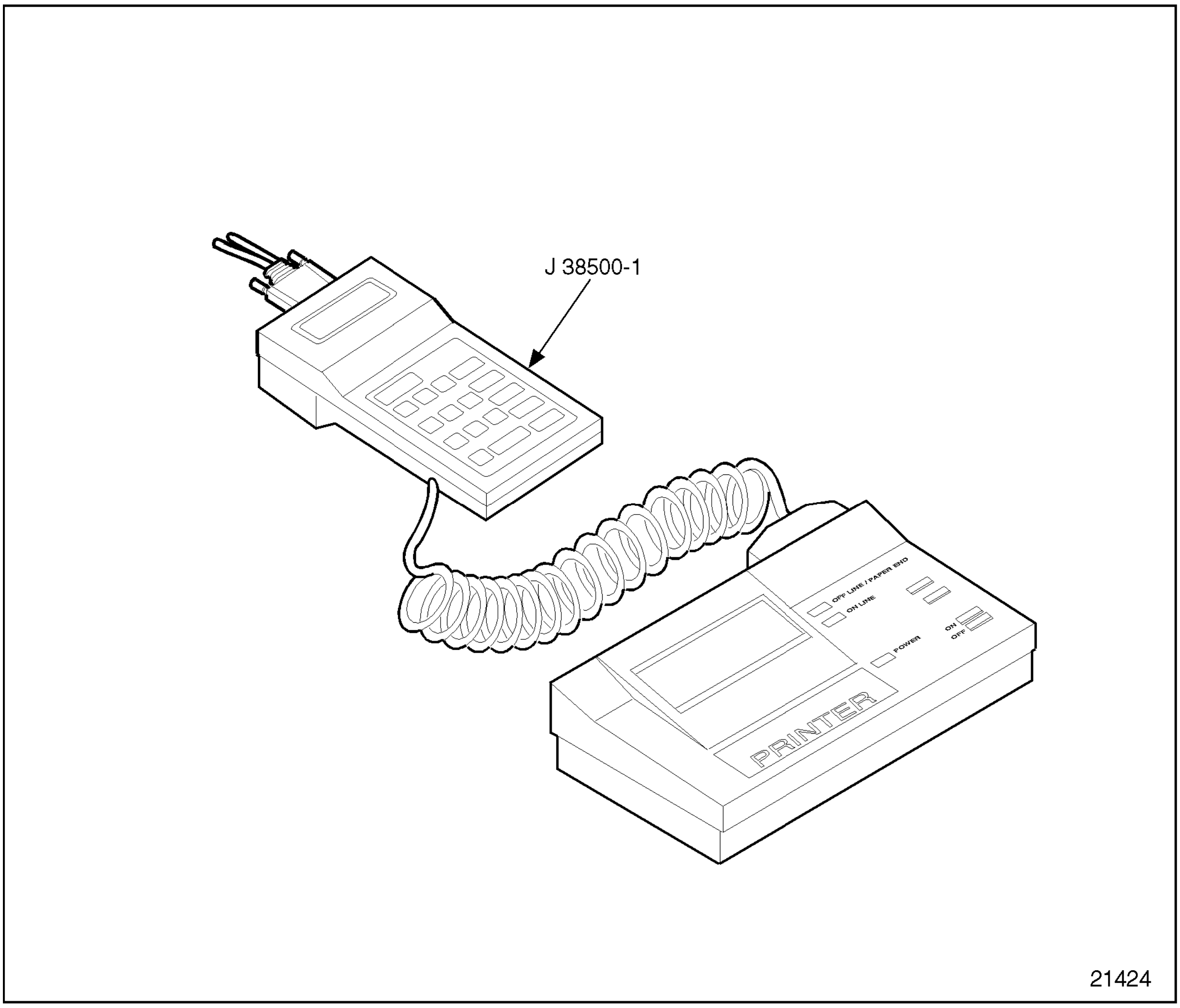


Figure 2-53 The DDR and Printer

The SAE Standard Communications of the DDEC III system are listed in Table 2-2. The fan control inputs and outputs for DDEC III are listed in Table 2-3. The engine brake control features of DDEC III are listed in Table 2-4. DDEC III can identify faulty components and other engine-related problems by providing the technician with a diagnostic code. A comparison of DDEC II and DDEC III engine hardware is listed in Table 2-5. A comparison of DDEC II and DDEC III standard sensors is listed in Table 2-6 and a comparison of optional sensors is listed in Table 2-7. Standard sensors for the S50G are listed in Table 2-8.

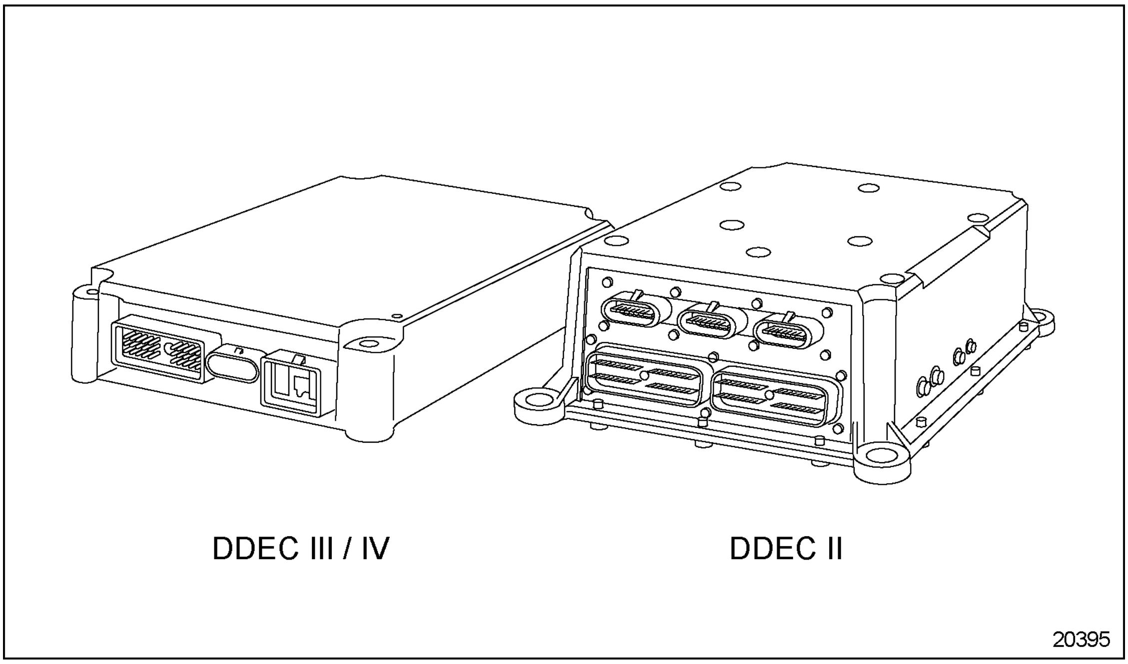


Figure 2-54 DDEC III and DDEC II Electronic Control Module (ECM)

SAE Standard Communication
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
Vehicle controls

Table 2-2 SAE Standard Communications for DDEC III

Inputs	Outputs
Coolant temperature	Single on/off fan clutch
Oil temperature	Dual on/off fan clutch
Air temperature	2-speed single fan
Air conditioning	Modulated fan clutch

Table 2-3 Fan Controls for DDEC III

Engine Brake Control
Eliminates OEM engine brake module
Compatible with cruise control
Engine brake will go and off without disabling cruise control
Engine fan braking
Requires fan and engine brake control
Fan turn on when engine brake is on high
In cruise control, engine brake operates electronically
MPH activating speeds are set with DDR
Cruise control, engine brake operates manually

Table 2-4 Engine Brake Control with DDEC III

Engine Hardware	DDEC II	DDEC III
Electronic Foot Pedal Assembly	3 Wires	3/4 Wires
Coolant Level Sensor	Coolant Probe/Module	Coolant Probe Only
Diagnostic Request Stop Engine Override	2 Separate 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
Power Harness	6 Pin Connector	5 Pin Square Connector
Wiring	16 gage wire, 4 Power, 2 Ground	12 gage wire (Eliminates Splicing), 2 Power, 2 Ground

Table 2-5 DDEC II vs DDEC III

DDEC II	DDEC III
Oil Temperature (Truck)	Oil Temperature
Oil Pressure	Oil Pressure
Coolant Level	Coolant Level
Turbo Boost	Turbo Boost
Throttle Position (OEM Supplied)	Throttle Position
Timing Reference	Timing Reference
Synchronous Reference	Synchronous Reference
Fuel Temperature	Fuel Temperature, Air Temperature

Table 2-6 Standard Sensors

DDEC II	DDEC III
Fuel Pressure	Fuel Pressure
Pressure Governor (Firetruck)	Pressure Governor (Firetruck)

Table 2-7 Optional Sensors

Low Pressure Fuel System	High Pressure Fuel System
Oil Temperature	Exhaust Temperature
Oil Pressure	Oil Pressure
Coolant Temperature	Coolant Temperature
Coolant Level	Coolant Level
Turbo Boost (Inlet Manifold Pressure)	Turbo Boost (Inlet Manifold Pressure)
Timing Reference	Timing Reference
Synchronous Reference	Synchronous Reference
Fuel Temperature	Fuel Temperature
Air Inlet Temperature	Air Inlet Temperature
Throttle Position	Throttle Position
Knock	Knock
	Exhaust Gas Oxygen
	Barometric Pressure
	Fuel Pressure

Table 2-8 Standard Sensors for Series 50G Engines

2.11.1 Repair or Replacement of the DDEC III ECM (Horizontally Mounted)

The DDEC III ECM is a sealed, nonserviceable unit. Tag defective ECM for recore.

2.11.2 Removal of the DDEC III ECM

Perform the following steps for ECM removal:

1. Carefully disengage the lock tab on the power harness and injector harness connectors.
2. Remove the two wire and three wire harness connections at the ECM.
3. Remove the thru-bolts holding the ECM to the engine.
4. Remove the ECM and cold plate from the engine, if so equipped.
5. Remove the screws securing the cold plate to the ECM. Remove the cold plate from the ECM, if so equipped.

2.11.3 Installation of the DDEC III ECM

Perform the following steps for ECM installation:

1. Install the cold plate on the ECM, if so equipped. Tighten the screws securing the cold plate to the ECM. Use Loctite 262, or equivalent, on the cold plate-to-ECM screws. Torque to 9.5-12 N·m (84-106 lb· in.).
2. Inspect the ECM isolators for damage and replace if required.
3. Mount the ECM and cold plate to the engine.
4. Secure the ECM to the engine with thru-bolts. Torque the ECM-to-engine bolts to 23-27 N·m (17-20 lb·ft). Torque the ECM connector hold-down screws to 2.4-3.0 N·m (22-28 lb· in.).
5. Install the connectors in the ECM and torque the jack screws to 2.49–3.16 N·m (22–28 lb·in.).
6. Engage the lock tab on the power harness and injector harness connectors.
7. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code except code 25 is obtained, refer to the Detroit Diesel *DDEC III/IV Single ECM Troubleshooting Manual*, 6SE497.

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- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

8. Start the engine, and check for fuel leaks.

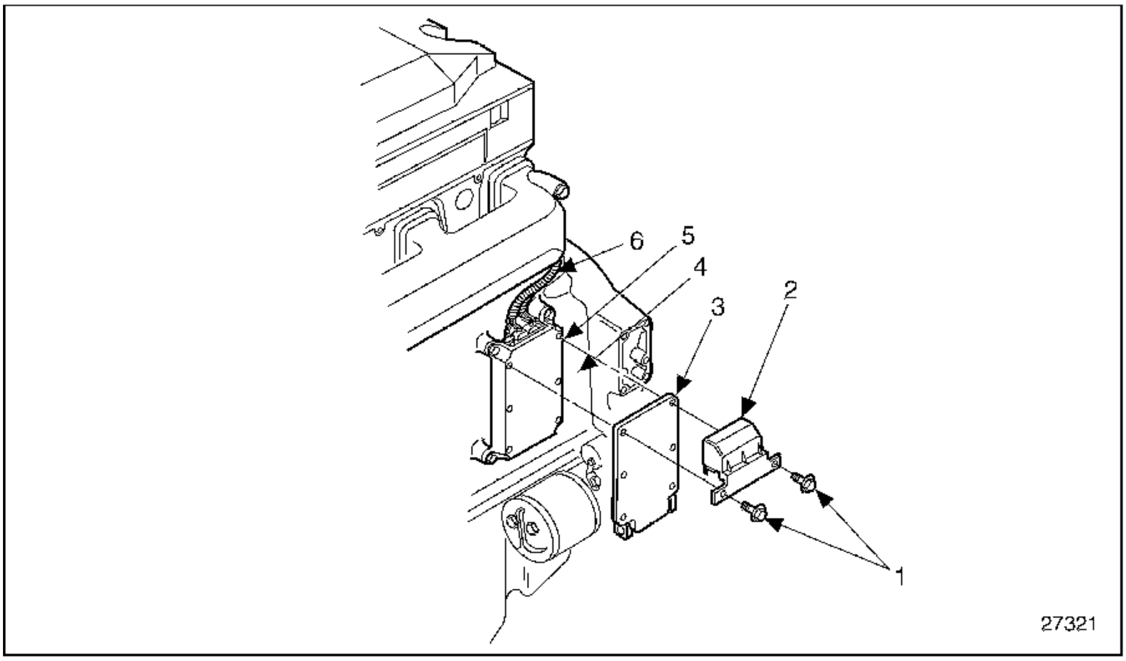
2.11.4 Repair or Replacement of the DDEC III ECM (Vertically Mounted)

A water shield may be installed on the vertically mounted ECM of DDEC III on-highway or coach engines. The water shield prevents the intrusion of high pressure water into the 30-pin and power plug connections of the ECM, which may cause corrosion of the terminals. Perform the following steps for removal of the ECM water shield:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Using a clean cloth, brush, or compressed air, remove any dirt or other contaminants from the ECM water shield. See Figure 2-55.



1. Bolts (2)
2. Water Shield
3. Cold Plate
4. Cylinder Block
5. Electronic Control Module
6. Engine Wiring Harness

Figure 2-55 Electronic Control Module Related Parts with Cold Plate

2. Remove the top two screws holding the water shield to the ECM or ECM cold plate and pull the shield away from the cold plate or ECM. Replace the mounting screws. See Figure 2-55.

2.11.4.1 Inspection of Electronic Control Module Water Shield

Inspect the water shield for cracks or other damage which could allow water to enter the ECM connections, resulting in possible corrosion of the terminals. Replace the water shield if cracked or damaged.

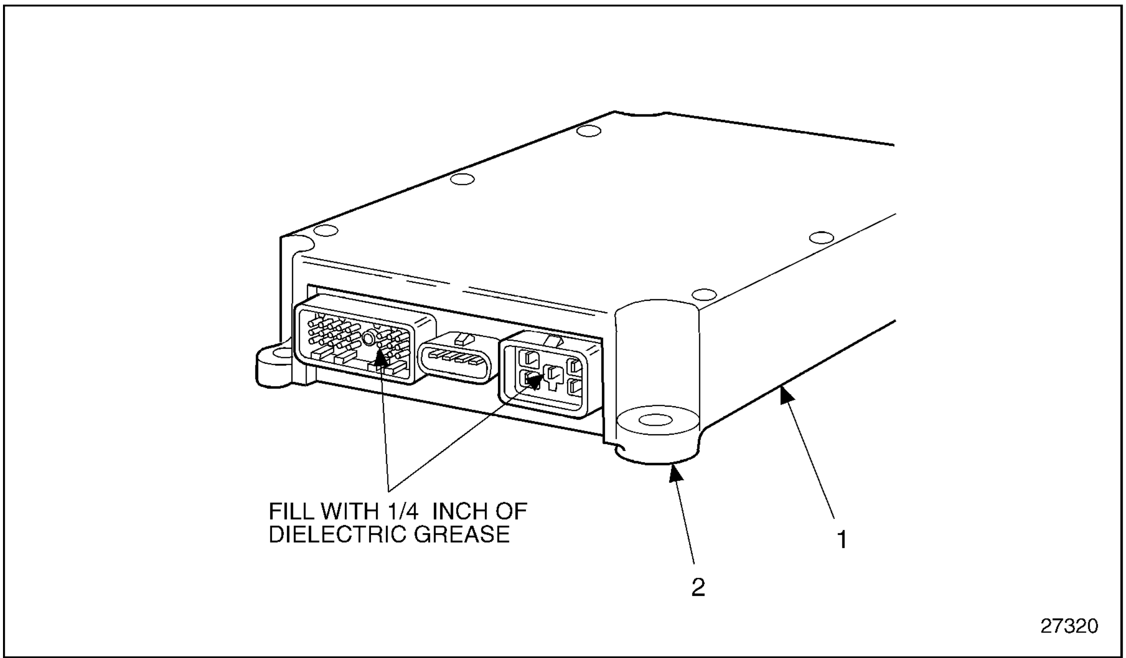
2.11.5 Installation of Electronic Control Module Water Shield

Install the ECM water shield as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

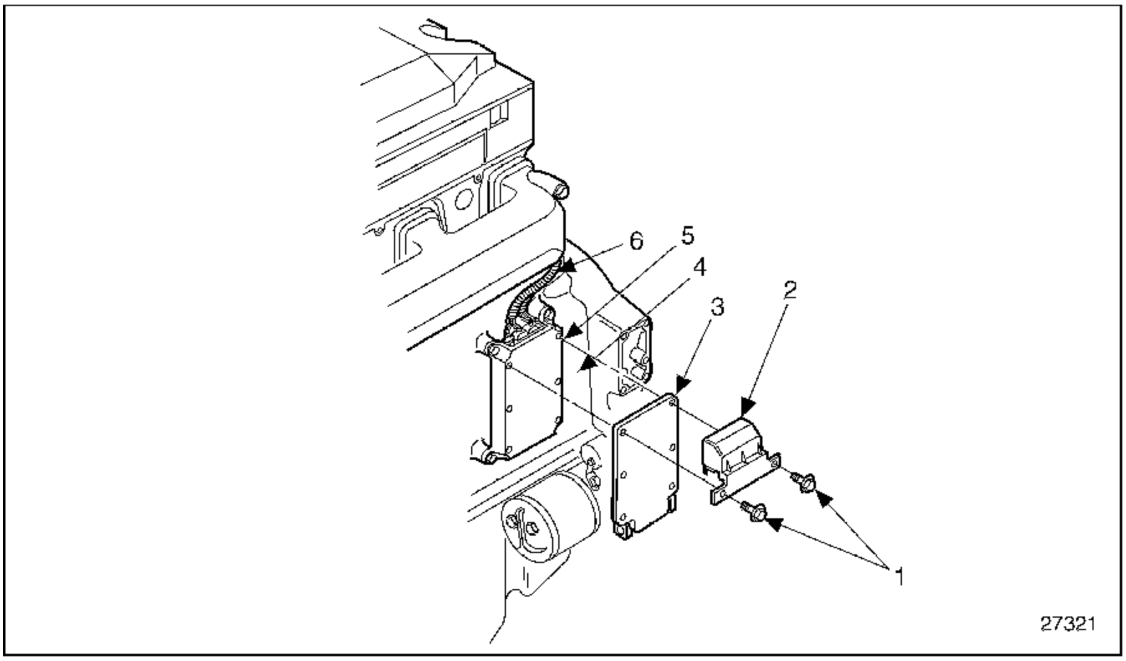
1. Using a clean cloth, brush, or compressed air, remove any dirt or other contaminants from the ECM or ECM cold plate.
2. Carefully remove the 30-pin harness connector and the power plug harness connector from the ECM. Cover immediately to prevent contamination by dirt from the engine installation.
3. Visually check ECM terminals. If clean and no dirt contamination of the dielectric grease used on the connectors is found, proceed to refer to Step 5 If terminals are dirty or if dirt is found in the dielectric grease used on the connectors, terminals *must*be cleaned. Use LPS Electro Contact Cleaner or LPS No-Flash Electro Contact Cleaner or equivalent and carefully clean the 30-pin connector terminals and the power plug terminals on the ECM.
4. Using a 10 cc tube of dielectric grease, apply an amount sufficient to cover the bottom of the 30-pin and power plug connectors on the ECM with 1/4 inch of the dielectric grease. See Figure 2-56.



1. Electronic Control Module
2. Mounting Boss

Figure 2-56 Electronic Control Module 30-Pin Location

5. Carefully install the 30-pin connector plug and the power plug onto the ECM. Torque the connector screw to 0.8-1.5 N·m (7-13 lb· in).
6. If the ECM has a cold plate, install the water shield as follows:
   [a] Remove the top two cold plate mounting screws and apply Loctite 252 sealant or equivalent to the threads.
   [b] Install the water shield and screws. See Figure 2-57. Torque screws to 9.5-12 N·m (84-106 lb· in).

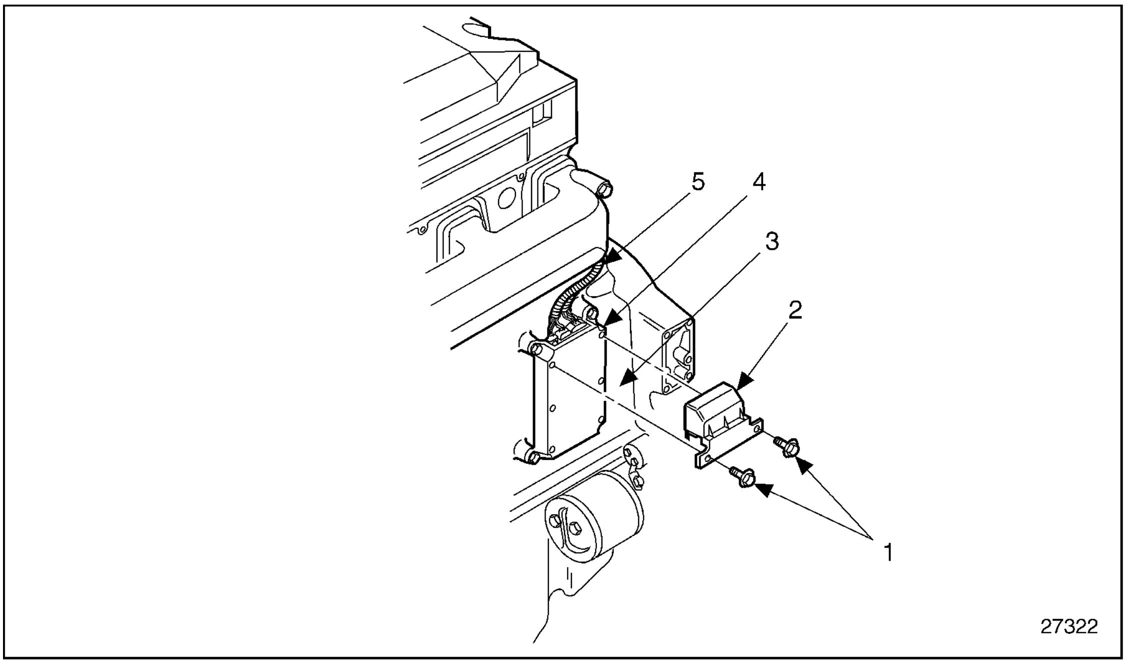


1. Bolts (2)
2. Water Shield
3. Cold Plate
4. Cylinder Block
5. Electronic Control Module
6. Engine Wiring Harness

Figure 2-57 Electronic Control Module Water Shield with Cold Plate

7. If the ECM does not have a cold plate, install the water shield as follows:
   [a] Remove the two top ECM mounting screws and apply Loctite 252 sealant or equivalent to the threads.

[b] Install the water shield and screws as shown. See Figure 2-58. Torque screws to 9.5-12 N ·m (84-106 lb· in).



1. Bolts (2)
2. Water Shield
3. Cylinder Block
4. Electronic Control Module
5. Engine Wiring Harness

Figure 2-58 Electronic Control Module Related Parts without Cold Plate

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

8. Start the engine and check for proper operation.

2.12 DDEC II ECM

This system utilizes an engine mounted ECM with a replaceable PROM in the DDEC II ECM and an EEPROM in the DDEC II ECM. The ECM has isolator mounts for both vibration and electrical isolation. Depending upon application, some units have fuel cooling of the ECM. The engine mounted system simplifies vehicle wiring for greater reliability.

The DDEC II ECM is a microprocessor. It is the control center of the DDEC II system. See Figure 2-59.

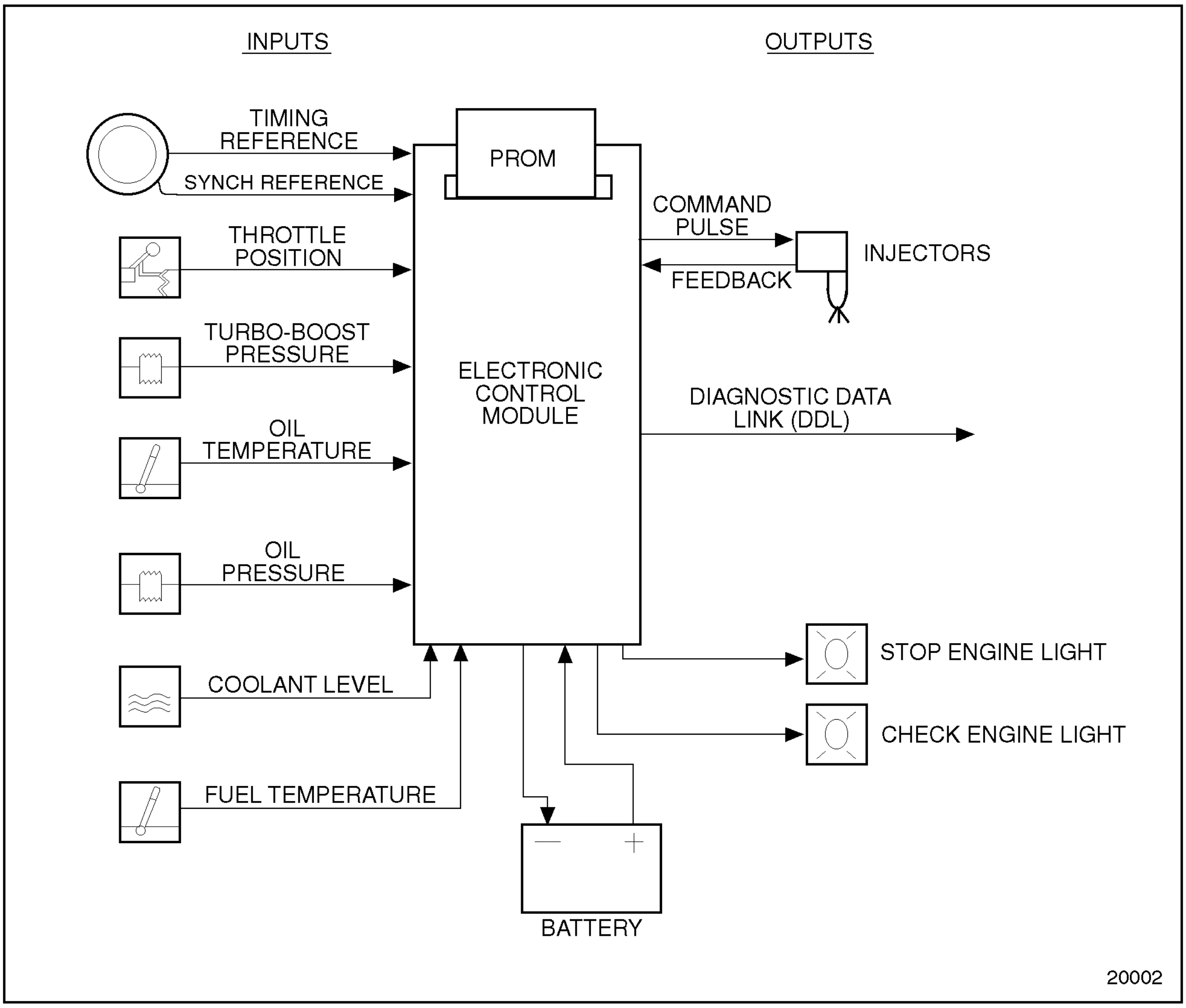


Figure 2-59 Schematic Diagram of DDEC II

The DDEC II ECM is packaged in a die-cast aluminum housing with sealed connectors, see Figure 2-59. It is mounted on the left side of the engine block.

The DDEC II consists of the following:

- ☐ The DDEC II ECM
- ☐ A replaceable EEPROM

- ☐ Connections to various engine sensors, operational displays, power and fuel injectors

2.12.1 Repair or Replacement of the DDEC II ECM

The DDEC II ECM is a sealed, nonserviceable unit. Tag defective ECM for recore.

2.12.2 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 II Troubleshooting Guide,* 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 II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Troubleshooting Guide,* 6SE497.

There are two Diagnostic Data Readers that can be used on DDEC II ECMs. See Figure 2-60, and see Figure 2-61.

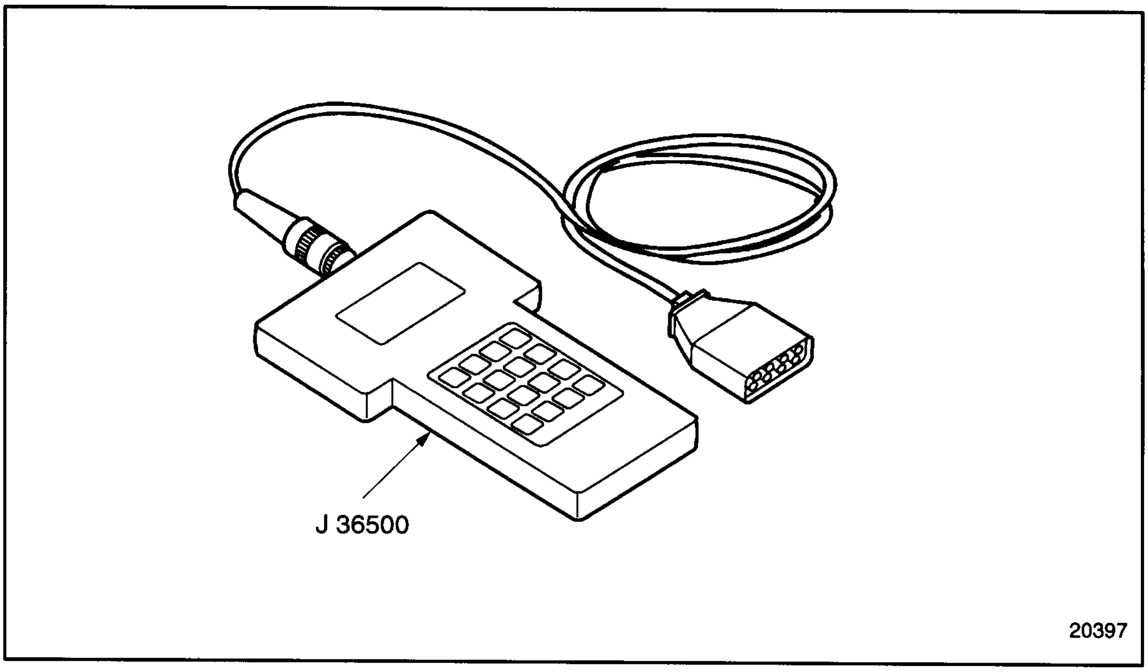


Figure 2-60 DDEC II Diagnostic Data Reader

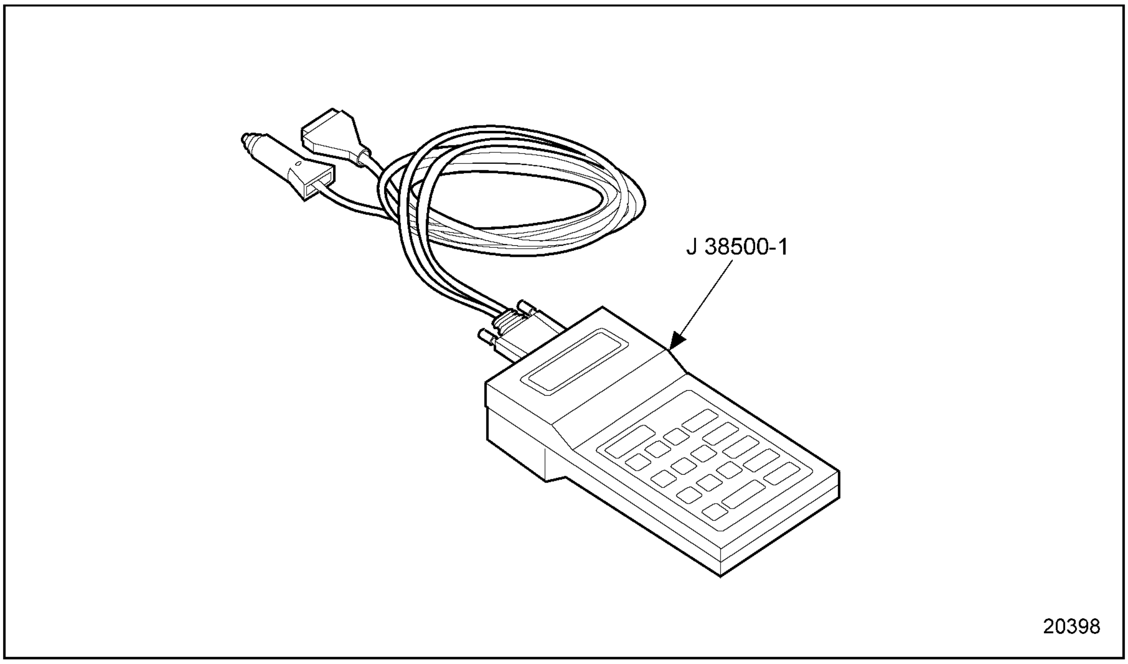


Figure 2-61 DDEC II Diagnostic Reader

2.12.3 Removal of DDEC II ECM

Perform the following steps for ECM removal:

1. Carefully disengage the lock tab on the power harness and injector harness connectors.
2. Remove the five wire harness connections at the ECM.
3. Remove the thru-bolts holding the ECM to the engine.
4. Remove the ECM and cold plate from the engine.

2.12.4 Installation of DDEC II ECM

Perform the following steps for ECM installation:

1. Inspect the ECM isolators for damage and replace if required.
2. Mount the ECM and on the engine.
3. Secure the ECM to the engine with thru-bolts. Torque the ECM-to-engine bolts to 23-27 N·m (17-20 lb·ft). Torque the ECM connector hold-down screws to 2.4-3.0 N·m (21-26 lb· in.).
4. Connect the five wire harness connections at the ECM.
5. Engage the lock tab on the power harness and injector harness connectors.
6. 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, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

7. Start the engine, and check for fuel leaks.

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. See Figure 2-62.

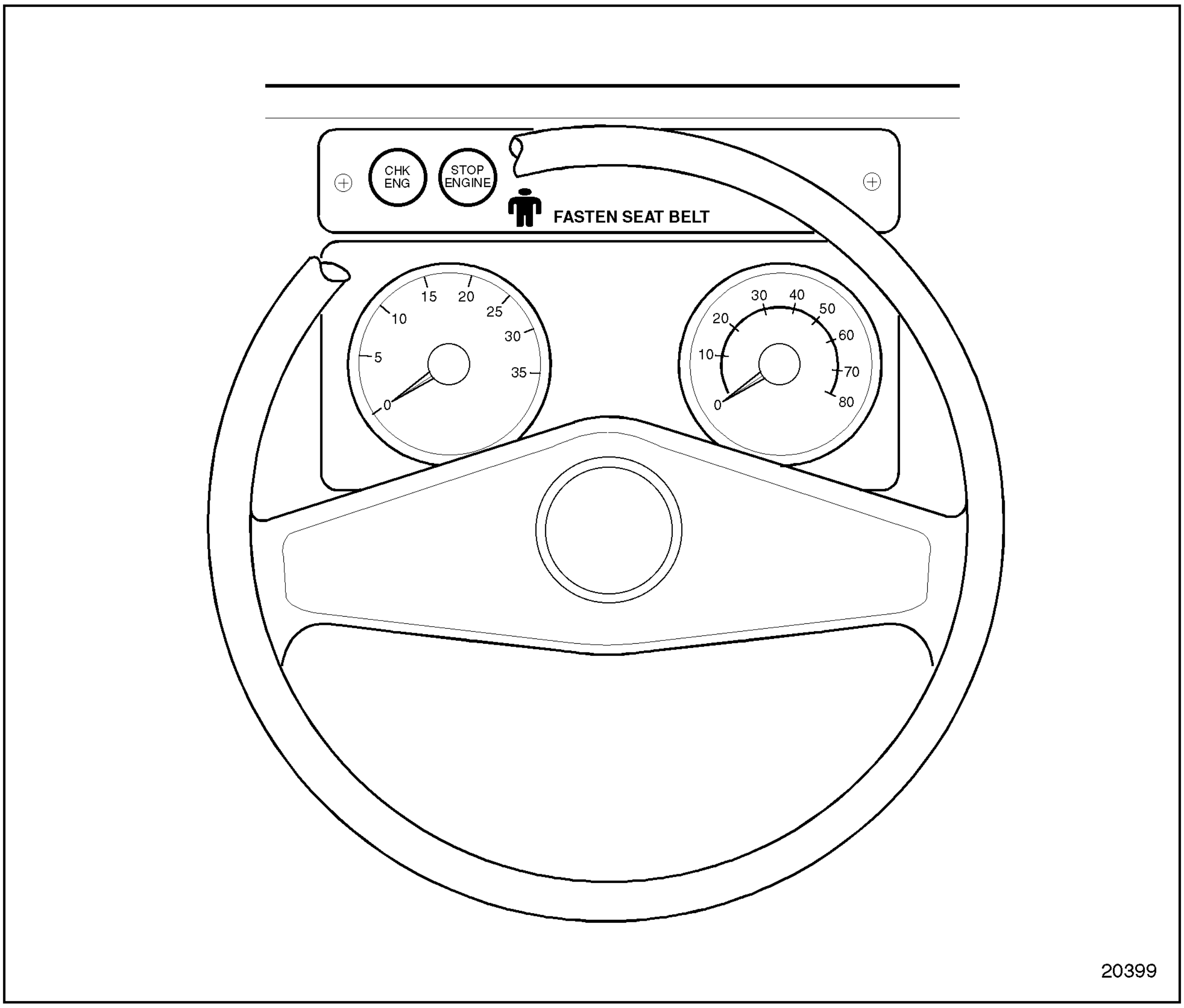


Figure 2-62 Dashboard Warning Lights

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.

If there is no diagnostic switch, locate the 12-pin Diagnostic Data Link (DDL) connector (DDEC II applications only) under the dash of the vehicle. See Figure 2-63.

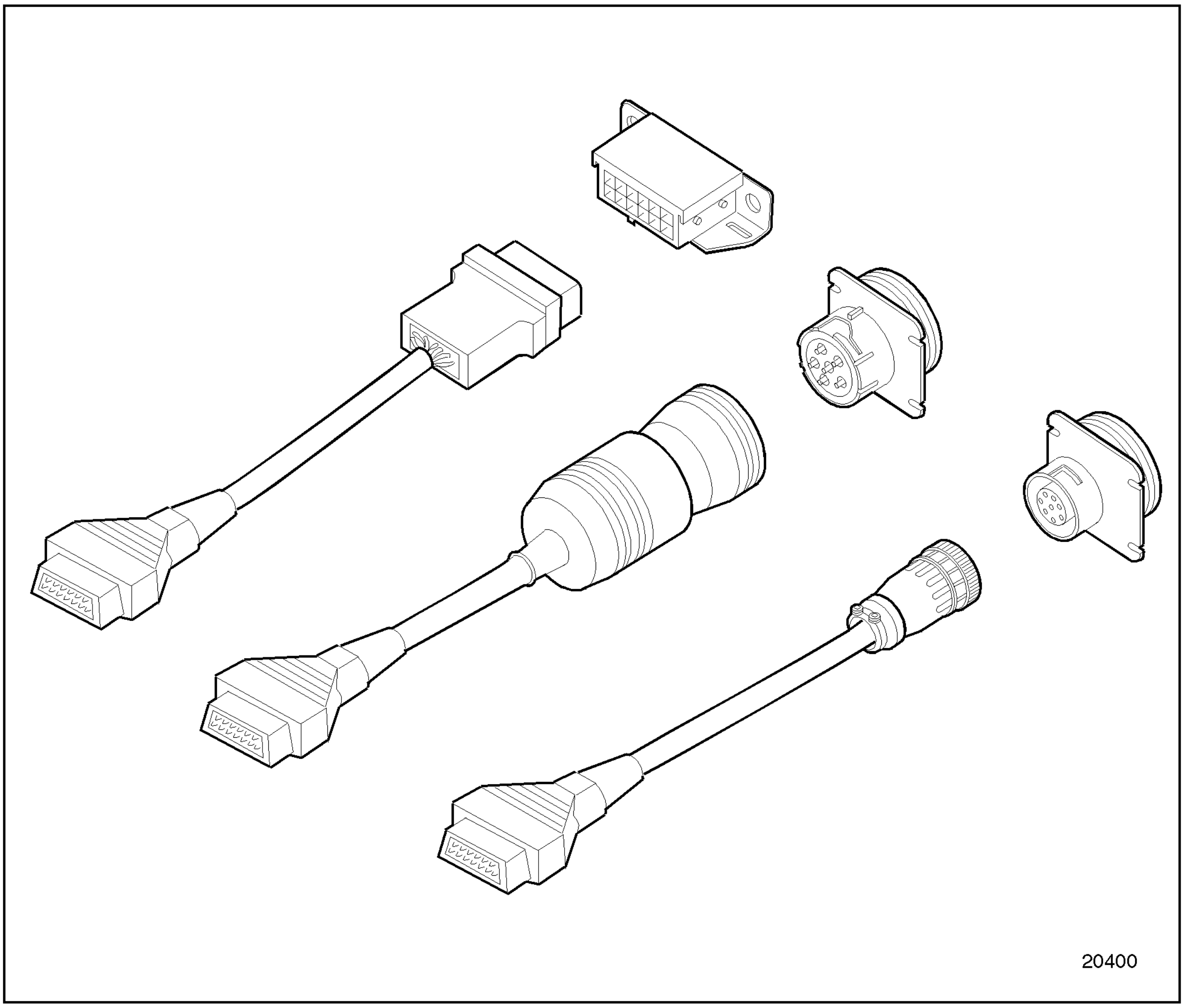


Figure 2-63 Examples of Diagnostic Data Link (DDL) Connector

NOTICE:
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. This condition will not occur when a diagnostic reader is used.

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 (on DDEC II engines only).

If a code other than 25 is read, refer to the correct chart as instructed by the *DDEC II Troubleshooting Guide,* 6SE498, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497 for repair instructions.

Fault codes can be cleared from the DDEC II and III systems only by using a diagnostic reader. Follow the instructions supplied with the reader to clear the fault codes.

NOTE:
Before beginning any repair procedures, the ignition switch must be in the "OFF" position.

Following are basic replacement procedures for the DDEC components. Components should NOT be replaced unless a defective unit has been concluded by the *DDEC II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

2.13 ELECTRONIC FOOT PEDAL ASSEMBLY

The Electronic Foot Pedal Assembly (EFPA) connects the accelerator pedal to a Throttle Position Sensor (TPS). See Figure 2-64. The TPS is a device that sends an electrical signal to the ECM. The signal varies in voltage according to the pressure on the pedal. The system is installed in the space normally occupied by the mechanical foot pedal. The EFPA has maximum and minimum stops that are built into the unit during manufacture.

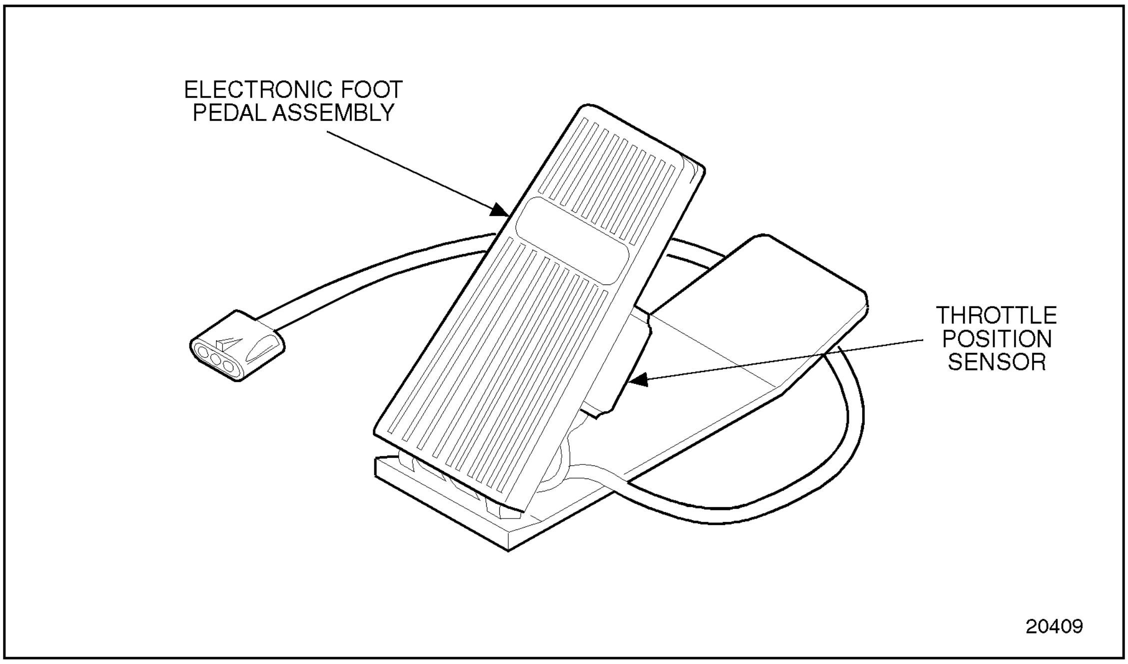


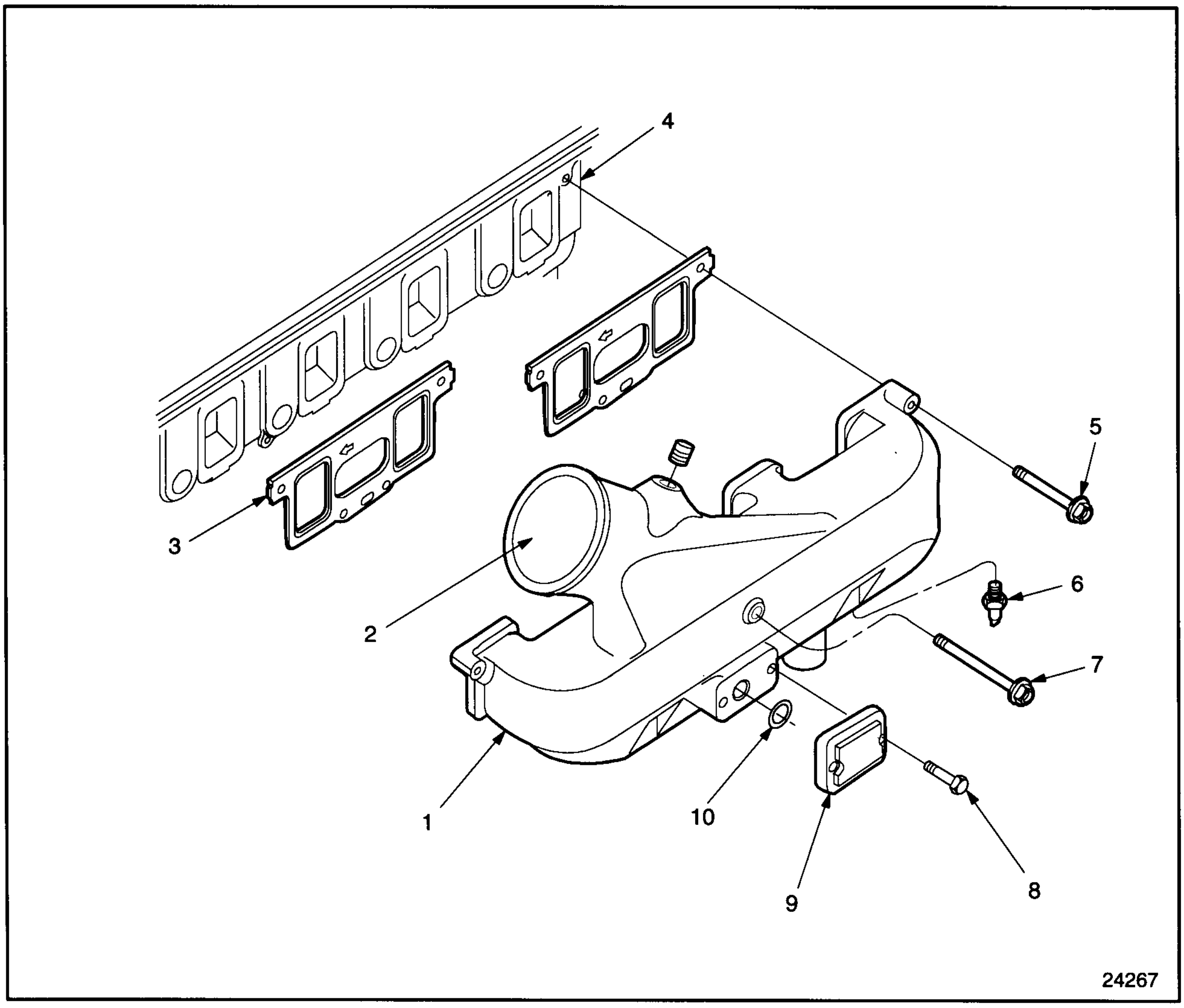
Figure 2-64 Electronic Foot Pedal Assembly

2.13.1 Repair or Replacement of Electronic Foot Pedal Assembly

The EFPA assembly is supplied by the vehicle manufacturer. Refer to the Original Equipment Manufacturer for service procedure.

2.14 TURBO BOOST PRESSURE SENSOR

The Turbo Boost Sensor (TBS) is mounted to the intake manifold with two bolts. A rubber O-ring is used to seal the sensor to the manifold. See Figure 2-65.



1. Intake Manifold
2. Intake Manifold Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Bolt
6. Air Temperature Sensor
7. Bolt
8. Turbo Boost Sensor Bolt
9. Turbo Boost Sensor
10. O-ring

Figure 2-65 Turbo Boost Pressure Sensor

This device is a pressure sensor that sends an electrical signal to the ECM. 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.

2.14.1 Repair or Replacement of Turbo Boost Sensor

The TBS is non-serviceable and must be replaced as an assembly. No adjustment is required.

2.14.2 Removal of Turbo Boost Sensor

Remove the TBS as follows:

1. Disengage the locking tang on the TBS connector body. Grasp the terminal body and gently pull it from the sensor.
2. Remove the two bolts that secure the TBS to the intake manifold.

NOTE:
Be careful not to lose the O-ring.

3. Remove the TBS from the intake manifold.

2.14.3 Installation of Turbo Boost Sensor

Install the TBS as follows:

NOTE:
The TBS is an electronic device. Use care during installation.

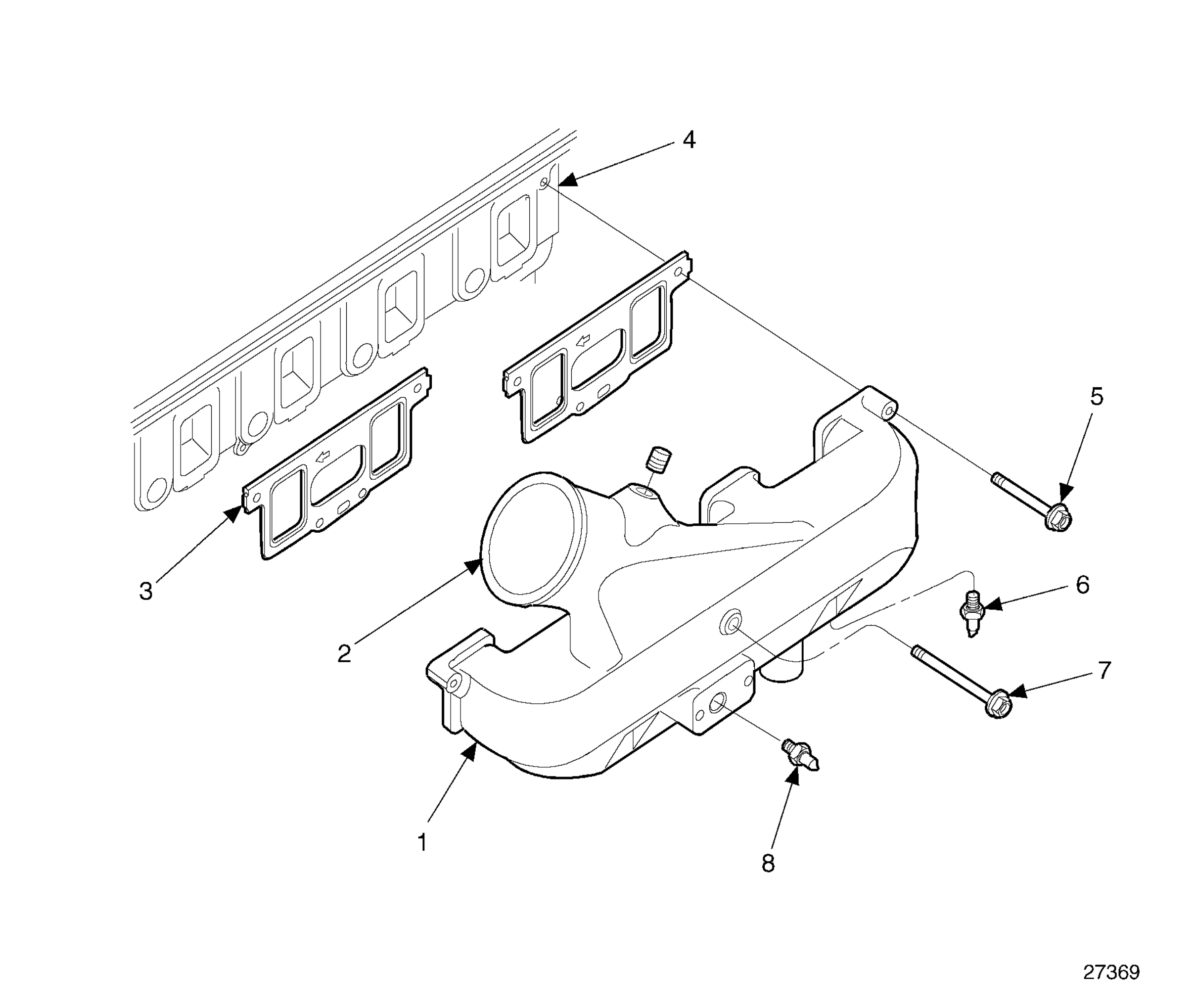
1. Apply petroleum jelly to the O-ring to hold it in position.
2. Install O-ring to the TBS.

NOTICE:
Do not overtighten the bolts that mount the TBS to the intake manifold. Damage to the TBS may result. Torque the bolts to no more than 2.4-3.0 N·m (21-26 in.·lb).

3. Install the TBS to the intake manifold.
4. Install the two bolts that secure the TBS to the intake manifold. Torque to 2.4-3.0 N·m (21-26 in.·lb).
5. Engage the locking tang on the TBS connector body. Grasp the terminal body and gently pull it towards the sensor.
6. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.15 TURBO BOOST PRESSURE SENSOR FOR THE SERIES 50G ENGINES

The Turbo Boost Sensor (TBS) is threaded into the intake manifold. See Figure 2-66. The Series 50G natural gas engines use a wide range sensor that allows pressure measurement under conditions of either manifold vacuum or boost.



1. Intake Manifold
2. Intake Manifold Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Bolt
6. Air Temperature Sensor
7. Bolt
8. Turbo Boost Sensor

Figure 2-66 Turbo Boost Pressure Sensor Series 50G

This device is a pressure sensor that sends an electrical signal to the ECM. 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 air fuel ratio. The TBS information is also used to control ignition timing.

2.15.1 Repair or Replacement of Turbo Boost Sensor

The TBS is non-serviceable and must be replaced as an assembly. No adjustment is required.

2.15.2 Removal of Turbo Boost Sensor

Remove the TBS as follows:

1. Disengage the locking tang on the TBS connector body. Grasp the terminal body and gently pull it from the sensor.
2. Remove the TBS from the intake manifold.

2.15.3 Installation of Turbo Boost Sensor

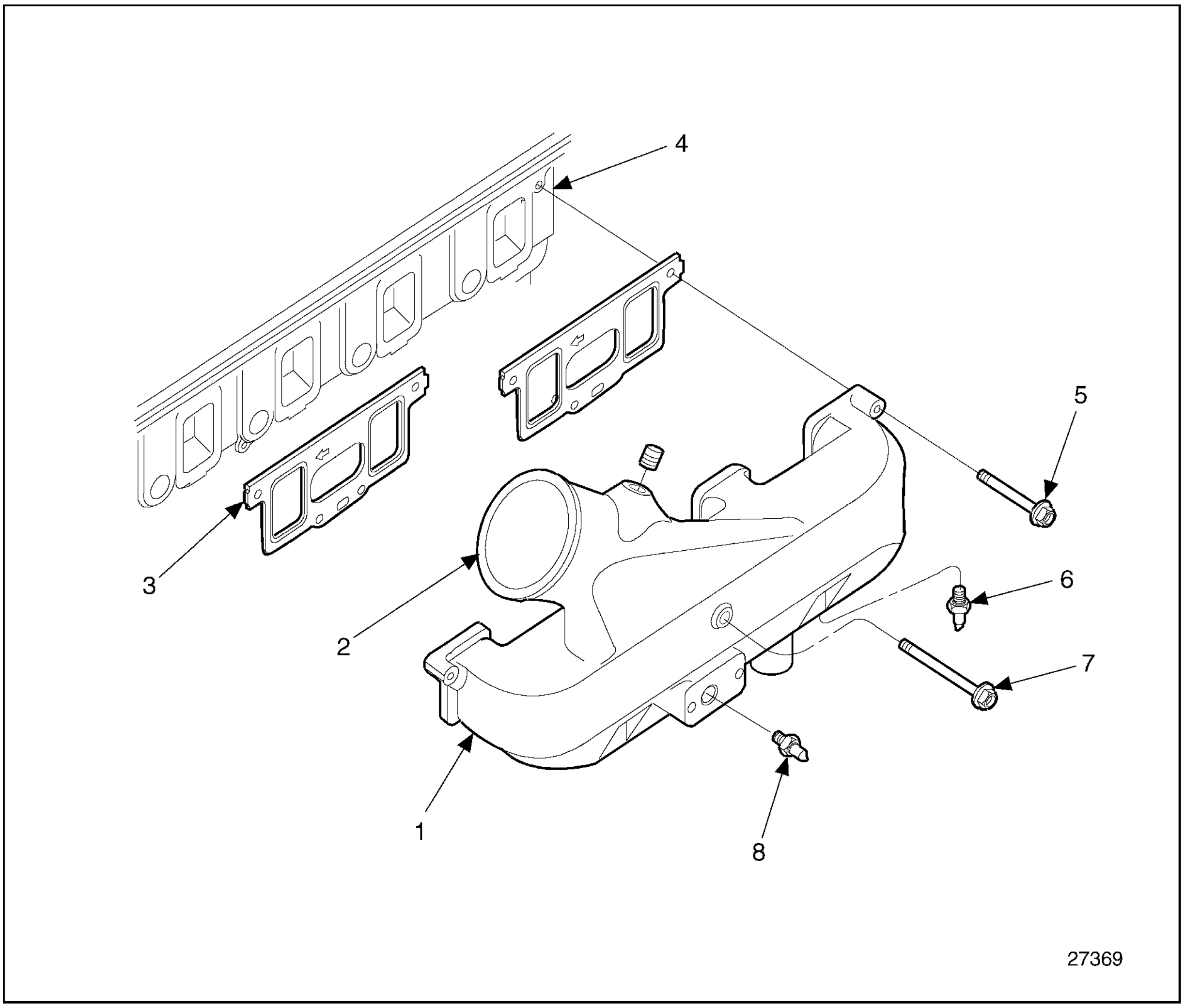
Install the TBS as follows:

NOTE:
The TBS is an electronic device. Use care during installation.

1. Install the TBS to the intake manifold.
2. Engage the locking tang on the TBS connector body. Grasp the terminal body and gently pull it towards the sensor.
3. Put petroleum jelly on O-ring to hold it in position.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other 25 appears, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

2.16 MANIFOLD ABSOLUTE PRESSURE SENSOR

The Manifold Absolute Pressure Sensor (MAP) is threaded into the intake manifold.
See Figure 2-67. The Series 50G natural gas engines use a wide range sensor that allows pressure measurement under conditions of either manifold vacuum or boost.



1. Intake Manifold
2. Intake Manifold Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Bolt
6. Air Temperature Sensor
7. Bolt
8. Manifold Absolute Pressure Sensor

Figure 2-67 Manifold Absolute Pressure Sensor Series 50G

This device is a pressure sensor that sends an electrical signal to the ECM. 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 air fuel ratio. The MAP information is also used to control ignition timing.

2.16.1 Repair or Replacement of Manifold Absolute Pressure Sensor

The MAP is non-serviceable and must be replaced as an assembly. No adjustment is required.

2.16.2 Removal of Manifold Absolute Pressure Sensor

Remove the MAP as follows:

1. Disengage the locking tang on the MAP connector body. Grasp the terminal body and gently pull it from the sensor.
2. Remove the MAP from the intake manifold.

2.16.3 Installation of Manifold Absolute Pressure Sensor

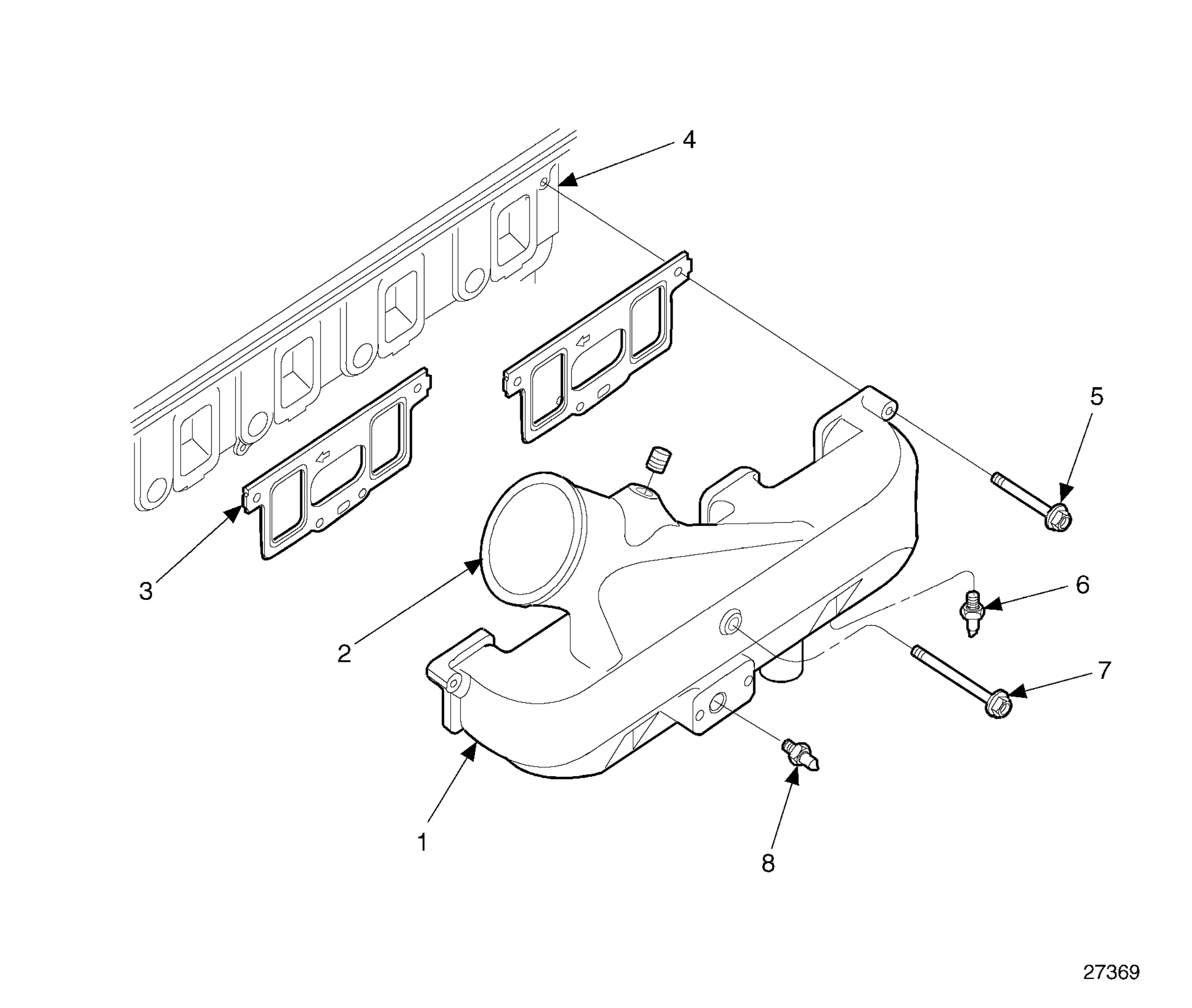
Install the MAP as follows:

NOTE:
The MAP is an electronic device. Use care during installation.

1. Install the MAP to the intake manifold.
2. Engage the locking tang on the MAP connector body. Grasp the terminal body and gently pull it towards the sensor
3. Put petroleum jelly on O-ring to hold it in position.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.17 AIR INTAKE PRESSURE SENSOR

The Air Intake Sensor (AIP) is threaded into the intake manifold. See Figure 2-68. The Series 50G natural gas engines use a wide range sensor that allows pressure measurement under conditions of either manifold vacuum or boost.



1. Intake Manifold
2. Intake Manifold Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Bolt
6. Air Temperature Sensor (different location on the high pressure fuel system)
7. Bolt
8. Turbo Boost Sensor

Figure 2-68 Air Intake Pressure Sensor Series 50G

This device is a pressure sensor that sends an electrical signal to the ECM. 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 air fuel ratio. The AIP information is also used to control ignition timing.

NOTE:
S50G GFI controlled fuel system that has been converted to the DDEC controlled closed loop fuel system, the AIP was moved from the intake manifold to the side of the intake elbow.

2.17.1 Repair or Replacement of Air Intake Pressure Sensor

The AIP is non-serviceable and must be replaced as an assembly. No adjustment is required.

2.17.2 Removal of Air Intake Pressure Sensor

Remove the AIP as follows:

1. Disengage the locking tang on the AIP connector body. Grasp the terminal body and gently pull it from the sensor.
2. Remove the AIP from the intake manifold.

2.17.3 Installation of Air Intake Pressure Sensor

Install the AIP as follows:

NOTE:
The AIP is an electronic device. Use care during installation.

1. Install the AIP to the intake manifold.
2. Engage the locking tang on the AIP connector body. Grasp the terminal body and gently pull it towards the sensor
3. Put petroleum jelly on O-ring to hold it in position.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.18 OIL PRESSURE SENSOR

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. See Figure 2-69.

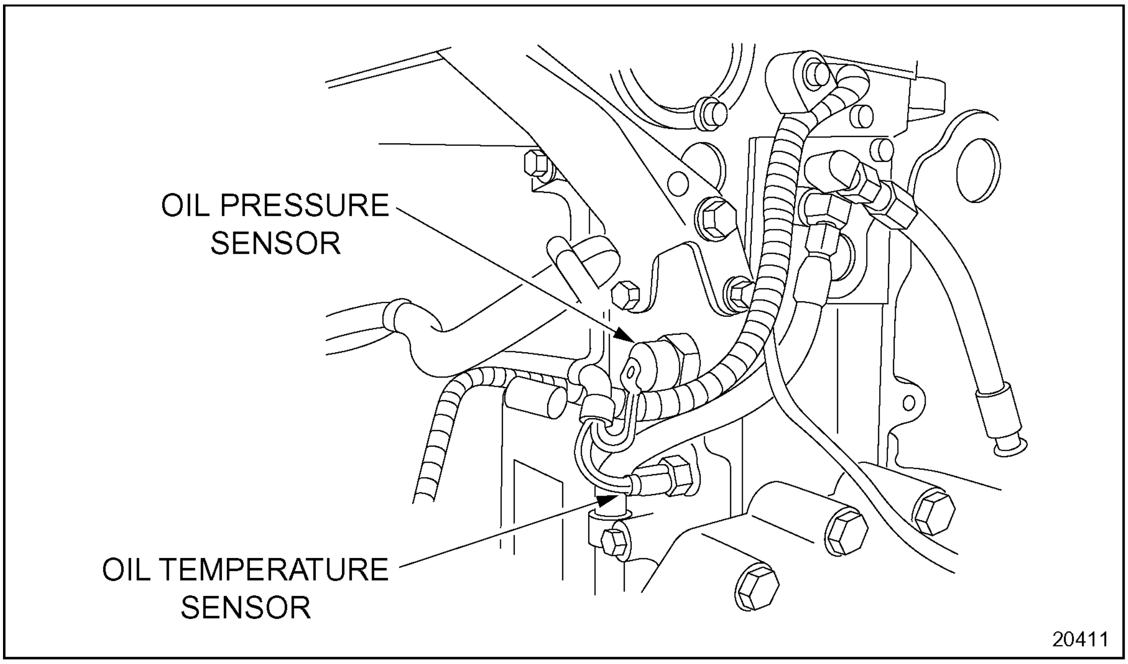


Figure 2-69 Engine Oil Pressure and Temperature Sensors

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.

2.18.1 Repair or Replacement of the Oil Pressure Sensor

The OPS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.18.2 Removal of Oil Pressure Sensor

Remove the OPS as follows:

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.

2.18.3 Installation of Oil Pressure Sensor

Install the OPS as follows:

NOTE:
The OPS is an electronic device. Use care on installation.

1. Place the sensor on the engine and using the appropriate wrench on the hex portion of the sensor tighten the screws.
2. Use Loctite Pipe Sealer with Teflon, J 26558-92 part of PT-7276, (or equivalent) on all but the first two threads of the OPS to prevent leaks.
3. Place the connector in the socket and engage the locking tang.
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 II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.19 OIL TEMPERATURE SENSOR

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. See Figure 2-70. 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.

NOTE:
Series 50G automotive (high pressure fuel system) engines do not have an oil temperature sensor. All DDEC and OEM functions reference coolant temperature.

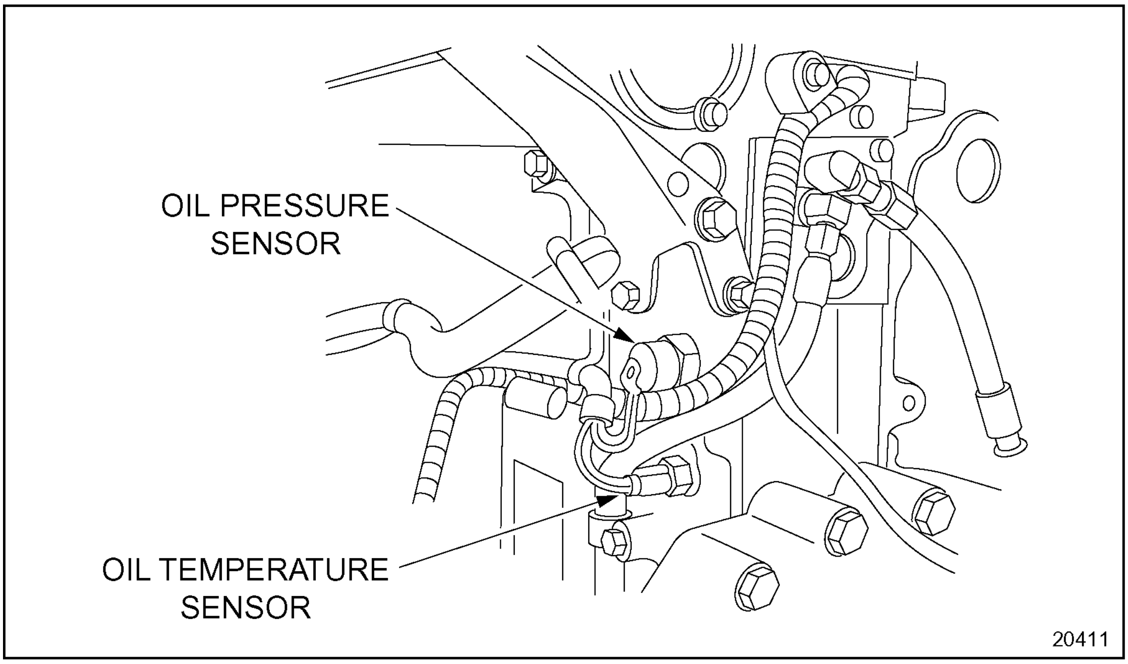


Figure 2-70 Engine Oil Pressure and Temperature Sensors

2.19.1 Repair or Replacement of Oil Temperature Sensor

The OTS is non-serviceable, and is replaced as a unit. No adjustment is required.

2.19.2 Removal of Oil Temperature Sensor

Removal the OTS as follows:

1. Disengage the locking tang on the two-wire connector.
2. Grasp the body of the connector and gently pull it from the socket.
3. Use the appropriate wrench on the hex portion of the sensor and unscrew it.

2.19.3 Installation of Oil Temperature Sensor

Install the OTS as follows:

NOTE:
The Oil Temperature Sensor is an electronic device. Use care in the installation process.

1. Place the sensor and using the appropriate wrench on the hex portion of the sensor tighten the screws.
2. Use Loctite Pipe Sealer with Teflon, J 26558-92 part of PT-7276(or equivalent) on all but the first two threads of the OTS to prevent leaks.
3. Place the connector in the socket and engage the locking tang.
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 II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.20 SYNCHRONOUS REFERENCE SENSOR

The Synchronous Reference Sensor (SRS) is an electronic component that is mounted to the rear of the gear case. See Figure 2-71.

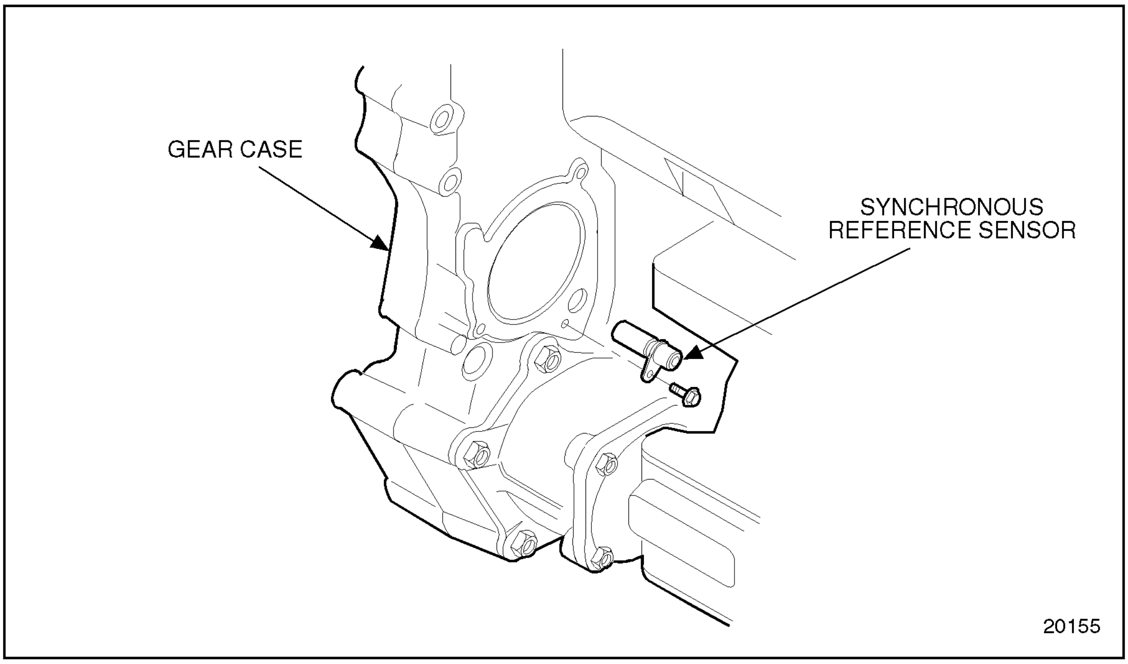


Figure 2-71 SRS Location

NOTE:
The length of the SRS sensor element is 33.15-33.66 mm (1.305-1.325 in.).

The sensor portion of the SRS extends through a hole in the gear case, and is positioned very near the rear of the bull gear. A bolt, inserted through a hole in the SRS bracket, secures the SRS assembly to the gear case. The SRS connector is black in color.

The SRS sends a signal to the ECM. This signal is generated by a raised metal pin on the rear of the bull gear. See Figure 2-72.

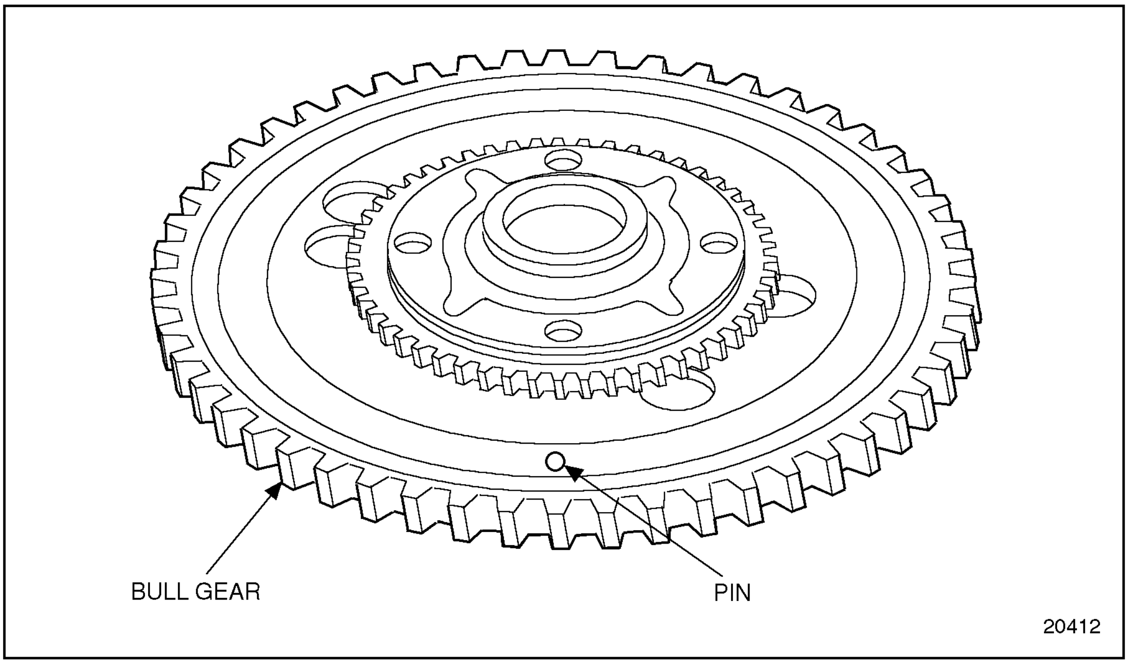


Figure 2-72 Bull Gear

The bull gear pin passes by the SRS as the number one piston reaches approximately 45° before Top-Dead-Center. This information is used by the ECM to determine engine speed.

2.20.1 Repair or Replacement Synchronous Reference Sensor

The SRS is a non-serviceable item and is replaced as a unit. No adjustment is required.

2.20.2 Removal of Synchronous Reference Sensor

Remove the SRS as follows:

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.

2.20.3 Installation of Synchronous Reference Sensor

Install the SRS as follows:

NOTE:
The SRS is an electronic component. Use care upon installation.

1. 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 torque it to 30-38 N·m (22-28 lb·ft).
4. Plug the connectors together, making sure the locking tang clicks into place.
5. Turn the ignition to the "ON" position. If any diagnostic code other than 25 appears, refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

2.21 TIMING REFERENCE SENSOR

The Timing Reference Sensor (TRS) is an electronic component that is mounted to the left side of the gear case, near the crankshaft centerline. See Figure 2-73.

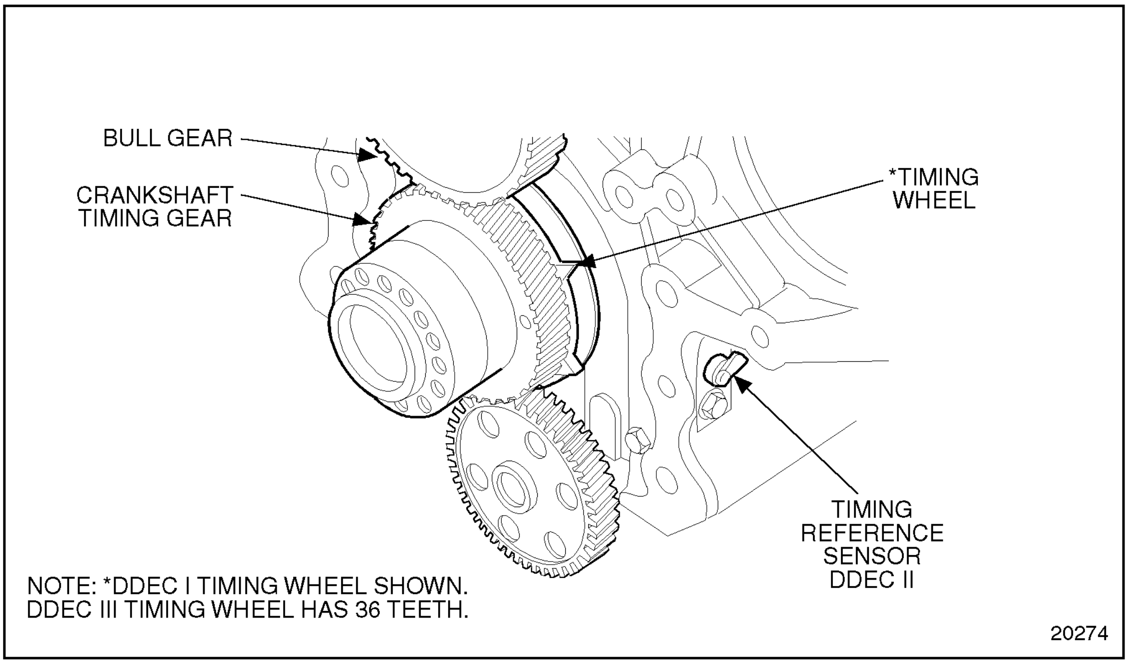


Figure 2-73 TRS and Related Parts

NOTE:
The length of the TRS sensor element is 56.08-56.57 mm (2.207-2.227 in.).

The sensor portion of the TRS extends through an opening in the gear case, and is positioned near the teeth of the timing wheel. A bolt, inserted through a hole in the TRS bracket, secures the TRS assembly to the gear case. The TRS connector is gray in color.

The TRS sends a signal to the ECM. This signal is generated by a series of evenly spaced teeth on the timing wheel. As the timing wheel rotates with the crankshaft, a tooth 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.

2.21.1 Repair or Replacement of Timing Reference Sensor

The TRS is a non-serviceable component and is replaced as a unit. No adjustment is required.

2.21.2 Removal of Timing Reference Sensor

Remove the TRS as follows:

1. Disengage the locking tang on the TRS connector. Grasp the connector bodies and gently pull them apart.

2. Remove the bolt that secures the TRS to the gear case.
3. Remove the TRS by pulling it straight out of the gear case.

2.21.3 Installation of Timing Reference Sensor

Install the TRS as follows:

NOTE:
The TRS is an electronic component. Use care upon installation.

1. 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 torque it to 30-38 N·m (22-28 lb·ft).
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 II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.22 COOLANT LEVEL SENSOR

The Coolant Level Sensor (CLS) is a two-piece sensor. See Figure 2-74. 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.

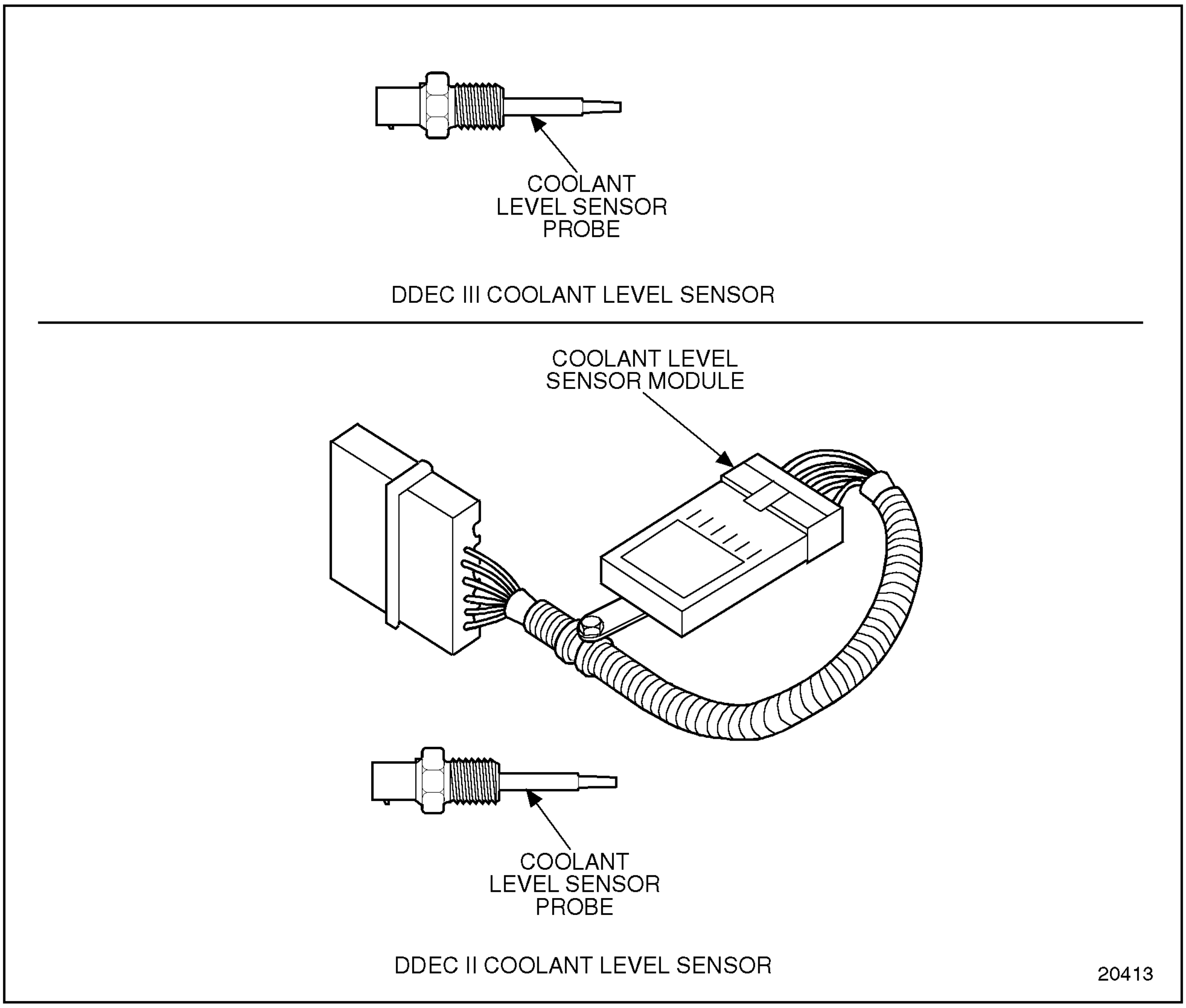


Figure 2-74 Two-piece Coolant Level Sensor (CLS)

2.22.1 Repair or Replacement of Cooling Reference Sensor

Both the CLS probe and module are non-serviceable and should be replaced as necessary.

2.22.2 Removal of Cooling Reference Sensor

Remove the CLS as follows:

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, or unplug the two-pin connector.
3. Use the appropriate wrench on the hex portion of the sensor and unscrew it from the radiator.

2.22.3 Installation of Cooling Reference Sensor

Install the CLS probe as follows:

1. Use the appropriate wrench on the hex portion of the sensor and screw it into the radiator.
2. Install ground wire screw and ground wire from side of probe. Install and tighten nut from sensor lead of probe. Install sensor lead, or unplug the two-pin connector.
3. Close the drain cock at the bottom of the radiator.
4. Refer to Section 4 and fill the cooling system.
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 II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

6. Start the engine and check for leaks.

2.22.4 Removal of Cooling Reference Sensor Module

Remove the CLS module as follows:

1. Disengage the locking tang on the CLS module connector. Grasp the connector bodies and gently pull them apart.
2. Remove module from vehicle.

2.22.5 Installation of Cooling Reference Sensor Module

Install the CLS module as follows:

NOTE:
The CLS module is an electronic component. Use care when installing.

1. Insert the CLS module to the vehicle.
2. Engage locking tang on CLS module connector.

2.23 FUEL PRESSURE SENSOR

The Fuel Pressure Sensor (FPS) is installed into the secondary fuel filter. See Figure 2-75. The 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.

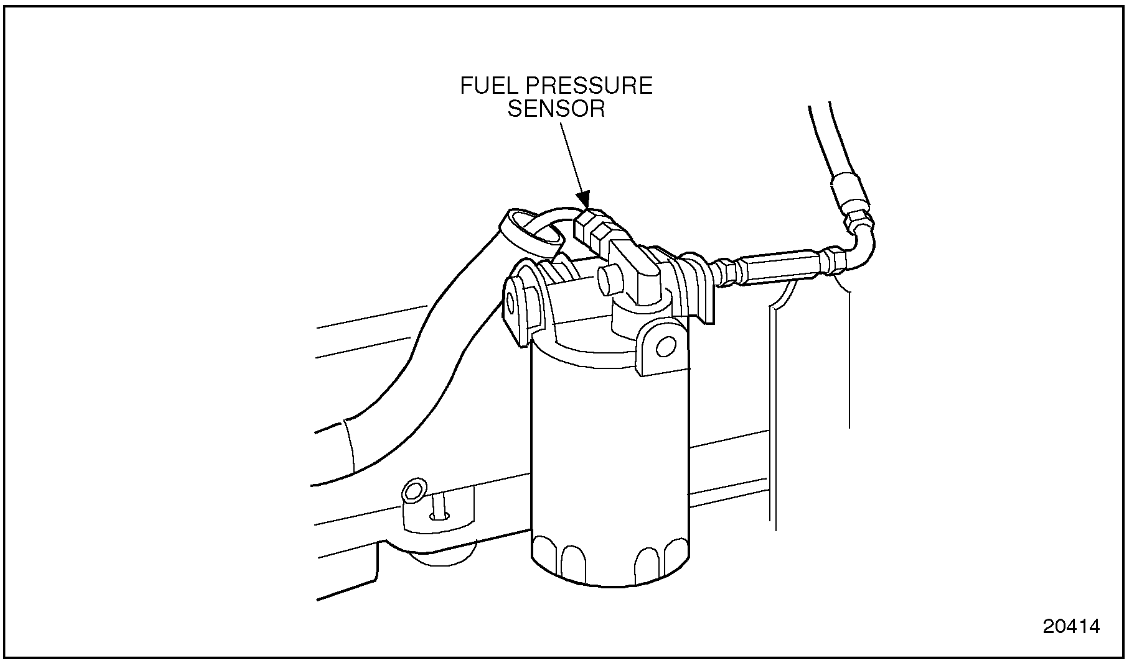
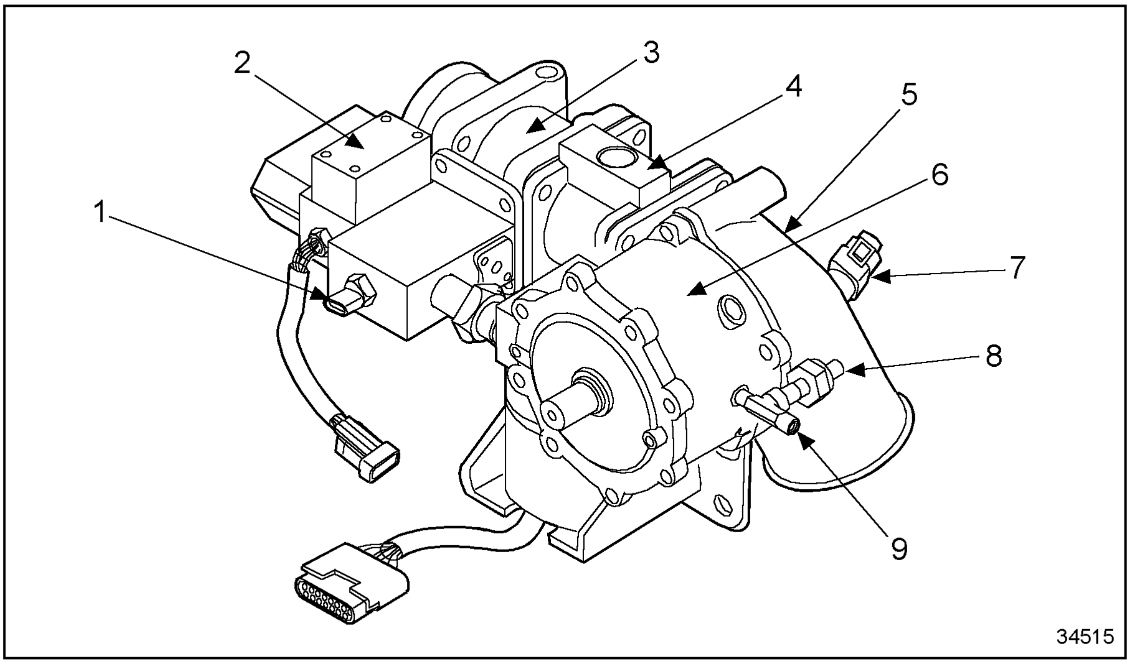


Figure 2-75 Engine Fuel Pressure Sensor

On Series 50G engines with the high pressure fuel system the fuel pressure sensor is installed in a tee at the inlet to the low pressure regulator. See Figure 2-76.



1. Fuel Temperature Sensor
2. PSV
3. Fuel Mixer
4. Throttle
5. Air Inlet Elbow
6. Low Pressure Regulator
7. Air Temperature Sensor
8. Fuel Pressure Sensor
9. Fuel Inlet Tee Fitting

Figure 2-76 Fuel Pressure Sensor for Series 50G

2.23.1 Repair or Replacement of Fuel Pressure Sensor

The FPS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.23.2 Removal of Fuel Pressure Sensor

Remove the FPS as follows:

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.

2.23.3 Installation of Fuel Pressure Sensor

Install the FPS as follows:

NOTE:
The FPS is an electrical device. Use care on installation.

1. Use Loctite Pipe Sealant with Teflon, J 26558-92 part of PT-7276 (or equivalent) on all but the first two threads of the FPS to prevent leaks.
2. Screw FPS into the filter head or regulator inlet tee.
3. Turn the ignition to the "ON" position. If any diagnostic code other than 25 is obtained, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

2.24 FUEL TEMPERATURE SENSOR

The Fuel Temperature Sensor (FTS) is installed into the secondary fuel filter. See Figure 2-77. The FTS sends an electrical signal to the ECM indicating fuel inlet temperature. The ECM uses this information to calculate fuel consumption.

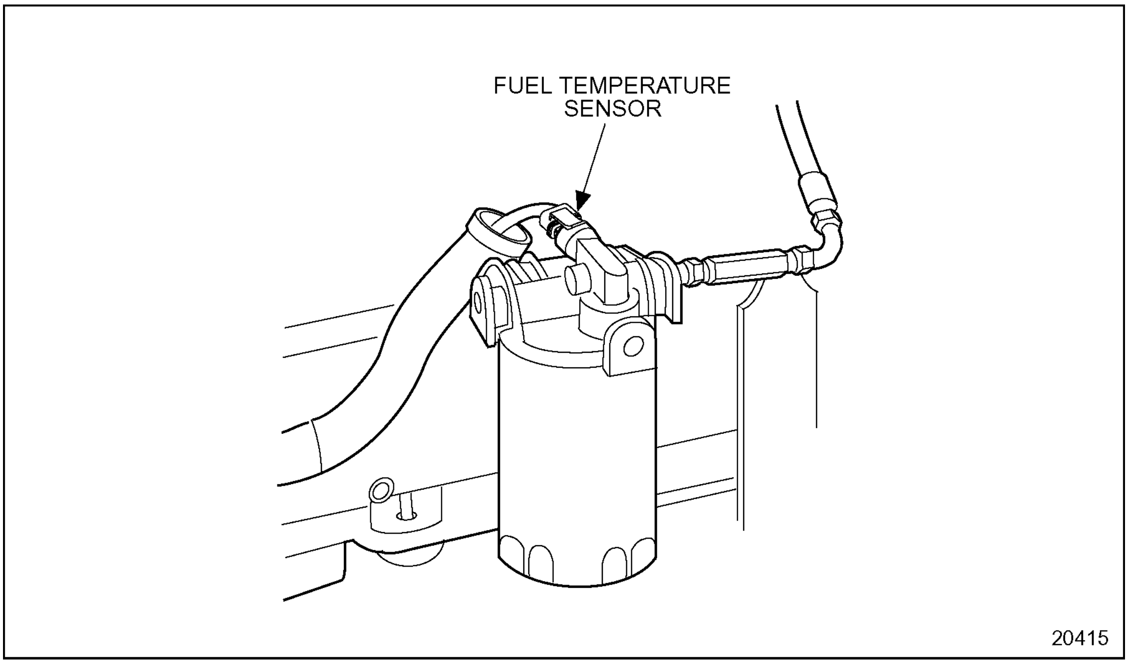
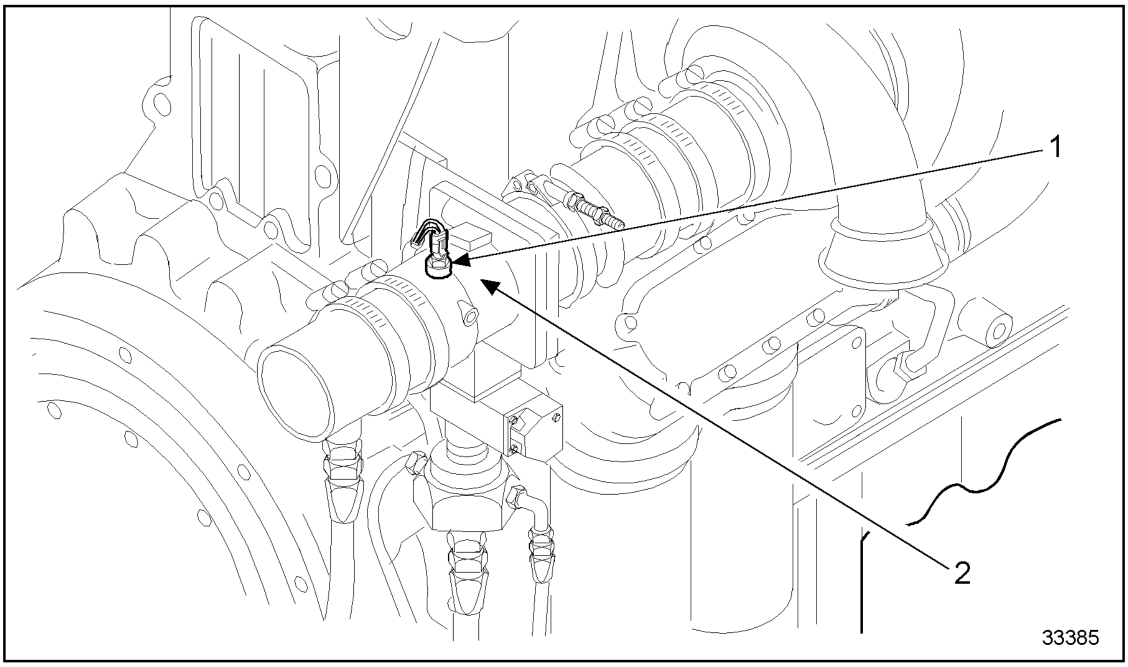


Figure 2-77 Engine Fuel Temperature Sensor

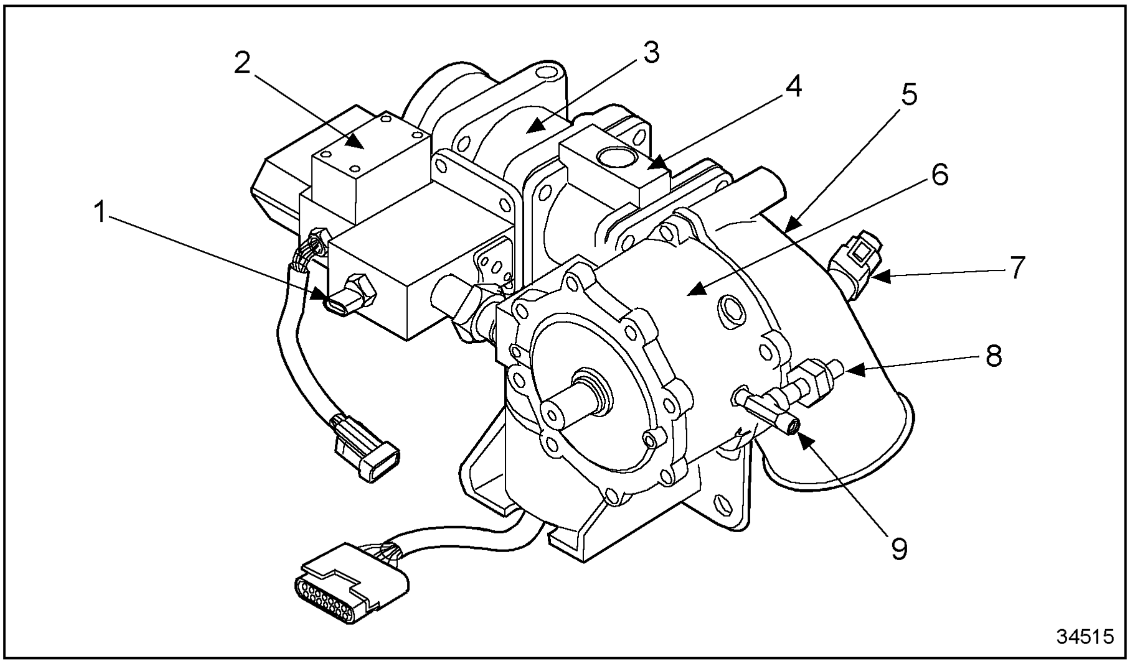
On natural gas engines with the low pressure fuel system, the fuel temperature sensor is located in the fuel mixer housing. See Figure 2-78.



1. Fuel Temperature Sensor
2. Mixer Housing

Figure 2-78 Fuel Temperature Sensor Series 50G Engine with Low Pressure Fuel System

On Series 50G engines with the high pressure fuel system the fuel temperature sensor is located in the PSV. See Figure 2-79.



1. Fuel Temperature Sensor
2. PSV
3. Fuel Mixer
4. Throttle
5. Air Inlet Elbow
6. Low Pressure Regulator
7. Air Temperature Sensor
8. Fuel Pressure Sensor
9. Fuel Inlet Tee Fitting

Figure 2-79 Fuel Temperature Sensor Series 50G Engine with High Pressure Fuel System

2.24.1 Repair or Replacement of Fuel Temperature Sensor

The FTS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.24.2 Removal of Fuel Temperature Sensor

Remove the FTS as follows:

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 from the fitting.

2.24.3 Installation of Fuel Temperature Sensor

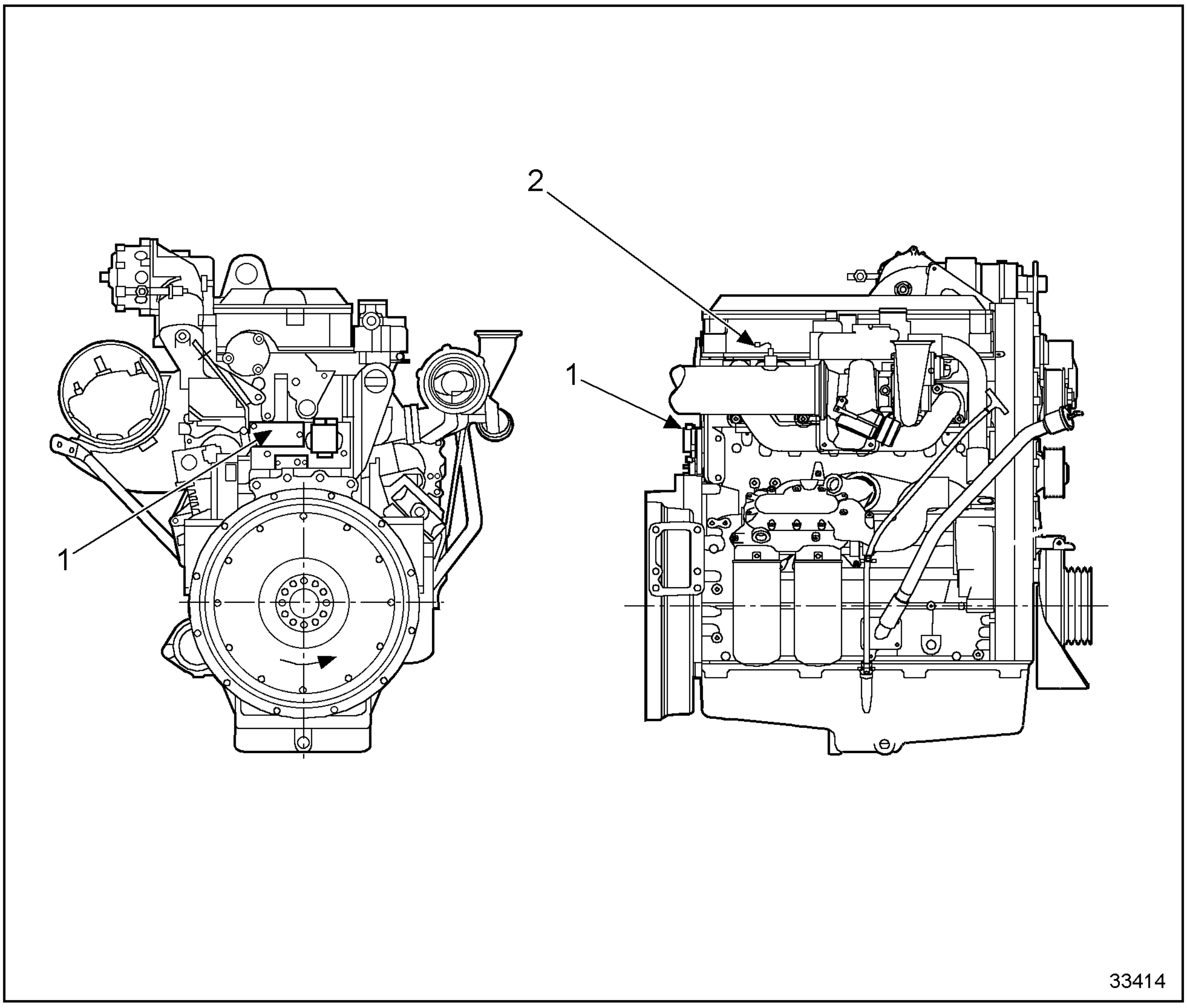
Install the FTS as follows:

NOTE:
The Fuel Temperature Sensor is an electrical device. Use care in the installation process.

1. Use Loctite Pipe sealer with Teflon J 26558-92 part of PT-7276 (or equivalent) on all but the first two threads of the FTS to prevent leaks.
2. Screw FTS into the fitting.
3. Engage the locking tang.
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 II Troubleshooting Guide*, 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497.

2.25 EXHAUST GAS OXYGEN SENSOR FOR SERIES 50G ENGINES

The Exhaust Gas Oxygen Sensor is mounted in the vehicle exhaust pipe within 12 inches of the turbocharger exhaust outlet in the top half of the pipe. See Figure 2-80. The sensor is threaded into an M18 boss welded to the exhaust pipe. See Figure 2-80. The sensor works in conjunction with an oxygen sensor interface module which is mounted to a sensor bracket located at the rear of the cylinder block above the flywheel housing. See Figure 2-80, see Figure 2-81, and see Figure 2-82.



1. Oxygen Sensor Interface Module
2. Exhaust Gas Oxygen Sensor

Figure 2-80 Location of the Exhaust Gas Oxygen Sensor and Oxygen Sensor Interface Module

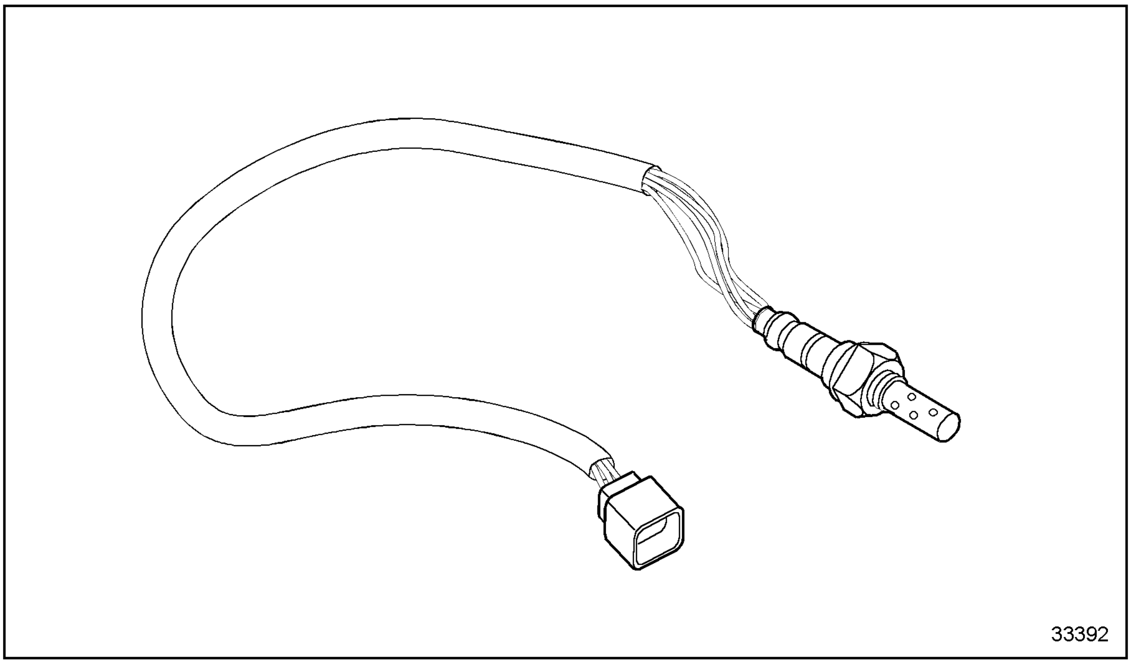


Figure 2-81 Exhaust Gas Oxygen Sensor

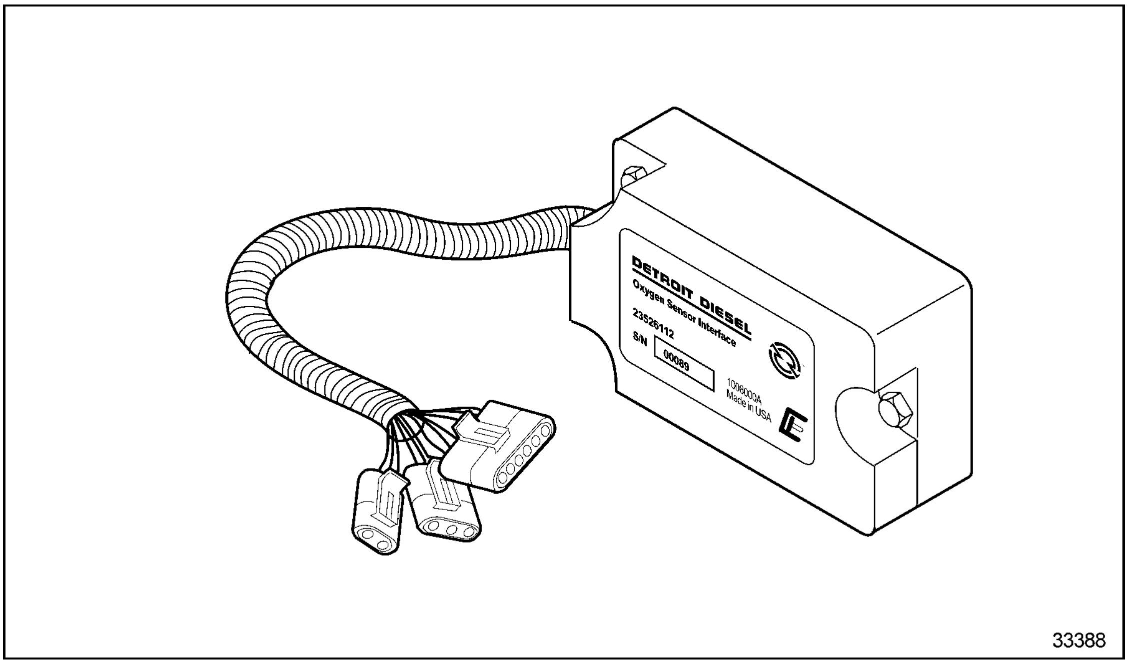


Figure 2-82 Oxygen Sensor Interface Module

The oxygen sensor and interface module provide a signal to DDEC which is proportional to the concentration of oxygen in the exhaust gas. DDEC calculates the air fuel ratio from this signal and uses the data in controlling fuel delivery to the engine. The exhaust gas oxygen sensor is electrically connected to the interface module through the oxygen sensor wiring harness. The oxygen sensor interface module is electrically connected to DDEC and to battery power through the engine sensor harness. The oxygen sensor is a heated sensor. This allows the sensor to function at the optimum temperature range for accuracy. The interface module is a micro processor that provides heater control, signal processing and diagnostic capabilities. The output from the oxygen sensor and interface module can be monitored using the Diagnostic Data Reader (DDR). The output is displayed as air/fuel ratio in Lambda units. Lambda is the ratio of actual air/fuel ratio to the stoichometric air/fuel ratio.

NOTICE:
Exposure to solvents, silicone sprays or excessive amounts of oil or water can cause exhaust gas oxygen sensor failure. Exercised care when cleaning or performing repairs on air system, cylinder kit, valve train, turbocharger and exhaust system components. It may be necessary to replace the oxygen sensor with a plug and run engine without the sensor briefly to prevent exposure.

2.25.1 Replacement of the Exhaust Gas Oxygen Sensor and the Oxygen Sensor Interface Module

The exhaust gas oxygen sensor and the oxygen sensor interface module are not serviceable and must be replace as an assembly. No adjustments are required.

2.25.2 Removal of the Exhaust Gas Oxygen Sensor and the Oxygen Sensor Interface Module

Remove the exhaust gas oxygen sensor as follows:

1. Disengage the connector between the oxygen sensor wire harness and oxygen sensor wire pig tail.
2. Loosen and remove the oxygen sensor from the exhaust pipe.

Remove the oxygen sensor interface module as follows:

1. Disconnect oxygen sensor harness 6 pin connector at interface module.
2. Disconnect 3 pin engine sensor wire harness connector at interface module.
3. Disconnect 2 pin engine sensor wire harness connector at interface module.
4. Remove three M6 bolts that attach the module to the sensor bracket.
5. Remove module from bracket.

2.25.3 Installation of the Exhaust Gas Oxygen Sensor and the Oxygen Sensor Interface Module

Install the exhaust gas oxygen sensor as follows:

1. New sensors have anti-seize compound pre-applied to the threads of the sensor. If reinstalling a used sensor, lightly apply anti-seize compound to threads of sensor.

NOTICE:
Use of excessive amount of anti-seize compound or direct sensing element contact with compound can cause sensor poisoning and erroneous sensor readings or failure.

2. Install sensor in boss and torque to 40–50 N·m.
3. Connect oxygen sensor harness to sensor.
4. Turn on ignition and, with the Diagnostic Data Reader, clear the AFR (air fuel ratio) learn table.
5. Start engine and check for check engine or stop engine light.

Install the oxygen sensor interface module as follows:

1. Position module on sensor bracket and install three M6 attaching bolts.
2. Connect to three pin and two pin connectors in engine sensor wire harness.
3. Connect to six pin connector in oxygen sensor wire harness.
4. Turn on ignition and, with the Diagnostic Data Reader, clear the AFR (air fuel ratio) learn table.
5. Start engine and check for check engine or stop engine light or read any diagnostic codes. If any code other than 25 is obtained, refer to the *DDEC II Troubleshooting Guidel,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

2.26 EXHAUST TEMPERATURE SENSOR FOR THE SERIES 50G ENGINES

The Exhaust Gas Temperature Sensor is threaded into the exhaust pipe within 12 inches of the turbocharger turbine outlet in the top half of the pipe. The devise is a temperature sensor that provides an electrical signal to the ECM. The sensor is electrically connected to the ECM through the engine sensor wiring harness. Temperature data from the sensor is used for engine protection and diagnostics.

2.26.1 Replacement of the Exhaust Gas Temperature Sensor

The Exhaust Gas Temperature Sensor is non-serviceable and must be replaced as an assembly. No adjustment is required.

2.26.2 Removal of the Exhaust Gas Temperature Sensor

Remove the exhaust gas temperature sensor as follows:

1. Disengage the connector from the engine sensor harness.
2. Loosen the nut remove sensor from the exhaust pipe.

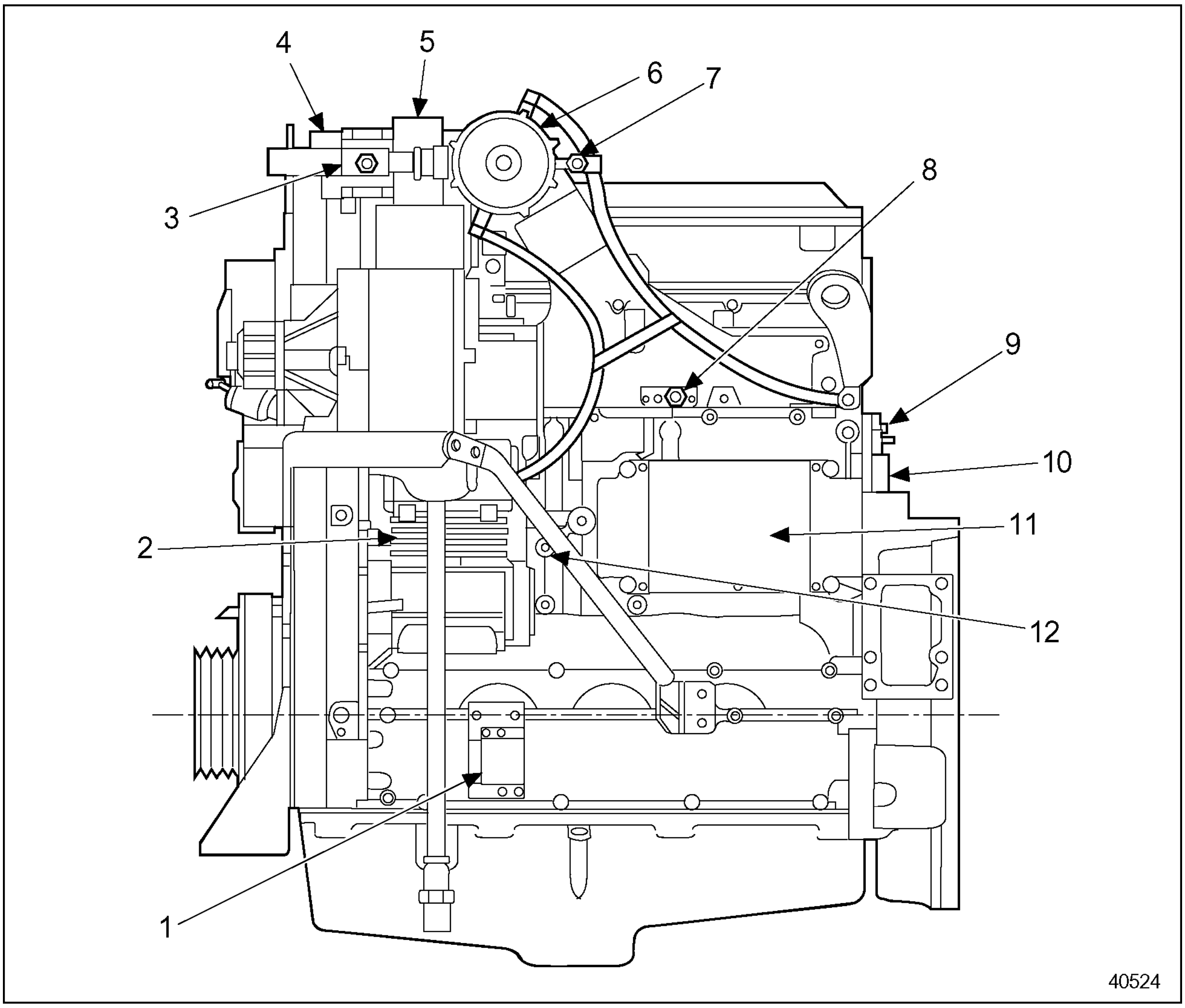
2.26.3 Installation of the Exhaust Gas Temperature Sensor

Install the exhaust gas temperature sensor as follows:

1. Insert in fitting in exhaust pipe.
2. Tighten nut.
3. Connect sensor to engine sensor wire harness.
4. Turn the ignition to the ON position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

2.27 KNOCK SENSOR AND SIGNAL TO NOISE ENHANCEMENT FILTER (S.N.E.F.) MODULE FOR THE SERIES 50G AUTOMOTIVE ENGINES

The Knock Sensor is mounted in the cylinder head or in the left side of the cylinder block. See Figure 2-83. The sensor works in conjunction with a Signal to Noise Enhancement Filter (S.N.E.F.) module which is mounted to a bracket located on the left side of the cylinder block.



1. S.N.E.F. Module
2. Air Compressor
3. PSV
4. Fuel Mixer
5. Throttle
6. Low Pressure Regulator
7. Regulator Gas Inlet Tee
8. Manifold Pressure "Boost" Sensor
9. Barometric Pressure Sensor
10. Oxygen Sensor Interface Module
11. DDEC ECM
12. Knock Sensor

Figure 2-83 Knock Sensor and Signal to Noise Enhancement Filter (S.N.E.F.) Module for Series 50G Automotive

The Knock Sensor and S.N.E.F. module provide a signal to DDEC which is proportional to the knock level. DDEC uses the data in engine protection logic. The knock sensor is electrically connected to the S.N.E.F. module through the sensor wiring harness. The S.N.E.F. module is electrically connected to the ECM and to battery power through the engine sensor harness. The output from the S.N.E.F. module can be monitored using the Diagnostic Data Reader (DDR). The output is displayed as knock level.

2.27.1 Replacement of Knock Sensor and S.N.E.F. Module

The knock sensor and S.N.E.F. module are not serviceable and must be replaced as an assembly. No adjustments are required.

2.27.2 Removal of Knock Sensor and S.N.E.F. Module

Remove the knock sensor as follows:

1. Disengage the connector between the knock sensor and engine sensor harness.
2. Loosen and remove the sensor.

Remove the S.N.E.F. module as follows:

1. Disconnect S.N.E.F. module connector from the engine sensor harness.
2. Remove two M6 bolts that attach the module to the bracket.
3. Remove module from bracket.

2.27.3 Installation of Knock Sensor and S.N.E.F. Module

Install the knock sensor as follows:

1. Install sensor in boss and torque to 17–21 N·m (2.5–3.0 lb·ft).
2. Connect knock sensor pigtail to sensor wiring harness connector.

Install the S.N.E.F. module as follows:

1. Position module on bracket and install two M6 attaching bolts.
2. Connect to engine sensor wire harness.
3. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497

2.28 OVERVIEW OF THE HIGH PRESSURE FUEL SYSTEM FOR THE SERIES 50G AUTOMOTIVE ENGINE (PRE 1998)

The purpose of the fuel system is to store the fuel, keep it clean and free from air, water, or other impurities and to deliver it to the combustion chamber at the correct pressure, temperature, air and fuel mixture. The Series 50G engine requires an adequate fuel supply for proper performance and to develop full rated power. This section describes the function requirements for the Detroit Diesel Series 50G high pressure natural gas fuel system.

The following are DDC supplied parts:

- ☐ Gas Mixer
- ☐ Compuvalve
- ☐ GFI pressure regulator
- ☐ Hose from compuvalve to Gas Mixer

The following are OEM supplied parts and are not serviced by Detroit Diesel:

- ☐ Tescom regulator
- ☐ Fuel tank
- ☐ Line from tank to regulator
- ☐ GFI pressure regulator bracket
- ☐ Fuel filters and brackets
- ☐ Hose from regulator to coalescing fuel filter
- ☐ Manual gas shutoff valve
- ☐ DDEC controlled shutoff valve
- ☐ Pressure gages
- ☐ Vehicle vent system
- ☐ Hose from coalescing fuel filter to compuvalve. See Figure 2-84 and see Figure 2-85.

The Series 50G spark ignited natural gas engine utilizes both Detroit Diesel Electronic Controls (DDEC) and the Gaseous Fuel Ignition (GFI) system to provide engine control. DDEC provides ignition timing, throttle position, and engine protection. The GFI system provides control and metering of the natural gas, based on input from sensors mounted directly on the engine.

The fuel system uses computer calculations for both fuel flow and air flow, and maintains a lean air - fuel mixture for low emissions and good fuel economy. Calculations are based on knowing the temperature and pressure of the air and fuel. The manifold absolute pressure (MAP), barometric absolute pressure (BAP), fuel absolute pressure (FAP), and fuel regulated temperature (FRT) are sensors internally located in the metering valve. The intake air temperature (IAT) sensor is mounted in the intake tube between the throttle and the air intake manifold. The additional oil temperature sensor (OTS) (displayed as MST on GFI fuel monitor) that is used by the fuel system is located in the left rear of block a few inches above the current DDEC oil temperature sensor.

2.28.1 Compressed Natural Gas Fuel System

The Series 50G engine has been designed for operation with two types of high pressure fuel systems, either compressed natural gas (CNG) or liquefied natural gas (LNG).

In CNG installations, fuel is stored in the fuel tanks under pressure as high as 3615 PSIA (3600 PSIG). In some installations, a high pressure fuel line supplies natural gas from the fuel tank to a Tescom regulator where it is reduced to an approximate pressure of 515 PSIA (500 PSIG) prior to entering the GFI pressure regulator. In newer CNG installations the TESCOM regulator has been eliminated and fuel is supplied to a different GFI regulator at pressures up to 3615 PSIA (3600 PSIG). Regardless of which installation type is used, the fuel pressure out of the GFI regulator should remain above 125 PSIA (110 PSIG). From the regulator, the fuel passes through a 1 micron coalescing gas filter to the computer and metering valve (compuvalve). The compuvalve then regulates fuel flow by means of a series of electronically controlled solenoids and injectors. Fuel is then passed to the gas mixing unit located in the air intake system upstream of the engine throttle. See Figure 2-84.

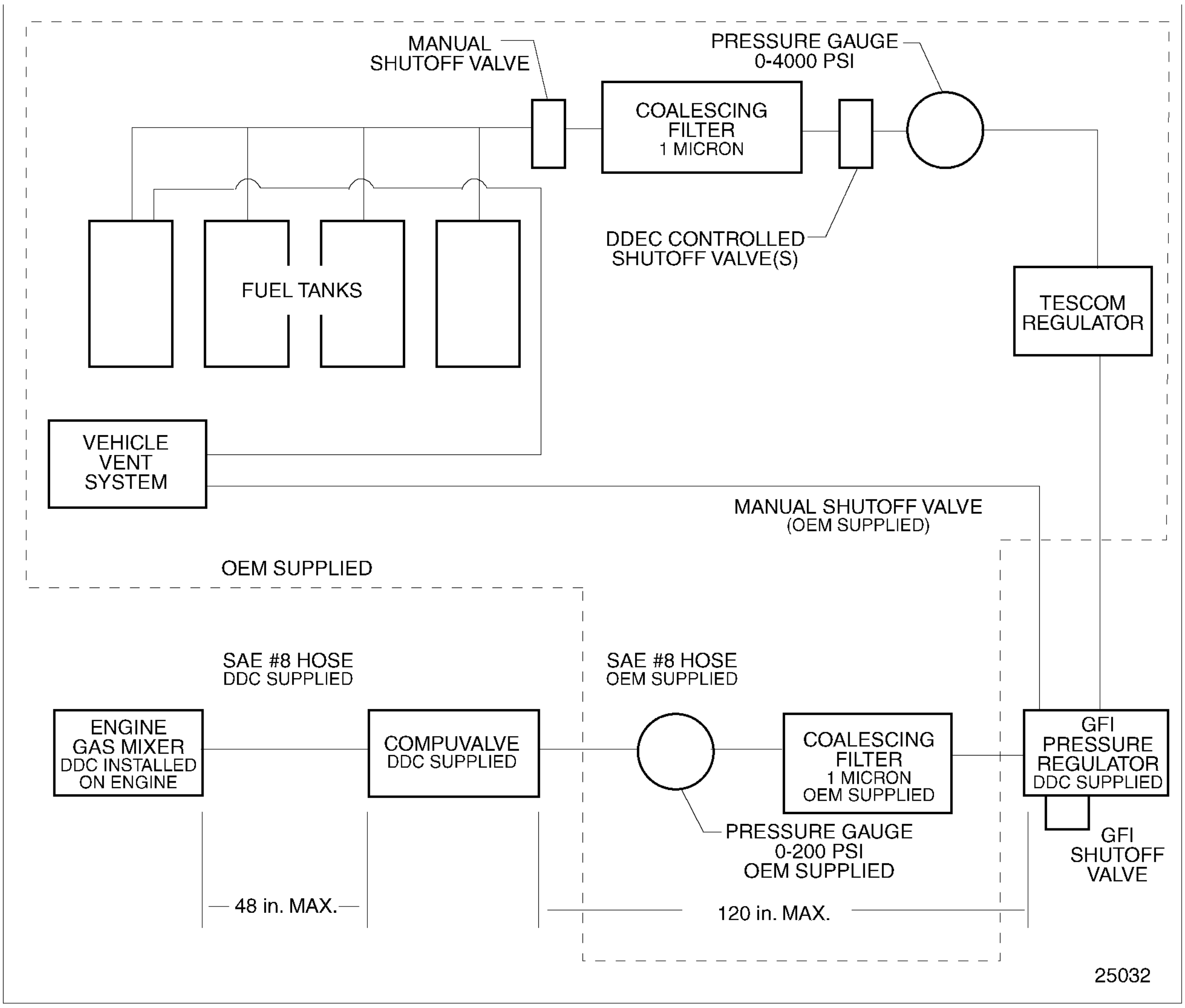


Figure 2-84 Compressed Natural Gas Fuel System Description

2.28.2 Liquefied Natural Gas Fuel System

In LNG installations fuel is stored in cryogenic storage tanks under pressure at extremely cold temperatures. The LNG fuel flows from the tank as a liquid or mixture of liquid and vapor through the manual shutoff valve to the vaporizer. The fuel is heated in the vaporizer and any liquid natural gas is vaporized or changed to a gaseous state. Regulators and control valves in the vehicle fuel system control the rate that fuel is supplied to the vaporizer and control the pressure of the gaseous fuel supply exiting the vaporizer. The vaporized fuel passes through an ignition controlled fuel shutoff valve to a one micron fuel filter and then on to the GFI regulator and compuvalve. The minimum inlet pressure to the GFI regulator 135 PSIA (120 PSIG). The pressure may be as high as 265 PSIA (250 PSIG). The GFI regulator and compuvalve for the LNG fuel system are different than those for the CNG fuel system. Fuel is metered from the compuvalve and passed to the gas mixing unit located in the air intake system upstream from the throttle. See Figure 2-85.

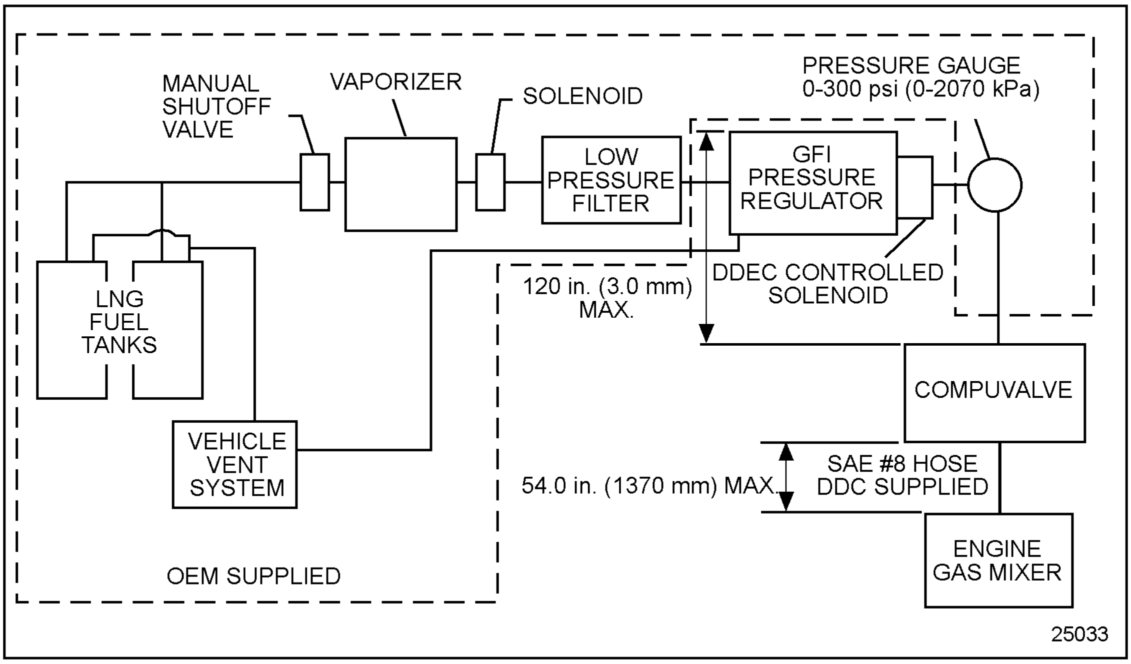


Figure 2-85 Liquefied Natural Gas Fuel System

2.29 OVERVIEW OF HIGH PRESSURE FUEL SYSTEM FOR 1998 AND LATER SERIES 50G AUTOMOTIVE ENGINES

For 1998 a new fuel system was introduced for Series 50G automotive model engines. For a schematic diagram of a typical CNG fuel system, see Figure 2-86.

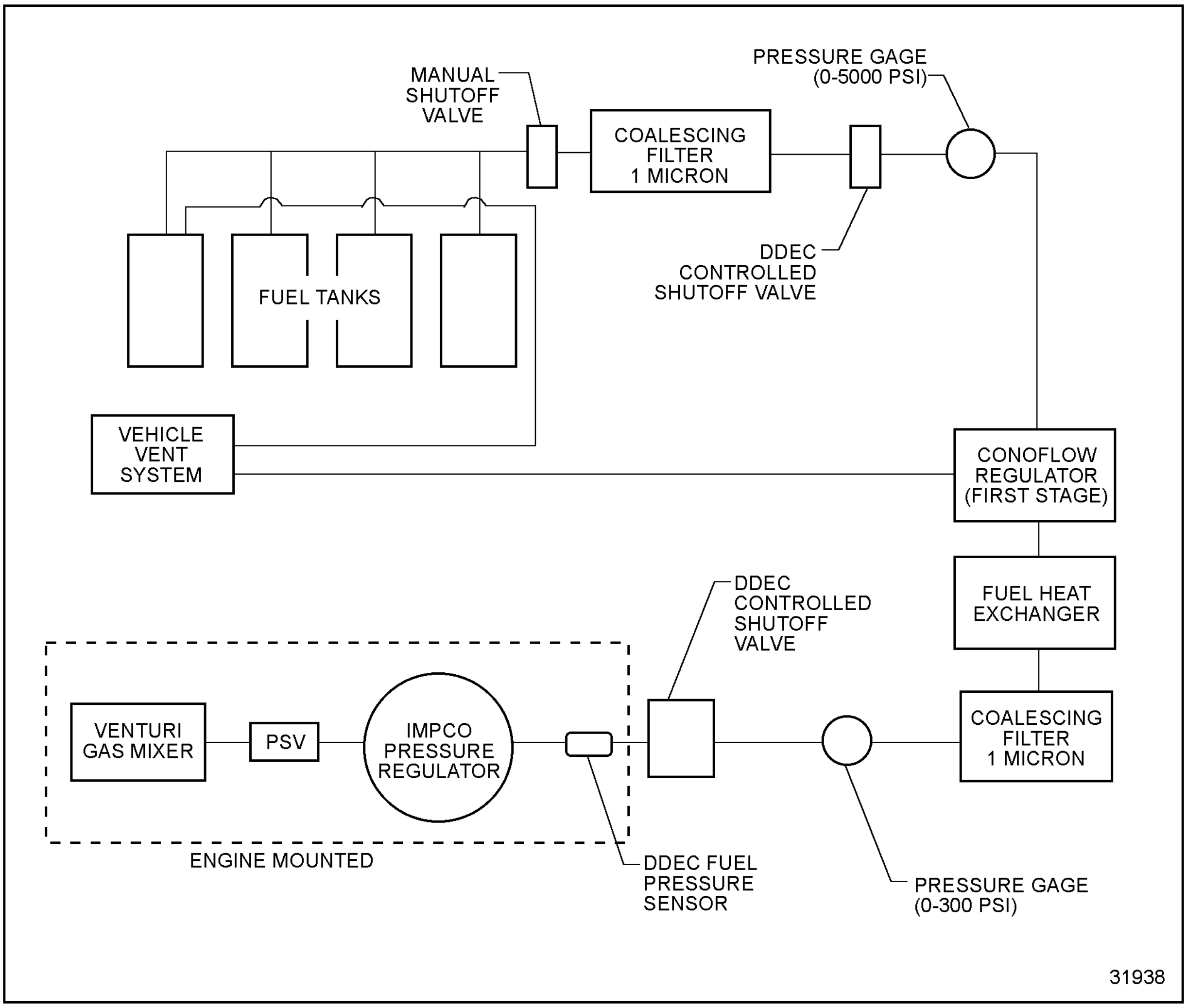


Figure 2-86 Schematic Diagram of Typical CNG Fuel System for 1998 and Later Series 50G Engines

The fuel system includes the following components:

DDC supplied:

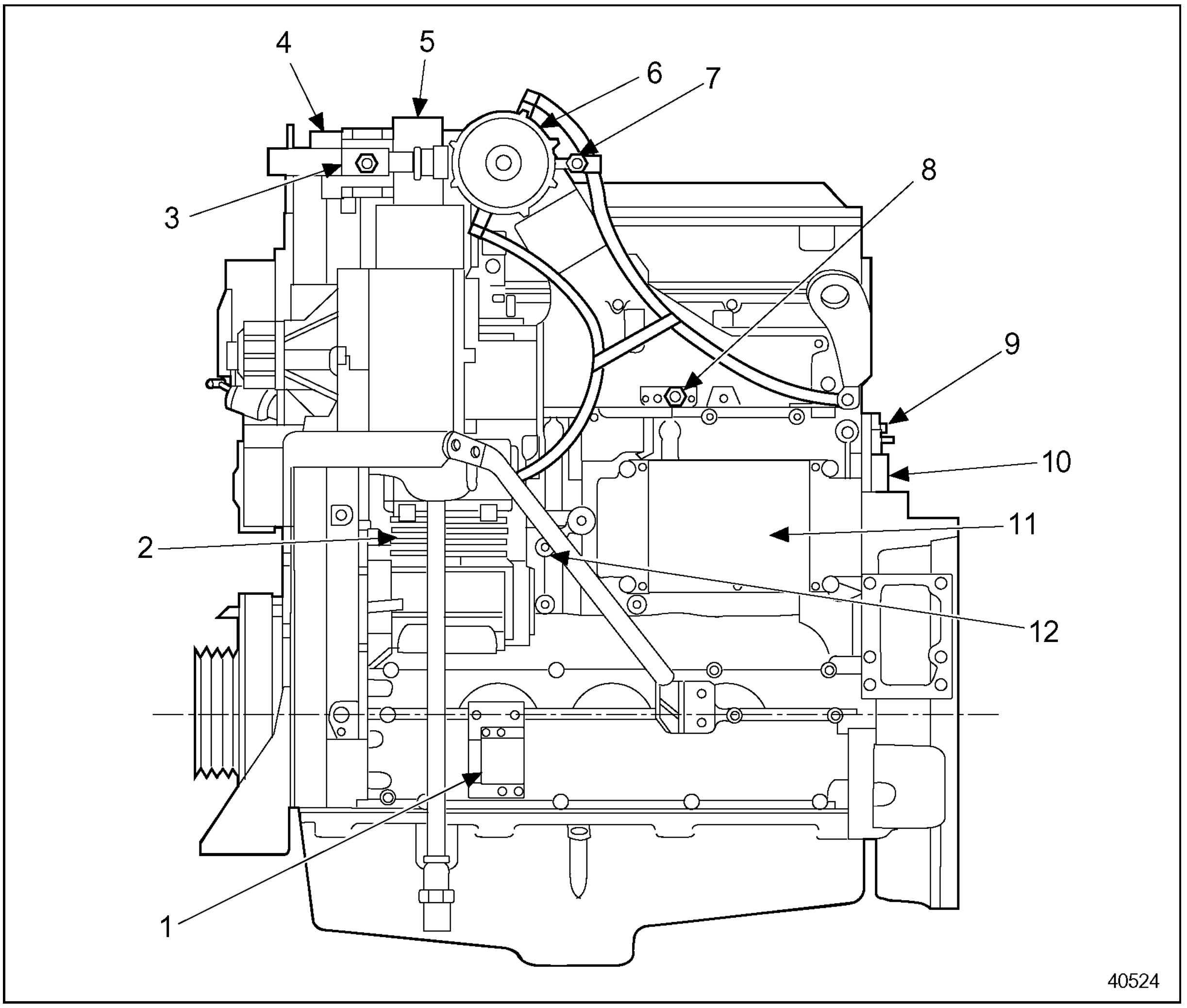
- ☐ Venturi Type Gas Mixer
- ☐ PSV (Pulse width modulated Stepper motor Valve)
- ☐ IMPCO Low Pressure Regulator
- ☐ ITT Conoflow High Pressure Regulator
- ☐ Low Pressure DDEC Controlled Gas Shutoff Valve

OEM supplied:

- ☐ Fuel Tanks
- ☐ Fuel Lines
- ☐ Manual Shutoff Valves
- ☐ Coalescing Fuel Filters
- ☐ High Pressure DDEC Controlled Gas Shutoff Valve
- ☐ Pressure Gages
- ☐ Fuel Heat Exchanger

See Figure 2-87for a component overview of the High Pressure fuel system.

The fuel system is designed to accurately deliver clean fuel at the correct air fuel mixture to the combustion chamber at any engine operating condition.



1. SNEF Module
2. Air Compressor
3. Fuel Temperature Sensor
4. PSV
5. Throttle Actuator
6. IMPCO Regulator
7. Fuel Pressure Sensor, Fuel Inlet
8. Manifold Air Pressure Sensor
9. Barometric Air Pressure Sensor
10. Ignitor Module
11. Electronic Control Module
12. Knock Sensor and Stud

Figure 2-87 Series 50G Automotive Engine Component Location

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

CAUTION:

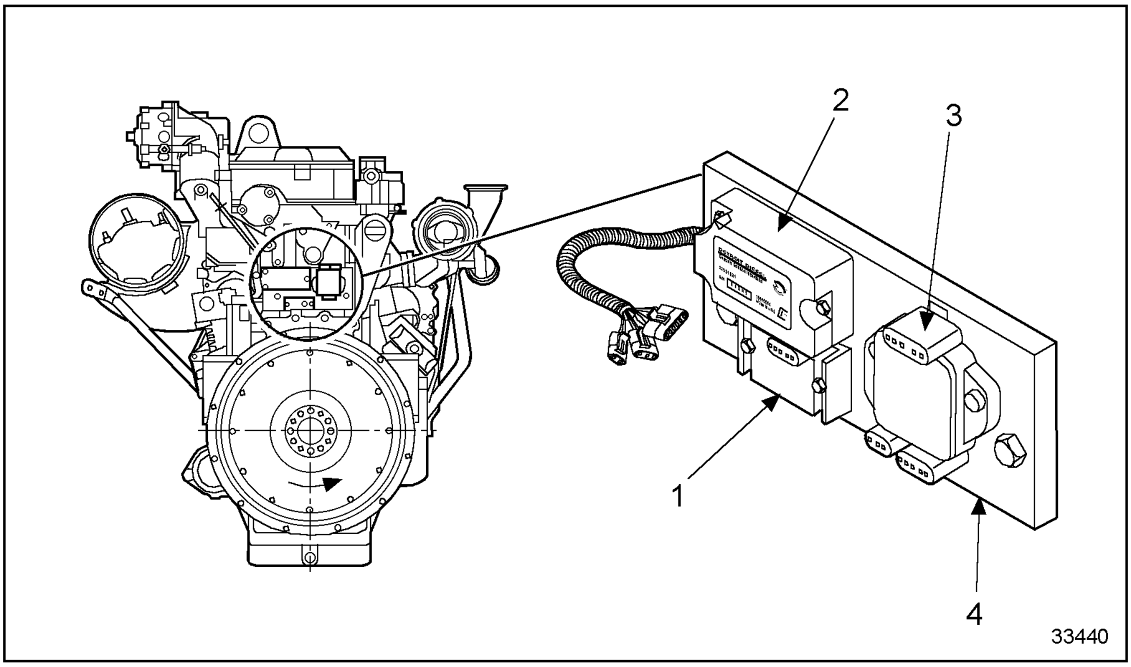
To avoid injury from fire, check for fuel or oil leaks before welding or carrying an open flame near the engine.

Fuel is stored in the fuel tanks at a pressure as high as 3600 PSI. The fuel passes through high pressure fuel shutoff valves, typically controlled by both DDEC and OEM systems, through primary fuel filters to the high pressure regulator. The pressure is reduced by the high pressure regulator to approximately 110 PSI. Flow continues through the secondary fuel filter, through the DDEC controlled low pressure fuel shutoff valve on to the low pressure regulator. The low pressure regulator is balanced to the air system at the inlet to the fuel mixer assembly. It maintains outlet fuel pressure slightly higher than turbo boost pressure at the mixer inlet. Fuel from the regulator passes through the PSV, enters the venturi mixer and is mixed with incoming air. Air flow through the venturi creates a pressure drop at the throat of the venturi that increases and decreases in proportion to air flow. This pressure differential is used to draw fuel through the venturi insert, the PSV and low pressure regulator. The system is sometimes referred to as a demand system. Increases in pressure drop across the venturi increases the demand for fuel flow required to maintain the fuel outlet pressure at the low pressure regulator. Fine control of fuel flow is achieved by positioning of the gas valve. Changes in gas valve position change the flow restriction between the venturi and low pressure regulator. For a given set of engine speed and load conditions, reducing the valve opening increases restriction resulting in reduced fuel flow and a leaner air fuel mixture. Likewise, increasing the valve opening reduces restriction resulting in increased fuel flow and a richer air fuel mixture.

In part, fuel flow is controlled by calibration and matching of the key fuel system components, the venturi mixer, the PSV (gas valve position) and the low pressure regulator. Electronics are used to further refine control. Electric control is provided by DDEC. The DDEC output which allows control of fuel delivery is gas valve position. Input to DDEC for fuel delivery control is provided by engine speed, inlet manifold pressure, inlet manifold temperature, fuel temperature, coolant temperature, throttle position and exhaust gas oxygen sensors. In addition exhaust gas temperature, fuel pressure and knock sensors provide engine protection and diagnostics capabilities unique to the S50 natural gas engine. The system is a closed loop system. This refers to the fact that input or feedback from the exhaust gas oxygen sensor is used to make adjustments in fuel delivery. The system is constantly making use of this feedback to adjust air fuel ratio to the desired value. Electronic control of the fuel system provides the capability to adjust and correct for changes in operating condition, environmental condition, changes in fuel quality, differences in components and component changes that occur over time. For fuel quality specifications refer to Section 5.1. Refer to Section 2.11for details on the DDEC system for Series 50 Natural Gas engines.

2.30 BAROMETRIC PRESSURE SENSOR FOR THE SERIES 50G ENGINE WITH HIGH PRESSURE FUEL SYSTEM 1998 AND LATER

The Barometric Pressure Sensor (BARO sensor) is mounted to the sensor bracket at the rear of the cylinder block just above the flywheel housing. The sensor sends an electrical signal to the ECM indicating barometric pressure. It is electrically connected to the ECM through the engine sensor wire harness. A hose is attached to the inlet of the sensor to protect it form dirt and prevent plugging. The ECM uses the data in controlling fuel delivery to the engine. See Figure 2-88.



1. Barometric Pressure Sensor
2. Oxygen Sensor Interface Module
3. Ignitor Module
4. Sensor Bracket

Figure 2-88 Barometric Pressure Sensor for Series 50G Engines

2.30.1 Replacement of the Barometric Pressure Sensor

The barometric pressure sensor is non-serviceable and must be replaced as an assembly.

2.30.2 Removal of the Barometric Pressure Sensor

Remove the Barometric Pressure Sensor as follows:

1. Disengage the locking tang on the BARO sensor.
2. Disconnect the hose from the inlet of the sensor.
3. Loosen two attaching bolts and remove sensor from bracket.

2.30.3 Installation of the Barometric Pressure Sensor

Install the BARO sensor as follows:

NOTICE:
Use care tightening sensor attaching bolts. Overtightening the bolts will damage the sensor.

1. Install the sensor on the bracket. Torque bolts to 24 in·lbs.
2. Connect the inlet hose.
3. Engage it to the sensor wire harness connector.
4. Turn ignition on and, with Diagnostic Data Reader, clear the AFR (air fuel ratio) learn table.
5. Turn ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,*6SE497

2.31 HIGH PRESSURE FUEL REGULATOR FOR THE SERIES 50G ENGINE

The Conoflow high pressure fuel regulator is typically mounted in the vehicle's engine compartment. The function of the regulator is to supply fuel flow based on engine demand at a reduced pressure. The regulator reduces tank pressure, which can be as high as 3600 PSI, to approximately 110 PSI. The regulator is coolant heated with coolant supply from the cylinder head and return to the water pump inlet. The regulator includes a pressure relief device to protect down stream components. The pressure relief valve is set to open at approximately 300 PSI. The pressure relief is connected to the vehicle gas vent system. The gas inlet connection to the regulator is a female SAE No. 6 O-ring connection. The gas outlet is a female SAE No. 8 O-ring connection. The pressure relief is a male 1/4 NTPF connection. Coolant supply and return connections are 1/4 inch NPTF female pipe thread holes. See Figure 2-89.

NOTE:
The O-ring material is nitrile. If the O-ring is replaced, it must be replaced by a nitrile based O-ring.

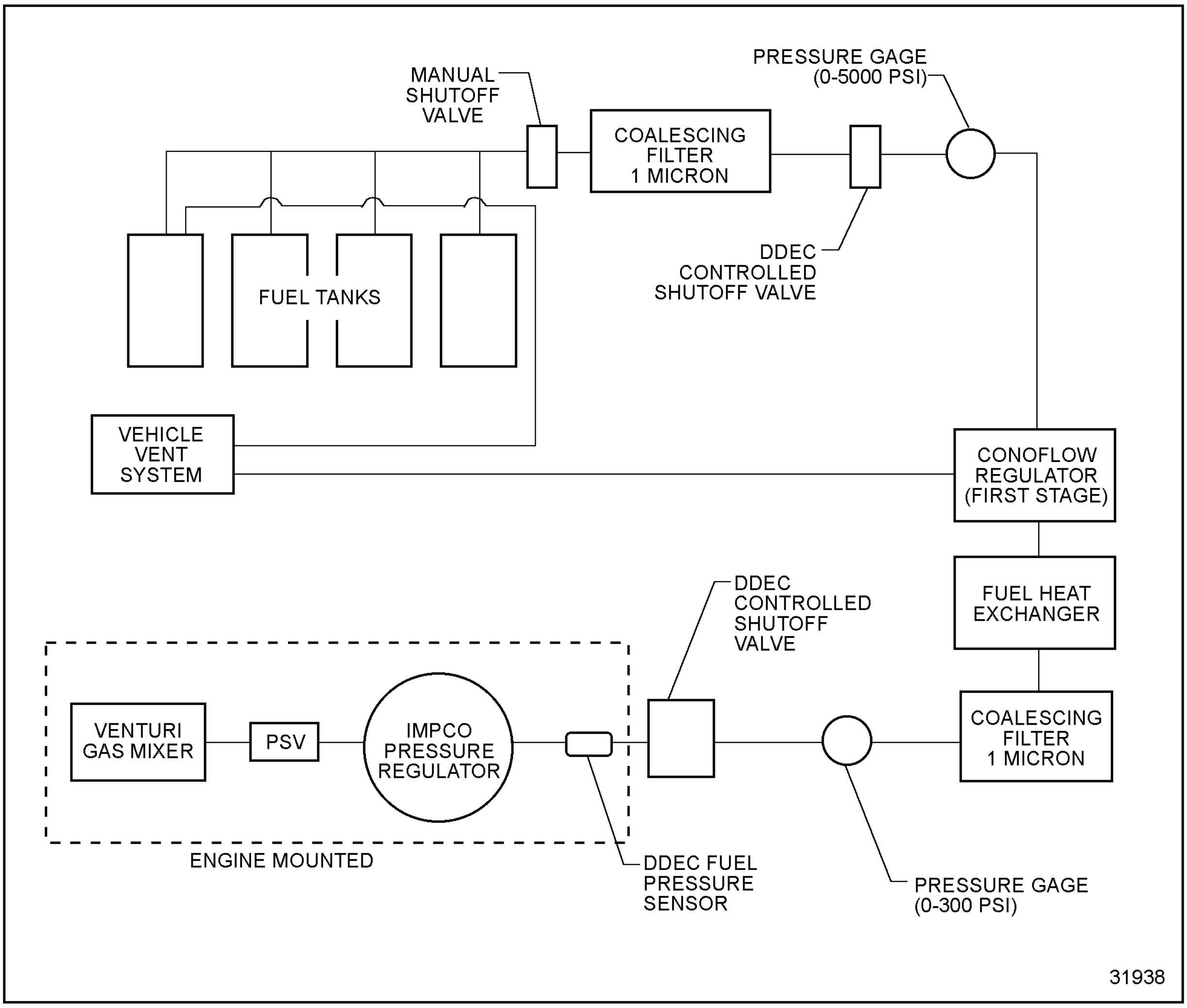


Figure 2-89 High Pressure Fuel Regulator for Series 50G Engines

2.31.1 Replacement of the High Pressure Regulator for the Series 50G Engine

The high pressure fuel regulator is not serviceable and should be replaced as a unit. No adjustment is required.

2.31.2 Removal of the High Pressure Regulator for the Series 50G Engine

Remove the high pressure fuel regulator as follows:

1. Vent fuel system, refer to Section 2.43.
2. Disconnect fuel supply pipe at regulator inlet.
3. Disconnect fuel pipe from regulator outlet.
4. Drain coolant.
5. Disconnect coolant supply and return hoses at regulator.
6. Disconnect vent pipe at regulator.
7. Remove two M8 bolts attaching the regulator to its mounting bracket.
8. Remove regulator from bracket and remove fittings for reuse.

2.31.3 Installation of the High Pressure Regulator for the Series 50G Engine

Install the high pressure fuel regulator as follows:

1. Install gas inlet and outlet O-ring fittings.

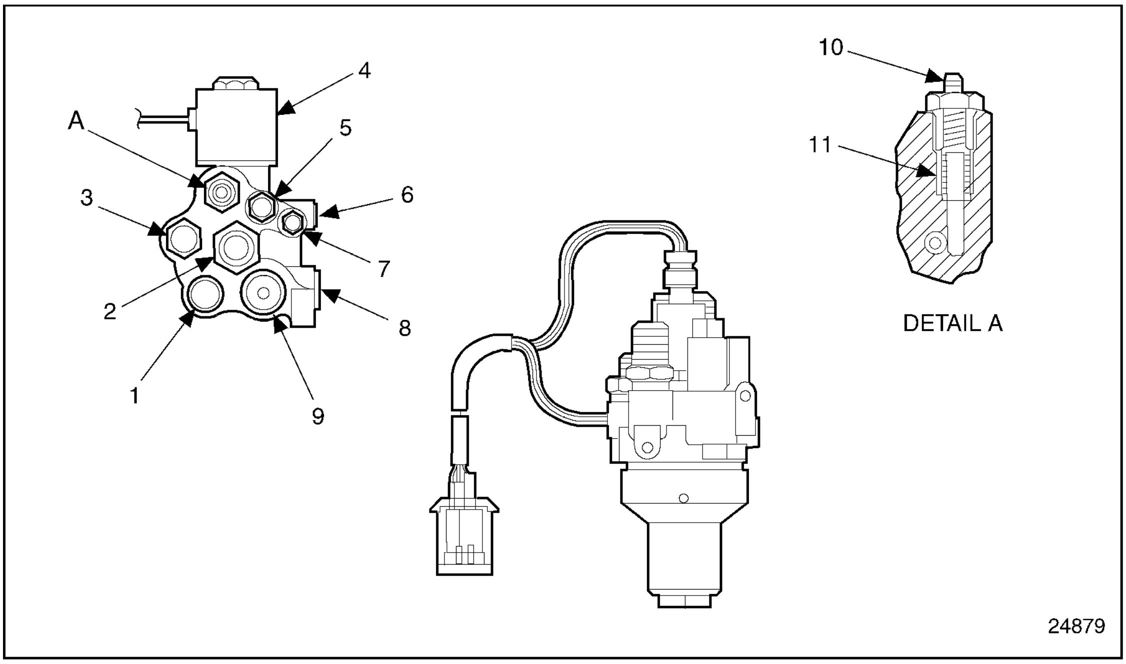
NOTE:
The O-ring material is nitrile. If the O-ring is replaced, it must be replaced by a nitrile based O-ring.

2. Position regulator on mounting bracket.
3. Install two M8 mounting bolts.
4. Connect fuel outlet pipe.
5. Connect fuel supply pipe.
6. Connect coolant supply and return hoses.
7. Refill with coolant.
8. Connect vent pipe.
9. Open fuel shutoff valves and crank engine to supply fuel to regulator.
10. Check for leaks, refer to Section 2.43.3.

2.32 HIGH PRESSURE FUEL REGULATOR FOR THE SERIES 50G ENGINE PRIOR TO 1998

The GFI system uses a high pressure single stage regulator to control gas pressure. See Figure 2-90. Natural gas enters the regulator at the inlet port and goes through an integral 40 micron filter. Filtered gas flows to the high pressure solenoid activated valve that, when activated, allows natural gas to flow to the pressure regulator section and high pressure transducer.

NOTE:
In some installations, a Tescom 500 PSI step down regulator is installed upstream of the GFI pressure regulators.



1. Relief Port
2. High Pressure Sensor
3. Gas Outlet
4. Solenoid
5. Coolant Inlet
6. Alternate
7. Coolant Outlet
8. Alternate Relief Port
9. Relief Valve
10. Gas Inlet
11. Filter

Figure 2-90 High Pressure Fuel Regulator for the Series 50G Engine Prior to 1998

The regulator section uses a conventional spring-diaphragm-pintle mechanism to regulate pressure in the outlet chamber. From the outlet chamber, regulated gas is passed to the outlet port. The outlet chamber is also connected to a 175 PSIG pressure relief valve. If the outlet chamber pressure exceeds 175 PSI, the valve opens and vents to relief port or alternate relief port. The pressure regulator relief valve must be incorporated into the vehicle vent system in accordance with N.F.P.A. 52 "Compressed Natural Gas (CNG) Vehicular Fuel Systems."

This regulator uses a counterflow coolant circuit. Two standard ports and one alternate port are provided. Engine coolant is circulated through hoses to one port then returned through one of the other ports. The coolant must have 35°F (37°C) capability.

2.32.1 Replacement of the High Pressure Fuel Regulator for the Series 50G Engine Prior to 1998

Prior to removal of the high pressure fuel system regulator, the fuel system must be vented. Refer to Section 2.36.1 and refer to Section 2.36.2.

The GFI regulator is non-serviceable and should be replaced as a unit. No adjustment is required. Several different type GFI regulations are used depending on the installation type and all are very similar in appearance. When replacing a GFI regulator be certain to replace with the same part number or the correct service replacement part number regulator.

2.32.2 Removal of the High Pressure Fuel Regulator for the Series 50G Engine Prior to 1998

Prior to removal or replacement of the high pressure fuel regulator, the fuel system must be vented. Refer to Section 2.36.1and refer to Section 2.36.2.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

After the fuel system has been properly vented, remove the regulator as follows:

1. Disconnect the wire harness.
2. Drain cooling system.
3. Disconnect supply and return hoses at regulator.
4. Disconnect gas outlet hose at regulator gas outlet.
5. Disconnect gas inlet hose at regulator gas inlet.
6. Disconnect vent hose at regulator relief port.
7. Remove two attaching bolts to loosen the regulator from its bracket.

2.32.2.1 Inspection of the High Pressure Fuel Regulator for the Series 50G Engine Prior to 1998

Inspection of the regulator is not required.

2.32.3 Installation of the High Pressure Fuel Regulator for the Series 50G Engine Prior to 1998

Install the High Pressure Fuel Regulator as follows:

NOTICE:
During all operations, ensure no dirt or debris is allowed to enter unit. Tightly cap or cover all open ports and openings. Do not remove the factory caps until it is time to install the hoses.

1. Mount the regulator on its bracket and install 2 attaching bolts.

NOTICE:
The regulator must be located such that it is protected from road hazards, accidents, or any other external items that could damage the pressure regulator or adjoining fuel lines.

2. Connect vent hose at regulator relief port.
3. Connect gas inlet host at regulator gas inlet.
4. Connect gas outlet hose at regulator gas outlet.
5. Connect coolant supply and return hoses at regulator.
6. Refill cooling system.
7. Connect the wire harness.
8. Open manual gas shutoff valve and start engine.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

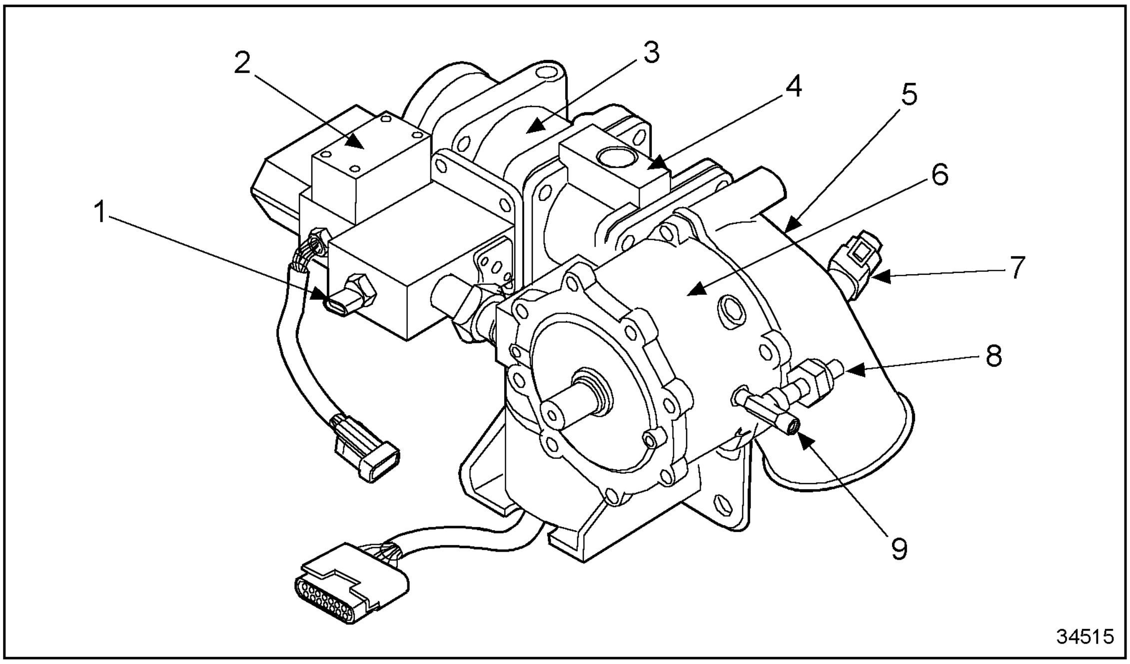
- ☐ **Do not smoke when installing or servicing the engine or fuel system.**
- ☐ **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- ☐ **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- ☐ **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- ☐ **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- ☐ **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- ☐ **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- ☐ **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

[a] Refer to Section 2.36.3 for leak checking procedure.

2.33 FUEL MIXER FOR THE SERIES 50G HIGH PRESSURE SYSTEM 1998 AND LATER

The venturi fuel mixer assembly consists of a die cast aluminum body with a spun aluminum venturi permanently inserted into it. The unit has no moving parts. The mixer assembly is attached to the throttle located at the left front of the engine. See Figure 2-91.



1. Fuel Temperature Sensor
2. PSV
3. Fuel Mixer
4. Throttle
5. Air Inlet Elbow
6. Low Pressure Regulator
7. Air Temperature Sensor
8. Fuel Pressure Sensor
9. Fuel Inlet Tee Fitting

Figure 2-91 Fuel Mixer for the Series 50G

2.33.1 Replacement of Fuel Mixer for the Series 50G Engine

The fuel mixer is non-serviceable and should be replaced as a unit. No adjustment is required.

2.33.2 Removal of Fuel Mixer for the Series 50G Engine

Remove the fuel mixer as follows:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Vent fuel system; refer to Section 2.43.1and refer to Section 2.43.2.
2. Disconnect hose between mixer and charge cooler outlet tube.
3. Disconnect and remove the PSV from the fuel mixer, refer to Section 2.38.3.
4. Disconnect air balance hose at mixer.
5. Remove four fuel mixer mounting bolts.
6. Separate and remove the fuel mixer from the throttle.

2.33.3 Installation of Fuel Mixer for the Series 50G Engine

Install the fuel mixer as follows:

1. Clean gasket surface and install a new gasket.
2. Secure the fuel mixer to the throttle with four bolts finger tight.
3. Install the PSV to the fuel mixer, refer to Section 2.38.3.
4. Connect air balance hose to PSV and mixer.
5. Torque mixer bolts to 20 N·m (15 ft·lbs).
6. Connect hose between mixer and charge cooler outlet tube.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

7. Perform a leak check procedure. Refer to Section 2.43.3.

2.34 FUEL SHUTOFF VALVE FOR 1998 AND LATER SERIES 50G ENGINE WITH HIGH PRESSURE FUEL SYSTEM

The fuel shutoff valve is typically mounted in the engine compartment. It **must be no further than 24 inches away** from the low pressure fuel regulator. The function of the valve is to shutoff fuel at the inlet of the IMPCO regulator. The valve is powered by an electric solenoid. The valve is normally closed and is available with either 12 volt or 24 volt solenoids. Electrical power to the solenoid is controlled by both DDEC and vehicle electrical systems. The DDEC ECM supplies a signal to open the valve when ignition is on and engine speed is above 60 RPM. The valve is closed when ignition is switched off, or when engine speed falls below 60 RPM or when an engine protection shutdown occurs. Vehicle systems typically tie power to the valve with the ignition switch and other safety systems such as fire suppression or methane (gas leakage) detection systems. The solenoid power is supplied through the vehicle wire harness. The gas inlet and outlet are female 1/2 inch NPTF connections. The shutoff valve comes with a mounting bracket attached. See Figure 2-92.

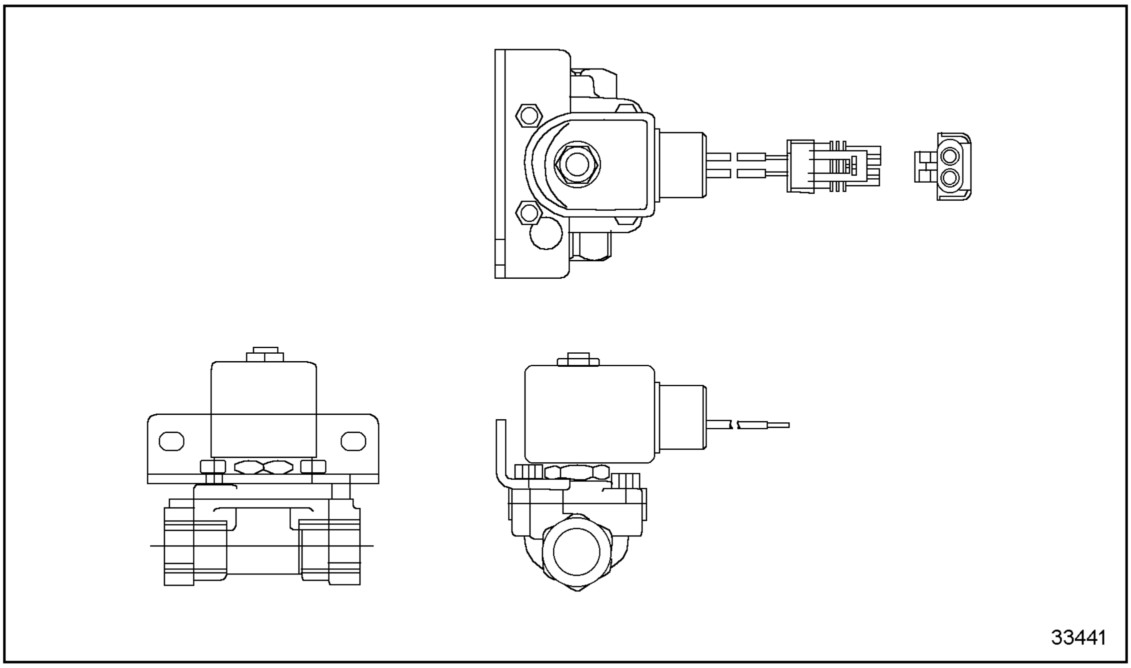


Figure 2-92 Fuel Shutoff Valve for Series 50G Engine

2.34.1 Replacement of the Fuel Shutoff Valve for the Series 50G Engine

The fuel shutoff valve is not serviceable and should be replaced as a unit. No adjustment is required.

2.34.2 Removal of the Fuel Shutoff Valve for the Series 50G Engine

Remove the fuel shutoff valve as follows:

1. Vent fuel system, refer to Section 2.43.
2. Disconnect fuel supply pipe at shutoff inlet.
3. Disconnect fuel pipe from shutoff outlet.
4. Disconnect electrical connector.
5. Remove two bolts attaching the shutoff valve bracket to its mounting bracket and remove shutoff valve and bracket assembly.

2.34.3 Installation of the Fuel Shutoff Valve for the Series 50G Engine

Install the fuel shutoff valve as follows:

1. Install gas inlet and outlet fittings.
2. Position shutoff valve on mounting bracket.
3. Install mounting bolts.
4. Connect fuel outlet hose to outlet fitting.
5. Connect fuel supply pipe to inlet fitting.
6. Connect solenoid electrical connector to connector in vehicle wire harness.
7. Open manual fuel shutoff valves and crank engine to supply fuel.
8. Check for leaks, refer to Section 2.43.3.

2.35 FUEL PRESSURE GAGES FOR THE SERIES 50G ENGINE WITH A HIGH PRESSURE FUEL SYSTEM

Fuel pressure gages should be installed on both high and low pressure sides of fuel system. The high pressure gage should have a range of 0 - 4000 PSI mounted between the tank and 1st stage regulator. The low pressure gage should have a range of 0 - 300 PSI. The gages should be located for ready access for maintenance mounted between the GFI regulator and Compuvalve.

2.35.1 Replacement of Fuel Pressure Gages for the Series 50G Engine

Detroit Diesel does not service the fuel pressure gages. Refer to OEM to replace as necessary.

2.35.2 Removal of Fuel Pressure Gages for the Series 50G Engine

Prior to removal or replacement of fuel system pressure gages, the fuel system must be vented. Refer to Section 2.36.1 and refer to Section 2.36.2.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

Refer to OEM for removal procedure for the fuel pressure gages.

2.35.2.1 Inspection of Fuel Pressure Gages for the Series 50G Engine

Refer to OEM for inspection procedure for the fuel pressure gages.

2.35.3 Installation of Fuel Pressure Gages for the Series 50G Engine

Refer to OEM for installation procedure for the fuel pressure gages.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

Refer to Section 2.36.3 for leak checking procedure.

2.36 VENTING AND LEAK CHECKING PROCEDURES FOR A NATURAL GAS ENGINE (HIGH PRESSURE SYSTEM)

To vent and leak check an operable engine, refer to Section 2.36.1:

2.36.1 Venting an Operable Engine to Relieve Natural Gas Pressure

Vent an operable engine as follows:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Shut off manual valves on natural gas supply tanks and main shutoff valve on natural gas fuel supply line.
2. Start engine and run until it stalls due to fuel starvation.
3. Check to make sure gage pressure at point on the natural gas fuel line to be vented has been reduced to zero. If not, repeat step 1. Then repeat step 2.
4. Disconnect the vehicle batteries using switch(s) in the battery compartment or by disconnecting battery ground cable.
5. Slightly loosen the CNG fuel line fitting to be serviced in a well-ventilated area to allow any remaining gas to vent.
6. Completely open the fitting that was slightly opened and allow to vent in a well-ventilated area.

2.36.2 Venting an Inoperable Engine to Relieve Natural Gas Pressure

If the engine *cannot run*, use the following venting procedure to relieve the natural gas pressure downstream of the shutoff valve:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Shut off manual valves on natural gas supply tanks and main shutoff valve on natural gas fuel supply line.
2. Disconnect the vehicle batteries using switch(s) in the battery compartment or by disconnecting the battery ground cable.
3. Open a fitting to assure all pressure has been relieved in the natural gas vehicle fuel line.
4. Check all connections that were loosened for leaks after installation, service and troubleshooting are complete.

2.36.3 Leak Checking the Natural Gas Fuel System

Use the following steps to check for leaks:

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

1. Spray soapy water or commercially available leak checking solutions on connections which are pressurized to working pressure. Bubbles will form if there is a leak.
2. Repair any leak by:

   [a] Tightening connection using the fitting manufacturer's technique.

NOTE:

Bleed the fuel lines before replacing leaking components using the procedure in this section. This will prevent a discharge of gas.

[b] Replacing leaking component.

[c] Replace the pipe threaded connector with a new one if the leak is a pipe thread connection. Use anaerobic sealant with Teflon (such as SWAK®) applied to the threads.SWAK® is a registered trademark of the Cajon Company.

3. Re-check connection with procedure in step1.
4. Use a combustible gas detector to check for presence of natural gas. If natural gas is detected, continue looking for leaks until the locations of all the leaks are determined.
5. Repair the leak using the procedure in step2.

2.37 FUEL MIXER FOR THE SERIES 50G ENGINE WITH HIGH PRESSURE FUEL SYSTEM (PRIOR TO 1998)

The fuel mixer assembly consists of a die cast aluminum body with a spun aluminum insert permanently installed. The unit has no moving parts. The mixer assembly is attached to the throttle on the left front side of the engine. See Figure 2-93.

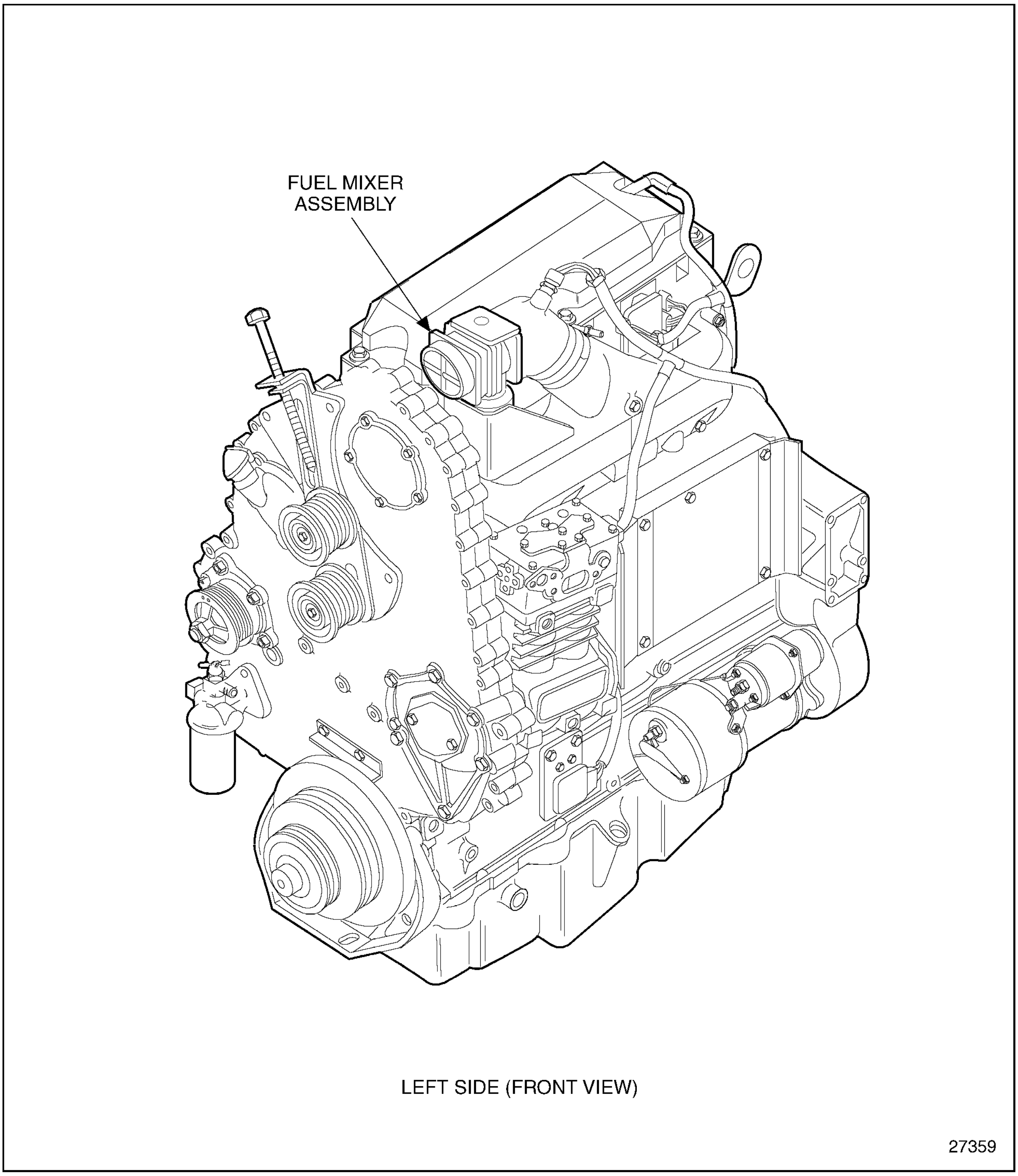


Figure 2-93 Fuel System (Series 50G Engine)

2.37.1 Replacement of Fuel Mixer for the Series 50G Engine

The fuel mixer is non-serviceable and should be replaced as a unit. No adjustment is required.

2.37.2 Removal of Fuel Mixer for the Series 50G Engine

Remove the fuel mixer as follows:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Vent fuel system; refer to Section 2.43.1and refer to Section 2.43.2.
2. Disconnect gas inlet hose at mixer.
3. Disconnect air inlet hose at mixer housing.
4. Remove bolts attaching mixer housing to throttle.
5. Separate and remove the fuel mixer from the throttle.

2.37.3 Disassembly of Fuel Mixer for the Series 50G Engine

Disassembly of the fuel mixer is not required.

2.37.4 Cleaning of Fuel Mixer for the Series 50G Engine

Cleaning of the fuel mixer is not required.

2.37.4.1 Inspection of Fuel Mixer for the Series 50G Engine

Inspection of the fuel mixer is not required.

2.37.4.2 Test of Fuel Mixer for the Series 50G Engine

Test of the fuel mixer is not required.

2.37.5 Installation of Fuel Mixer for the Series 50G Engine

Install the fuel mixer as follows:

1. Clean gasket surface and install a new gasket.
2. Secure the fuel mixer to the throttle with four bolts. Torque to 20 N·m (15 lb·ft).
3. Connect fuel inlet hose.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

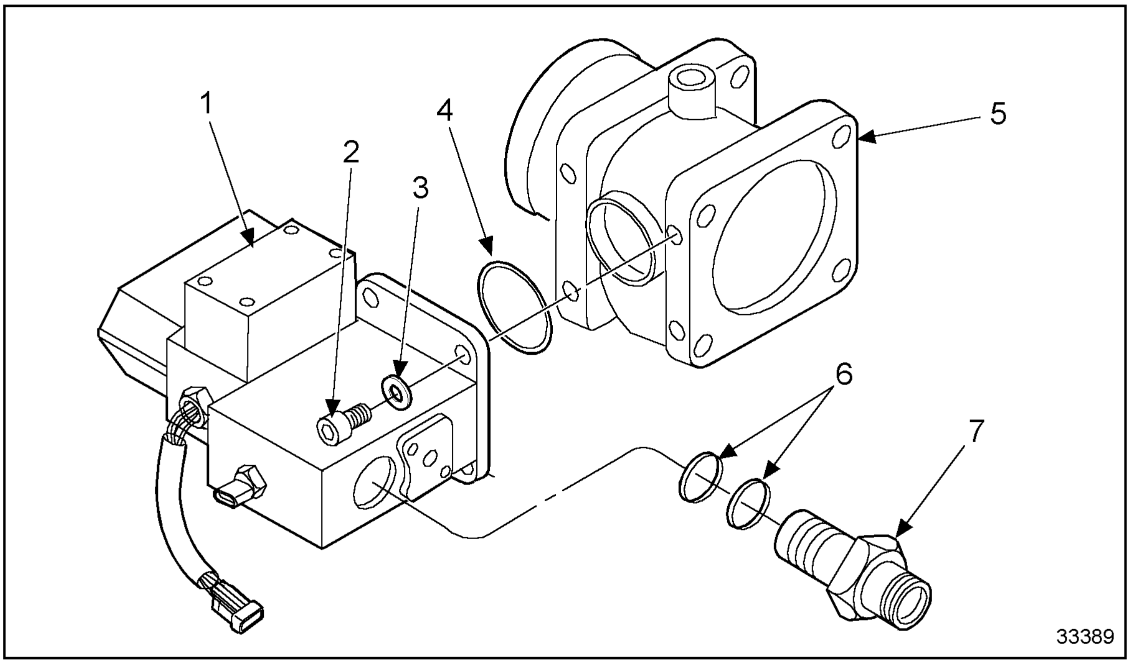
Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

4. Install air inlet hose and secure with V-band clamp. This hose must be of the current design that has a black interior surface. All former hoses have a blue interior surface and must be replaced. Also, the part number is printed on the exterior surface of the hose.
5. Refer to Section 2.43.3 for leak checking procedure.

2.38 PULSE WIDTH MODULATED STEPPER MOTOR VALVE (PSV) FOR 1998 AND LATER SERIES 50G AUTOMOTIVE ENGINES

A pulse width modulated stepper motor valve (PSV) is used to bias gas flow to the venturi mixer as a means of air/fuel ratio control. The PSV is connected to the low pressure regulator through a special connector tube with two O-rings that seal against the inside diameter of the gas inlet port in the PSV. It is mounted to the mixer housing with 4 attaching bolts and uses an O-ring to seal the mounting flange. Gas flows through the PSV housing. The gas outlet passage in the PSV is intersected by a bore in which a piston operates. Gas flow is controlled by precise positioning of the piston and the amount that the piston protrudes into the gas outlet passage. Greater protrusion into the gas passage increases restriction and results in reduced gas flow and a leaner air/fuel ratio. Similarly, less protrusion reduces restriction resulting in higher gas flow and a richer air/fuel mixture.

The piston is driven by a stepper motor which positions the piston based on a (PWM) position command signal from DDEC. The PSV is electrically connected to the ECM and 12 volt battery power through an 7 pin connector that mates to the engine sensor harness. The PSV supplies a "gas valve position" analog signal to DDEC which can be monitored using the diagnostic data reader (DDR). The signal indicates valve opening position and is scaled from 0 to 100 percent. A diagnostic signal is supplied to DDEC for loss of command signal, piston obstruction or valve electronics failure. See Figure 2-94.



1. PSV
2. Bolt
3. Washer
4. PSV O-ring
5. Mixer
6. Connector O-rings
7. Fuel Transfer Tube

Figure 2-94 Series 50G Automotive PSV 1998 and Later Engines

2.38.1 Replacement of Pulse Width Modulated Stepper Motor Valve for the Series 50G Engine

The PSV is non-serviceable and should be replaced as a unit. No adjustment is required.

2.38.2 Removal of Pulse Width Modulated Stepper Motor Valve for the Series 50G Engine

Remove the PSV as follows:

> **CAUTION:**
>
> **To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.**

1. Vent fuel system, refer to Section 2.43.
2. Disconnect the seven wire connector from the engine sensor wiring harness.
3. Remove the four bolts connecting the PSV to the fuel mixer.
4. Slide the PSV forward to separate from the connecting tube.

2.38.3 Installation of Pulse Width Modulated Stepper Motor Valve for the Series 50G Engine

Install the PSV as follows:

1. Lubricate connector O-rings and PSV O-ring.
2. Loosen bolts attaching fuel mixer to throttle.

NOTE:
The bolt holes in the throttle are slotted to allow adjustment to align the PSV with the connector tube in the low pressure regulator.

3. Position PSV against mixer with O-ring in place and align gas inlet port with connector. Slide rearward to engage connector until bolts holes are aligned.
4. Secure PSV to the fuel mixer with four bolts and torque to 20 N·m (15 lb·ft).
5. Tighten fuel mixer to throttle attaching bolts.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- ☐ **Do not smoke when installing or servicing the engine or fuel system.**
- ☐ **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- ☐ **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- ☐ **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- ☐ **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- ☐ **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- ☐ **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- ☐ **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

6. Clear AFR learn table using the Diagnostic Data Reader (DDR).
7. Check for diagnostic codes using DDR.
8. Check for leaks, refer to Section 2.43.

2.39 OVERVIEW OF THE LOW PRESSURE FUEL SYSTEM FOR THE SERIES 50G GENERATOR SET ENGINE (1998 AND LATER)

The purpose of the fuel system is to store the fuel, keep it clean and free from air, water, or other impurities and to deliver it to the combustion chamber at the correct pressure, temperature, air and fuel mixture. The Series 50G engine requires an adequate fuel supply for proper performance and to develop full rated power. This section describes the Detroit Diesel Series 50G compressed natural gas fuel system.

The following are DDC supplied parts:

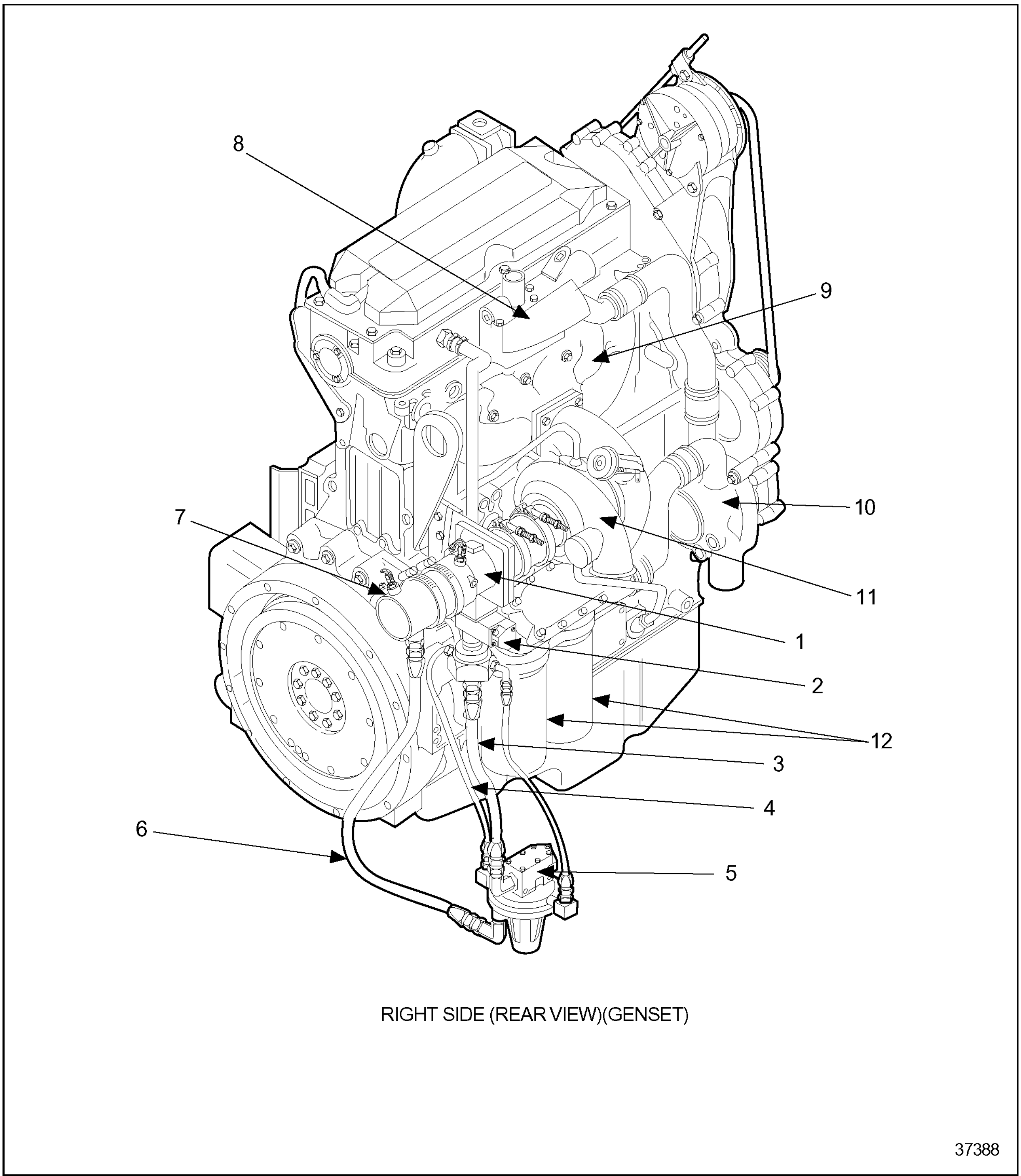
- ☐ Pulse width modulated stepper motor valve (PSV)
- ☐ Low pressure regulator
- ☐ Venturi fuel mixer
- ☐ Regulator hoses
- ☐ Air inlet tube

The following are OEM supplied parts:

- ☐ Gas inlet pipe
- ☐ Genset controlled gas shutoff valve

The fuel system uses computer calculations for both fuel flow and air flow, while maintaining a lean air - fuel mixture for low emissions and good fuel economy. Calculations are based on knowing the temperature of the air and fuel along with the temperature and pressure of the fuel and air mixture in the inlet manifold. The air temperature sensor is located in the air intake tube located in front of the gas mixer. The fuel temperature sensor is located in the gas mixer. An intake manifold pressure sensor is located in the intake manifold. See Figure 2-95 and see Figure 2-96.

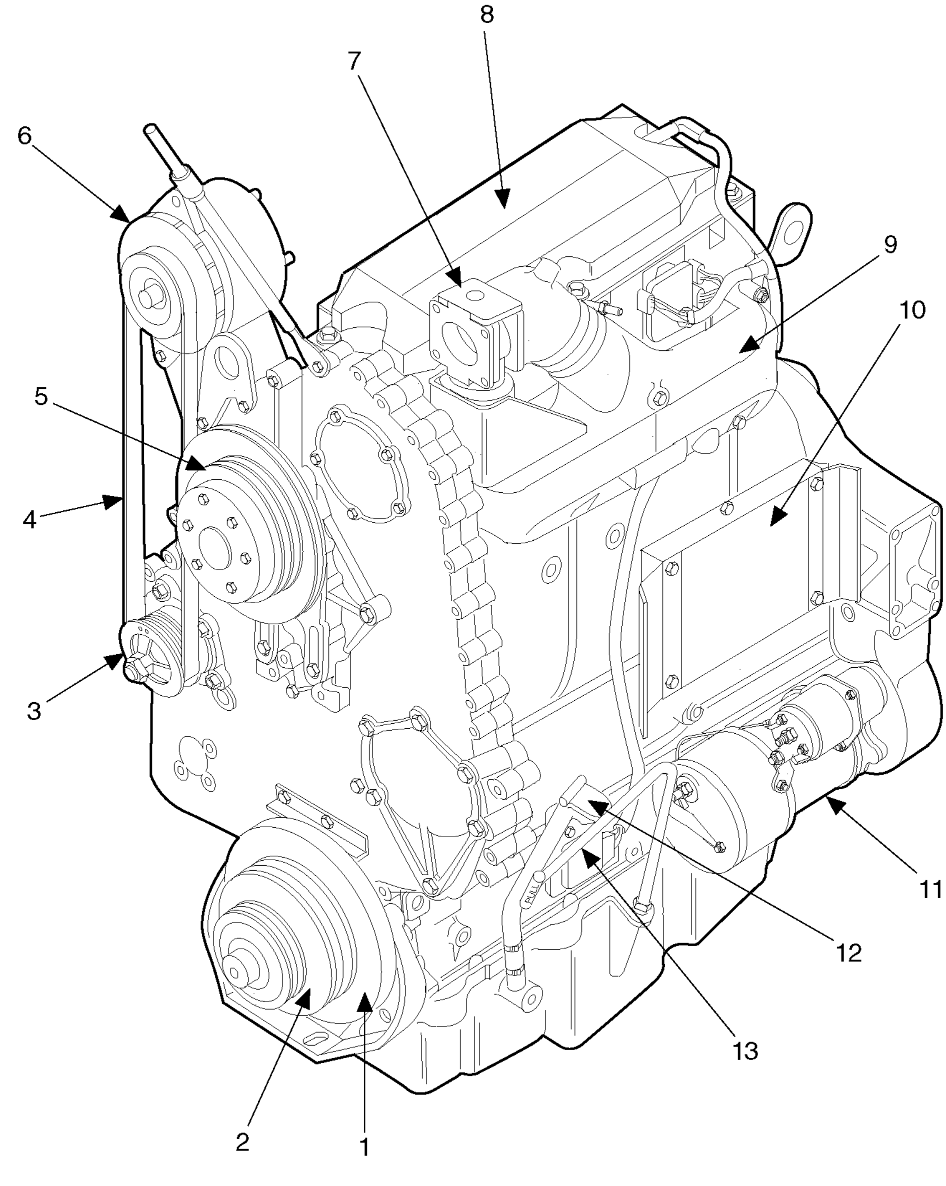
2.39 OVERVIEW OF THE LOW PRESSURE FUEL SYSTEM FOR THE SERIES 50G GENERATOR SET ENGINE (1998 AND LATER)



1. Fuel Mixer Assembly
2. Pulse Width Modulated Stepper Motor Valve
3. Fuel Supply Hose
4. Fuel Balance Hose
7. Air Inlet Tube
8. Thermostat Housing
9. Exhaust Manifold
10. Fresh Water Pump

5. Low Pressure Regulator
6. Air Balance Hose
11. Turbocharger
12. Lube Oil Filters

Figure 2-95 Series 50G Generator Set Engine — Right Side, Rear View



1. Vibration Damper
2. Crankshaft Pulley
3. Accessory Drive Assembly
4. Alternator Drive Belt
5. Fan Pulley
6. Alternator
7. Throttle
8. Rocker Cover
9. Intake Manifold
10. Electric Control Module
11. Electric Starting Motor
12. Oil Filter
13. Dipstick

Figure 2-96 Series 50G Generator Set Engine — Left Side, Front View

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

CAUTION:

To avoid injury from arc welding, gas welding, or cutting, wear required safety equipment such as an arc welder's face plate or gas welder's goggles, welding gloves, protective apron, long sleeve shirt, head protection, and safety shoes. Always perform welding or cutting operations in a well-ventilated area. The gas in oxygen/acetylene cylinders used in gas welding and cutting is under high pressure. If a cylinder should fall due to careless handling, the gage end could strike an obstruction and fracture, resulting in a gas leak leading to fire or an explosion. If a cylinder should fall resulting in the gage end breaking off, the sudden release of cylinder pressure will turn the cylinder into a dangerous projectile. Observe the following precautions when using oxygen/acetylene gas cylinders:

- **Always wear required safety shoes.**
- **Do not handle tanks in a careless manner or with greasy gloves or slippery hands.**
- **Use a chain, bracket, or other restraining device at all times to prevent gas cylinders from falling.**
- **Do not place gas cylinders on their sides, but stand them upright when in use.**
- **Do not drop, drag, roll, or strike a cylinder forcefully.**
- **Always close valves completely when finished welding or cutting.**

The Series 50G engine low pressure fuel system consists of a venturi type fuel mixer, Pulsewidth Modulated Stepper Motor Valve (PSV), throttle actuator, and low pressure regulator. It is referred to as a "demand" system in that the venturi mixer generates a suction at the regulator outlet. The regulator adjusts its outlet pressure in response to the demand (suction) of the venturi resulting in an increase of fuel flow. The opposite is true for conditions requiring a decrease in fuel flow. See Figure 2-97.

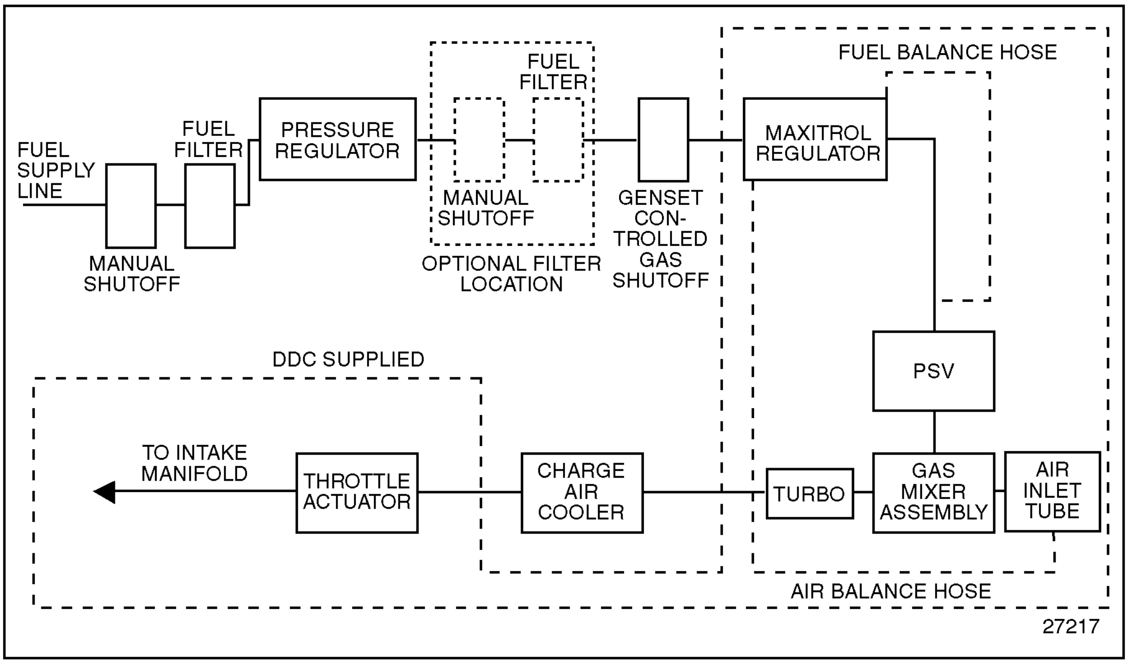


Figure 2-97 Low Pressure Natural Gas Fuel System (Series 50G)

Fuel supply is routed to the inlet side of the low pressure regulator at a pressure of 1-5 kPa (5-20 in. H^2 O). The low pressure regulator is a "balanced" regulator and as such, reduces this pressure to a level approximately equal to air inlet pressure.

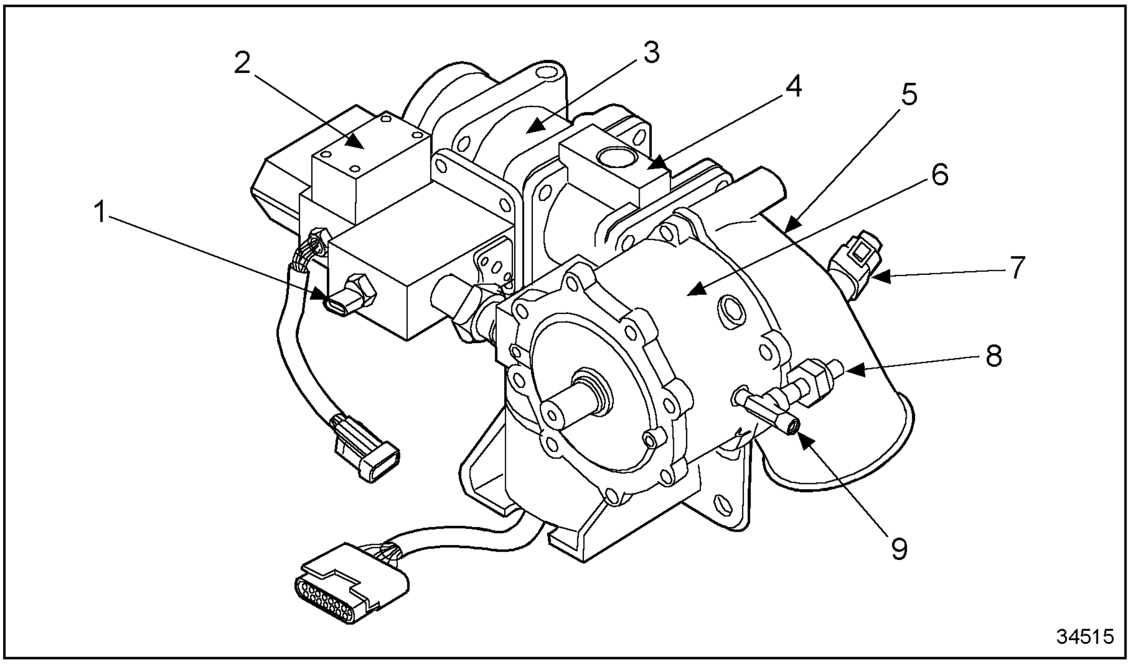
Regulated fuel is routed from the low pressure regulator to the PSV. The PSV is fully controlled by DDEC III/IV and is used to bias fuel flow, rich or lean, based on a predetermined engine calibration.

Fuel from the PSV enters the venturi mixer where it is drawn into and mixed with the airstream ahead of the turbocharger compressor inlet, charge air cooler, throttle and intake manifold.

2.40 IMPCO LOW PRESSURE FUEL REGULATOR FOR THE SERIES 50G ENGINE

The IMPCO low pressure regulator is mounted to the air inlet elbow at the front left side of the engine. The gas inlet connection is a 1/4" NPTF pipe thread and is connected through a special natural gas compatible No. 6 hose to the low pressure DDEC controlled fuel shutoff valve. The gas outlet connection is mated to the inlet of the PSV through a special tube connector. The regulator is heated by engine coolant. The regulator outlet fuel pressure is balanced to turbo boost pressure at the mixer inlet. This pressure is communicated to the regulator through a No. 6 hose that connects to a 1/8" NPTF pipe thread hole in the regulator cover and to a 1/4" NPTF pipe thread connection in the top of the mixer housing.

The purpose of the regulator is to provide a controlled flow of natural gas to the PSV and mixer at a pressure just above the air pressure (turbo boost) at the inlet to the mixer. Gas enters the regulator at a pressure of approximately 110 PSI. See Figure 2-98.



1. Fuel Temperature Sensor
2. PSV
3. Fuel Mixer
4. Throttle
5. Air Inlet Elbow
6. Low Pressure Regulator
7. Air Temperature Sensor
8. Fuel Pressure Sensor
9. Fuel Inlet Tee Fitting

Figure 2-98 50G Throttle with Integrated Actuator

2.40.1 Replacement of the Low Pressure Regulator for the Series 50G Engine

The low pressure fuel regulator is not serviceable and should be replaced as a unit. No adjustment is required.

2.40.2 Removal of the Low Pressure Regulator for the Series 50G Engine

Remove the low pressure fuel regulator as follows:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Vent fuel system, refer to Section 2.43.
2. Disconnect fuel supply hose at the regulator.
3. Disconnect fuel pressure sensor from engine sensor wiring harness.
4. Drain coolant.
5. Disconnect coolant supply and return hoses at regulator.
6. Disconnect air balance hose at regulator cover.
7. Remove two M6 regulator to air inlet elbow mounting bolts. Support regulator to avoid cocking the connector tube in the PSV and possibly damaging the PSV gas inlet bore.
8. Slide regulator rearward to disengage outlet connector tube from the PSV.
9. Remove gas inlet tee, fuel pressure sensor, coolant inlet fittings, coolant outlet fittings, balance hose fitting, outlet connector tube and O-rings for reuse.

2.40.3 Installation of the Low Pressure Regulator for the Series 50G Engine

Install the low pressure fuel regulator as follows:

NOTE:
Use caution when installing hoses to avoid twisting or kinking the hose. This could result in increased flow restriction and effect engine performance.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- ☐ **Do not smoke when installing or servicing the engine or fuel system.**
- ☐ **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- ☐ **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- ☐ **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- ☐ **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- ☐ **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- ☐ **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- ☐ **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

1. Install gas inlet tee, fuel pressure sensor, coolant inlet fittings, coolant outlet fittings, balance hose fitting, outlet connector tube and O-rings.
2. Lubricate connector O-rings.
3. Position regulator on air inlet elbow with outlet connector aligned with bore in PSV. Slide regulator forward engaging outlet tube in PSV until regulator mounting bolt holes are aligned.
4. Install two M6 mounting bolts.
5. Connect fuel supply hose.

6. Connect coolant supply and return hoses.
7. Refill with coolant.
8. Connect air balance hose.
9. Connect fuel pressure sensor to engine sensor wiring harness.
10. Clear AFR learn table using DDR.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

11. Start engine and check hoses and fitting for leaks. Refer to Section 2.43.3.

2.41 LOW PRESSURE FUEL REGULATOR FOR THE SERIES 50G ENGINE

The low pressure fuel regulator is mounted on the generator base on the right side of the engine. This location minimizes the distance between the regulator outlet and the inlet of the PSV. There are four hoses connecting the regulator to the engine; the fuel supply, one air balance and two fuel balance hoses. See Figure 2-95.

2.41.1 Replacement of the Low Pressure Fuel Regulator for the Series 50G Engine

The low pressure fuel regulator is not serviceable and should be replaced as a unit. No adjustment is required.

2.41.2 Removal of the Low Pressure Fuel Regulator for the Series 50G Engine

Remove the low pressure fuel regulator as follows:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Vent fuel system; refer to Section 2.43.1and refer to Section 2.43.2.
2. Disconnect and remove 1 in. air balance hose.
3. Disconnect and remove the two 3/8 in. fuel balance lines.
4. Disconnect and remove the 11/4 in. fuel supply line.
5. Remove the low pressure fuel regulator and fuel inlet pipe from the mounting bracket.
6. Remove fuel inlet pipe from regulator.

2.41.3 Disassembly of the Low Pressure Fuel Regulator for the Series 50G Engine

Disassembly of the low pressure fuel regulator is not required.

2.41.4 Cleaning of the Low Pressure Fuel Regulator for the Series 50G Engine

Cleaning of the low pressure fuel regulator is not required.

2.41.4.1 Inspection of the Low Pressure Fuel Regulator for the Series 50G Engine

Inspection of the low pressure fuel regulator is not required.

2.41.4.2 Test of the Low Pressure Fuel Regulator for the Series 50G Engine

Test of the low pressure fuel regulator is not required.

2.41.5 Installation of the Low Pressure Fuel Regulator for the Series 50G Engine

Install the low pressure fuel regulator as follows:

1. Install fuel inlet pipe into the regulator
2. Secure the low pressure fuel regulator and inlet pipe to the mounting bracket.
3. Connect the 1 1/4 in. fuel supply line.
4. Connect the two 3/8 in. fuel pressure balance lines.

NOTE:
Use caution when installing hoses to avoid twisting or kinking the hose. This could result in increased flow restriction and affect engine performance.

5. Connect the 1 in. air balance line.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

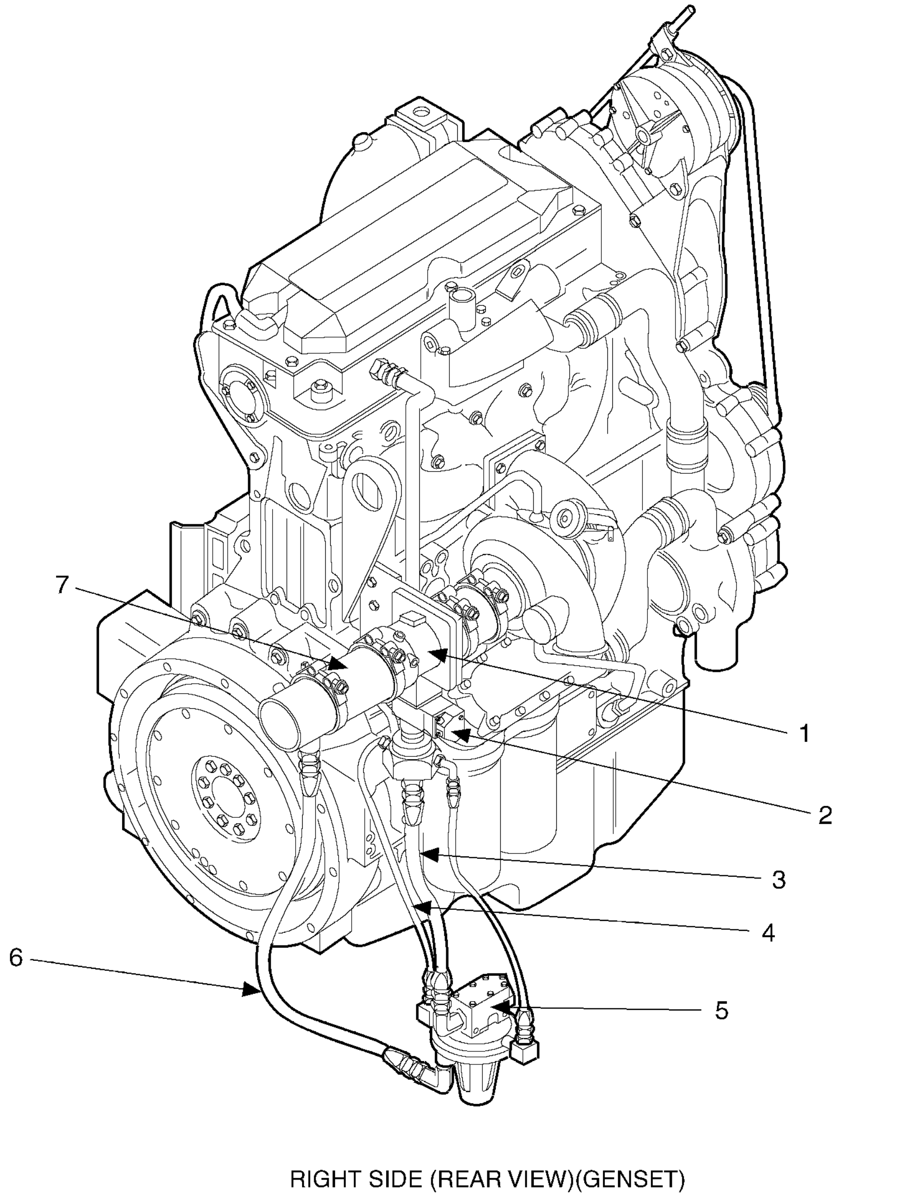
- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

6. Check hoses and fittings for leaks; refer to Section 2.43.3.

2.42 FUEL MIXER FOR THE SERIES 50G LOW PRESSURE SYSTEM

The venturi fuel mixer assembly consists of a die cast aluminum body with a spun aluminum venturi permanently inserted into it. The unit has no moving parts. The mixer assembly is attached to support brackets and located at the right rear of the engine. See Figure 2-99.



RIGHT SIDE (REAR VIEW)(GENSET)

27302

1. Fuel Mixer Assembly
2. Pulse Width Modulated Stepper Motor Valve (PSV)
3. Fuel Supply Hose
4. Fuel Balance Hose
5. Low Pressure Regulator
6. Air Balance Hose
7. Air Inlet Tube

Figure 2-99 Low Pressure Fuel System (Series 50G Engine)

2.42.1 Replacement of Fuel Mixer for the Series 50G Engine

The fuel mixer is non-serviceable and should be replaced as a unit. No adjustment is required.

2.42.2 Removal of Fuel Mixer for the Series 50G Engine

Remove the fuel mixer as follows:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Vent fuel system; refer to Section 2.43.1and refer to Section 2.43.2.
2. Disconnect and remove the PSV from the fuel mixer, refer to Section 2.38.2.
3. Remove four fuel mixer mounting bolts.
4. Separate and remove the fuel mixer from the mounting bracket.

2.42.3 Disassembly of Fuel Mixer for the Series 50G Engine

Disassembly of the fuel mixer is not required.

2.42.4 Cleaning of Fuel Mixer for the Series 50G Engine

Cleaning of the fuel mixer is not required.

2.42.4.1 Inspection of Fuel Mixer for the Series 50G Engine

Inspection of the fuel mixer is not required.

2.42.4.2 Test of Fuel Mixer for the Series 50G Engine

Test of the fuel mixer is not required.

2.42.5 Installation of Fuel Mixer for the Series 50G Engine

Install the fuel mixer as follows:

1. Clean gasket surface and install a new gasket.
2. Secure the fuel mixer to the mounting bracket with four bolts. Torque to 20 N·m (15 lb·ft).
3. Install the PSV to the fuel mixer, refer to Section 2.38.3.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

4. Perform a leak check procedure. Refer to Section 2.43.3.

2.43 VENTING AND LEAK CHECKING PROCEDURES FOR A NATURAL GAS ENGINE (LOW PRESSURE SYSTEM)

Refer to Section 2.43.1 for venting and checking of an operable engine and refer to Section 2.43.2 for venting and checking of an inoperable engine.

2.43.1 Venting an Operable Engine to Relieve Natural Gas Pressure

If the engine *can run*, use the following venting procedure to relieve the natural gas pressure downstream of the shutoff valve:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Turn off manual shutoff valve on natural gas fuel supply line.
2. Start engine and run until it stalls due to fuel starvation.
3. Disconnect the batteries using switch(s) in the battery compartment or by disconnecting the battery ground cable.
4. Slightly loosen the NG fuel line fitting to be serviced in a well ventilated area to allow any remaining gas to vent.
5. Completely open the fitting that was slightly opened and allow to vent in a well-ventilated area.

2.43.2 Venting an Inoperable Engine to Relieve Natural Gas Pressure

If the engine *cannot run*, use the following venting procedure to relieve the natural gas pressure downstream of the shutoff valve:

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

1. Turn off manual shutoff valve on natural gas fuel supply line.
2. Disconnect the batteries using switch(s) in the battery compartment or by disconnecting the battery ground cable.

3. Open fitting (before and after genset shut-off valve) to assure all pressure has been relieved in the natural gas fuel line.
4. Check all connections that were loosened for leaks after installation, service and troubleshooting are complete.

2.43.3 Leak Checking the Natural Gas Fuel System

Use the following steps to check for leaks:

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

1. Open manual shutoff valve.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

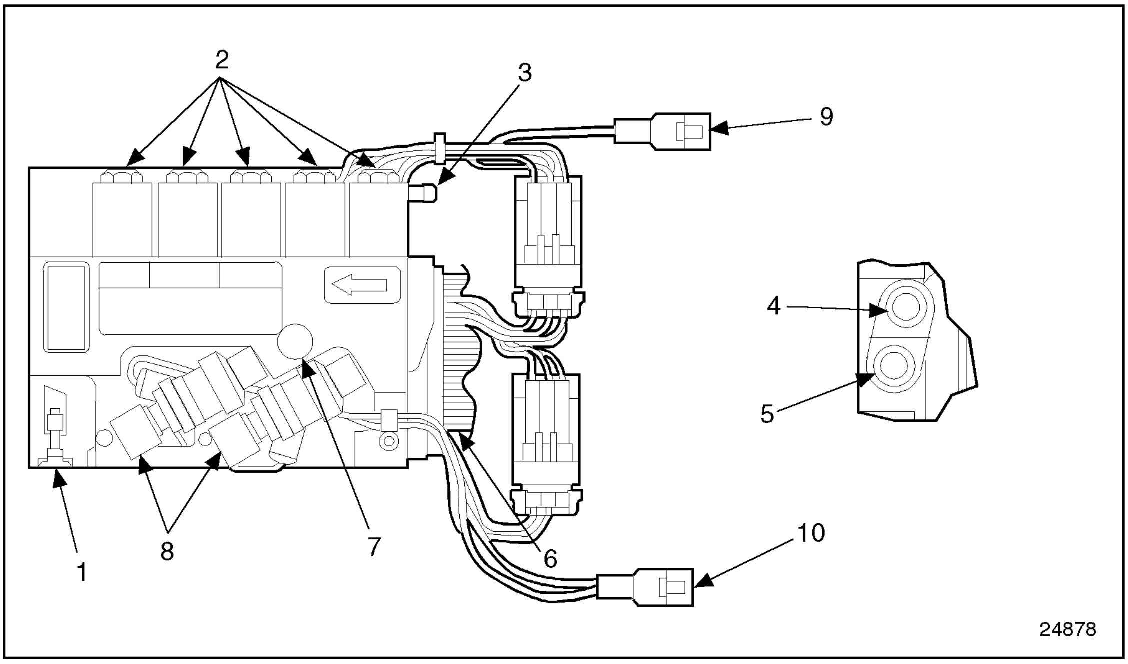
2. Start engine and run with no electrical load on generator.
3. Spray soapy water or commercially available leak checking solutions on connections. Bubbles will form if there is a leak.
4. Repair any leak by:
   [a] Shut down the engine and close the manual shutoff valve.
   [b] Tightening connection using the fitting manufacturer's technique.

NOTE:
Vent fuel lines before replacing leaking components; refer to Section 2.43.1 and refer to Section 2.43.2. This will prevent a discharge of gas.

   [c] Replacing leaking component.
   [d] Replace the pipe threaded connector with a new one if the leak is a pipe thread connection. Use anaerobic sealant with Teflon (such as SWAK®) applied to the threads.SWAK® is a registered trademark of the Cajon Company.
5. Re-check connection with procedure in step 1thru step 3.
6. Use a combustible gas detector to check for presence of natural gas. If natural gas is detected, continue looking for leaks until the locations of all the leaks are determined.
7. Repair the leak using the procedure in step 4.

2.44 COMPUVALVE FOR THE SERIES 50G ENGINE

The compuvalve contains the metering valve and computer for the system. See Figure 2-100.



1. BAP Sensor and Filter
2. High Flow Injectors
3. MAP Barb
4. Inlet Port
5. Outlet Port
6. Main Wire Harness
7. FRT Sensor
8. Low Flow Injectors
9. 10 AMP Fuse
10. 3 AMP Fuse

Figure 2-100 Compuvalve for the Series 50G Engine

Regulated gas from the GFI regulator, enters the compuvalve through the inlet port and flows through the fuel rail. The flow is then regulated by 7 injectors that are computer controlled and operated by electronic solenoids. There are 5 high flow injectors for on/off operation for major flow changes and 2 low flow injectors that are pulse width modulated for flow trimming. There are four sensors in the metering valve, and two additional engine mounted sensors that the computer uses to calculate open loop fueling requirements. The sensors located in the metering valve are: Manifold Absolute Pressure (MAP), Barometric Absolute Pressure (BAP), Fuel Absolute Pressure (FAP) and Fuel Regulated Temperature (FRT). The engine mounted sensors are the Inlet Air Temperature (IAT), and Oil Temperature Sensor (OTS). The regulated gas flow is then released through the outlet port to the gas mixing unit located in the air intake system upstream of the engine throttle.

The computer controls fuel flow. The computer section consists of a 2 board computer module inside the electronics cavity of the metering valve. For calibration and adaptive memory, the ECM uses SRAM (Static Random Access Memory). Program memory is stored in ROM (Read Only Memory). The memory is non-volatile and is neither reset nor lost when battery voltage is removed.

The software is responsible for calculations, based on calibration and sensor input, that result in computer commands that adjust fuel flow. The calibrations are programmable.

2.44.1 Replacement of the GFI Compuvalve for the Series 50G Engine

The GFI compuvalve is non-serviceable and should be replaced as a unit. No adjustment is required.

2.44.2 Removal of Compuvalve for the Series 50G Engine

Prior to removal of the compuvalve, the fuel system must be vented. Refer to Section 2.36.1 and refer to Section 2.36.2.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

NOTICE:

When disconnecting the GFI compuvalve wire connectors, all power, including the ignition and the batteries, must be off. If this is not done, the injector drivers may be damaged.

After the fuel system has been properly vented, remove the compuvalve as follows:

1. Turn off ignition and disconnect batteries by turning off the battery switch or removing the ground cable from the battery.
2. Disconnect all wire harness connections at the compuvalve.
3. Disconnect gas inlet hose at the compuvalve.
4. Disconnect the gas outlet hose.
5. Disconnect map sensor hose assembly at the compuvalve.
6. Remove bolts attaching the compuvalve to its mounting bracket.

2.44.2.1 Inspection of Compuvalve for the Series 50G Engine

Inspection of the compuvalve is not required.

2.44.3 Installation of Compuvalve for the Series 50G Engine

Install the compuvalve as follows:

NOTICE:
Make sure that no dirt or debris is allowed to enter unit during installation. Tightly cap or cover all open ports and openings. Do not remove factory caps until time to connect hoses.

1. Mount compuvalve in its bracket and install attaching bolts.
2. Connect map sensor hose.
3. Connect gas outlet hose.
4. Connect gas inlet hose.
5. Connect wiring harness.
6. Turn on battery switch or reconnect battery ground cable.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

7. Start engine and check for leaks; refer to Section 2.36.3.

2.45 FUEL SHUTOFF VALVES FOR THE SERIES 50G ENGINE PRIOR TO 1998

Fuel shutoff valves are required for safety and maintenance. Series 50G installations utilize shutoff valves controlled by DDEC and GFI in addition to manual shutoff valves. See Figure 2-101.

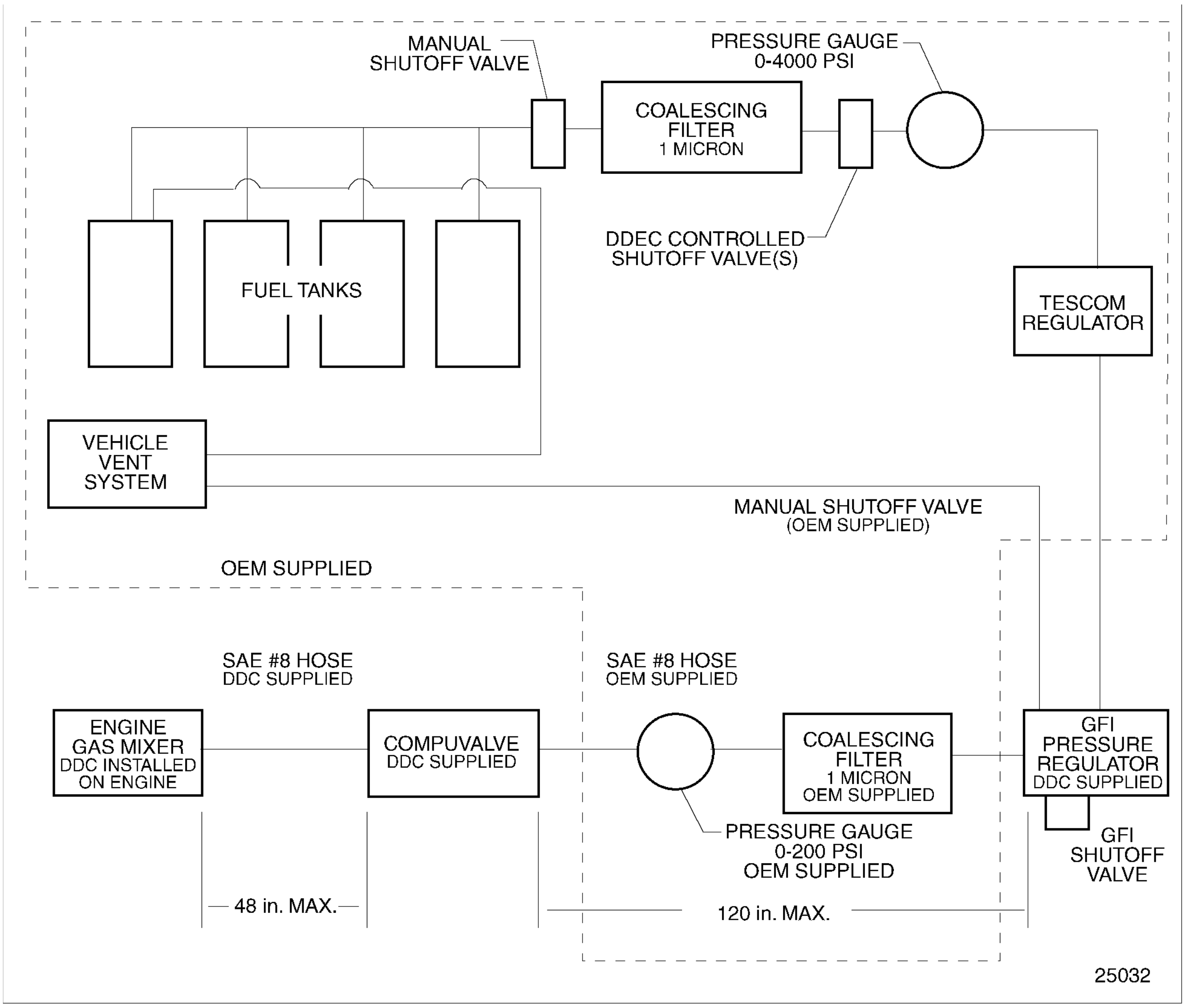


Figure 2-101 Compressed Natural Gas Fuel System Description

The manual shutoff valve is located upstream of both gas filters in order to facilitate element replacement. The manual shutoff valves should be readily accessible for safety and service.

The DDEC controlled fuel shutoff valve is located downstream of the high pressure coalescing filter but as close to the fuel tank(s) as possible.

The GFI pressure regulator is equipped with its own integrated fuel shutoff valve. This shutoff valve is controlled by the GFI compuvalve.

The DDEC controlled shutoff valve will close and shut off fuel flow for any of the following:

1. After the ignition is switched on, the fuel supply is shut off until the engine reaches 60 r/min.
2. In the event engine speed exceeds a calibrated value, the fuel supply will be shut off.
3. If the engine speed drops below the minimum acceptable (60) r/min the engine is deemed to be no longer running and the fuel is shut off.
4. For the instances where the throttle diagnostics indicate that the throttle should be shut down, the fuel supply will be shut off.

The GFI system will shut off the fuel for the following condition:

After the ignition is switched on, if there is no indication of engine speed for 20 seconds, the fuel supply is shut off until there is an indication of engine speed.

2.45.1 Replacement of the Fuel Shutoff Valves for the Series 50G Engine

Detroit Diesel does not service the fuel shutoff valves. Refer to OEM to replace as necessary.

2.45.2 Removal of the Fuel Shutoff Valves for the Series 50G Engine

Refer to OEM for removal procedure for the fuel shutoff valves.

2.45.2.1 Inspection of the Fuel Shutoff Valves for the Series 50G Engine

Refer to OEM for inspection procedure for the fuel shutoff valves.

2.45.3 Installation of the Fuel Shutoff Valves for the Series 50G Engine

Refer to OEM for installation procedure for the fuel shutoff valves.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

2.46 HOSE, FITTING, AND FILTER FOR THE SERIES 50G ENGINE

The following criteria apply to all fuel hoses used on a Series 50G engine:

- ☐ All fuel supply hoses must be properly specified per the operating pressure and temperature requirements. Typically, pressure at fuel tanks is 3600 PSIG, pressure into the GFI regulator is 500 PSIG, and pressure out of regulator is 129-144 PSIA.
- ☐ All fuel hoses must be Teflon with stainless steel braid. The hoses must have a sufficient amount of the homogenous material carbon black added to the Teflon inner core to bleed off static electricity.

2.46.1 Removal of Hose, Fitting and Filter for the Series 50G Engine

Prior to removal or replacement of fuel system hoses, fittings or filter, the fuel system must be vented. Refer to Section 2.43.1and refer to Section 2.43.2.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

Refer to OEM for removal procedure for the hose, fitting and filter.

2.46.1.1 Inspection of Hose, Fitting and Filter for the Series 50G Engine

Refer to OEM for inspection procedure for the hose, fitting and filter.

2.46.2 Installation of Hose for the Series 50G Engine

DDC gives the following recommendations for hose routing as follows:

CAUTION:

To avoid injury from penetrating fluids, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing.

1. Optimize for the shortest and simplest routing without conflicting with other criteria.
2. Use routing that will not cause hoses to kink.
3. Route hoses at least 12 in. away from all exhaust components (e.g. exhaust manifold, exhaust piping, catalytic converter, and turbocharger).

4. Route hoses at least 6 in. away from high energy spark ignition wires to avoid electrical noise following hoses into wire harnesses or computer.
5. Route hoses at least 3 in. away from moving vehicle parts (e.g. fan belts).
6. Do not route hose against sharp edges or in an area where hose may rub or vibrate against vehicle parts.
7. Route hoses such that there is a minimum 2 in. clearance when the cab or rear engine compartment door is closed.
8. Secure all hoses with clips.

Install the fuel hoses as follows:

NOTICE:
Do not cut hoses so that installation and/or vehicle operation creates hose strain that may cause hoses to pull from fittings or otherwise rupture.

1. Determine the proper routing as described previously.
2. Remove protective caps and covers from fittings and ports.
3. Thoroughly clean any dirt and debris from threads of fittings and sealing surfaces.

NOTICE:
Do not scratch or mar sealing surfaces. Scratches can cause poor seals and subsequent gas leaks.

4. Connect the fitting nut into port threads and position hose as desired. Hand tighten nut.

NOTE:
When tightening the nut, fitting and hose may "travel" clockwise. Position hose and fitting a few degrees counter clockwise from desired position.

5. Torque nut. Do not over tighten. Torque specifications are listed in Table 2-9.

NOTICE:

Always use wrench flats to tighten. Never use barbed fitting end to torque or tighten or prevent fitting rotation during tightening. *Always use proper tools. Do not use pliers. Do not clamp or apply leverage to regulator parts (i.e. high pressure solenoid). Do not clamp or apply leverage to compuvalve solenoids and injectors. Do not clamp or apply leverage to filter.*

Size	Swivel Torque, lb·ft	Swivel Torque, N·m	Lock Nut Torque, lb·ft	Lock Nut Torque, N·m
2	6	8	6	8
3	6	8	6	8
4	10	14	8	11
5	15	20	10	14
6	20	27	13	18
8	30	41	21	28
10	40	54	33	45
12	70	95	48	65
14	80	108	56	76
16	90	122	63	85
20	120	163	80	108
24	131	178	110	149
32	300	407	230	312

Table 2-9 Torque Values for Tube and Pipe Fittings

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

6. Check for and eliminate external leaks, refer to Section 2.43.3. DO NOT tighten fittings to stop leaks; proper torque is sufficient with clean threads and using a new copper washer.

2.47 FUEL FILTER TYPE FOR THE SERIES 50G ENGINE

The primary (High Pressure) natural gas filter and secondary (Low Pressure) natural gas filter must be a coalescing 0.3 micron @ 99.97% efficiency fuel filter. Detroit Diesel recommended filters include the following:

- ☐ Racor — fuel filter 23529393 for use only with fuel filter housing FFC-113
- ☐ Racor — fuel filter 23529394 for use only with fuel filter housing FFC-114

The high pressure gas filter is mounted between the manual shutoff valve and the DDEC controlled shutoff valve.

2.47.1 Replacement of Fuel Filter for the Series 50G Engine

Replacement of the fuel filter. See Figure 2-102.

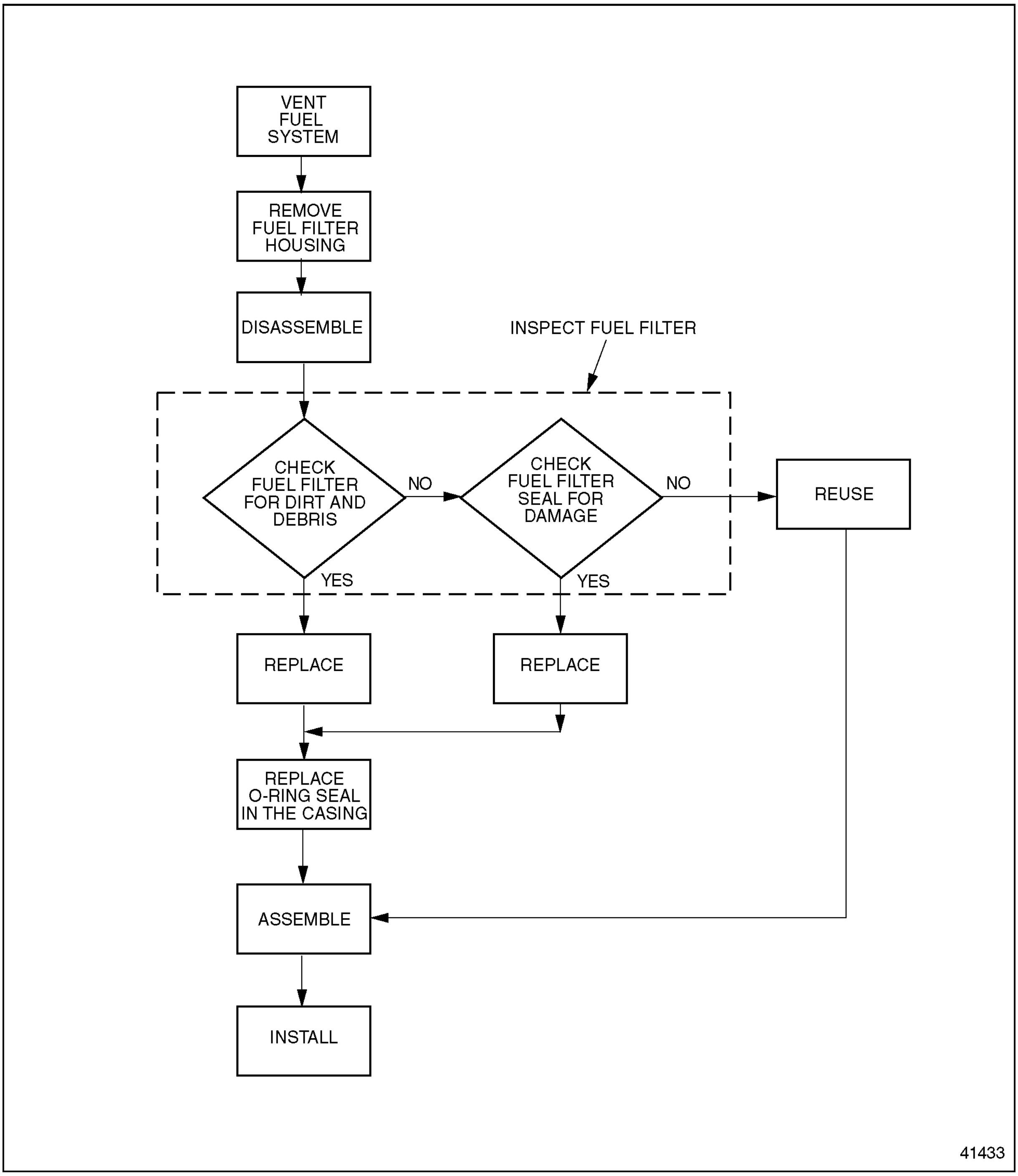


Figure 2-102 Replacement of the Fuel Filter

2.47.2 Removal of Fuel Filter for the Series 50G Engine

Prior to removal or replacement of the fuel filter, the fuel system must be vented. Refer to section 2.43.1 and refer to section 2.43.2.

CAUTION:

To avoid injury from the explosion of natural gas, the engine must be kept in a well-ventilated area away from open flames, sparks, and electrical resistance (heating) coils.

CAUTION:

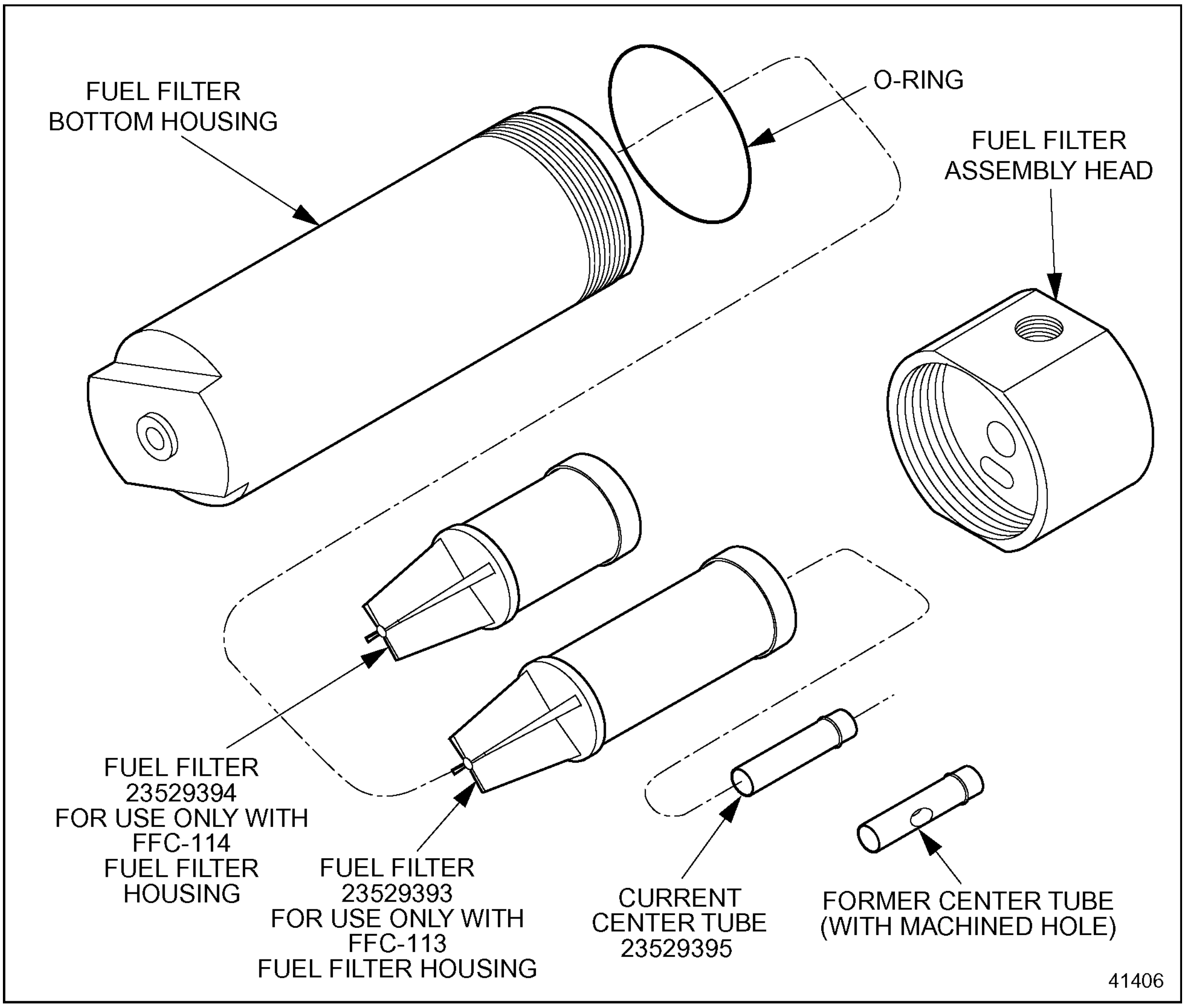
To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

Remove fuel filter as follows:

1. Unscrew the bottom fuel filter housing and filter element from fuel filter housing head. See Figure 2-103.



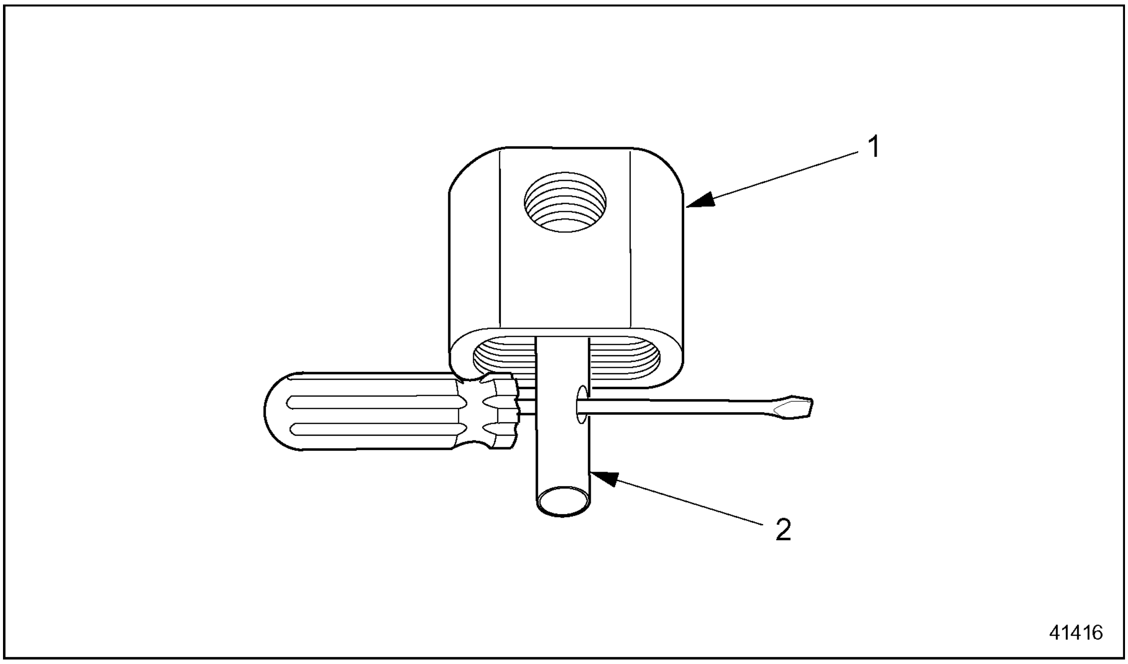
Note: Fuel filter seal is located on top of the fuel filter.

Figure 2-103 Current Fuel Filter Assemblies

2. Remove the two bolts from fuel filter housing head.

NOTICE:
Ensure the handle rests on the outer edge of the filter head to avoid damage to the threads.

3. Place a screwdriver or equivalent tool with a soft handle through the bypass holes in the center tube. See Figure 2-104.



1. Filter Housing Head
2. Former Center Tube

Figure 2-104 Removal of Former Center Tube

4. Remove the center tube by gently tapping the metal end of the screwdriver, down away from the filter head.

NOTE:
Discard bypass spring and former center tube with holes.

2.47.2.1 Inspection of Fuel Filter for the Series 50G Engine

Inspect the fuel filter as follows:

1. Inspect the inside of the fuel filter for dirt, debris, foreign objects.
   [a] If dirt, debris, foreign objects are found; replace the fuel filter.
   [b] If no damage if found, reuse the fuel filter.

NOTE:
Oil saturation on the outside of the fuel filter is a NORMAL condition of the oil coalescing process.

2. Inspect the fuel filter seal on the fuel filter.
   [a] If the fuel filter seal is worn, ripped, torn; replace the fuel filter.
   [b] If no damage is found on the fuel filter seal ; reuse the fuel filter.

2.47.3 Installation of Fuel Filter for the Series 50G Engine

NOTICE:
The fuel filter is directional. Gas from the regulator must be plumbed to the fuel filter inlet port and from the fuel filter outlet port to the compuvalve. This provides proper filtration.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

Install the fuel filter as follows:

1. Place the fuel filter housing head on a flat surface facing up.
2. Insert new center tube in the center hole of the fuel filter housing head.

NOTE:
Use a press to push the center tube into the hole of the fuel filter housing head. Center tube should seat flush at rolled portion of tube.

3. Install fuel filter housing head on mounting bracket with the two bolts torque to 40.67–47.45 N·m (30–35 lb·ft).
4. Install correct fuel filter element into fuel filter housing head.

NOTE:
Ensure that the correct fuel filter is being used with the correct fuel filter housing unit. FFC-113 and FFC-114 are *not* interchangeable. Fuel filter 23529393 cannot be used in the FFC-114 fuel filter housing; and fuel filter 23529394 cannot be used in the FFC-113 fuel filter housing. Fuel filter assemblies are listed in Table 2-10.

Fuel Filter Housing	**Former Fuel Filter Part Number**	**Current Fuel Filter Part Number**
FFC-113	23528074	23529393*
FFC-114	23528074	23529394*

* A new center tube (P/N 23529395) *must* be installed on the current FFC-113 and FFC-114 fuel filters. Discard former center tube with hole.

Table 2-10 Former and Current Part Numbers for the Fuel Filter Center Tube

5. Insert the O-ring and install bottom fuel filter housing and torque to 33.90– 47.45 N·m (25–35 lb·ft).
6. Pressurize fuel system.
7. Refer to section 2.43.3 for leak checking procedure.

2.A ADDITIONAL INFORMATION

Description **Page**

SHOP NOTES

The following shop notes describe flexible fuel lines and their installation.

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.

An 0.080 in. (2.0 mm) restricted orifice is incorporated in the fuel return fitting (upper fitting) at the rear of the cylinder head to maintain fuel pressure in the cylinder head. Do not use restricted fittings anywhere else in the fuel system, and do not substitute a standard fitting for the restricted fitting.

The 0.080 in. (2.0 mm) restricted orifice is designed to provide the proper fuel system pressure under all conditions. Do not alter or substitute another size since this may alter engine performance and emissions.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine if all the connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check that the fuel filters are tight against the filter adaptors. Do not overtighten filters.

High fuel temperatures can cause low power and reduced fuel economy.

Detroit Diesel requires that all OEM's follow special fuel line configuration requirements to eliminate high fuel temperature concerns. Some of these configurations are as follows:

1. A dual draw/dual return style fuel line system should be used with vehicles having dual fuel tank configurations.
2. When a single tank with a 75 gallon (284 L) or greater capacity is employed, the return and supply line should be at opposite ends of the tank.
3. When a single tank with less than a 75 gallon (284 L) capacity is used, a fuel cooler is required on the spill side of the fuel system. The fuel cooler should be sized to allow a 40°F (22.2°C) temperature drop under the following conditions with a 1.5 gal/min (5.7 L/min) flow rate:Temperature Drop Conditions:

- □ 110°F (61°C) Maximum Ambient
- □ 180°F (100°C) Fuel Temperature into Cooler

The return fuel line must be connected to the top or face of the fuel tank opposite the pickup line. The fitting should spray the returning fuel along the inside wall of the tank or onto the surface of the fuel to dissipate as much heat as possible. Returning fuel to the bottom of the fuel tank or using a stand pipe is not permitted.

In addition, the fuel return line should be designed to prevent air from bleeding back into the cylinder head fuel passages after the engine is shut down. The possible configurations for this are a looped fuel line or the addition of a fuel check valve (23509140) in the fuel return line. See Figure 2-105.

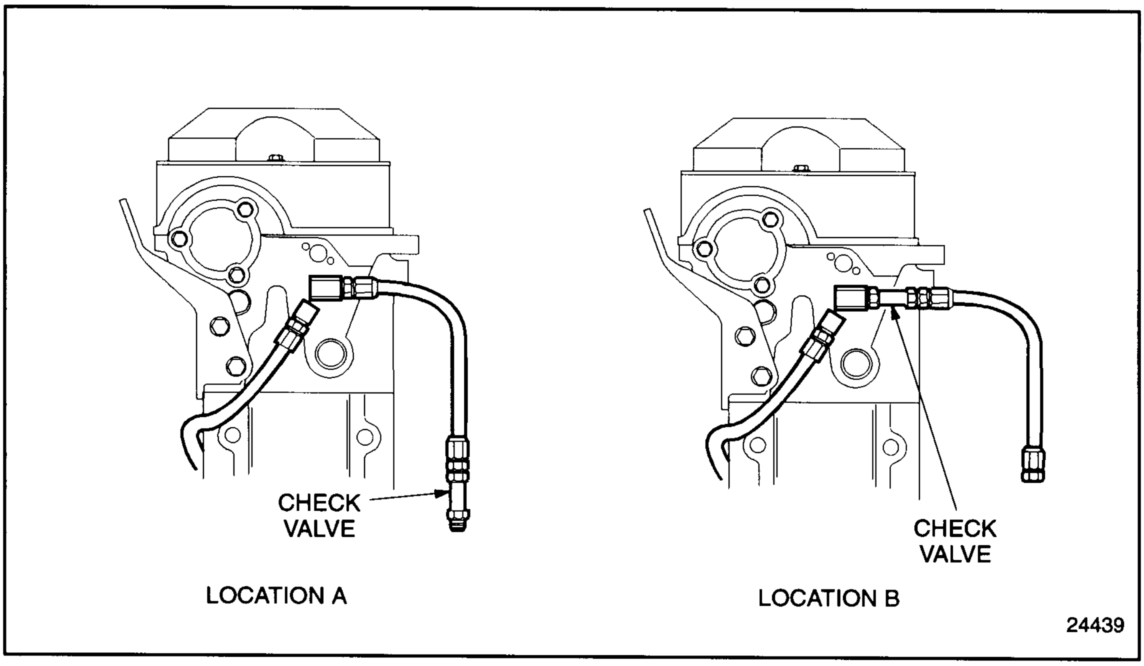


Figure 2-105 Fuel Return Check Valve

SPECIFICATIONS

Specifications can be found in the General Information section at the beginning of the manual. Exceptions are listed below:

Exceptions to Standard Fastener Torque Specifications

Exceptions to Standard Fastener Torque Specifications supporting the Series 50 Engine are listed in Table 2-11 and also listed in Table 2-12.

Fastener	Size	Torque, N·m	Torque, lb·ft
Bolt, Injector Clamp	M10 x 1.5	58-66	43-49

Table 2-11 Exceptions to Standard Fastener Specifications

Fastener	Size	Torque, N·m	Torque, in.·lb
Bolt, Turbo Boost Sensor-to-inlet	M5 x 0.8	2.4-3.0	21-26
Screw, Harness Connector-to-EDU	#10-24	2.4-3.0	21-26
Screw, Harness Connector-to-ECM	#10-24	2.4-3.0	21-26
Screw, Injector Wire Connector	M3 x 0.5	M3 x 0.5	12-17

Table 2-12 Exceptions to Standard Fastener Torque Specifications

3 LUBRICATION SYSTEM

Section **Page**

3.1 OVERVIEW OF LUBRICATING SYSTEM

The lubrication system consists of the following components:

- ☐ Oil pump
- ☐ Pressure regulator valve
- ☐ Pressure relief valve
- ☐ Oil filters
- ☐ Oil filter adaptor
- ☐ Oil cooler
- ☐ Oil level dipstick
- ☐ Oil pan
- ☐ Ventilating system

A schematic of the lubricating system is shown in the following illustration. See Figure 3-1.

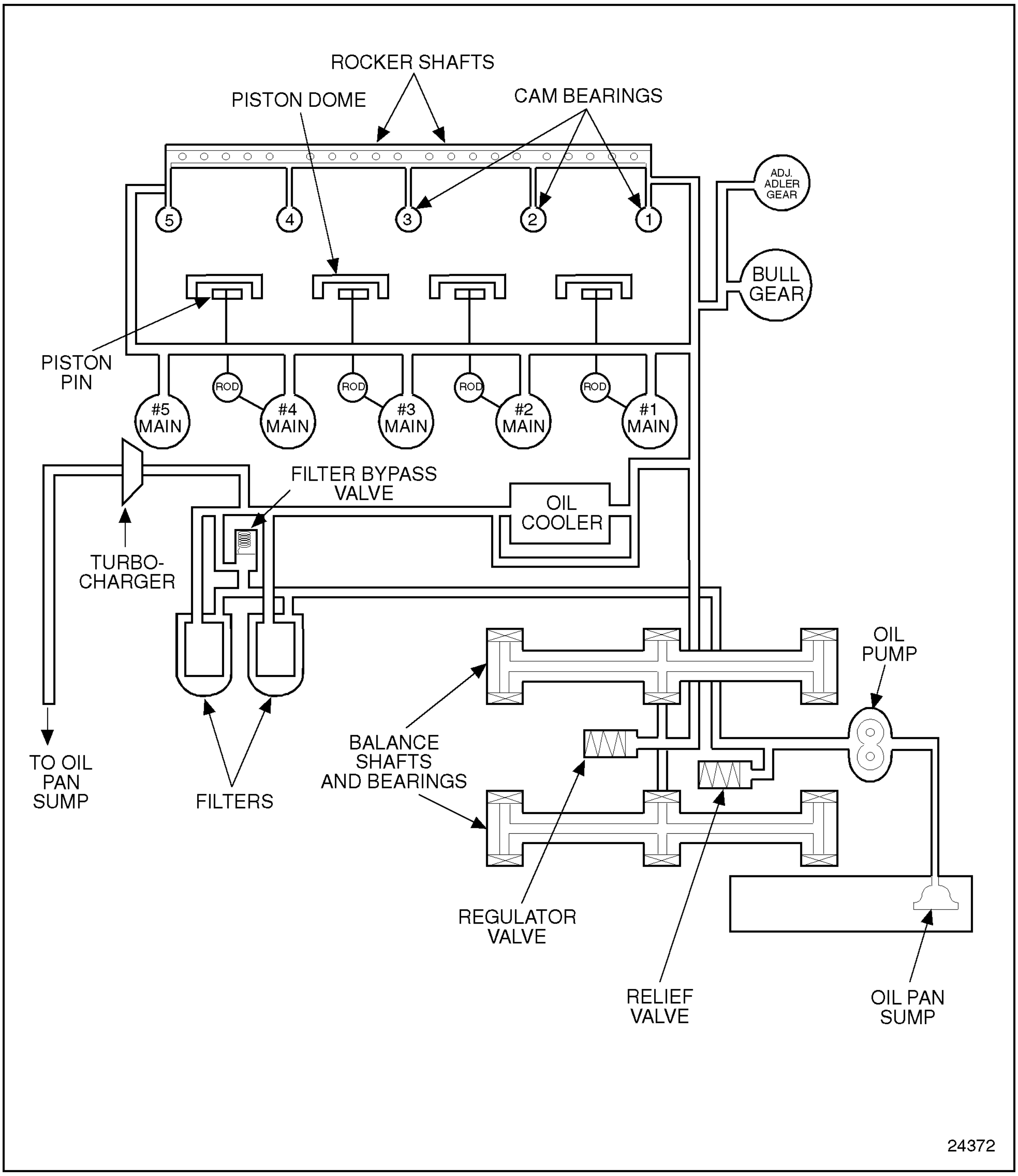


Figure 3-1 Schematic Diagram of Current Lubrication System

The lubricating oil is circulated by a gear-type pressure pump mounted to the front bulkhead of the balance support and has a gear driven front crankshaft through the balance shaft idle gear.

Clean engine oil is assured at all times by the use of 2 spin-on type, full flow oil filters incorporated in the engine lubrication system. These filters, which are installed in the lubrication system between the pump and the cooler, filter all of the oil before it enters the engine.

Oil leaving the pump is forced through full flow filters to the oil cooler and bypass passage and then into the oil gallery in the cylinder block from where it is distributed to the various engine bearings and moving parts. The oil then drains from the cylinder head and other engine parts return oil back to the oil pan.

A spring-loaded, integral plunger-type relief valve, attached to the balance support, bypasses excess oil from the discharge back to the oil pan when the pressure in the oil pump exceeds approximately 690 kPa (100 lb/in.^{2}).

If the oil cooler should become clogged, the oil will flow from the pump through a drilled passage directly into the oil gallery.

Stabilized oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve also attached to the balance support. When the oil pressure at the valve exceeds 380 kPa (55 lb/in.^{2}), the regulator valve opens and remains open until the pressure is less than the opening pressure.

Oil from the cooler is directed to a longitudinal main oil gallery on the cooler side of the cylinder block. See Figure 3-1. This gallery distributes the pressurized oil 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 into two vertical bores (one at each end of the cylinder block) to vertical passages in the cylinder head.

These passages in the cylinder head deliver oil from the cylinder block to the No. 1 and 5 lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 5 upper camshaft bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each rocker arm shaft. The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushing passes through the oil hole in the bushing to the injector arm.

The injector rocker is drilled to supply oil to the fuel injector follower and splash oil on the camshaft follower roller, adjuster screw, valve buttons, retainer clips intake and exhaust valve stems. The No. 3 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. The oil then drains through passages in the cylinder head and block, and back to the oil pan.

Oil for lubricating the connecting rod bearings, piston pins and for cooling the piston dome is provided through the drilled crankshaft from the adjacent forward main bearings.

Two holes in the bull gear recess area of the cylinder block are drilled into the cylinder block front-cross oil gallery. These holes supply oil to the bull gear bearings, bull gear, and camshaft idler gear and hub. See Figure 3-2.

Excess oil from the bull gear lubricates the crankshaft timing gear, and oil pump drive gear, and balance shaft gear. A hole at the top, front of the block, is drilled into the block front-cross oil gallery, which mates with an oil passage in the gear case that directs oil to the adjustable idler gear assembly. See Figure 3-2. Excess oil from the adjustable idler gear lubricates the accessory drive and water pump drive gears. The bearings and shafts of these two drive assemblies are splash-fed oil through holes in their housings.

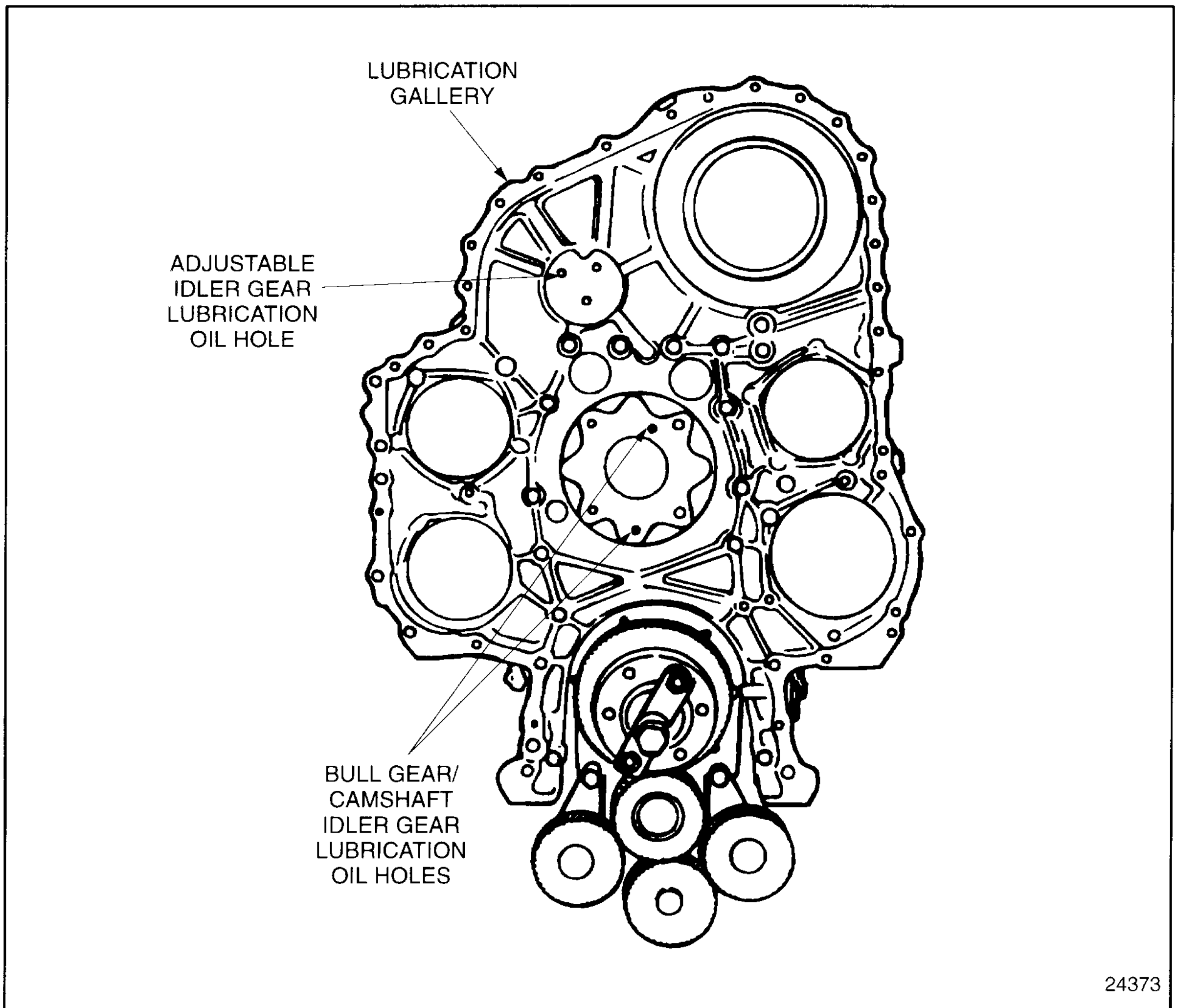


Figure 3-2 Gear Train Oil Supply Holes

A flexible, external oil line runs from a threaded hole at the top, front corner of the left side of the cylinder block, which is tapped into the main oil gallery. The flexible line runs to a fitting at the air compressor assembly.

Oil drains from the air compressor through a hole in the air compressor drive housing into the gear case.

A flexible, external oil line feeds oil from the oil filter adaptor housing pressure gallery, to the turbocharger bearings and shaft. This oil is returned through an external line to the block near the block-to-oil pan split line, and then back to the oil pan.

Series 50 engines use red dye to detect lube oil system leaks during engine testing at the factory. Customers receiving new engines may notice some residual dye remaining in the lube oil systems. This dye should be quickly dispersed after the first few hours of engine operation, and will have no detrimental effect on the engine.

3.2 OIL PUMP

The gear-type oil pump, see Figure 3-3, is mounted to the front bulkhead of the balance support and is gear driven from the front end of the crankshaft through the oil pump idler gear.

NOTE:
Effective with engine serial number 4R25678 manufactured on September 18, 1998, an improved oil pump and balance shaft assembly is used. The oil pump assembly can be identified by the increased material thickness in the bolt hole location.

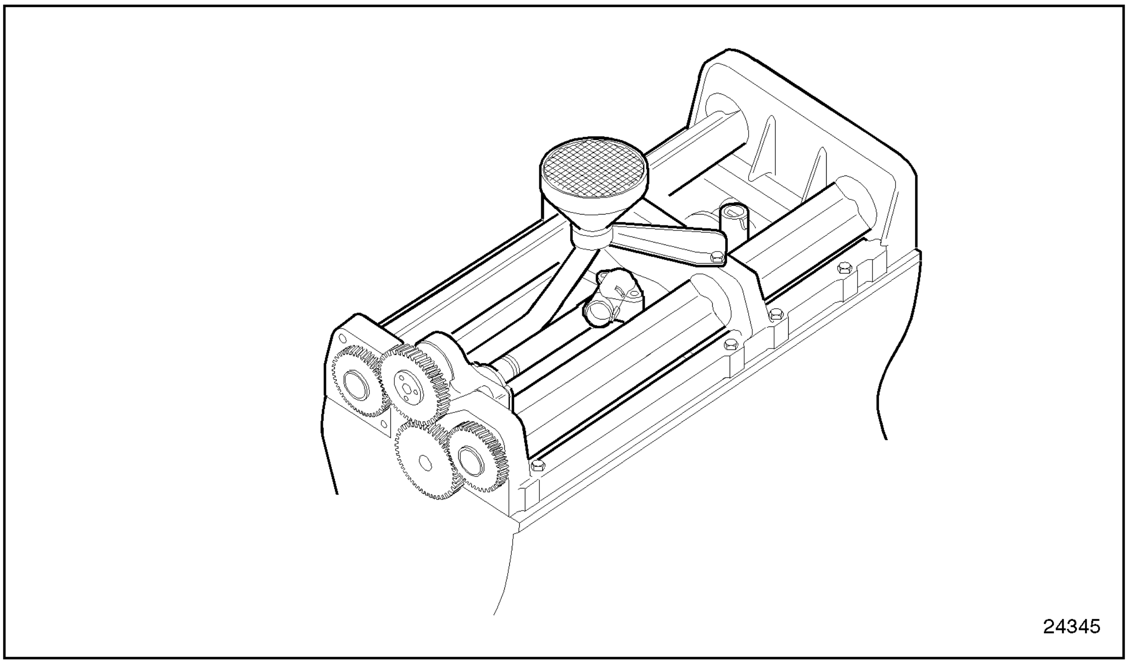
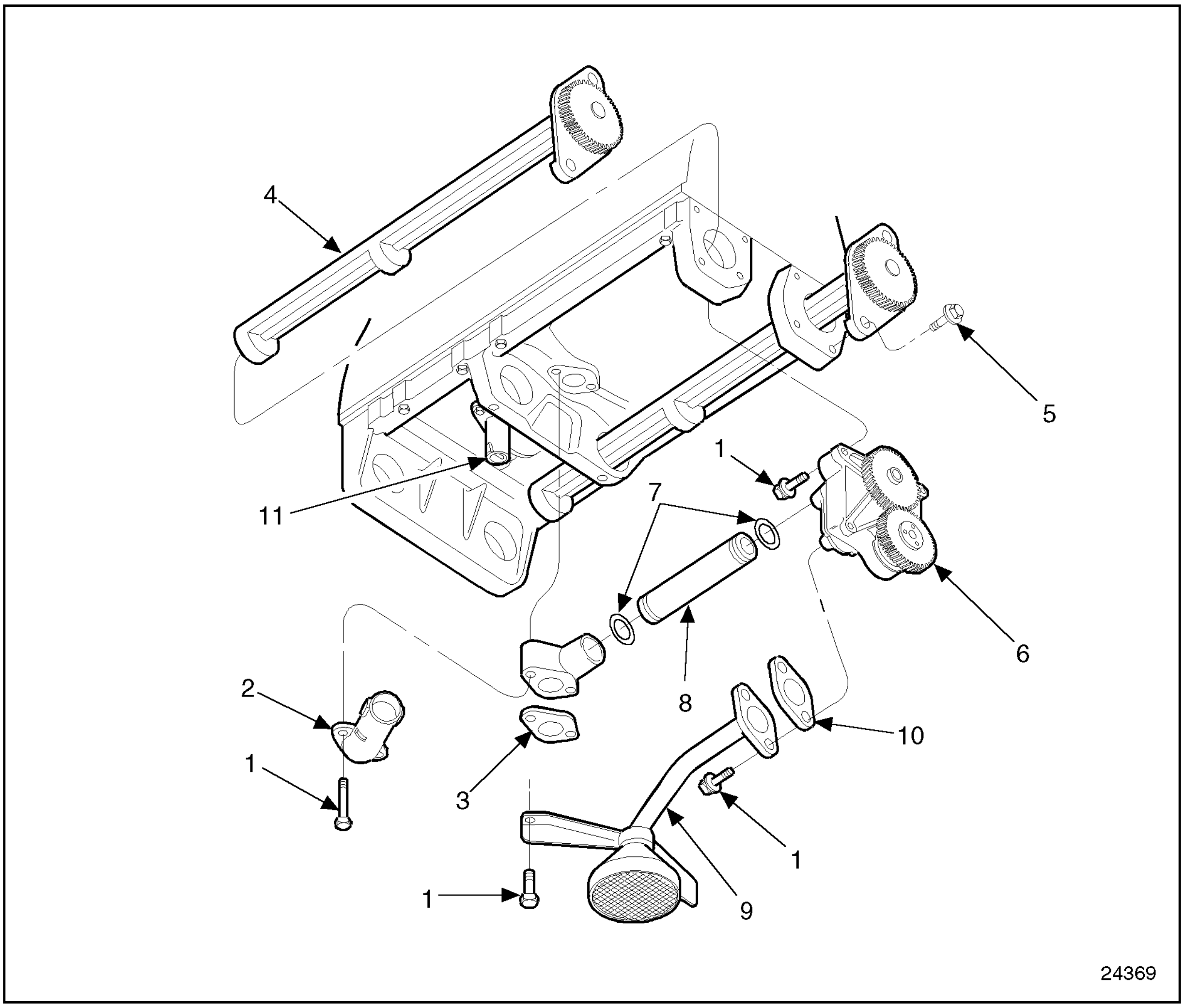


Figure 3-3 Oil Pump Mounting

The drive gear is pressed on the driveshaft, which is supported inside the housing on two bushings. The driven gear is pressed on the driven gear shaft, which is supported inside the housing on two bushings.

A plunger-type relief valve is attached to the adaptor at the end of the oil supply tube. The relief valve bypasses oil back to the pan when the pressure in the pump exceeds 724 kPa (105 lb/in.^{2}).

The oil pump helical gears rotate inside a housing. See Figure 3-4.



1. Bolt
2. Relief Valve
3. Gasket
4. Balance Shaft Assemblies
5. Thrust Plate Bolt
6. Oil Pump Assembly
7. O-rings (2)
8. Oil Feed Tube
9. Pickup Tube and Brackets
10. Pickup Tube Gasket
11. Regulator Valve

Figure 3-4 Oil Pump and Parts Components

An inlet pipe assembly, with screen, is attached to the inlet opening in the pump body. The screen end of the inlet pipe assembly is supported with brackets mounted to the balance support.

The inlet screen is located below the oil in the pan and serves to strain out any foreign material which might damage the pump.

3.2.1 Repair or Replacement of Oil Pump

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-5.

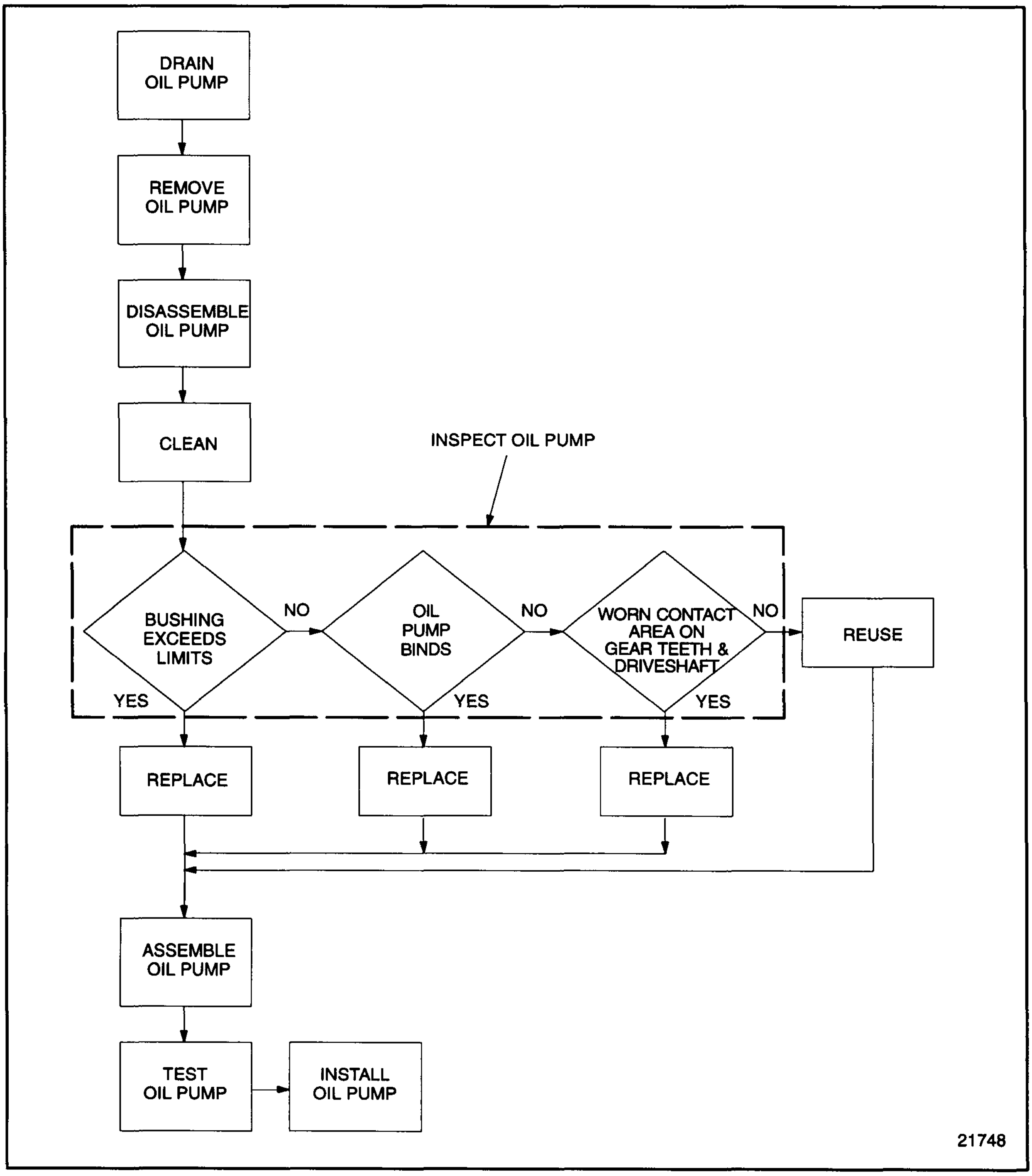


Figure 3-5 Flowchart for Repair or Replacement of Oil Pump

3.2.2 Cleaning and Removal of Oil Pump

Precleaning is not necessary to remove the oil pump.

To remove the oil pump, refer to Section 1.28.2.

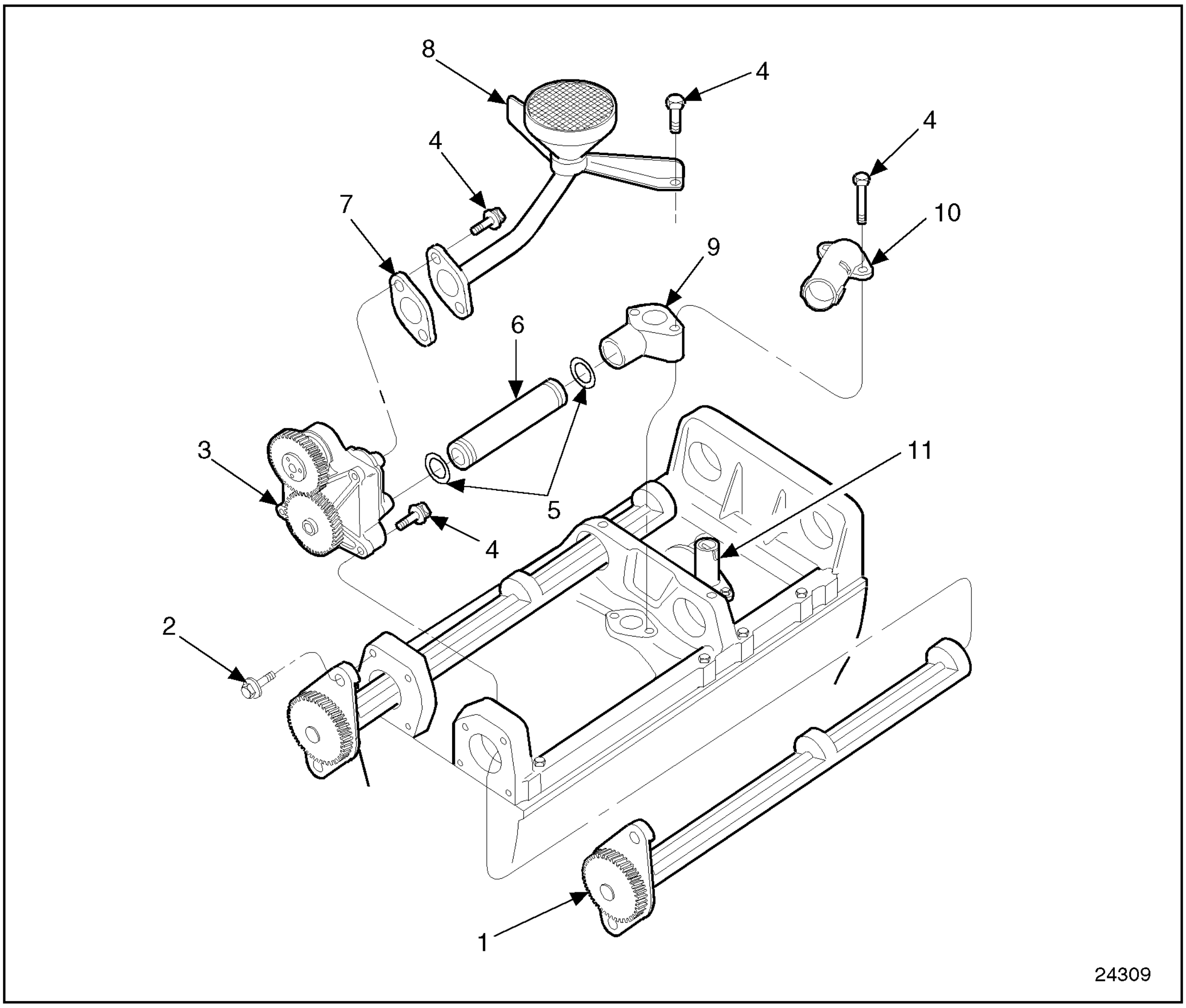
3.2.3 Disassembly of Oil Pump

Observe the position of all parts including the oil pickup tube and outlet pipe during disassembly to facilitate reassembly of the pump.

Disassemble the oil pump as follows:

1. Set cylinder No. 1 at top dead center by barring the engine over until the piston reaches the top of the cylinder. The cylinder will then be at top-dead-center (TDC).
2. Drain the engine oil. Refer to Section 13.5.1.
3. Remove the oil pan. Refer to Section 3.9.2.

4. Remove the two bolts that fasten the oil suction tube braces to the balance support. See Figure 3-6.



1. Balance Shaft Assembly
2. Thrust Plate Bolt
3. Oil Pump Assembly
4. Bolt
5. O-Rings
6. Oil Feed Tube
7. Gasket
8. Pickup Tube and Brackets
9. Adaptor
10. Relief Valve
11. Regulator Valve

Figure 3-6 Oil Pump Removal

5. Remove the bolts that attach the suction tube flange to the oil pump body and remove the pickup tube assembly.
6. Install the oil pump gear holding tool J 39816.

7. Support the balance shaft assembly on the center and front bulkhead using tool J 39814.
8. Remove the nine bolts that fasten the balance assembly to the cylinder block and lower the assembly.
9. Lift the balance assembly from the transmission stand, turn it over and set it on a clean working surface using care not to damage the locating dowels.

3.2.3.1 Inspection of Oil Pump

Inspect the pump as follows:

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

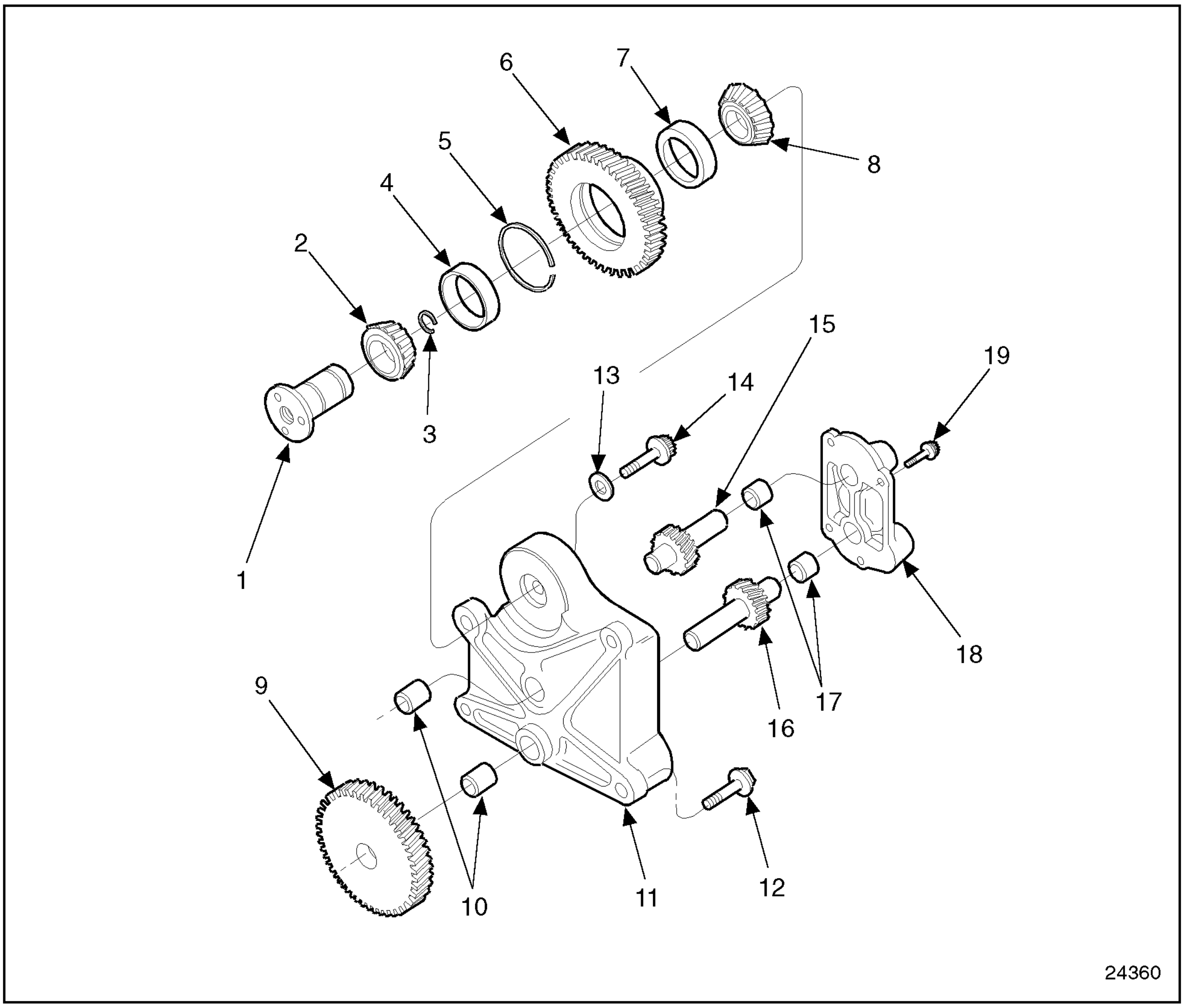
1. Wash all parts in clean fuel oil and dry with compressed air.
2. Inspect the bushings in the pump body and cover.
   [a] The shaft-to-pump cover bushing clearance should not exceed 0.089 mm (0.0035 in.).
   [b] If clearance exceeds 0.089 mm (0.0035 in.), replace bushing.

NOTICE:
The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious engine damage.

3. Inspect the oil pump gears.
   [a] Check to see if the gears turn freely in the pump housing.
   [b] If gear binds, replace it with a new gear.
4. Inspect gear teeth and driveshaft bushing contact areas.
   [a] Check for worn or scored contact areas on gear teeth and driveshaft.
   [b] If area is worn scored, replace gear and driveshaft assemblies with new parts, or replace the complete pump assembly.

3.2.4 Assembly of Oil Pump

Assemble the oil pump as follows: See Figure 3-7.



1. Oil Pump Idler Shaft
2. Oil Pump Bearing
3. Snap Ring
4. Bearing Race
5. Snap Ring
6. Oil Pump Idler Gear
7. Oil Pump Idler Gear Bushing
8. Oil Pump Bearing
9. Oil Pump Drive Gear
10. Oil Pump Body Bushing
11. Oil Pump Body
12. Oil Pump Body Bolt
13. Washer
14. Oil Pump Body Bolt
15. Oil Pump Shaft Gear
16. Oil Pump Shaft Gear
17. Oil Pump Body Bushing
18. Oil Pump Body Cover
19. Bolt

Figure 3-7 Oil Pump Assembly

1. Lubricate the driveshaft bushing with clean engine oil.
2. Insert the driveshaft and gear assembly into the pump body. See Figure 3-7.

3. Position the oil pump assembly on a press, pump body down, supporting the driveshaft. The pump body should be free of the press bed supported by the pump gear contacting the bottom of the pump cavity.
4. Coat the bore of the drive gear with a light film of Lubriplate (or equivalent).
5. Position drive gear squarely on the end of the shaft.
6. Press the drive gear onto the shaft with timing mark side outside until a clearance of 1.00 mm (0.039 in.) is obtained between the inner face of the gear and the pump body. See Figure 3-8.

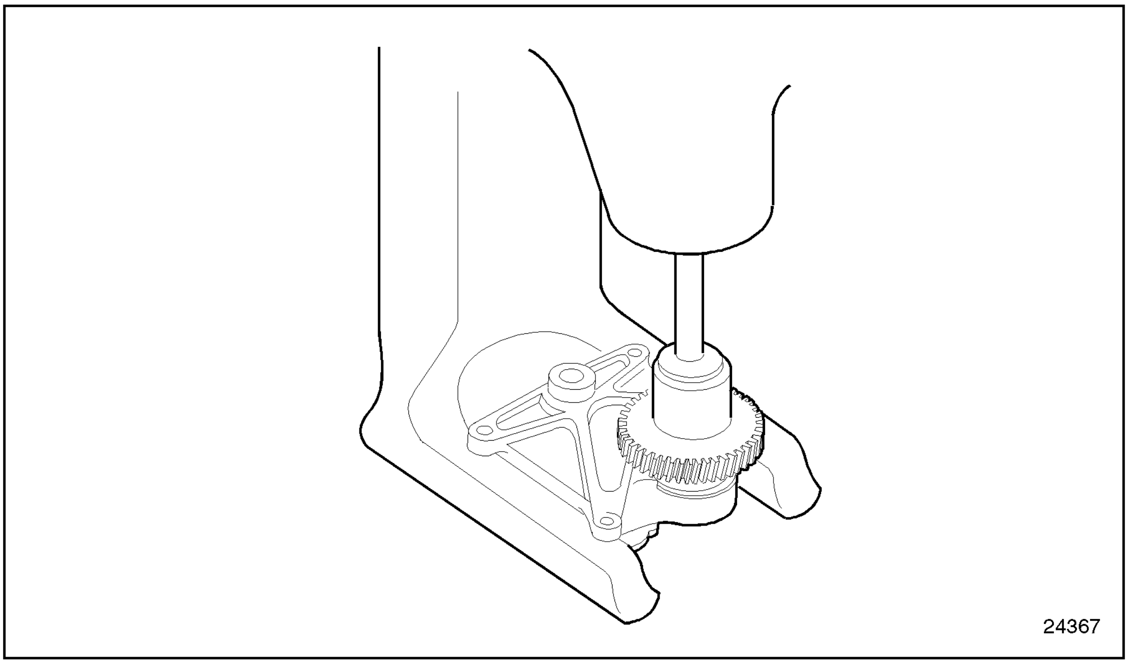


Figure 3-8 Oil Pump Drive Gear Installation

NOTE:
A minimum press load of 8.8 kN (1,978 lb) must be obtained when pressing the gear onto the shaft. When completed, an end play of 0.85-1.15 mm (0.033-0.044 in.) must be obtained.

7. Lightly coat the driven gear bushing with clean engine oil.
8. Insert the driven shaft and gear assembly into the pump body.
9. Lightly coat both bushings in the pump cover with clean engine oil.
10. Index them with the shafts.
11. Install the four cover bolts, hand-tighten.
12. Rotate the oil pump by hand. The oil pump must turn freely without binding.

NOTICE:
The cause of oil pump binding must be corrected before installation is complete or severe engine damage may result.

13. If binding occurs, stop assembly and disassemble until the cause can be detected and corrected. Refer to Section 3.2.3.
14. Torque the four cover bolts to 30-38 N·m (22-28 lb·ft).

3.2.4.1 Test Assembled Oil Pump

Test oil pump as follows:

1. Rotate the pump by hand.
   [a] Check for binding.
   [b] If binding occurs, disassemble oil pump again. Refer to Section 3.2.3.
2. With a dial indicator mounted on the pump mounting surface, rotate the gear and check the gear run-out. See Figure 3-9.

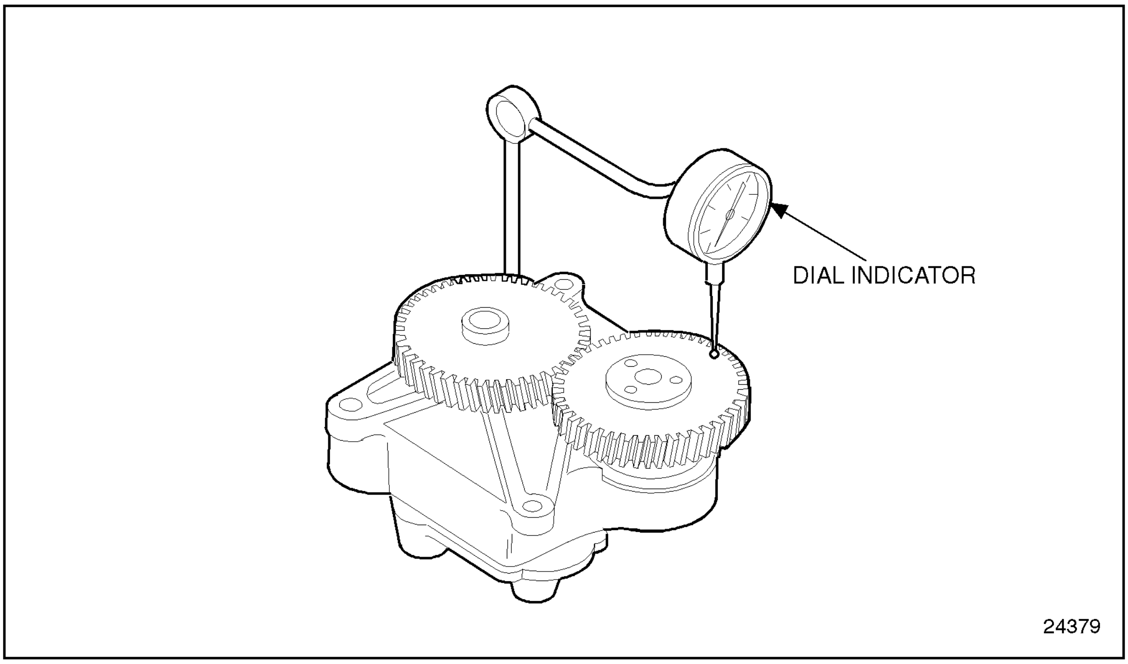


Figure 3-9 Gear Run-out Measurement

[a] The run-out may not exceed 0.05 mm (0.002 in.).
[b] If run-out exceeds 0.05 mm (0.002 in.), disassemble oil pump. Refer to Section 3.2.3.

After testing is completed, finish assembly of oil pump as follows:

1. Press cups in idler gear to snap ring.

NOTE:
Tool J 39769 is a holding tool only. Do not torque.

2. Install the idler gear, shaft, and tapered roller bearings cone and spacer in the pump housing.
3. Align the teeth of the idler gear, so that the "Y" on the gear and the "Y" on the drive gear are aligned.
4. Using tool J 39769, hold the shaft in place, and torque the left-hand threaded bolt to 199-231 N·m (147-170 lb·ft).
5. Check the gear lash between gears. Lash should read 0.051-0.203 mm (0.002-0.008 in.). See Figure 3-10.

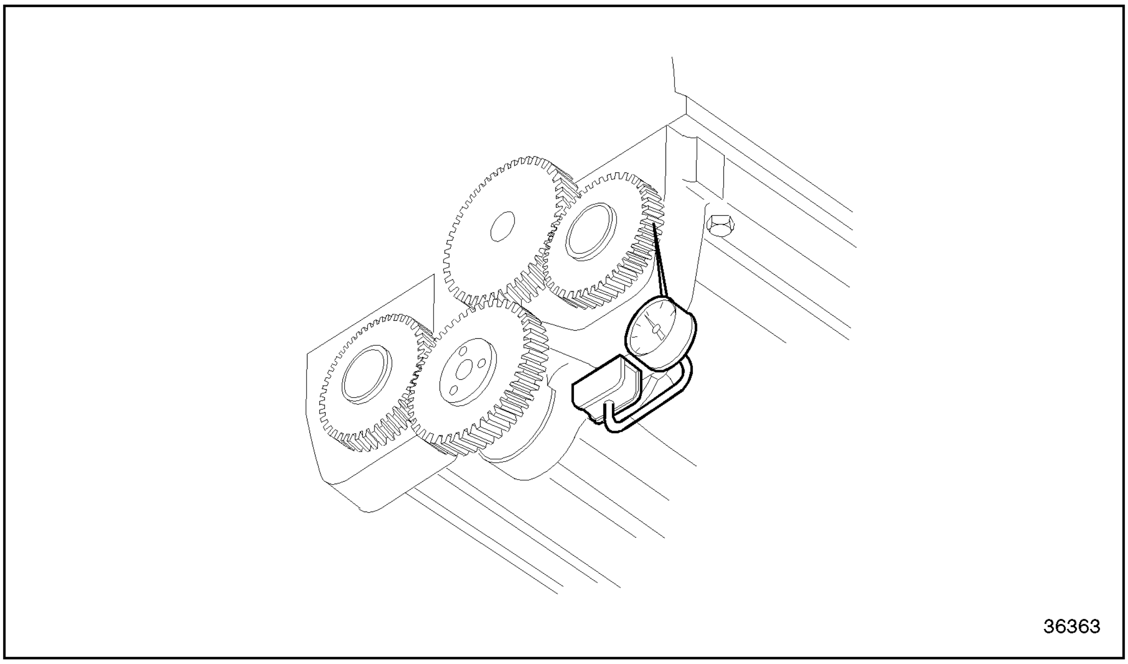


Figure 3-10 Checking Gear Lash

3.2.5 Installation of Oil Pump

Perform the following steps to install the oil pump:

1. Install the oil pump, taking care to match each of the letters stamped on the oil pump idler gear and oil pump drive gear with the same letter of the left and right side balance shafts. See Figure 3-11.

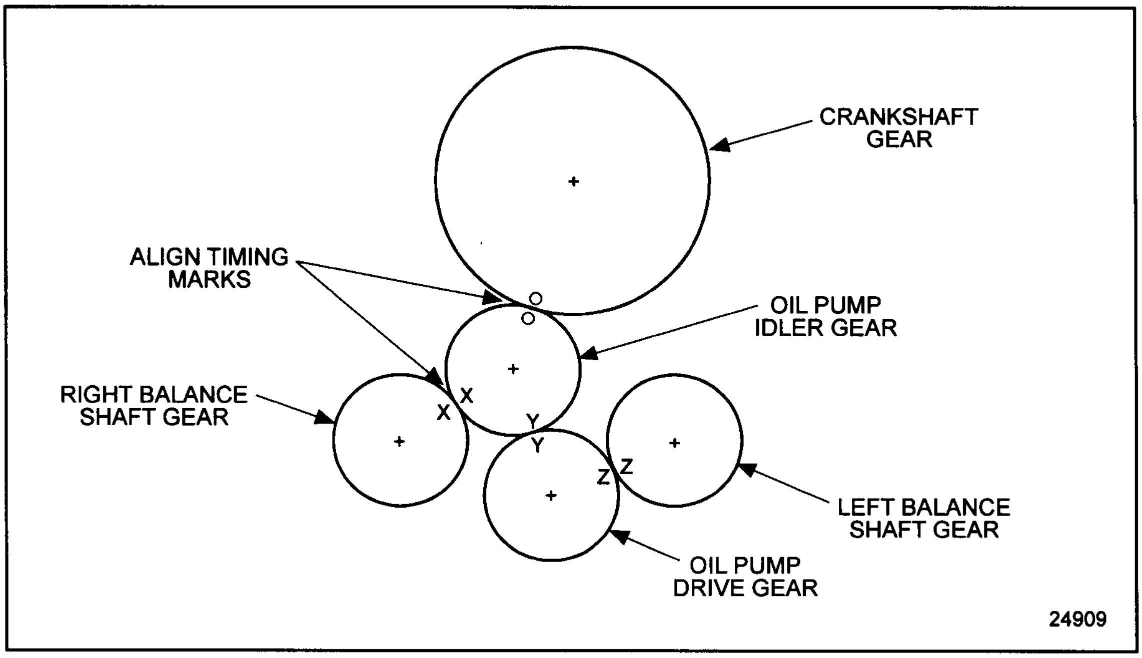


Figure 3-11 Balance Shaft Drive Gear Timing

2. When all the gears are aligned correctly, install the M8 bolts and torque to 34 N·m (25 lb·ft).
3. Install the four M8 bolts that attach the oil pump to the balance support and torque to 34 N·m (25 lb·ft).
4. To aid balancer timing, leave the oil pump gear holding tool J 39816 in place until the balance assembly is installed in the engine.
5. Install new o-ring seals on both ends of the oil pump outlet tube and lubricate them with clean engine oil.
6. Loosely assemble the left and right side oil inlet tube brackets to the inlet tube using the M10 nuts and bolts.
7. Install one end of the oil pump outlet tube into the inlet tee, the other into the pump body.
8. Install the inlet tee and attach the relief valve using two M8 bolts and torque to 34 N·m (25 lb·ft).
9. Install the regulator valve using two M8 bolts and torque to 34 N·m (25 lb·ft).
10. Install the two M10 bolts that attach the left and right side oil inlet tube brackets to the support and torque to 47 N·m (35 lb·ft).
11. Tighten the M10 bolts and nuts that fasten the tube bracket assembly to the inlet tube.

12. Attach the balancer assembly to the transmission jack stand J 39814.
13. Use guide studs in opposite center holes to properly align the balance shaft support.
14. Before attaching the balance shaft assembly to the block, make sure the timing marks are aligned correctly. See Figure 3-12.

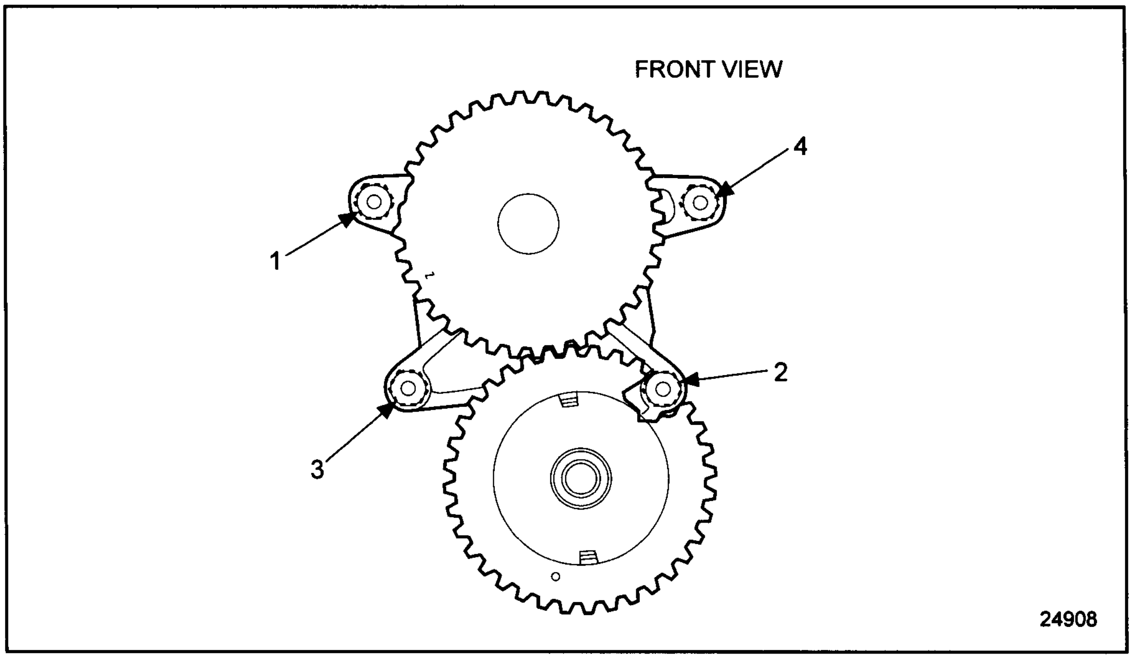


Figure 3-12 Oil Pump Torque Sequence

15. Raise the balance shaft assembly to the cylinder block and attach it using the nine M12 bolts and torque to 115 N·m (85 lb·ft).
16. Remove guide studs and install remaining two M12 bolts and torque to 115 N·m (85 lb·ft).
17. Remove the oil pump gear holding tool J 39816 from the balance shafts.
18. Install the oil pan. Refer to Section 3.9.3.

3.3 OIL PRESSURE REGULATOR VALVE

An oil pressure regulator valve maintains stable lubricating oil pressure within the engine, regardless of the oil temperature. Oil leaving the pump under pressure passes into the pressure relief valve. The valve is installed into a vertically drilled passage in the balance assembly. See Figure 3-13.

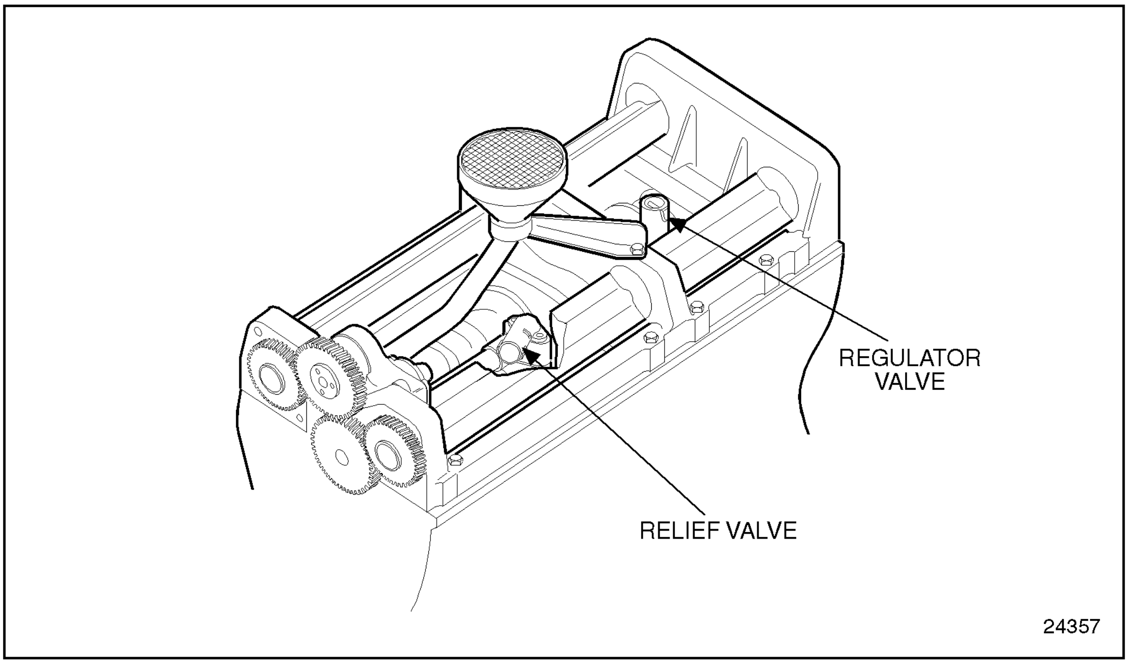
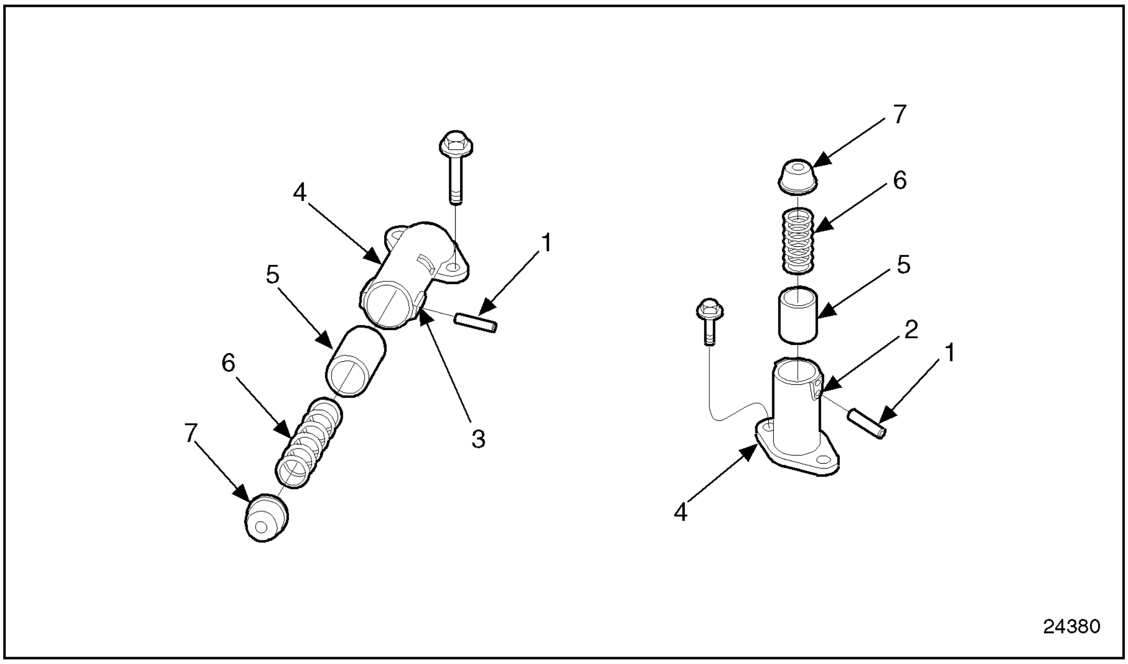


Figure 3-13 Oil Pressure Regulator and Relief Valve Mounting

The oil pressure regulator consists of a valve body, a hollow, piston-type valve, a spring, a spring seat and a pin to retain the valve assembly within the valve body. See Figure 3-14.



1. Pin
2. Pressure Regulator Pin Location
3. Pressure Relief Valve Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

Figure 3-14 Oil Pressure Regulator and Relief Valve Details

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the balance support and sealed against leaks by a gasket between the block and valve body. When conditions are such that the oil pressure at the regulator valve exceeds 427 kPa (62 lb/in.^{2}), the valve begins to be forced from its seat and oil from the engine gallery is bypassed to the engine oil pan. Thus, stable lubricating oil pressure is maintained at all times.

NOTE:
Whenever the lubricating oil pump is removed for inspection, remove the regulator valve and spring and thoroughly clean and inspect them.

3.3.1 Repair or Replacement of Oil Pressure Regulator Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-15.

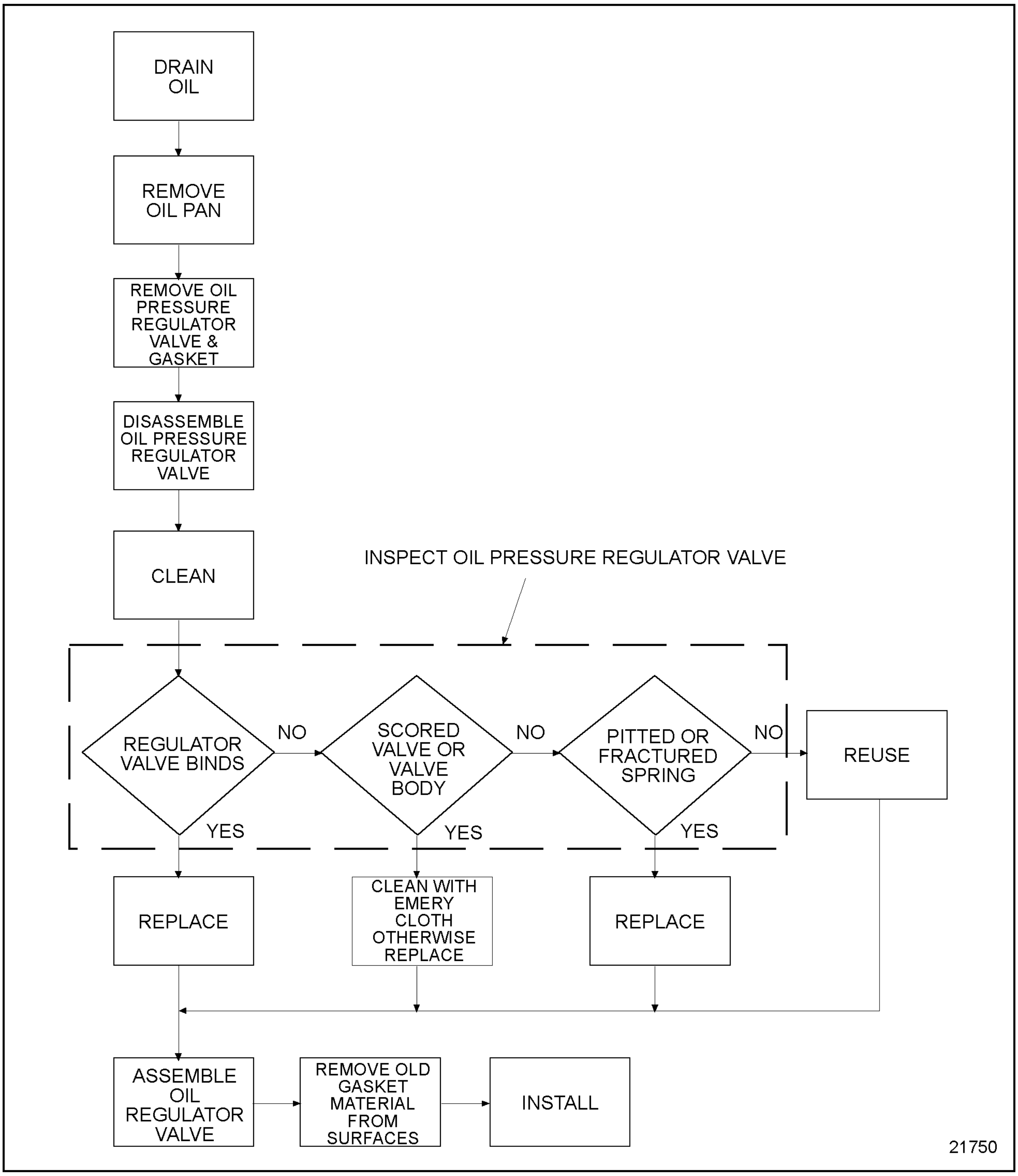


Figure 3-15 Flowchart for Repair or Replacement of Oil Pressure Regulator Valve

3.3.2 Draining and Removal of Oil Pressure Regulator Valve

Precleaning is not necessary.

Remove the oil pressure regulator valve as follows:

1. Drain the lubricating oil and remove the oil pan. Refer to Section 3.9.2.
2. Remove the two regulator-to-balance support attaching bolts and washers.
3. Tap the regulator body lightly to loosen it from the balance support.
4. Remove the oil pressure regulator valve.

3.3.3 Disassembly of Oil Pressure Regulator Valve

Disassemble the oil pressure regulator valve as follows:

1. Clamp the regulator in the soft jaws of a bench vise.

CAUTION:
To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

2. Depress spring seat and hold it securely while removing the spring seat retaining pin from the regulator body.
3. Remove the spring seat, spring and valve from the regulator body.

3.3.3.1 Inspection of Oil Pressure Regulator Valve

Inspect the oil pressure regulator valve as follows:

1. Clean all of the oil pressure regulator valve components in fuel oil.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the components with compressed air.
3. Inspect the oil pressure regulator valve for movement.
   [a] Check to see if the oil pressure regulator valve moves freely in the valve body.
   [b] If oil pressure regulator valve binds, replace it with a new part.
4. Inspect the components for wear or damage.
   [a] Check to see if valve or the valve body are scored.

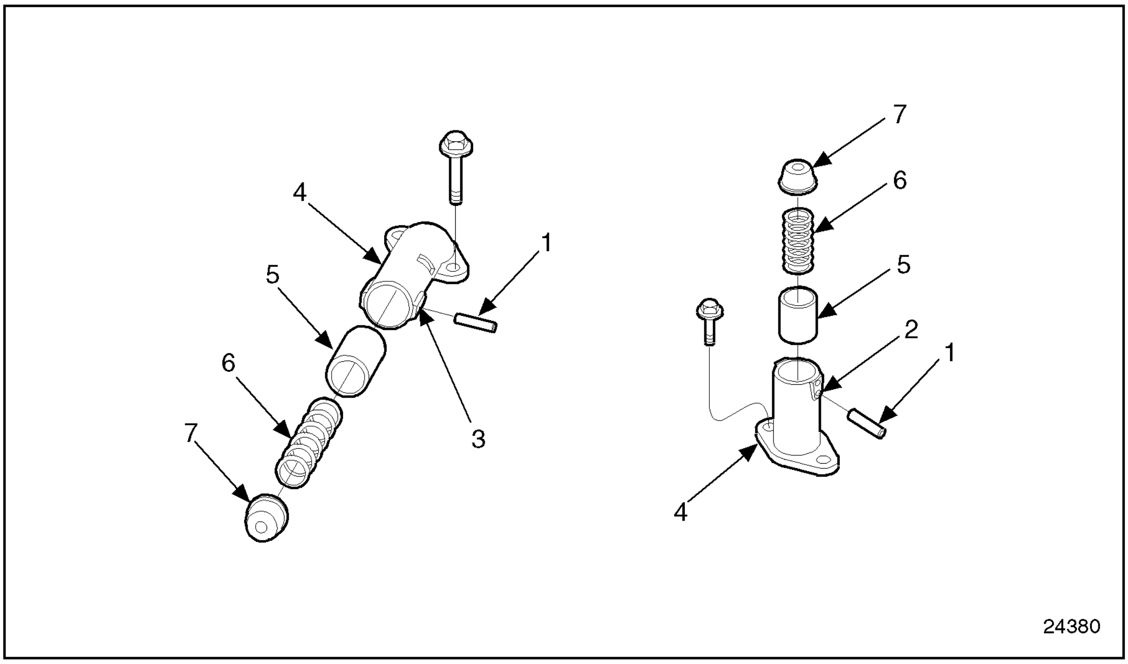
[b] If the valve or valve body parts cannot be cleaned up with a fine emery cloth, replace with new parts.

5. Inspect spring for following:
   [a] Check for pitting or fractures.
   [b] If spring is damaged, replace it with a new part.

3.3.4 Assembly of Oil Pressure Regulator Valve

Assemble the regulator valve as follows:

1. Apply clean engine oil to the outer face of the valve.
2. Slide it into the regulator body, closed end first. See Figure 3-16.



1. Pin
2. Pressure Regulator Pin Location
3. Pressure Relief Valve Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

Figure 3-16 Oil Pressure Regulator and Relief Valve Details

3. Insert the spring in the valve and install the spring seat.
4. While compressing the spring, install the retaining pin behind the spring seat.

5. Press the pin flush to 0.254 mm (0.010 in.) below the surface of the valve body.

NOTE:
The valve body has two retaining pin holes. Install the pin in the outermost hole for the regulator valve. The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3-17.

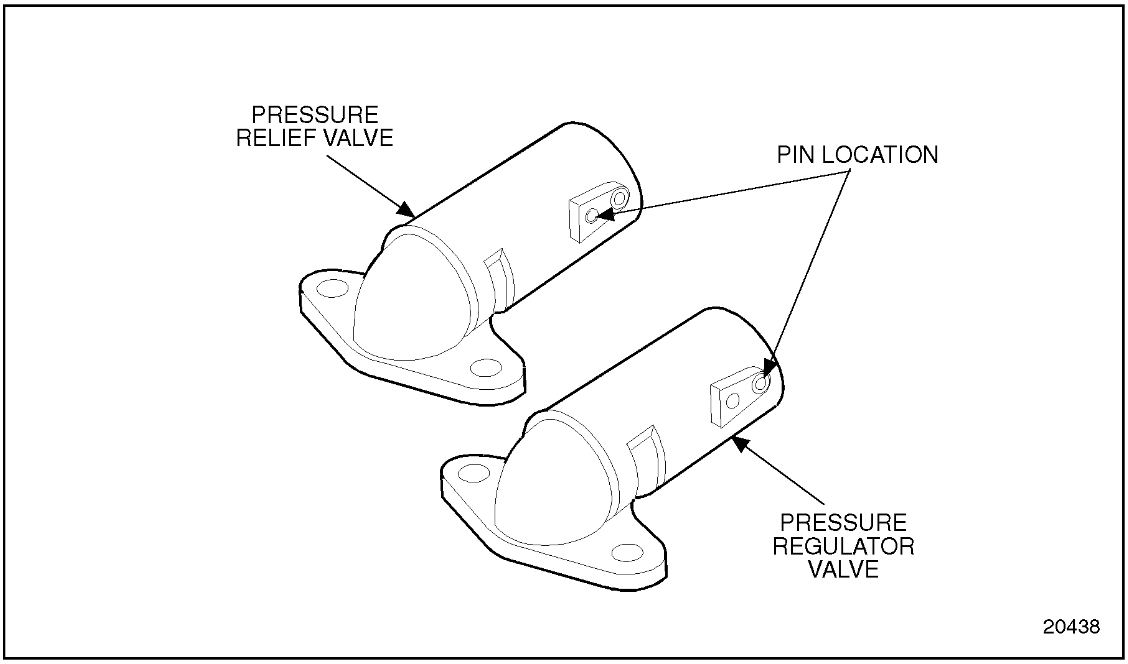


Figure 3-17 Comparison of Pressure Regulator and Relief Valve Assemblies

3.3.5 Installation of Oil Pressure Regulator Valve

Install the oil pressure regulator valve as follows:

1. Remove all traces of old gasket material from the mating surfaces of the regulator body and the balance support.

NOTE:
Detroit Diesel has determined that, when the oil pressure regulator is properly fastened to the cylinder block, a gasket between the block oil gallery and the valve body is not required. Due to the flatness tolerances of the valve face and the block mounting surfaces, the seepage of lubricating oil around the valve body at this joint is minimal and has no significant effect on oil system pressure requirements. For this reason, the regulator valve-to-block gasket has been eliminated from all Series 50 engines.

2. Secure the regulator assembly to the balance support with two bolts. Torque the bolts to 30-38 N·m (22-28 lb·ft).

3. Refer to Section 11.1.2 for verification of proper oil pressure regulator installation.

3.4 OIL PRESSURE RELIEF VALVE

Oil leaving the pump under pressure passes into the pressure relief valve body. The spring-loaded valve opens when the pressure exceeds 690 kPa (100 lb/in.^{2}) and directs the excess oil to the oil pan. The pressure relief valve is mounted on the oil outlet adaptor in the balance support assembly.

The pressure relief valve consists of a valve body, a hollow piston-type valve, spring, spring seat and pin to retain the valve assembly within the valve body.

The relief valve assembly used is composed of the same parts as the regulator valve assembly with the exception of the body. See Figure 3-14.

NOTE:
The valve body has two retaining pin holes. Install the pin in the outermost hole for the regulator valve. The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3-17.

The spring in the relief valve assembly is the same as used in the oil pressure regulator assembly.

3.4.1 Repair or Replacement of Oil Pressure Relief Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-18.

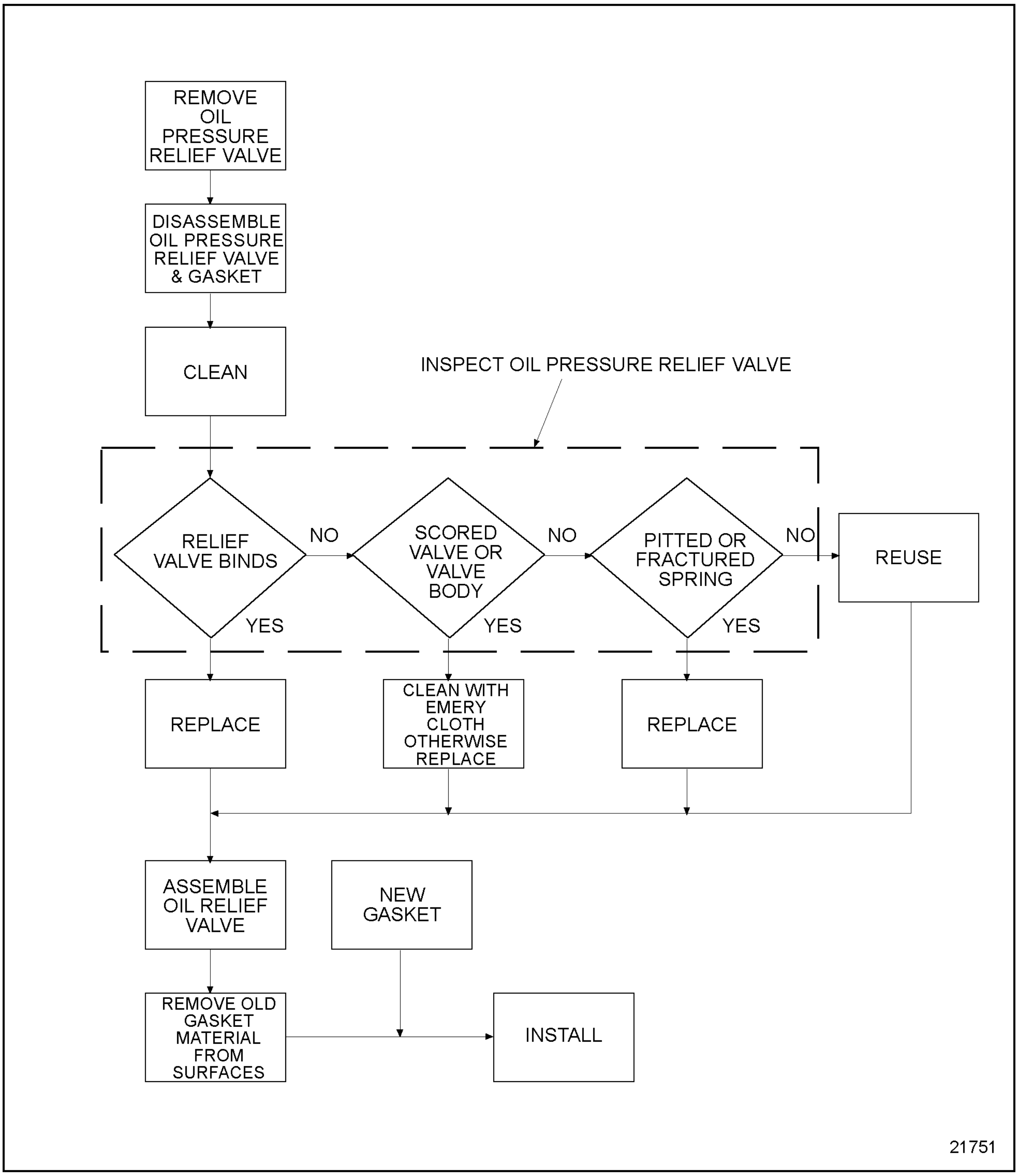


Figure 3-18 Flowchart for Repair or Replacement of Oil Pressure Relief Valve

3.4.2 Cleaning and Removal of Oil Pressure Relief Valve

Precleaning is not necessary.

Remove the oil pressure relief valve as follows:

1. Drain the lubricating oil and remove the oil pan. Refer to Section 3.9.2.
2. Remove the two bolts and washers securing the relief valve to the balance support.
3. Tap the oil pressure relief valve body lightly to loosen it from the balance support.
4. Remove the oil pressure relief valve and gasket.

3.4.3 Disassembly of Oil Pressure Relief Valve

Disassemble the oil pressure relief valve as follows:

1. Clamp the oil pressure relief valve in the soft jaws of a bench vise.

CAUTION:
To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

2. Depress spring seat and holt it securely while removing the spring seat retaining pin from the oil pressure relief valve body.
3. Remove the spring seat, spring and valve from the oil pressure relief valve body.

3.4.3.1 Inspection of Oil Pressure Relief Valve

Clean the oil pressure relief valve prior to inspection as follows:

1. Clean all of the oil pressure relief valve components in fuel oil.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the components with compressed air.

Inspect the oil pressure relief valve as follows:

1. Inspect the oil pressure relief valve for movement.
   [a] Check to see if the oil pressure relief valve moves freely in the valve body.
   [b] If relief valve binds, replace it with a new part.
2. Inspect the components for wear or damage.
   [a] Check to see if valve or the valve body are scored.

[b] If the valve and valve body parts cannot be cleaned up with a fine emery cloth, replace with new parts.

3. Inspect spring for following:
   [a] Check for pitting or fractures.
   [b] If spring is damaged, replace it with a new part.

3.4.4 Assembly of Oil Pressure Relief Valve

Assemble the relief valve as follows:

1. Apply clean engine oil to the outer face of the valve.
2. Slide it into the oil pressure relief body, closed end first. See Figure 3-14.
3. Insert the spring in the valve and install the spring seat.

NOTICE:
The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3-17.

4. While compressing the spring, install the retaining pin behind the spring seat.
5. Press the pin flush to 0.254 mm (0.010 in.) below the surface of the valve body.

3.4.5 Installation of Oil Pressure Relief Valve

Install the oil pressure relief valve as follows:

1. Remove all traces of old gasket material from the mating surfaces of the oil pressure relief valve body and the balance support.
2. Secure the oil pressure relief valve assembly to the balance support with two bolts. Torque the bolts to 30-38 N·m (22-28 lb·ft).
3. Refer to Section 11.1.2 for verification of proper oil pressure relief valve installation.

3.5 OIL FILTER

Two full-flow type lubricating oil filters are used on the Series 50 engine. The oil filters are mounted in a downward position. The filters are the throw away, spin-on type. See Figure 3-19.

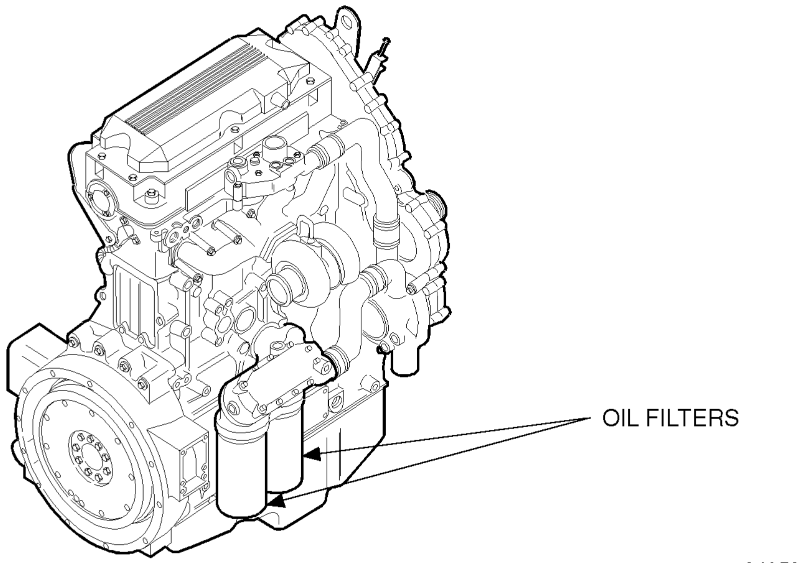


Figure 3-19 Spin-on Oil Filters

Oil supplied by the engine oil pump passes through the full-flow filters before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor and into the elements. Impurities are filtered out as the oil passes through the elements and out through another passage in the filter adaptor.

3.5.1 Repair or Replacement of Oil Filters

Repair is not possible. Replace using the following procedure:

1. Remove oil filter. Refer to Section 3.5.2.
2. Install new oil filter. Refer to Section 3.5.3.

3.5.2 Cleaning and Removal of Oil Filter

Precleaning is not necessary.

Remove oil filter as follows:

1. Remove the oil filter using oil filter wrench J 29917 and discard the used oil filters.
2. Examine the sealing surface of the filter to ensure that the seal ring is attached to the filter. If not, remove it from the adaptor.

Prior to installation, clean the filter adaptor with a clean, lint-free cloth.

3.5.3 Installation of Oil Filter

Install oil filter as follows:

1. Lightly coat the new oil filter seal with clean engine oil.
2. Start a new filter on the adaptor, and tighten it by hand until the seal touches the adaptor filter head.

NOTICE:
Mechanical tightening is not necessary and will distort or crack the adaptor.

3. Tighten the filter an additional 2/3 turn after contact.
4. Refer to Section 11.1.2 or refer to Section 13.5.10for verification of proper oil filter installation.

3.6 OIL FILTER ADAPTOR

The oil filter adaptor is located on the right side of the engine and is joined to the oil cooler.

A bypass valve in the filter adaptor opens at approximately 124-145 kPa (18-21 lb/in.^{2}) pressure differential, and will bypass the oil filters should the full flow filters become plugged.

3.6.1 Repair or Replacement of Oil Filter Adaptor

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-20.

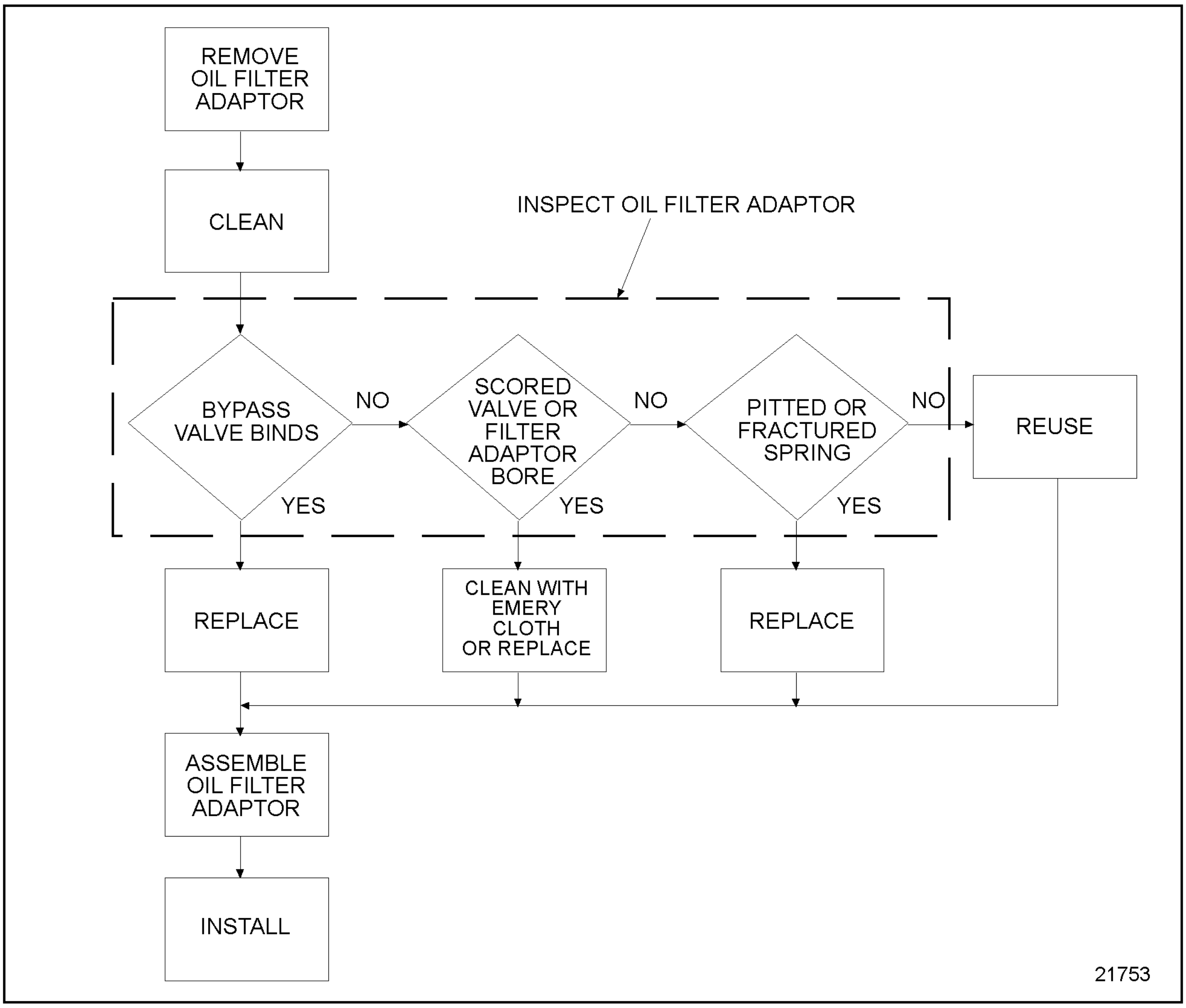


Figure 3-20 Flowchart for Repair or Replacement of Oil Filter Adaptor

3.6.2 Cleaning and Removal of Oil Filter Adaptor

Precleaning is not necessary.

Remove the oil filter adaptor as follows:

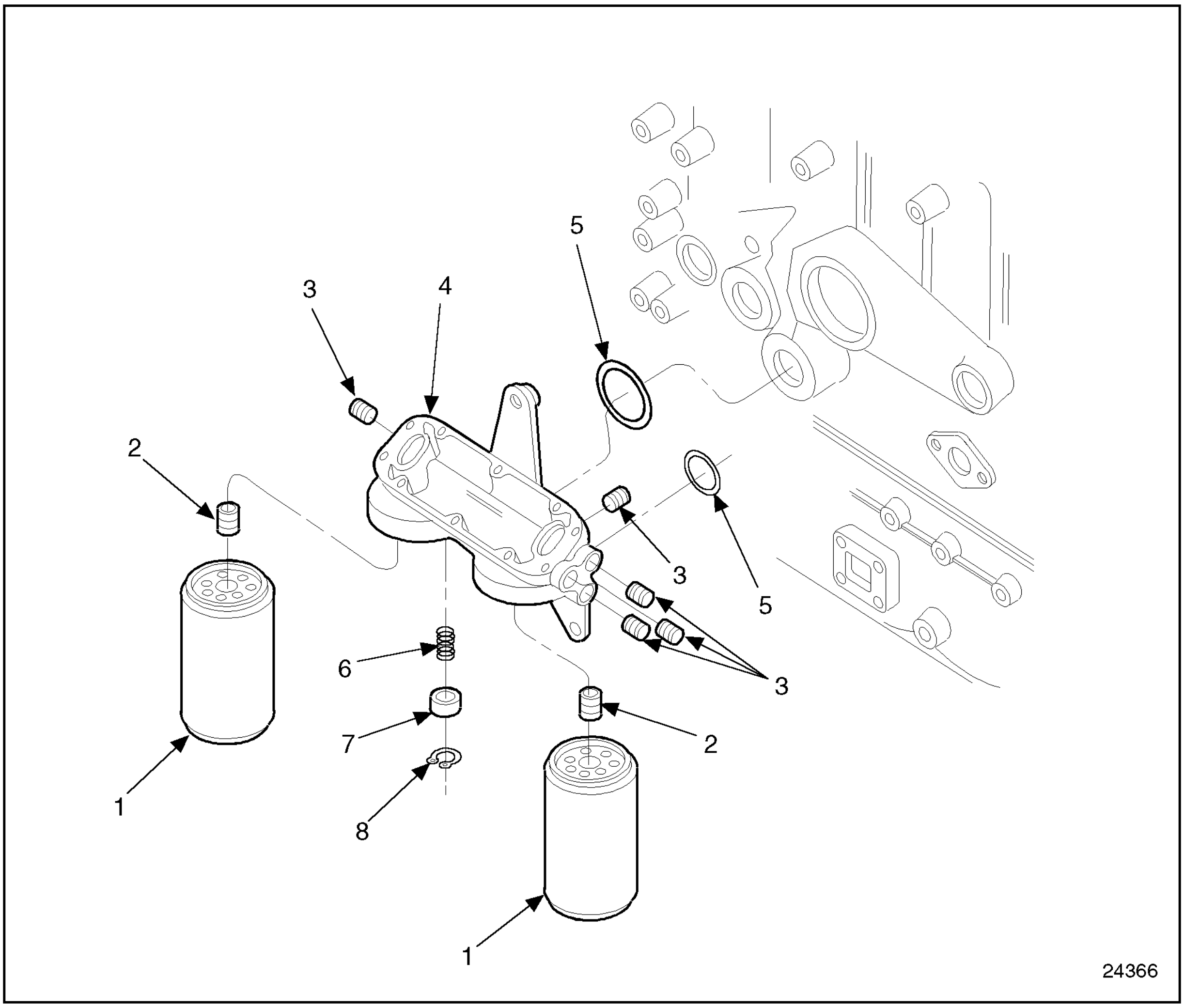
1. Remove the four bolts that connect the oil filter adaptor to the block.

CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

2. Remove the snap ring.

3. Withdraw the spring and bypass valve. See Figure 3-21.



1. Oil Filter, Full-Flow
2. Insert, Full-Flow Filter-to-Adaptor
3. Pipe Plugs (5)
4. Oil Filter Adaptor
5. O-ring, Adaptor-to-Block
6. Spring, Bypass
7. Valve, Bypass
8. Snap Ring

Figure 3-21 Oil Filter Adaptor, Bypass Valve and Related Parts

4. Remove the pipe plugs.

3.6.2.1 Inspection of Oil Filter Adaptor

Inspect the oil filter adaptor as follows:

1. Clean all of the oil filter adaptor components in fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the parts with compressed air.
3. Inspect the bypass valve for movement.
   [a] Check to see if the bypass valve moves freely in the adaptor.
   [b] If the bypass valve binds, replace it with a new part.
4. Inspect the components for wear or damage.
   [a] Check to see if the valve or the filter adaptor bore are scored.
   [b] If the valve and the filter adaptor bore parts cannot be cleaned up with a fine emery cloth, replace with new parts.
5. Inspect the spring for damage.
   [a] Check for pitting or fractures.
   [b] If spring is damaged, replace it with a new part.

3.6.3 Assembly of Oil Filter Adaptor

Assemble the oil filter adaptor as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Install bypass spring and bypass valve into the oil filter adaptor.
2. Using tool J 23432 part of J 5586–A, install snap rings.
3. Install oil filter adaptor inserts, if removed.
4. Install the pipe plugs.
   [a] Apply a sealant such as, Loctite 620, (or equivalent) to the threads of the bolts that will engage the adaptor.
   [b] Wipe off any sealant remaining exposed on the threads.
   [c] Torque all pipe plugs to 129-161 N·m (95-119 lb·ft).
5. Coat new O-rings with petroleum jelly.

6. Install the O-rings in the recesses in the oil filter adaptor.

3.6.4 Installation of Oil Filter Adaptor

Install oil filter adaptor as follows:

CAUTION:

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

NOTICE:

Failure to tighten oil filter adaptor mounting bolts to the required torque may lead to a loss of lubricating oil during engine operation. Inadequate lubrication can result in severe engine damage.

1. Install the oil filter adaptor to the cylinder block. Torque the mounting bolts to 58-73 N·m (43-54 lb·ft).
2. Install full-flow oil filters. Refer to Section 13.5.10.
3. Refer to Section 11.1.2 for verification of proper oil filter adaptor installation.

3.7 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, and it cannot carry away enough heat. High oil temperature may cause, oil pressure to drop below acceptable limits and oil consumption to become excessive.

While performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat, and this heat must be dissipated by an oil cooler.

Series 50 engines use a 9-plate oil cooler.

The lubricating oil cooler is mounted on the right side of the cylinder block near the water pump. See Figure 3-22.

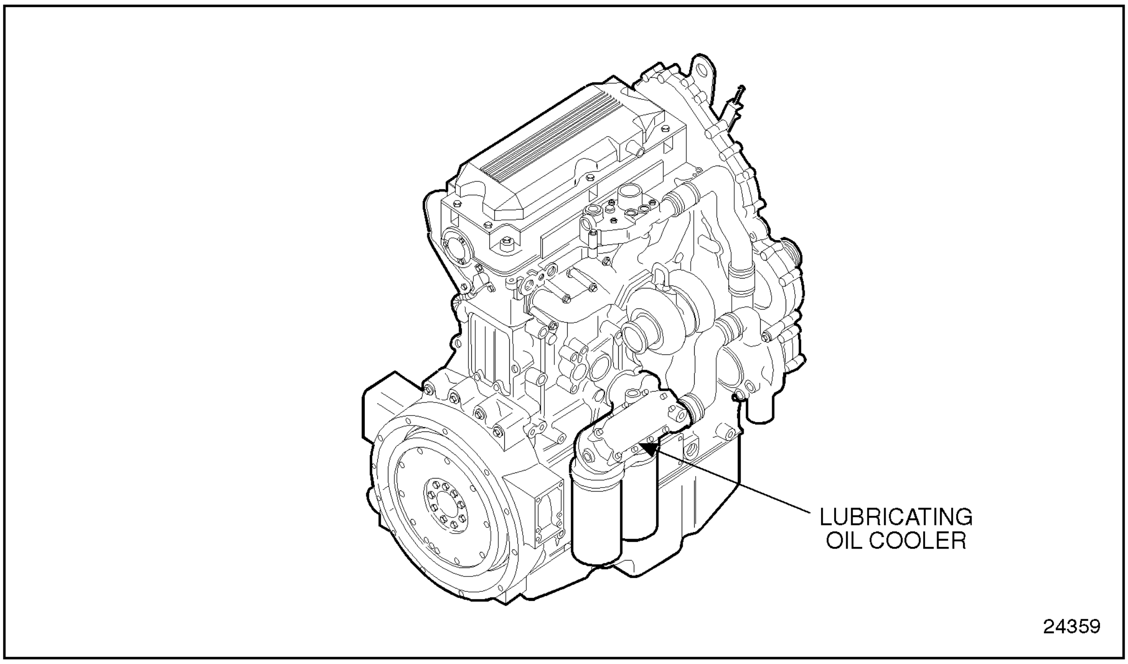
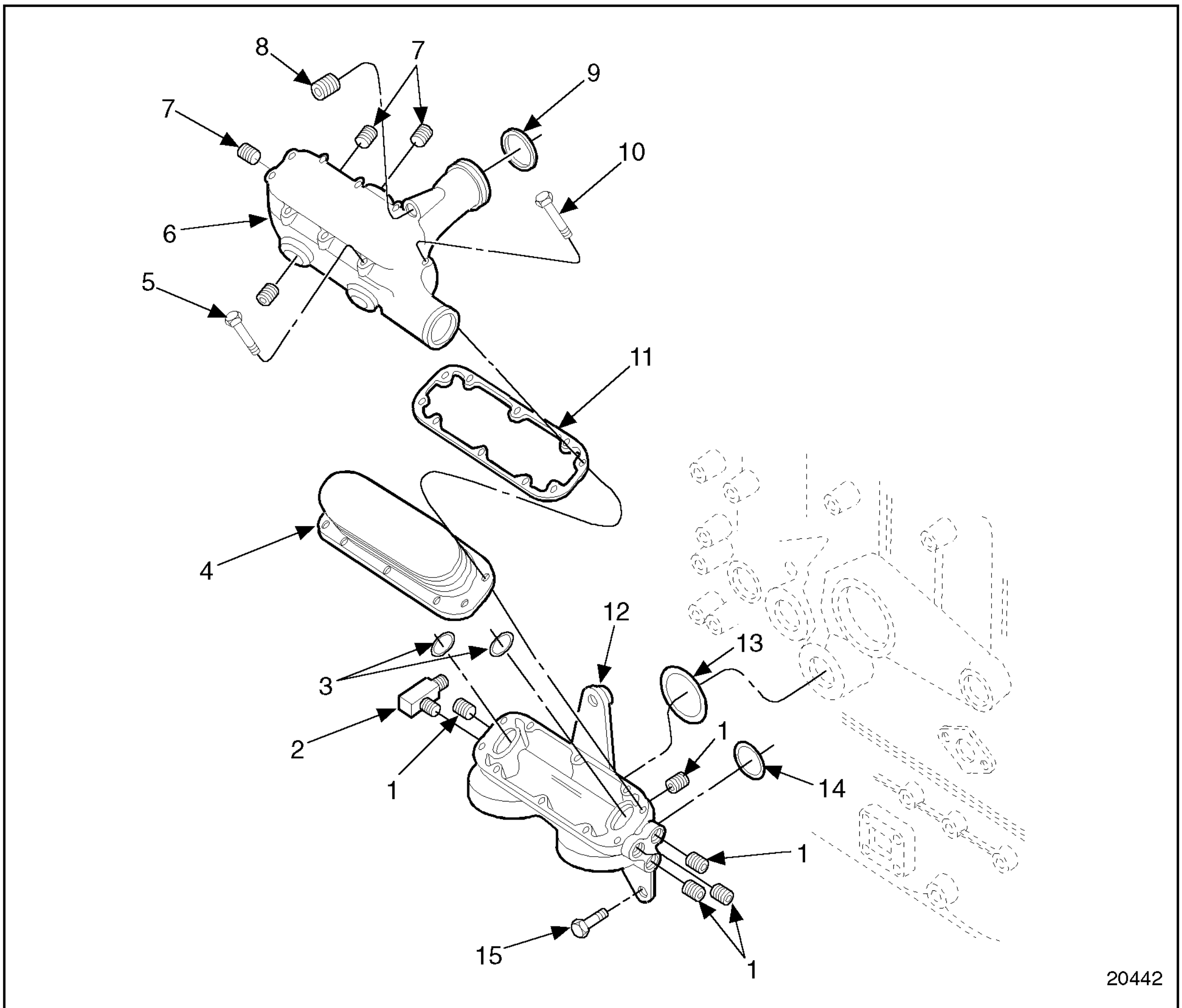


Figure 3-22 Lubricating Oil Cooler

To assure continued engine lubrication if the oil cooler becomes plugged, a bypass passage, located at the oil cooler inlet, bypasses oil around the cooler directly to the oil gallery in the cylinder block.

Cooling water is circulated through the oil cooler housing completely surrounding the oil cooler core. Therefore, whenever an oil cooler is assembled, care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing coolant outlet uses one large rubber O-ring seated in a groove in the outlet neck. See Figure 3-23.



1. Pipe Plugs (5)
2. Fitting
3. O-rings (2)
4. Oil Cooler
5. Bolt, Oil Cooler Housing-to-Adaptor (3)
6. Oil Cooler Housing
7. Pipe Plugs (4)
8. Pipe Plug
9. O-ring
10. Bolt, Oil Cooler Housing-to-Adaptor (7)
11. Gasket, Oil Cooler-to-Housing
12. Oil Filter Adaptor
13. O-ring
14. O-ring
15. Bolt, Oil Filter Adaptor-to-Block (5)

Figure 3-23 Oil Cooler Housing and Related Parts

Two small O-rings are positioned in oil filter adaptor counterbores to seal the lubricating oil passages between the oil filter adaptor and the cooler core.

The oil cooler housing is attached to the oil filter adaptor. The flow of oil is from the oil pump, through a vertical passage in the cylinder block, through the full-flow oil filters and then through the oil cooler core and the cylinder block main oil galleries.

3.7.1 Repair or Replacement of Oil Cooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-24.

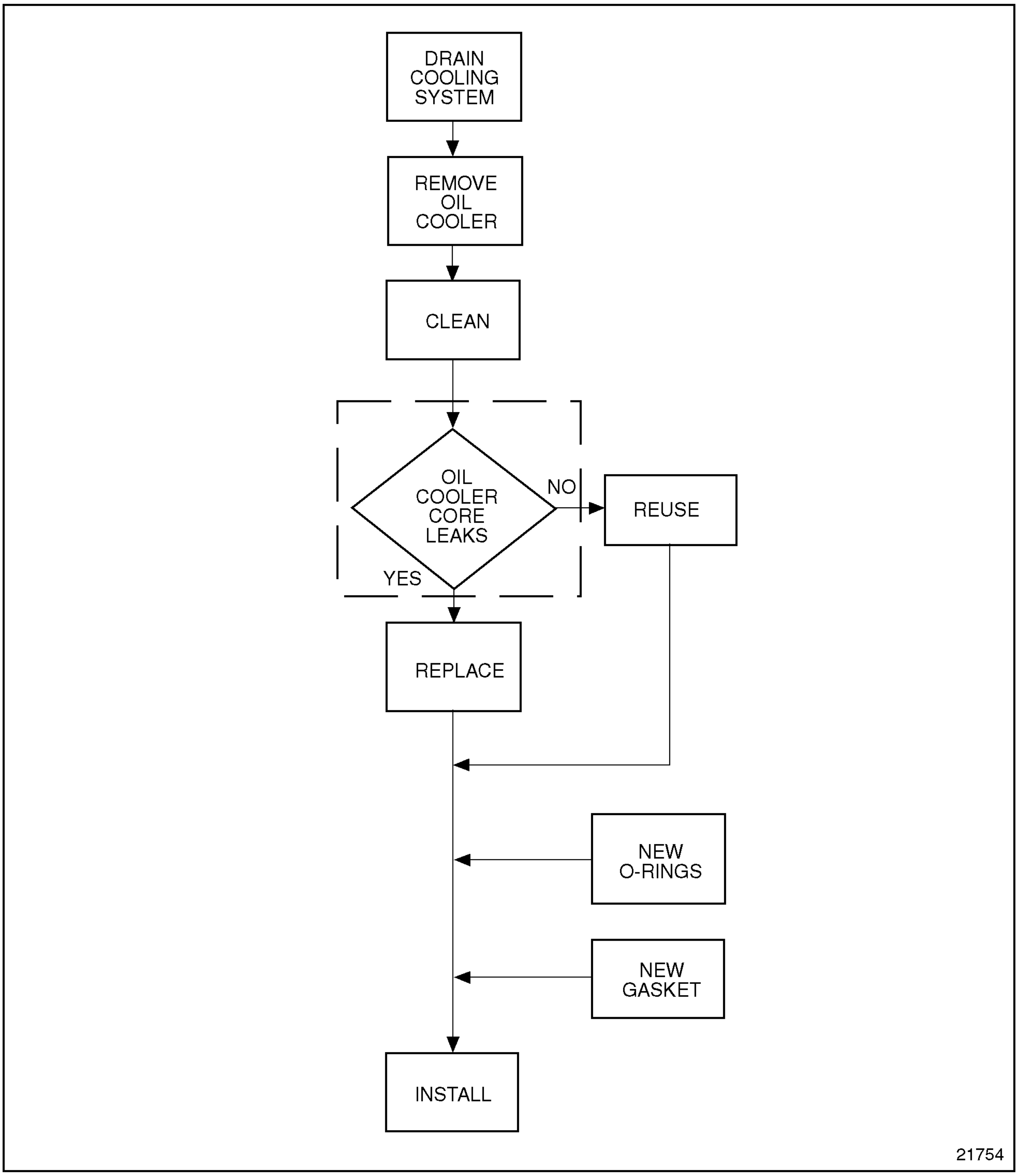


Figure 3-24 Flowchart for Repair or Replacement of Oil Cooler

3.7.2 Cleaning and Removal of Oil Cooler

Precleaning is not necessary.

Remove the oil cooler core and housing as follows:

1. Drain the cooling system by opening the drain cocks at the right rear of the cylinder block, and in the bottom of the water pump housing.
2. Disconnect the hose from the water pump at the lower neck of the oil cooler housing.
3. Match-mark the oil cooler core and housing to ensure correct reinstallation.
4. Remove the bolts which attach the oil cooler housing and core to the oil filter adaptor.
5. Place a pry bar between the oil cooler housing and cylinder block, just below the upper neck. Gently pry the oil cooler housing from the cylinder block and the oil filter adaptor.
6. Use a gasket scraper or chisel and a fiber mallet or plastic hammer to separate the oil cooler core and housing.
7. Remove all traces of gasket material from the oil cooler and housing.

Clean the oil cooler core prior to inspection as follows:

1. Remove the core from the oil cooler.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

NOTICE:

Do not attempt to clean an oil cooler when an engine failure releases metal particles from worn or broken parts into the lubricating oil. The oil cooler core must be replaced. Otherwise, severe engine damage may result.

2. Circulate a solution of 1,1,1-trichloroethylene through the core passages with a force pump to remove the carbon and sludge.
3. Clean the core before the sludge hardens.
4. If the oil passages are badly clogged, circulate an alkaline solution through the core and flush thoroughly with clean, hot water.

Clean the outside of the core:

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

1. Mix the following solutions: 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.
2. Immerse the core in the solution.
3. Watch the process carefully. When bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution.
4. Thoroughly flush it with clean, hot water.
5. Dip the core in light oil.

3.7.2.1 Inspection of Oil Cooler

Inspect oil cooler as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to insure a tight seal.
2. Drill and tap the plate prior to mounting to permit an air hose fitting to be attached at the inlet side of the core. See Figure 3-25.

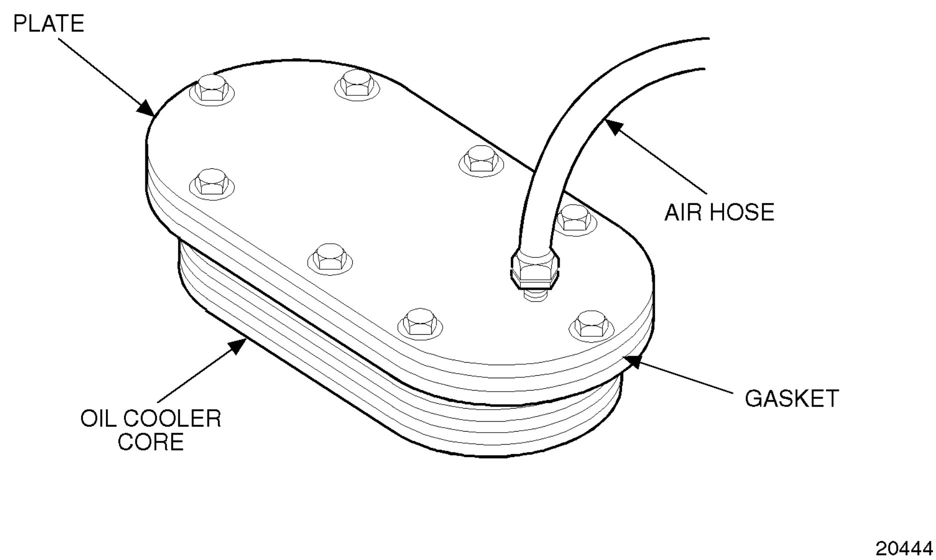


Figure 3-25 Preparing Oil Cooler Core for Pressure Test

CAUTION:

To avoid injury from failure of a fitting, hose, or oil cooler core, wear a face shield or goggles when conducting a pressure test.

3. Attach an air hose to the air hose fitting.
4. Regulate air pressure to 517-690 kPa (75-100 lb/in.^{2}) and submerge the oil cooler and plate assembly in a container of water heated to 82°C (180°F).
   [a] Check for leaks as indicated by air bubbles in the water.

NOTICE:

In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent corrosion to its internal components. Refer to Section 13.5.4.

   [b] If leaks are indicated, replace the core.
5. After the pressure check is completed, remove the plate and air hose from the cooler core.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

6. Dry the core with compressed air.

3.7.3 Installation of Oil Cooler

Install the oil cooler core as follows:

1. Lubricate new O-rings with a light coat of petroleum jelly.
2. Install the new O-rings in the counterbores in the oil filter adaptor.
3. Coat the O-ring with ethylene glycol (coolant).
4. Install a new O-ring in the groove on the oil cooler housing outlet neck.
5. Install a new gasket on the face of the core that will contact the housing.

NOTICE:
Use care when installing the oil cooler housing to prevent damaging the outlet neck O-rings on the sharp edges of the opening in the cylinder block. Some cleaning of the block opening is usually needed.

6. Install the core to the housing and install the assembly on the oil filter adaptor.
7. Align the oil cooler housing assembly to the oil filter adaptor. Install the ten oil cooler housing bolts and torque to 30-38 N·m (22-28 lb·ft) using the correct sequence. See Figure 3-26.

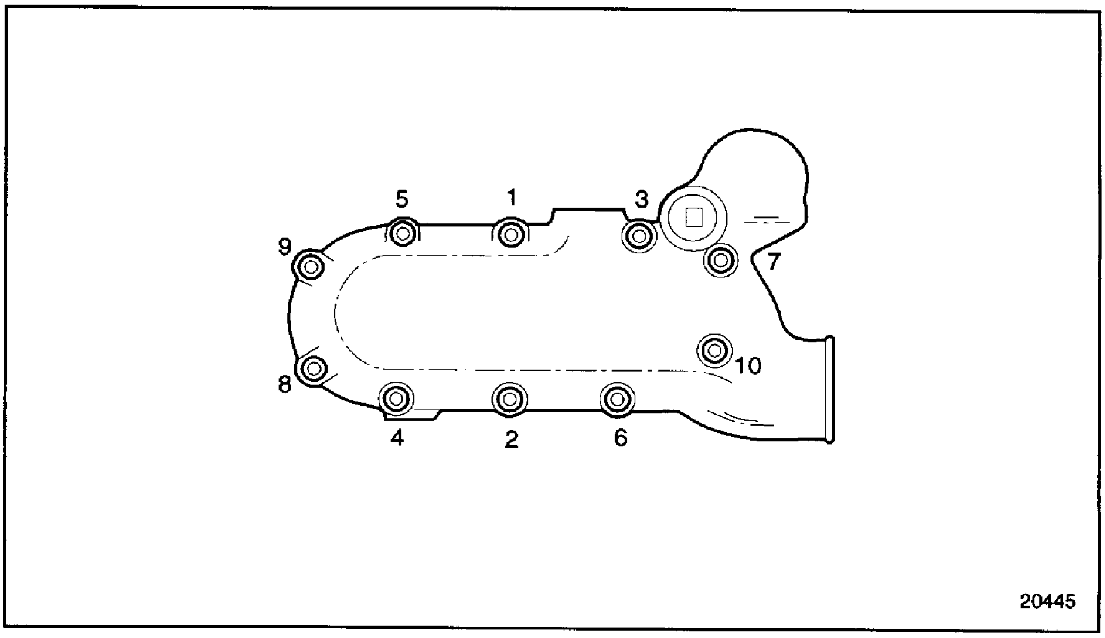


Figure 3-26 Oil Cooler Housing Bolt Torque Sequence

8. Position the hose and clamps in place at the lower neck of the oil cooler housing, making sure the clamps are positioned inside the lip on both the housing and tube. Tighten the clamps.
9. Close the draincocks in the cylinder block and water pump housing. Fill the cooling system. Refer to Section 13.5.4.
10. Fill the lubricating system. Refer to Section 13.5.1.
11. Refer to Section 11.1.1 for verification of proper oil cooler installation.

3.8 OIL LEVEL DIPSTICK ASSEMBLY

A steel ribbon-type oil level dipstick may be used to check the level of oil in the engine oil pan. The dipstick is located in a tube attached by a threaded adaptor to an opening in the oil pan. See Figure 3-27.

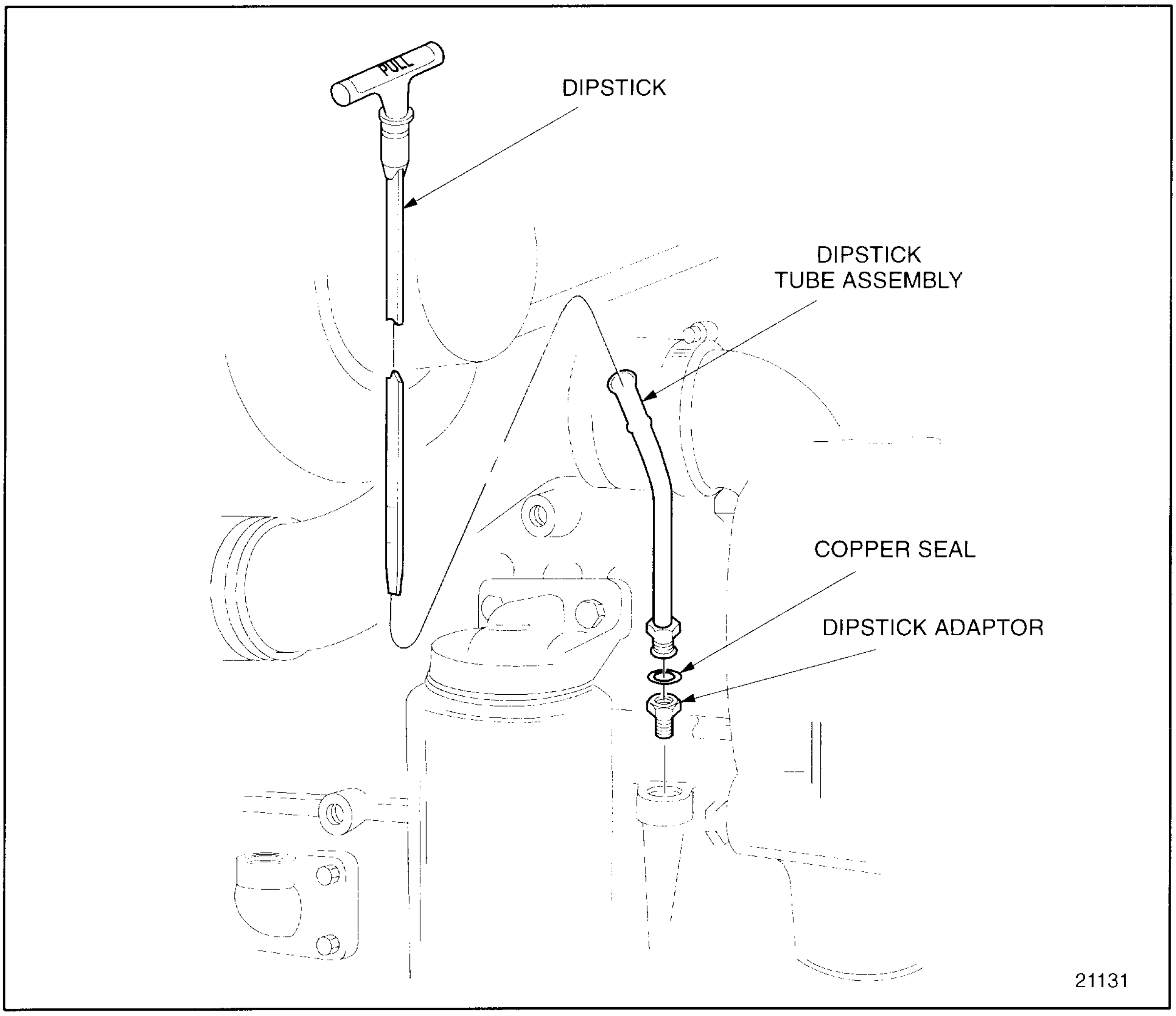


Figure 3-27 Oil Dipstick Mounting

Snap action dipsticks have locking tangs and an O-ring seal in the tee handle. A copper sealing ring between the adaptor and dipstick tube insures a tight seal.

NOTICE:

Maintain the oil level between the full and low marks on the dipstick. Never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling may cause the oil to be churned by the balance shafts and crankshaft throws causing foaming or aeration of the oil. Operation below the low mark may expose the pump pickup causing aeration, loss of pressure and engine damage.

Check the oil level after the engine has been stopped for a minimum of ten 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, or if insufficient time is allowed for oil to drain back to the sump. For additional information, consult Service Information Bulletin "Oil Level Gage Calibration Inspection and Fabrication" (SIB 12-50-94).

The current dipstick adaptor has a thicker wall than the former adaptor and requires a copper seal between the adaptor and the nut on the oil gage tube assembly.

3.8.1 Repair or Replacement of Oil Dipstick Assembly

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-28.

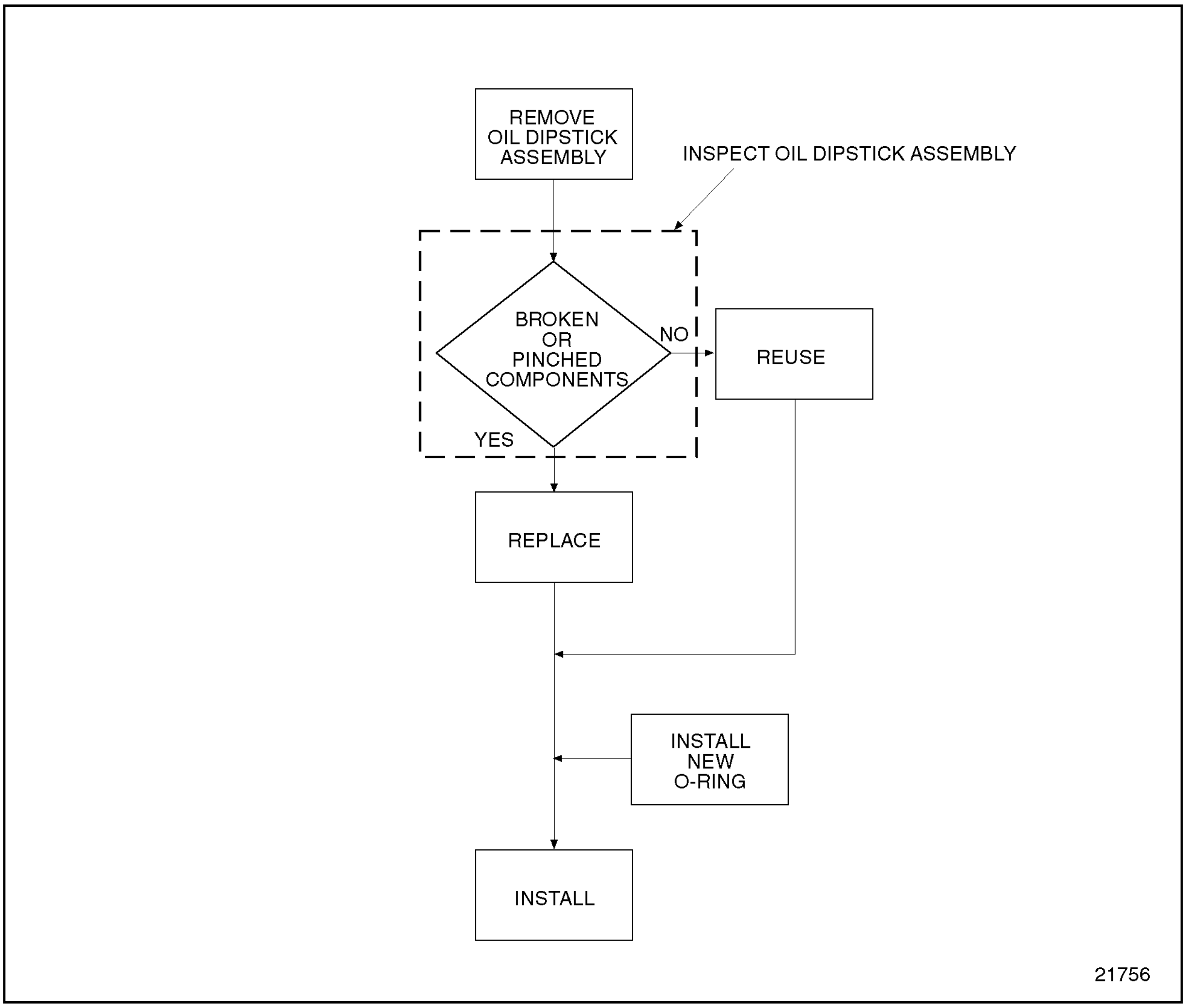


Figure 3-28 Flowchart for Repair or Replacement of Oil Dipstick Assembly

3.8.2 Cleaning and Removal of Oil Dipstick Assembly

Precleaning is not necessary.

Remove oil dipstick assembly as follows:

1. Remove dipstick from dipstick adaptor.
2. Remove oil tube assembly, copper seal, and dipstick adaptor from cylinder block. Discard copper seal.

3.8.2.1 Inspection of Oil Dipstick Assembly

Inspect oil dipstick assembly as follows:

1. Inspect dipstick assembly for any damaged parts.
   [a] Check components for any broken or pinched parts.
   [b] If any components are damaged, replace with new parts.

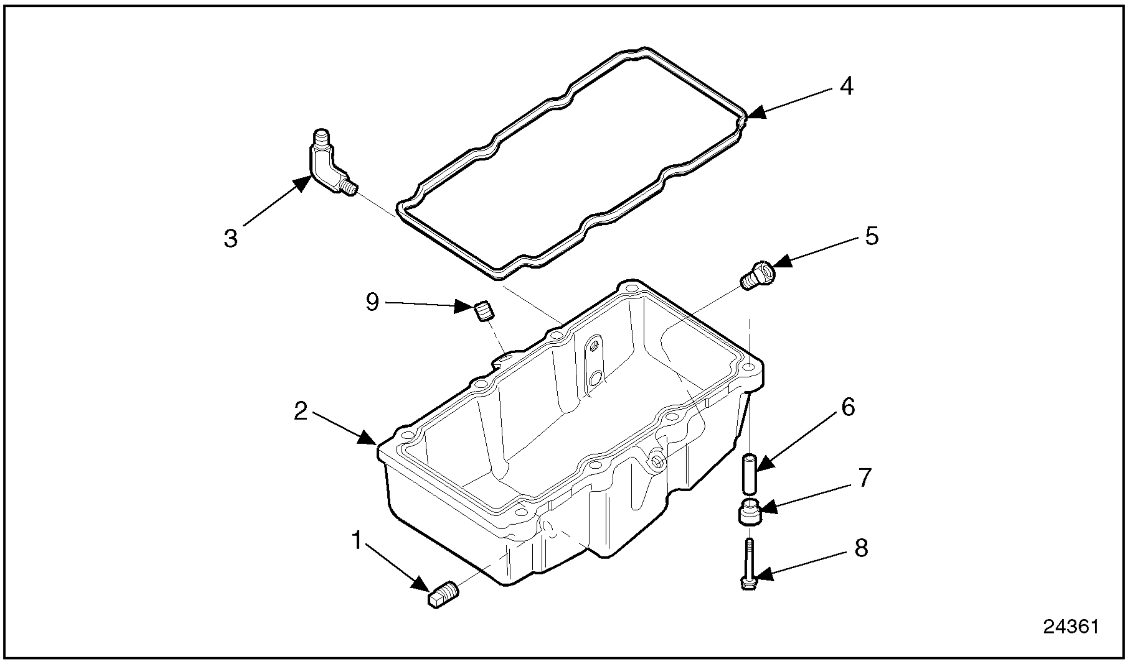
3.8.3 Installation of Oil Dipstick Assembly

Assemble oil dipstick assembly as follows:

1. Install dipstick adaptor onto cylinder block. Torque to 22 N·m (16 lb·ft).
2. Insert the new copper seal and thread the oil gage tube assembly nut into the adaptor.
3. While holding the adaptor with a wrench, properly align the oil gage tube assembly.
4. Tighten the nut on the tube securely.
5. Install dipstick into tube assembly.

3.9 OIL PAN

The oil pan used on the Series 50 engine is made of aluminum. A one-piece, non-reusable isolator seal is used between the oil pan and block. See Figure 3-29.



1. Drain Plug
2. Oil Pan
3. Elbow
4. Gasket
5. Adaptor
6. Sleeve
7. Isolator
8. Bolt
9. Pipe Plug

Figure 3-29 Typical Oil Pan Assembly

Rubber isolator-washer assemblies and sleeves are used for attaching the oil pan. The metal sleeve spacer is inserted through the isolator and limits the travel of the oil pan bolts to prevent over-tightening and damaging the oil pan and isolator.

Effective August 1995, isolators made of an improved vibration-absorbing material were released to reduce noise emissions. In addition, isolator bolt sleeve length was increased by 0.8 mm (0.032 in.) to accommodate the slightly longer isolators.

When installing a pipe plug, coat the threads with Loctite PT7271 sealant (or equivalent), hold the insert to keep it from turning, and torque the plug to 45-56 N·m (33-41 lb·ft).

3.9.1 Repair or Replacement of Oil Pan

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-30.

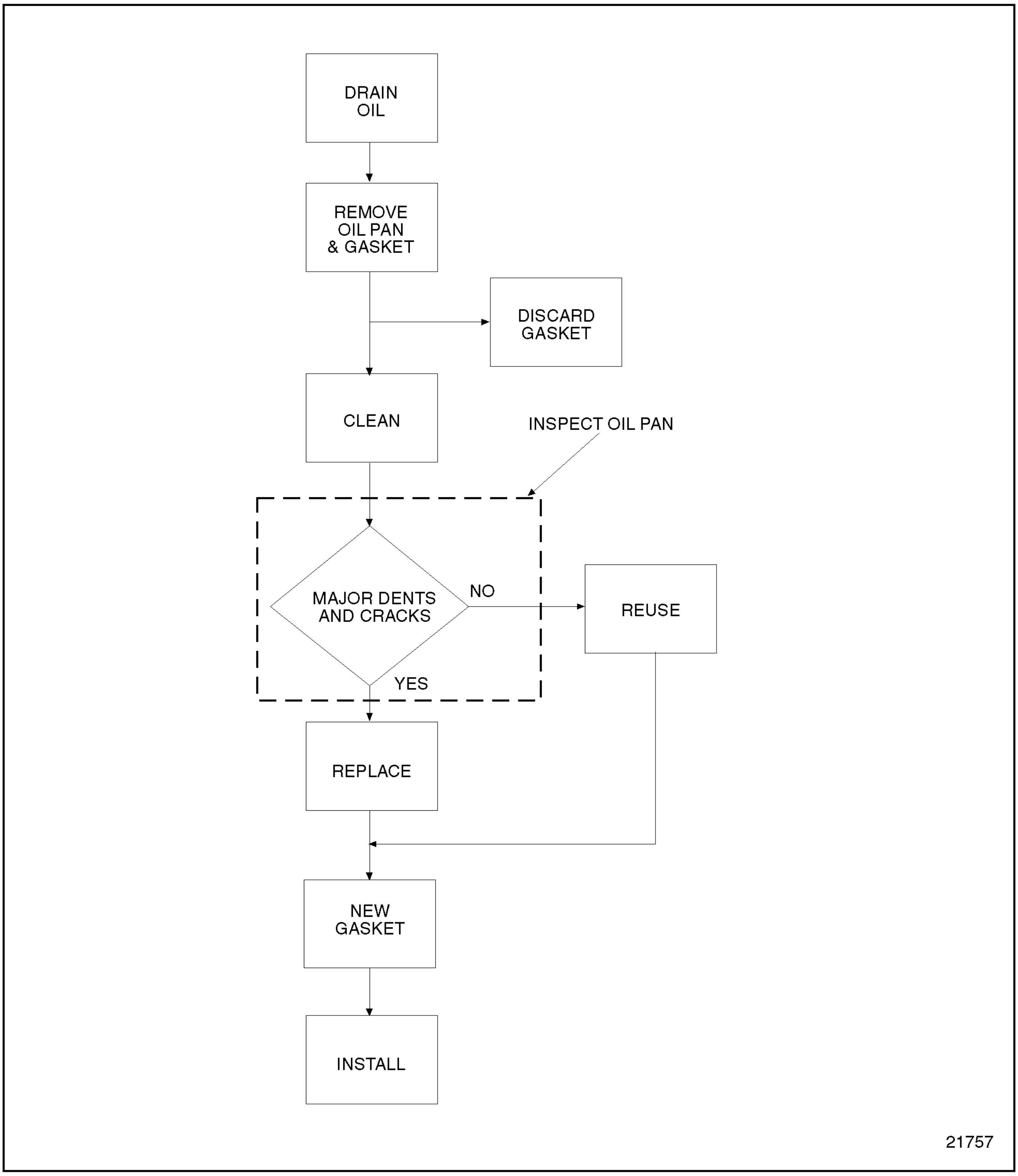


Figure 3-30 Flowchart for Repair or Replacement of Oil Pan

3.9.2 Cleaning and Removal of Oil Pan

Precleaning is not necessary.

NOTICE:
Do not support the engine on the oil pan. Damage to the oil pan or engine could result.

NOTE:
On almost all engine applications it is possible to remove the oil pan without removing the engine.

If the engine is to be removed from the vehicle, the oil pan should be left in place until the engine is removed.

The procedure for removing the oil pan will vary with each installation. However, the following procedures will generally apply.

NOTICE:
When removing a side plug, hold the flats of the insert with a 2 1/8 in. open end or large adjustable wrench to keep it from turning. If the insert is loosened, it may be necessary to remove the oil pan and retighten the nut to prevent a possible oil leak. If required, torque the nut to 186-199 N·m (137-147 lb·ft).

Remove the oil pan as follows:

1. Remove the drain plug and drain the engine oil. Refer to Section 13.5.1.
2. Remove the eight oil pan bolts, washers, isolators and sleeves. Remove the center bolts on each side last.
3. Remove the oil pan, taking care not to damage the oil pump inlet pipe and screen.
4. Remove the oil pan isolator seal and discard.

Clean the oil pan prior to inspection as follows:

NOTICE:
Do not use solvents to clean isolators. Damage to the isolator will result.

1. Clean the oil pan and attaching hardware with clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry with compressed air.
3. Clean the surfaces of the cylinder block, gear case and flywheel housing where they mate with the oil pan.

3.9.2.1 Inspection of Oil Pan

Inspect the oil pan inserts, oil pan, and bolt isolators as follows:

1. Check the bolt isolators for dryness, cracks or tears.
   [a] If isolator is damaged, replace with new part.
2. Check oil pan for major dents, cracks and other damage.
   [a] If oil pan is damaged, replace with new part.

3.9.3 Installation of Oil Pan

Install the oil pan as follows:

1. Insert the raised lip portion of the new isolator seal into the groove in the oil pan.
2. Press down on the isolator seal and insert it completely around the oil pan. Be careful not to stretch or bunch the seal. For best results, install the seal at each corner, then at points half way between the corners. Continue in this manner, halving the distance and seating the seal.
3. Insert a metal sleeve spacer into each isolator.
4. Install the eight oil pan bolts into isolator assemblies.
5. Install the oil pan assembly in position on the cylinder block.

NOTE:
If interference occurs between the oil pan and the balance shaft assembly, it will be necessary to acquire an improved oil pan that provides the clearance necessary for the installation.

6. Ensure that the isolator seal has not been disturbed. Torque the eight oil pan bolt assemblies to 24-30 N·m (18-22 lb·ft), using the proper sequence. See Figure 3-31.

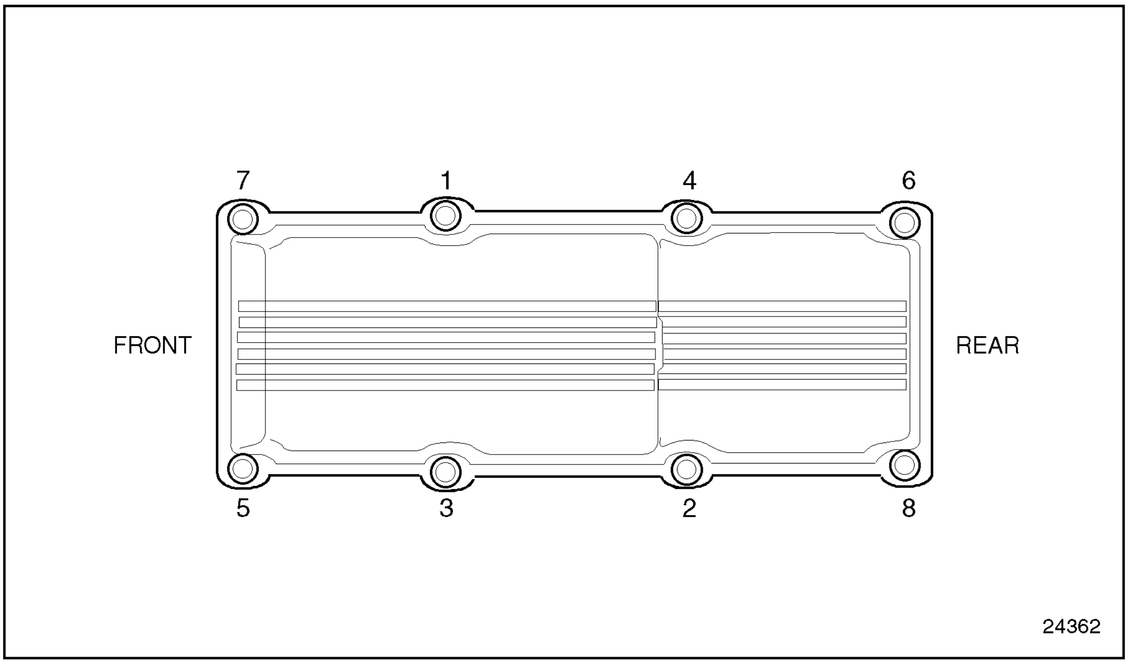


Figure 3-31 Oil Pan Bolt Torque Sequence

7. Install and tighten the 3/4 in.-14 square, magnetic, oil drain plug to 45-56 N·m (33-41 lb·ft) torque.
8. Install and tighten any other plugs that were removed from the oil pan.

NOTE:
When installing a pipe plug, coat the threads with Loctite PT7271 sealant (or equivalent).

9. Add 23 quarts (22 L) of new, clean lube oil (15W-40).

NOTE:
The extra quart of oil (23 verses 22) is added to account for oil in the oil filter adaptor, gallery, etc.

10. Refer to Section 11.1.2 for verification of proper oil pan installation.

3.10 VENTILATING SYSTEM

Vapors, formed within the engine, are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the normal seepage of a small amount of air and combustion gases past the piston rings. These gases are swept up through the engine and pass through a crankcase breather. The gases are then vented to the atmosphere.

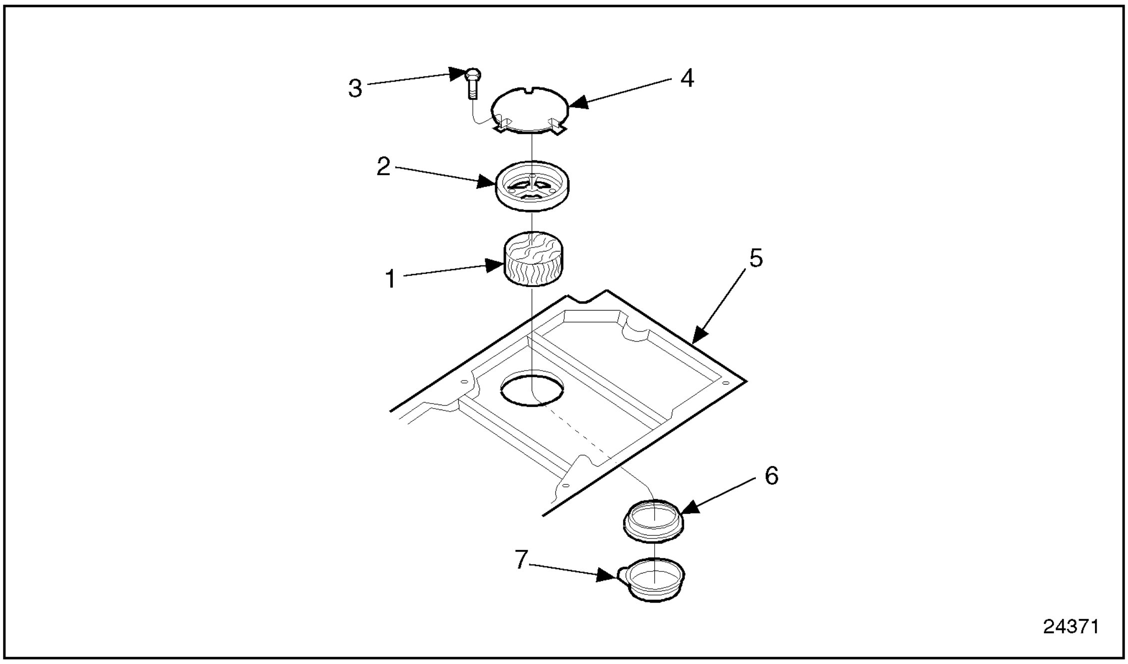
Breather extension hoses may be required on certain Series 50 engines used in on-highway vehicle applications.

Under certain conditions, the vapors from an operating engine may be circulated through the battery charging alternator by the alternator cooling fan. Excessive ingestion of vapors may lead to alternator malfunction. This can occur if the internal components of the alternator become coated with oil-laden dust or road grit.

To minimize the potential for this condition, check the length of the engine breather tube and add an extension hose, if necessary. For proper dissipation of vapors, the end of the breather hose *must*extend at least twelve inches below the oil pan rail.

NOTE:
The S50G automotive engine uses a closed crankcase breather system. Refer to Section 6.4 for more information.

A wire mesh element is located inside the valve cover, or in a separate housing on the valve cover cap or at the gear case cover. This element traps excess engine oil particles in the vapor and returns them to the crankcase. See Figure 3-32.

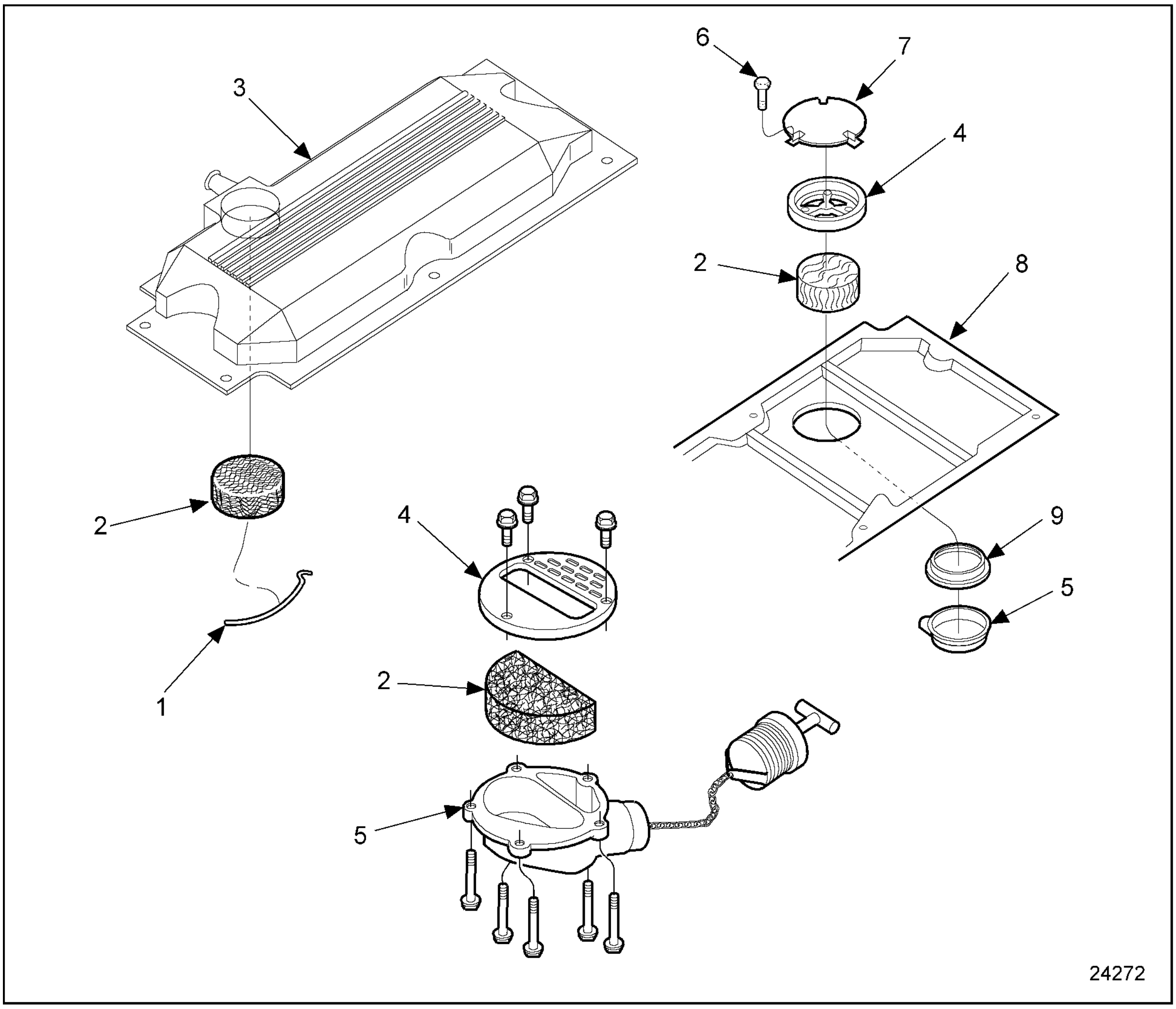


1. Wire Mesh Element
2. Retainer
3. Screw
4. Baffle
5. Valve Cover Cap
6. Seal
7. Breather Housing

Figure 3-32 Wire Mesh Elements

A new baffle (23515095) has been added to the breather assembly on the two-piece, low profile aluminum valve rocker cover used on Series 50 engines. This change went into production on June 29, 1993, effective with unit serial number 04R001729. The change was also made to unit 04R001001 (built June 5, 1993) on a single engine pre-production basis.

The new baffle redirects oil splash from the rocker arms, preventing oil from contaminating the breather element. See Figure 3-33. Oil trapped in the breather medium can drip out of the breather tube and may cause faulty high crankcase pressure readings.



1. Retainer Clip
2. Wire Mesh Element
3. Rocker Cover
4. Retainer
5. Breather Housing
6. Bolt
7. Baffle
8. Valve Cover Cap
9. Seal

Figure 3-33 Breather Component Location

3.10.1 Repair or Replacement of Ventilating System

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-34.

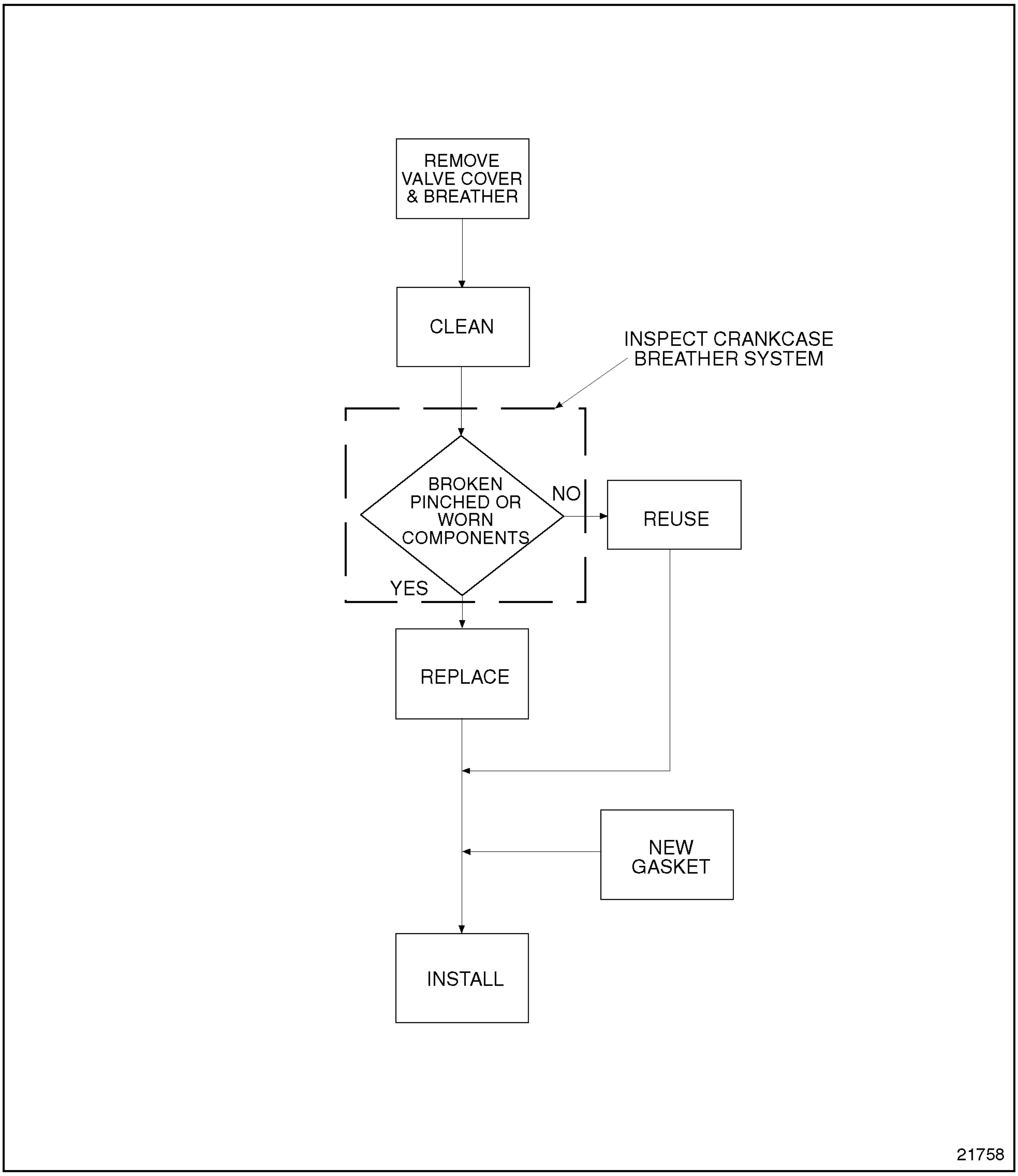


Figure 3-34 Flowchart for Repair or Replacement of Ventilating System

3.10.2 Removal of Ventilating System

Precleaning is not necessary.

Remove ventilating system as follows:

1. The two-piece low profile valve rocker cover cap has a removable breather housing. Remove as follows:
   [a] Remove the valve cover. Refer to Section 1.6.2.
   [b] Remove the three screws, baffle and retainer that retains the breather housing.
   [c] Remove the breather housing, seal, and wire mesh element.
2. If the engine is equipped with a gear case cover breather, remove as follows:
   [a] Remove the 5 bolts that secure the breather-oil fill housing to the gear case cover. See Figure 3-35.

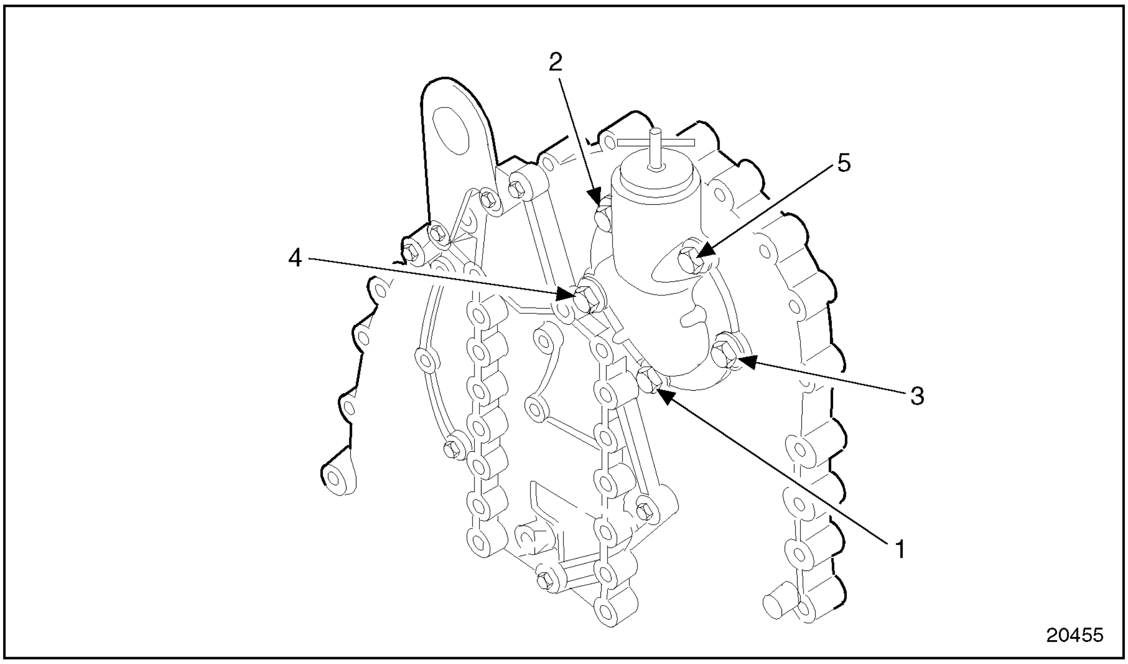
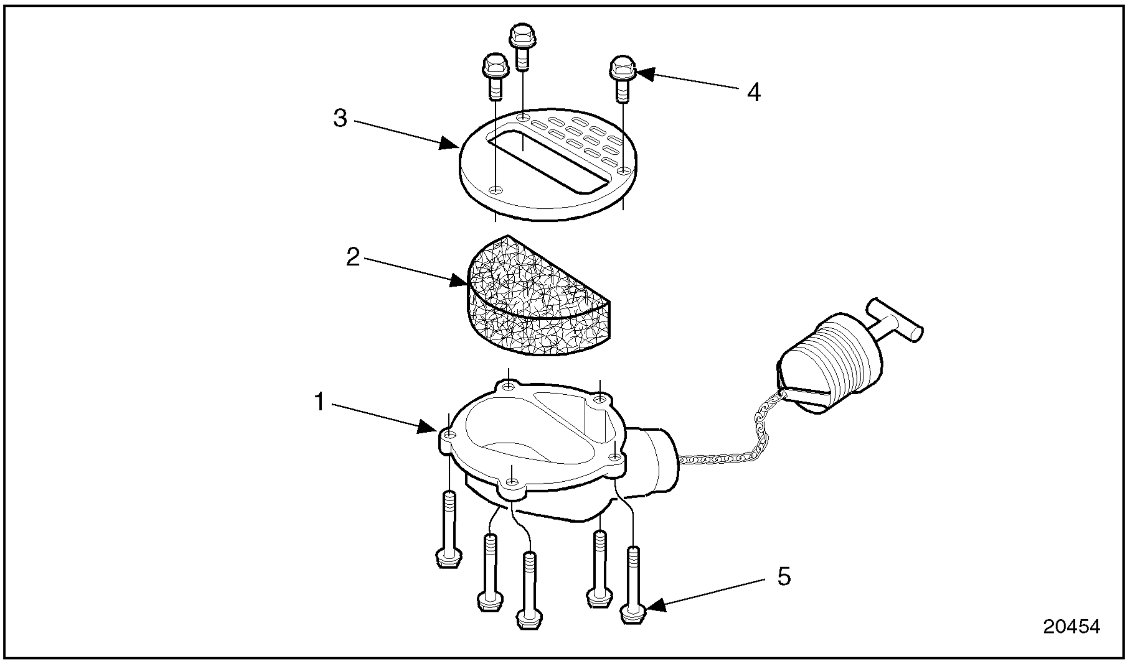


Figure 3-35 Breather-Oil Fill Tightening Sequence

[b] Remove the 3 screws that secure the retainer to the housing. See Figure 3-36.



1. Breather Housing
2. Wire Mesh Element
3. Retainer
4. Retainer Bolts
5. Housing Bolts

Figure 3-36 Breather-Oil Fill Housing

[c] Remove the retainer and wire mesh element from the breather housing.

3.10.2.1 Inspection of Ventilating System

Clean the wire mesh element components prior to inspection as follows:

1. Wash the components in clean fuel oil.

> **CAUTION:**
>
> **To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.**

2. Blow dry with compressed air.
3. Clean all old gasket material from the mating surfaces of the breather-oil fill housing and the gear case cover.

Inspect the ventilating system as follows:

1. Inspect the ventilating system for damaged parts.
   [a] Check components for pinched, broken, worn, and unclean parts.
   [b] If any components are damaged, replace with new parts.

3.10.3 Installation of Ventilating System

Install the ventilating system as follows:

1. Install the gear case cover mounted breather as follows:
   [a] Install the wire mesh element in breather housing.

NOTE:
Do not leave gaps around the edges.

   [b] Install the 3 screws and retainer to breather housing. Torque the screws to 2.5 N·m (22 lb· in.).
   [c] Install new gasket, between the breather/oil fill housing and the gear case cover. Torque the five bolts to 30-38 N·m (22-28 lb·ft) using the proper tightening sequence. See Figure 3-35.
2. Install the valve cover mounted breather as follows:
   [a] Install wire mesh element in valve cover.
   [b] Install retaining clip in valve cover by engaging curved end in valve cover and then engaging straight end.
   [c] Place the baffle on the retainer with 3 flat bolting flanges against the retainer.

NOTE:
The baffle must be installed with bolting flanges against the retainer to permit proper engine breathing.

   [d] Install the 3 screws into baffle and torque to 2.5 N·m (22 lb· in.).
   [e] Install seal and breather housing in valve cover.
3. Install valve covers. Refer to Section 1.6.6.

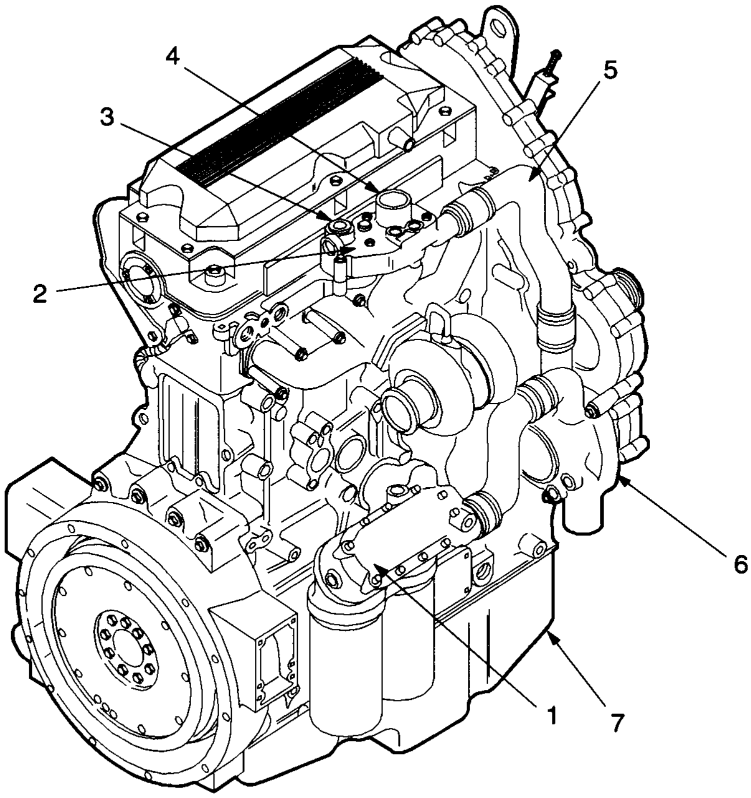
4 COOLING SYSTEM

Section **Page**

4.1 COOLING SYSTEM OVERVIEW

The cooling system consists of the following components (see Figure 4-1):

- ☐ Water pump
- ☐ Pressure control cap
- ☐ Thermostat
- ☐ Engine coolant fan
- ☐ Coolant filter and conditioner
- ☐ Radiator



1. Oil Cooler Housing
2. Thermostat Housing
3. Vent Line Outlet
4. Water Outlet (To Radiator)
5. Water Bypass Tube
6. Water Pump
7. Oil Pan

Figure 4-1 Cooling System Operation

An OEM supplied radiator along with a factory installed thermo-modulated fan are used to effectively dissipate the heat generated by the engine. A centrifugal-type water pump is used to circulate the engine coolant.

Two full blocking-type thermostats are used in the water outlet passage to control the flow of coolant, providing fast engine warm-up and regulating coolant temperature. Listed in Table 11-2 are the normal cooling system operational parameters.

The pressurized engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block. See Figure 4-2.

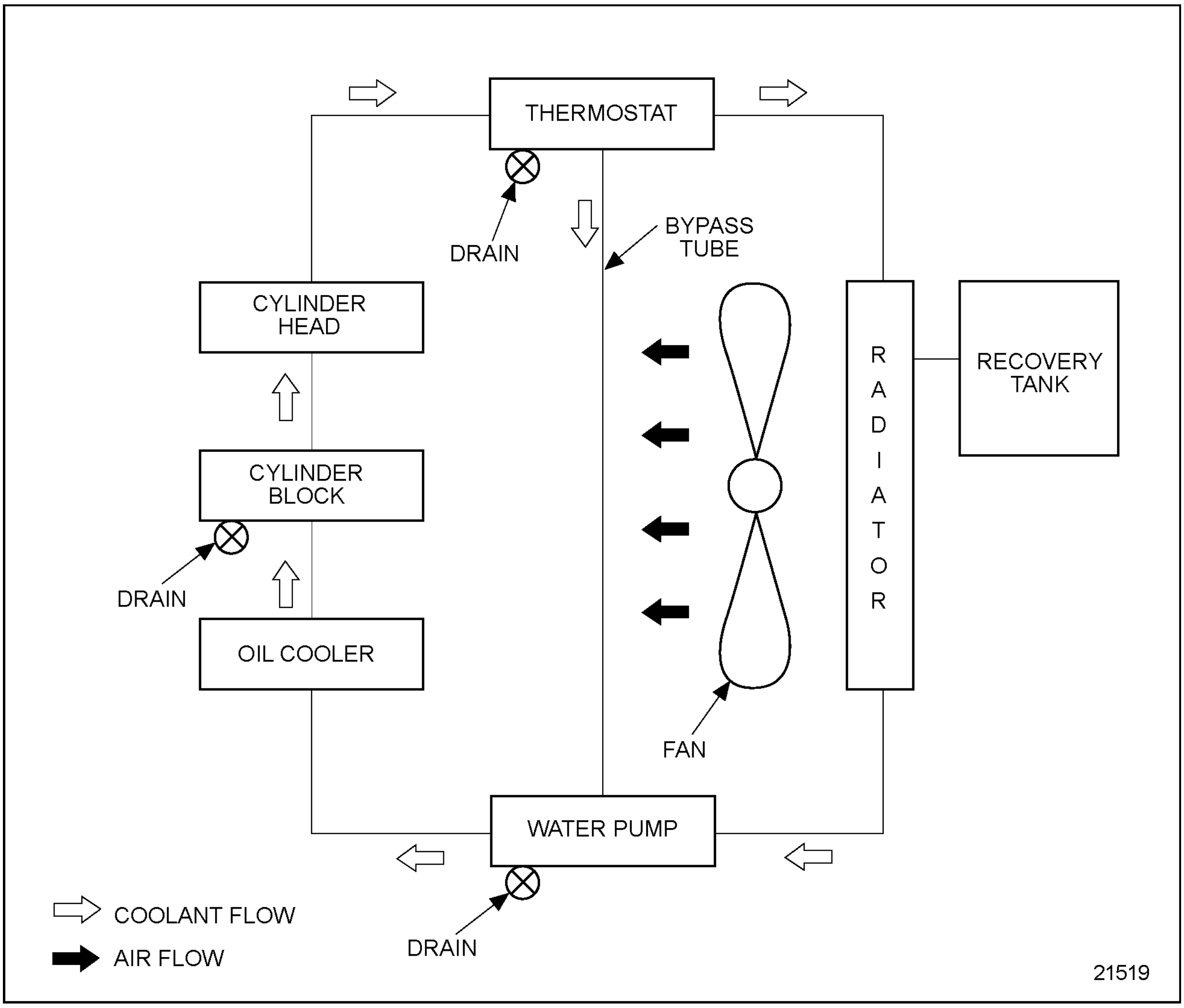


Figure 4-2 Coolant Flow Schematic

When the engine is at normal operating temperature, the coolant passes from the cylinder block up through the cylinder head, through the thermostat housing and into the upper portion of the radiator. The coolant then passes through a series of tubes where the coolant temperature is lowered by the airflow created by the revolving fan and the motion of the vehicle.

Upon starting a cold engine or when the coolant is below operating temperature, the closed thermostats direct coolant flow from the thermostat housing through the bypass tube to the water pump. Coolant is recirculated through the engine to aid engine warm-up. When the thermostat opening temperature is reached, coolant flow is divided between the radiator inlet and the bypass tube. When the thermostats are completely open, all of the coolant flow is to the radiator inlet.

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 the valves 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. Refer to Section 5.4 for coolant recommendations.

A pressurized cooling system permits higher temperature operation than a non-pressurized system. It is essential that the cooling system is kept clean and leak-free, that the filler cap and pressure relief mechanisms are properly installed and operate correctly, and that the coolant level is properly maintained.

As the engine temperature increases, the coolant and air in the system starts to expand and build pressure. The valve in the radiator pressure cap unseats and allows the coolant to flow into the coolant recovery tank. See Figure 4-3.

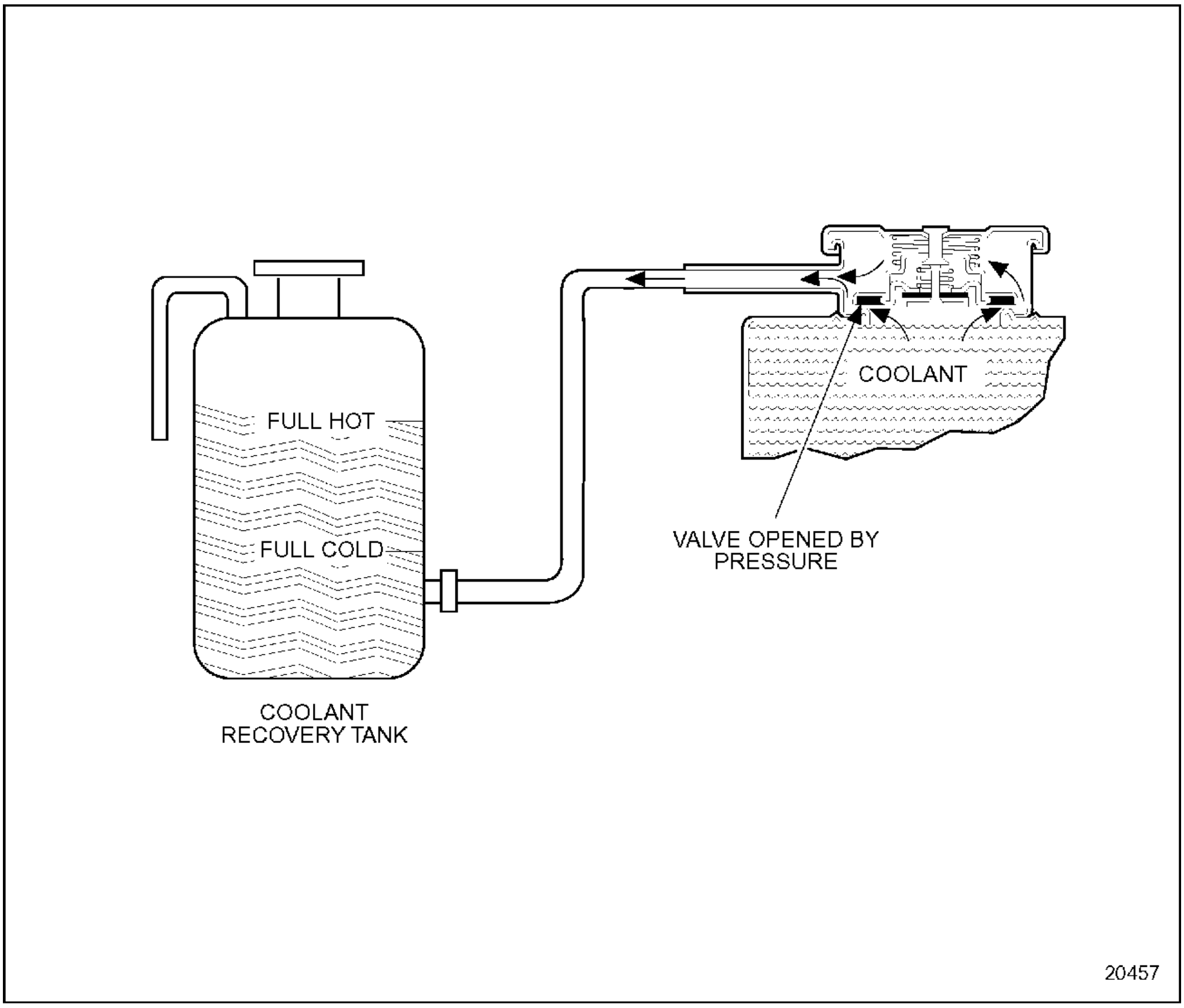


Figure 4-3 Coolant Expansion

When the engine starts to cool down, the air and coolant contract, causing a void and creating a vacuum in the system. The vacuum unseats another valve in the radiator pressure cap, allowing the coolant to flow back into the expansion tank or radiator. See Figure 4-4.

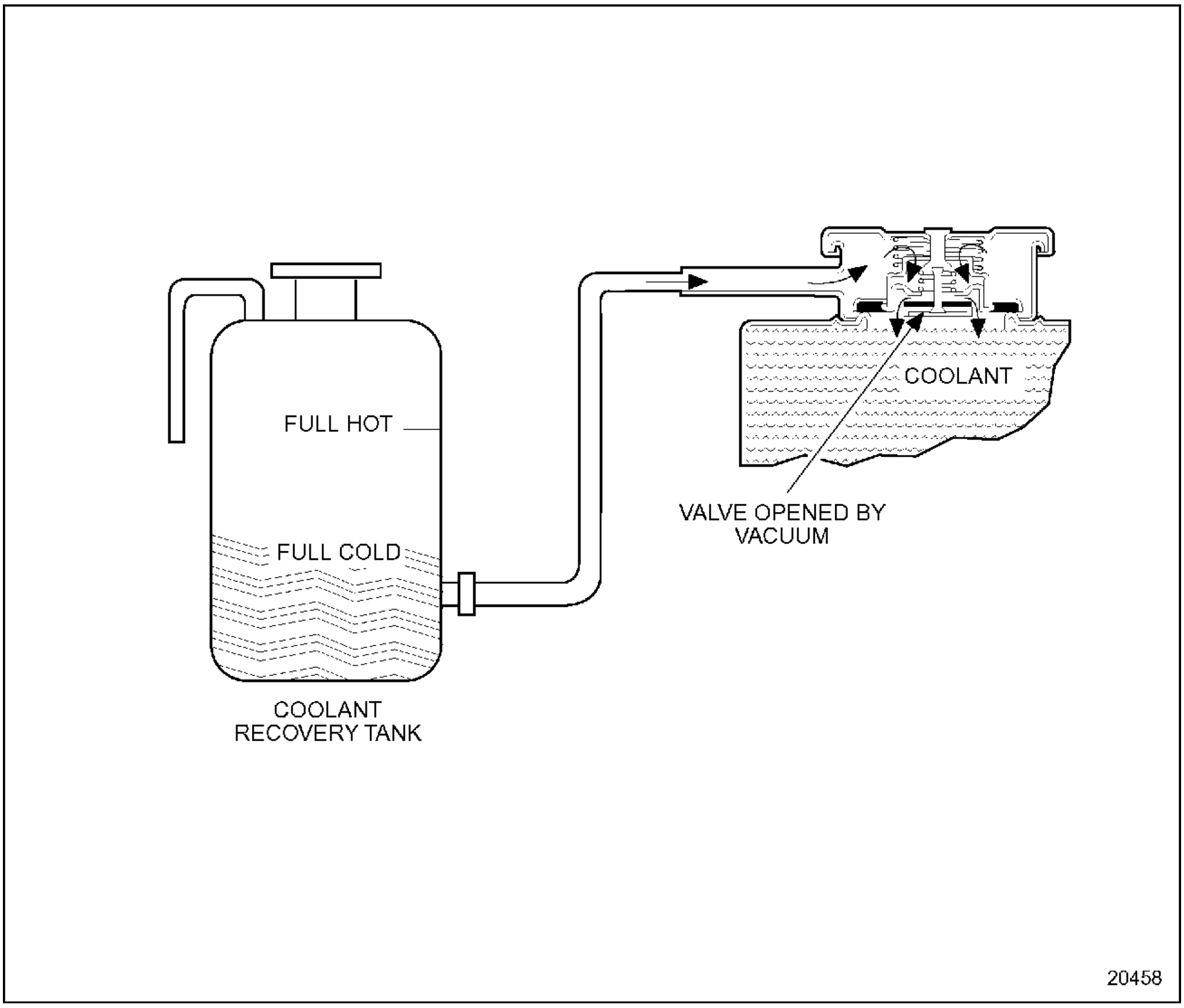


Figure 4-4 Coolant Recovery

4.2 WATER PUMP

The centrifugal-type water pump circulates the engine coolant through the cooling system.

The pump is mounted on the rear of the gear case and is driven by the water pump drive gear. See Figure 4-5. The water pump drive gear meshes with the bull gear.

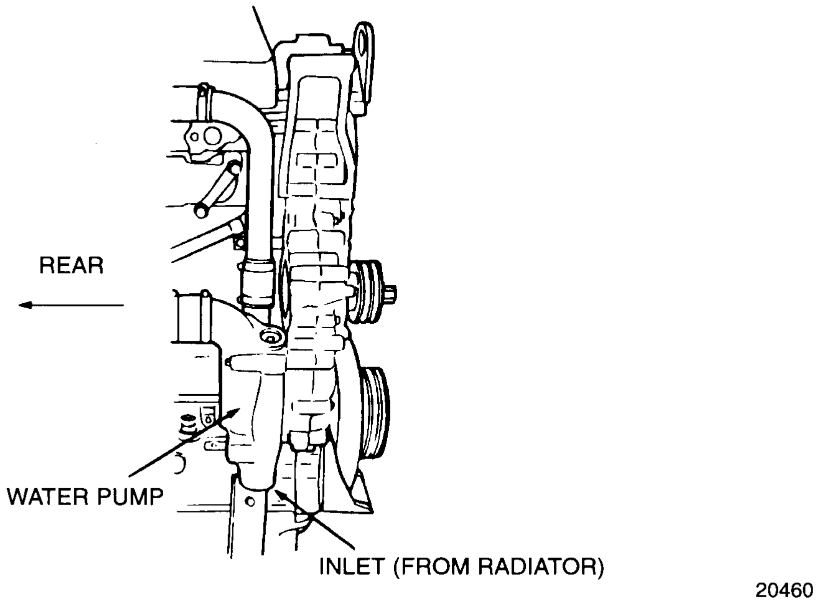
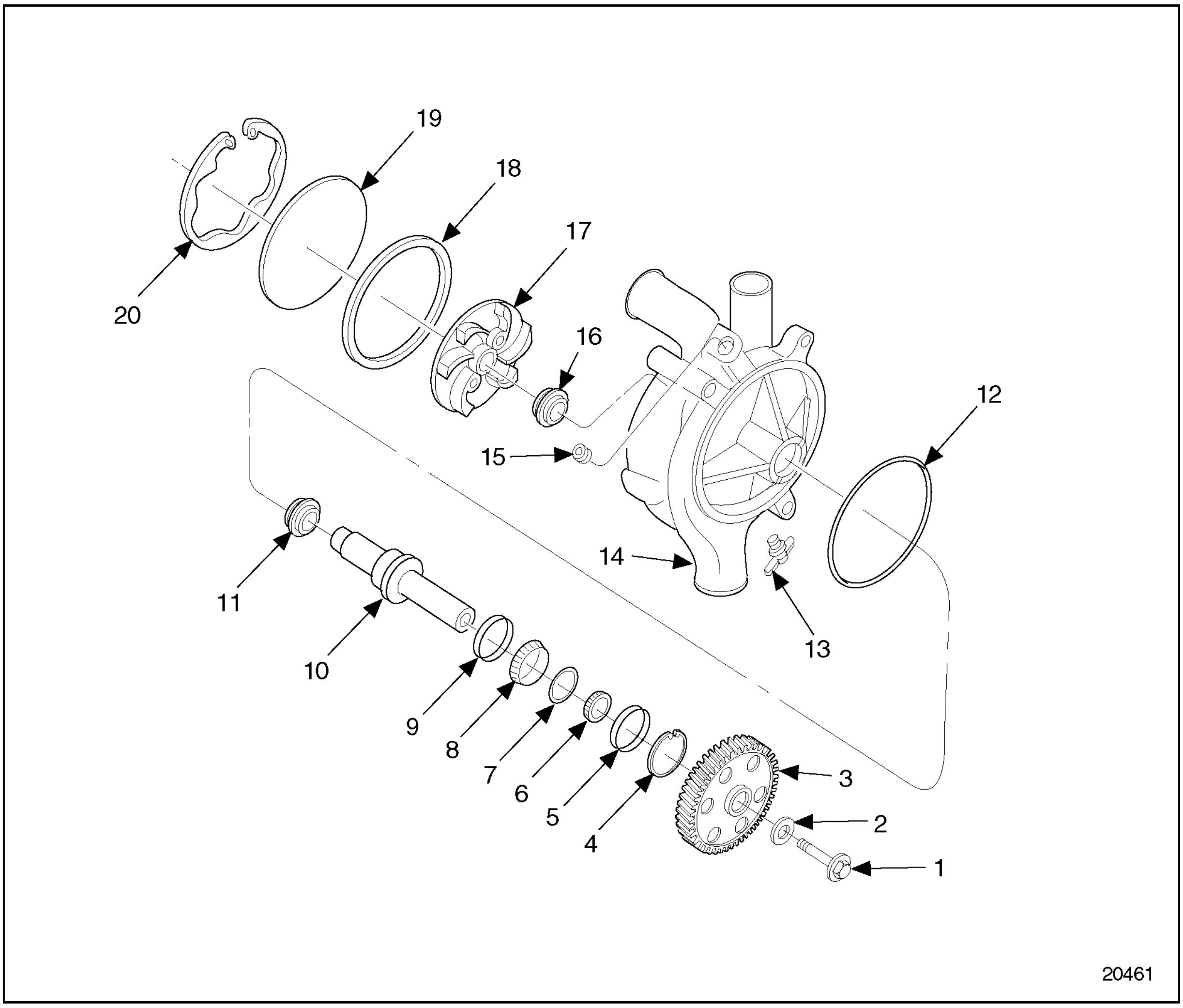


Figure 4-5 Water Pump Mounting

An impeller is pressed on one end of the stainless steel drive shaft. The other end of this shaft has internal threads, and a retaining bolt secures the water pump drive gear to the shaft. Two tappered roller bearing assemblies are used to support the shaft. See Figure 4-6.



1. Retaining Bolt	11. Oil Seal
2. Washer	12. O-ring Seal
3. Gear, Water Pump Drive	13. Drain Cock
4. Snap Ring	14. Housing, Water Pump
5. Bearing Race	15. Pipe Plug, Water Pump Housing
6. Roller Bearing, Small	16. Water Seal
7. Spacer Rings	17. Impeller
8. Roller Bearing, Large	18. O-ring, Water Pump Cover
9. Bearing Race	19. Water Pump Cover
10. Drive Shaft	20. Snap Ring, Water Pump Cover

Figure 4-6 Water Pump Details and Relative Location of Parts

An O-ring rubber ring, located in a groove in the water pump housing, seals the water pump to the gear case. An O-ring, located under the water pump cover, seals the cover to the water pump housing. The water pump bearings are lubricated by splash oil through a passage from the front of the pump housing.

An oil seal is located behind the bearing assemblies, and a unitized, spring-loaded, face type water seal is used behind the impeller. This seal prevents water from leaking down the shaft and into the gear case. It also prevents lubricating oil from entering the cooling system. The water and oil seals cannot be replaced without removing the water pump from the engine.

4.2.1 Repair or Replacement of Water Pump

To determine if repair or replacement is necessary, perform the following procedure. See Figure 4-7.

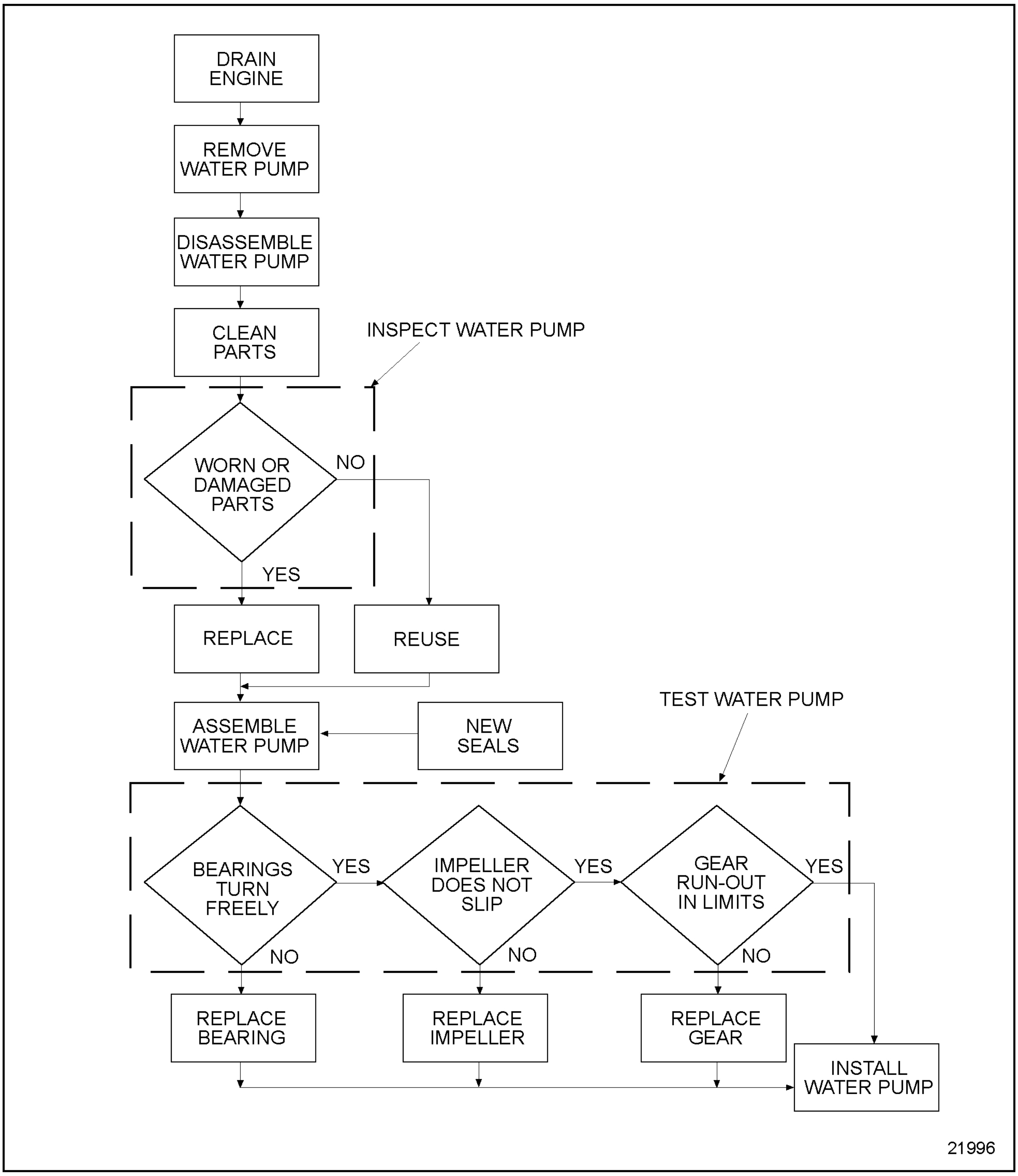


Figure 4-7 Flowchart for Repair or Replacement of Water Pump

4.2.2 Draining and Removal of Water Pump

Drain the cooling system before removal of the water pump as follows:

1. Open the drain cocks located at the right rear corner of the engine at the bottom of the water pump and in the thermostat housing.

Remove the water pump as follows:

1. Loosen the hose clamps and remove the coolant hoses from the water pump housing.
2. Loosen and remove the three water pump housing-to-gear case bolts. Remove the water pump from the engine by pulling it straight out of the gear case.

4.2.3 Disassembly of Water Pump

Disassemble the water pump as follows:

CAUTION:
To avoid injury, wear a face shield or goggles.

1. Remove water pump cover snap ring with snap ring pliers, J 28507 or equivalent. Remove water pump cover and seal ring.

NOTICE:
When clamping gears, use soft jaws on vise to prevent damage to the gear teeth.

2. Clamp the water pump drive gear in a vise, with the impeller facing up. Use a two-screw gear puller and remove the water pump impeller from the shaft, using the two threaded holes in the impeller.

3. Hold square end of water pump shaft and remove water pump drive gear retaining bolt and washer. See Figure 4-8.

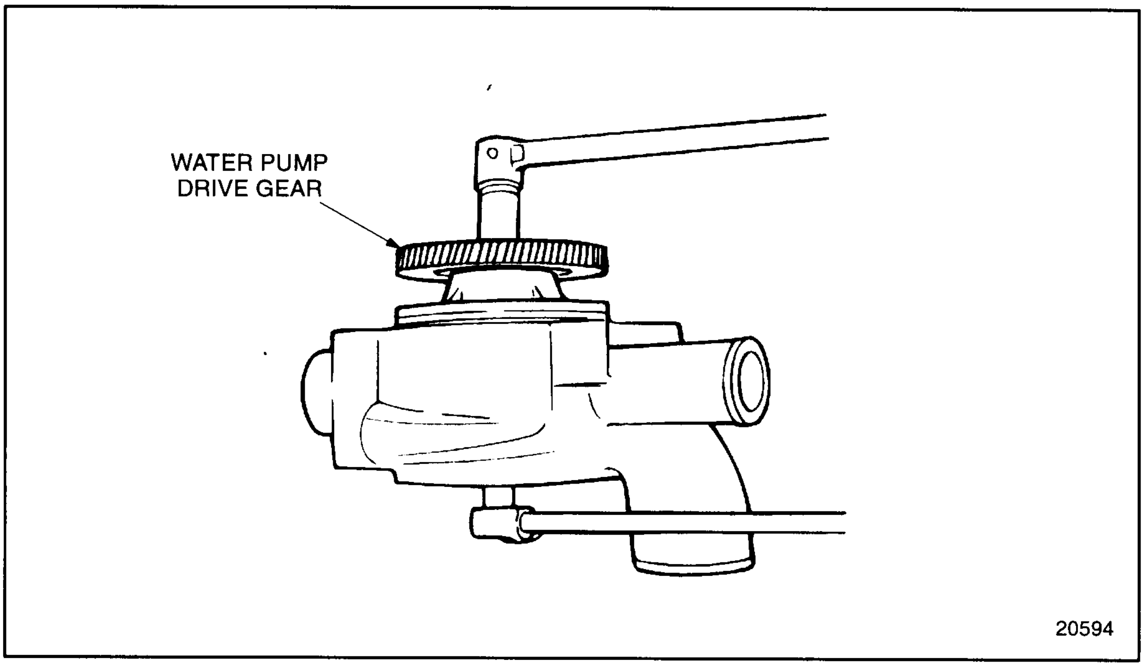


Figure 4-8 Water Pump Drive Gear Retaining Bolt Removal

4. Use a two-jaw gear puller to remove the water pump drive gear from the drive shaft.

NOTE:
The water pump drive gear may be a slip fit on the drive shaft because of manufacturing tolerances.

5. Remove the snap ring from the water pump housing. See Figure 4-9.

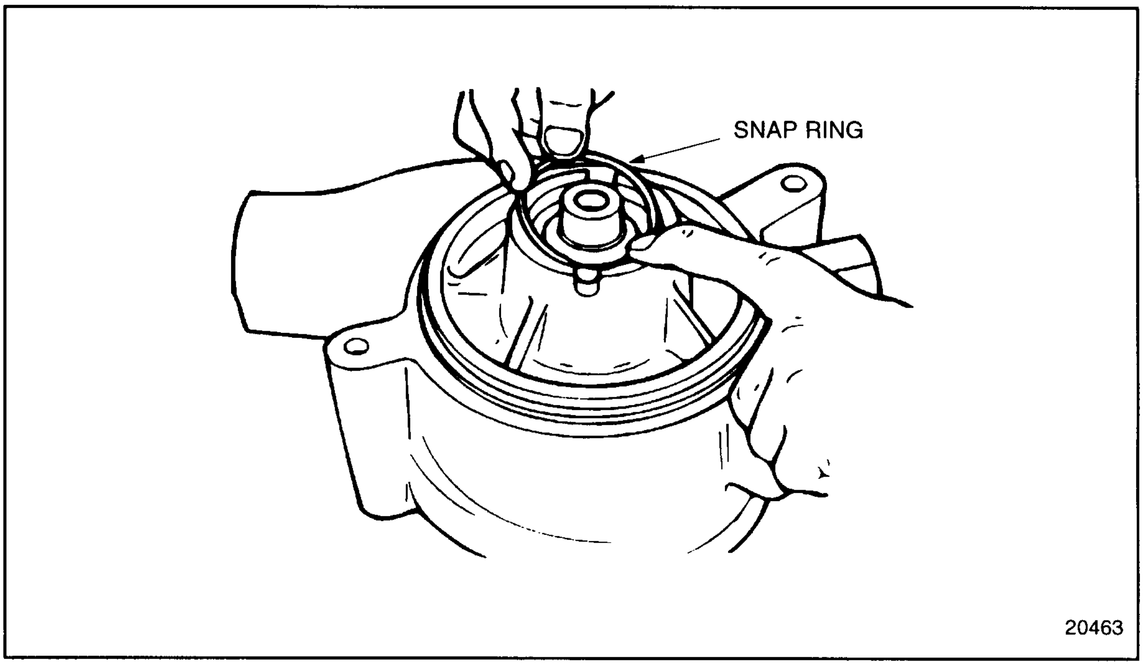


Figure 4-9 Snap Ring Removal

6. Support the water pump housing, engine side down, using steel blocks or plates, to allow at least 76 mm (3 in.) of clearance between the pump housing and the press bed.
7. Press the drive shaft and bearings assembly out through the front (engine side) of the water pump housing, until both bearing races are clear of the housing.

NOTE:
Once the bearing assemblies are pressed out of the water pump housing, they must be replaced with new assemblies.

NOTICE:

Do not allow brass drift to score housing bore when tapping out seals. A scored bore will cause coolant leaks and can damage engine.

CAUTION:

To avoid injury from chemical burns, wear a face shield and neoprene or PVC gloves when handling fluoroelastomer O-rings or seals that have been degraded by excessive heat. Discard gloves after handling degraded fluoroelastomer parts.

8. Remove both the water and oil seals from the housing using a brass drift and hammer.
9. Support the drive shaft assembly on two steel blocks, at the bearing inner race.
10. Insert extension tool, J 35988-3A, part of tool set J 35988-B, in end of drive shaft. See Figure 4-10.

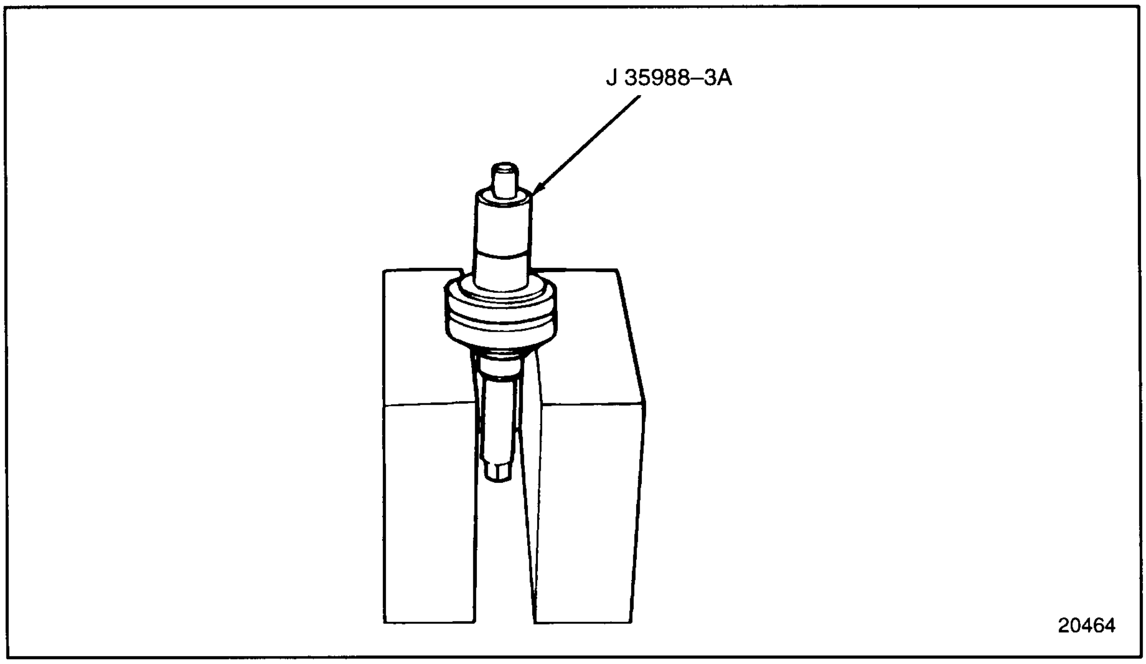


Figure 4-10 Removing Bearing Assemblies

11. Press the drive shaft out until it is clear of both bearing and race assemblies. Discard the used bearings, races and the two spacer rings located between the bearing packs.

4.2.3.1 Inspection of Water Pump

Inspect the water pump parts as follows:

1. Wash all of the pump parts in clean fuel oil.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the parts with compressed air.
3. Visually inspect the water pump housing, cover O-rings and all other water pump parts for cracks, wear or other damage.
   [a] Replace damaged or worn parts.
   [b] Reuse remaining components.
4. Replace the twin bearing assemblies, the oil seal and water seal.

4.2.4 Assembly of Water Pump

Assemble the water pump as follows:

1. Coat the bearing bores of the water pump housing and the drive shaft bearing surfaces with clean engine oil.

NOTICE:
Although the bearings are identical, the bearings and races are matched parts, and should be installed as they are removed from the box. Parts that are not matched will cause damage to the water pump.

2. Assemble the new bearing packs, as follows:
   [a] Place the small spacer ring on the inner bearing race. See Figure 4-11.

[b] Place the larger spacer ring on the outer bearing race.

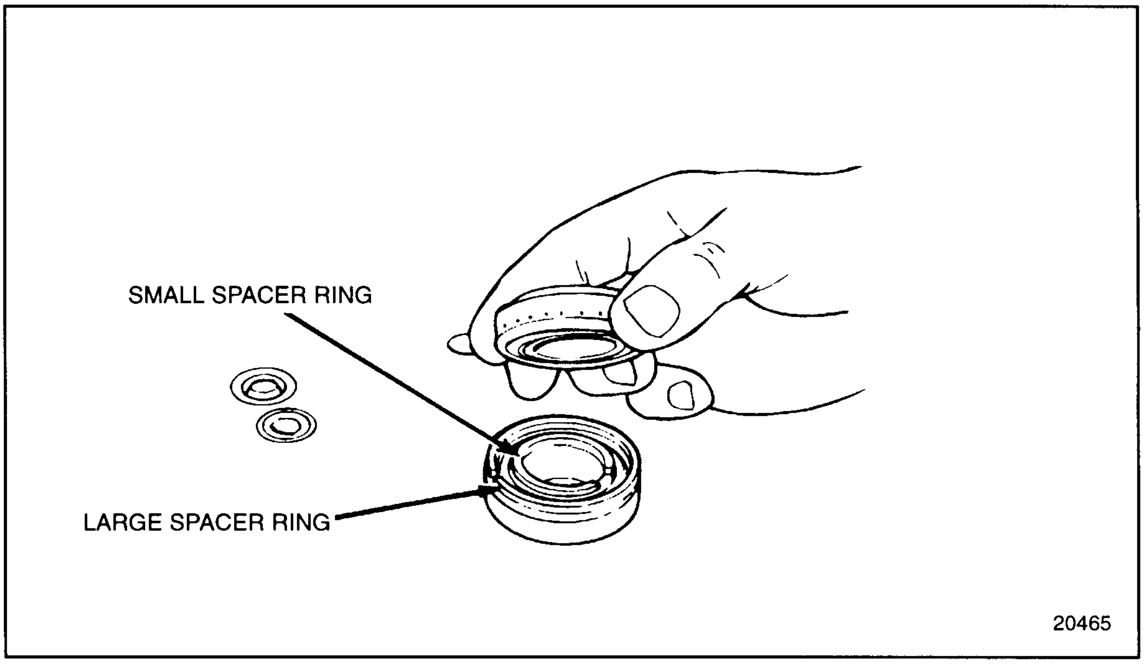


Figure 4-11 Bearing Pack Assembly

3. Using the drive shaft support tool, J 35988-18 part of J 35998–B and the water pump fixture J 35988-2 part of J 35998–B, parts of tool set J 35988-B. Install the support tool into the center of the fixture. See Figure 4-12.

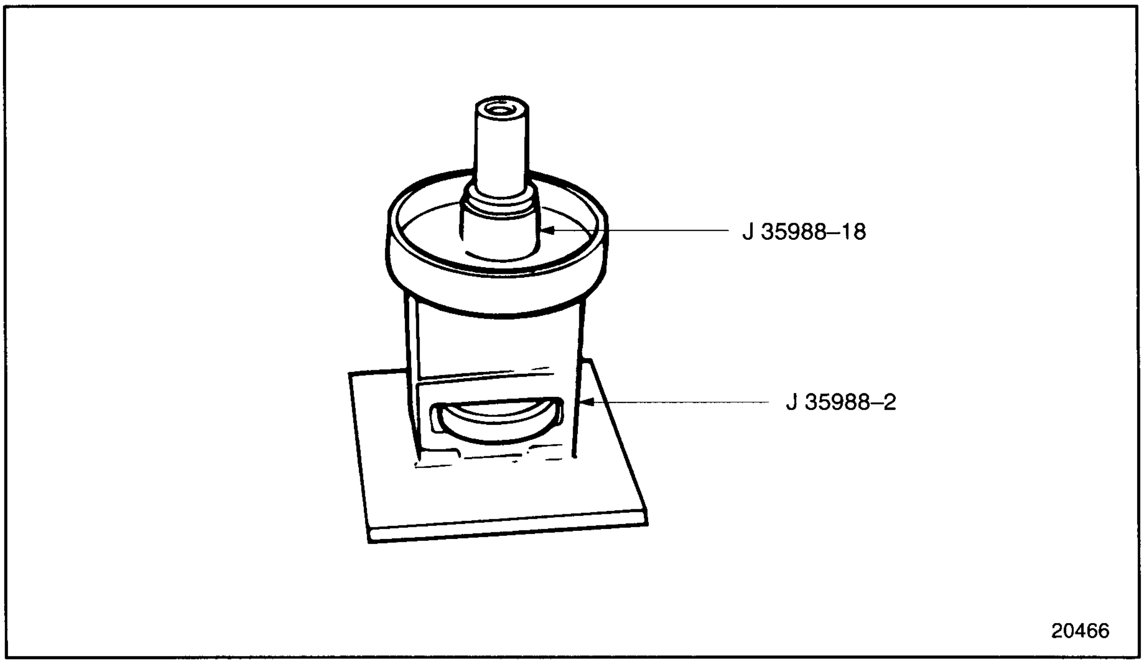


Figure 4-12 Bearing Installation Set-Up

4. Install the extension tool, J 35988-3A part of tool set J 35988-B , on the end of the water pump shaft. Install the assembled bearing packs to the drive shaft. See Figure 4-13.

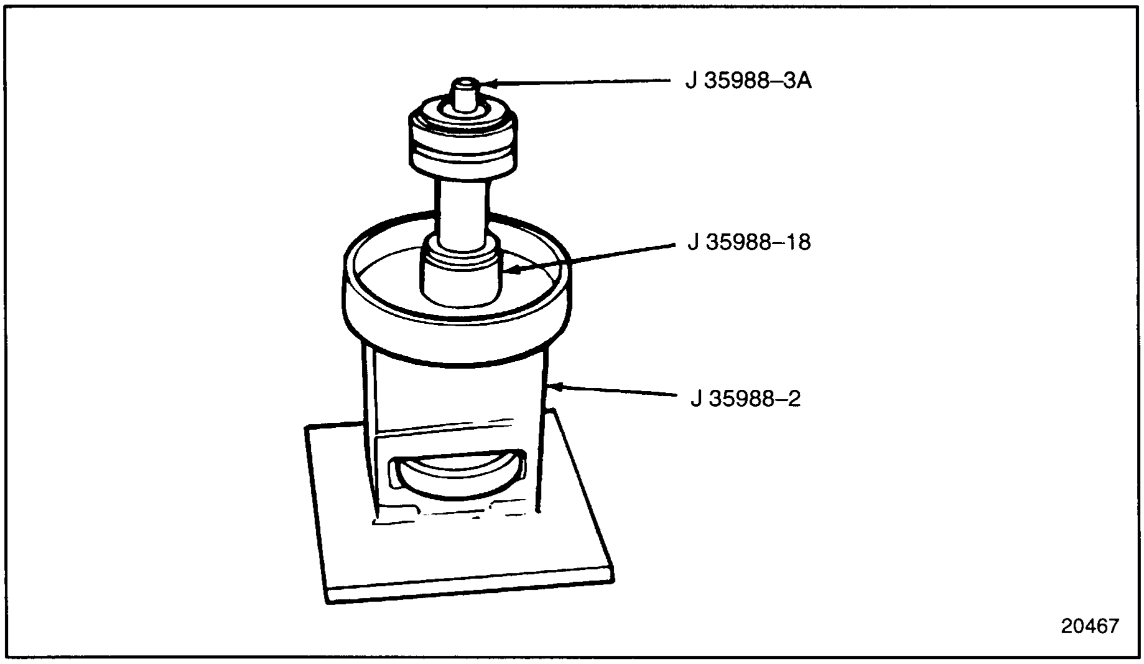


Figure 4-13 Bearing Placement

5. Center the small end of tool J 35988-1 part of J 35998–B, part of tool set J 35988-B, on the bearing inner race. See Figure 4-14. Press the bearing pack onto the shaft until it contacts the shoulder of the shaft. Remove the tool used to pilot the bearings.

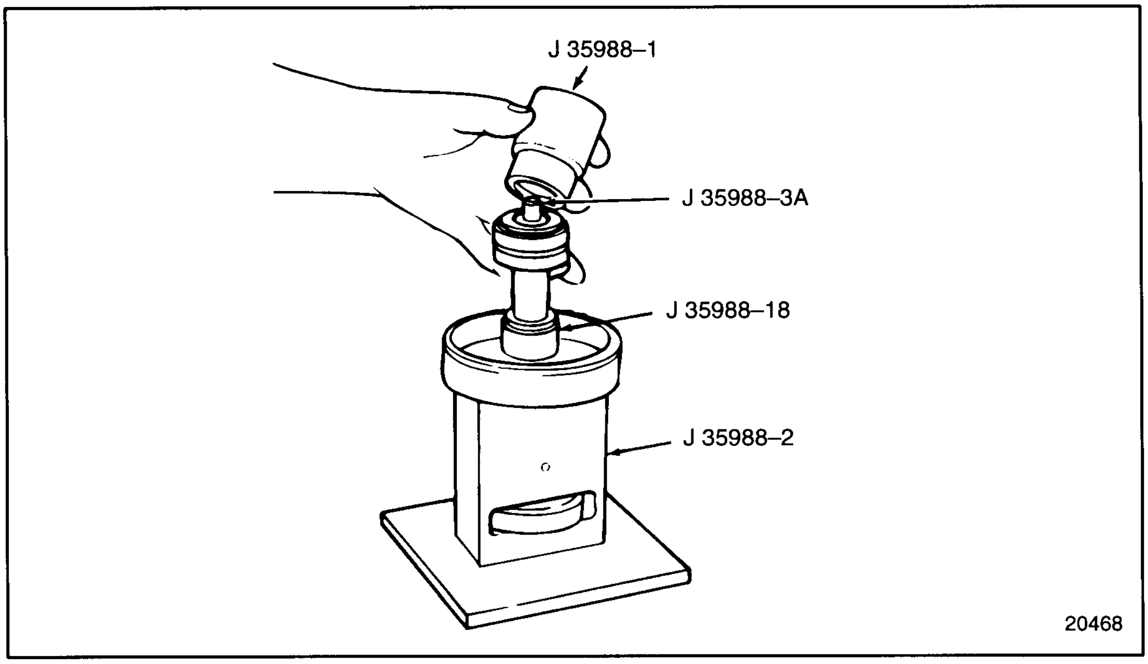


Figure 4-14 Bearing Installation

6. Remove the shaft and bearing assembly from the press.

4.2.4.1 Test Bearing Assembly

Check bearing assembly as follows:

1. Turn bearings to ensure they turn freely.
2. If bearings bind, disassemble water pump and replace bearing assembly. Refer to Section 4.2.3.

4.2.5 Assembly of Water Pump - cont'd

Continue assembling the water pump, as follows:

1. Coat the oil seal contact area of the water pump housing with a thin film of clean engine oil. See Figure 4-15.

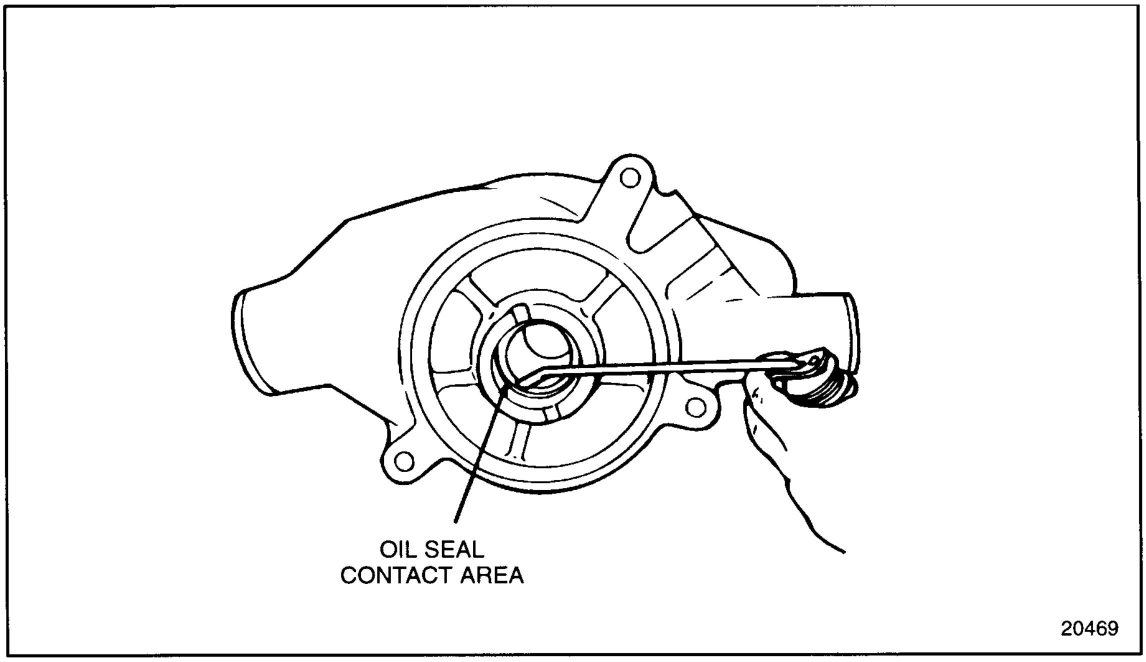


Figure 4-15 Oil Seal Contact Area Lubrication

2. Install a new oil seal into the water pump housing from the front (gear side). See Figure 4-16.

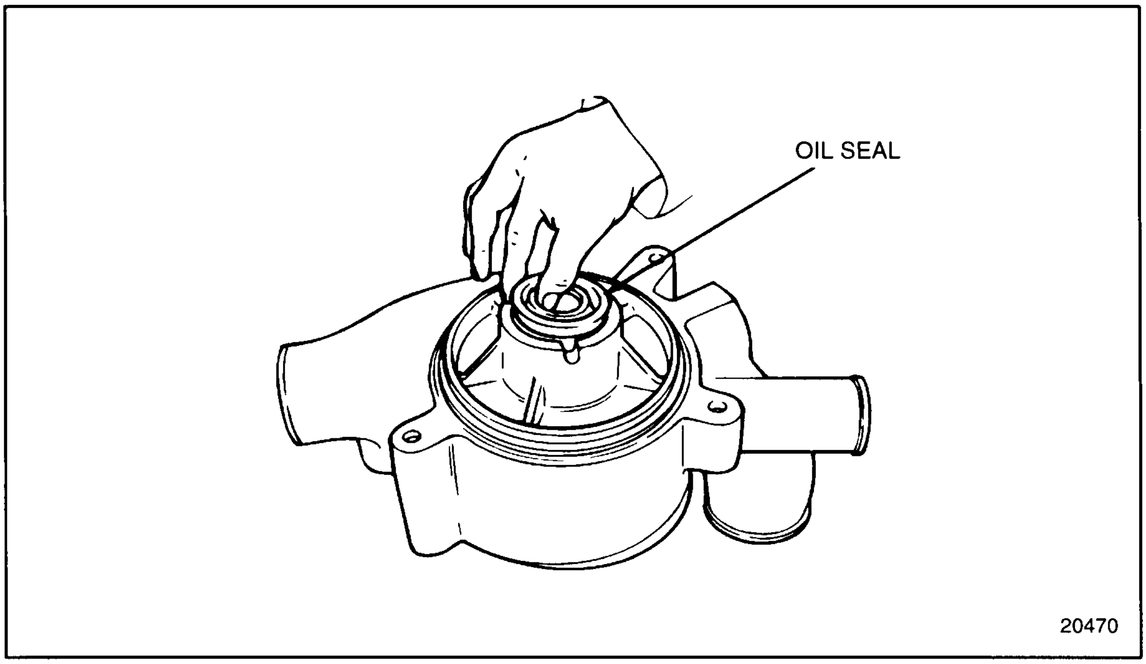


Figure 4-16 Oil Seal Positioning

NOTICE:
The contact surface of the oil seal is coated with a special sealant. Do NOT remove this sealant before installing the oil seal. If sealant is removed, leakage can occur.

3. Place the small end of tool J 35988-1 part of J 35998–B, part of tool set J 35988-B, into the water pump housing until it contacts the oil seal. See Figure 4-17.

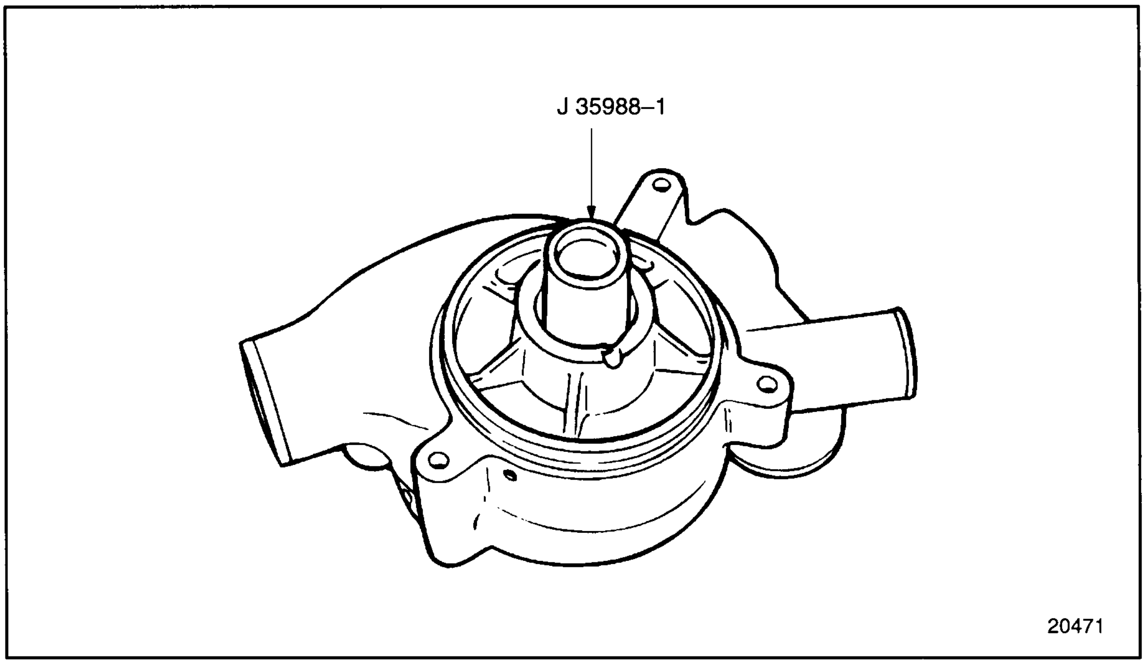


Figure 4-17 Oil Seal Installation

4. Press the oil seal into the housing until the seal lip is bottomed in the pump housing. Remove the tool J 35988-1 part of J 35998–B, part of tool set J 35988-B.
5. Coat the bearings with clean engine oil.
6. Place the water pump housing, with the gear side up, on a press bed.

7. Install the drive shaft, with bearings installed, to the water pump housing. See Figure 4-18.

NOTE:
During the bearing installation, the water pump housing must be parallel to the press bed or table surface.

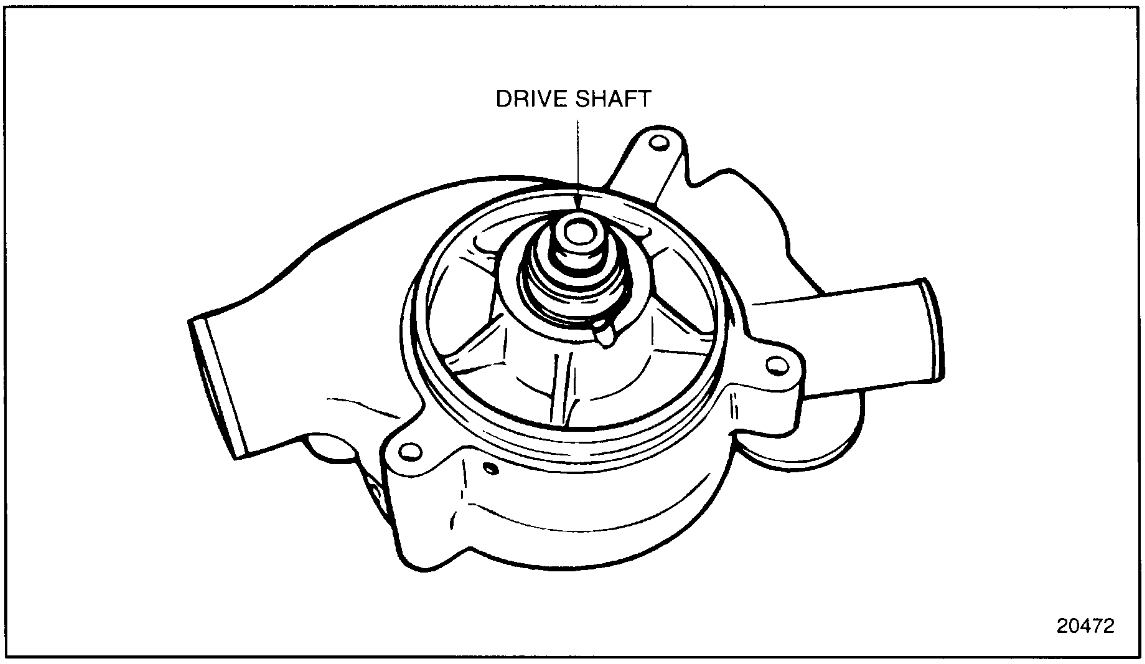


Figure 4-18 Drive Shaft Insertion

NOTICE:
The drive shaft must be installed using the outer bearing race only. Any other attempt at installation may damage the bearings.

8. Place the large end of tool J 35988-1 part of J 35998–B, part of tool set J 35988-B, over the drive shaft so that the lip of the tool rests squarely on the outer bearing race. See Figure 4-19.

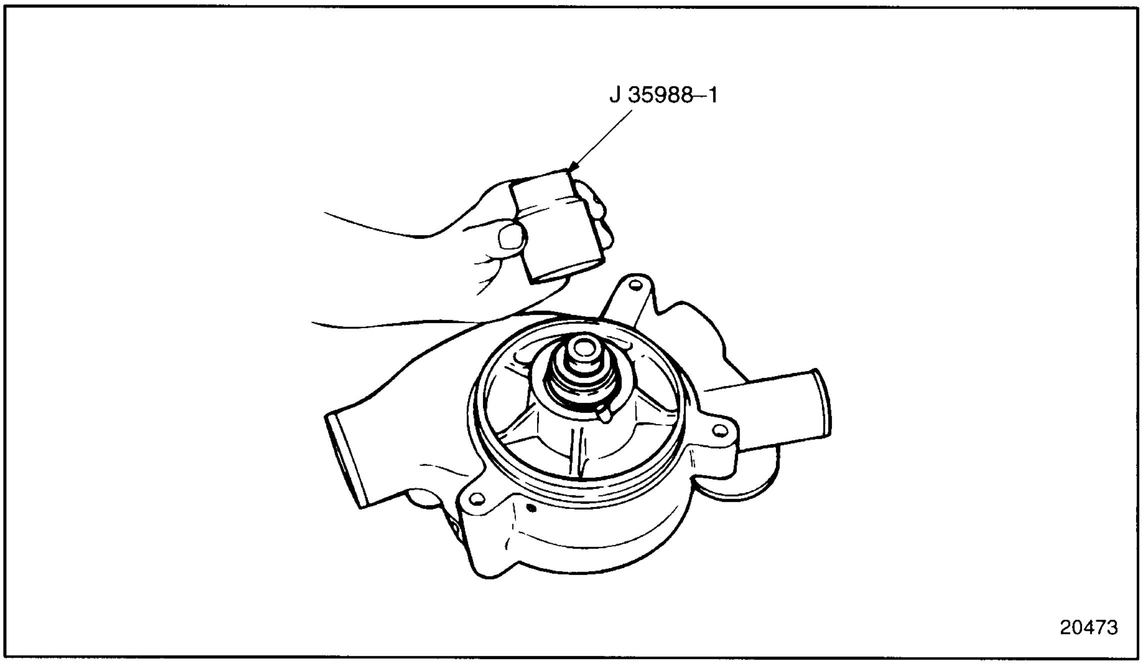


Figure 4-19 Drive Shaft Installation

9. Press the drive shaft and bearing assembly into the water pump housing, using tool J 35988-1 part of J 35998–B, part of tool set J 35988-B, until it is seated firmly against the shoulder in the housing.

10. Install the snap ring to the water pump housing. See Figure 4-20.

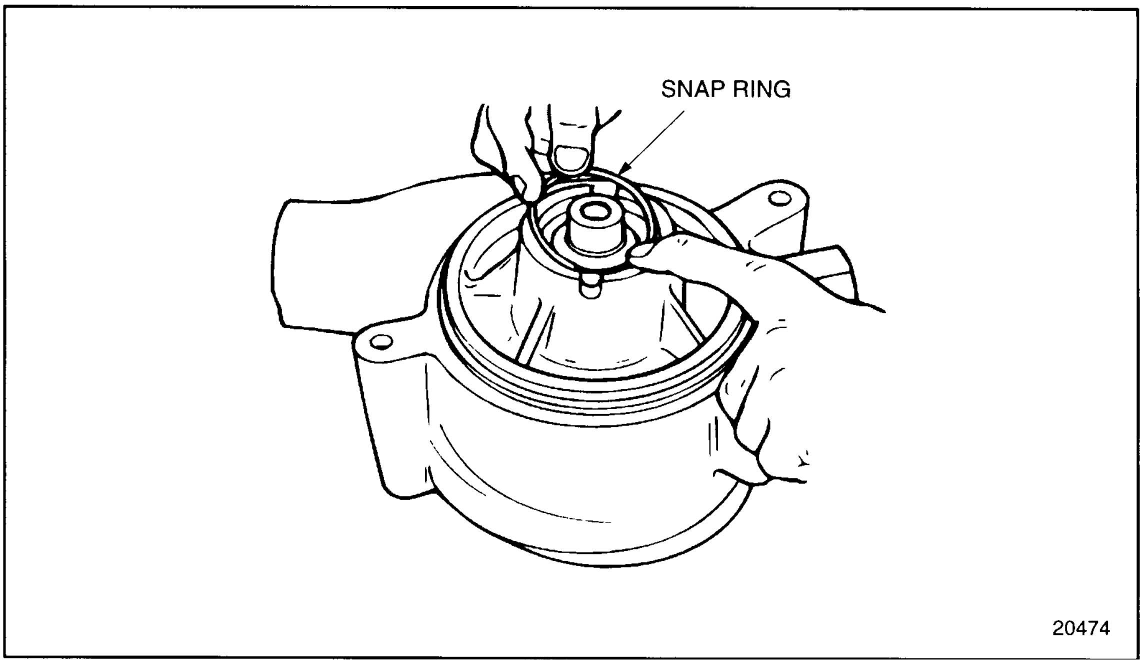
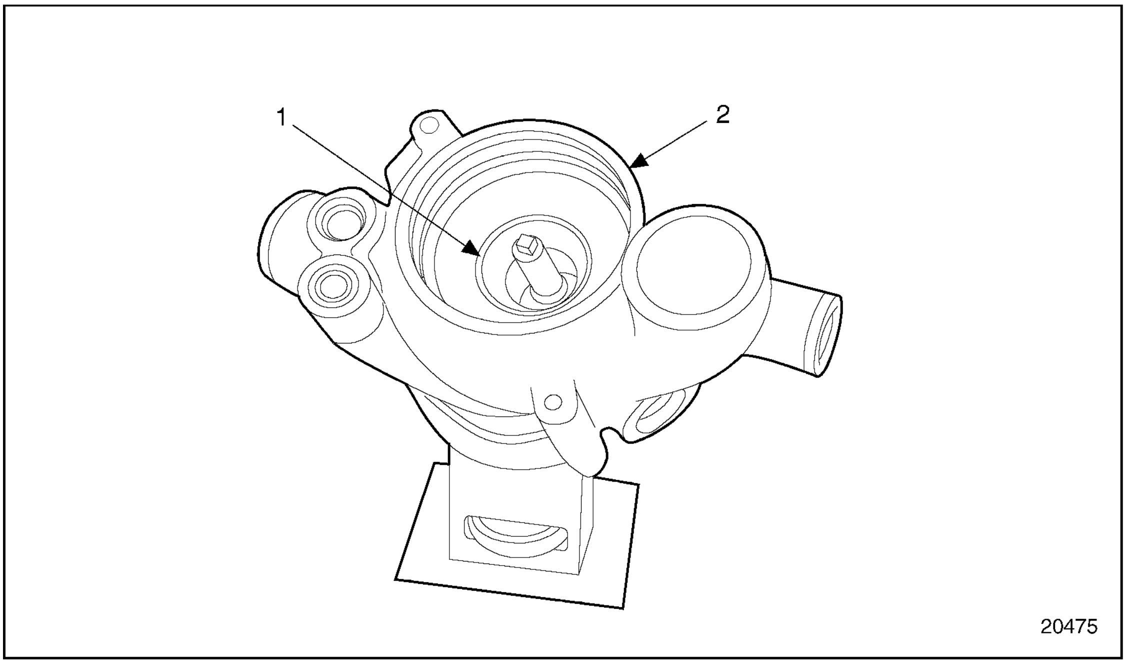


Figure 4-20 Snap Ring Installation

NOTICE:
Current water pump seals have a green sealant applied by the manufacturer, Do not apply additional sealant to the outside of the seal case or to the seal contact area on the pump housing. Excess sealant in these areas may result in failure of the seal to seat properly in the bore, causing shortened seal life or leakage.

11. Turn the water pump housing over and check to make sure no residual sealant remains in the water seal bore or on the seal flange contact surface. See Figure 4-21. Remove any residual sealant found in these areas.



1. Seal Bore
2. Water Pump Housing

Figure 4-21 Water Pump Housing Seal Bore

NOTICE:
The extension must contact and support the shaft when installing the water seal and impeller to prevent damage to the bearings.

12. Install the extension J 35988-3A part of J 35998–B, part of tool set J 35988-B, to the fixture tool. See Figure 4-22.

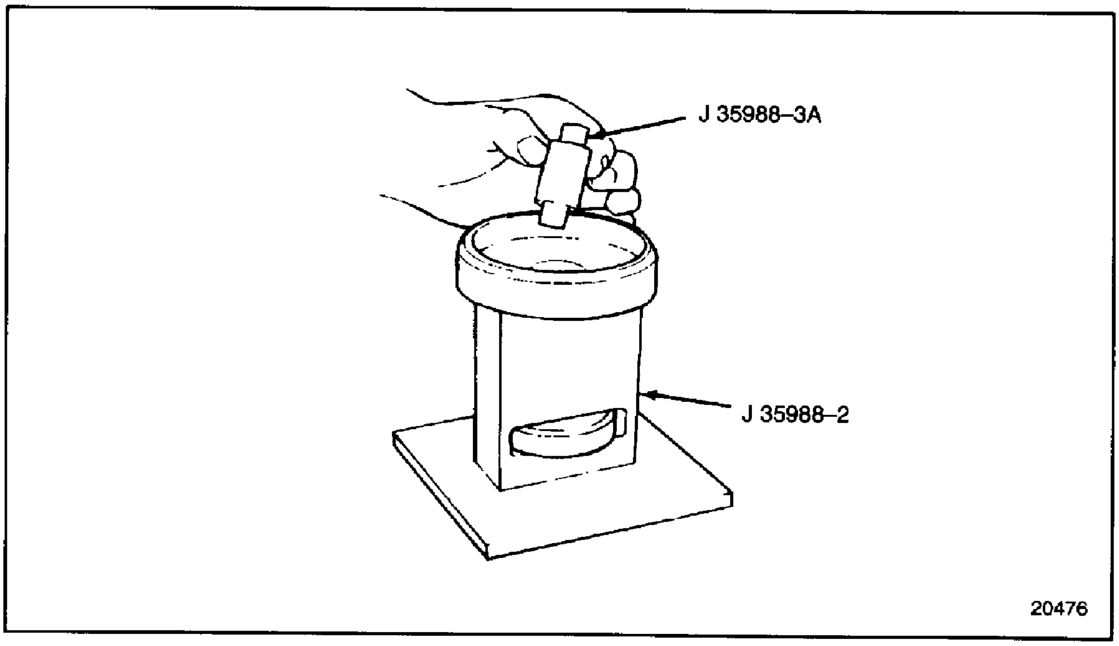


Figure 4-22 Support Installation

13. Install the water pump housing assembly to the fixture. See Figure 4-23.

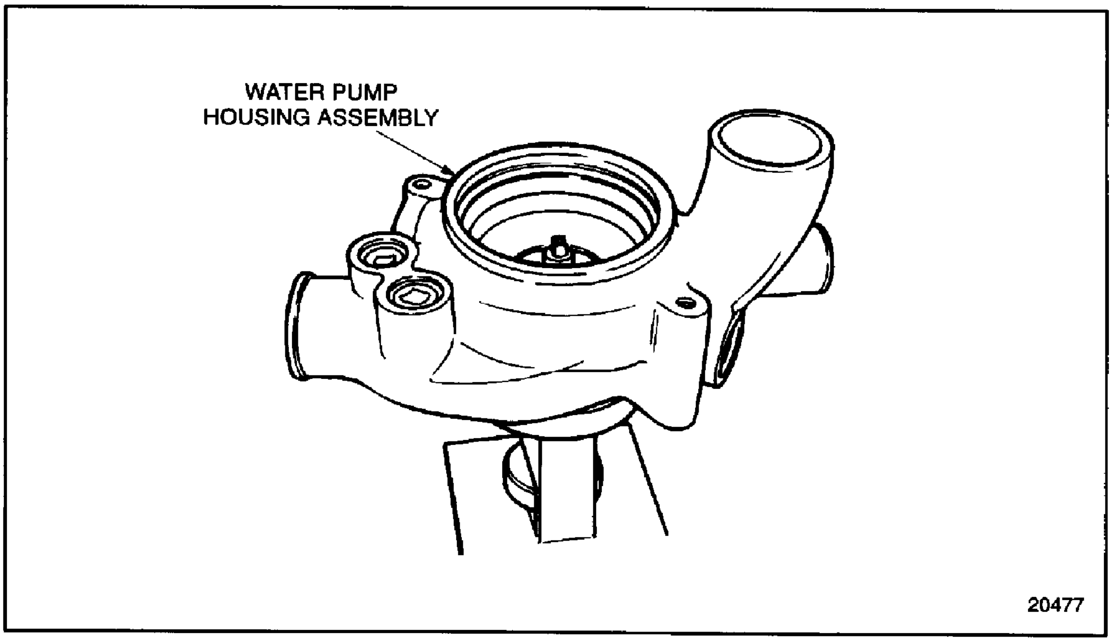


Figure 4-23 Water Pump Impeller Installation Set-up

14. Turn the adjustor wheel to raise the extension until it contacts the drive shaft in the water pump housing.
15. Apply Loctite primer (Locquic Primer N, Part No. 764) by swabbing onto the I.D. of the rotor of the seal.

16. Install a new water seal over the drive shaft and seat it in the water pump housing. See Figure 4-24.

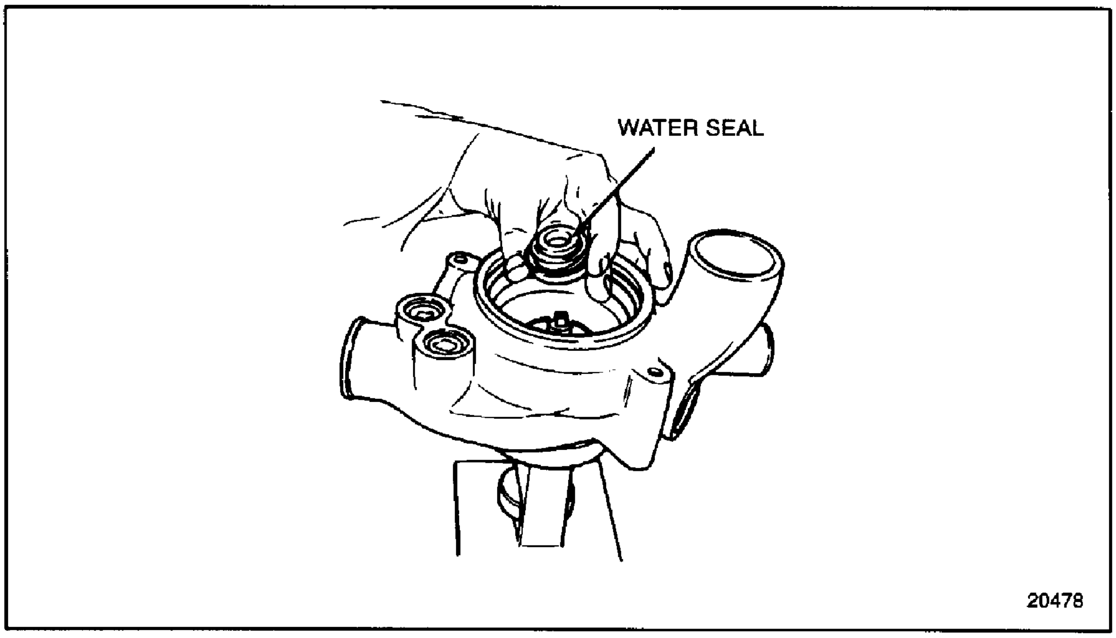


Figure 4-24 Water Seal Insertion

Detroit Diesel has released a new water pump coolant seal and oil seal. The new coolant seal requires the use of new seal installer J 35988–19, part of tool set J 35988–D. The new seals went into effect with engine serial number 4R38836. The use of Loctite® 290 is not required with the new coolant seal.

17. Position seal installer J 35988–19, part of tool set J 35988-D over the water seal. See Figure 4-25.

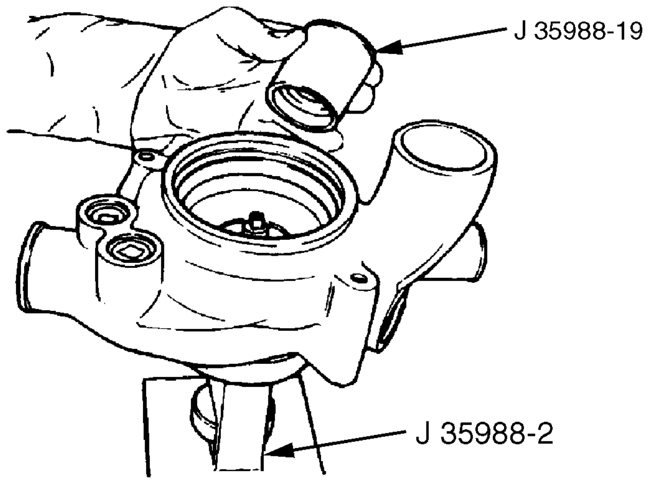


Figure 4-25 Water Seal Installation

18. Press the water seal into the housing until the flange of the seal case contacts the water pump housing a full 360°. Remove tool J 35988–19, part of tool set J 35988-D.

19. With the water pump housing still housed in tool J 35988-2 , part of tool set J 35988-B, and located on a press bed, position the impeller over the square end of the drive shaft with the vanes of the impeller facing down. See Figure 4-26.

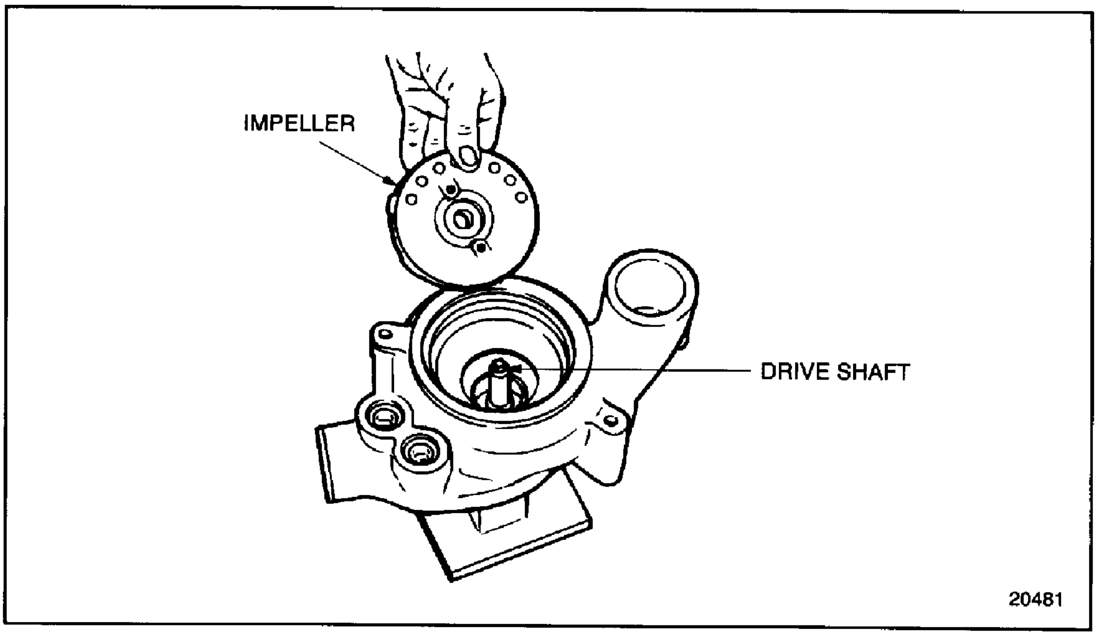


Figure 4-26 Water Pump Impeller Installation

NOTICE:
During this procedure, the drive shaft must be supported by the extension tool J 35988-3A, part of tool set J 35988-B. Failure to support the drive shaft while installing the impeller may result in bearing damage.

20. Using the impeller installation tool J 35988-14 part of J 35998–B, part of tool set J 35988-B, press the impeller on until the tool is flush against the water pump body. See Figure 4-27.

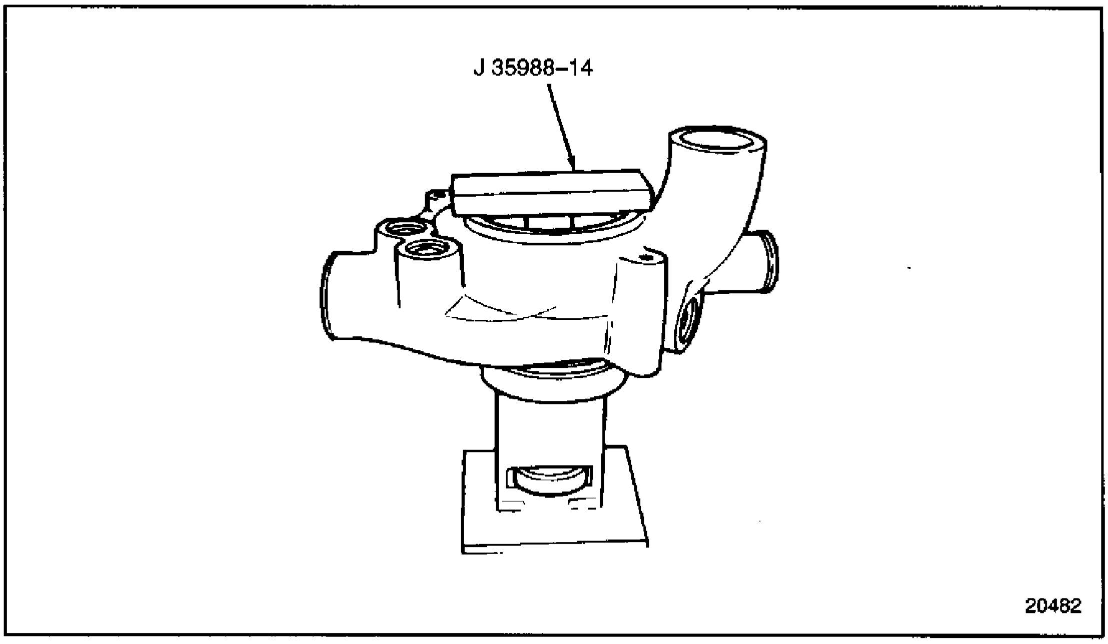


Figure 4-27 Water Pump Impeller Location

21. Turn the housing over and place it face (impeller side) down on the fixture J 35988-2 part of J 35998–B, part of tool set J 35988-B. See Figure 4-28.

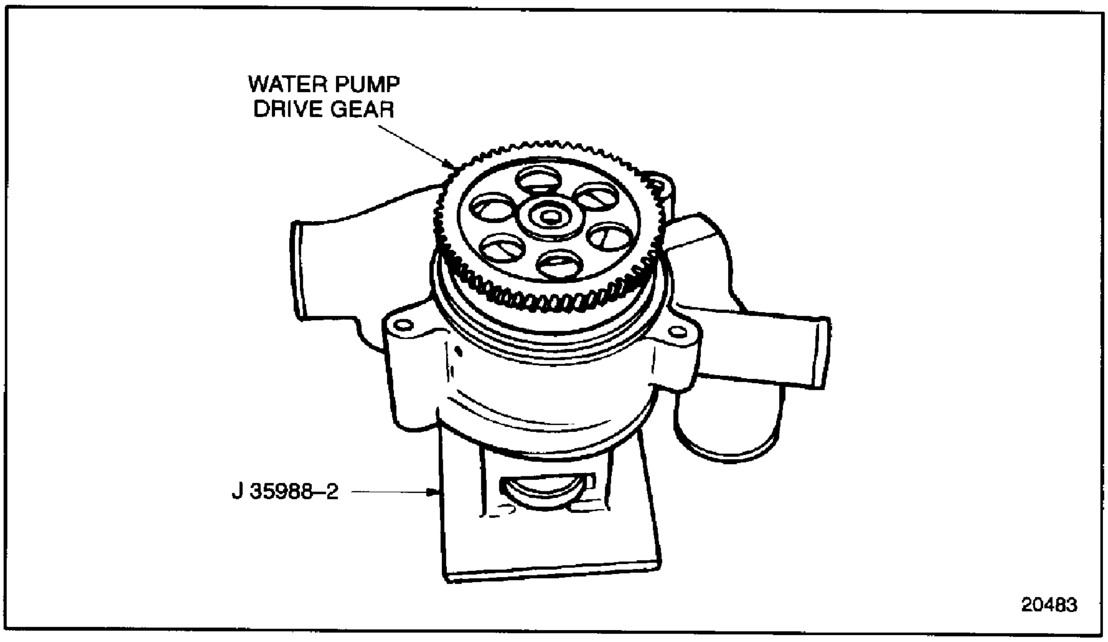


Figure 4-28 Water Pump Drive Gear Installation

22. Install the water pump drive gear to the drive shaft.

NOTE:
The water pump drive gear may have a slip fit. This is due to manufacturing tolerances and is acceptable.

NOTICE:
If the gear has a press fit, turn the adjustor wheel to raise the extension J 35988-3A, part of tool set J 35988-B, until it contacts and supports the shaft. This is necessary to prevent damage to the bearings when pressing the gear onto the shaft.

23. Using the small end of tool J 35988-1 part of J 35998–B, part of tool set J 35988-B, press the drive gear down onto the drive shaft until it touches the bearings. See Figure 4-29.

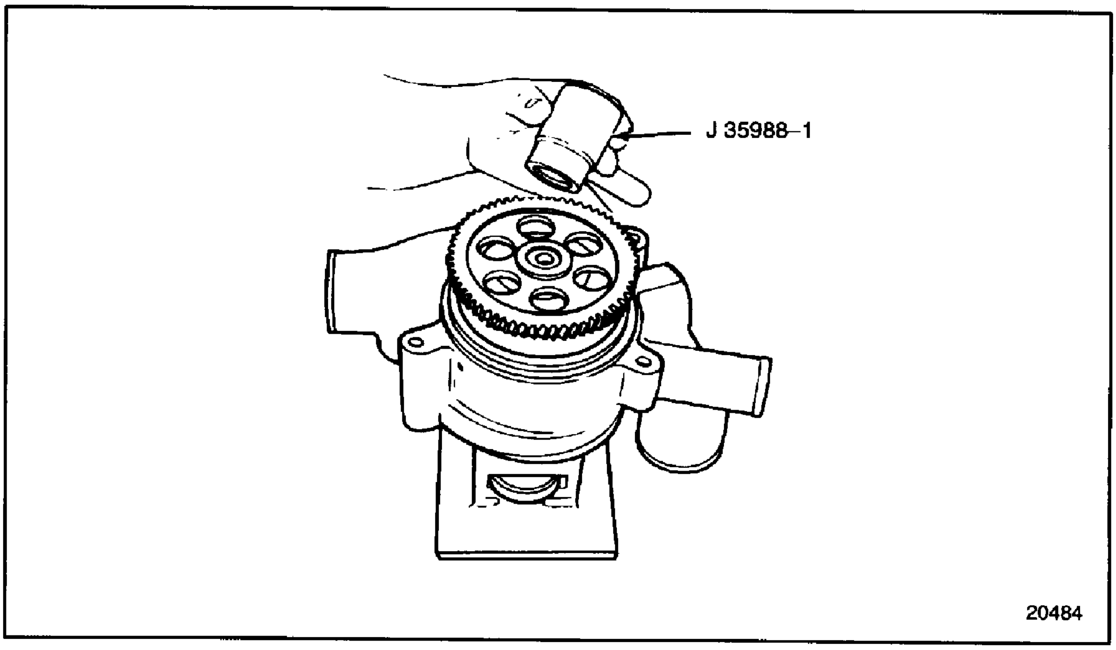


Figure 4-29 Water Pump Drive Gear Installation

24. Install the retaining bolt and washer. Hold the square end of the drive shaft and torque the retaining bolt to 102-126 N·m (75-93 lb·ft).

4.2.5.1 Assembly Integrity Test

Verify the assembly integrity as follows:

1. Turn the pump over and install the water pump impeller slip and lash tester, J 35687, into the tapped holes provided in the impeller.

NOTICE:
When clamping gears, use soft jaws on vise to prevent damage to the gear teeth.

2. Clamp the water pump drive gear in a vise, with the impeller facing up.
3. Using a 1/2 in. drive torque wrench in the hole provided in the center of the slip and lash tester, J 35687, apply 68 N·m (50 lb·ft) torque in either direction.
   [a] The impeller must withstand 68 N·m (50 lb·ft) torque without slipping.
   [b] If the torque specification is not satisfied, disassemble water pump and replace the impeller. Refer to Section 4.2.3.
4. Using a dial indicator with magnetic base, measure the total runout of the water pump drive gear at four places, at 90° intervals. Maximum allowable runout is 0.0635 mm (0.0025 in.). See Figure 4-30.

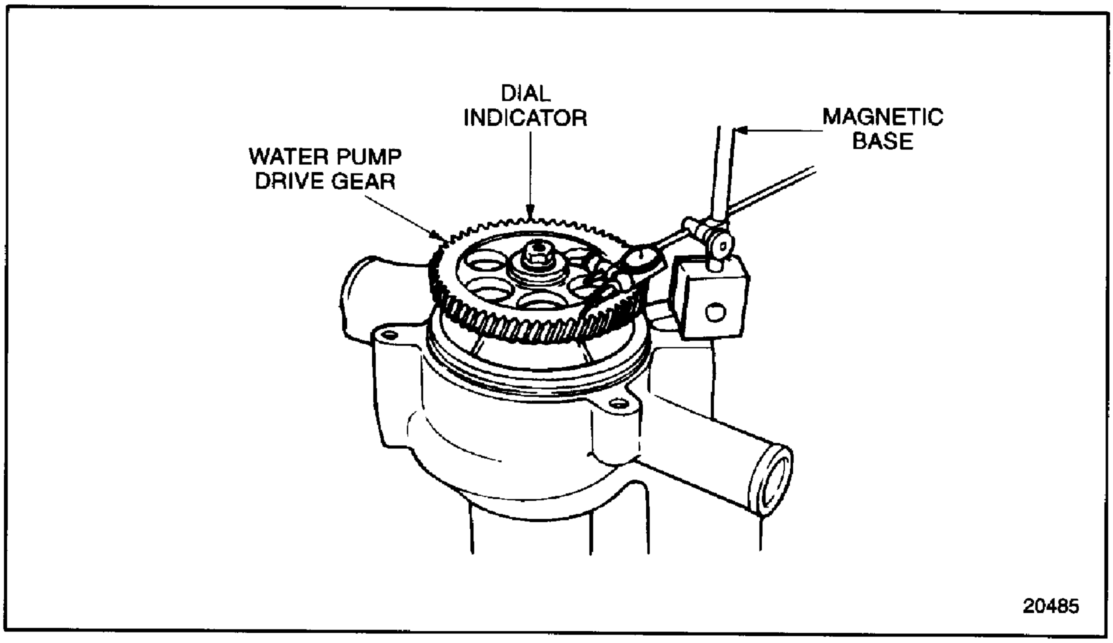


Figure 4-30 Measuring Water Pump Drive Gear Runout (GCM)

   [a] If this value is exceeded, disassemble the water pump and check for burrs or foreign particles. Refer to Section 4.2.3.
   [b] If runout still exceeds limits, disassemble water pump and replace the drive gear or drive shaft as necessary. Refer to Section 4.2.3.
5. Remove dial indicator and magnetic base.

4.2.6 Assembly of Water Pump (Continued)

Continue assembly of the water pump as follows:

CAUTION:
To avoid injury, wear a face shield or goggles.

1. Install seal ring, water pump cover, and snap ring with the beveled side of snap ring facing out. Tap around the inside rim of the snap ring with a brass drift and hammer to seat snap ring in groove fully.

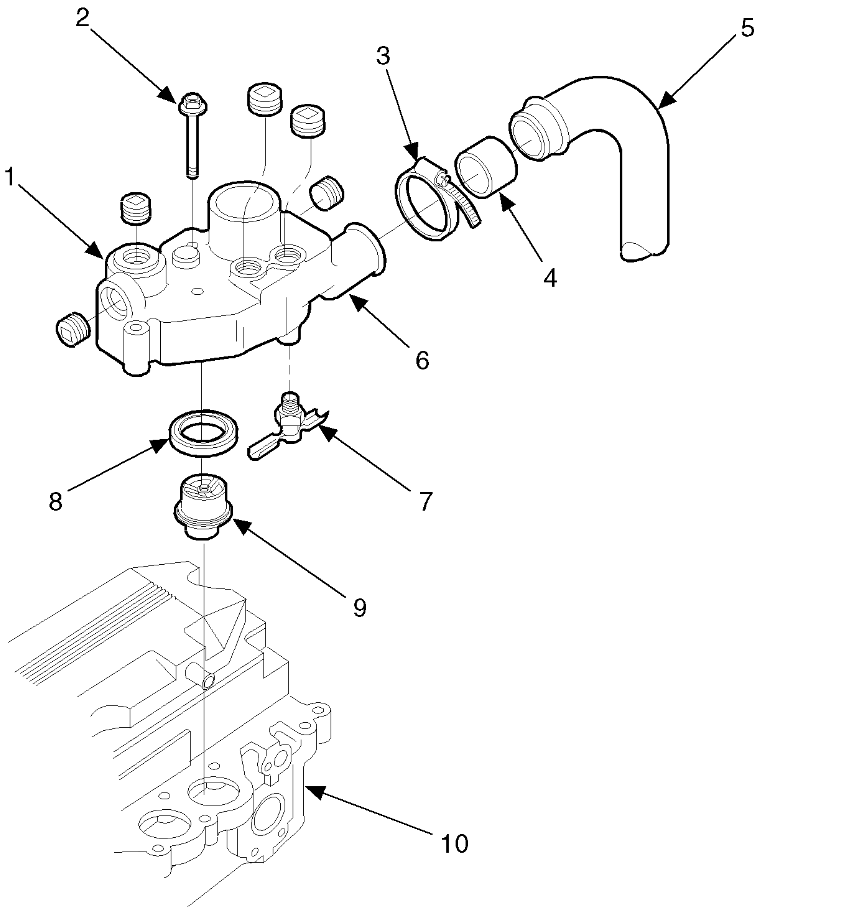
4.2.7 Installation of Water Pump

Install the water pump as follows:

1. Coat the water pump seal ring with clean engine oil.
2. Install the seal ring to the groove in the water pump housing.
3. Coat the water pump drive gear with clean engine oil.
4. Install the water pump to the engine, meshing the water pump drive gear with the bull gear.
5. Install the three water pump housing-to-gear case bolts. Tighten the bolts alternately and evenly to draw the water pump straight into the engine. Torque the bolts to 58-73 N·m (43-54 lb·ft).
6. Measure the gear backlash. Refer to Section 1.21.
7. Slide the coolant hoses into position and tighten the hose clamps.
8. Refer to Section 11.3.5 for verification of proper water pump installation.

4.3 THERMOSTAT

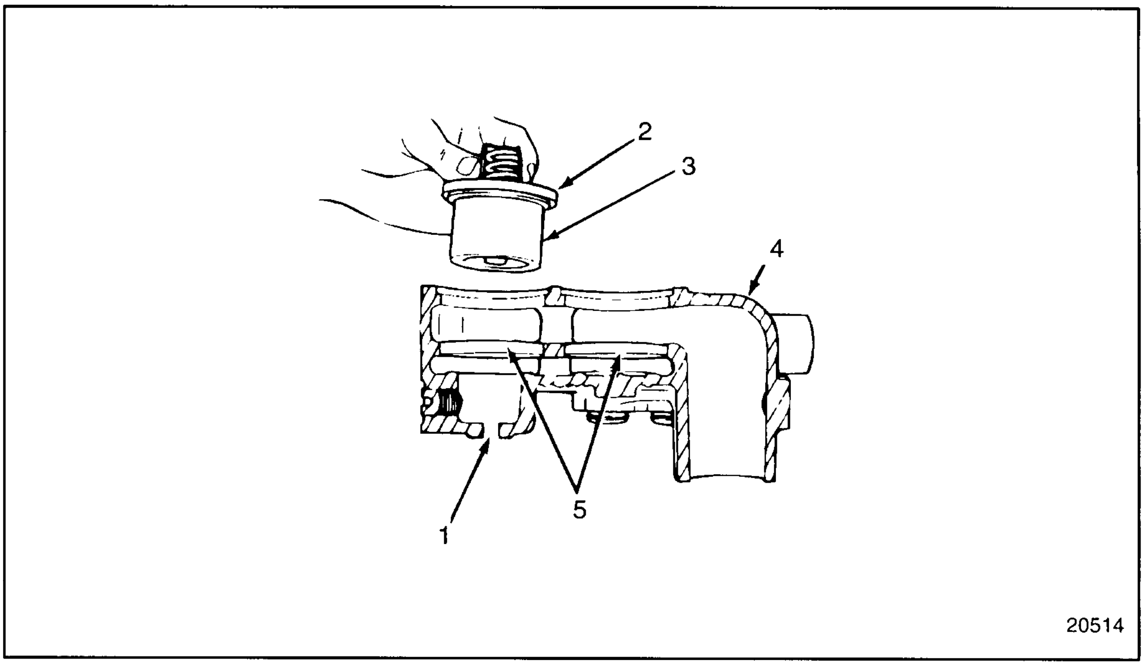
The temperature of the engine coolant is controlled by two blocking-type thermostats located in a housing attached to the right side of the cylinder head. See Figure 4-31.



1. Vent Line Connection
2. Bolts, Thermostat Housing-to-Cylinder Head (4)
3. Hose Clamps (2)
4. Hose, Coolant
5. Bypass Tube
6. Thermostat Housing
7. Drain Cock
8. Seals, Thermostat Housing (2)
9. Thermostats (2)
10. Cylinder Head

Figure 4-31 Thermostat and Related Parts

In addition to a rubber seal that is part of the thermostat, there is a lip-type seal for each thermostat that is installed in a bore in the thermostat housing. See Figure 4-32.



1. Connection Opening, Vent Line
2. Seal, Thermostat (2)
3. Thermostat (2)
4. Thermostat Housing
5. Seals, Thermostat Housing (2)

Figure 4-32 Thermostat Seals

At coolant temperatures below approximately 86-89°C (186-193°F), the thermostat valves remain closed and block the flow of coolant from the engine to the radiator. During this period, all of the coolant in the system is recirculated through the engine and is directed back to the suction side of the water pump via a bypass tube. As the coolant temperature rises above 86-89°C (186-193°F) the thermostat valves start to open, restricting the bypass system, and allowing a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 97°C (207°F) the thermostat valves are fully open, the bypass system is blocked off, and the coolant is directed through the radiator. See Figure 4-33.

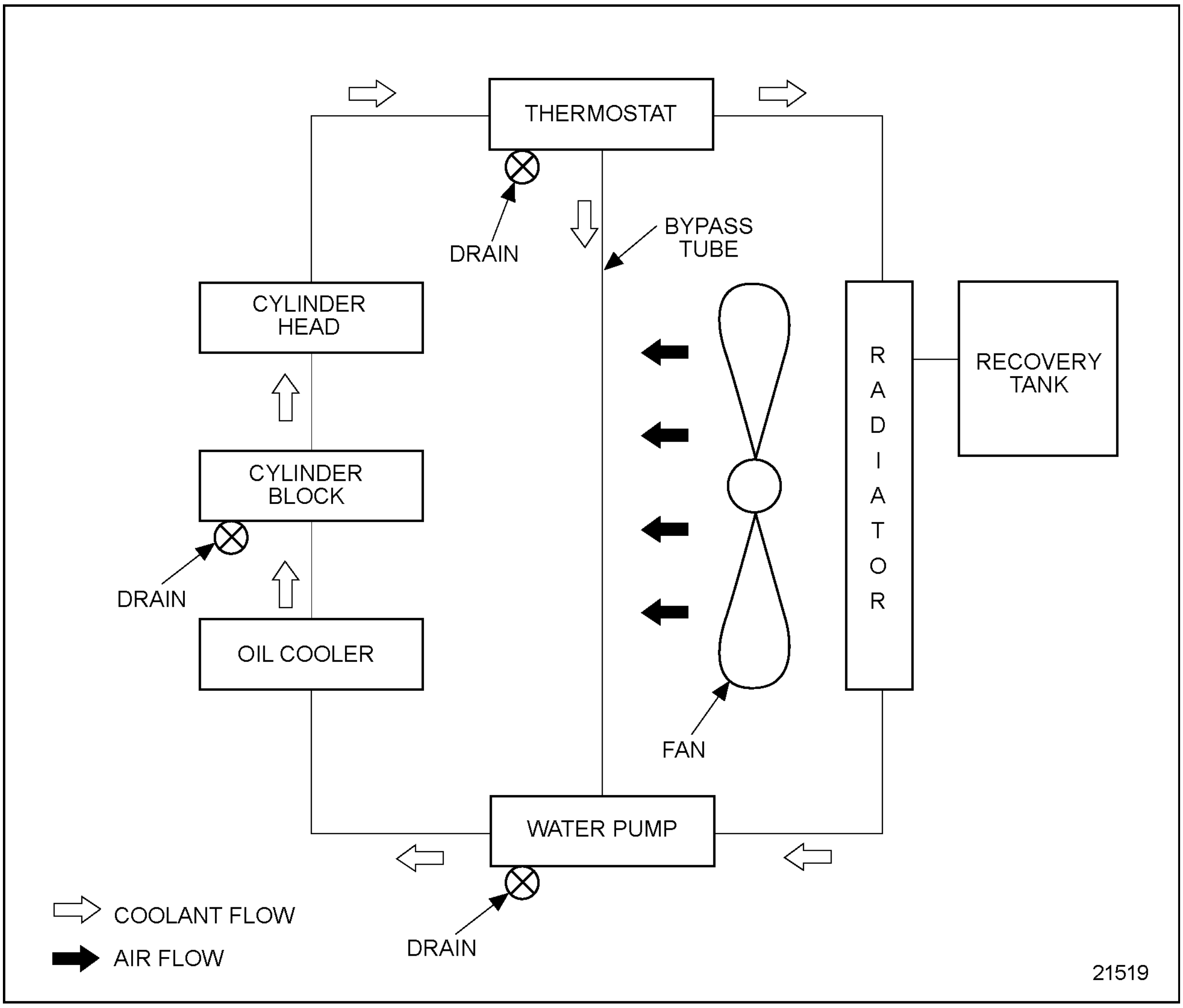


Figure 4-33 Coolant Flow Schematic

Properly operating thermostats are essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 86-99°C (186-211°F) remove, inspect and replace the thermostats if necessary.

4.3.1 Repair or Replacement of Thermostat

To determine if repair or replacement of the thermostat is necessary, perform the following procedure. See Figure 4-34.

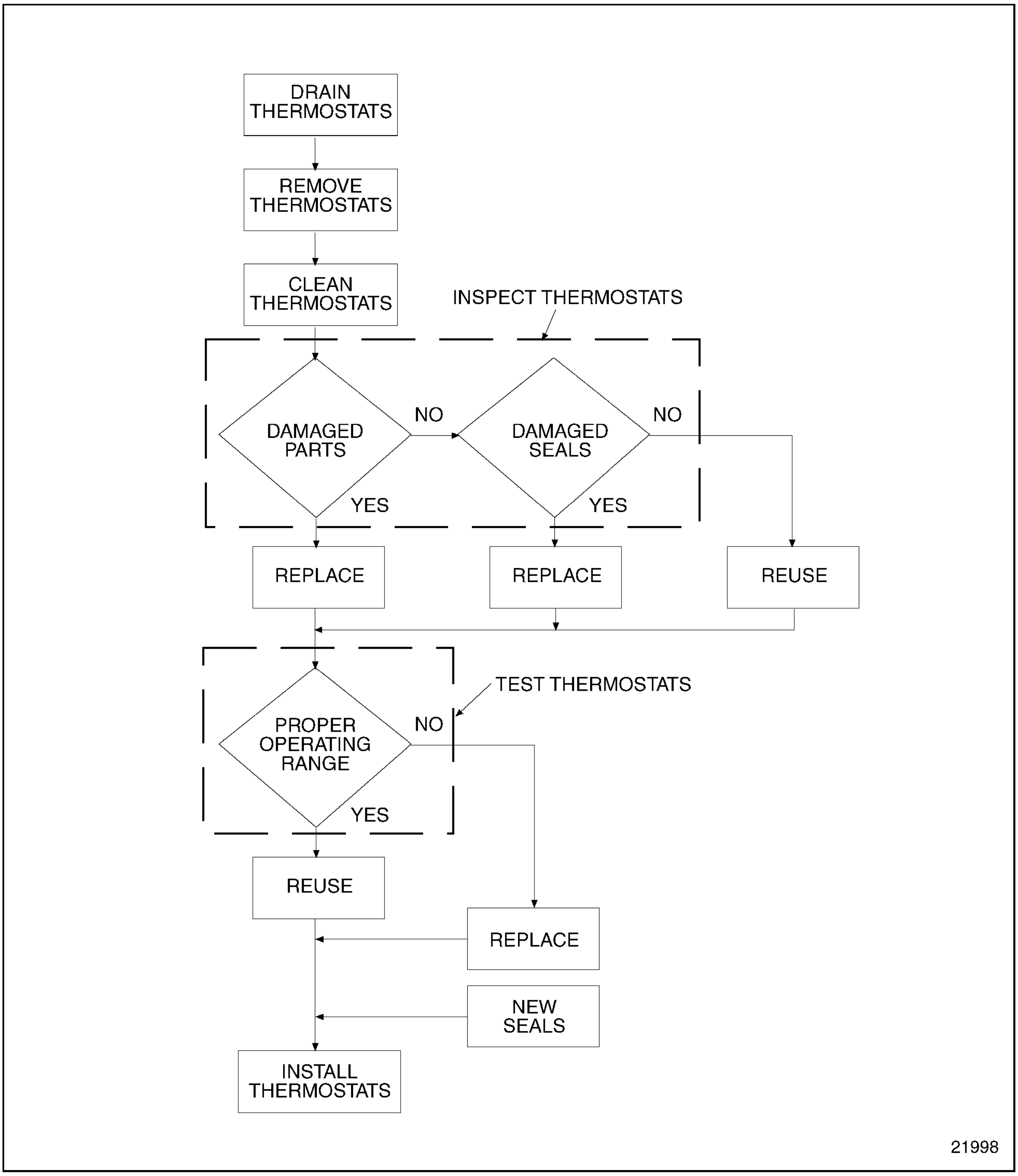


Figure 4-34 Flowchart for Repair or Replacement of Thermostat

4.3.2 Draining and Removal of Thermostat

Drain the thermostat as follows:

CAUTION:

To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

1. Slowly open the coolant pressure control (radiator) cap.
2. Open the draincock located on the bottom of the thermostat housing.
3. Drain the cooling system so that the coolant is below the thermostat level.

Remove the thermostat as follows:

1. Loosen the hose clamps on the coolant hoses connected to the thermostat housing.
2. Slide the hoses off the housing.
3. Disconnect the vent line and any other lines which are connected to the thermostat housing.
4. Remove the four thermostat housing-to-cylinder head attaching bolts.
5. Remove the thermostat housing assembly from the engine.
6. Remove the thermostats from the thermostat housing.
7. Remove and discard the thermostat housing seals.

4.3.2.1 Inspection of Thermostat

Inspect thermostat as follows:

1. Clean all of the parts in clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry all parts with compressed air.
3. Inspect thermostat body seal for damage, cracks or nicks.
   [a] If any damage is noted, replace seal.

4.3.3 Testing Thermostat

Check the operation of a thermostat as follows:

NOTICE:
Ensure thermostat is operational. If thermostat motion becomes impaired, overheating may result. An engine which has overheated may also cause the thermostats to become inoperative. A thermostat stuck in the open position may not allow the engine to reach 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. A thermostat that does not fully open may cause engine overheating.

1. Immerse the thermostat in a metal container of water. See Figure 4-35.

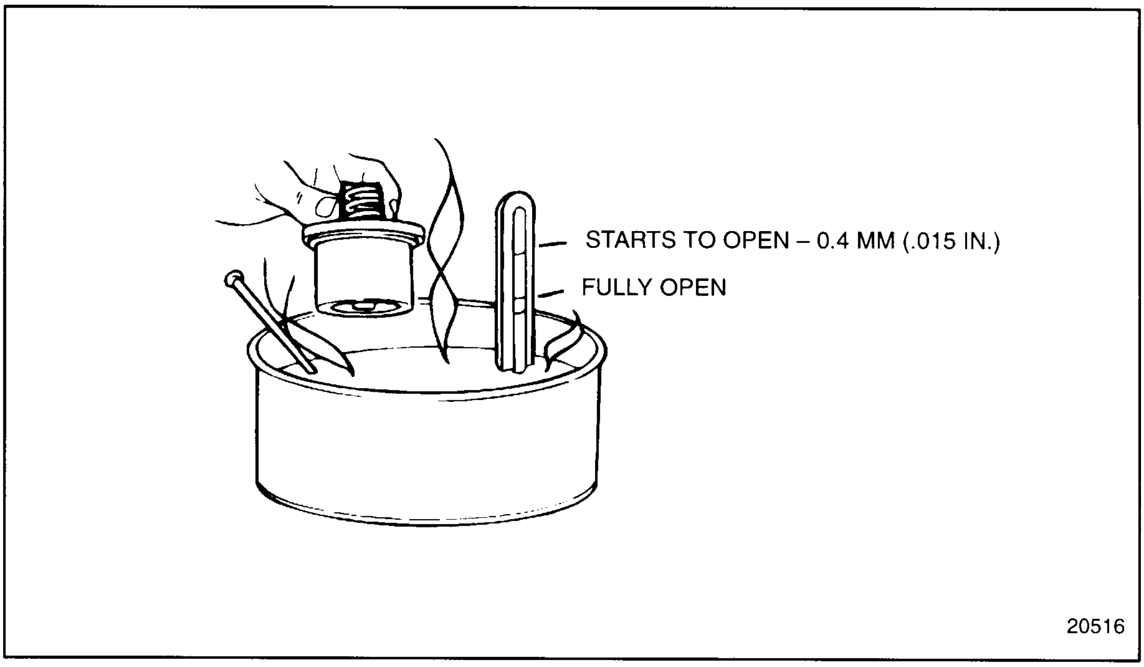


Figure 4-35 Checking Thermostat Operation

2. Place a thermometer in the container using care not to allow the thermometer to touch the bottom or sides of the container.
3. While slowly agitating the water to maintain an even temperature, apply heat to the container. Allow at least 10 minutes for the thermostats to react before determining if the thermostats are opening in the correct temperature range and are fully opened at 97°C (207°F).

CAUTION:

To avoid injury from scalding, use lifting tools and wear heat-resistant gloves when retrieving the thermostat from boiling water.

4. As the water is heated, the thermostat should begin to open (the normal opening temperature is stamped on the thermostat). 88°C (190°F) thermostats are used on the Series 50 engine with a start-to-open temperature range of 86-89°C (186-193°F). The thermostat is fully open (9.5 mm [0.375 in.]) at 97°C (207°F).
5. If thermostat does not operate properly replace.

4.3.4 Installation of Thermostat and Seal

Install new thermostat as follows:

1. Position the new seal onto seal installer, J 8550, and handle, J 7079-2. See Figure 4-36.

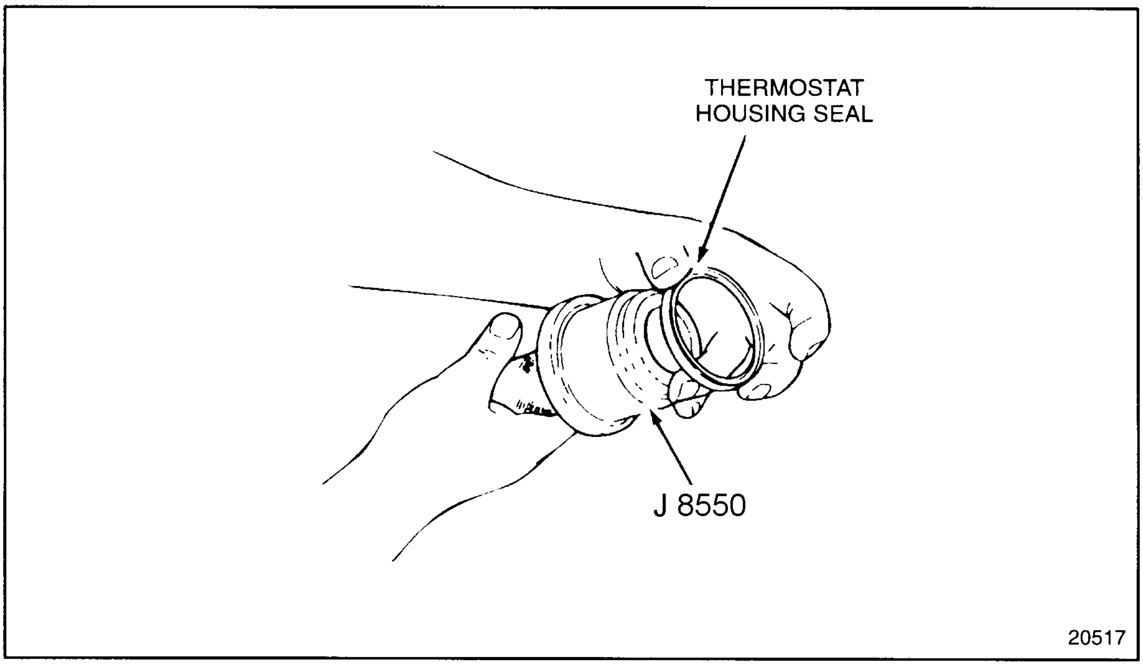


Figure 4-36 Positioning the Seal onto Seal Installer

2. Support the thermostat housing on a work bench so that it is level. See Figure 4-37.

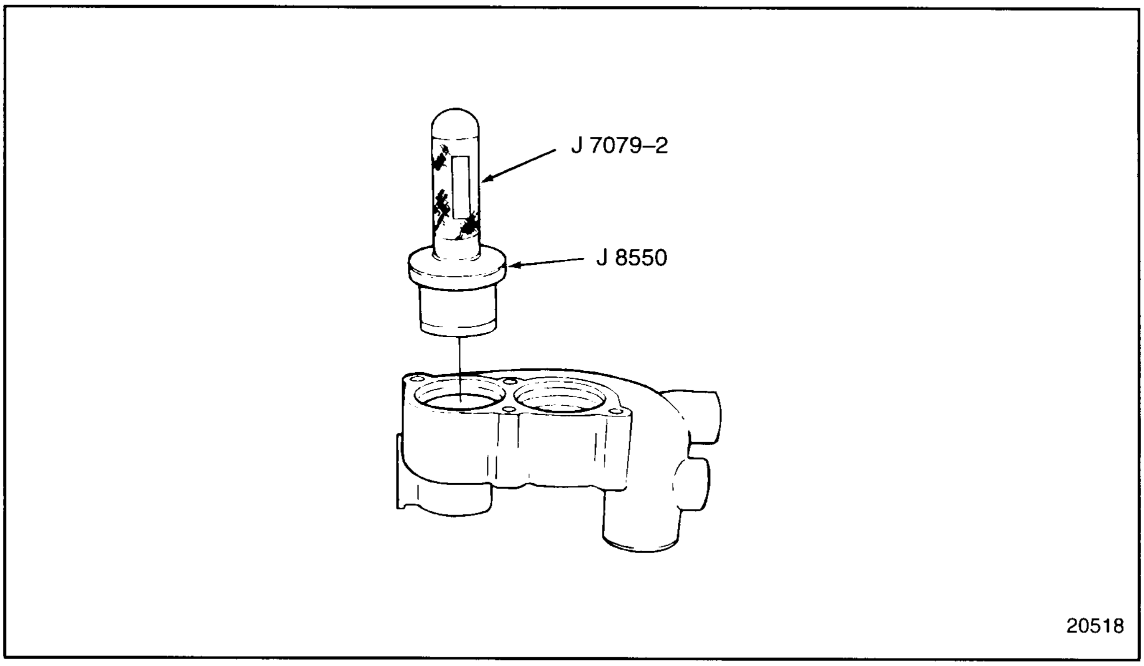


Figure 4-37 Thermostat Housing Seal Insertion

3. Insert the seal driver with seal installed, into the thermostat housing.

4. Drive the seal into the bore with a hammer, until the installation tool bottoms on the housing. See Figure 4-38. Rotate the tool during installation to ensure the seal is installed straight. Remove tools J 7079-2 and J 8550.

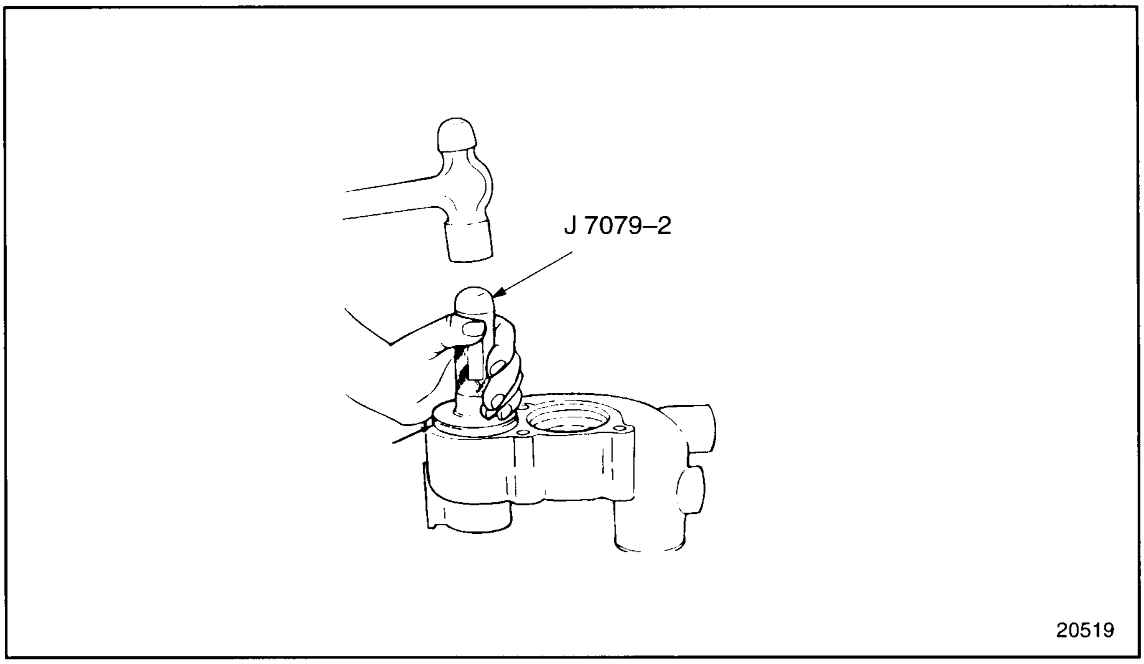


Figure 4-38 Thermostat Housing Seal Installation

5. Repeat step 1 through step 4 for the other seal.
6. Coat the lip of the seals with clean engine oil.
7. Place the thermostats, spring up, into the thermostat housing.

8. Press down on the thermostats to seat them. See Figure 4-39.

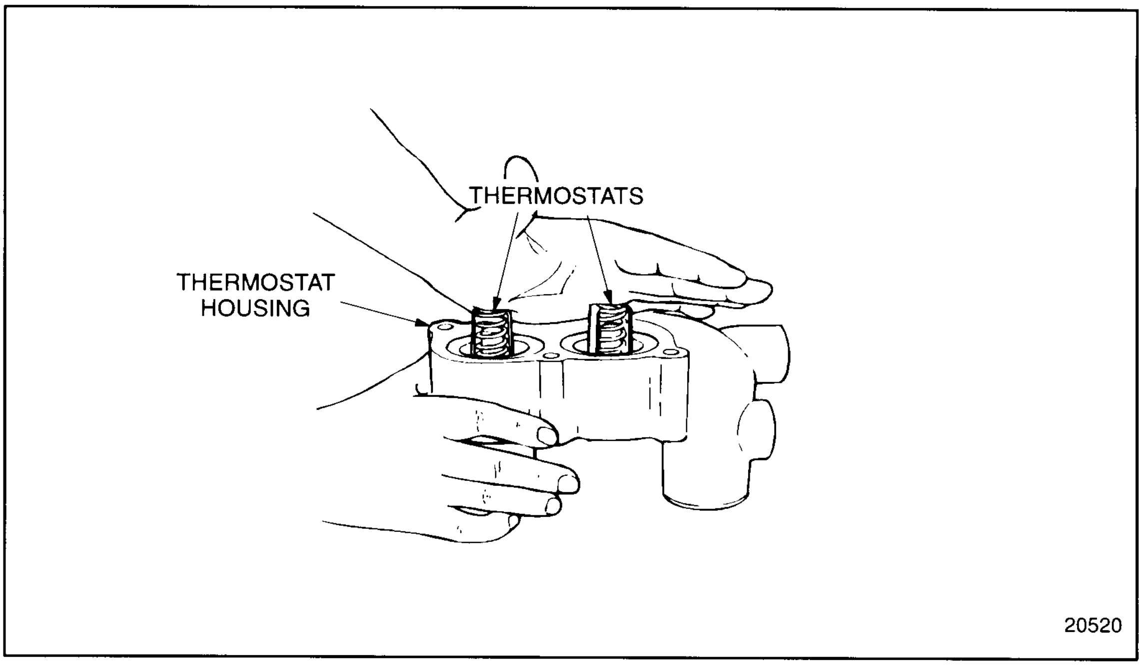


Figure 4-39 Seating Thermostats

9. Be sure the machined surface of the thermostat housing, where it contacts the cylinder head, is clean and dry.
10. Install the thermostat housing to the cylinder head with the four attaching bolts. Torque the bolts to 58-73 N·m (43-54 lb·ft).
11. Install the coolant hoses to the thermostat housing. Tighten the hose clamps.
12. Apply a coating of Loctite Pipe Sealer with Teflon, J 26558-92 part of PT-7276, or equivalent to the threads of the draincock if it was removed from the bottom of the thermostat housing.
13. Install and tighten the drain cock.
14. Install any other components removed for this operation.
15. Close the draincocks in the water pump housing and at the right rear of the cylinder block.
16. Install the thermostat housing vent line and any other lines that were removed from the housing.
17. Fill the cooling system. Refer to Section 13.5.4.
18. Refer to Section 11 for verification of thermostat installation. Listed in Table 11-2are the normal cooling system operational parameters.

4.4 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 in the cooling system equal to the rating stamped on the top of the cap. A cap with a "9" on the top allows the cooling system to develop 62 kPa (9 lb/in.^{2}) before the valve opens. This system pressure raises the boiling point of the coolant and reduces coolant loss. The maximum allowable coolant temperature, regardless of the pressure cap used, is 99°C (210°F).

To prevent collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools. See Figure 4-40. It also permits coolant to flow from coolant recovery bottle (when used) to the radiator tank.

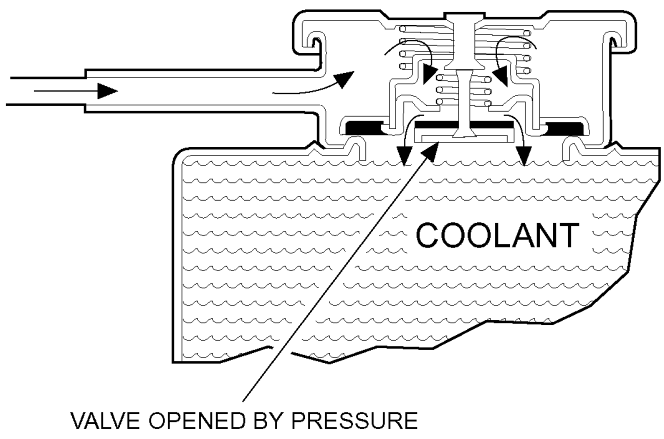


Figure 4-40 Pressure Control Cap (Vacuum Valve Open)

4.4.1 Repair or Replacement of Pressure Control Cap

Refer to the OEM guideline for pressure control cap service procedure.

4.4.2 Cleaning and Removal of Pressure Control Cap

Remove the pressure control cap as follows:

CAUTION:

To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

1. Wipe the outside area on the pressure control cap clean before removal.
2. Push down on pressure control cap while turning counter-clockwise.

4.4.2.1 Inspection of Pressure Control Cap

Detroit Diesel does not offer pressure control (radiator) caps as original equipment on Series 50 engines.

Clean and inspect cap periodically. Check operation of both valves using test kit J 24460-01 or equivalent. Replace if necessary. Inspect and clean fill neck. Replace if damaged.

It is recommended that all Series 50 on-highway vehicle engines use a minimum 62 kPa (9 lb/in.^{2}) pressure control cap. If the pressure valve does not open between 55 kPa (8 lb/in.^{2}) and 69 kPa (10 lb/in.^{2}) or the vacuum valve does not open at 4.3 kPa (0.625 lb/in.^{2}) (differential pressure), replace the pressure control cap.

4.4.3 Installation of Pressure Control Cap

Install the pressure control cap as follows:

1. Wipe area clean before installing the pressure control cap.
2. Push down on pressure control cap while turning clockwise.

4.5 ENGINE COOLING FAN

The engine cooling fan can be mounted at the front of the engine and is belt driven from the crankshaft pulley. See Figure 4-41.

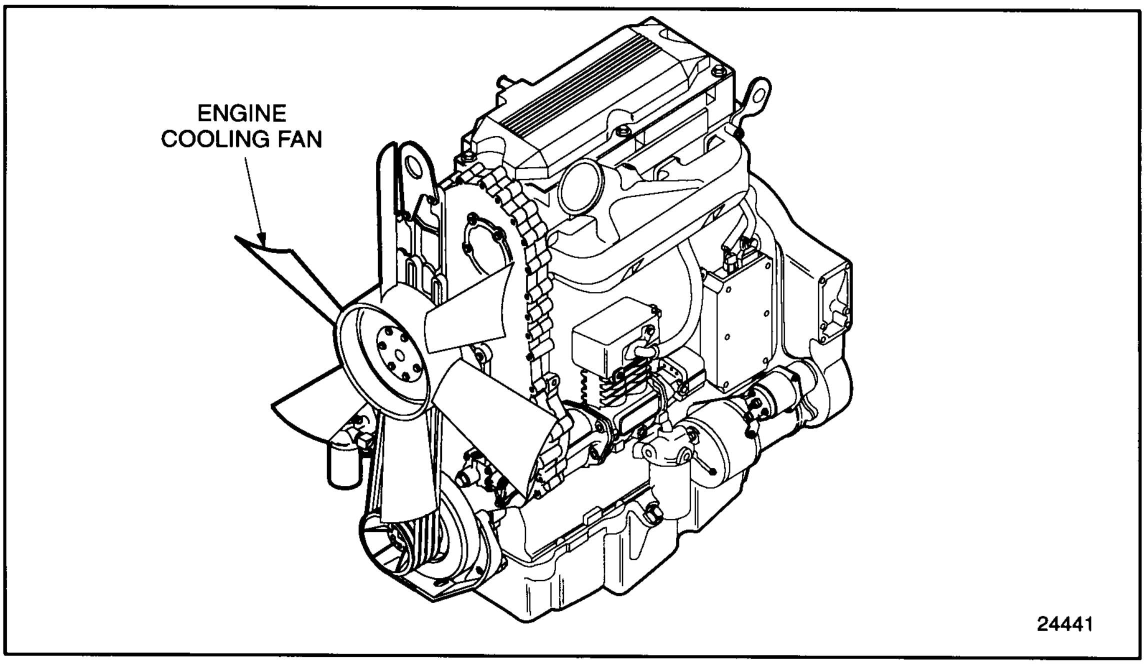
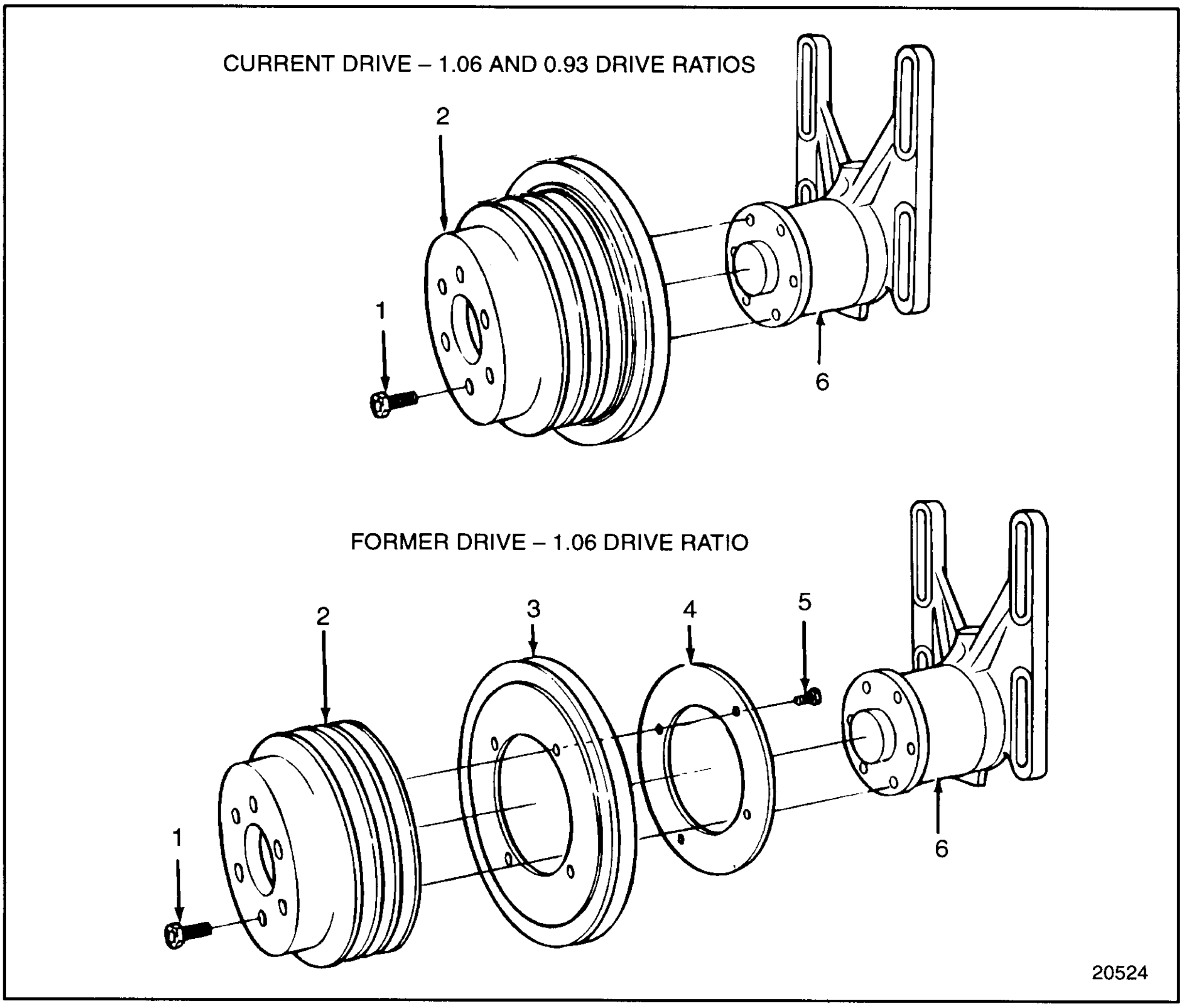


Figure 4-41 Engine Cooling Fan Location

On most applications, the fan is thermostatically controlled. 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. No adjustment of the thermostatic control is necessary.

The three-groove pulley hub uses a matched set of three drive belts. On some units equipped with an air conditioning compressor, an additional pulley and retaining plate are attached to the three-groove pulley. See Figure 4-42.

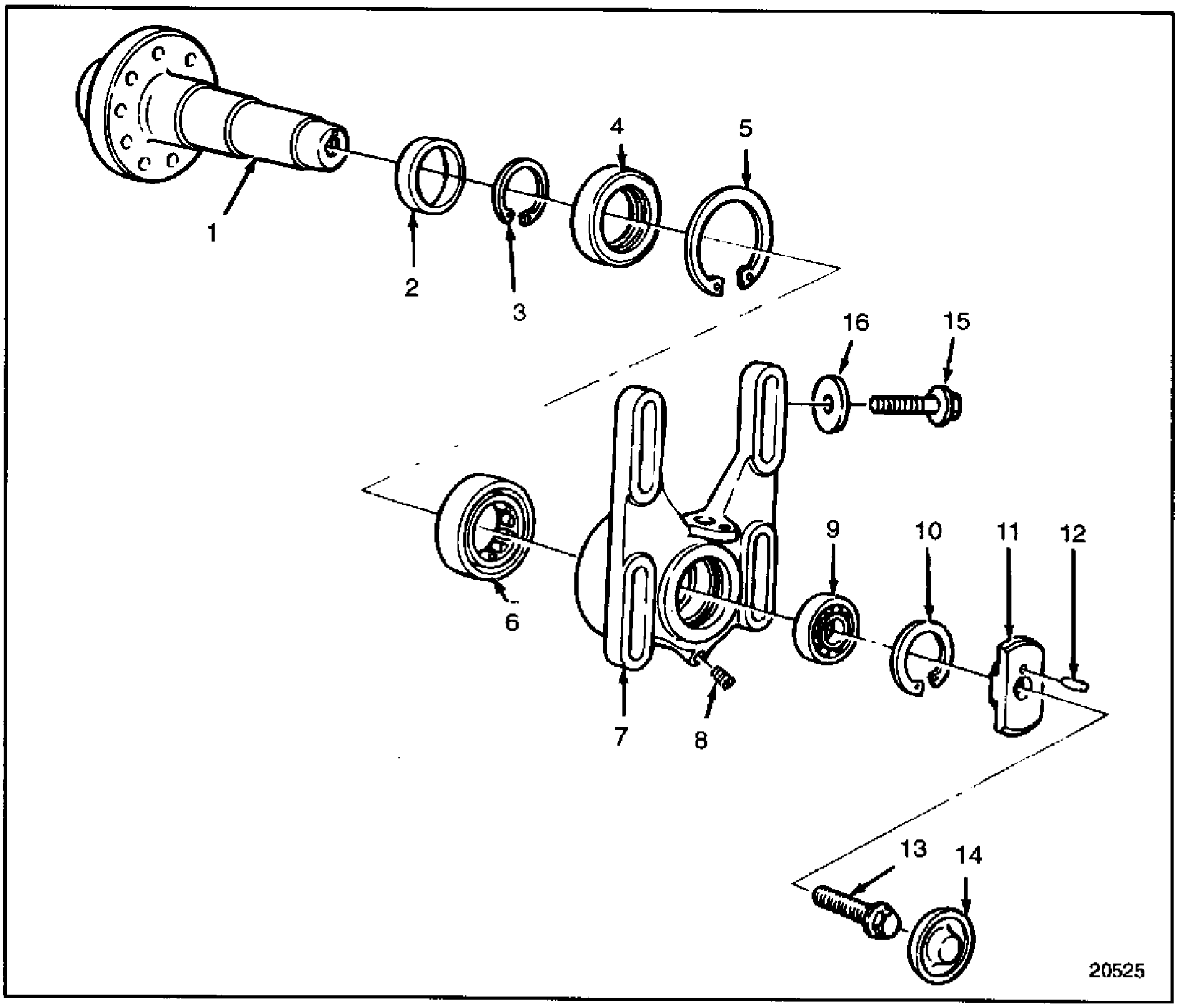


1. Bolt, Fan Retaining (6)
2. Fan Pulley
3. Drive Pulley, Air Conditioning Compressor
4. Retaining Plate
5. Bolt, Air Conditioning Retaining
6. Fan Hub Assembly

Figure 4-42 Air Conditioning Compressor Drive Pulley and Related Parts

Whenever it is necessary to replace one of the crankshaft pulley-to-fan hub drive belts, all three belts must be replaced as a matched set. Refer to Section 13.5.7 for belt adjustment or replacement information.

The fan hub is supported by a front roller bearing and a rear ball bearing. Internal snap rings are used to retain the bearings in the housing and on the shaft. A single lip grease seal is mounted in the fan hub housing. A hub cap seals the bearing cavity at the rear of the housing. See Figure 4-43.



1. Drive Shaft, Fan
2. Race, Front Bearing Inner
3. Snap Ring, Inner Race Retaining
4. Grease Seal
5. Snap Ring, Front Bearing Retaining
6. Bearing, Front Roller
7. Housing, Fan Hub
8. Pipe Plug
9. Ball Bearing, Rear
10. Snap Ring, Rear Bearing Retaining
11. Spacer
12. Pin
13. Bolt, Spacer-to-drive
14. Hub Cap
15. Bolt, Fan Hub Mounting (4)
16. Hardened Washer (4)

Figure 4-43 Fan Hub and Related Parts

The fan hub utilizes four elongated mounting holes and a single threaded rod for adjustment. The fan hub is mounted to the fan support bracket with four bolts. See Figure 4-44.

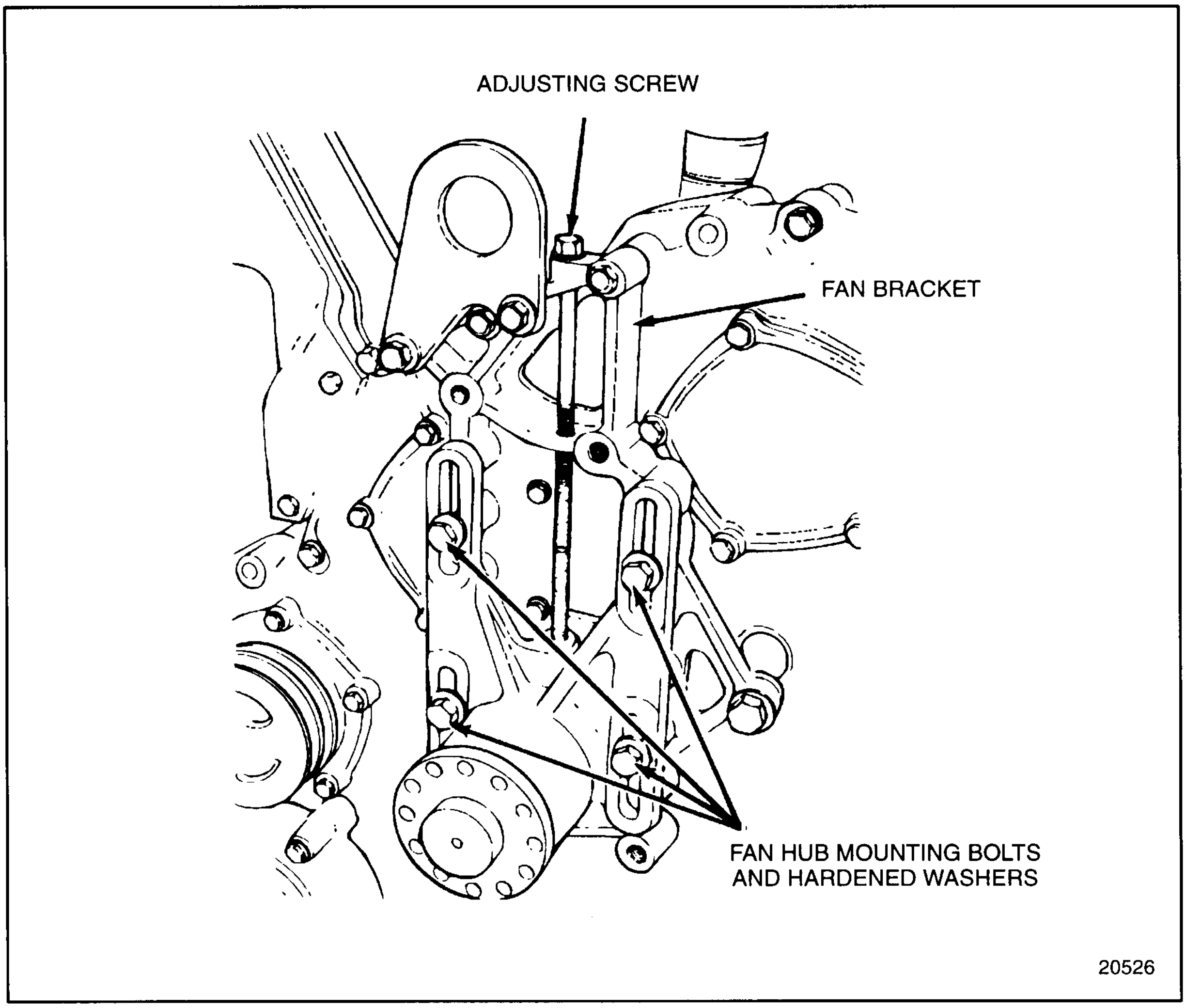


Figure 4-44 Fan Hub Mounting

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to Section 13.5.23for the maintenance schedule.

4.5.1 Repair and Replacement of Engine Cooling Fan

To determine if repair is possible or replacement of the engine cooling fan is necessary preform the following procedure. See Figure 4-45.

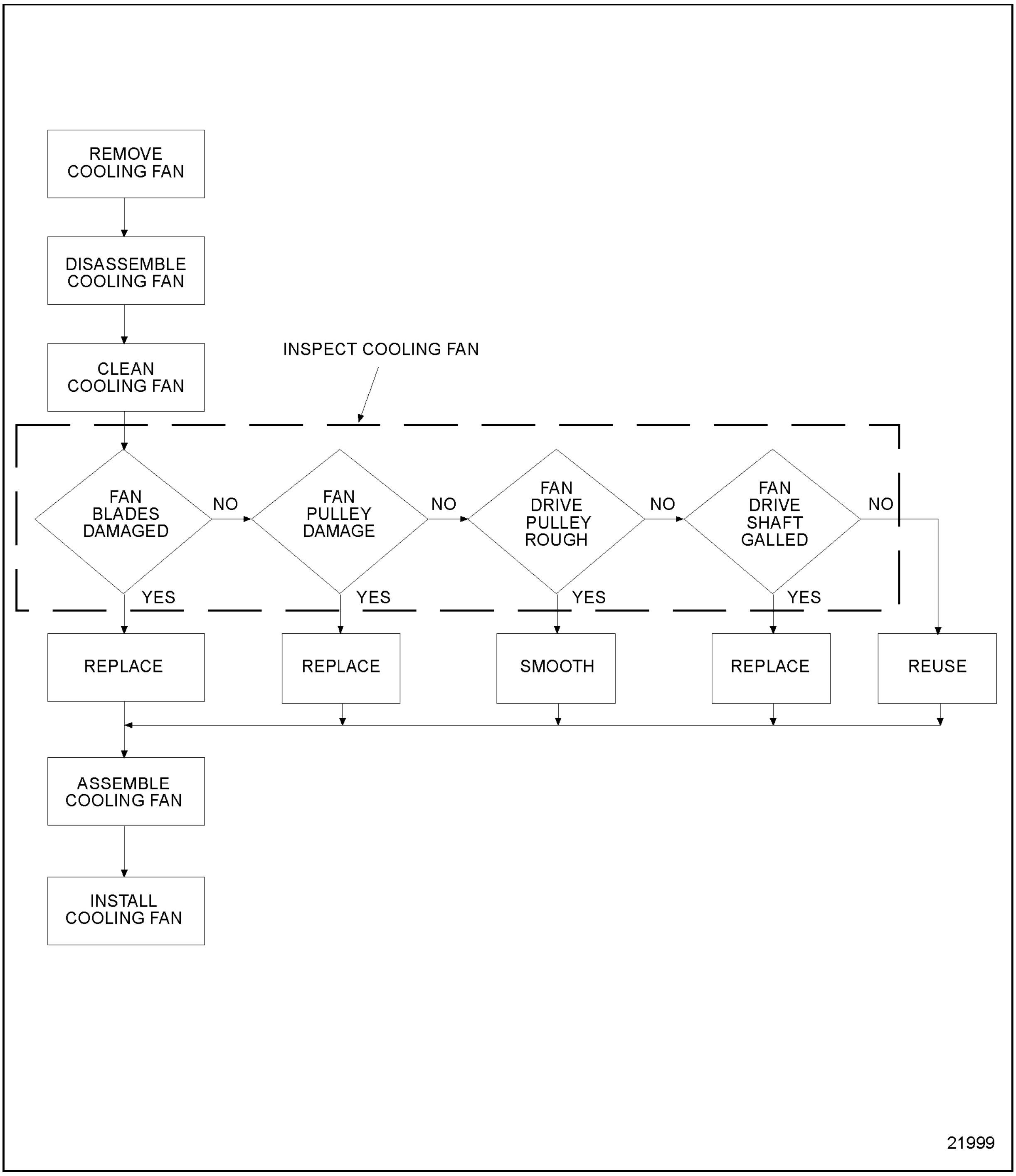


Figure 4-45 Flowchart for Repair or Replacement of Engine Cooling Fan

4.5.2 Cleaning and Removal of Engine Cooling Fan

Remove the engine cooling fan as follows:

NOTICE:
Before removing the fan, check the blades for alignment or damage. Do not rotate the fan by pulling on the fan blades. Engine damage and radiator damage could result.

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Cracked, deformed or otherwise damaged fan blades may reduce the efficiency of the cooling system, throw the fan out of balance, or damage the radiator cores.

1. If equipped with air conditioning, loosen the air conditioning compressor mounting bolts. Remove the compressor drive belt.
2. Loosen the four fan hub-mounting bolts. See Figure 4-44.
3. Turn the adjusting rod counterclockwise enough to allow slack in the drive belts.
4. Remove the fan attaching bolts and remove the fan, fan drive belts and fan pulley.
5. Remove the adjusting rod from the housing by unscrewing it.
6. Remove the four fan hub-mounting bolts. Remove the fan hub assembly.

4.5.3 Disassembly of Engine Cooling Fan

Disassemble the engine cooling fan as follows:

1. Remove the hub cap at the rear of the housing by piercing the cap with a punch and prying the cap out of the housing.

NOTICE:
If a vise is used to secure the fan hub, use wood or leather between hub and vise. Exercise extreme caution to prevent damage to the fan hub.

2. Secure the fan hub in a vise. Loosen and remove the bolt, securing the spacer to the shaft.
3. Remove the spacer.
4. Place the housing, fan mounting surface down, on a press bed on wood blocks high enough to allow the shaft to be removed. Press the shaft to remove it from the housing.

CAUTION:
To avoid injury, wear a face shield or goggles.

5. Remove the roller bearing inner race snap ring from the shaft using snap ring pliers.

6. Remove the roller bearing inner race using a two-jaw puller.

NOTE:
Any time the shaft is removed from the housing, the ball bearing assembly (rear bearing) must be replaced. Any time the roller bearing inner race is removed from the shaft or the roller bearing assembly is removed from the housing, the roller bearing assembly must be replaced.

7. Remove the grease seal from the housing and discard the seal.
8. Remove the bearings from the housing as follows:
   [a] Remove the rear ball bearing snap ring using snap ring pliers.
   [b] Support the housing, fan side up, on two wood blocks spaced far enough apart to permit removal of the rear bearing from the housing.
   [c] Remove the bearing from the housing by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.
   [d] Reverse the housing on the wood blocks. Remove the front bearing snap ring using snap ring pliers.
   [e] Remove the front bearing from the hub in the same manner as the rear bearing. Refer to step 8[a] through step 8[d].

4.5.3.1 Inspection of Engine Cooling Fan

Inspect the engine cooling fan as follows:

1. Clean the fan, fan hub and related parts with clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry the fan, fan hub and related parts with compressed air.
3. Check the fan blades for cracks or other damage.
4. Replace the fan if the blades are cracked or deformed.
5. Inspect fan pulley for wear or damage to grooves.
   [a] If fan pulley grooves are damaged or severely worn, replace the pulley.
6. Inspect fan pulley for rust or rough spots.
7. Remove any rust or rough spots in the grooves of the fan pulley.
8. Inspect the fan drive shaft for galling, pitting, scoring or cracks.

9. Replace as necessary. Small imperfections in the bearing contact surfaces may be removed using crocus cloth wet with fuel oil.

4.5.4 Assembly of Engine Cooling Fan

Assemble the engine cooling fan as follows:

1. Install the roller bearing inner race to the fan hub shaft. Support the shaft (fan side down) on a press bed. Use tool, J 36310-4 part of J 36310–A to press the race on the shaft firmly against the shoulder. See Figure 4-43.

NOTE:
The identification number side of the race should be against the tool.

CAUTION:
To avoid injury, wear a face shield or goggles.

2. Using snap ring pliers, install the inner race retaining snap ring on the shaft.

NOTE:
Be sure the snap ring is fully seated in the groove.

3. Using Mobilgrease® HP or equivalent lithium base multipurpose grease, pack the roller bearing.Mobilgrease® is a registered trademark of Mobil Oil Corporation.
4. With the fan drive housing on a press bed (fan side up) install the roller bearing into the housing. Using the stepped side of tool, J 36310-2 part if J 36310–A, press the bearing firmly against the shoulder in the housing.
5. Install the roller bearing retaining snap ring.

NOTE:
Be sure the snap ring is fully seated in the groove in the housing.

NOTICE:
Care must be taken to only apply enough pressure to seat the seal against the snap ring. Excess pressure will deform the seal case.

6. Using the opposite (smooth side) of tool J 36310-2, part of tool set J 36310-A, press the oil seal into the housing against the snap ring.
7. Using Mobilgrease® HP or equivalent lithium base multipurpose grease, pack the ball bearing.
8. Using the wider end of tool J 36310-1, part of tool set J 36310-A, to press on the outer race of the bearing, turn the fan hub housing over (fan side down) on the press bed and install the ball bearing assembly into the housing.

9. Press the bearing firmly against the shoulder in the housing.
10. Install the ball bearing retaining snap ring in the housing.

NOTE:
Be sure the snap ring is fully seated in the groove.

11. Pack the housing with Mobilgrease® HP or equivalent lithium base multipurpose grease. Do not overfill the housing.

NOTE:
The housing should be between 1/2 to 2/3 full.

12. Coat the lip of the new oil seal with clean engine oil.
13. With the fan hub shaft (fan side down) supported on a press bed, carefully install the housing over the shaft.
14. Using the narrow end of tool J 36310-1, part of tool set J 36310-A, press the inner race of the ball bearing onto the shaft until it is firmly seated against the shoulder on the shaft.
15. Secure the fan hub shaft in a vice with soft (brass) jaws.
16. Index the locating pin in the shaft with its mating hole in the spacer and install the spacer.
17. Install the spacer retaining bolt and torque to 58-73 N·m (43-54 lb·ft).
18. Coat the edge of the hub cap with a sealant such as Loctite 620 or equivalent.
19. Install the cap into the end of the housing.
20. Using the flat side of tool J 36310-2, part of tool set J 36310–A, press the cap into the housing.

NOTE:
The raised center section of the cap should be flush with the surface of the housing.

4.5.5 Installation of the Engine Cooling Fan

Install the engine cooling fan as follows:

1. Install the fan hub assembly to the support bracket using the four bolts and hardened washers. Do not tighten the bolts.
2. Install the adjusting rod in the housing.
3. If removed, install the air conditioning compressor drive pulley and retaining plate to the fan drive pulley. Torque the retaining bolts to 30-38 N·m (22-28 lb·ft).
4. Install the fan drive pulley on the fan hub assembly.
5. Install the fan to the fan drive pulley. Align the holes in the fan, drive pulley and drive shaft.
6. Install the attaching bolts through the fan and pulley and thread them into the tapped holes in the fan hub. Torque the bolts in a crisscross pattern to 47-53 N·m (35-39 lb·ft).

7. Install the drive belts to the fan pulley and crankshaft pulley.
8. Adjust the drive belts to provide the proper tension. Refer to Section 13.5.7.
9. Torque the fan hub-mounting bolts to 102-126 N·m (75-93 lb·ft).

4.6 COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a replaceable spin-on type element. See Figure 4-46. The factory installed coolant filter is mounted on the gear case cover.

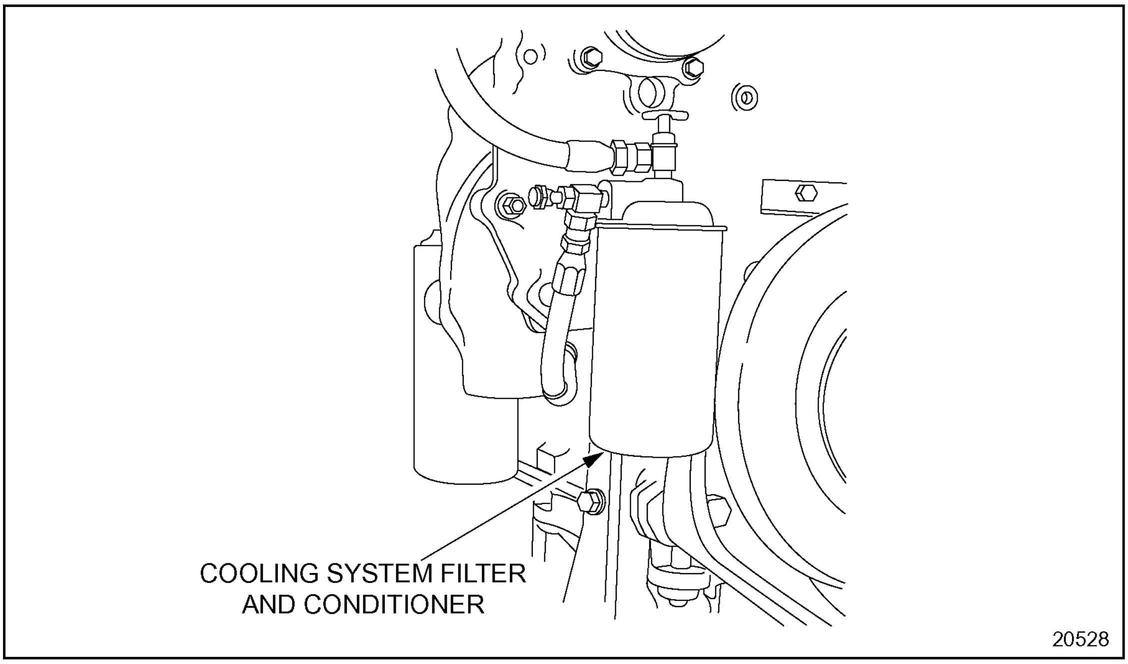


Figure 4-46 Coolant Filter

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system. Refer to Section 5.4.3.

4.6.1 Repair or Replacement of Coolant Filter and Conditioner

Replace filters at recommended scheduled maintenance intervals. Refer to Section 13.5.12.

4.6.2 Installation of Coolant Filter and Conditioner

Refer to Section 13.5.12 for coolant filter and conditioner replacement procedure.

4.7 RADIATOR

The radiator is an OEM supplied component. Follow OEM guidelines.

4.7.1 Repair or Replacement of Radiator

Perform the following steps to reverse flush the radiator:

1. Remove scale in cooling system by using a descaling solvent. Follow manufacturer's instructions.
2. Neutralize the system with a neutralizing agent. Follow manufacturer's instructions.
3. Drain the cooling system. Refer to Section 13.5.4.
4. Remove the radiator inlet and outlet hoses.
5. Remove the water pump inlet and outlet hoses.
6. Attach a hose to the top of the radiator to lead water away from the engine.
7. Attach a hose at the bottom of the radiator and insert a flushing gun in the hose.
8. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.

NOTICE:
Apply air gradually. Do not exert more than 138 kPa (20 lb/in.^{2}) air pressure. Too great a pressure may rupture a radiator tube.

9. Turn on the water and when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between blasts.
10. Continue flushing until only clean water is expelled from the radiator.
11. Remove flushing gun and hoses from radiator.
12. Attach the water pump inlet and outlet hoses.
13. Attach the radiator inlet and outlet hoses.
14. Fill cooling system. Refer to Section 13.5.4.
15. Refer to Section 11.3.5 for verification of proper radiator installation.

4.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 8 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 4-1. Standard (nonmetric) nut and bolt torque specifications are listed in Table 7 in the "General Information" section at the beginning of this manual.

EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS

Bolt and Size, mm	Torque, N·m	Torque, lb·ft
M24 X 1.0	203-230	150-170

Table 4-1 Exceptions - Metric Fastener Torque Specifications

NOTE:
The water pump drive gear retaining nut is M24 X 1.0.

5 FUEL, LUBRICATING OIL, AND COOLANT

Section **Page**

5.1 FUEL

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. The Series 50 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 ASTM D 975 specification, however, does not in itself adequately define the fuel characteristics necessary to assure fuel quality. The properties listed in Table 5-1, Diesel Fuel Specification table, provide optimum engine performance.

General Fuel Classification	ASTM Test	No. 1-D	No. 2-D#
API Gravity, @ 60° F*	D 287	40 - 44	34 - 38
Specific Gravity, @ 60°F*	D 1298	0.806 - 0.825	0.835 - 0.855
Flash Point,°C, Minimum	D 93	38	52
Viscosity, Kinematic - cSt @ 40°C	D 445	1.3 - 2.4	1.9 - 4.1
Sulfur wt% Maximum for On-Road Use ‡	D 2622	0.05	0.05
Cloud Point °F (°C) †	D 2500	See Note	See Note
Cetane No., Minimum †	D 613	45	45
Cetane Index, Minimum †	D 4737	40	40
Distillation % Vol. Recovery, °C (°F)	D86	-	-
- IBP, Typical*	-	350 (177)	375 (191)
- 10% Typical*	-	385 (196)	430 (221)
- 50% Typical*	-	425 (218)	510 (256)
- 90% Maximum	-	500 (260)	625 (329)
- 95% Maximum*	-	550 (288)	671 (355)
- Recovery Volume, % Minimum*	-	98	98
Water & Sediment, % Maximum	D 2709	0.05	0.05
Ash, % Maximum	D 482	0.01	0.01
Carbon Residue on 10%, wt%, Maximum	D 524	0.15	0.35
Copper Corrosion, Maximum 3h	D 130	No. 3	No. 3
Accelerated Storage Stability, Maximum*	D 2274	15 mg/L	15 mg/L

General Fuel Classification	ASTM Test	No. 1-D	No. 2-D#
Dupont Pad Test, Rating Maximum*	TM-F21-61 ||	7	7
Lubricity, gm, Minimum*	SLWT §	2800	2800

* Not specified in ASTM D 975

† Differs from ASTM D 975

‡ The sulfur content of diesel fuel for off road use is 0.5% maximum. This fuel is dyed red.

§ Scuffing load, ball on cylinder wear test, higher values indicate less wear and greater lubricity.

|| Alternate test method predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

#No. 2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

Note: The cloud point should be 10 °F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

Table 5-1 Diesel Fuel Specification

5.1.1 Fuel Lubricity

Fuels such as those containing kerosene and jet fuel and some low sulfur fuels have characteristics which may cause operational concerns in some engine designs. The unit fuel injection system used on all Detroit Diesel - manufactured engines has demonstrated trouble-free operation on a wide variety of fuels without the need for supplemental additives.

5.1.2 Biodiesel Fuels

Biodiesel fuels may be produced from a wide variety of sources and may be used in all DDC engines provided (1) they are derived from soy methyl ester (SME) and/or rape methyl ester (RME) and (2) are blended to a maximum of 20% by volume in diesel fuel. The resulting blend must meet the properties. listed in Table 5-1.

Although such blends purport to reduce exhaust emission particulates, they increase the nitrogen oxides in engine exhaust. They also tend to have poorer thermal stability and may deteriorate engine oil TBN more rapidly than wholly petroleum-based diesel fuels. These fuel blends have not been fully evaluated relative to diesel fuel system durability or engine oil effects.

5.1.3 Other Fuels

In addition to the diesel fuels listed in Table 5-1, customers have used other fuels successfully, including fuels marketed as premium diesel fuels, kerosene-based jet fuels, and other fuels listed in Table 5-2. These fuels have provided economic and availability advantages for some applications, particularly where 1-D type fuels are required, and may be used in all Detroit Diesel engines. These fuels should be accompanied by exhaust emission data demonstrating emission equivalency to 1-D for those engines requiring 1-D fuel. Fuel type specifications and applications are listed in Table 5-3.

Property	Jet A/A-1 D 1655	JP-5	JP-8	CONUS DF-1	CONUS DF-2	OCONUS DF-2
API Gravity, @ 605F	44.3	41.1	45.6	42.3	34.2	38.5
Flash Point, 5C	38	62	45	50	74	70
Viscosity, Kin., cSt @ 405C	-	1.5	1.2	1.6	2.8	3.0
Cloud Point 5C	- 40	- 46	- 47	- 41	- 12	- 19
Sulfur, % mass	0.3 Max.	0.4 Max.	0.4 Max.	0.05 Max.	0.05 Max.	0.3 Max.
Cetane Number	-	42	45	44	47	49
Distillation % Vol. Recovery, 5C	-	-	-	-	-	-
IBP	-	180	157	174	190	176
10% Typical	205	191	175	196	222	219
50% Typical	Report	215	200	219	265	365
90% Max.	Report	242	236	246	313	311
Final Boiling Point, Max. Temp.	300	-	-	-	-	-
Heat Content, Btu/gal., Net	123,608	125,270	123,069	125,960	131,207	127,820

Table 5-2 Selected Typical Fuel Properties

Type	NATO Spec.	Mil Spec.	Application
JP-4	F-40	Mil-T-5624	Jet Fuel, Contains 50% Gasoline, *Not Recommended*
JP-5	F-44	Mil-T-5624	Jet Fuel, Kerosene Based
JP-8	F-34	Mil-T83133	Jet A-1 with De-icer and Corrosion Inhibitor
Jet A	None	None	Industry Standard Jet Fuel
Jet A-1	F-35	None	Jet Fuel, ASTM D 1655
DF-1/DF-2	F-54	VVF-800 CONUS	Specified Military Use Inside Continental U.S.
DF-2	F-54	VVF-800 OCONUS	Specified Military Use Outside Continental U.S.

Table 5-3 Fuel Type Specifications and Applications

Lower density fuels, such as those listed in Table 5-2 and "winter blended" diesel fuels, have a lower volumetric heat content than the standard 2-D fuel listed in Table 5-2, "Diesel Fuel Specifications table." Operating with these fuels will result in reduced engine output and reduced fuel mileage, compared to standard 2-D fuel. Reductions of 5% are not unusual and may be as high as 10%. A good rule of thumb is this: The engine power is proportional to the heating value of the fuel. Lower density fuels also tend to have lower viscosity and poor lubrication characteristics.

5.1.4 Fuel Cleanliness

Fuel 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:

NOTICE:

Do not use a fuel storage tank or lines made from galvanized steel. The fuel 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.

- ☐ Keep the storage tank filler cap covered to prevent contamination by rain water.
- ☐ Keep the tank clean, especially around the filler cap and tap areas.
- ☐ Position the tank so that it tilts slightly toward the bottom drain. This will make it easier to drain accumulated water and sediment.
- ☐ Minimize condensation by keeping the tank reasonably filled at all times.
- ☐ After filling the fuel storage tank, wait a few hours before filling equipment tanks. This will allow contaminants to settle.

5.1.5 Cold Weather Operation

In cold weather, diesel fuel will form wax crystals that can restrict flow and clog filters. Fuel 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.

5.1.6 Prohibited Fuel Additives

Used Lubricating Oil: Detroit Diesel specifically prohibits the use of drained lubricating oil in diesel fuel. Used lubricating oil contains combustion acids and particulate materials which erode injector components, resulting in loss of power and increased exhaust emissions. In addition, the use of drained lubricating oil will increase maintenance requirements due to filter plugging and combustion deposits. Refer to the Section on "Waste Oil Disposal and Rerefined Oils" for recommendations on proper used oil disposal.

Gasoline: The addition of gasoline to diesel fuel will create a serious fire hazard. The presence of gasoline in diesel fuel will reduce fuel cetane number and increase combustion temperatures. Tanks which contain such mixtures should be drained and cleaned as soon as possible.

Detroit Diesel Corporation will not be responsible for any detrimental effects which it determines resulted from the use of used lubricating oil or gasoline in the diesel fuel.

5.1.7 Waste Oil Disposal and Rerefined Oils

With over one billion gallons of waste oil generated annually in the U.S. alone, disposal of waste oil has become a serious environmental concern. Rerefining waste oils provides an environmentally viable way of handling this material. Detroit Diesel favors the recycling of waste oil and permits the use of rerefined oils in all engine product lines, provided the rerefined oil meets the SAE Viscosity and API specifications previously mentioned.

CAUTION:

To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

Consideration for the disposal of waste oil should begin when negotiating the purchase of new oil. Oil supplier selection criteria should include a proposal for handling waste oil. It is important to know exactly how the oil will be disposed of since it is the generator, not the hauler, that is ultimately responsible for its proper disposal.

5.1.8 Specifications for Natural Gas Engine

Listed in Table 5-4 are the natural gas specifications for Detroit Diesel engines.

Property	Limit	ASTM Test Method
Hydrocarbon Methane Ethane Propane C4 and Higher	mole percent 88% Minimum 6% max. 1.7% max. 0.3% max.	D 1945
Other Gaseous Species Hydrogen Carbon dioxide + Nitrogen + Oxygen Oxygen Carbon Monoxide **Other Species** Methanol Sulfur, Total	mole percent 0.1% max. 5.0% max. 0.5% max. 0.1% max. 0% mass max. 1.0 grains / 100 SCF, max. (32 ppm mass, max., ‖)	D 2650 D1945 D-1945 D 2650 No Test Method ASTM D 5504
Performance Related Properties Motor Octane Number Wobbe Number	115 Minimum 1290-1380 BTU/SCF	*D 2623 D 3588
Contaminates	†	
Pressure Water Dew Point Temperature, max.	‡	D 1142
Pressure Hydrocarbon Dew Point Temperature, max.	‡ Below which will form 1% condensate	D 1142
Odorant	§	

*Test Method D 2623 was obsoleted by ASTM in 1991. Wobbe Index (WI), also known as Wobbe Number, is a measure of fuel energy flow rate through a fixed orifice under given inlet conditions. Numerically, WI= (dry, higher heating value)/(Specific gravity).

† The compressed natural gas shall not contain dust, sand, dirt, gums, oils, or other substances in an amount sufficient to be injurious to the fuel station equipment or the vehicle being fueled.

‡ The water and hydrocarbon dew point at fuel pressure shall be at least 10°F below the 99.0% winter design temperature listed in Chapter 24, Table 1, Climatic Conditions for the United States, in *American Society of Heating, Refrigerating and Air Conditioning Engineer's (ASHRAE) Handbook,* 1989 fundamentals volume. Testing for water and hydrocarbon vapor shall be in accordance with ASTM D 1142, utilizing the Bureau of Mines apparatus.

§ The natural gas at ambient conditions must have a distinctive odor potent enough for its presence to be detected down to a concentration in air of 1% by volume. ‖ When using fuel containing sulfur in excess of 16 ppm, the oil change interval must be reduced. Refer to Item 1 in the Lubrication and Preventive Maintenance Intervals Section s.

Table 5-4 Natural Gas Specifications for Detroit Diesel Natural Gas Engines

5.2 LUBRICATING OIL

The selection of the proper lubricating oil is important for achieving the long and trouble-free service Detroit Diesel Series 50 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.

5.2.1 Lubricant Requirement

Lubricants meeting the API criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules. See Figure 5-1.

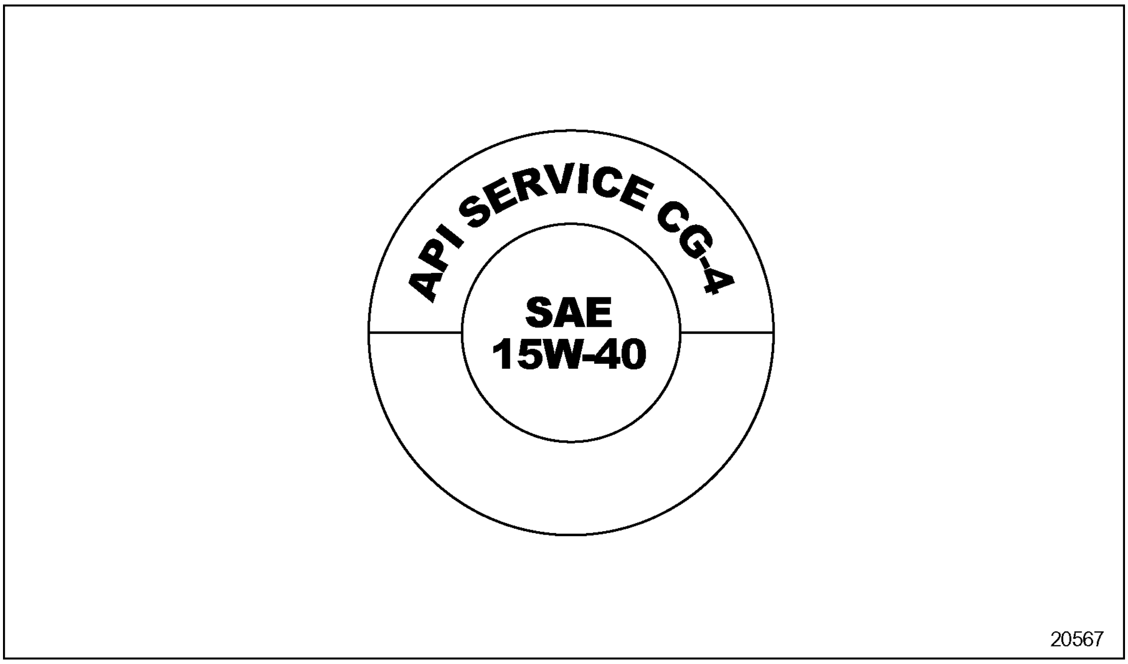


Figure 5-1 API Symbol

Lubricants meeting these criteria have provided maximum engine life when used in conjunction with specified oil drain and filter maintenance schedules. *Only oils licensed by API may used in Detroit Diesel engines.* Lubricants meeting API Service category CG-4 are intended for use primarily with low (0.05%) sulfur fuel and may be used in all Detroit Diesel Series 40, 50,55, and 60 engines.

API CF-4 oils may be used when CG-4 oils are not available; however, their use may require a reduction in oil drain interval depending upon the application and the fuel sulfur level.

At ambient temperatures below -20°C (-4°F) when sufficient starter speed cannot be achieved with SAE 15W-40 oils, the use of 5W-XX and 10W-XX oils, where XX is 30 or 40, may be used to improve startability provided they are API CG-4 and have demonstrated field performance in DDC engines. These oils must possess a HT/HS of 3.7 minimum. Monograde oils should not be used in these engines regardless of API Service Classification unless reviewed and approved by Detroit Diesel.

When the use of high sulfur fuel (greater than 0.5% mass sulfur) is unavoidable, higher alkalinity lubricants are recommended. High sulfur fuels require modification to oil drain intervals. For further information refer to the section titled "The Use of High Sulfur Fuels."

5.2.2 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 maximum interval the engine may operate before changing oil is listed in Table 5-5. Oil analysis may be used to determine whether this interval should be shorter, but should not be used to lengthen the interval.

Application	Oil Drain Schedule
Highway Truck and Motor Coach	15,000 miles (24,000 km)
City Transit Coach, Pick-up and Delivery, Stop-and-Go, Short Trip	6,000 Miles (9,600 Km) or 3 months*
Fire Truck Crash/Rescue or Emergency Vehicle	6,000 Miles (9,600 Km) 300 hours or 1 year*
Industrial and Agricultural	250 hours or 1 year*
Stationary Electrical Gen Sets, Continuous	250 hours or 3 months*
Stationary Electrical Gen Sets, Standby	150 hours or 1 year*

*Whichever comes first.

Table 5-5 Maximum Oil Drain Intervals (Fuel Sulfur Content Less than 0.5%)

NOTE:
The use of fuels with sulfur content above 0.5% will require a shorter drain interval, and/or the use of a higher TBN oil. Refer to DDC Publication 7SE270, *Lubricating Oil, Fuel, and Filter Recommendations*, for details.

Extending Oil Drain Intervals: Some oil companies may promote engine lubricants with a claimed useful life that would allow customers following certain maintenance and operating parameters to elect to extend oil drain intervals beyond the recommended periods. The ability of such lubricants to maintain their protective qualities over a longer period and the acceptability of maintenance and operating parameters must be established by the oil company and the customer. Claims for engine failure attributable to the inadequacy of the lubricant are not covered under the terms of the engine's limited warranty.

5.2.3 Statement of Policy on Supplemental Fuel and Lubricant Additives

The Series 50 engine will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets.

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. The regular and continued use of supplementary additives in fuels and lubricants is not recommended.

NOTE:
DDC is not responsible for the cost of maintenance or repairs due to lack of required maintenance services performance or the failure to use fuel, oil, lubricants and coolant meeting DDC-recommended specifications. Performance of required maintenance and use of proper fuel, oil, lubricants and coolant are the responsibility of the owner. See the OEM's guidelines for details.

5.2.4 Filter Selection and Change Intervals for Series 50

The engine oil and fuel filters recommended for use on the Series 50 engine are as follows:

- ☐ Engine Oil Filter
  - ☐ Full Flow - DDC Part No. 23527033
- ☐ Fuel Filters, Spin-on:
  - ☐ Primary- DDC Part No. 23518481
  - ☐ Primary w/Separator - DDC Part No. 23512317
  - ☐ Primary w/Separator - DDC Part No. 23514654*
  - ☐ Secondary- DDC Part No. 23518482
- ☐ Fuel Filters, Fuel Pro ® :
  - ☐ Fuel Pro 321 - DDC Part No. 23518481
  - ☐ Fuel Pro 380 - DDC Part No. 23514049

*Requires installation of reusable plastic bowl.

Fuel Pro ® is a registered trademark of Davco Manufacturing, L.L.C.

The change interval for oil and fuel filters is listed in Table 5-6.

Application	Replacement Intervals (Fuel Sulfur Content Less Than 0.5 wt.%)
Highway Truck and Motor Coach	15,000 miles (24,000 km)
Industrial and Agricultural	250 hours or 1 year*
City Transit Coach, Pick-up and Delivery, Stop-and-Go, Short Trip	6,000 miles (9,600 Km) or 3 months*
Fire Fighting, Crash/Rescue, and Emergency Vehicle	6,000 miles (9,600 Km), 300 hours or 1 year*
Stationary Electrical Generator Sets, Continuous	250 hours or 3 months*
Stationary Electrical Generator Sets, Standby	150 hours or 1 year*

*Whichever comes first.

Table 5-6 Maximum Lubricating Oil and Fuel Filter Replacement Schedule

NOTE:
The spin-on fuel filter replacement intervals listed in Table 5-5 do not apply to Fuel Pro filter elements, which must be replaced when the fuel level in the see-through cover reaches the top of the element or after 1 year of service, whichever comes first.

5.2.5 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 source(s) of leaks, if the values listed in Table 5-7 are realized. Contact your DDC distributor or dealer regarding oil analysis services.

Warning Limits	ASTM Designation	Condition Measured	Series 50 Limit
Viscosity at 40 °C cS Maximum Increase-% Maximum Decrease-%	D-445	Engine & Oil	 40.0 15.0
Carbon (Soot) Content, Maximum - Mass %	E-1131 or LEM^{SM}	Engine Combustion	1.5
Pentane Insolubles - Mass %	D-893	Engine Combustion	1.0
Total Base Number (TBN) Minimum	D–4739 D–2896	Oil Oil	1.0 2.0
Water Content (Dilution), Maximum - Vol. %	D–1744	Engine	0.30
Fuel Vol., % Maximum	D–3524	Engine	2.5
Antifreeze Maximum	D–2982	Engine	Neg.
Iron Content, Maximum - ppm (Fe)	D–5185	Engine Wear	150
Copper Content, Maximum - ppm (Cu)	D–5185	Engine Wear	30

*LEM^{SM}is a patented soot measurement process by Analysts, Inc.

NOTE: These limits are intended to be used for guidance when a single oil sample is tested. Actual limits are dependent on engine, application, and oil type. Refer to DDC Publication 7SE398 to determine the warning limits specific to your application.

Table 5-7 Single Sample Used Oil Analysis Warning Limits

5.2.6 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

5.3 LUBRICATING OIL FOR THE SERIES 50G ENGINE

Lubricants formulated for use in natural gas fueled engines must provide adequate engine lubrication, minimal thermal degradation, and good deposit control. No API category currently exists for natural gas engine oils. Therefore, selection of the proper engine oil is limited to the two lubricants listed in Table 5-8. These oils have demonstrated adequate performance in these engines.

Viscosity Grade, SAE	15W40
Sulfated Ash Content, % max.	0.50%
Phosphorous, ppm max.	800 ppm max.

Table 5-8 Series 50G Engine Lubricating Oil Specifications

While Detroit Diesel does not maintain an approved list for these lubricants, other lubricants may be selected by the customer provided the oil supplier can demonstrate equivalent performance with the two oils identified. Detroit Diesel will not determine this equivalency.

5.3.1 Oil Change Intervals for Series 50G Engine

During engine operation, lubricating oil deteriorates due to combustion by-products and contamination. Oil change intervals may vary depending on engine operation, fuel quality, and lubricant quality. The oil drain intervals are listed in Table 5-9 and listed in Table 5-10.

Application	Oil Drain Interval*
City Transit Coach	6,000 miles (9,600 km) or 3 months*
Pick-up and Delivery Stop and Go	6,000 miles (9,600 km) or 3 months*

Table 5-9 Maximum Recommended Oil Drain Intervals (Normal Operation) for Series 50G Engine

Application ‡	Oil Drain Interval*
Standby Set Full Time	250 hours or 12 month* 250 hours or 3 months*
Stand-by † Continuous/Prime †	200 hours or 6 months* 200 hours or 3 months*
Stand-by ‡ Continuous/Prime ‡	150 hours or 3 months* 150 hours or 3 months*

† Fuel with total sulfur greater than 17 ppm, but less than 24 ppm.

‡ Fuel with total sulfur greater than 24 ppm, but less than 32 ppm.

* Whichever comes first.

Table 5-10 Maximum Recommended Oil Drain Intervals for Series 50G Generator Set Engine

5.3.2 Used Lubricating Oil Analysis for the Series 50G Engine

A used lubricating oil analysis, such as Detroit Diesel's "Power Trac," is recommended for monitoring crankcase oil in all engines. The application of used engine oil analysis to natural gas fueled engines can help to identify contamination from excessive wear metals and foreign substances and monitor oil degradation through oxidation. If any abnormal conditions are identified, the oil should be changed immediately. Warning limits are listed in Table 5-11.

Viscosity Increase, % from new, max. (ASTM D 445) Kinematic @ 100_C	**10%**
Total Base Number decrease, max. (ASTD D 4739)	3
Total Acid Number increase, max. (ASTM D 664)	2
Iron Content, ppm	150 max.
Oxidation/Nitration, Infrared Spectroscopy	25 absorbency units

Table 5-11 Used Oil Analysis Warning Limits for Series 50G Engine

5.4 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 circulating in the engine cooling system.
- ☐ IEG - Full strength (non-diluted) Inhibited Ethylene Glycol meeting applicable heavy-duty formulation specifications.
- ☐ IPG -Full strength (non-diluted) Inhibited Propylene Glycol meeting applicable heavy-duty formulation specifications.
- ☐ SCA - Supplemental Coolant Additives. Used to prevent corrosion, cavitation, and the formation of deposits.
- ☐ Initial fill - Any time the cooling system is empty, then filled with new coolant.
- ☐ 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. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IPG at initial fill.
- ☐ Dropout - Sludge or deposit formation in or on cooling system components.

Using a coolant with the appropriate concentrations of SCA 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 Series 50 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 Series 50 engines must meet the following basic requirements:

- ☐ 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.

5.4.1 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 listed in Table 5-12. The procedure for evaluating the quality of water is shown in the next illustration. see Figure 5-2.

Mineral	Limit-ppm	Limit -grains per gallon
Chlorides	40	2.5
Sulfates	100	5.8
Total dissolved solids	340	20
Total Hardness: Magnesium & Calcium	170	10

Table 5-12 Maximum Allowable Limits for Minerals in Water

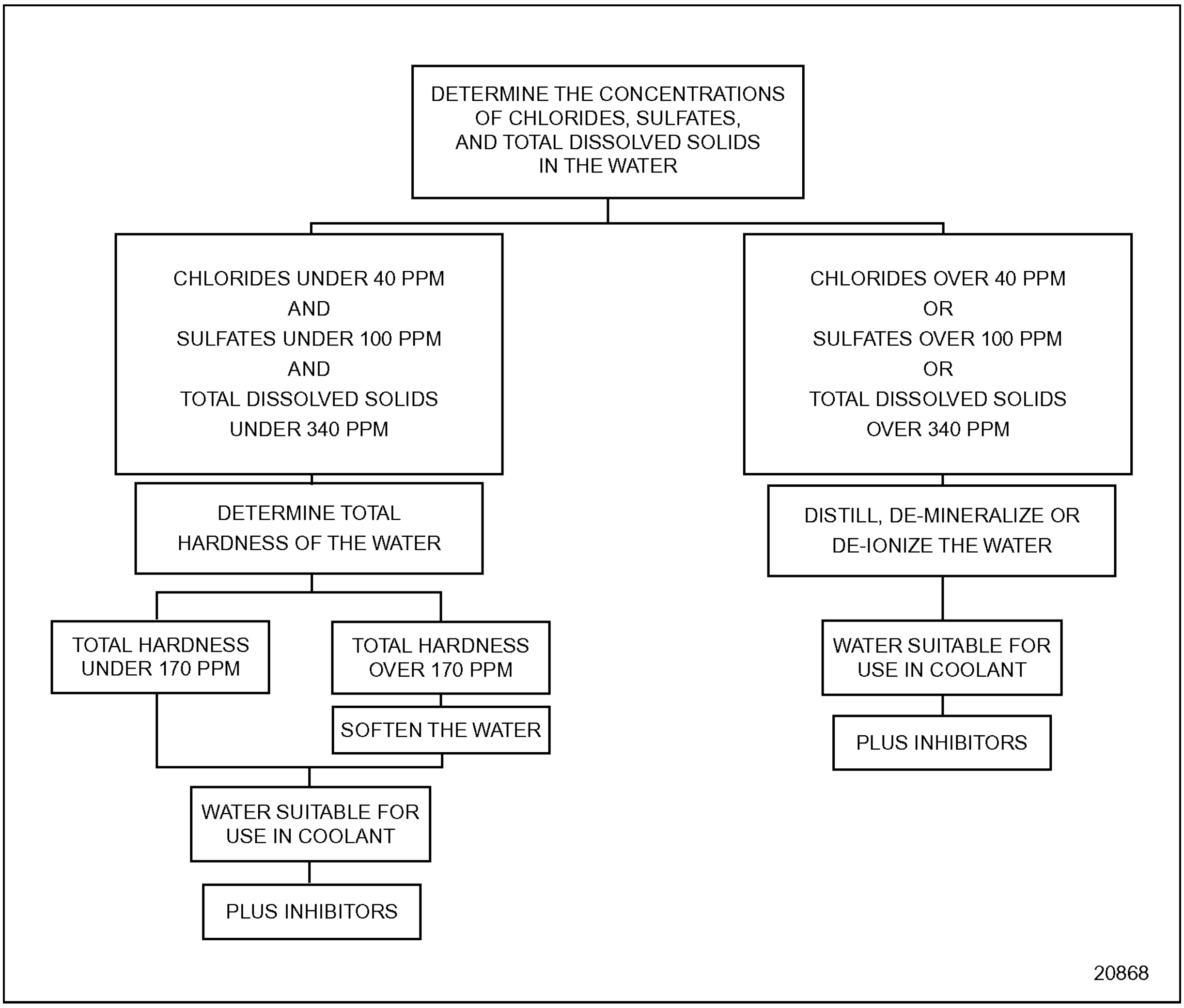


Figure 5-2 Water Evaluation Procedure

5.4.1.1 Antifreeze, Inhibited Ethylene Glycol

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.

5.4.1.2 Antifreeze, Inhibited Propylene Glycol

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 Series 50 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 (see Figure 5-3, see Figure 5-4, and see Figure 5-5).

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 over inhibiting 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 (listed in Table 5-13). Over concentration will result if SCAs 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 Number	Size
23512138	1 gallon
23512139	55 gallons
23512140	bulk

Table 5-13 Powercool ® Fully Formulated/Precharged IEG

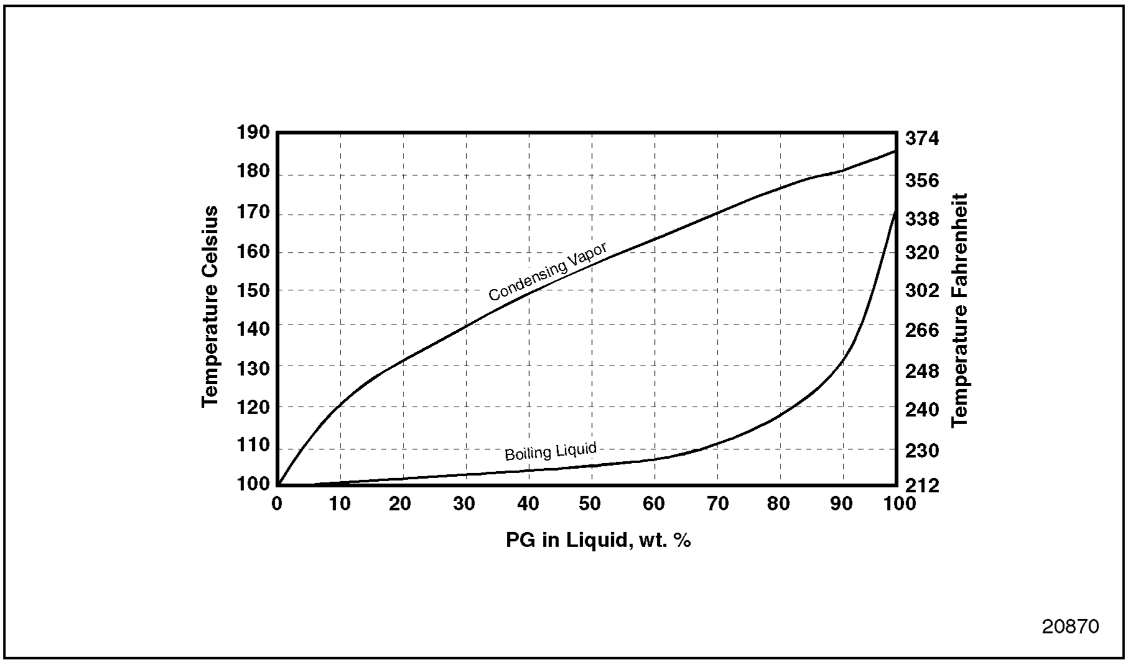


Figure 5-3 IPG Boiling Point

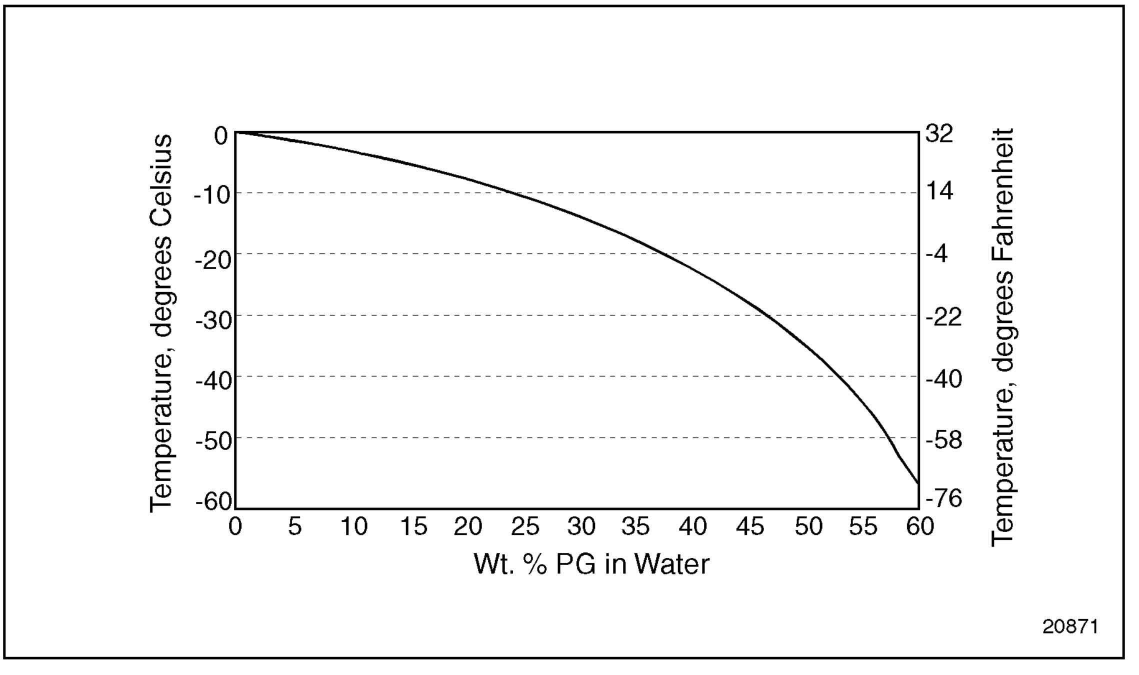


Figure 5-4 IPG Freezing Point

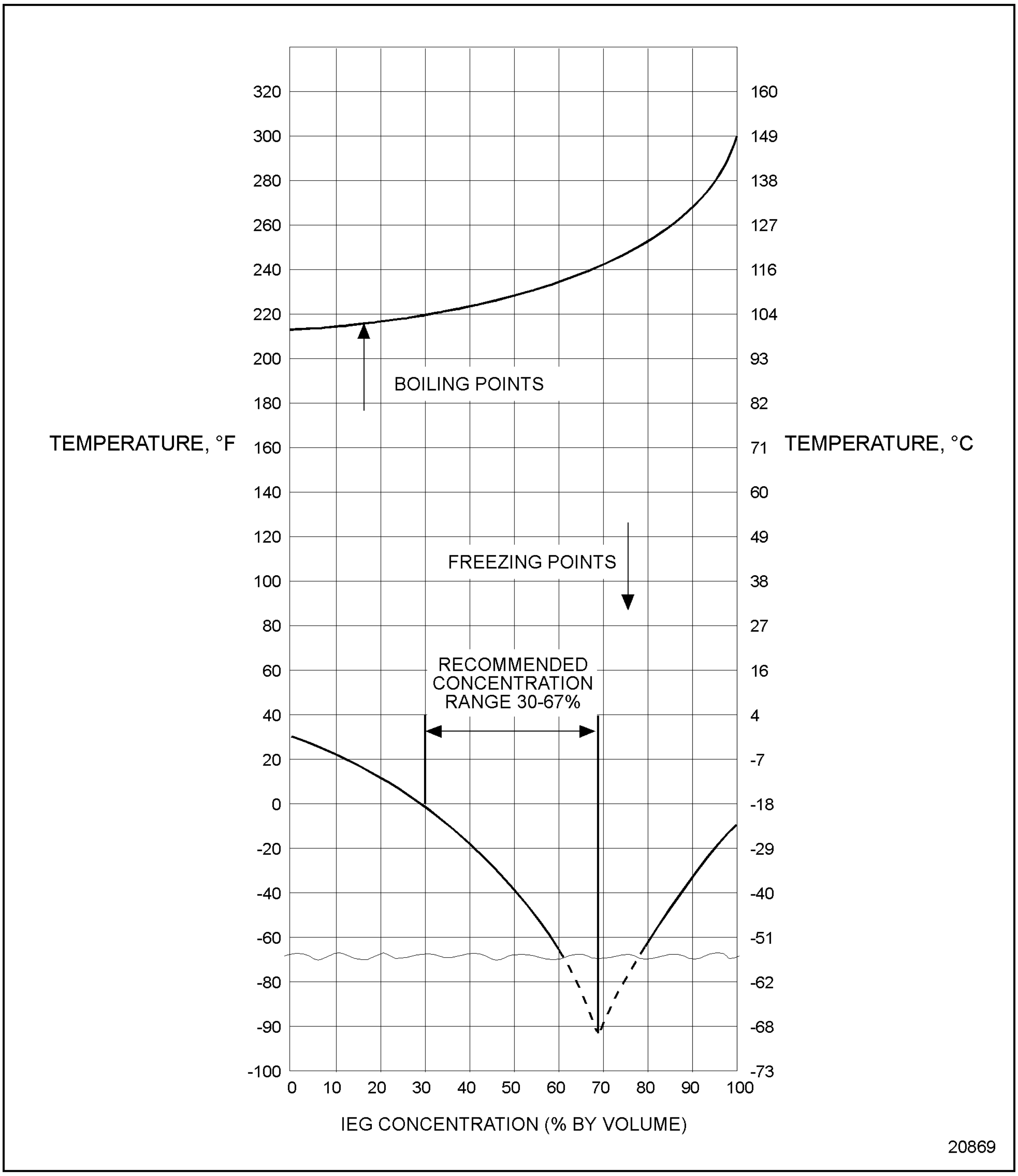


Figure 5-5 Coolant Freezing and Boiling Temperature vs. Inhibited Ethylene Glycol Concentration (Sea Level)

5.4.2 Coolants Not Recommended

Methyl alcohol-based antifreeze should not be used in Detroit Diesel Series 50 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 Series 50 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 Series 50 engines. These coolants generally contain high levels of phosphates, which can deposit on hot internal engine surfaces and reduce heat transfer.

5.4.3 Supplemental Coolant Additive

SCAs provide protection for the cooling system components. The coolant must have the proper concentration of SCAs. Detroit Diesel Maintenance Products are recommended for use in Detroit Diesel Series 50 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 is listed in Table 5-14. Maintenance cooling system fill is listed in Table 5-15, initial coolant inhibitor element size requirements for IPG and IEG plus water coolant mixtures are listed in Table 5-16. Coolant inhibitor element size requirements, initial dosage for water-only systems, are listed in Table 5-17. The proper maintenance dosages are listed in Table 5-18.

Coolant	Coolant Element	Liquid *
Precharged IEG and Water	NONE	NONE
IEG and Water	Select Element listed in Table 5-16.	3% by Volume, or 1 pint per 4 gallons
Water only	Select Element listed in Table 5-17.	6% by Volume, or 1 quart per 4 gallons

* 1 gallon= 3.785 L; 2 pints= 1 quart; 4 quarts= 1 gallon

Table 5-14 Initial Fill SCA Dosage

Coolant Element	Liquid *
Select element listed in Table 5-18.	0.6% by Volume or 1 pint per 20 gallons

* 1 gallon= 3.785 L; 8 pints per gallon

Table 5-15 Maintenance SCA Dosage

Cooling System Capacity, Gallons (L)	Quantity	DDC Part Number	NALCO Part Number
9-12 (34-45)	1	23508426	DDF-3000.12
13-16 (49-61)	1	23507189	DDF-60.16
24-32 (91-121)	1	23508427	DDF3000.32

Table 5-16 Coolant Inhibitor Element Size Requirements-Initial Fill Dosage for IEG or IPG plus Water Coolant Mixtures

Cooling System Capacity Gallons (L)	SCA Element Quantity	Detroit Diesel SCA Element Part Number	Nalco Element Part Number	Additional SCA Liquid Required
5 (19)	1	23508427	DDF-3000.4	None
7 (26)	1	23508426	DDF-3000.12	None
10 (38)	1	23507189	DDF-60.12	None
15 (57)	2	23508426	DDF-3000.12	None
20 (77)	1	23508427	DDF-3000.32	None

Table 5-17 Coolant Inhibitor Element Size Requirements-Initial Dosage for Water-Only System

Cooling System Capacity, Gallons (L)	Quantity	DDC Part Number	NALCO Part Number
9-12 (34-35)	1	23507545	DDF-3000
13-16 (49-61)	1	23507545	DDF-3000
24-32 (91-121)	1	23508425	DDF-3000.8

Table 5-18 Coolant Inhibitor Element Size Requirements-Maintenance 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 listed in Table 5-19. Additional SCA must be added to the coolant when it becomes depleted below a specified level (listed in Table 5-20). 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 km)
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, Generator Set, and all other applications	200 hours or yearly, whichever comes first.

Table 5-19 Required Coolant Inhibitor Test Intervals

SCA	Minimum SCA ppm	Maximum SCA 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 5-20 SCA Limits with GM6038-M or ASTM-D 4985 (50/50 Coolant/Water Mixture)

5.4.4 Soluble Oils

Soluble oil additives are not approved for use in the Detroit Diesel Series 50 engine cooling systems. A small amount of oil adversely affects heat transfer. A 1.25% concentration of soluble oil increases the firedeck temperature 6%. A 2.50% concentration increases the fire deck temperature 15%.

5.4.5 Chromate

Chromate additives are not approved for use in the Detroit Diesel Series 50 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 Nalcool 2015 cooling system cleaner and 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.

5.4.6 Detroit Diesel Cooling System Maintenance 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.

5.4.7 Coolant Inhibitor Elements

Replaceable coolant inhibitor elements (spin-on canisters) are available in various sizes suitable for cooling systems of varying capacity. If a fully formulated IEG or IPG coolant *is not* used, a pre-charge element *must*be installed. Selection of the proper element size is vital when precharging the coolant system at initial fill. If a coolant inhibitor element is used, it is important to make sure that the coolant inlet/outlet valves on the element adaptor head are fully opened prior to filling the cooling system with coolant.

NOTE:
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.

5.4.8 Supplemental Coolant Additive 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 listed in Table 5-19. SCA levels must be within the ranges listed in Table 5-20.

NOTICE:

Do not use Detroit Diesel **POWERTrac** ® test strips to determine the inhibitor levels of coolant with non-DDC approved additive packages. Incompatible chemicals and variance in inhibitor levels in the additive packages may cause inaccurate interpretation of test strip readings. This can lead to under-inhibiting the coolant, which may result in cavitation erosion.

5.4.8.1 Liquid Supplemental Coolant Additive

Detroit Diesel Cooling System Maintenance Procedures SCA and Cleaners are available in liquid form and are listed in Table 5-21.

Product	Size *	DDC Part No.
NALCOOL ® 2000-Liquid SCA	1 pint (12 per case)	23507858
NALCOOL ® 2000-Liquid SCA	half gallon (6 per case)	23507859
NALCOOL ® 2000-Liquid SCA	5 gallons	23507860
NALCOOL ® 2000-Liquid SCA	55 gallons	23507861
NALCOOL ® 3000 † - Liquid SCA	1 pint (12 per case)	23507854
NALCOOL ® 3000 † - Liquid SCA	half gallon (6 per case)	23507855
NALCOOL ® 3000 † - Liquid SCA	5 gallons	23507856
NALCOOL ® 3000 † - Liquid SCA	55 gallons	23507857
NALPREP ® 2001 ON-LINE CLEANER	half gallon (6 per case)	23507862
NALPREP ® 2001 ON-LINE CLEANER	5 gallons	23507863
NALPREP ® 2001 ON-LINE CLEANER	55 gallons	23507864
NALCOOL ® 2015, Twin Pac, Dry, Chemical Cleaner/Conditioner	2 per case	23507867

* 1 gallon=3.785 L; 8 pints=1 gallon

† 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 5-21 Liquid SCA and Additional Coolant Treatment Products

5.4.8.2 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, over concentration of SCA inhibitor can result in poor heat transfer, leading to engine damage. Always maintain concentrations at recommended levels.

Freeze/boil over 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 and 140°F (10-60°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.

5.4.9 Summary of Coolant Recommendations

Coolant recommendations may be summarized as follows:

CAUTION:
To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

1. Always maintain the engine coolant to meet Detroit Diesel specifications.

NOTE:
Propylene glycol meeting ASTM D 4985, and ASTM D 5216 is approved for use in Series 50 engines.

2. Only use water that meets Detroit Diesel specifications. Distilled or deionized water is preferred.
3. The proper dosage of SCA must be included in the coolant at initial fill for all Detroit Diesel Series 50 engines.This dosage can be either included in part or entirely in the IEG used, or it may need to be added. Dosage is also dependent on whether water or IEG is used. The user is urged to refer to the full text of this bulletin to determine the proper

dosage. Mixing of different manufacturers' inhibitors (SCAs) could cause cooling system problems.

4. Maintain the SCA to the prescribed concentration. Test the nitrite concentration by using a titration kit or Detroit Diesel 2-Way Coolant Test Strips. Add SCA only if the nitrite concentration is below 800 ppm.Do not use another manufacturer's test kit to measure the SCA concentration of Detroit Diesel Maintenance Products.
5. Pre-mix coolant makeup solutions at the proper concentration before adding to the coolant system.
6. Where antifreeze/boil over protection is required, use only ethylene glycol coolant (low silicate formulation) meeting GM 6038-M, GM 1899-M, or ASTM D 4985.
7. Always maintain proper coolant level.
8. A properly maintained cooling system can be operated for up to two years, 200,000 miles (320,000 km) or 4000 hours, whichever comes first. At this interval the cooling system must be thoroughly cleaned and the coolant replaced.
9. Do not use the following in Detroit Diesel engine cooling systems:
   - Soluble oil
   - Chromate SCA
   - Methoxy propanol-base coolant
   - Methyl alcohol-base coolant
   - Sealer additives or coolant containing sealer additives
   - HVAC coolant

6 AIR INTAKE SYSTEM

Section **Page**

6.1 AIR INTAKE SYSTEM OVERVIEW

The air intake system consists of the following components:

- ☐ Air cleaner
- ☐ Intake manifold
- ☐ Turbocharger diesel
- ☐ Turbocharger gas
- ☐ Charge air cooler
- ☐ Throttle Actuator (Series 50 Gas)
- ☐ Air dryer

6.1.1 Air System for Series 50 Diesel

The turbocharger supplies air under pressure to the intake manifold. The air enters the turbocharger after passing through the air cleaner. Power to drive the turbocharger is extracted from energy in the engine exhaust gas. The expanding exhaust gases turn a single stage turbocharger wheel, which drives an impeller, thus pressuring intake air. This charge air is then cooled by an air-to-air heat exchanger before the engine intake manifold for improved combustion efficiency. See Figure 6-1.

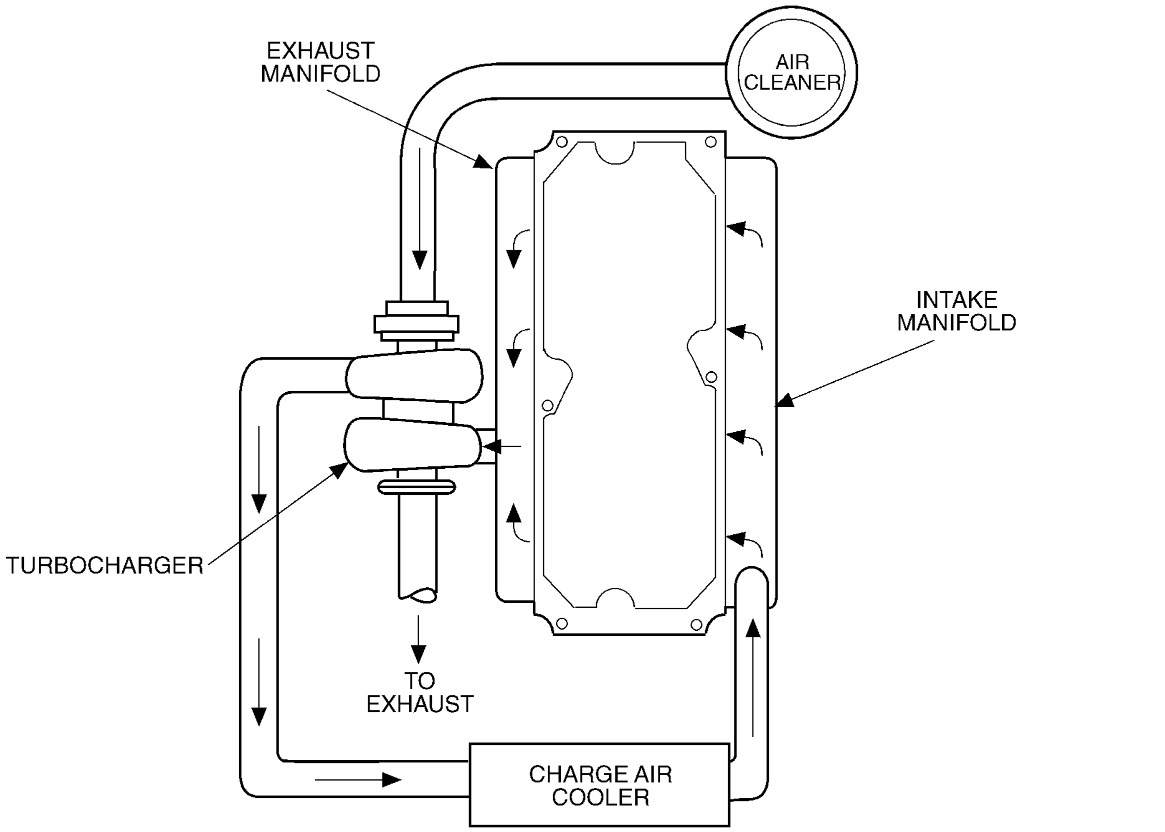


Figure 6-1 Air Intake System Schematic Series 50 Diesel

A charge air cooler (CAC) is mounted ahead or beside the engine coolant radiator. The pressurized intake charge is routed from the discharge side of the turbocharger, through the CAC to the intake manifold, which directs the air to ports in the cylinder head, through two intake valves per cylinder, and into each cylinder. At the beginning of the compression stroke, each cylinder is filled with clean air.

Repair and replacement procedures for the individual components of the air intake system are contained in this section.

6.1.2 Air System for Series 50G (High Pressure)

The air system components on the Series 50G engine with high pressure fuel system are similar to the diesel engine air system except for the addition of a gas mixer and throttle, see Figure 6-2. The turbocharger for this engine is also different and features a turbine bypass (wastegate) and compressor recirculation valve. These features are described in more detail in the turbocharger section ; refer to Section 6.5.

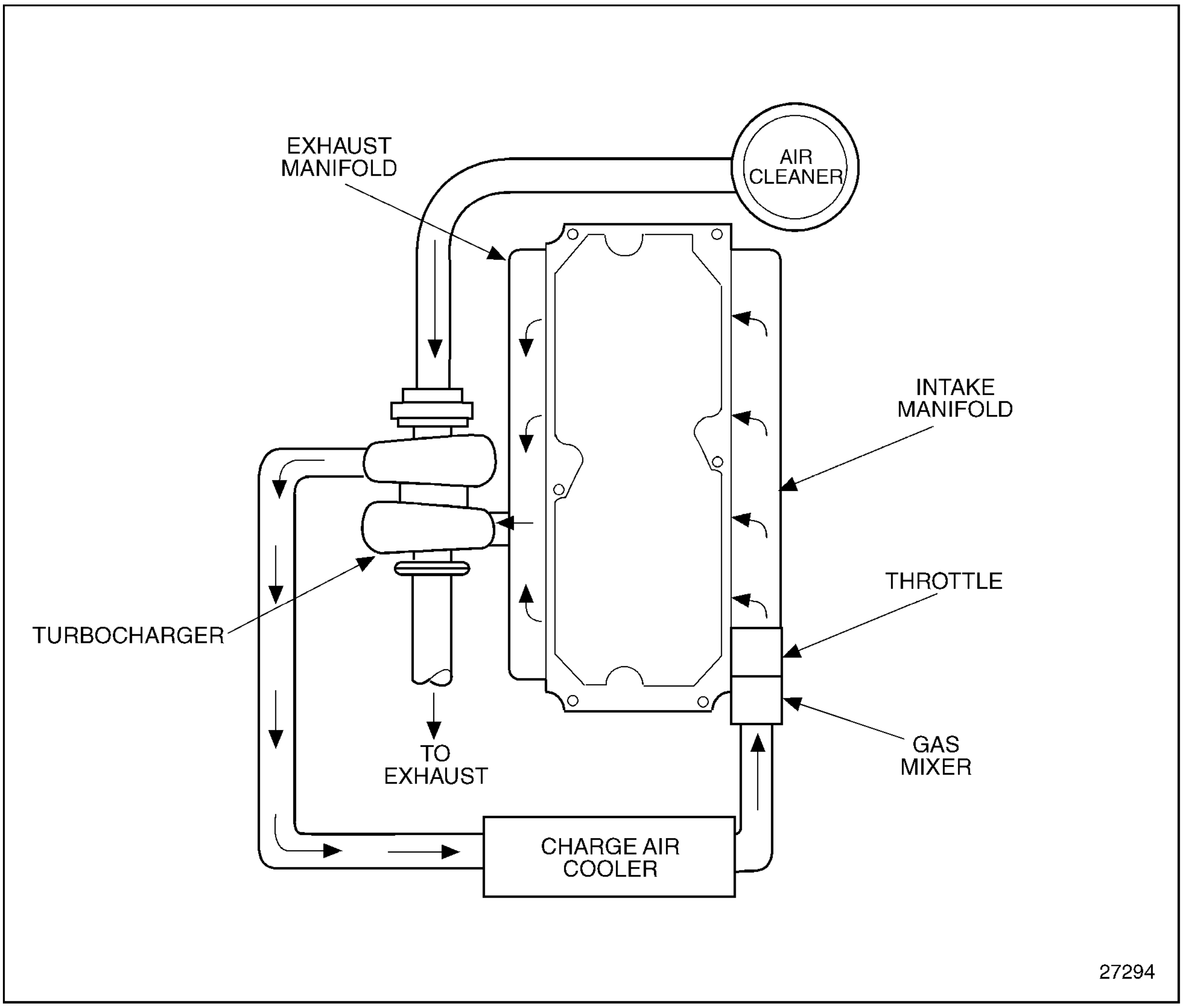


Figure 6-2 Air Intake System Schematic Series 50G (High Pressure)

In this system, air leaving the charge air cooler enters the mixer assembly and is mixed with a precisely controlled flow of natural gas. This combustible air fuel mixture then passes through the throttle and into the intake manifold. The throttle controls the flow of air-fuel mixture to the intake manifold thereby providing control over the power output of the engine. On automotive (bus) engines an oxygen sensor is installed within 12 inches of the turbocharger turbine exhaust outlet and adjacent to the exhaust temperature sensor. A harness connects the sensors to the ECM.

6.1.3 Air System for Series 50G (Low Pressure)

The air system components on the Series 50G engine with low pressure fuel system are similar to the diesel engine air system except for the addition of a gas mixer and throttle; see Figure 6-3. The turbocharger for this engine is also different and features a turbine bypass (wastegate) and compressor recirculation valve. These features are described in more detail in the turbocharger section. Refer to Section 6.5.

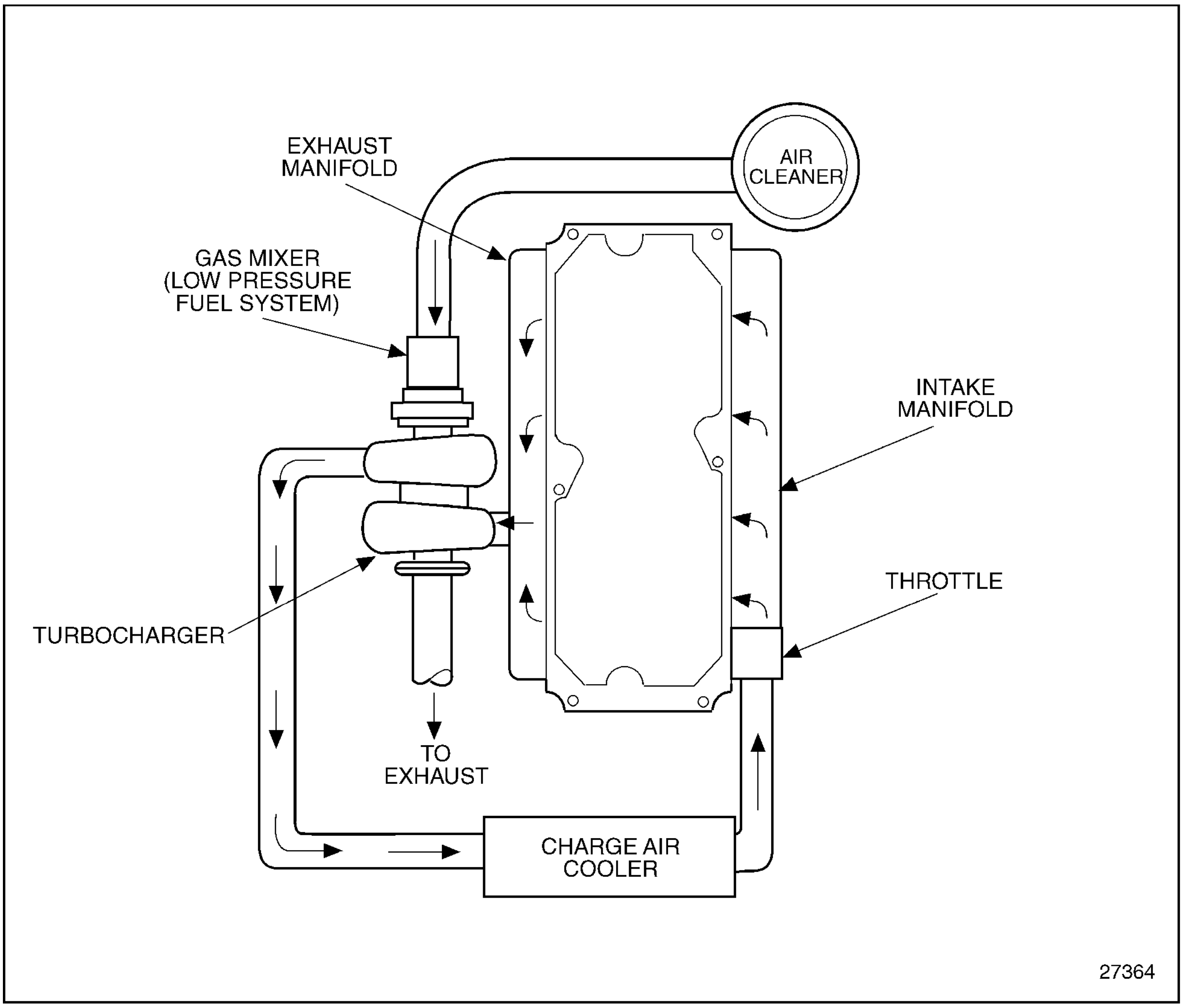


Figure 6-3 Air Intake System Schematic 50G (Low Pressure)

On engines with the low pressure fuel system air is drawn into the gas mixer ahead of the turbocharger. A precisely controlled flow of natural gas is mixed with the air and flows into the turbocharger where it is compressed before flowing through the charge air cooler. This combustible air fuel mixer then passes through the throttle and into the intake manifold. The throttle controls the flow of air-fuel mixture to the intake manifold thereby providing control over the power output of the engine.

6.2 AIR CLEANER

Air cleaners are designed to remove foreign matter from the air and pass the required volume of air for proper combustion. Manufacturers guidelines should be consulted to maintain efficient operation for a reasonable period of time before requiring service.

The importance of keeping dust and grit-laden air out of the engine cannot be overemphasized, since clean air is essential to satisfactory engine operation and long engine life. Should dust in the air supply enter the engine, it would be carried into the cylinders and, due to its abrasive properties, cause premature wear of the moving parts. Dirt, which is allowed to build up in the air cleaner passages, will eventually restrict the air supply to the engine and result in heavy carbon deposits on the valves and pistons due to incomplete combustion. The air cleaner must have a capacity large enough to retain the material separated from the air to permit operation for a reasonable length of time before cleaning is required.

NOTICE:
Detroit Diesel is aware of attempts to use air cleaner elements made of foam or fabric batting material soaked with a sticky substance to improve dirt-holding capability. In some installations this substance has been found to transfer from the filter media, coating the inside surfaces of air ducts and engine air inlet systems, blowers, air boxes, and turbochargers. The result has been reduced engine performance and a change in engine operating conditions.

Only dry paper element type air cleaners are recommended for use on all Detroit Diesel Series 50 engines. Alternate types of air filtration systems may be available in the after-market. However, Detroit Diesel does not recommend use or extend warranty to cover damage or malfunction of engine components as a result of usage of alternate air filtration devices on Detroit Diesel Series 50 engines.

If a foam or fabric air cleaner element soaked with a sticky, dirt-holding substance was previously installed, check for the presence of coated engine components. Remove and clean coated engine components as required.

6.2.1 Repair or Replacement of Air Cleaner

Refer to the OEM guidelines for air cleaner service procedures.

6.2.2 Cleaning and Removal of Air Cleaner

Detroit Diesel does not offer air cleaners as original equipment on Series 50 engines.

NOTICE:
Always vacuum check air intake restriction indicators after cleaning to ensure proper operation. Failure to observe this step may result in faulty indicator readings, which may lead to inefficient engine operation and damage.

Refer to air cleaner manufactures guidelines for cleaning and removal procedures.

6.2.3 Installation of Air Cleaner

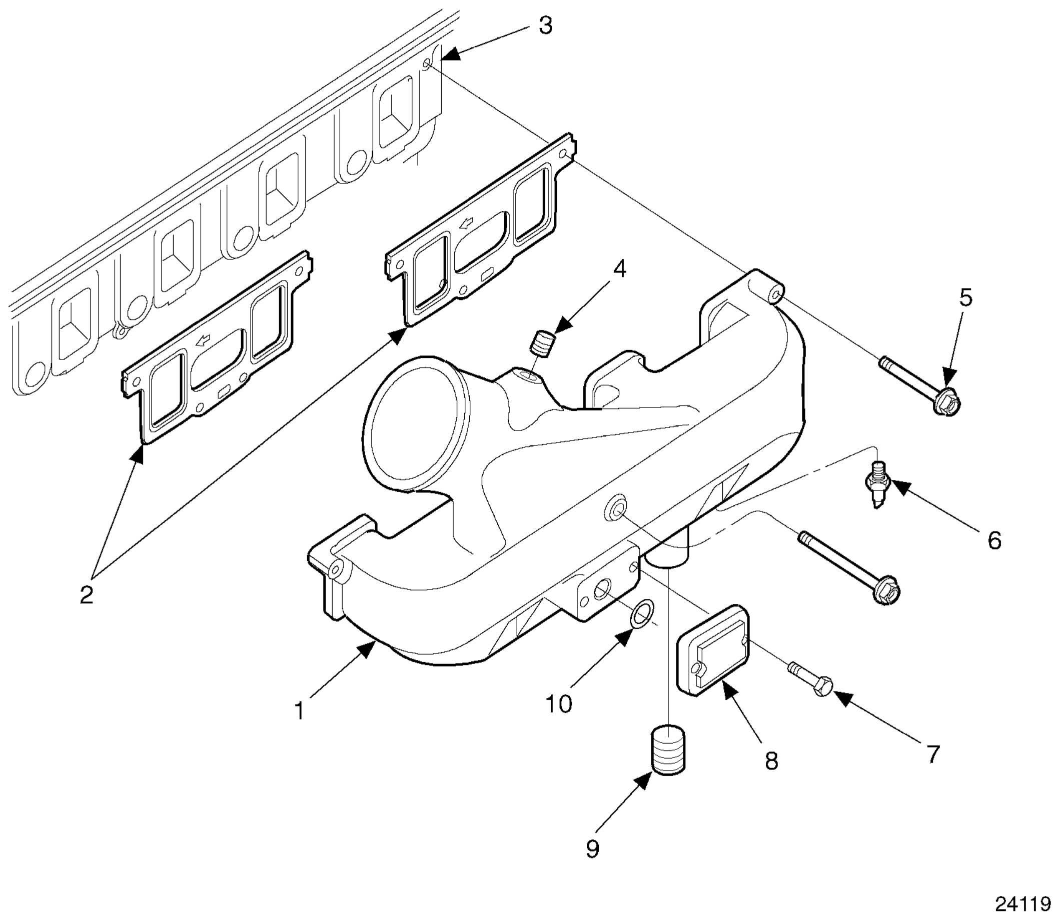
Refer to vehicle or equipment manufacturer for installation and verification procedures.

6.3 INTAKE MANIFOLD

The intake charge air is routed to the individual cylinders by an intake manifold that is bolted to the cylinder head with five bolts. The mating surface of the manifold and cylinder head is machined. The intake manifold is sealed to the cylinder head with two 2-port graphite coated gaskets. If the manifold is removed, new gaskets must be installed to maintain seal under high boost pressure.

6.3.1 Intake Manifold for Series 50 Diesel

On Series 50 Diesel engines a turbo-boost pressure sensor is mounted to the intake manifold with two bolts. An O-ring seals the boost sensor where it enters a hole in the manifold. On DDEC III engines there is an air temperature sensor located on the bottom of the manifold. See Figure 6-4. The intake manifold air inlet is attached to the CAC ducting and the air compressor using flexible hoses and clamps.



1. Intake Manifold
2. Intake Manifold Gasket
3. Cylinder Head
4. Pipe Plug
5. Manifold Bolt
6. Air Temperature Sensor
7. Turbo-boost Pressure Sensor Bolt
8. Turbo-boost Pressure Sensor
9. Pipe Plug
10. O-ring

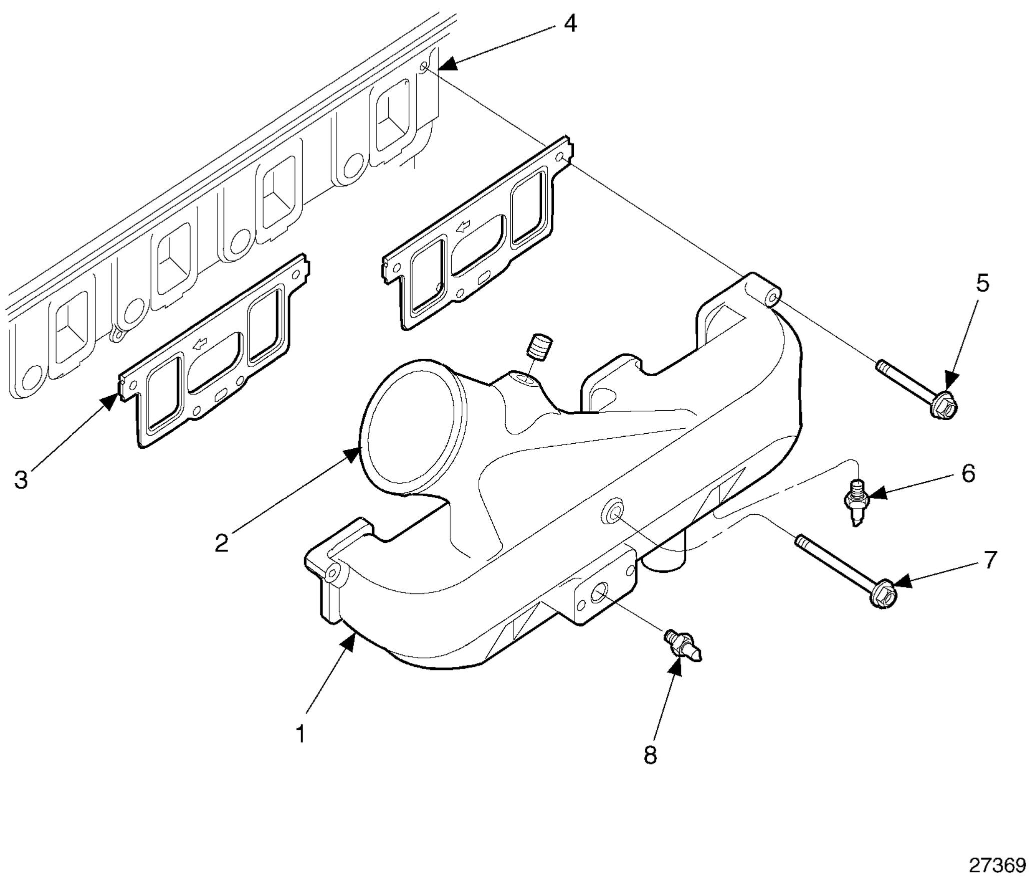
Figure 6-4 Intake Manifold and Related Parts Series 50 Diesel

6.3.2 Intake Manifold Series 50 Gas

On Series 50 Gas engines a pipe thread hole is provided for mounting the boost sensor. The Series 50G engines are throttled and therefore require a wide range boost sensor capable of measuring both negative and positive pressures in the intake manifold. In natural gas engines the intake manifold contains a combustible air-fuel mixture. See Figure 6-5.

CAUTION:

The air inlet manifold contains combustible gas. To avoid injury from explosion, do not connect the air inlet manifold to any devices or lines external to the manifold.



1. Intake Manifold
2. Intake Manifold Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Manifold Bolt
6. Air Temperature Sensor
7. Bolt
8. Turbo-boost Pressure Sensor

Figure 6-5 Intake Manifold and Related Parts Series 50 Gas

6.3.3 Repair or Replacement of Intake Manifold Series 50

To determine if repair is possible or replacement of the intake manifold is necessary perform the following procedure. See Figure 6-6.

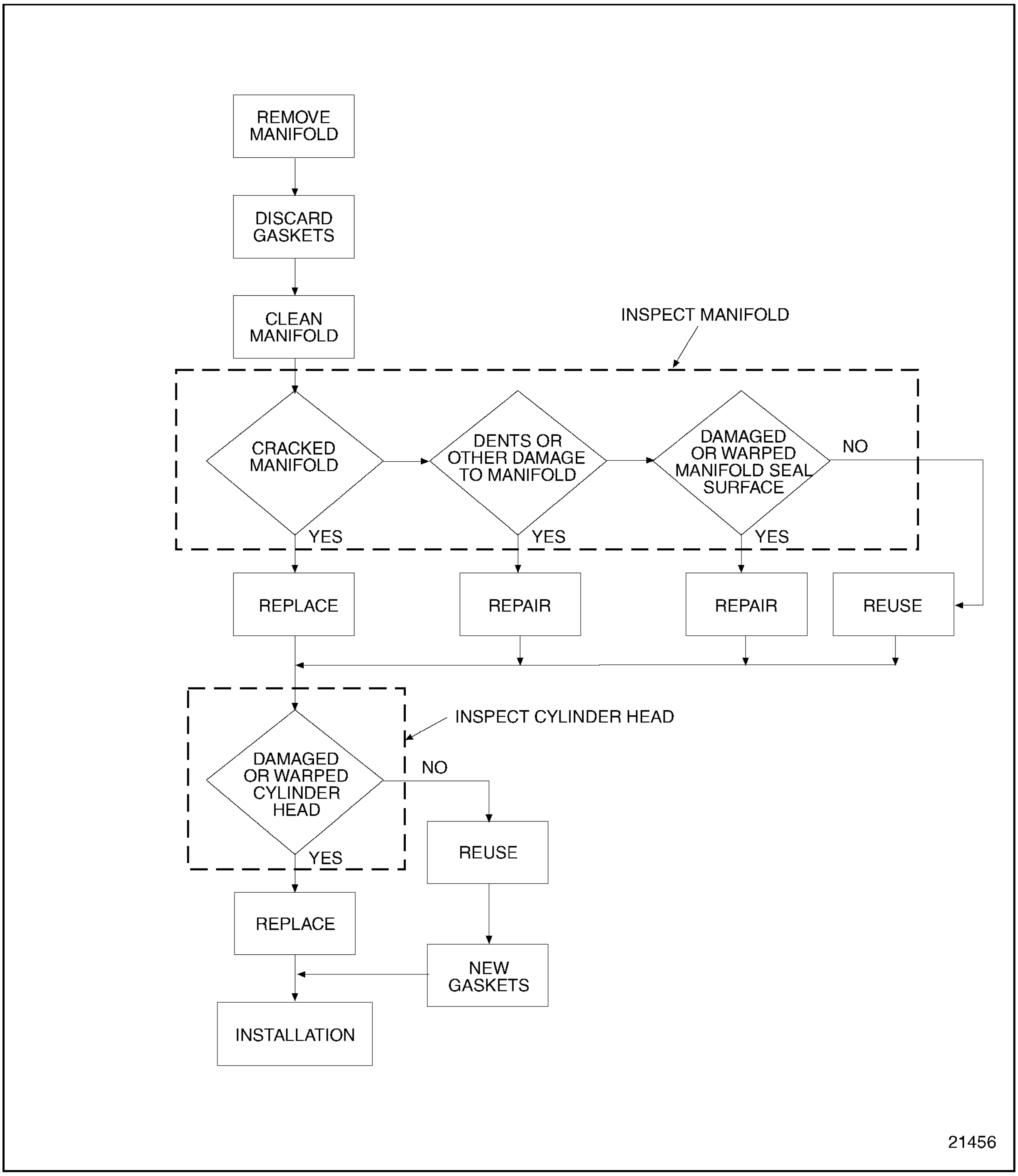


Figure 6-6 Flowchart for Repair or Replacement of Intake Manifold

6.3.4 Cleaning and Removal of Intake Manifold

Remove the intake manifold as follows:

1. Disengage the locking tang on the turbo-boost pressure sensor connector. Grasp the connector body and pull it straight out of the turbo-boost pressure sensor.
2. If servicing a DDEC III engine, disengage the locking tang on the air temperature sensor connector. Grasp the connector body and pull it straight out of the air temperature sensor.
3. Loosen the hose clamps connecting the hose coupling between the intake manifold and the CAC ducting. Slide the clamps and hose away from the intake manifold.
4. Remove the air compressor intake air line from the bottom of the intake manifold if used.
5. Loosen and remove the five bolts that retain the intake manifold to the cylinder head.
6. Tap the intake manifold lightly to separate the intake manifold from the cylinder head.
7. Remove and discard manifold seals.

NOTE:
Units built prior to 4R1945 may not have gasket seals.

8. Remove the intake manifold.

Clean the intake manifold, prior to inspection as follows:

NOTICE:
When removing and cleaning the intake manifold and cylinder head J 36571 *must* be used. Failure to do so may damage the intake manifold or cylinder head or both.

1. Remove loose gasket material from the cylinder head and intake manifold mating surfaces.
2. To clean the intake manifold mating surface and the head port area, use the surface conditioning set J 36571. See Figure 6-7.
   [a] To clean steel surfaces use a coarse grit disc (brown), part of the surface conditioning set, J 36571 with an electric or air powered hand drill operating at a speed of 15,000-18,000 r/min. The pads are easily interchangeable using the disc holder provided in the set.
   [b] To clean aluminum surfaces use a medium grit disc (maroon), part of the surface conditioning set, J 36571 with an electric or air powered hand drill operating at a

speed of 15,000-18,000 r/min. The pads are easily interchangeable using the disc holder provided in the set.

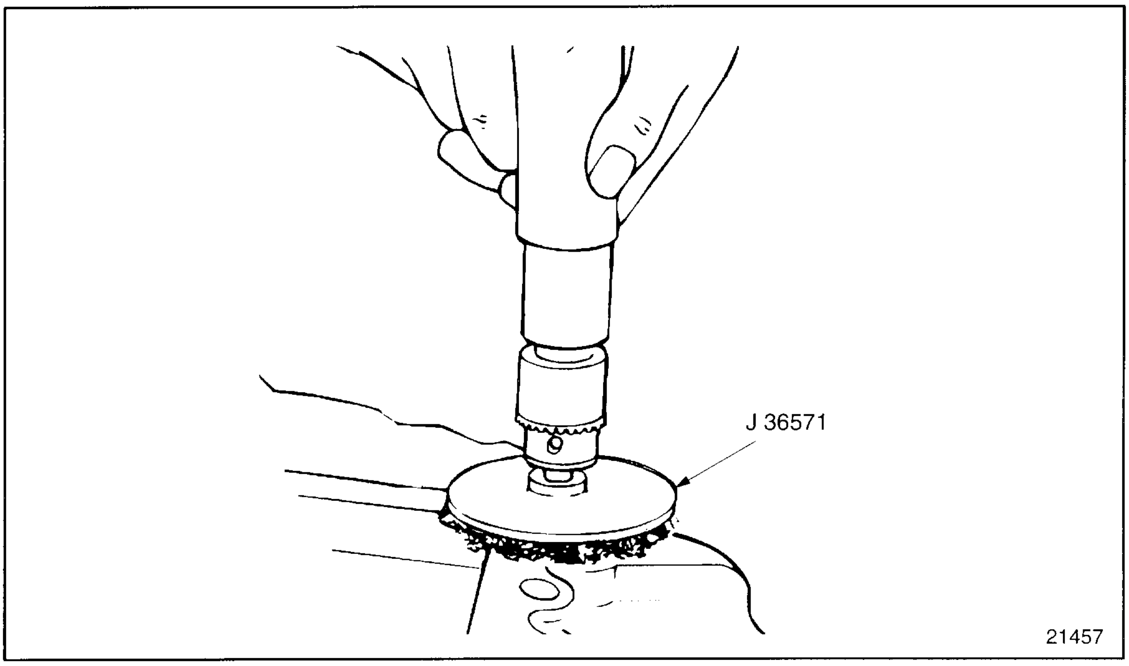


Figure 6-7 Cleaning the Manifold

3. Wash all of the parts in clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

4. Blow dry with compressed air.

6.3.4.1 Inspection of Intake Manifold

Inspect the intake manifold as follows:

1. Visually inspect the manifold for any cracks, dents or other damage. Pay particular attention to the bolt areas.
   [a] If a crack is found, replace the intake manifold.
   [b] Refer to Section 6.3.5 for installation procedure of new manifold.
2. Inspect the manifold mating surface for imperfections that could affect its sealing to the cylinder head.

[a] Replace if necessary.

3. Check the mating ports for warpage, using a 0.35 mm (1.4 in.) long by 6 mm (0.25 in.) wide straight edge bar laying the bar across the manifold.

   [a] If all port flange area measurements are less than 0.127 mm (0.005 in.), the manifold is reusable and can be reinstalled with new gaskets. Refer to Section 6.3.5 for installation.

   [b] If the manifold does not meet this requirement the manifold *must* be replaced.

6.3.5 Installation of Intake Manifold

Install the intake manifold as follows:

NOTICE:
It is necessary to completely seal the intake manifold to the cylinder head, due to the high pressure of the intake charge provided by the turbocharger. The arrow on the gasket must point to the front of the engine. Gasket eliminator can not be used with intake manifold seals. Failure to seal this interface will reduce engine performance.

1. Install two new manifold gaskets to the mating surfaces of the intake manifold with the arrow on the gasket pointing to the front of the engine. See Figure 6-8.

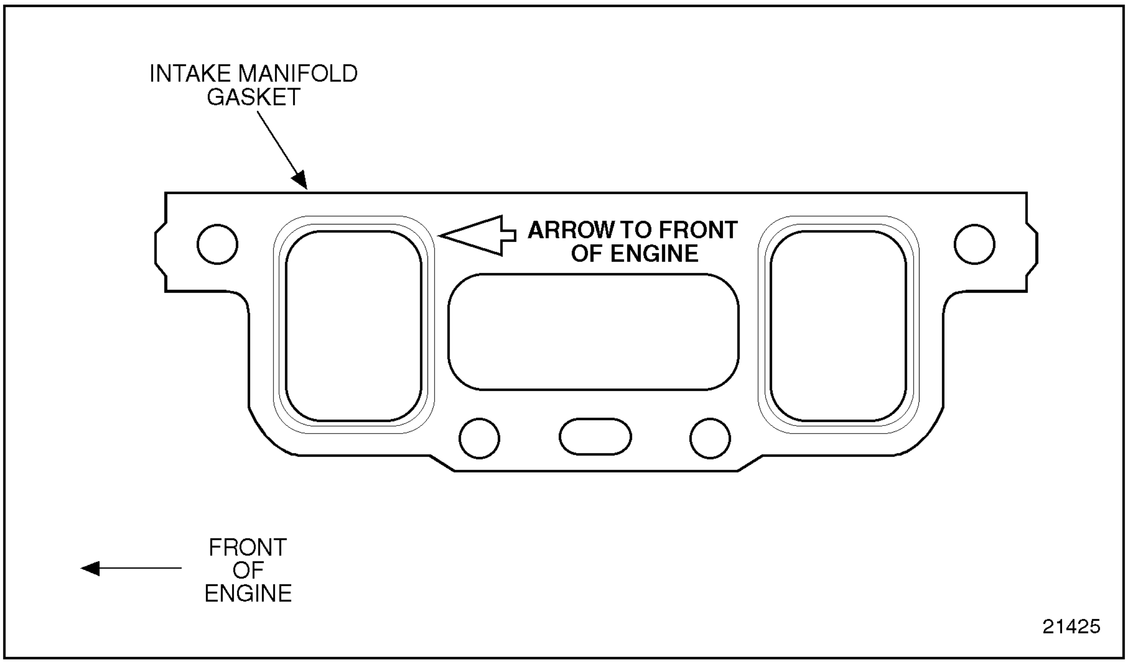


Figure 6-8 Intake Manifold Gasket Orientation

2. Install bolts four and five through the intake manifold and into the cylinder head and hand tighten. See Figure 6-9.
3. Install the three remaining bolts through the intake manifold and into the cylinder head. Torque all of the intake manifold retaining bolts to 58-73 N·m (43-54 lb·ft) in the proper tightening sequence. See Figure 6-9.

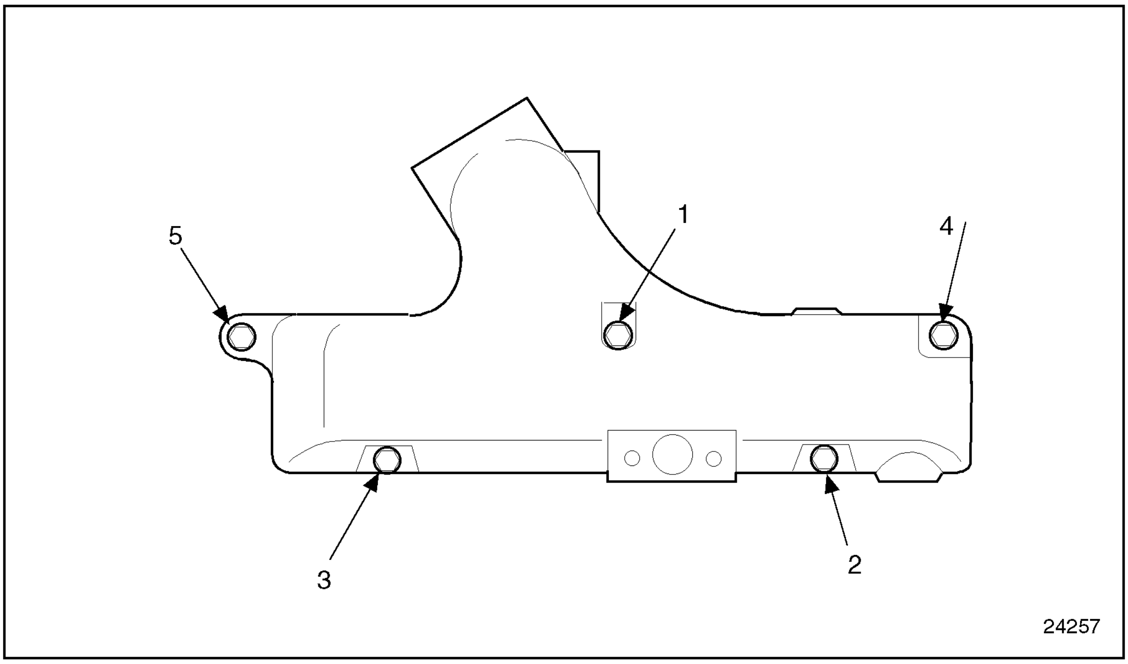


Figure 6-9 Intake Manifold Bolt Position and Torque Sequence

NOTE:
The numbers on this illustration signifies both position and torque sequence.

4. Plug in the turbo-boost pressure sensor wiring connector by pressing the connector into the body of the sensor until the locking tang snaps into place.
5. If servicing a DDEC III engine, plug in the air temperature sensor wiring connector by pressing the connector into the body of the sensor until the locking tang snaps into place.

CAUTION:

To avoid injury, wear a face shield or goggles.

NOTICE:

Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

6. Slide the hose over the intake manifold and position it to its original location.
7. Slide the hose clamps into place and tighten them alternately. Insure that hose clamps are installed away from the cast bead on the manifold inlet to prevent separation of the joint.

CAUTION:

The air inlet manifold contains combustible gas. To avoid injury from explosion, do not connect the air inlet manifold to any devices or lines external to the manifold.

8. Reattach air line to air compressor, if used, and tighten clamp.

NOTE:
In Series 50 engines the intake manifold contains combustible air-fuel mixture.

6.4 CLOSED CRANKCASE BREATHER FOR S50G AUTOMOTIVE ENGINES (1998 AND LATER)

Closed breathers are required for natural gas automotive engines in 1998. The S50G engine uses a remote mount Racor® CV4500 crankvent breather/filter. See Figure 6-10.

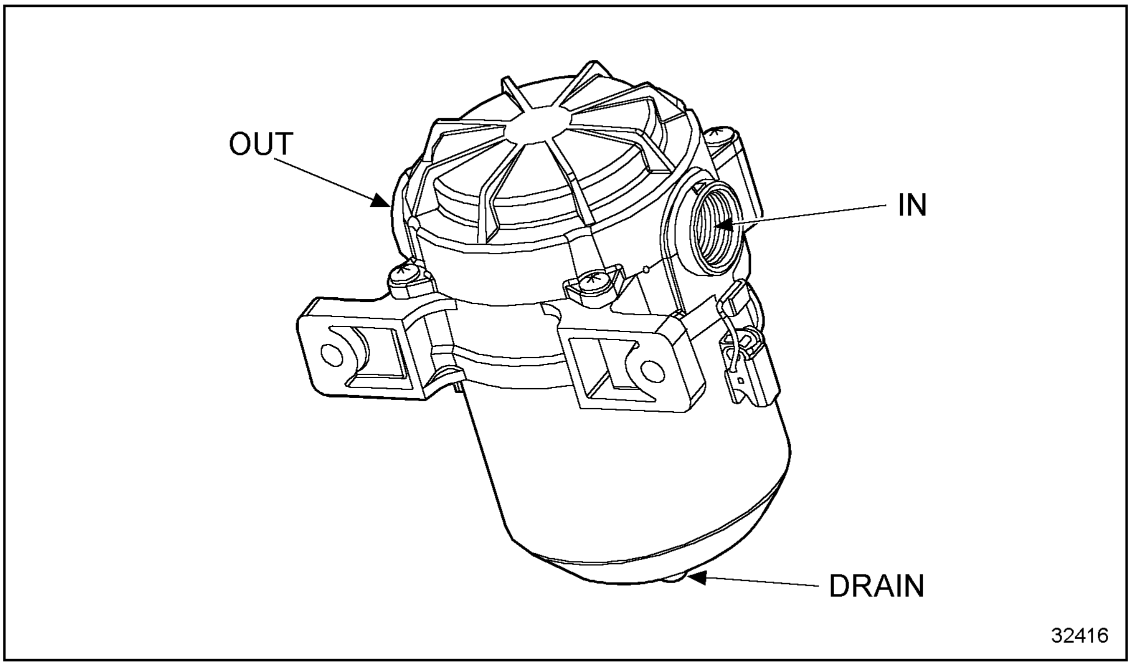


Figure 6-10 Crankvent

The crankvent contains a coalescing filter to remove liquid from the blowby gas. The liquid that is coalesced from the blowby is drained back to the ground. The blowby gas is routed out of the rocker cover, through the filter element and returns to the inlet side of the turbo.

6.4.1 Replacement of the Closed Crankcase Breather

The crankvent coalescing filter is a nonservicable component but should be changed in conjunction with oil service intervals. Refer to Section 13.6.3.

6.4.2 Removal of Closed Crankcase Breather

Remove the closed crankcase breather as follows:

1. Release latches on the side of the breather assembly and lower canister away from the assembly.
2. Remove the filter from the assembly.
3. Dispose of the used filter in an environmentally responsible manner.
4. Clean the filter canister with a clean lint-free cloth.

6.4.3 Installation of the Closed Crankcase Breather

Install the closed crankcase breather as follows:

1. Insert new filter into the top of the assembly, ensuring the new filter contains the top O-ring. See Figure 6-11.

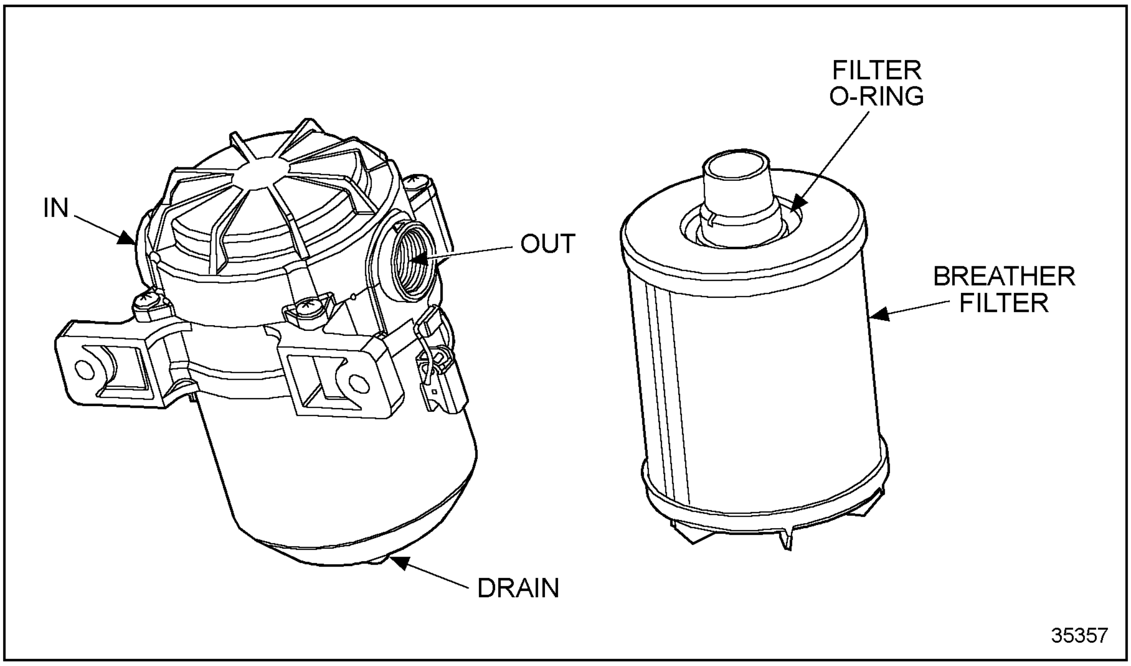


Figure 6-11 Location of O-ring and Breather Filters

2. Replace the lower canister ensuring the larger O-ring is secure in the top half of the assembly.
3. Secure the latches on the side of the can.
4. There are two O-rings in the system. One on the filter element itself and one that seals between the lower canister and the upper body. Ensure both O-rings are secure before reassembling the crankvent.

6.5 TURBOCHARGER SERIES 50 DIESEL

The Honeywell TV 45 turbocharger is used on all Series 50 engines. See Figure 6-12.

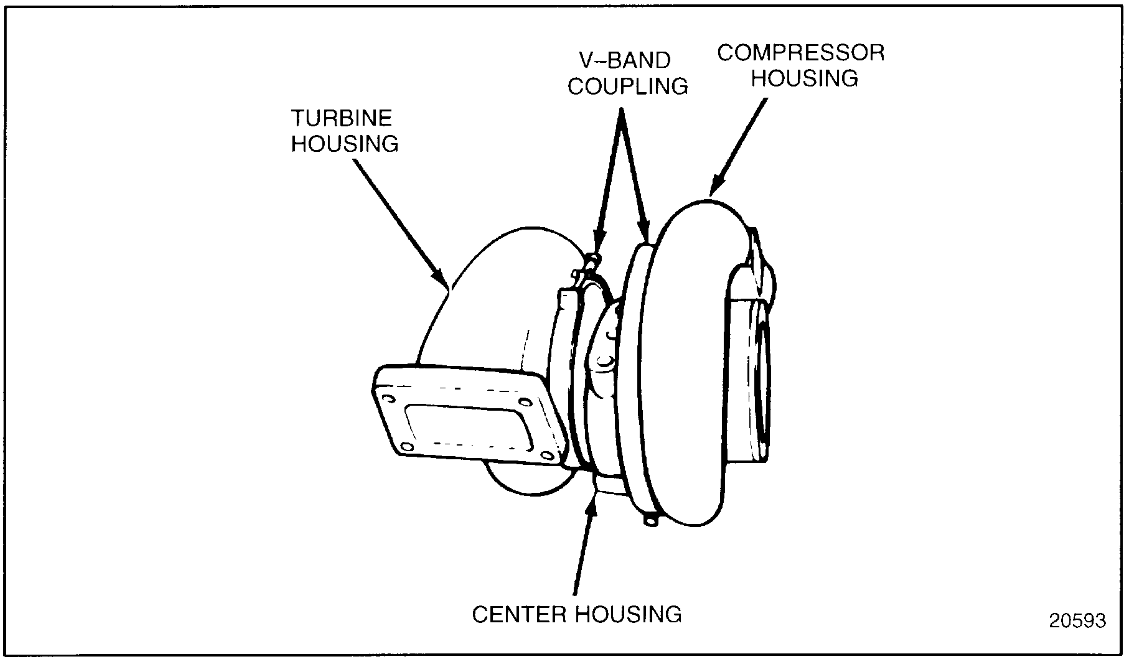


Figure 6-12 TV 45 Turbocharger Assembly (Series 50 Diesel)

The turbocharger is designed to increase the overall efficiency of the engine. Power to drive the turbocharger is extracted from the energy in the engine exhaust gas.

The turbocharger consists of a turbine wheel and shaft, a compressor wheel, and a center housing that supports 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 rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel, and wheel retaining nut. The rotating assembly is supported on two pressure-lubricated bearings that 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.

The turbine housing is a heat-resistant alloy casting that encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing.

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flow from the engine and through the turbine housing causing the turbine wheel and shaft to rotate. See Figure 6-13.

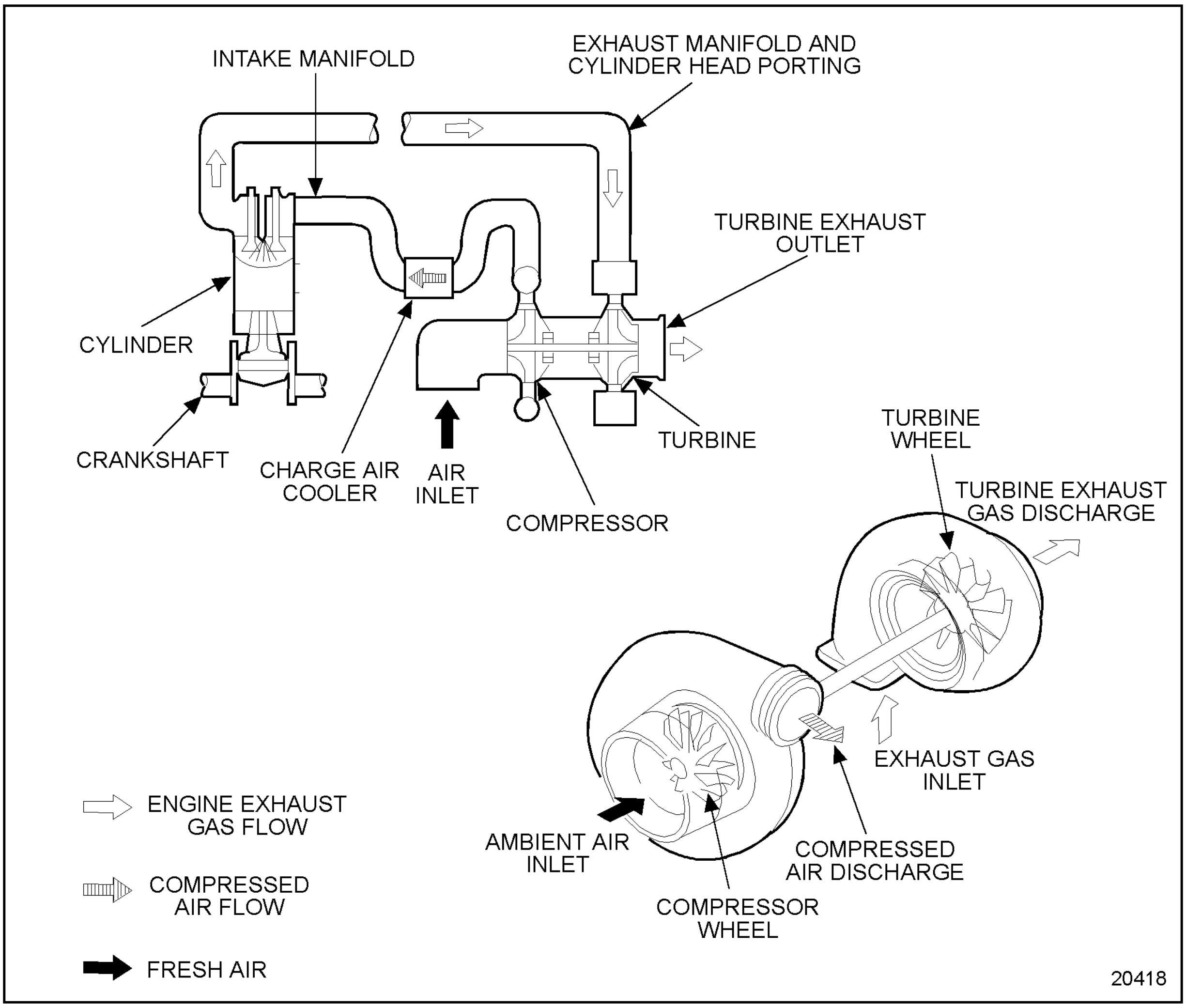
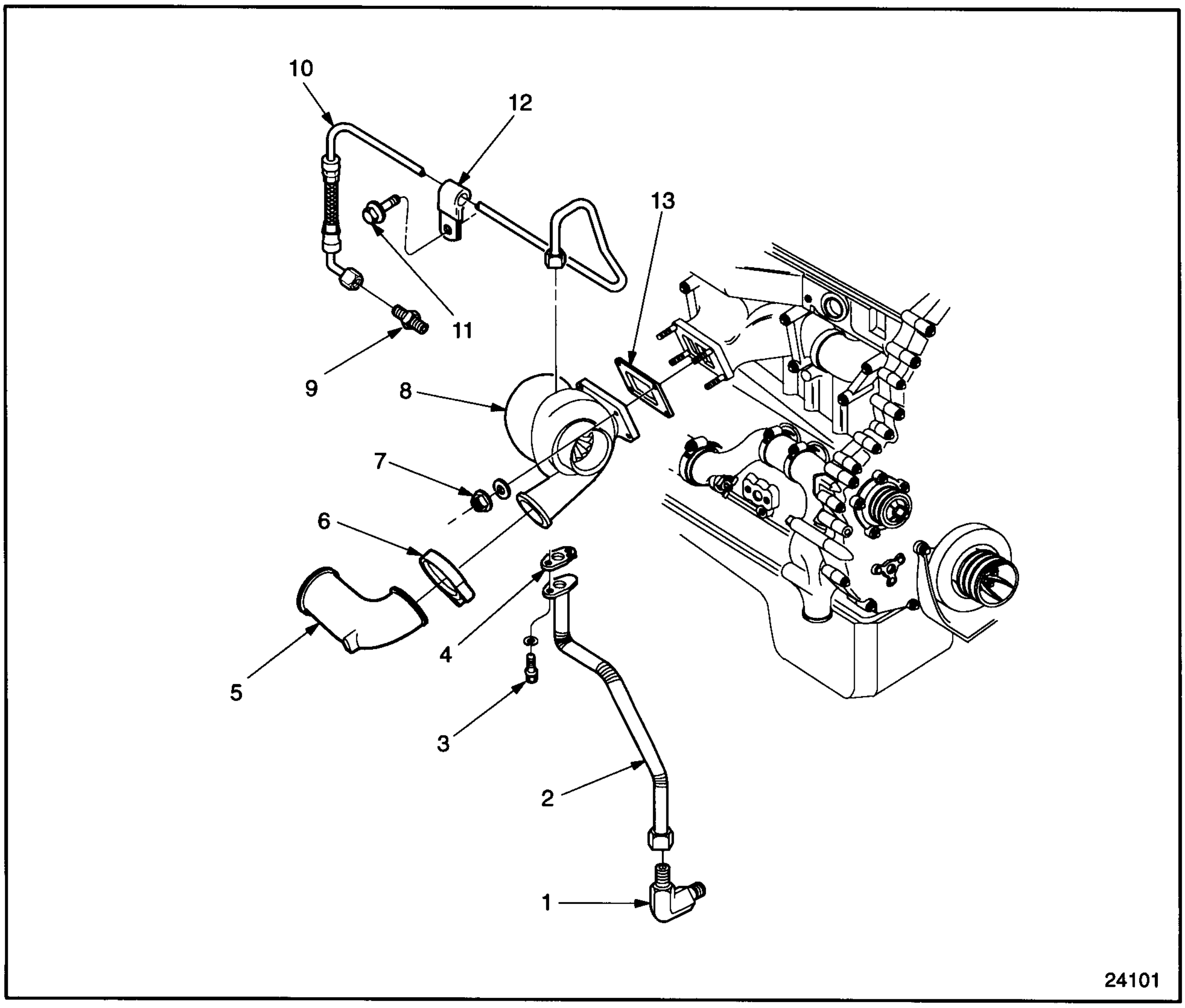


Figure 6-13 Schematic Air Flow Diagram (Series 50 Diesel)

The gases are discharged into the exhaust system after passing through the turbine housing.

The compressor wheel, in the compressor housing, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in clean air, compresses it, and delivers high pressure air through the intake manifold to the engine cylinders.

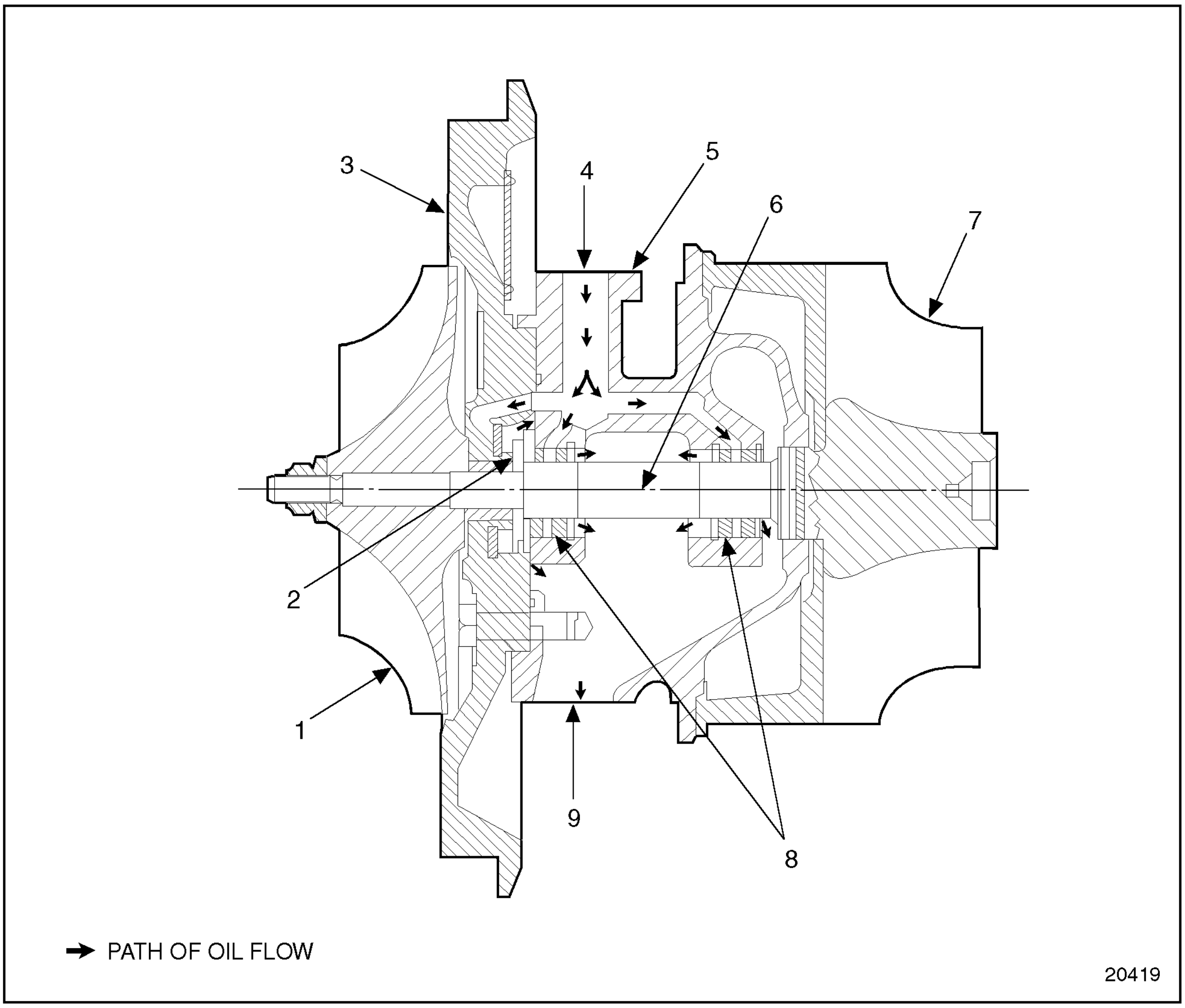
Oil for lubricating the turbocharger is supplied under pressure through an external oil line extending from the oil filter adaptor to the top of the center housing. See Figure 6-14.



1. Elbow, Oil Drain Tube
2. Tube, Turbo Oil Drain
3. Bolt, and Lockwashers, Oil Drain Tube Mounting
4. Gasket, Oil Drain Tube
5. Elbow
6. Clamp
7. Nut, and Washer Turbo Mounting
8. Turbocharger Assembly
9. Connector, Oil Supply Tube (from oil filter adaptor)
10. Tube Assembly, Turbo Oil Supply
11. Bolt, Oil Supply Tube Clip
12. Clip, Oil Supply Tube
13. Gasket, Turbo Exhaust Inlet

Figure 6-14 Turbocharger Oil Lines (Series 50 Diesel)

From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing, and backplate or thrust plate. See Figure 6-15.

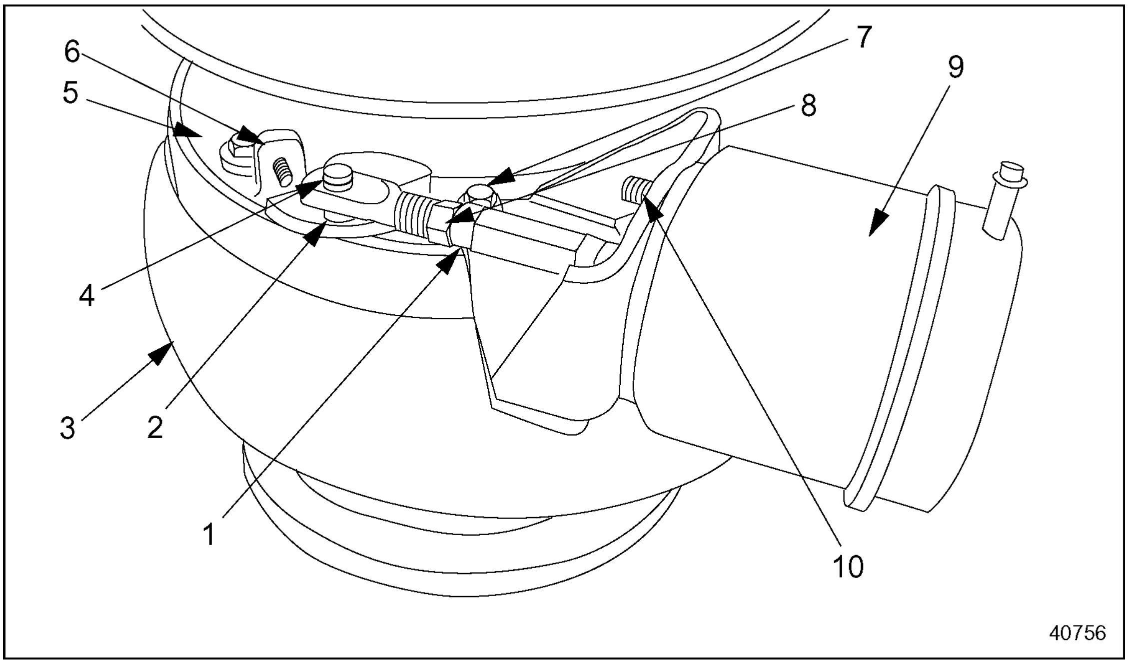


1. Compressor Wheel
2. Thrust Bearing
3. Backplate
4. Oil Inlet
5. Center Housing
6. Shaft
7. Turbine Wheel
8. Shaft Bearings
9. Oil Outlet

Figure 6-15 Turbocharger Oil Flow Diagram (Series 50 Diesel)

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. See Figure 6-15.

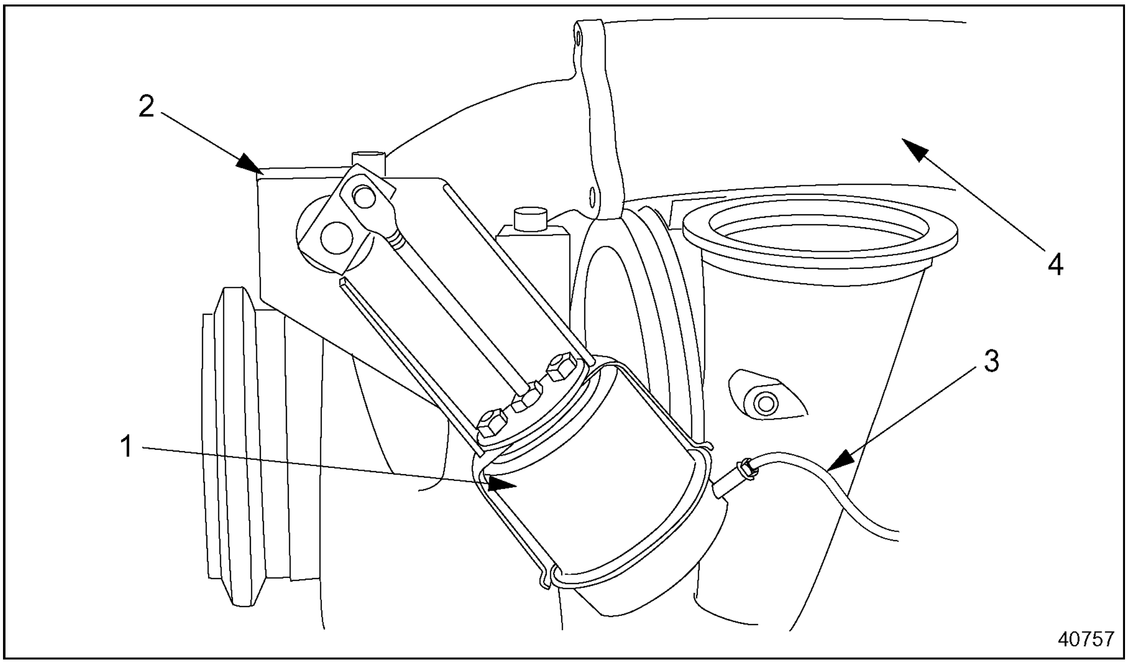
For Series 50 bus engines with Honeywell 4 Gm Exhaust Gas Recirculation (EGR) Systems: The variable nozzle turbine (VNT) turbocharger uses two, high-pressure, pneumatic actuators to regulate and control the EGR system. These actuators are mounted on brackets, attached to the turbocharger, and receive air pressure from the engine-mounted PWM/EGR valve assembly module. See Figure 6-16. The VNT actuator connects via a rod-end to a pin on the turbine external arm. Rotation of the external arm simultaneously rotates 15 pivoting nozzle vanes positioned inside the turbine housing at the outer periphery of the turbine wheel, adjusting turbocharger speed and boost in accordance with the DDEC engine management control.



1. Adjustable Rod End Assembly
2. External Arm Pin
3. Turbocharger
4. Retaining Ring (not shown)
5. Turbine Housing Bolt Circle
6. Stop and Stop Screw
7. Bracket Bolt (3)
8. Adjusting Arm Locknut
9. VNT Actuator
10. Actuator Mounting Stud and Nut (3)

Figure 6-16 VNT Actuator and Mating Parts

The second, called the EGR valve actuator, opens and closes the EGR valve. The EGR valve outlet is connected to the EGR cooler and recirculates a fraction of the engine exhaust gases to the intake manifold for purposes of engine emission control. See Figure 6-17.



1. EGR Actuator
2. Bracket
3. Pressure Line
4. Hot Pipe

Figure 6-17 EGR Housing Assembly

Servicing of both actuators is limited to their replacement. The EGR actuator is serviced by replacing the EGR Valve Assembly and does not require calibration. Servicing can usually be accomplished without removing the turbocharger from the engine. With the VNT actuator, it is recommended that the turbocharger first be removed from the engine to perform the necessary calibration settings of the replacement actuator.

6.5.1 Repair or Replacement of Turbocharger (Series 50 Diesel)

To determine if repair is possible or replacement of the turbocharger is necessary perform the following procedure. See Figure 6-18.

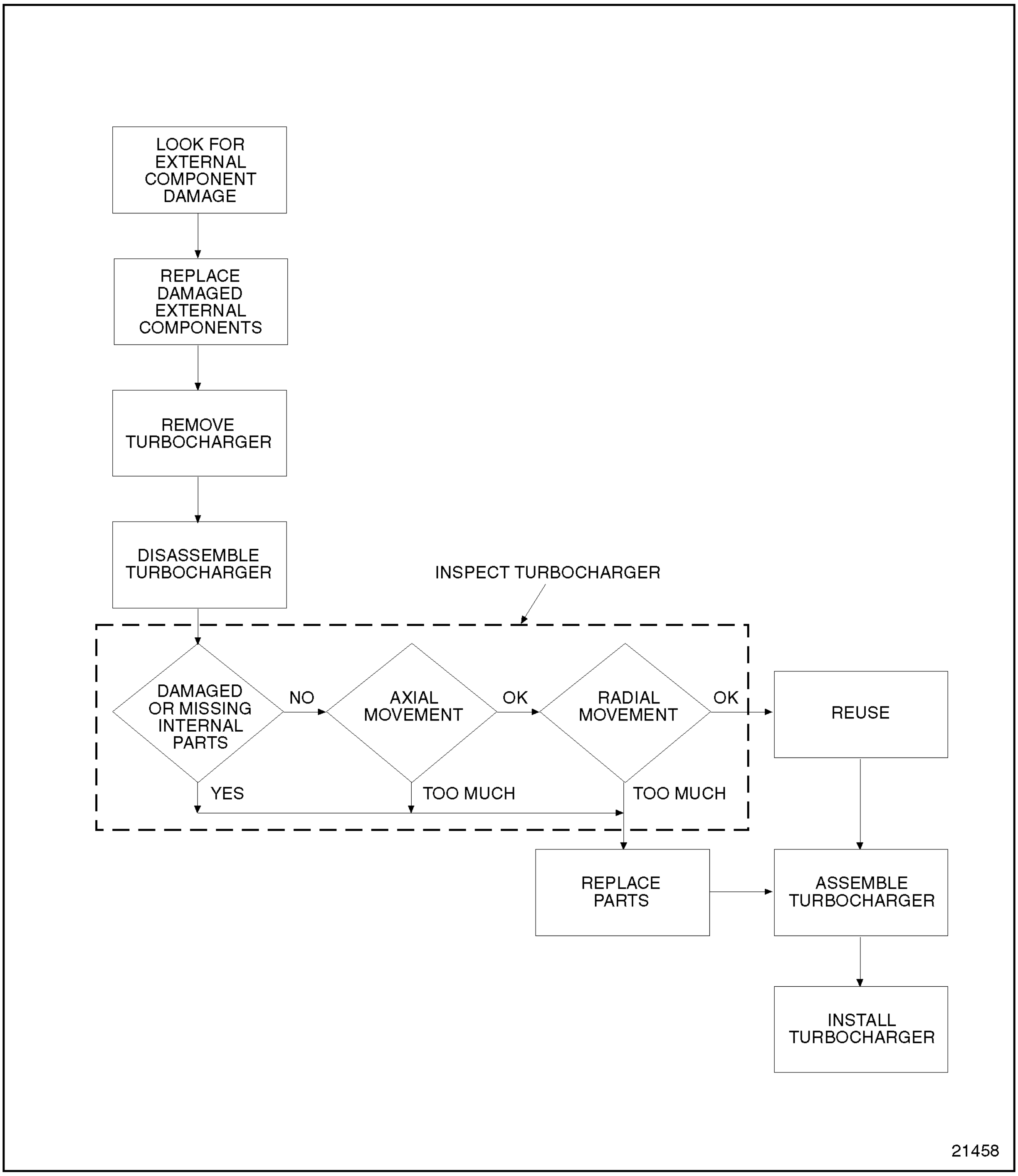


Figure 6-18 Flowchart for Repair or Replacement of Turbocharger (Series 50 Diesel)

6.5.2 Cleaning and Removal of Turbocharger

Cleaning the turbocharger is not necessary before removal.

CAUTION:
To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil supply and drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage.
6. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

NOTICE:
Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup.

1. Disconnect and remove the CAC ducting at the compressor housing.
2. Disconnect and remove the air inlet hose attached to the compressor housing.
3. Disconnect the exhaust outlet pipe from the turbine housing of the turbocharger. For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.
4. Remove the inlet oil line from the top of the center housing.
5. Remove the oil drain line from the bottom of the center housing.
6. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
7. Remove the nuts securing the turbocharger assembly to the exhaust manifold. Then, lift the turbocharger assembly away from the engine and place it on a bench.
8. Cover the end of the oil drain line, the oil outlet line, the air inlet and the exhaust outlet openings on the engine and turbocharger to prevent the entry of foreign material.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer’s usage, handling, and disposal instructions. Observe all manufacturer’s cautions.

9. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly.

6.5.3 Disassembly of Turbochargers

EGR system turbochargers are not repairable. EGR/VNT turbocharger servicing is limited to it's replacement.

Disassemble the turbocharger as follows:

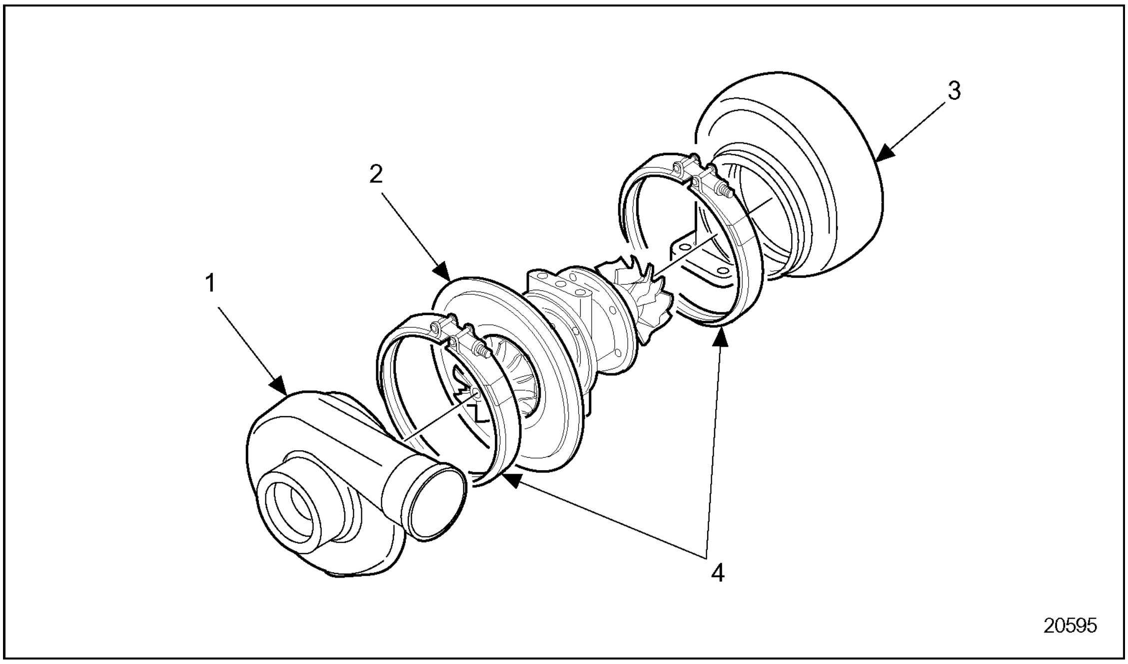
1. Mark the related positions of the compressor housing, center housing and turbine housing with a punch or scribe to assure reassembly in the same relative position.

NOTICE:

Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen the V-band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and V-band.

3. Loosen the V-band coupling securing the turbine housing to the center housing. See Figure 6-19.



1. Compressor Housing
2. Compressor Housing and Rotating Assembly
3. Turbine Housing
4. V-Band Couplings

Figure 6-19 Series TV45 Turbocharger (Series 50 Diesel)

4. Remove the turbine housing from the center housing.

6.5.3.1 Inspection and Cleaning of Turbocharger

Ceramic turbine wheels are extremely resistant to high temperatures, but at the same time are brittle. If debris is left in the air intake system, it may find its way through the engine and into the exhaust path. If large enough, these particles may cause turbine wheel chipping or "wheel burst."

NOTICE:
If the ceramic wheel becomes damaged or bursts, Detroit Diesel recommends replacing the exhaust system muffler if positioned in such a way that debris will fall back into the turbine housing. This precaution will prevent damage to the turbocharger at engine start-up.

Similar damage can result from a contaminated exhaust system. Any debris left in the exhaust system after service work can fall back into the exhaust wheel. If large enough, these particles may cause turbine wheel damage at initial engine startup. The exhaust manifold and exhaust piping attached to the turbocharger should also be inspected for debris and cleaned, if necessary, before being installed.

Any time the charge air cooler is removed, all charge air cooling system components *must* be inspected to make sure they are clean and free of any casting slag, core sand, welding slag, or any other contaminants that could break free during engine operation and damage the ceramic turbine wheel.

Inspect the disassembled turbocharger, discarding any damaged parts, in the following manner:

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.
3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.

4. Check the bearing axial end play:

   [a] Clamp the center housing assembly in a bench vise equipped with soft jaws. See Figure 6-20.

   [b] Fasten the dial indicator and magnetic clamp, part of magnetic base dial indicator set, J 7872-2 part of J 7872, to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. See Figure 6-20.

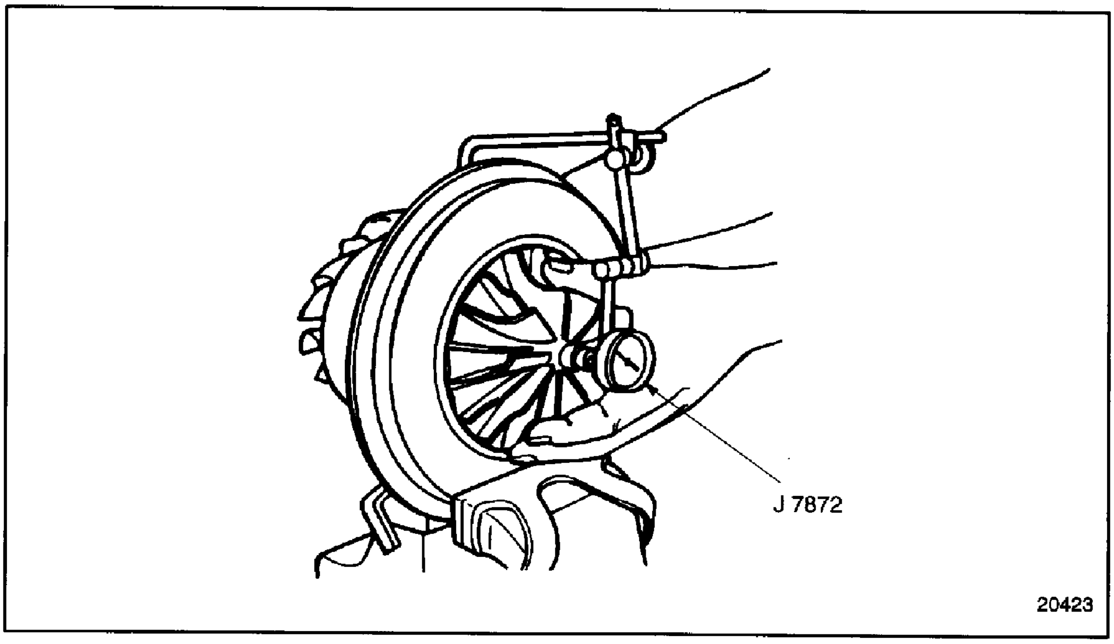


Figure 6-20 Checking Bearing Axial End Play (Series 50 Diesel)

   [c] Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be 0.0762-0.254 mm (0.003 to 0.010 in.). If the total dial indicator readings do not fall within the specified limits, replace the rotating assembly.

5. Check the shaft radial movement as follows:

   [a] Install the turbo shaft checker, J 39164, to the oil drain opening of the center section. The special curved end of the tool must contact the wheel shaft through the oil outlet port and an internal opening in the center casting. See Figure 6-21.

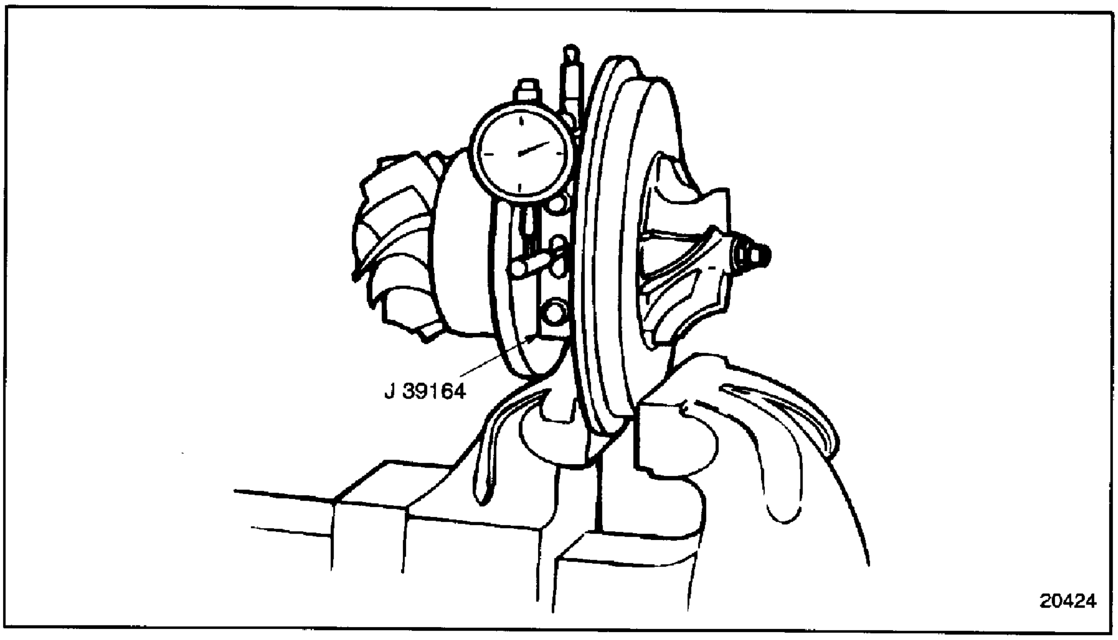


Figure 6-21 Checking Shaft Radial Movement

   [b] Install a dial indicator. See Figure 6-21.

   [c] Place the swivel adaptor, part of magnetic base dial indicator set, against the scribed line of the turbo shaft checker, J 39164.

   [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 total indicator reading (radial movement) should be 0.127-0.165 mm (0.005-0.0065 in.). If the total indicator readings do not fall within the specified limits, replace the rotating assembly.

6.5.3.2 Checking Wastegate Calibration

Check the wastegate calibration as follows:

1. Remove hose from wastegate actuator.
2. Using DDC tool set, TLZ00100, set up an indicator at the end of the wastegate actuator adjusting rod to measure actuator rod travel. The indicator should have a minimum travel of 2.54 mm (0.100 in.).
3. Connect regulator and pressure gage setup to wastegate actuator. See Figure 6-22.

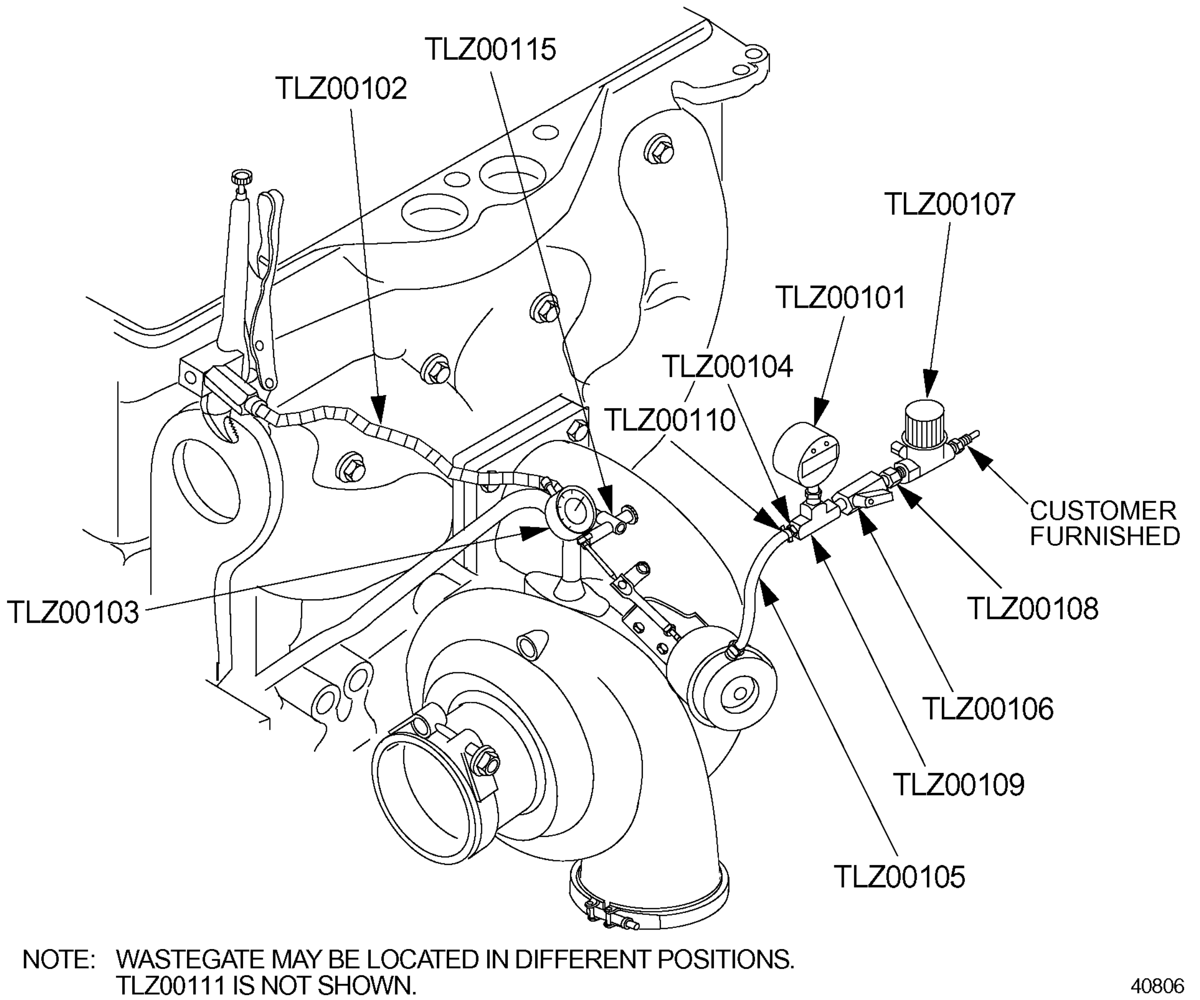


Figure 6-22 Checking Wastegate Calibration

4. Apply specified calibration pressure as listed in Table 6-1, to the wastegate actuator.

Manufacturer	Model	Rating	Can Pressure	Rod Travel
Garrett®	8.5L	250–350 Hp	210.29–217.19 kPa (30.5–31.5 lb·in.^{2})	1.016 mm (0.040 in.)

Garrett® is a registered trademark of Honeywell.

Table 6-1 Wastegate Calibrations

5. Close air supply shutoff valve. The pressure should hold at 210.29–217.19 kPa (30.5–31.5 lb·in.^{2}). If not, check air hose and fitting connections for leaks. If none are found, replace wastegate actuator. Refer to section 6.5.4.
6. Open vent to relieve pressure. Check gage for zero pressure reading. Adjust regulator to zero pressure and close vent valve.
7. Adjust dial indicator so it just contacts the actuator rod end and adjust to zero reading.
8. Open air supply shutoff valve and slowly adjust regulator until dial indicator reads 1.016 mm (0.040 in.) for Garrett turbo systems. Switch pressure on and off, opening and closing supply air and vent valves, to ensure dial indicator travel is from 0.00–1.016 mm (0.00–0.040 in.); and that the pressure reading is consistent.
9. For currently calibrated wastegate actuator, a pressure within 210.29–217.19 kPa (30.5–31.5 lb·in.^{2}) will be required to obtain precisely the correct amount of actuator rod travel. If the pressure required is outside this range, wastegate adjustment is necessary. Refer to section 6.5.5.1.

6.5.4 Removal of Wastegate Actuator

Remove the wastegate actuator as follows:

1. Remove actuator hose from top side of actuator can. See Figure 6-22. With the pressure gage setup, apply enough pressure to the actuator can until the rod begins to move. Refer to section 6.5.5.1.
2. Remove the retaining clip that holds the actuator rod end on the worm pin. Lift rod off the wastegate lever pin.

NOTICE:
Never remove the rod end from the wastegate lever pin without applying pressure to the top side actuator port, or damage to the actuator diaphragm may result.

3. Remove the locknuts that secure the actuator can to the base of the actuator bracket and remove the can from the turbocharger assembly.

6.5.5 Installation of Wastegate Actuator

Further adjustment of the actuator will be necessary to achieve the correct pressure setting, listed in Table 6-1.

Install the wastegate actuator as follows:

1. Install actuator can on bracket; tighten locknuts.
2. Using pressure gage setup, apply enough pressure to the new service actuator can until the rod begins to move.
3. Adjust actuator rod end by turning either clockwise or counterclockwise on rod so that the rod end hole lines up with the wastegate lever arm. While wastegate is held shut, slip rod over pin.
4. Before installing retaining clip, the rod end will need to be adjusted to the correct setting. Refer to section 6.5.5.1.

6.5.5.1 Setting the Wastegate

Before performing this procedure, check the actuator set pressure to see if adjustment is needed. Refer to section 6.5.3.2.

Set pressure adjustment as follows:

1. Loosen the jam nut that secures the rod end on the actuator rod. If locking collar is present on the actuator rod, remove and discard collar. See Figure 6-23.

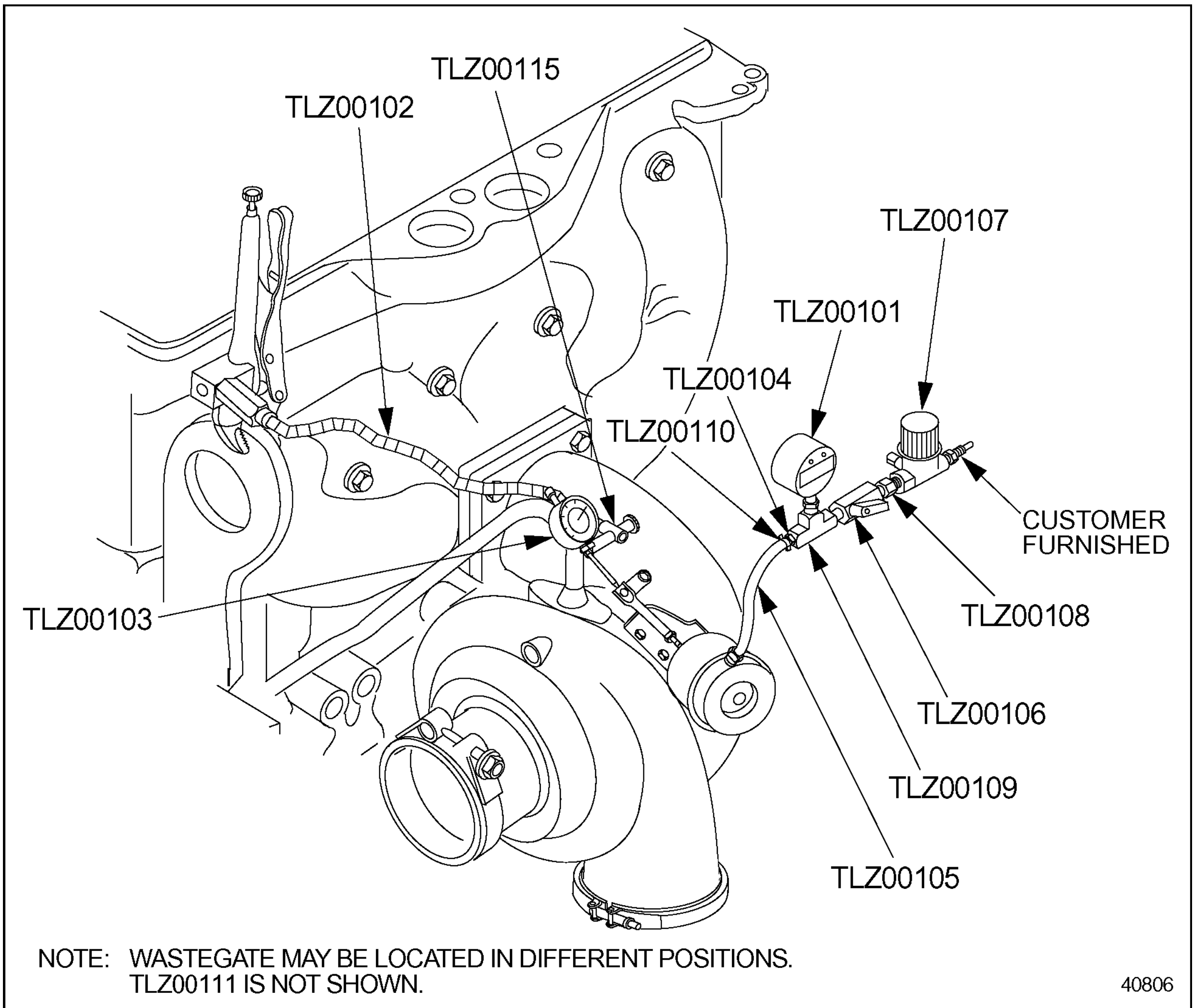


Figure 6-23 Wastegate Adjustment

2. Remove the retaining clip that holds the actuator rod end on the wastegate lever arm pin.
3. Using pressure gage setup, apply enough pressure to the top side actuator can port until the rod begins to move, lifting the wastegate valve off its seal. See Figure 6-23.
4. Slip rod end off the wastegate lever arm pin.
5. Adjust rod as needed:
   [a] To INCREASE pressure setting at 0.04 in., turn rod end CLOCKWISE.
   [b] To DECREASE pressure setting at 0.04 in., turn rod end COUNTERCLOCKWISE.
6. With pressure still applied to actuator, replace rod end on wastegate lever arm.
7. Check actuator set pressure again.

[a] If actuator is still out of adjustment. Refer to section 6.5.3.2.

[b] If actuator is within specified set pressure, install retaining clip on wastegate lever arm pin.

8. Tighten jam nut to secure rod end.

6.5.6 Assembly of Turbocharger

Use the following procedure to assemble the turbocharger:

NOTICE:
As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material, which may cause component damage.

1. Cover all openings.
2. Position the turbine housing as marked at disassembly against the center housing and secure it in place.

NOTICE:
Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak, turbine wheel damage or both.

3. Position the V-band coupling between the turbine housing and center housing so that the "T" bolt end does not interfere with the turbine housing. Then tighten the V-band coupling nut, as follows:

   [a] Lubricate the toggle bolt threads with a high temperature anti-seize compound.

   [b] Torque the nut on the V-band toggle bolt to approximately 18 N·m (160 lb·in.).

NOTE:
Do not pull a misaligned turbine housing into alignment with the V-band coupling. The parts must be aligned and seated first.

   [c] Loosen the V-band coupling nut to approximately 6 N·m (50 lb·in.) torque, then torque the nut to 12-15 N·m (106-130 lb·in.).

4. Position the compressor housing as marked at disassembly against the backplate assembly and secure it in place with the V-band coupling.
5. Lightly lubricate the threads of the toggle bolt with engine oil and torque the nut to 12-15 N·m (106-130 lb·in.).

6.5.7 Installation of Turbocharger

To install the turbocharger:

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
3. Remove any covers on the oil inlet and drain lines, and the oil inlet and drain openings on the turbocharger.
4. Place the turbocharger assembly into position on the exhaust manifold. Use a new gasket between the exhaust manifold and the turbine housing flange.
5. Secure the turbocharger to the exhaust flange. Tighten the nuts just enough to hold the turbocharger in place.
6. Slide the charge air cooler air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

CAUTION:
To avoid injury, wear a face shield or goggles.

NOTICE:
Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

7. Torque the turbocharger to exhaust manifold locknuts to 58-73 N·m (43-54 lb·ft).
8. Install the oil drain line, using a new gasket, between the opening in the bottom side of the turbocharger center housing and the drain hose that runs to the cylinder block. Torque the bolts to 30-38 N·m (22-28 lb·ft).
9. Refer to section 11.1.3 for verification of proper turbocharger installation.

6.5.8 Removal of VNT Actuator

For engines equipped with a VNT actuator, remove as follows:

NOTE:
The actuator is an assembly and internal parts are not available.

1. Remove turbocharger. Refer to section 6.5.2.

CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

NOTICE:

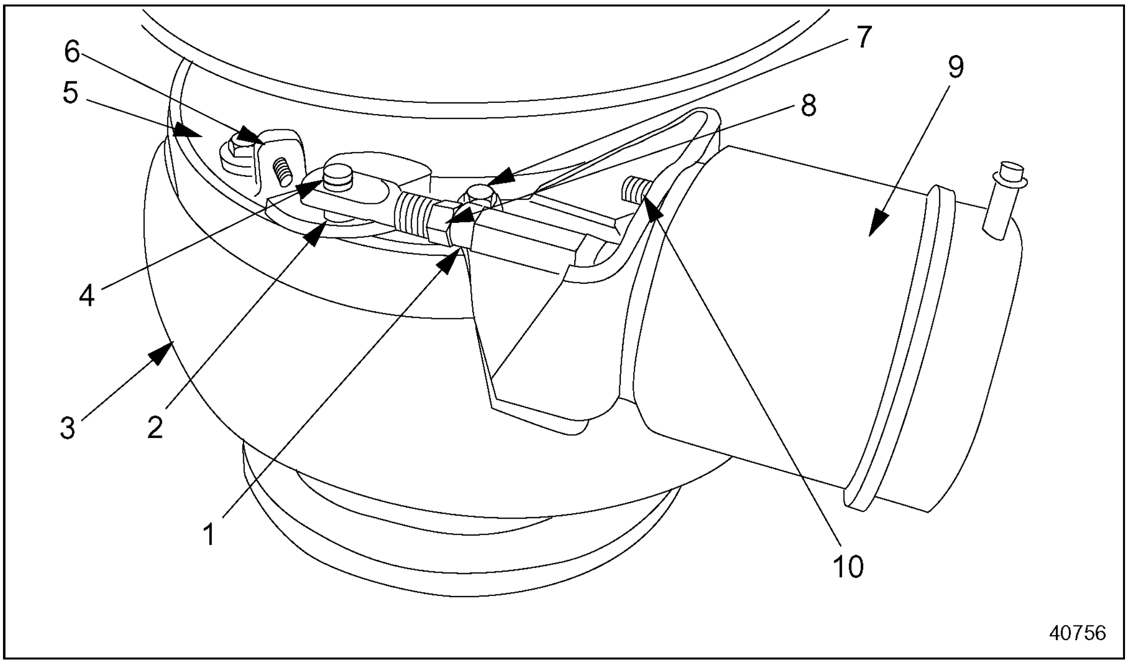
Ensure the speed sensor (black plastic plug and green-colored wire) electrical connector/lead wire does not become trapped under the turbocharger. Position the turbocharger on workbench in a matter that it does not cause damage to external parts.

NOTICE:

Fit a temporary mask using either tape, shipping plug, shop towel, etc. to the compressor inlet to preclude the entry of foreign material/objects, which could cause damage to the compressor wheel blades.

2. Place turbocharger on bench with the compressor inlet pointing upwards to expose the actuator and adjusting linkage.

3. Clean the actuator and VNT external linkage with a non-caustic solvent. See Figure 6-24.



1. Adjustable Rod End Assembly
2. External Arm Pin
3. Turbocharger
4. Retaining Ring (not shown)
5. Turbine Housing Bolt Circle
6. Stop and Stop Screw
7. Bracket Bolt (3)
8. Adjusting Arm Locknut
9. VNT Actuator
10. Actuator Mounting Stud and Nut (3)

Figure 6-24 VNT Actuator and External Linkage

CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

NOTICE:

Do not attempt to remove the rod end from the pin at this time as the rod is still under residual load from the internal actuator spring. Attempts to pry the rod end off can result in damage to the actuator or to the VNT linkage.

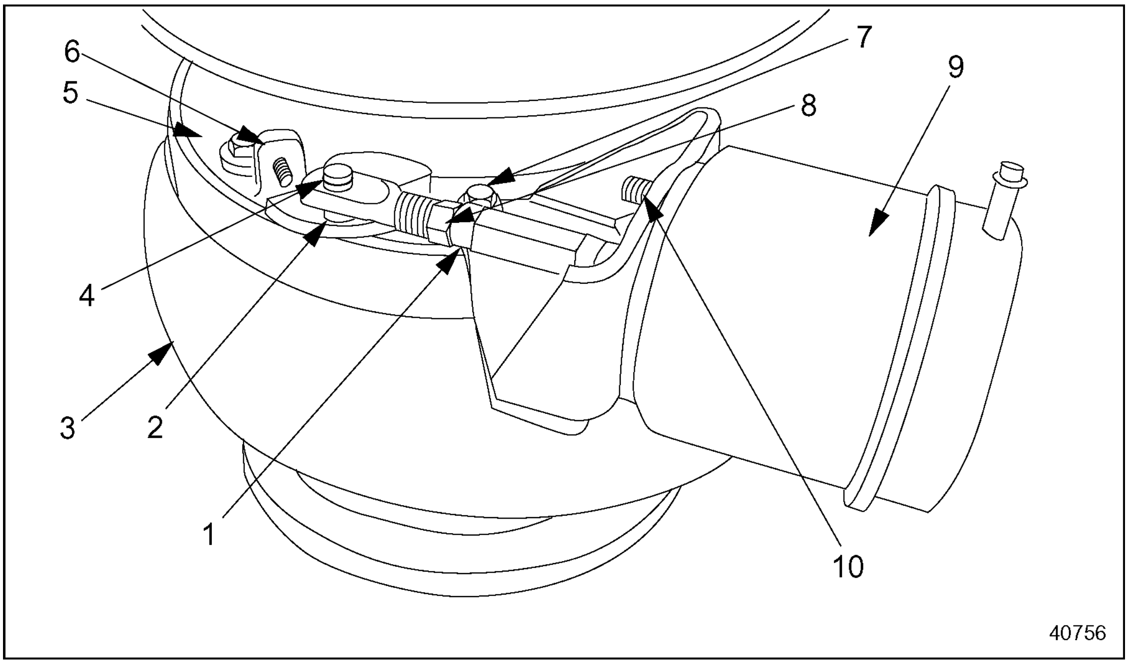
4. Using Waldes Tru-Arc #5304 Klip Ring tool, or suitable equivalent tool, to remove the Truarc retaining ring and save for reuse.

NOTE:
In the event this tool is not available, a small screwdriver tip and needle-nose pliers may be used. Place a shop towel in the cupped hand close to the ring. This is to help catch the ring during its removal.

NOTE:
It is advisable to have a spare ring on hand in the event the original becomes deformed or lost.

5. Remove the three, 12–point actuator bracket attachment bolts from the turbine housing bolt circle. See Figure 6-25.

NOTE:
Penetrating oil may be needed to assist in removal.



1. Adjustable Rod End Assembly
2. External Arm Pin
3. Turbocharger
4. Retaining Ring (not shown)
5. Turbine Housing Bolt Circle
6. Stop and Stop Screw
7. Bracket Bolt (3)
8. Adjusting Arm Locknut
9. VNT Actuator
10. Actuator Mounting Stud and Nut (3)

Figure 6-25 Removal of VNT Actuator and Mating Parts

6. Slip off the rod end from the external arm pin.

NOTE:
Clean and lightly oil the bolt threads in preparation for reuse.

7. Remove the three locknuts that fasten the actuator to the bracket and save for reuse.
8. With a pocket scale, measure and record the approximate distance from the rod end to the base of the actuator can.

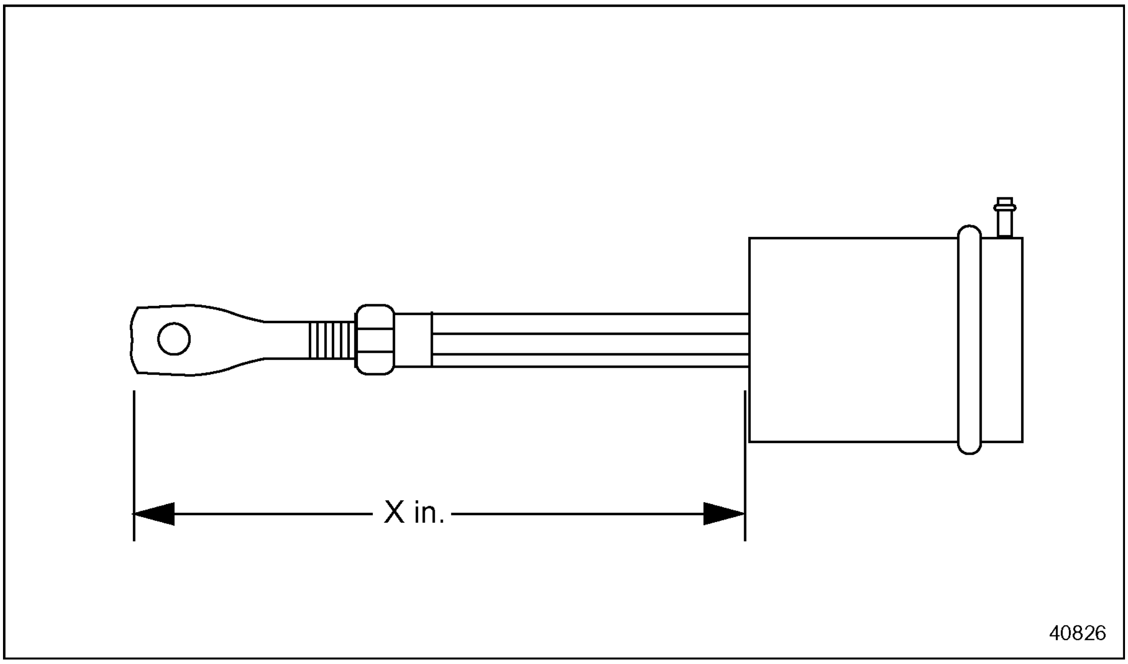


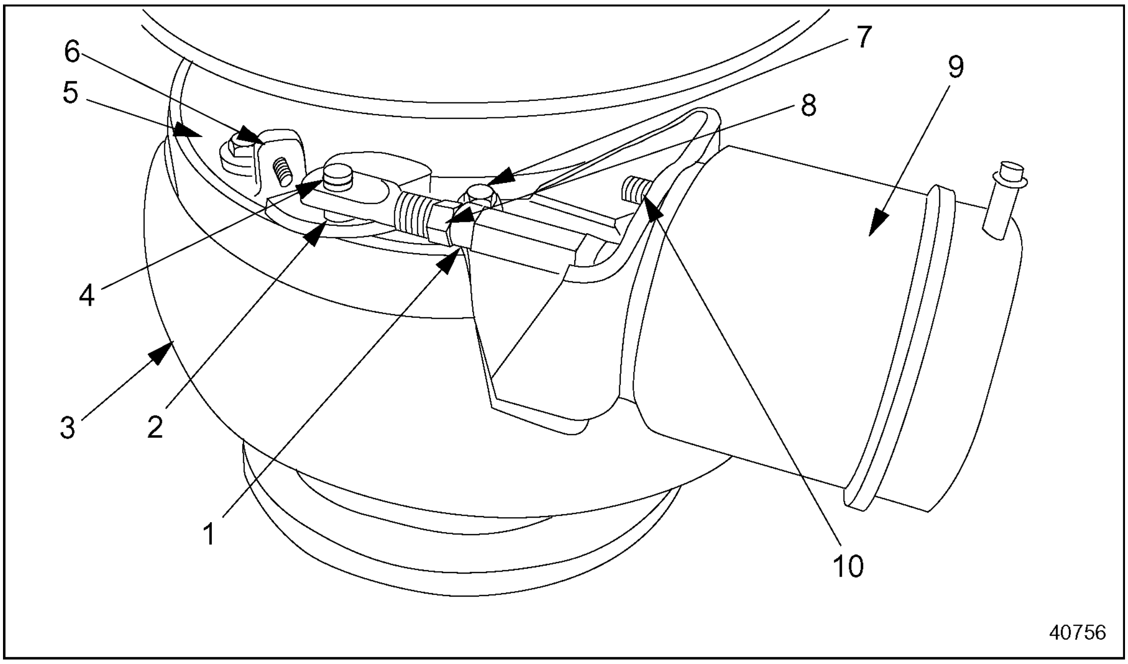
Figure 6-26 Measurement of the Rod End to Actuator Can Base

9. Remove the locknut and adjustable rod end assembly from the threaded actuator rod; save locknut for installation of the replacement actuator.

6.5.9 Installation and Calibration of VNT Actuator

For engines equipped with a VNT actuator, install and calibrate as follows:

1. Assemble the replacement actuator to the bracket, installing the three locknuts and torque to 6–7 N·m (55–70 lb·in.). See Figure 6-27.



1. Adjustable Rod End Assembly
2. External Arm Pin
3. Turbocharger
4. Retaining Ring (not shown)
5. Turbine Housing Bolt Circle
6. Stop and Stop Screw
7. Bracket Bolt (3)
8. Adjusting Arm Locknut
9. VNT Actuator
10. Actuator Mounting Stud and Nut (3)

Figure 6-27 VNT Actuator

2. Install the adjustable rod end assembly with locknut loosely on to the threaded actuator rod at the same distance as measured in step 8. Refer to section 6.5.8.
3. Attach the air hose from the pressure regulator to the fitting. Apply approximately 20–25 psig pressure to the actuator. See Figure 6-27.
4. Rotate the external arm pin while fitting the rod end over the pin.
5. Install the three, 12–point bracket mounting bolts and torque to 20–23 N·m (185–210 lb·in.). See Figure 6-27.

CAUTION:

To avoid injury, wear a face shield or goggles.

6. Using a Waldes Tru-Arc #5304 Klip Ring tool, install retaining clip.
7. Gradually increase the pressure to the actuator to 75 psig minimum pressure. The actuator rod should extend approximately a half-inch and be at, or near, the minimum stop (adjustable screw and locknut, with blue “tattle-tale” paint).

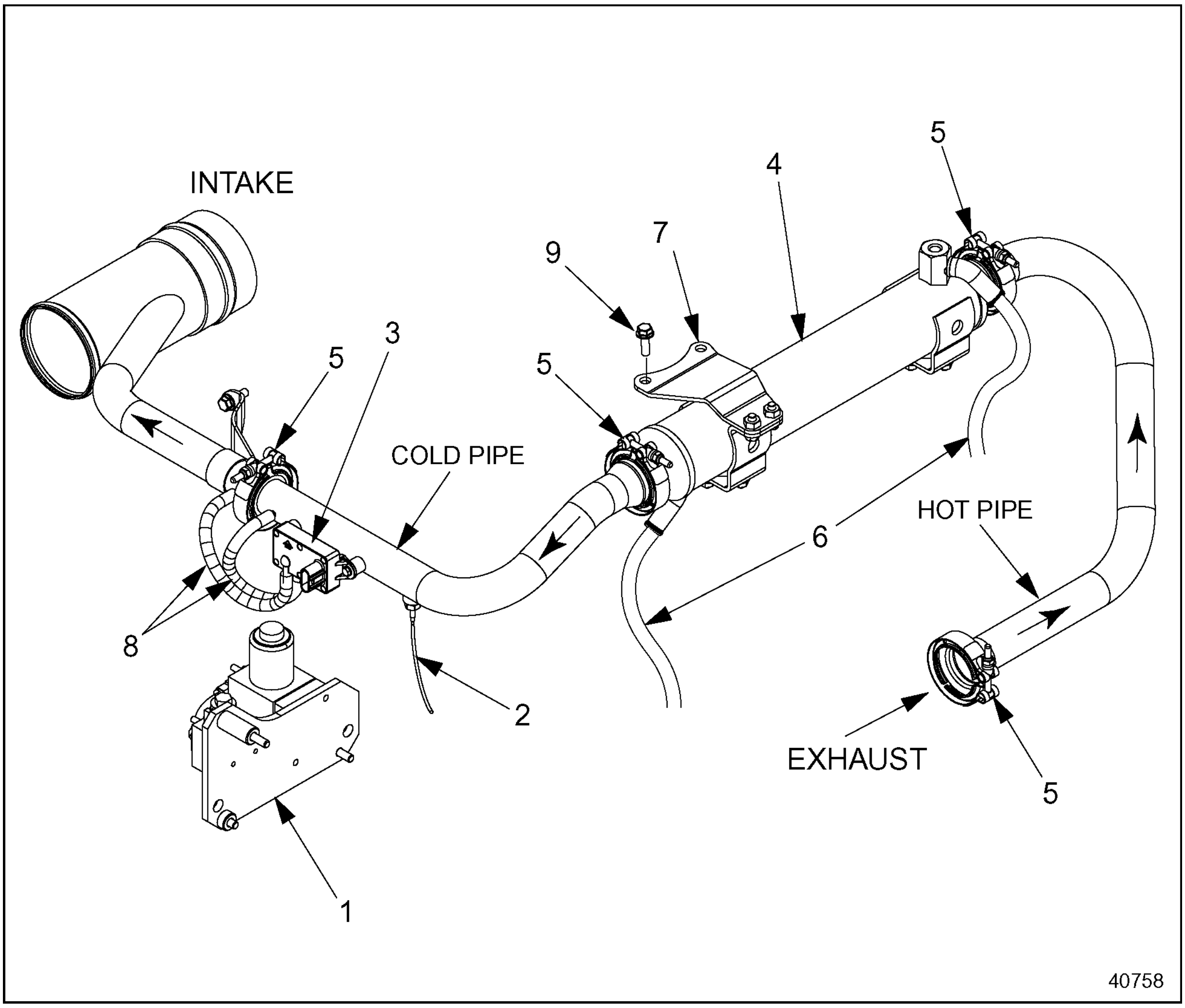
NOTE:
The adjustable stop screw and locknut has been preset at the factory and sealed with a special paint. Under NO circumstances should this stop be readjusted in the field.

8. Reduce pressure to a value between 62.7–63.3 psig. Allow pressure to stabilize and readjust as required.
   - [a] If the external arm is not touching the end of the stop screw, rotate the adjuster body until contact is made.
   - [b] If the external arm is touching the end of the stop screw, rotate the adjuster body until clearance is obtained and then rotate in the reverse direction until contact with the end of the stop screw is made as in step 8[a].
9. Without rotating the adjuster body, torque the adjuster locknuts to 6–7 N·m (55–70 lb·in.).
10. Reduce pressure to zero and check for proper operation. Slowly changing pressure from approximately zero to 65 psig should cycle the actuator from the maximum to the minimum stop.
11. Cycle a few times until satisfied that the rod position at minimum stop has been satisfactorily set and the actuator is stroking from one stop to the other.
12. Remove the compressor inlet cover.
13. Install turbocharger on the engine. Refer to section 6.5.7.

6.5.10 Removal of EGR Cooler and Piping Assembly

For engines equipped with the EGR cooler, remove as follows:

1. Drain coolant. Refer to section 13.5.4 or you may clamp off coolant hoses with vice-grips.
2. Remove clamp from each end of the EGR cooler assembly. See Figure 6-28.



1. PWM Valve Assembly
2. EGR Temperature Sensor
3. EGR Pressure Sensor
4. EGR Cooler
5. Clamp(s)
6. Coolant Line(s)
7. Bracket
8. Pressure Sensor Connection/Hoses
9. Bolts

Figure 6-28 EGR Cooler

3. Disconnect coolant lines.
4. Remove bracket attaching bolts.
5. Remove EGR cooler.
6. Loosen the clamp on the other end of the cold pipe.
7. Disconnect pressure sensor connection and hoses.
8. Disconnect temperature sensor connection.
9. Remove the cold pipe.
10. Loosen the clamp on the other end of the hot pipe.
11. Remove the hot pipe.

6.5.10.1 Inspection of the EGR Cooler and Piping Assembly

Inspect the EGR cooler as follows:

1. Examine flanges for corrosion.
   [a] If corroded, bent or damaged, replace the EGR cooler.
   [b] If no damage found, reuse component.
2. Test EGR cooler for leakage as follows:
   [a] Plug one end of the coolant connection.

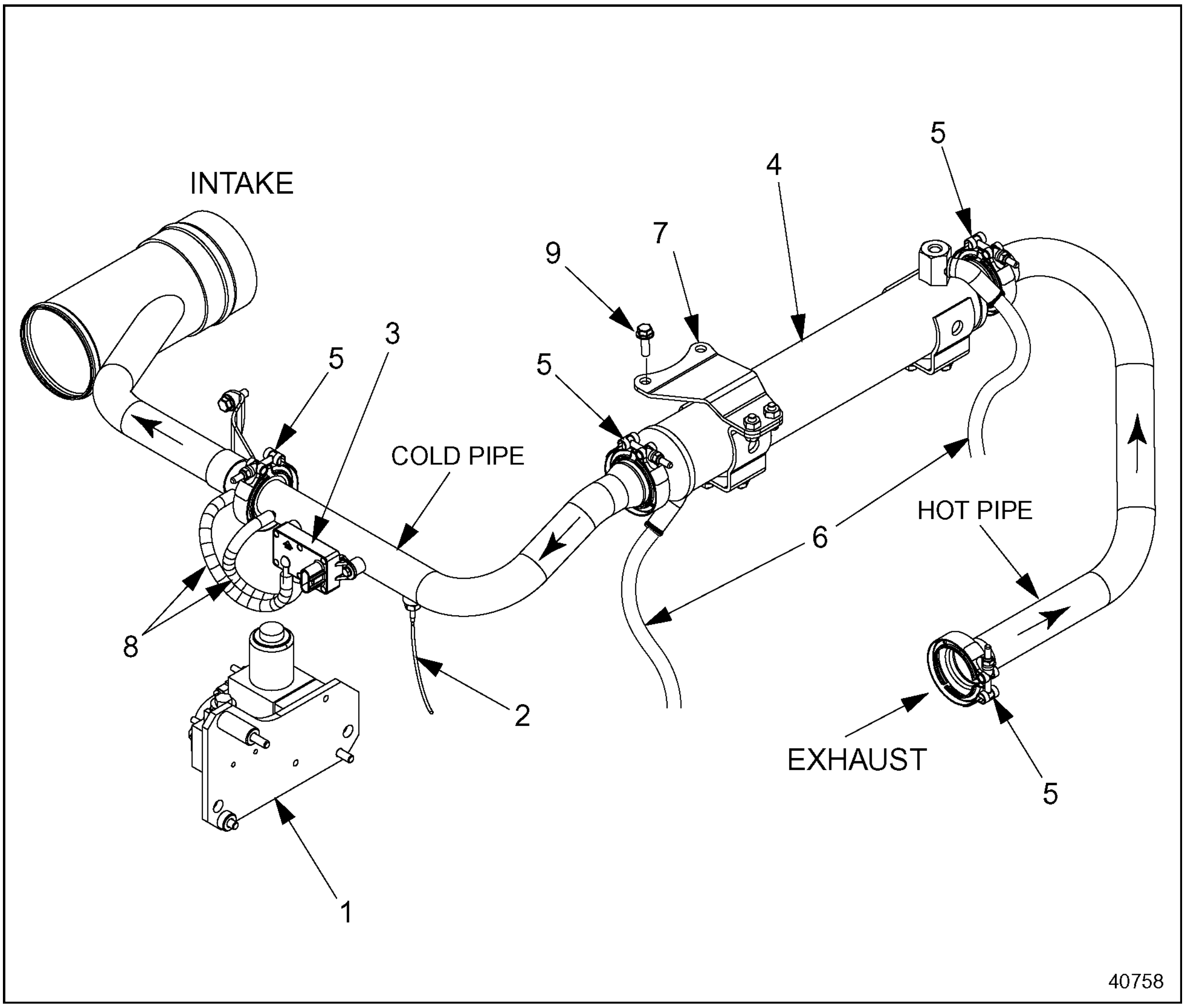
CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

   [b] Apply air pressure, maximum of 15 psi.
   [c] Listen for leakage, or immerse into a tank of water to view for any bubbles. If any bubbles appear, replace the cooler.
3. Inspect the cold pipe for damage.
   [a] If the cold pipe is cracked, corroded or damaged; replace the pipe.
   [b] If no damage was found on the cold pipe; reuse the pipe.
4. Inspect the hot pipe for damage.
   [a] If the hot pipe is cracked, corroded or damaged; replace the pipe.
   [b] If no damage was found on the hot pipe; reuse the pipe.

6.5.11 Installation of the EGR Cooler and Piping Assembly

Install the EGR cooler as follows: (See Figure 6-29.)



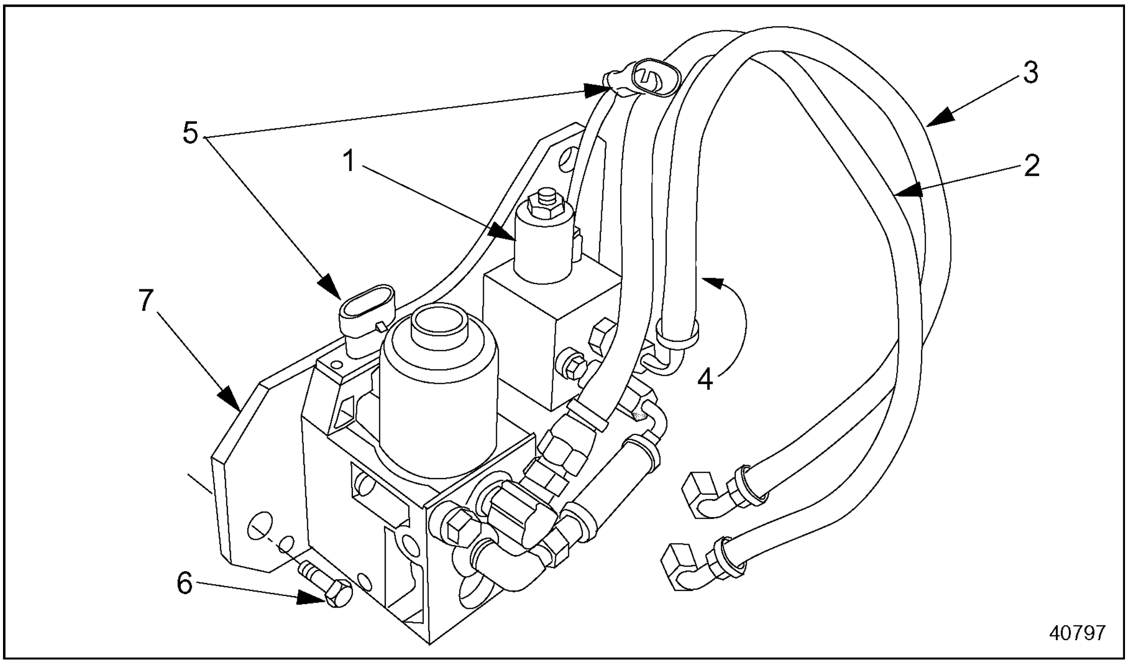
1. PWM Valve Assembly
2. EGR Temperature Sensor
3. EGR Pressure Sensor
4. EGR Cooler
5. Clamp(s)
6. Coolant Line(s)
7. Bracket
8. Pressure Sensor Connection/Hoses
9. Bolts

Figure 6-29 EGR Cooler

1. Connect temperature sensor connection.
2. Connect pressure sensor connection and hoses.
3. Loosely assemble clamp on the intake end of the cold pipe.
4. Loosely assemble the clamp on the turbo end of the hot pipe.
5. Fit EGR cooler to the engine, loosely assemble both clamps on each end of the EGR cooler.
6. Tighten EGR cooler clamps.
7. Tighten bolts on clamp to the turbocharger.
8. Tighten clamp on the cold pipe to the intake.
9. Torque bolts from bracket to cooler at 30–38 N·m (22–28 lb·ft).
10. Torque bolts from bracket to engine at 58–73 N·m (42–53 lb·ft).
11. Connect coolant lines.
12. Fill with coolant. Refer to section 13.5.4. Remove vice-grips, if used.
13. Refer to section 11.1.3 for verification of proper EGR cooler installation.

6.5.12 Removal of PWM Valve Assembly

Remove the pulse width modulated (PWM) assembly as follows: (See Figure 6-30.)



1. EGR Solenoid
2. PWM Valve Air Line
3. EGR Solenoid Air Line
4. Air Supply Air Line (hidden)
5. Electrical Connectors
6. Bolt
7. Bracket

Figure 6-30 PWM Valve Assembly

1. Disconnect the PWM valve air line to the VNT actuator.
2. Disconnect the EGR solenoid air line to the EGR actuator.
3. Disconnect the air supply air line.
4. Disconnect both electrical connectors.
5. Remove the two bolts that hold the bracket to the cylinder block.

NOTICE:
When removing the PWM valve assembly, take care not to damage the engine harness.

6. Remove the PWM valve assembly.

6.5.13 Installation of PWM Valve Assembly

Install the PWM assembly as follows: (See Figure 6-30.)

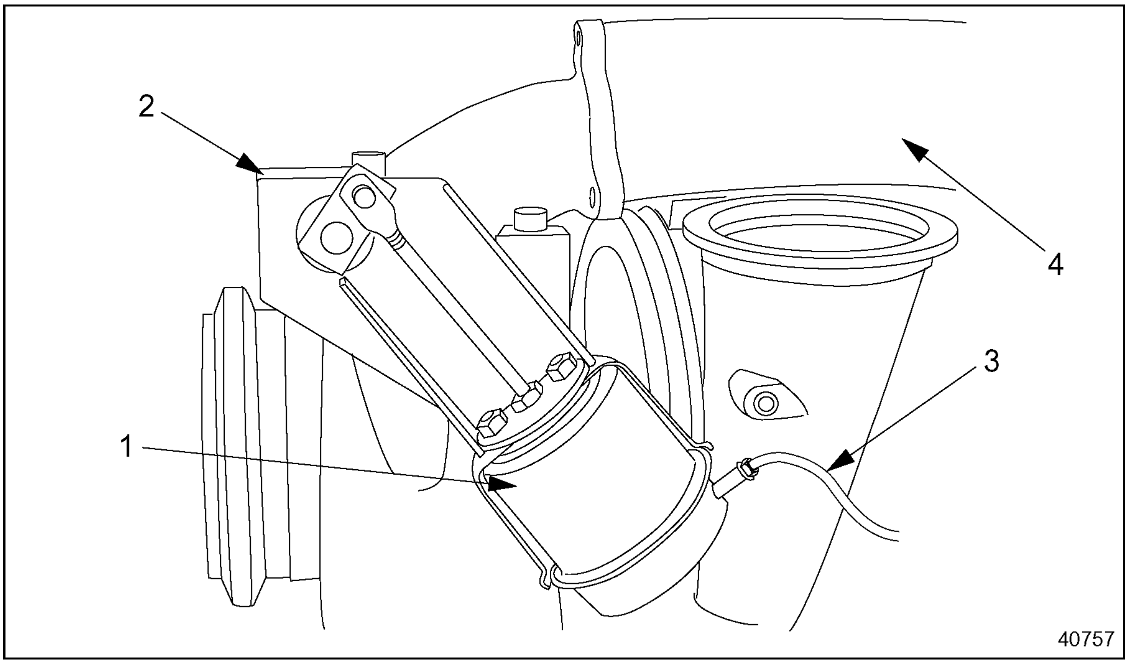
1. Install the two bolts that hold the bracket to the cylinder block.
2. Connect both electrical connectors.
3. Connect the air supply air line.
4. Connect the EGR solenoid air line to the EGR actuator.
5. Connect the PWM valve air line to the VNT actuator.

6.5.14 Removal of EGR Valve Assembly

The EGR valve assembly includes the EGR valve and actuator. It is only serviced as a complete assembly. The EGR valve actuator rod is preset at the factory and should not be altered in the field.

For engines equipped with the EGR Valve Assembly, remove as follows:

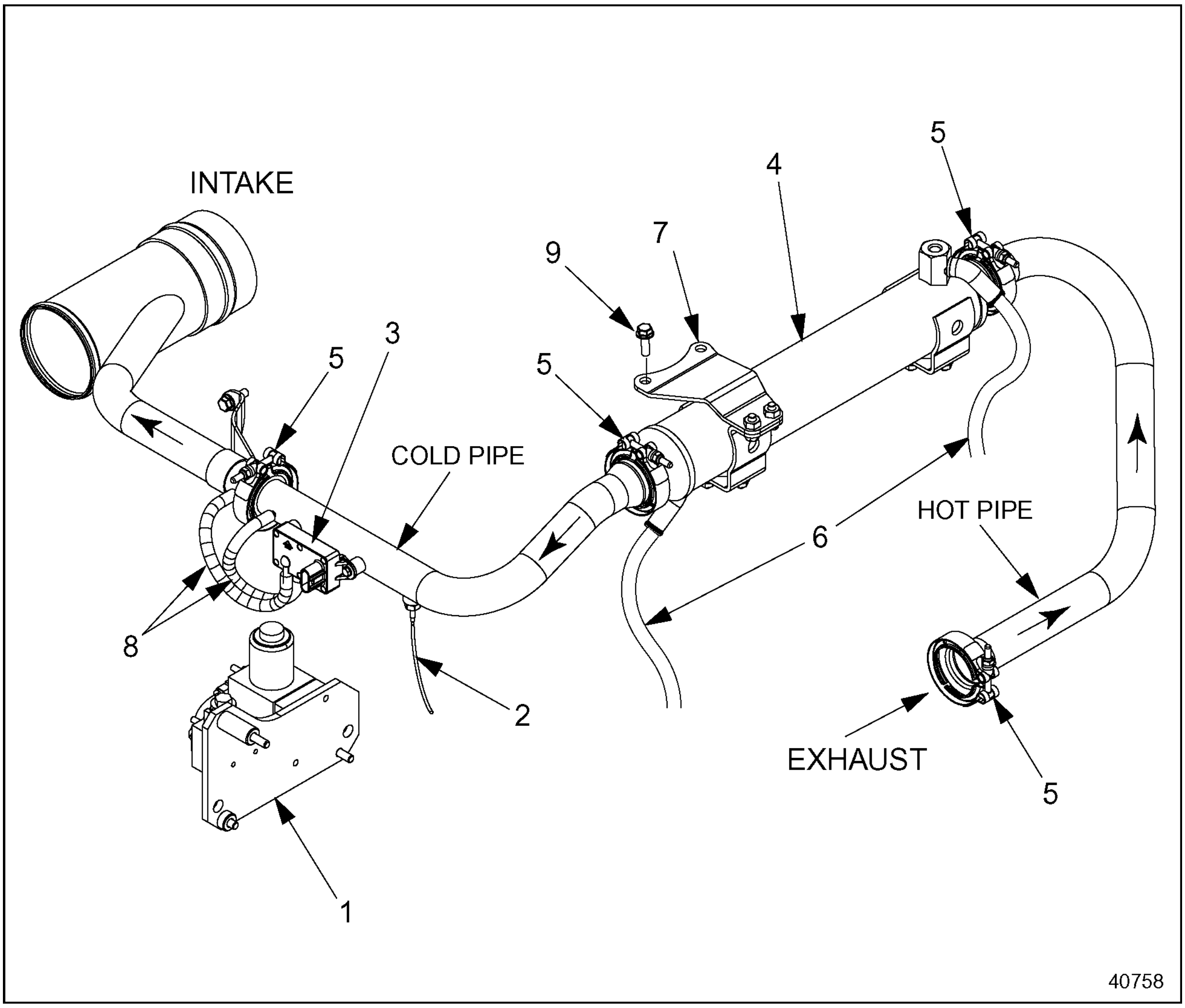
1. Disconnect the air supply line to actuator. See Figure 6-15.



1. EGR Actuator
2. Bracket
3. Pressure Line
4. Hot Pipe

Figure 6-31 EGR Valve Assembly

2. Remove the coupling from EGR housing to “hot” pipe leading to the EGR cooler. See Figure 6-32.



1. PWM Valve Assembly
2. EGR Temperature Sensor
3. EGR Pressure Sensor
4. EGR Cooler
5. Clamp(s)
6. Coolant Line(s)
7. Bracket
8. Pressure Sensor Connection/Hoses
9. Bolts

Figure 6-32 EGR Valve and Piping Assemblies

3. Apply approximately 60 psig air pressure to the actuator to remove spring tension.
4. Remove the five, 12–point headed EGR housing bolts.

NOTE:
Penetrating oil may be needed to facilitate removal.

5. Remove EGR housing assembly.

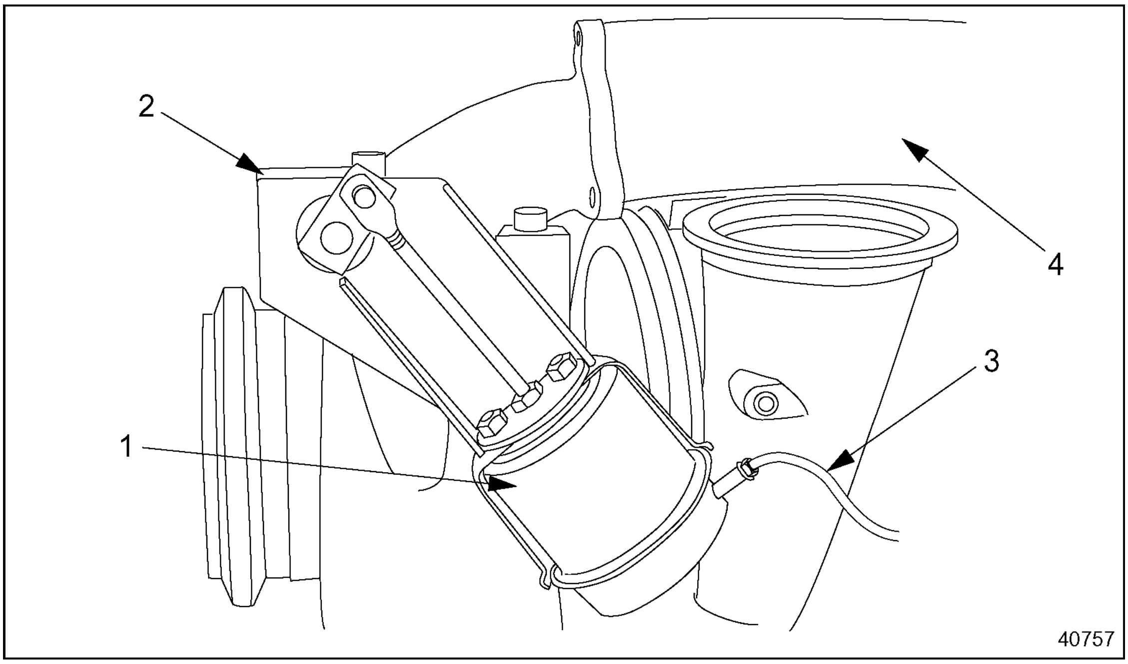
6.5.15 Installation of EGR Valve Assembly

For engines equipped with an EGR valve assembly, install as follows:

1. Clean the mounting surface prior to installing the replacement EGR valve assembly.

NOTE:
No gasket or sealing compound is used between the EGR housing and the turbine housing.

2. Apply approximately 60 psig air pressure to the actuator to remove spring tension.
3. Install replacement assembly and torque the five attachment bolts to 20–23 N·m (185–210 lb·in.). See Figure 6-33.



1. EGR Actuator
2. Bracket
3. Pressure Line
4. Hot Pipe

Figure 6-33 EGR Actuator

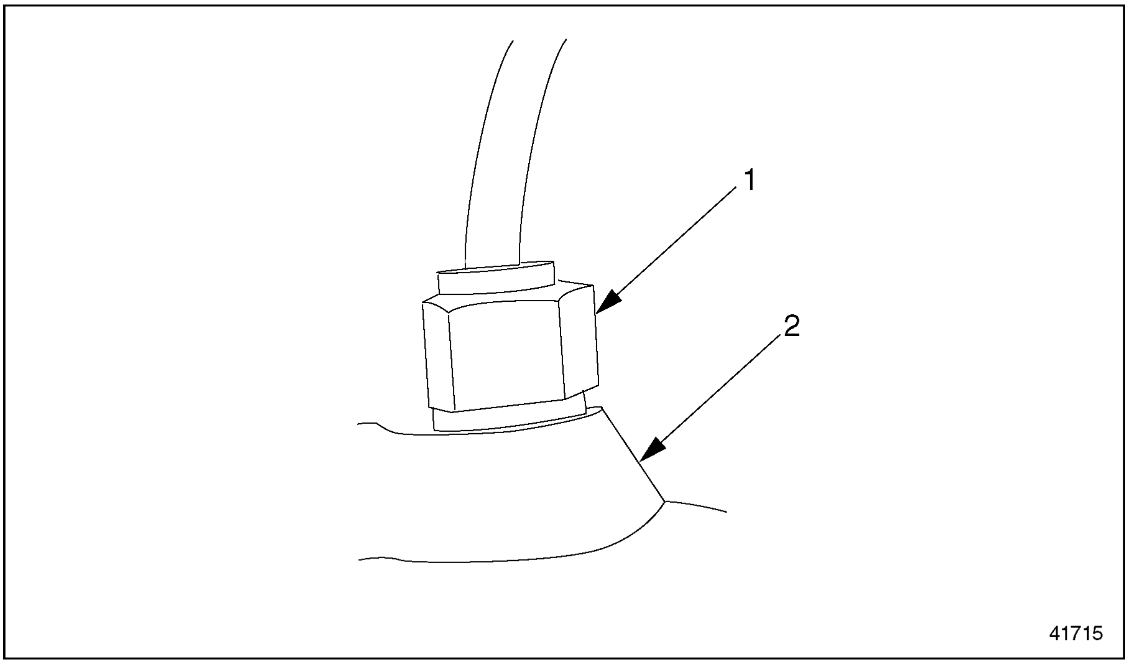
4. Check function of new EGR valve by connecting a regulated source of compressed air to the actuator fitting. A minimum pressure of approximately 41 psig is required to start opening the valve arm. A pressure of approximately 72 psig is required for full stroke.
5. Connect the pressure line to the actuator and the “hot” pipe to the EGR housing outlet.

6.5.16 Removal of the Speed Sensor

Remove the turbocharger speed sensor from the turbocharger as follows:

NOTE:
If the turbocharger speed sensor is difficult to access, removal of the turbocharger may be required. Refer to section6.5.2.

1. Clean the center housing area around the base of the speed sensor. See Figure 6-34.

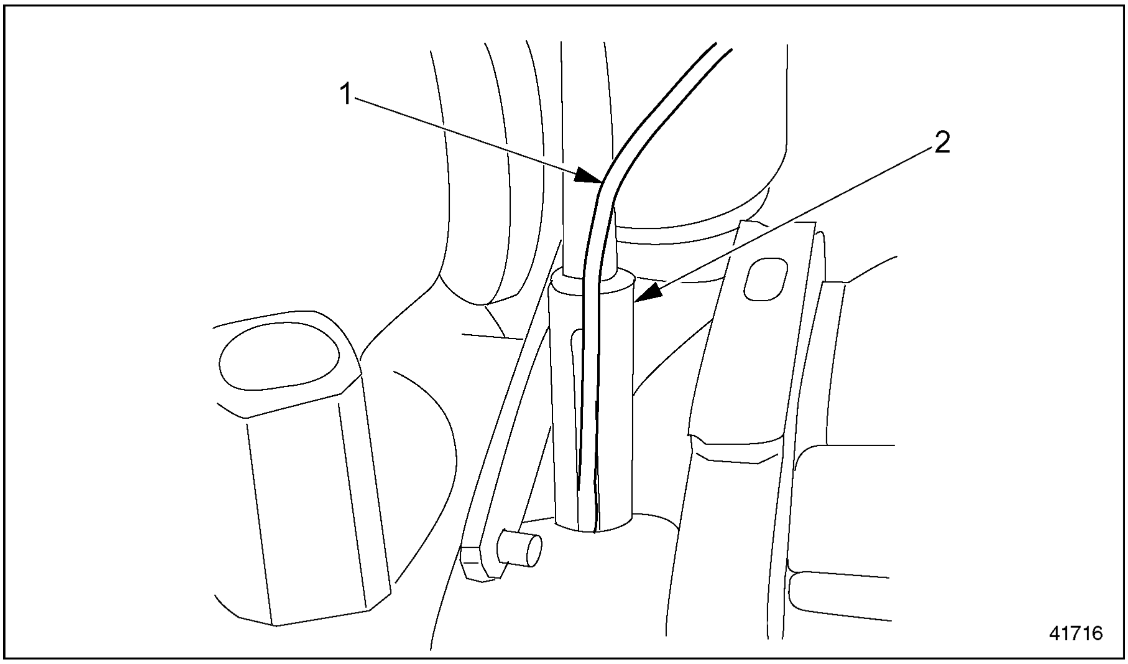


1. Turbocharger Speed Sensor
2. Center Housing

Figure 6-34 Location of Speed Sensor

2. Remove 12–point bracket bolt in line with the speed sensor.

3. Place turbocharger speed sensor socket J 45643 on speed sensor while threading the lead wire through the slot in the side. See Figure 6-35.

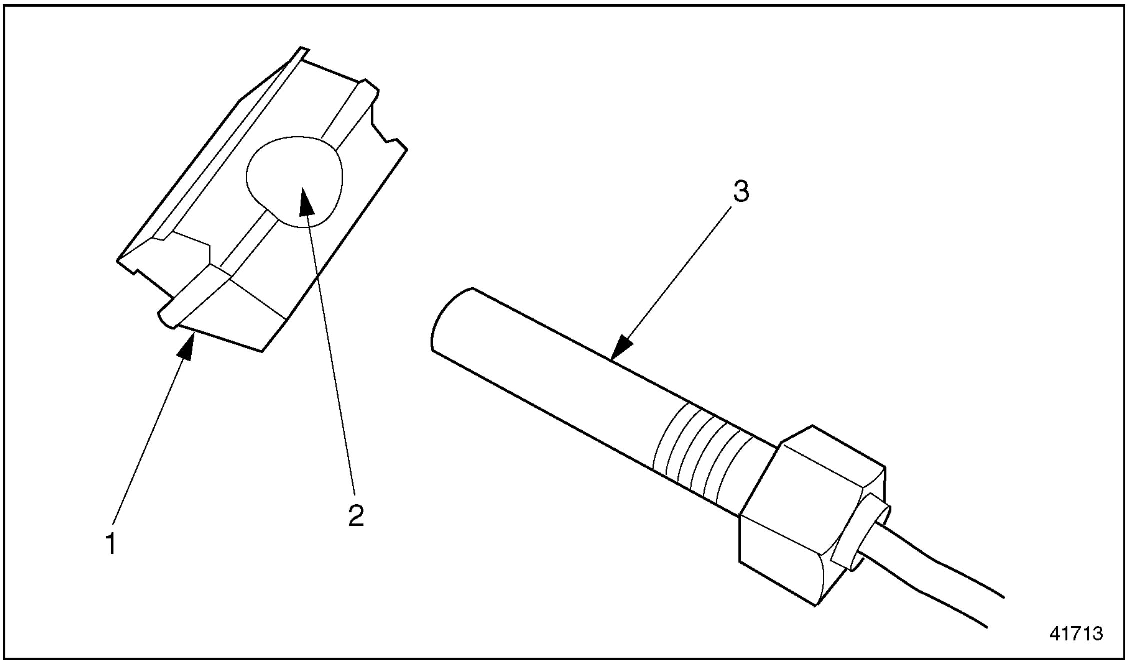


1. Sensor Lead Wire
2. Turbocharger Speed Sensor Socket

Figure 6-35 Installation of Turbocharger Speed Sensor Socket

NOTICE:

Ensure the turbocharger shaft is secured and not rotated when the turbocharger speed sensor is removed from the bearing spacer. Turning the shaft without the sensor in place can rotate the bearing spacer. If the sensor is not properly positioned in the opening of the bearing spacer, see Figure 6-36, the sensor and turbocharger bearings will be damaged during sensor installation.



1. Bearing Spacer
2. Through Hole of Spacer
3. Turbocharger Speed Sensor

Figure 6-36 Turbocharger Speed Sensor Position

4. Loosen and remove the sensor while avoiding excessive pulling, bending, or twisting of the sensor lead wire.

6.5.17 Installation of the Speed Sensor

Install the turbocharger speed sensor in the center housing as follows:

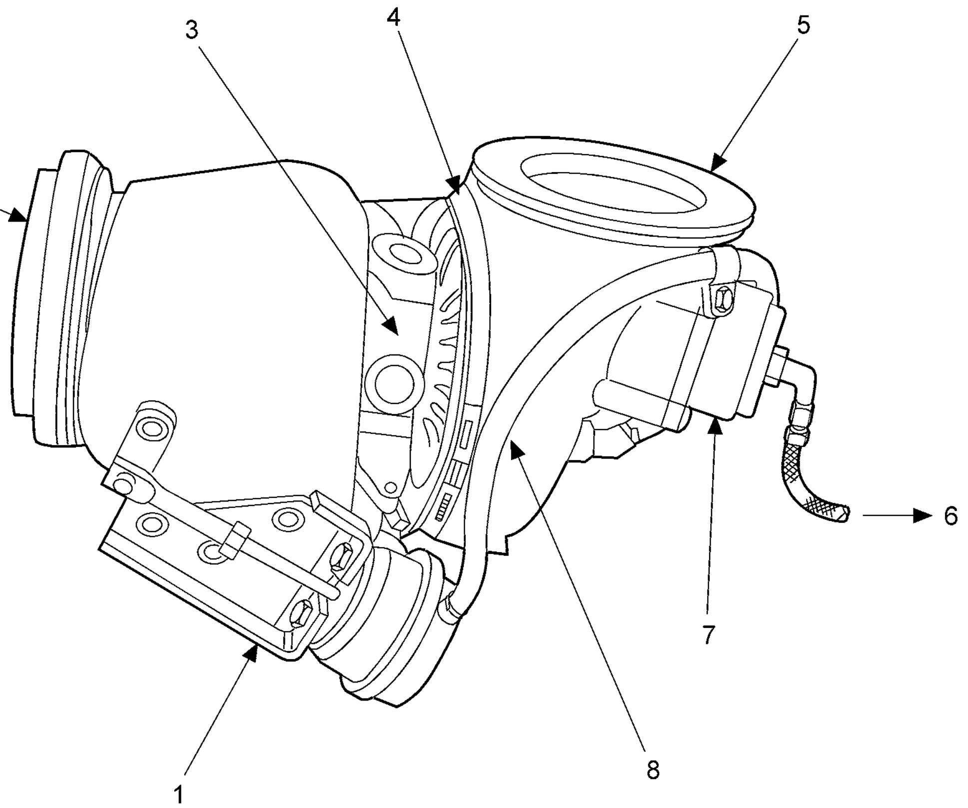
1. Place the turbocharger speed sensor socket J 45643 over the head of the turbocharger speed sensor with the lead wire through the slot on the side of the socket.
2. Inspect the threaded hole for the speed sensor and ensure the hole in the bearing spacer is aligned and the rotor shaft is visible.
3. Manually insert the turbocharger speed sensor into the threaded hole of the center housing wall. Turn the sensor until the sealing lip on the underside of the sensor seats against the flat on the center housing and the sensor is finger tight.
4. Turn the turbocharger rotor to ensure it spins freely with minimal resistance. If binding occurs, repeat speed sensor installation.

NOTICE:
Ensure the turbocharger rotor turns freely. If the shaft binds, the speed sensor is not aligned with the bearing spacer and damage can occur to the shaft and speed sensor.

5. Tighten the speed sensor to 10–11 N·m (90–100 lb·in.) torque.
6. Install the 12–point bracket bolt in line with the speed sensor. Tighten the bolt to 20–23 N·m (185–210 lb·in.) torque.

6.6 TURBOCHARGER SERIES 50 GAS

The Garrett (formerly Airesearch) GT 35 turbocharger is used on all Series 50G engines. See Figure 6-37.



1. Wastegate Actuator
2. Turbine Housing
3. Water-Cooled Center Housing Rotating Assembly (CHRA)
4. Bolted Joints
5. Compressor Housing
6. Braided Line to Intake Manifold
7. Compressor Recirculation Valve
8. Actuator Hose

Figure 6-37 GT 35 Turbocharger Assembly (Coach)

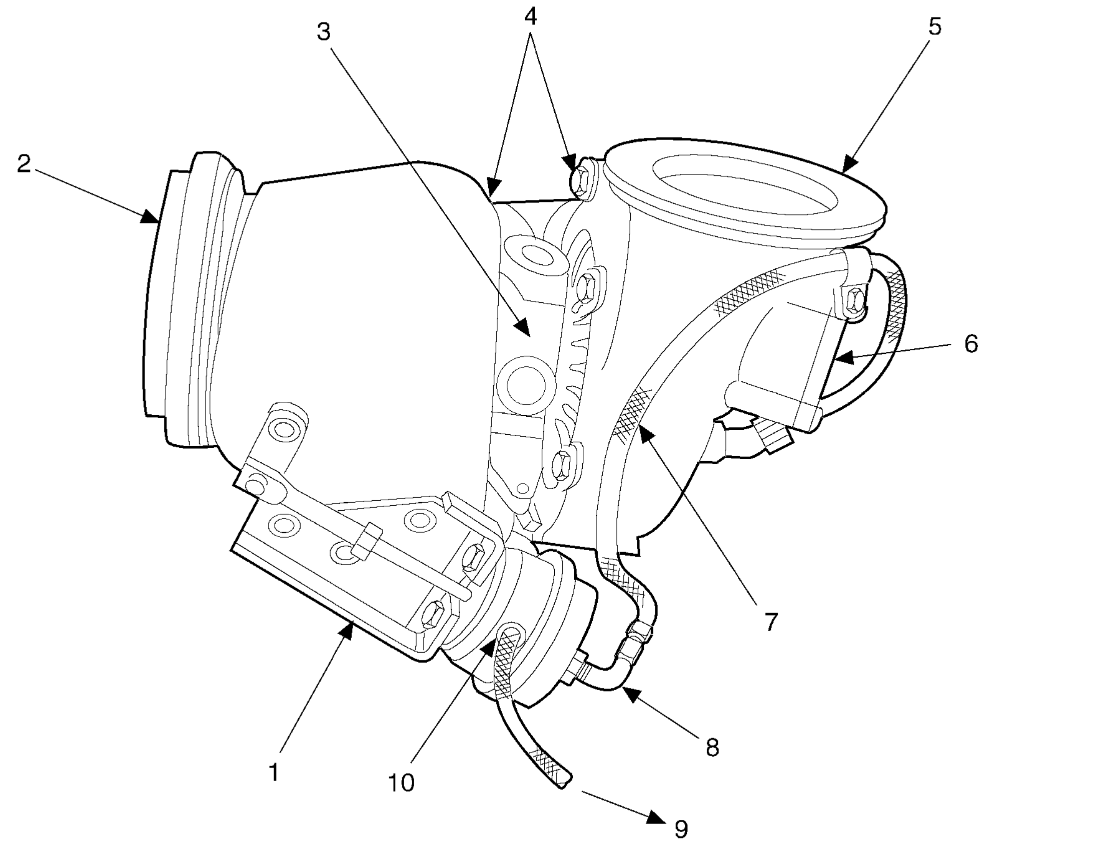
The turbocharger is designed to increase the overall power and efficiency of the engine. Power to drive the turbocharger is extracted from the energy in the engine exhaust gas.

The CHRA consists of a turbine wheel and shaft, a compressor wheel, and a center housing that serves to support the rotating assembly, bearings, seals, a turbine housing, and a compressor housing. The center housing has connections for oil inlet, oil outlet, water inlet and water outlet fittings.

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel, and wheel retaining nut. The rotating assembly is supported on two pressure-lubricated bearings that 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. Internal water passages provide cooling and subsequent protection against oil cooking in the housing.

The turbine housing is a heat-resistant alloy casting that encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing. An internal turbine bypass valve, commonly called a wastegate, allows exhaust gas to flow around the turbine wheel. This provides control over the maximum boost pressure.

The wastegate is controlled with a pneumatic actuator mounted on the side of the turbine housing. The Series 50G coach engine turbocharger has an actuator with a single hose port on the top side of the actuator can with a silicon hose that runs to a port on the compressor cover. The Series 50G Genset engine turbocharger is equipped with threaded ports on both the top and bottom sides of the can. Braided steel lines connect to these ports; the top port line is run to a port on the compressor outlet, while the bottom port line is run to the fuel mixer housing. See Figure 6-38 for Genset configuration. Air pressure from the compressor outlet is fed through the line to the top side of the actuator, which opens the wastegate valve at a specified pressure. To prevent natural gas from leaking into the atmosphere, the bottom port on the Genset actuator serves only as a safety return to the mixer housing, in case of an actuator diaphragm failure.



1. Wastegate Actuator
2. Turbine Housing
3. Water-Cooled Center Housing Rotating Assembly (CHRA)
4. Bolted Joints
5. Compressor Housing
6. Bypass Port Cover
7. Braided Line to Compressor Housing
8. #4 Threaded Top Port
9. Braided Line to Fuel Mixer Housing
10. #3 Threaded Bottom Port

Figure 6-38 GT 35 Turbocharger Assembly (Genset)

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flow from the engine and through the turbine housing causing the turbine wheel and shaft to rotate. See Figure 6-39.

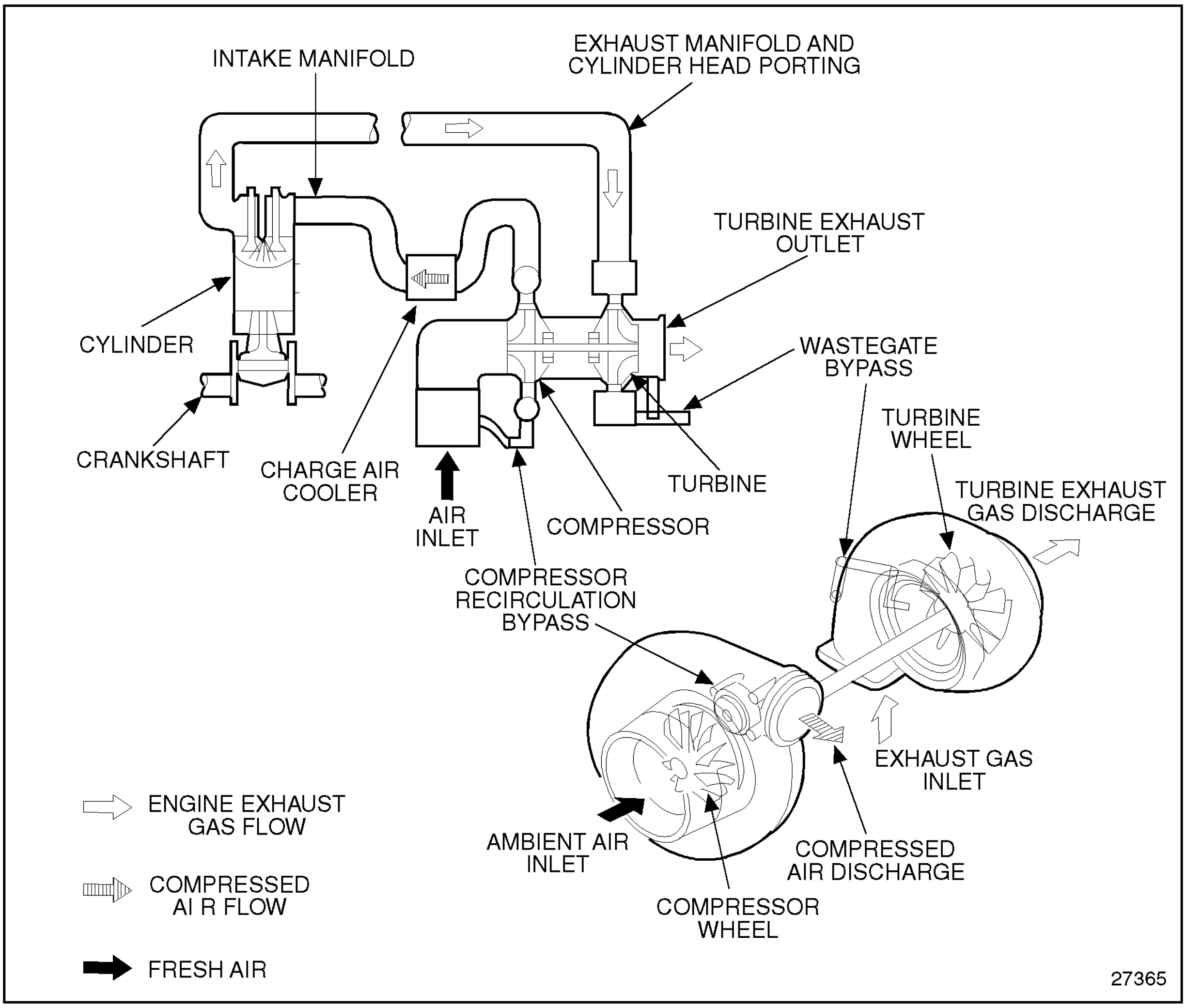
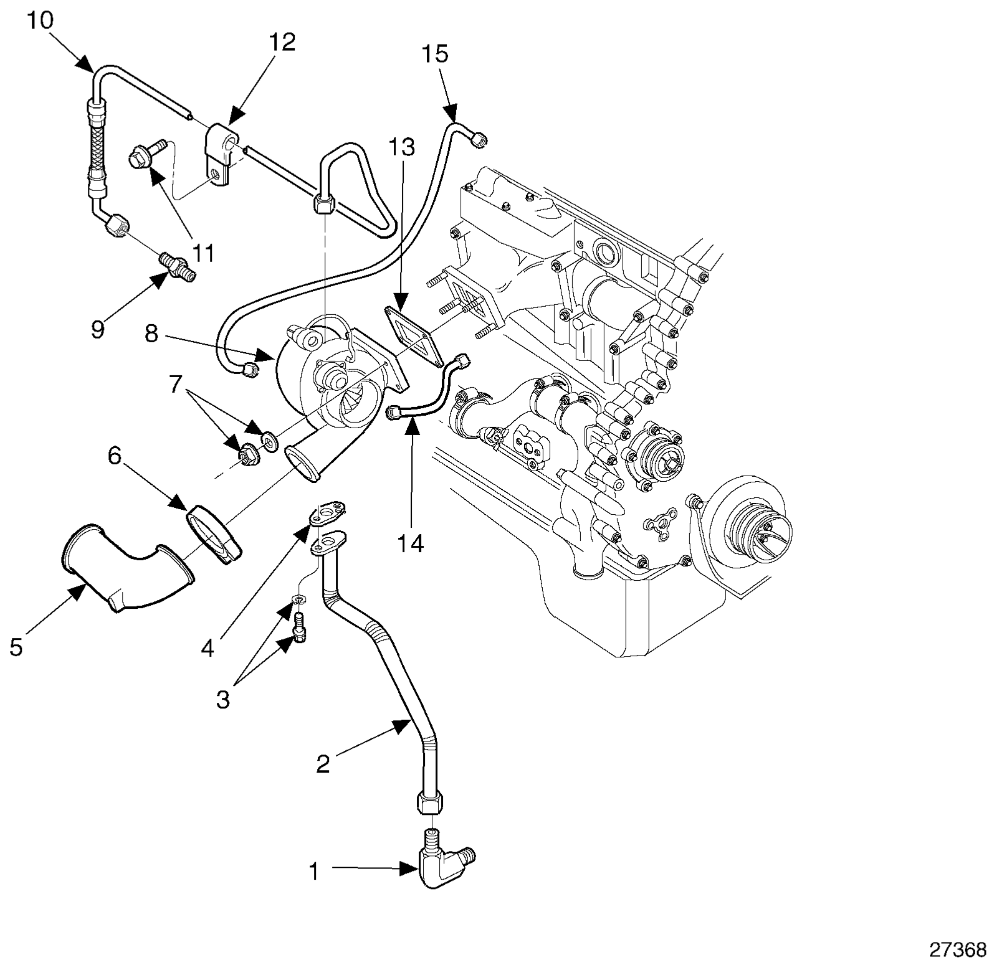


Figure 6-39 Schematic Air Flow Diagram (Series 50G)

The gases are discharged into the exhaust system after passing through the turbine housing. On automotive engines, an oxygen sensor and exhaust temperature sensor are installed within 12 inches of the turbocharger turbine outlet. A harness connects the sensors to the ECM.

The compressor wheel, in the compressor housing, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in clean air, compresses it, and delivers high pressure air through the intake manifold to the engine cylinders. The compressor housing (on the coach version only) also contains a bypass valve, referred to as a compressor recirculation valve. This valve relieves compressor boost during a rapid deceleration of the engine. The Genset turbo does not have a valve installed; a cover plate seals these passages on the compressor housing. See Figure 6-38.

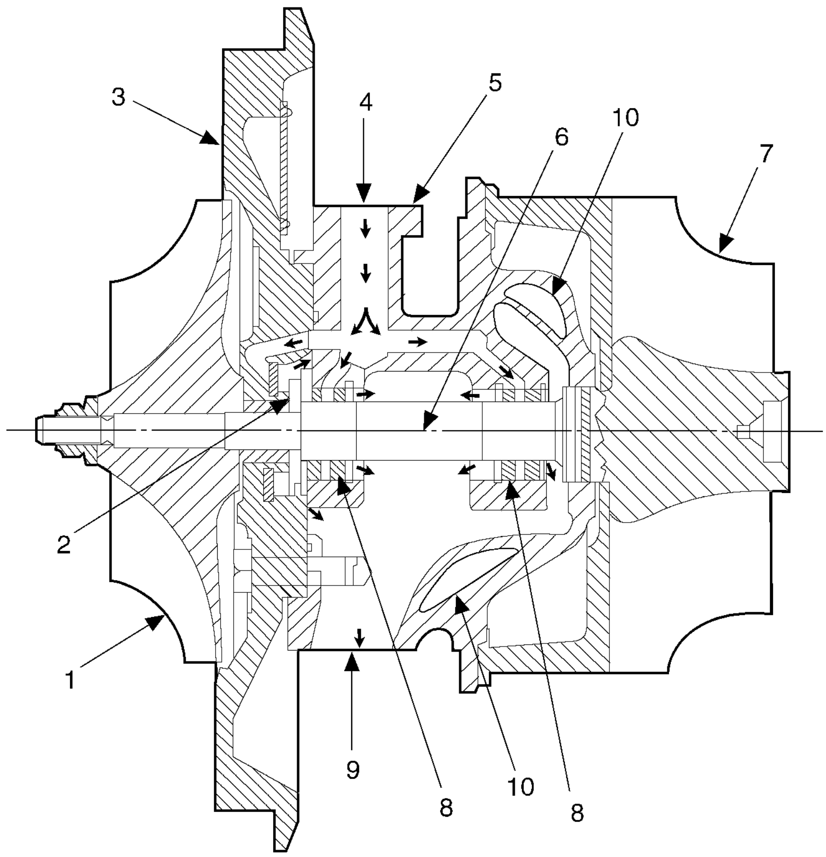
Oil for lubricating the turbocharger is supplied under pressure through an external oil line extending from the oil filter adaptor to the top of the center housing. Water for cooling the bearing housing is supplied from the oil cooler, and is returned to the top of the thermostat housing. See Figure 6-40.



1. Elbow, Oil Drain Tube
2. Tube, Turbo Oil Drain
3. Bolt, and Lockwashers, Oil Drain Tube Mounting
4. Gasket, Oil Drain Tube
5. Elbow
6. Clamp
7. Nut, and Washer Turbo Mounting
8. Turbocharger Assembly
9. Connector, Oil Supply Tube (from oil filter adaptor)
10. Tube Assembly, Turbo Oil Supply
11. Bolt, Oil Supply Tube Clip
12. Clip, Oil Supply Tube
13. Gasket, Turbo Exhaust Inlet
14. Water Supply Line
15. Water Return Line

Figure 6-40 Turbocharger Oil/Water Lines Series 50 Gas

From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing, and backplate or thrust plate. See Figure 6-41.



1. Compressor Wheel
2. Thrust Bearing
3. Backplate
4. Oil Inlet
5. Center Housing
6. Shaft
7. Turbine Wheel
8. Shaft Bearings
9. Oil Outlet
10. Water passages

Figure 6-41 Turbocharger Oil Flow Diagram (Series 50G)

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. Water flows through the bearing housing in a U-shape flow path, removing heat generated by the hot exhaust gas in the turbine.

6.6.1 Repair or Replacement of Turbocharger (Series 50 Gas)

To determine if repair is possible or replacement of the turbocharger is necessary perform the following procedure. See Figure 6-42.

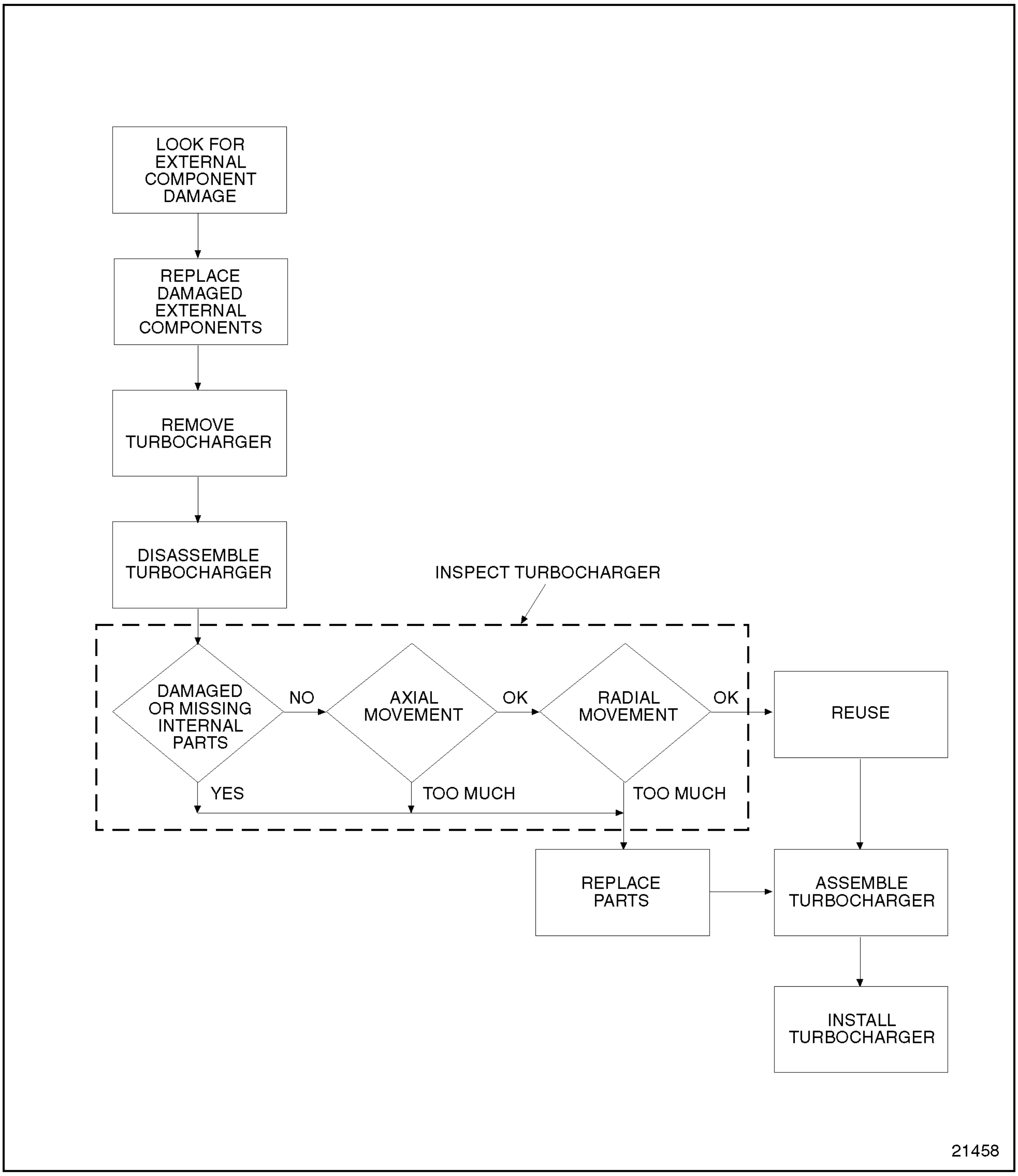


Figure 6-42 Flowchart for Repair or Replacement of Turbocharger (Series 50 Gas)

6.6.2 Cleaning and Removal of Turbocharger (Series 50G)

Cleaning the turbocharger is not necessary before removal.

CAUTION:

To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil supply and drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage.
6. Damaged water supply and return lines.
7. Damaged recirculation valve line.
8. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

NOTICE:

Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup.

1. Disconnect and remove the CAC ducting at the compressor housing.
2. Disconnect and remove the air inlet hose attached to the compressor housing.
3. Disconnect the exhaust outlet pipe from the turbine housing of the turbocharger. For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.
4. Remove the inlet oil line from the top of the center housing.
5. Remove the oil drain line from the bottom of the center housing.

NOTICE:
Be sure to drain coolant before removing water lines from bearing housing.

6. Remove water lines from bearing housing.
7. Remove recirc valve line (Coach only).
8. Remove actuator return line on bottom port of actuator.
9. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
10. Remove the nuts securing the turbocharger assembly to the exhaust manifold. Then, lift the turbocharger assembly away from the engine and place it on a bench.
11. Cover the end of the oil drain line, the oil outlet line, water supply, water return, the air inlet and the exhaust outlet openings on the engine and turbocharger to prevent the entry of foreign material.

CAUTION:
To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

12. Clean the exterior of the turbocharger with a non-caustic cleaning solvent before disassembly.

6.6.3 Disassembly of Turbochargers (50G)

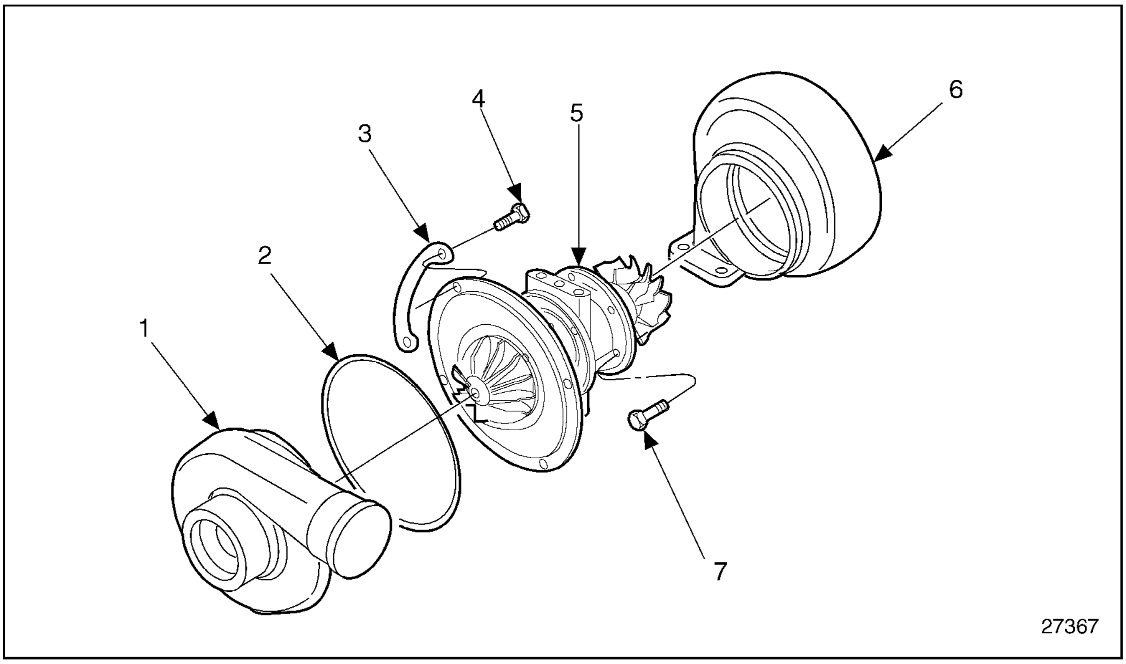
Disassemble the turbocharger as follows:

1. Mark the related positions of the compressor housing, center housing and turbine house with a punch or scribe to assure reassembly in the same relative position.

NOTICE:
Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen and remove the bolts and retaining clamps securing the compressor housing to the backplate assembly and remove the compressor housing.

3. Loosen and remove the bolts securing the turbine housing to the center housing. See Figure 6-43.



1. Compressor Housing
2. O-ring
3. Retaining clamp (compressor housing)
4. Bolt (compressor housing)
5. Center Housing Rotating Assembly (CHRA)
6. Turbine housing
7. Bolt (turbine housing)

Figure 6-43 Series GT 35 Turbocharger (50G)

4. Remove the turbine housing from the center housing.

6.6.3.1 Inspection and Cleaning of Turbocharger (Series 50G)

Damage can result from a contaminated exhaust system. Any debris left in the exhaust system after service work can fall back into the exhaust wheel. If large enough, these particles may cause turbine wheel damage at initial engine startup. The exhaust manifold and exhaust piping attached to the turbocharger should also be inspected for debris and cleaned, if necessary, before being installed.

Any time the charge air cooler is removed, all charge air cooling system components *must* be inspected to make sure they are clean and free of any casting slag, core sand, welding slag, or any other contaminants that could break free during engine operation and damage the turbine wheel.

Inspect the disassembled turbocharger, discarding any damaged parts, in the following manner:

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.

3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.
4. Check actuator can for external damage.
5. Check actuator pressure setting; refer to Section 6.6.7.
6. Check compressor cover recirculation valve (coach only).
7. Visually check wastegate lever arm, valves, and ports. Make sure the ports are completely covered by the valves.
8. Check the bearing axial end play:

   [a] Clamp the center housing assembly in a bench vise equipped with soft jaws. See Figure 6-44.

   [b] Fasten the dial indicator and magnetic clamp, part of magnetic base dial indicator set, J 7872-2 part if J 7872, to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. See Figure 6-44.

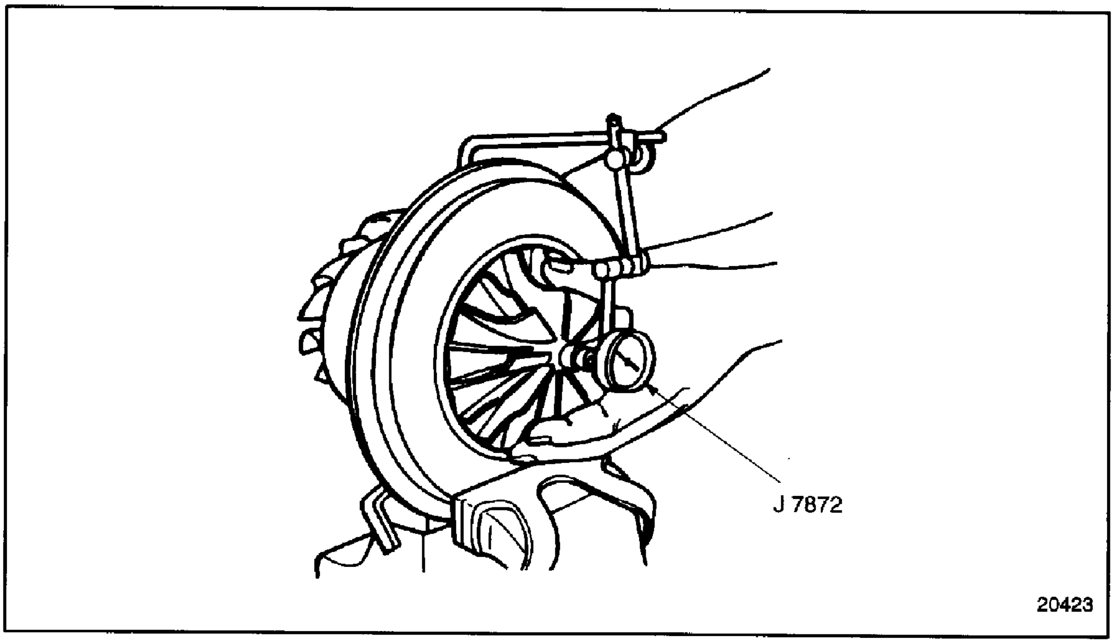


Figure 6-44 Checking Bearing Axial End Play

   [c] Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be 0.0127-0.0889 mm (0.0005-0.0035 in.). If the total dial indicator readings do not fall within the specified limits, replace the rotating assembly.

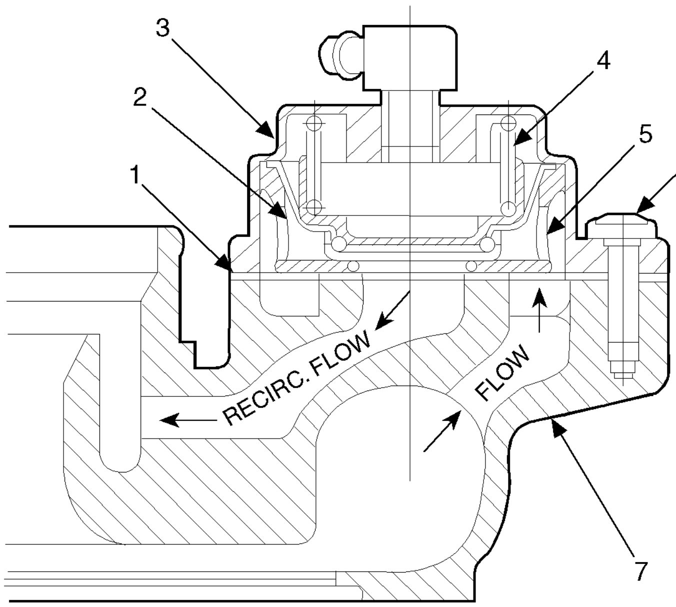
9. Check the shaft radial movement as follows:Due to the internal construction of the GT 35 bearing housing, access to the shaft through the oil drain is not possible. Therefore, radial movement cannot be accurately measured to determine the condition of radial turbine bearings.

To determine the general condition of the radial bearings, check radial end play after the turbocharger is cleaned and assembled. Push on the end of the shaft, towards the side of the compressor (or turbine) housing. If the wheel contacts either housing, the radial bearings may be worn out, and the CHRA should be replaced (be sure to check if the housing is seated and installed correctly also).

10. Service of the center housing rotating assembly (CHRA)The CHRA is serviced by replacement only. Do not attempt disassembly of the CHRA, as possible shaft imbalance and damage may result.

6.6.4 Compressor Recirculation Valve for Coach Engine

Garrett Turbochargers for the Series 50G coach engine are equipped with an integrally mounted compressor recirculation valve. See Figure 6-45. The Series 50G genset engines do not have this feature; a cover plate is installed over the compressor housing.



1. Gasket
2. Diaphragm and piston assembly
3. Cover
4. Spring
5. Diaphragm support
6. Screw
7. Compressor housing

Figure 6-45 Compressor Recirculation Valve for the Series 50G Engine

The recirculation valve is designed to prevent or significantly reduce engine air system pressure pulsation and turbocharger surging during engine throttling operations.

The recirculation valve consists of a spring-loaded diaphragm and piston assembly contained between a diaphragm support and a cover. Three screws are used to mount the cover, which is sealed by a gasket, to the compressor housing.

The recirculation valve is a self-contained unit and requires no adjustments or lubrication during normal operation.

The compressor recirculation valve permits some of the compressed charge air, which becomes trapped during engine throttling, to return back to the compressor intake system. This prevents or significantly reduces pressure pulsation otherwise experienced with compressor surging.

During acceleration and steady state operation the recirculation valve remains in its normally closed position. In this mode, engine intake manifold pressure admitted to the top of the recirculation valve, and assisted by a spring, keeps the diaphragm and piston assembly pressed against the diaphragm support, sealing off the recirculation port in the compressor housing.

The outside of the diaphragm is exposed to compressor boost pressure through the porting in the compressor housing and via the holes in the side of the diaphragm support. During engine throttling, while boost pressure is still available, but with intake manifold pressure dropping off sharply to a vacuum, the resulting pressure differential opens up the recirculating valve diaphragm and piston and permits the remaining compressed charge air to recirculate to the compressor intake system.

The recirculation valve is a small aluminum dome-like structure attached with three Torx head M6 screws to the turbocharger compressor housing near the discharge. When servicing the recirculation valve, the following tools and equipment are required:

- ☐ A Service Kit, consisting of a diaphragm and piston assembly and a gasket.
- ☐ A flat, clean work area.
- ☐ A pair of pliers to loosen the hose clamp on top of the valve.
- ☐ A T30-Torx driver for the three mounting screws.
- ☐ A hand-held vacuum pump is essential, for checking the proper function of the service assembly.
- ☐ Mark the orientation of the cover with respect to the compressor housing base, before removing the valve (helps during assembly).

6.6.5 Pre-Test Recirculation Valve for the Series 50G Engine

Inspect the recirculation valve as follows:

1. Attach a hand-held vacuum pump to the fitting on top of the valve and apply vacuum of 61-74 kPa (18-22 in. Hg.).
2. If this vacuum decays to half of its value in less than 5 seconds, or if a vacuum cannot be established at all, the valve is not functioning properly and needs to be replaced.

6.6.6 Removal and Replacement of Recirculation Valve for the Series 50G Engine

Remove recirculation valve as follows:

1. Remove the braided line that connects to the fitting on the top of the recirculation valve cover.
2. Remove the fitting from the valve cover.
3. Using a T30-Torx driver, loosen the three screws at the base of the valve cover. To facilitate backing out the screws, press the cover down against the internal spring force. Remove and save all three screws.
4. Slowly release the pressure and let the cover rise up from the base.
5. Reach below the cover and hold the internal assembly at the plastic diaphragm support. Lift it off and turn it over.
6. At this time, the gasket between the cover and the compressor housing can be removed and discarded.

NOTE:
Both surfaces must be clean and free of any gasket or other foreign particles before a new gasket will be installed during re-assembly.

7. With the assembly upside down, lift off the diaphragm support and lay it aside.
8. Lift off the diaphragm and piston assembly and discard it.
9. Clean off any foreign particles from the cover and the spring.
10. With the cover upside down, re-insert the spring, then drop the new diaphragm and piston assembly over the spring, followed by the previously laid-aside and cleaned diaphragm support.

NOTE:
That the diaphragm support squeezes the diaphragm against the upper shoulder in the cover after it is fully assembled and seated against the compressor housing base.

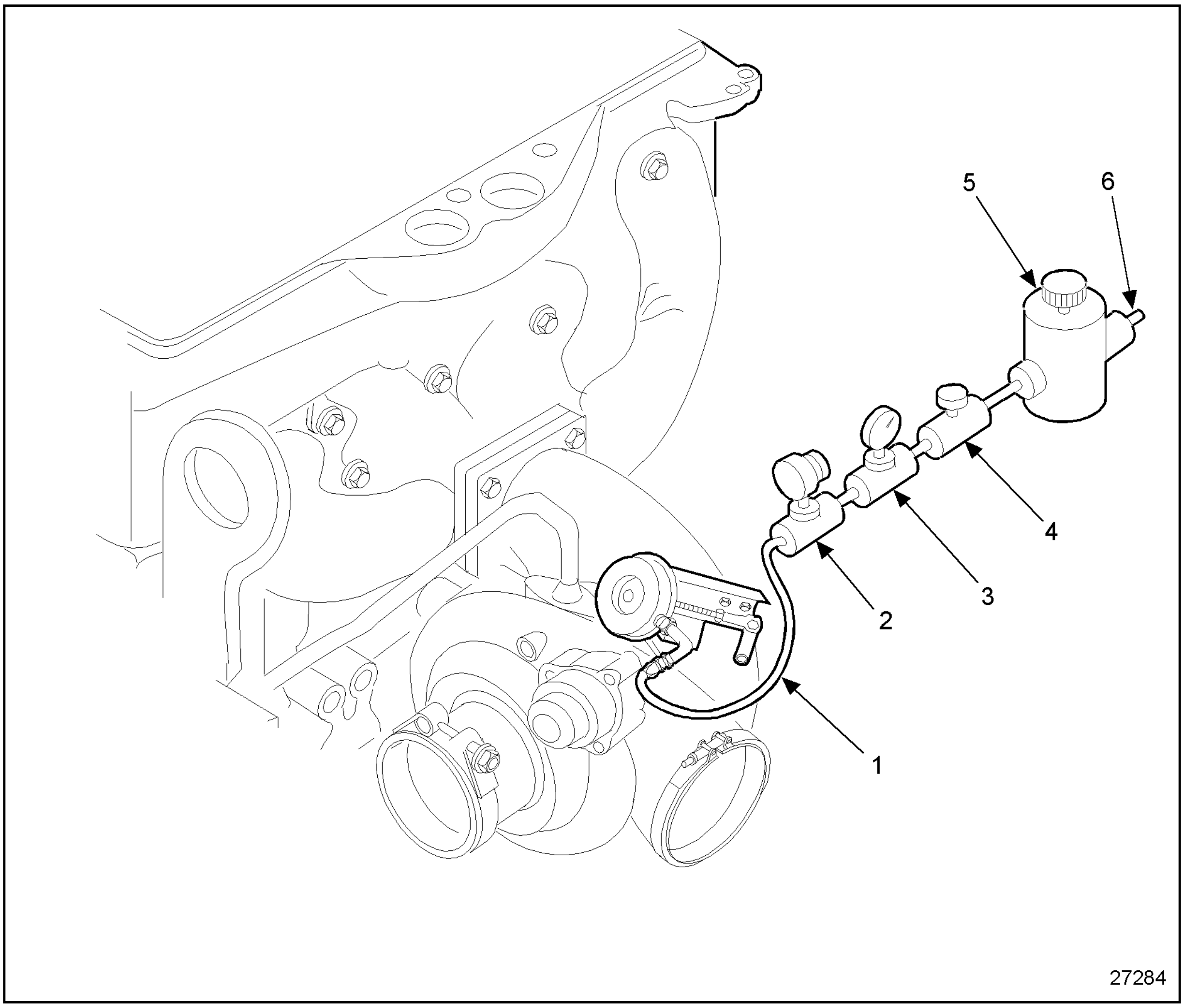
NOTE:
Lightly coat the base of the cover with a non-hardening grease, just enough to hold the NEW gasket in place when the assembly is turned over for installation.

11. Position the new gasket so it lines up with the rim of the cover and the three holes.
12. Hold the assembly loosely together and position it over the mounting base of the compressor housing.
13. Check for proper orientation (a mark applied before disassembly will come in handy) and compress the assembly against the spring force 1.47-1.58 N·m (13-14 lb· in) and install the three Torx screws. Continued pressure on the cover will facilitate the installation of the screws in an easy and even manner.
14. After the cover has seated, torque the screws evenly to a value of 5.9-6.6 N·m (52-58 lb· in).
15. Re-install fitting in the valve cover. Use sealant.
16. Re-attach braided steel line to fitting 8.13 N·m (6 lb·ft) of torque.

6.6.7 Checking Wastegate Calibration for the Series 50G Engine

This procedure provides a method for verifying proper wastegate calibration.

1. Remove hose from wastegate actuator (for gensets, remove line on top side of can).
2. Set-up an indicator at the end of the wastegate actuator adjusting rod to measure actuator rod travel. The indicator should have a minimum travel of 0.100 in.
3. Connect regulator and pressure gage set-up to wastegate actuator. See Figure 6-46.



1. Hose to Wastegate Actuator
2. Vent Valve
3. Pressure Gage
4. Supply Air Shutoff Valve
5. Pressure Regulator
6. Shop Air Supply

Figure 6-46 Checking Wastegate Calibration for the Series 50G Engine

4. Apply specified calibration pressure (listed in Table 6-2) to the wastegate actuator.

Model	Rating	Set Pressure Travel at 0.04 ″ Rod
Coach	275 Hp 275 Hp	18.5 lb/in.^{2}(short can) 21.0 lb/in.^{2}(long can)
Genset	180 Kw, 60 Hz150 Kw, 60 Hz	31 lb/in.^{2}19 lb/in.^{2}

Table 6-2 Series 50G Wastegate Calibration Pressure at 0.04 in. Rod Travel

NOTICE:
For genset turbochargers, NEVER apply pressure to bottom part of actuator can. Damage to actuator may result.

5. Close air supply shutoff valve. The pressure should hold at the specified pressure. If not, check air hose and fitting connections for leaks. If none are found, replace wastegate actuator assembly. Refer to Section 6.6.8.
6. Open vent to relieve pressure. Check gage for zero pressure reading. Adjust regulator to zero pressure and close vent valve.
7. Adjust dial indicator so it just contacts the actuator rod end and adjust to zero reading.
8. Open air supply shutoff valve and slowly adjust regulator until dial indicator reads 0.040 in. Switch pressure on and off, opening and closing supply air and vent valves, to make certain dial indicator travel is from 0.00 in. to 0.040 in. and that the pressure reading is consistent.
9. For currently calibrated wastegate actuator, a pressure within ± 0.25 lb/in.^{2}of the value listed in Table 6-2, will be required to obtain precisely 0.040 in. actuator travel. If the pressure required is outside this range, wastegate adjustment is necessary; refer to Section 6.6.8.

6.6.8 Removal and Replacement of Series 50G Wastegate Actuator

This procedure describes the removal of a actuator currently mounted on a turbocharger, and the replacement with a new service actuator. Further adjustment of the actuator will be necessary to achieve the correct pressure setting, listed in Table 6-2.

1. Remove actuator hose from the top side of the actuator can. With the pressure gage set-up (see Figure 6-46), apply enough pressure to the actuator can until the rod begins to move; refer to Section 6.6.9.
2. Remove the retaining clip that holds the actuator rod end on the wastegate lever pin. Lift rod off the wastegate lever pin.

NOTICE:
Never remove the rod end from the wastegate lever pin unless pressure is applied to the top side actuator port; otherwise, damage to the actuator diaphragm may result.

3. Remove the lock nuts that secure the actuator can to the base of the actuator bracket, and remove the can from the turbocharger assembly.

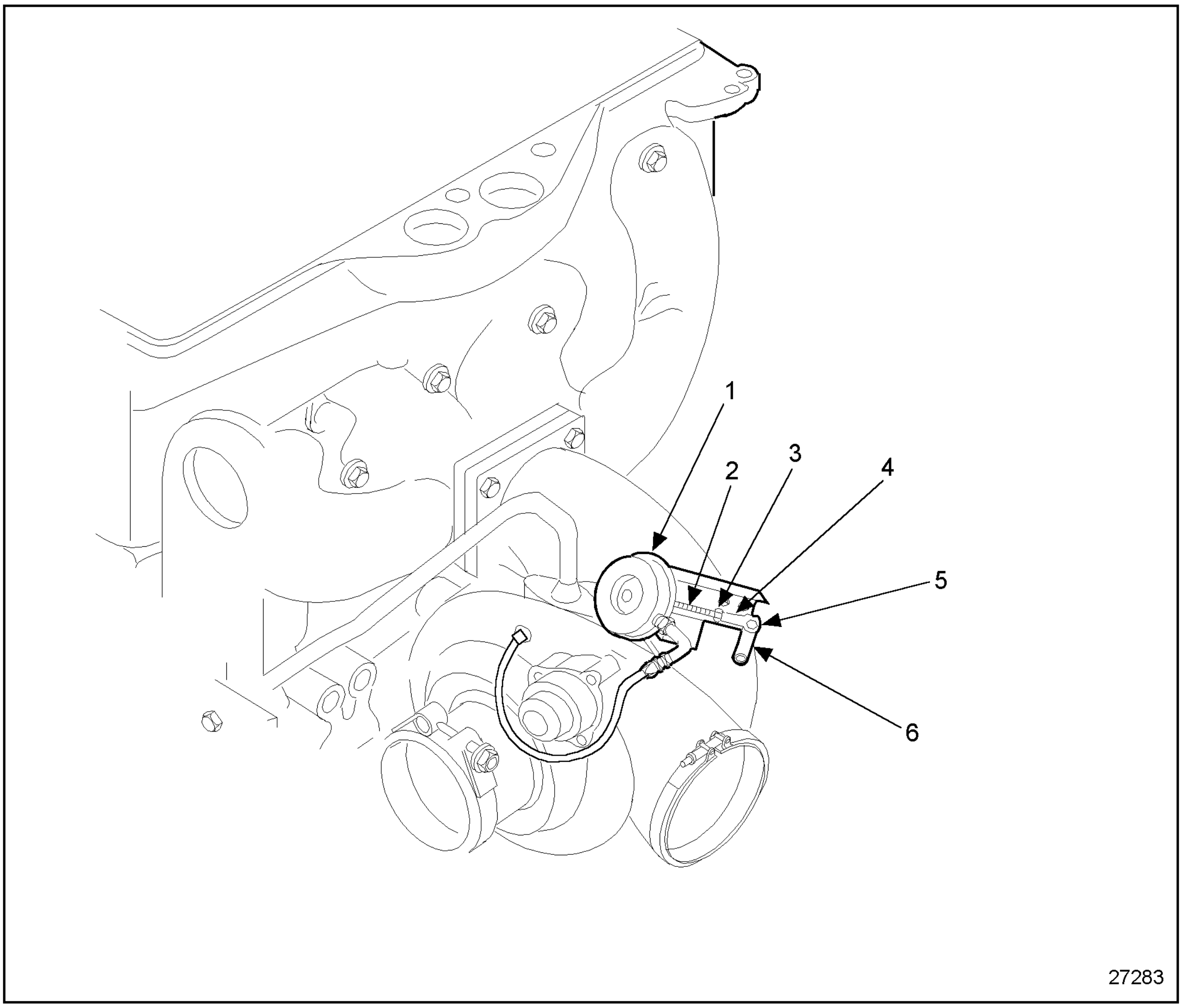
Replace wastegate actuator as follows:

1. Install actuator can on bracket; tighten lock nuts.
2. Using pressure gage set-up, apply enough pressure to the new service actuator can until the rod begins to move.
3. Adjust actuator rod end by turning either clockwise or counter-clockwise on rod so that the rod end hole lines up with the wastegate lever arm, while wastegate is held shut pin, slip rod over pin.
4. Before installing the retaining clip again, the rod end will need to be adjusted to the correct setting. Refer to Section 6.6.9.

6.6.9 Setting the Wastegate on the Series 50G

This procedure describes the set pressure adjustment of an installed wastegate actuator. Before following this procedure, first check the actuator set pressure to see if adjustment is needed refer to Section 6.6.7.

1. Loosen the jam nut that secures the rod end on the actuator rod. If locking collar is present on the actuator rod, remove and discard collar, see Figure 6-47.



1. Wastegate Actuator Assembly
2. Locking Collar
3. Jam Nut
4. Adjusting Rod End
5. Retainer Clip
6. Wastegate Lever and Pin Assembly

Figure 6-47 Wastegate Adjustment

2. Remove the retaining clip that holds the actuator rod end on the wastegate lever arm pin.

NOTICE:
For genset actuator, never apply pressure to the bottom side of actuator port. Damage to the actuator may result.

3. Using pressure gage setup (see Figure 6-47) apply enough pressure to the top side actuator can port until the rod begins to move, lifting the wastegate valve off of it's seal.
4. Slip rod end off of wastegate lever arm pin.
5. Adjust rod as needed
   - □ To INCREASE pressure setting at 0.04 in. turn rod end CLOCKWISE.
   - □ To DECREASE pressure setting at 0.04 in. turn rod end COUNTERCLOCKWISE.
6. With pressure still applied to actuator, replace rod end on wastegate lever arm
7. Check actuator set pressure again; refer to Section 6.6.9.
8. If actuator is still out of adjustment, repeat this procedure again.
9. If actuator is within specified set pressure, re-install retaining clip on wastegate lever arm pin.
10. Tighten jam nut to secure rod end.

6.6.10 Assembly of Turbocharger Series 50G

Use the following procedure to assemble the turbocharger:

NOTICE:
As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material, which may cause component damage.

1. Cover all openings.
2. Position the Center Housing Rotating Assembly (CHRA) into the turbine housing as marked at disassembly, and line up bolt holes. Apply anti-seize compound to bolts, and torque to 185-215 lb/in.^{2}(1276-1482 kPa).

NOTICE:
Always remove the compressor cover before positioning on the Center Housing Rotating Assembly (CHRA); as damage to the O-ring can result.

3. Position the compressor housing as marked at disassembly against the CHRA and secure it in place with the bolts and clamps.
4. Lightly lubricate the threads of the bolt with engine oil and torque the nut to 145-165 lb· in. (16-19 N·m).

6.6.11 Installation of Turbocharger Series 50G

To install the turbocharger:

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
3. Remove any covers on the oil inlet and drain lines, and the oil inlet and drain openings on the turbocharger.
4. Place the turbocharger assembly into position on the exhaust manifold. Use a new gasket between the exhaust manifold and the turbine housing flange.
5. Secure the turbocharger to the exhaust flange. Tighten the nuts just enough to hold the turbocharger in place.
6. Slide the charge air cooler air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

CAUTION:

To avoid injury, wear a face shield or goggles.

NOTICE:

Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold.

7. Torque the turbocharger to exhaust manifold locknuts to 58-73 N·m (43-54 lb·ft).
8. Install the oil drain line, using a new gasket, between the opening in the bottom side of the turbocharger center housing and the drain hose that runs to the cylinder block. Torque the bolts to 30-38 N·m (22-28 lb·ft).
9. Refer to Section 11.1.3 for verification of proper turbocharger installation.
10. Install water supply and return lines.
11. Install compressor recirculation line.

6.7 CHARGE AIR COOLER

A CAC is normally mounted ahead of or beside the cooling system radiator. The compressed air leaving the turbocharger is directed through the charge air cooler before it goes to the air inlet side of the intake manifold, see Figure 6-48.

In Series 50 gas engines operating with the low pressure fuel system, fuel is introduced ahead of the turbocharger. The following components are filled with combustible air-fuel mixture: turbocharger charge cooler inlet duct, charge cooler, charge cooler outlet duct, throttle and the intake manifold.

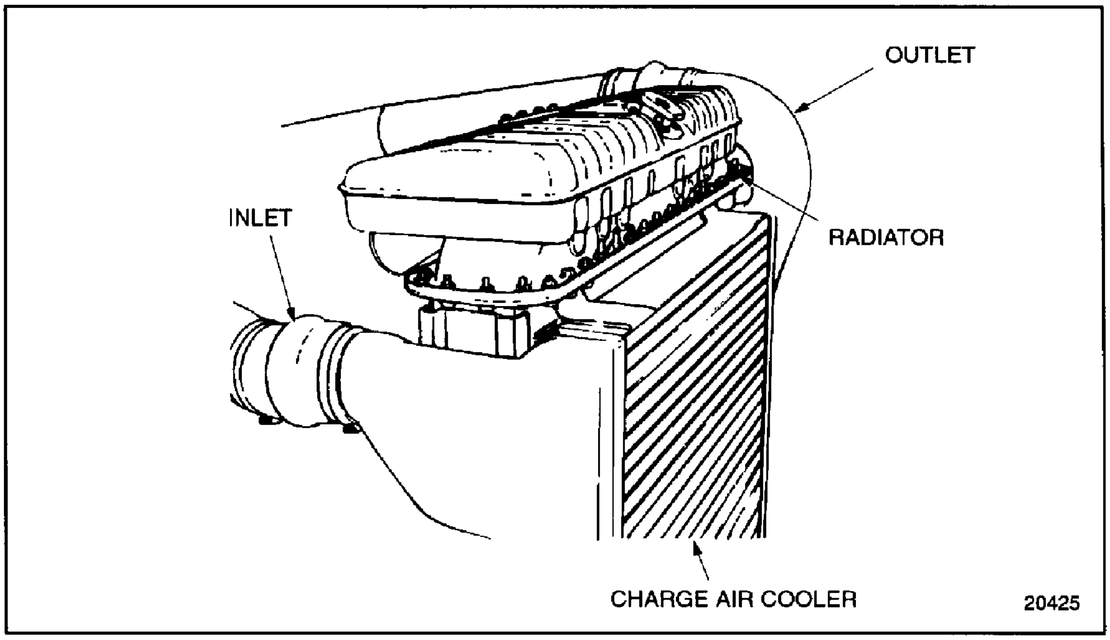
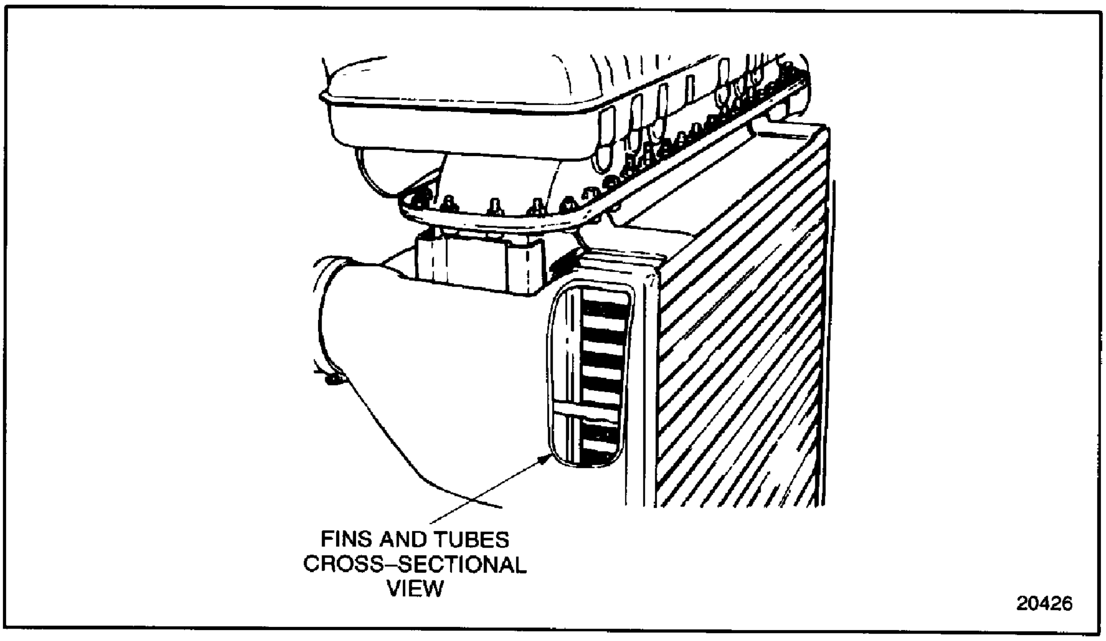


Figure 6-48 Typical Charge Air Cooler

The CAC is used to reduce the temperature of the compressed air or air-fuel mixture leaving the turbocharger before it reaches the intake manifold. This permits a more dense charge to be delivered to the engine.

Cooling is accomplished by incoming air flowing past the tubes and fins of the intercooler. The compressed intake charge flowing inside the CAC core transfers the heat to the tubes and fins where it is picked up by the incoming outside air. See Figure 6-49.

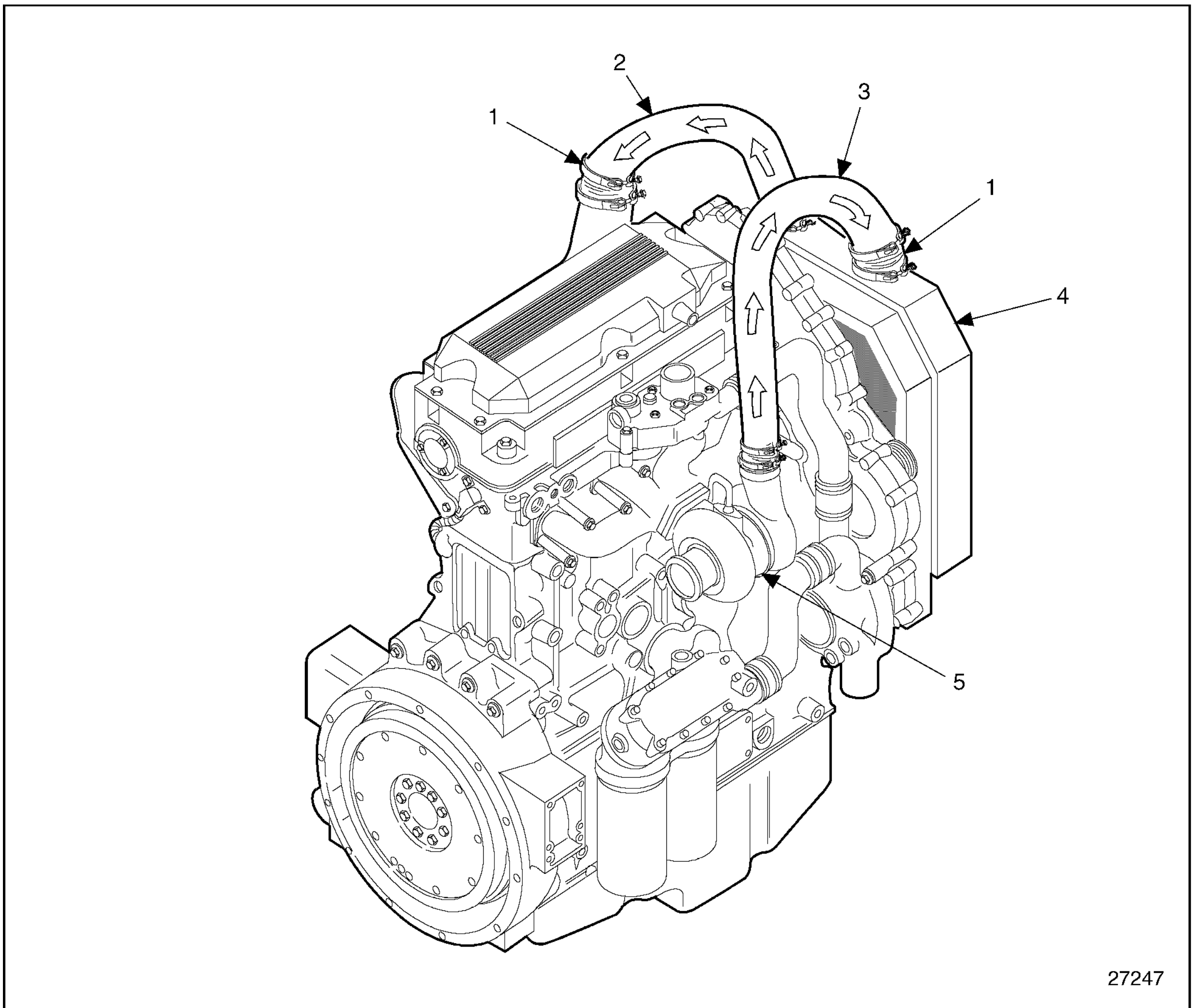


1. Cross Section Charge Air Cooler

Figure 6-49 Charge Air Cooler Cross Section

Metal ductwork is used to transfer the air from the turbocharger outlet to the CAC, and from there to the intake manifold. See Figure 6-50.

Flexible rubber couplings and hose clamps are used to secure the ductwork to the turbocharger, the CAC inlet and outlet, and the intake manifold.



1. Flexible Coupling
2. CAC Outlet Duct
3. CAC Inlet Duct
4. Charged Air Cooler (CAC)
5. Turbocharger

Figure 6-50 Charge Air Cooler and Related Parts

6.7.1 Repair or Replacement of Charge Air Cooler

Refer to the OEM guidelines to for CAC repair and replacement procedures.

6.7.2 Cleaning and Removal of Charge Air Cooler

Refer to the OEM guidelines for CAC service procedures.

6.7.2.1 Inspection of Charged Air Cooler

After a turbocharger failure, inspect charged air cooler as follows:

CAUTION:
To avoid injury when working near or on an operating engine, remove loose items of clothing, jewelry, tie back or contain long hair that could be caught in any moving part causing injury.

NOTICE:
To avoid charged air cooler damage while cleaning or inspecting, observe all NOTICES, CAUTIONS, WARNINGS, etc. provided by the OEM cooler manufacturer.

1. Remove all the piping to and from the charged air cooler and the air intake manifold.

NOTICE:
If the charged air cooler is contaminated with metal particles resulting from a damaged turbocharger, it *must* be replaced with a new charged air cooler. Any debris left in the charged air cooler, especially metal particles, can cause severe engine damage.

2. Inspect all parts carefully for metal and oil contamination.If the charged air cooler is contaminated with engine oil, contact the vehicle OEM and obtain the charged air cooler manufacturer's recommendations on cleaning and inspection.
3. Remove and inspect the air intake manifold for any accumulation of oil. Remove the oil from the manifold and from the area above the valves before replacing the charged air cooler system.

NOTICE:
Failure to remove residual lubricating oil from charge air cooler may allow the oil to act as an external fuel source at engine startup. This can cause a sudden engine overspeed condition, which may result in severe engine damage.

6.7.3 Installation of Charge Air Cooler

Refer to the OEM guidelines for CAC installation procedures.

6.8 THROTTLE ACTUATOR FOR THE SERIES 50G ENGINE

The throttle actuator is used to control the amount of the air and fuel mixture to the engine. A butterfly valve within the body is positioned by an electric actuator that is controlled by DDEC III.

Effective with January 1997 production, an improved throttle actuator replaced the former throttle actuator on all Series 50G engines in *transit bus applications.*

NOTE:
For optimum engine performance after replacement of the former actuator with the improved actuator, the engine must be re-programmed with the new calibration before being returned to service. Authorized Detroit Diesel distributors are properly equipped and have the trained personnel to perform this service. Failure to reprogram the engine after replacement of the former throttle actuator may result in the engine remaining in the maximum no-load idle mode after engine start-up.

6.8.1 Reuse or Replacement of Throttle Actuator for the Series 50G Engine

The throttle actuator is non-serviceable and should be replaced as a unit. No adjustment is required.

6.8.2 Removal of Throttle Actuator for the Series 50G Engine

Remove the throttle actuator as follows:

1. Vent fuel system; refer to Section 2.43.1and refer to Section 2.43.2.
2. Disconnect and remove the six wire power harness connector from the throttle actuator.
3. Remove the four bolts connecting the throttle actuator to the mounting bracket.
4. Remove 8 bolts and nuts attaching the throttle to the inlet and outlet tube assemblies.

6.8.3 Disassembly of Throttle Actuator for the Series 50G Engine

Disassembly of the throttle actuator is not required.

6.8.4 Cleaning of Throttle Actuator for the Series 50G Engine

Cleaning of the throttle actuator is not required.

6.8.4.1 Inspection of Throttle Actuator for the Series 50G Engine

Inspection of the throttle actuator is not required.

6.8.4.2 Test of Throttle Actuator for the Series 50G Engine

Test of the throttle actuator is not required.

6.8.5 Installation of Throttle Actuator for the Series 50G Engine

Install the throttle actuator as follows:

1. Secure the throttle actuator to the mounting bracket with the four bolts and washers and torque to 20 N·m (15 lb·ft).
2. Connect the six wire power harness.

NOTE:
If the engine was built prior to 1998 model year and has a 24–volt power supply, then a throttle jumper wiring harness must be installed between the engine throttle and the engine ECM sensor harness.

3. Install a new gasket and attach the outlet tube assembly using four bolts.
4. Install a new gasket and attach the inlet tube assembly using four bolts.

CAUTION:

To avoid injury from an explosion of natural gas, the following precautions must be taken:

- **Do not smoke when installing or servicing the engine or fuel system.**
- **Installation or servicing of natural-gas equipment must only be conducted in well-ventilated, natural gas compatible areas. Do not install or service equipment in an enclosed area where ignition sources are present without first ensuring that an undetected gas leak may be safely vented without being ignited.**
- **Bleed natural gas lines before installing or servicing any component connected to the fuel lines.**
- **Natural gas fuel systems are pressurized. Relieve pressure from any fuel system component prior to installation or service of that component.**
- **Use a combustible-gas detector. Liquefied natural gas (LNG) is odorless and cannot be detected by smell. Compressed Natural gas (CNG) may be odorless and may not be detected by smell.**
- **Equipment fuel systems are the responsibility of the Original Equipment Manufacturer (OEM). Equipment fuel system guidelines must be closely adhered to when installing or servicing equipment. Refer to OEM guidelines specifying which maintenance procedures require venting of fuel lines and fuel tanks.**
- **LNG systems are pressurized and contain extremely cold (-260°F [-162°C]) fluids. Contact the fuel supplier or OEM for LNG safety requirements. Contact with LNG may cause personal injury (freezing).**
- **Vent systems on the equipment should be ducted to a safe area whenever equipment is in an enclosed area.**

Natural gas is highly flammable and explosive and may be extremely cold (-260°F [-162°C]).

5. Run engine and check for air or air and fuel mixture leaks at the throttle and connecting hoses. Refer to Section 2.43.3.

6.9 AIR DRYER

Refer to OEM guidelines for air dryer for repair or replacement procedures.

6.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 8 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 6-3. Standard (nonmetric) nut and bolt torque specifications are listed in Table 7 in the "General Information" section at the beginning of this manual.

Bolt and Size *	Torque, N·m	Torque, lb·in.
M5 X 30.0 mm	2.37-2.94	21-26

* The turbo-boost pressure sensor retaining bolts are M5 x 30.0 mm long.

Table 6-3 Exceptions - Metric Fastener Torque Specifications

7 EXHAUST SYSTEM

7.1 OVERVIEW OF EXHAUST SYSTEM

The engine is equipped with a single-piece exhaust manifold. See Figure 7-1.

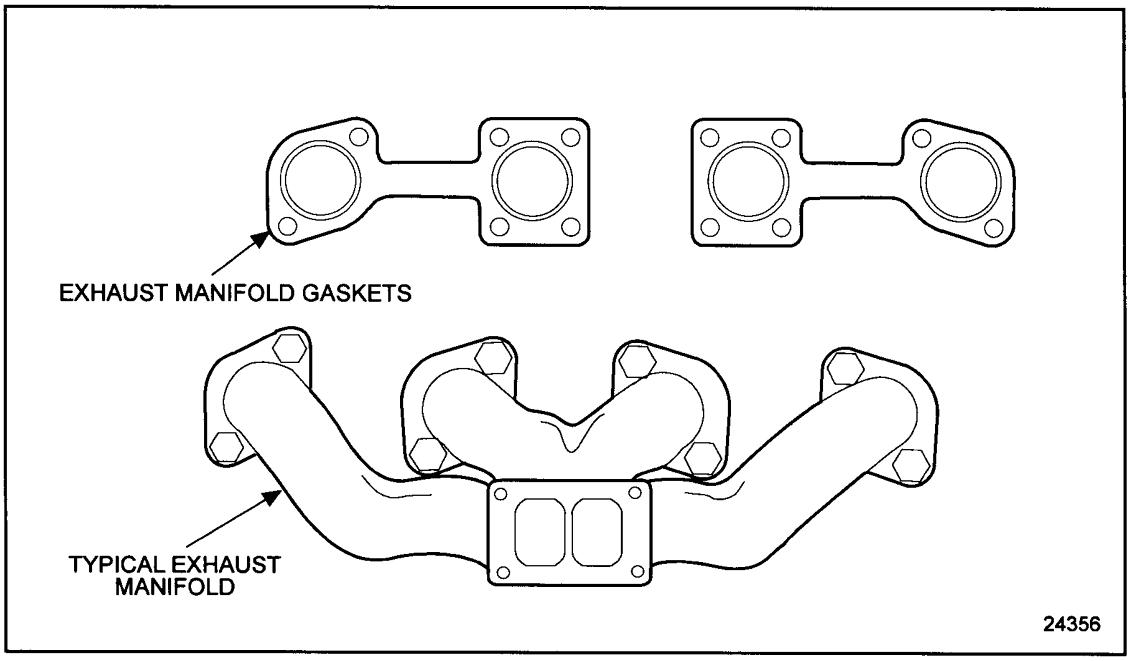
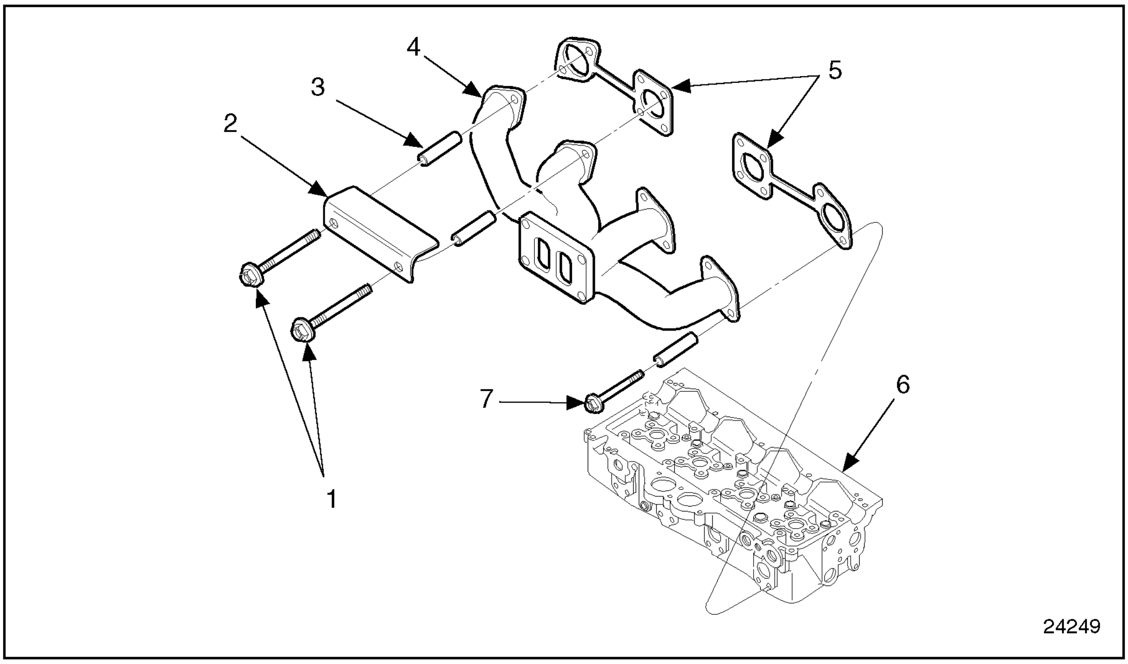


Figure 7-1 Exhaust Manifold Gaskets and Related Parts

The outlet flange is centrally located and connects directly to the turbocharger turbine housing. The exhaust manifold is attached to the cylinder head with eight specially hardened bolts. Spacers are used between the bolt head and exhaust manifold.

7.2 EXHAUST MANIFOLD

The cast-iron exhaust manifold is attached to the cylinder head with eight special alloy hardened bolts and eight bolt spacers. The manifold has a square outlet flange which is bolted directly to the turbocharger turbine housing. See Figure 7-2.

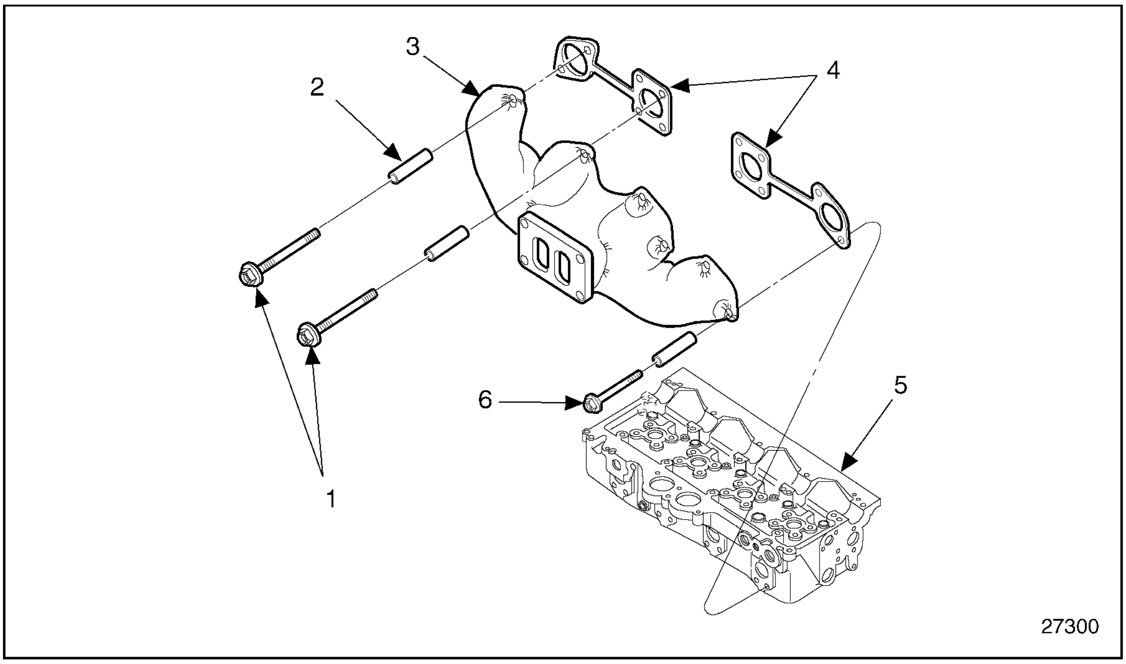


1. Stud
2. Heat Shield
3. Spacers
4. Exhaust Manifold
5. Exhaust Manifold Gasket
6. Cylinder Head
7. Bolt

Figure 7-2 Typical Exhaust Manifold Mounting

NOTE:
Exhaust manifolds on natural gas engines are thermal wrapped for efficiency, see Figure 7-3.

NOTE:
Exhaust manifolds on S50G automotive engines have an insulation wrap to contain heat.



1. Nut
2. Sleeves
3. Exhaust Manifold
4. Gaskets
5. Cylinder Head
6. Bolt

Figure 7-3 Typical Exhaust Manifold Mounting (Series 50G)

Two identical exhaust manifold gaskets are used between the manifold and the cylinder head. See Figure 7-1.

7.2.1 Repair or Replacement of the Exhaust Manifold

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 7-4.

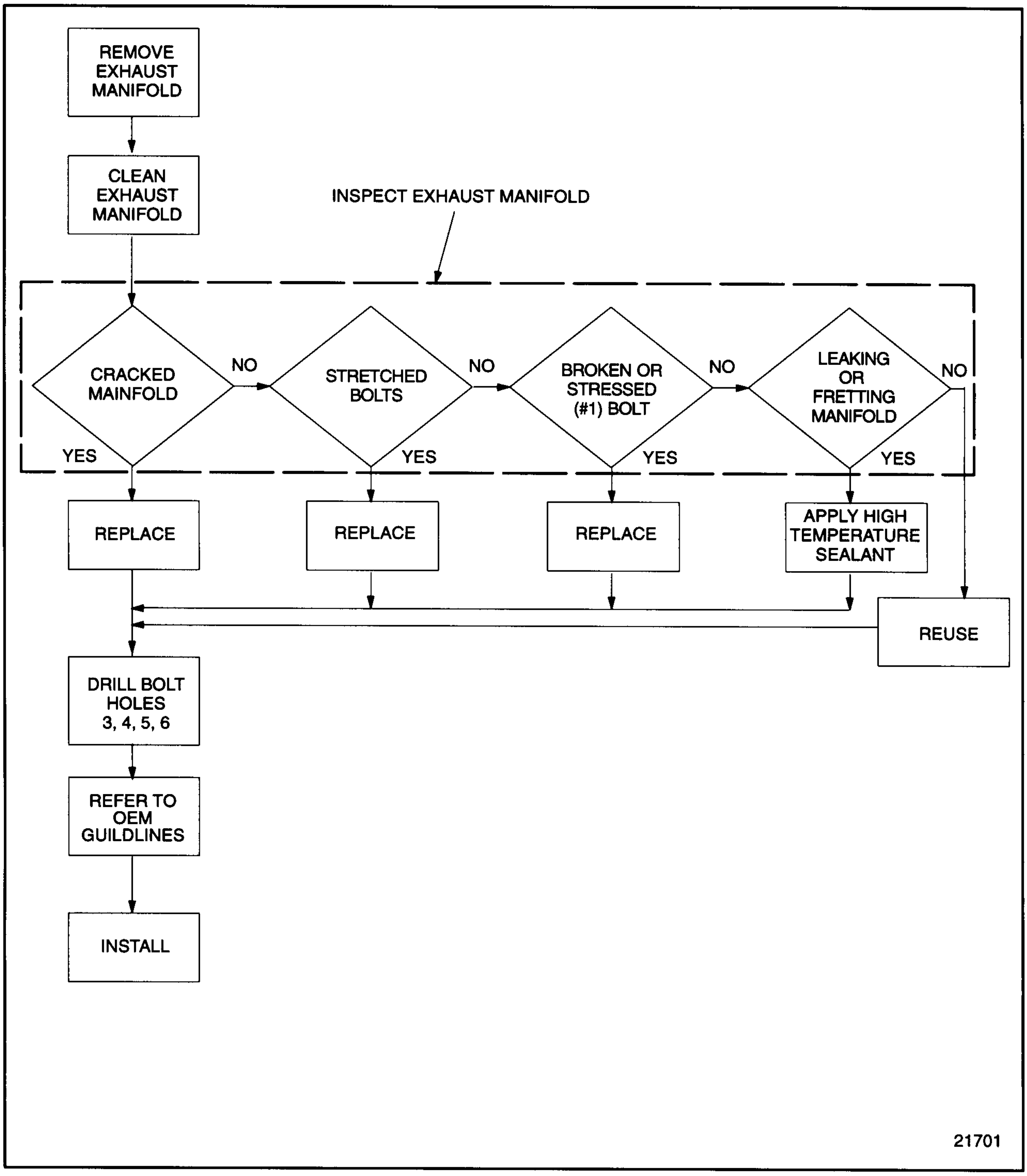


Figure 7-4 Flowchart for Repair or Replacement of Exhaust Manifold

7.2.2 Cleaning and Removal of the Exhaust System

Precleaning is not necessary.

Remove the exhaust manifold as follows:

1. Remove the turbocharger assembly. Refer to Section 6.5.2.
2. Remove the eight bolts and spacers that secure the exhaust manifold to the cylinder head.
3. Remove the manifold. Discard the two gaskets.

Clean the exhaust manifold prior to inspection as follows:

1. Remove any loose scale and carbon that may have accumulated on the internal walls of the manifold.
2. Clean the manifold exterior with a wire brush.

7.2.2.1 Inspection of the Exhaust Manifold

Inspect the exhaust manifold as follows:

1. Inspect the exhaust manifold for damage.
   [a] Check the exhaust manifold for cracks, especially in the bolt clamp areas.
   [b] If manifold is cracked, replace with a new manifold.
2. Inspect manifold mounting bolts for damage.
   [a] Visually check for bolt stretching and thread damage.
   [b] If bolts are excessively stretched, or if threads are excessively damaged, replace with new bolts.

7.2.3 Installation of Exhaust Manifold

Install the exhaust manifold as follows:

1. Install four exhaust manifold guide studs, J 36107 into the cylinder head to position and hold the two exhaust manifold gaskets correctly, and facilitate installation of the manifold.
2. Install the exhaust gaskets (2) to the guide studs.
3. Install the assembled manifold to the guide studs.
4. Install four of the bolts and spacers to the vacant holes. Tighten the bolts finger-tight.
5. Remove the four guide studs.
6. Install the remaining four manifold bolts and spacers to the holes from which the studs were removed.

7. Torque the bolts to 58-73 N·m (43-54 lb·ft) using the tightening sequence. See Figure 7-5.

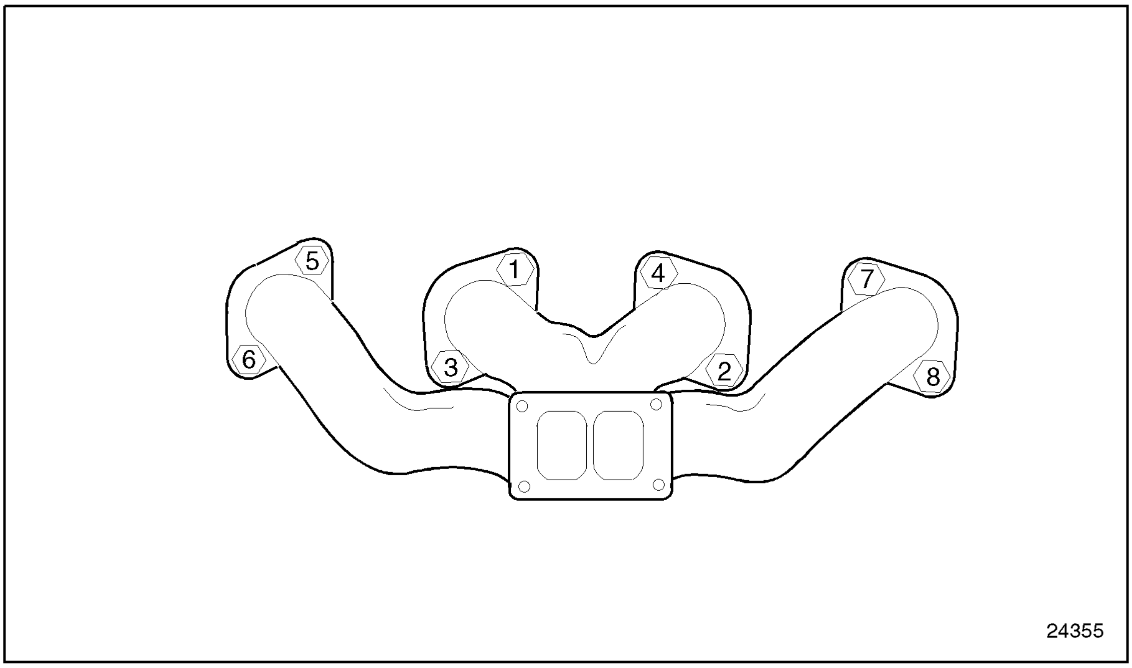


Figure 7-5 Exhaust Manifold Bolt Tightening Sequence

8. Install the turbocharger assembly. Refer to Section 6.5.7.
9. Install any other equipment that was removed for this procedure.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

10. Run the engine until normal operating temperature is reached.
11. Torque the bolts to 73 N·m (54 lb·ft) again. See Figure 7-5.
12. Refer to Section 11.3.6 for verification of proper exhaust manifold installation.

8 ELECTRICAL EQUIPMENT

8.1 OVERVIEW OF ELECTRICAL SYSTEM

The electrical system consists of the following components:

- ☐ Starting motor
- ☐ Battery-charging generator (alternator)
- ☐ Transistorized voltage regulator (normally integral to the alternator)
- ☐ Storage battery(s)
- ☐ Starting motor relay

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

Detailed information on the maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the OEM. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from an AC-Delco service outlet, or from the Technical Literature section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the original equipment manufacturer. With the exception of DDEC components, replacement parts for electrical equipment should be ordered through the original equipment manufacturer's outlets, since these parts are not normally supplied with the engine. For electrical equipment manufactured by Delco-Remy Division, service and parts are available through AC-Delco branches and repair stations.

8.2 OVERVIEW OF ELECTRICAL SYSTEM FOR SERIES 50G ENGINE

The Series 50G is Detroit Diesel's first spark-ignited engine. Detroit Diesel's ignition system consists of DDEC III, ignition coils, spark plugs, and wires. DDEC controls the spark.

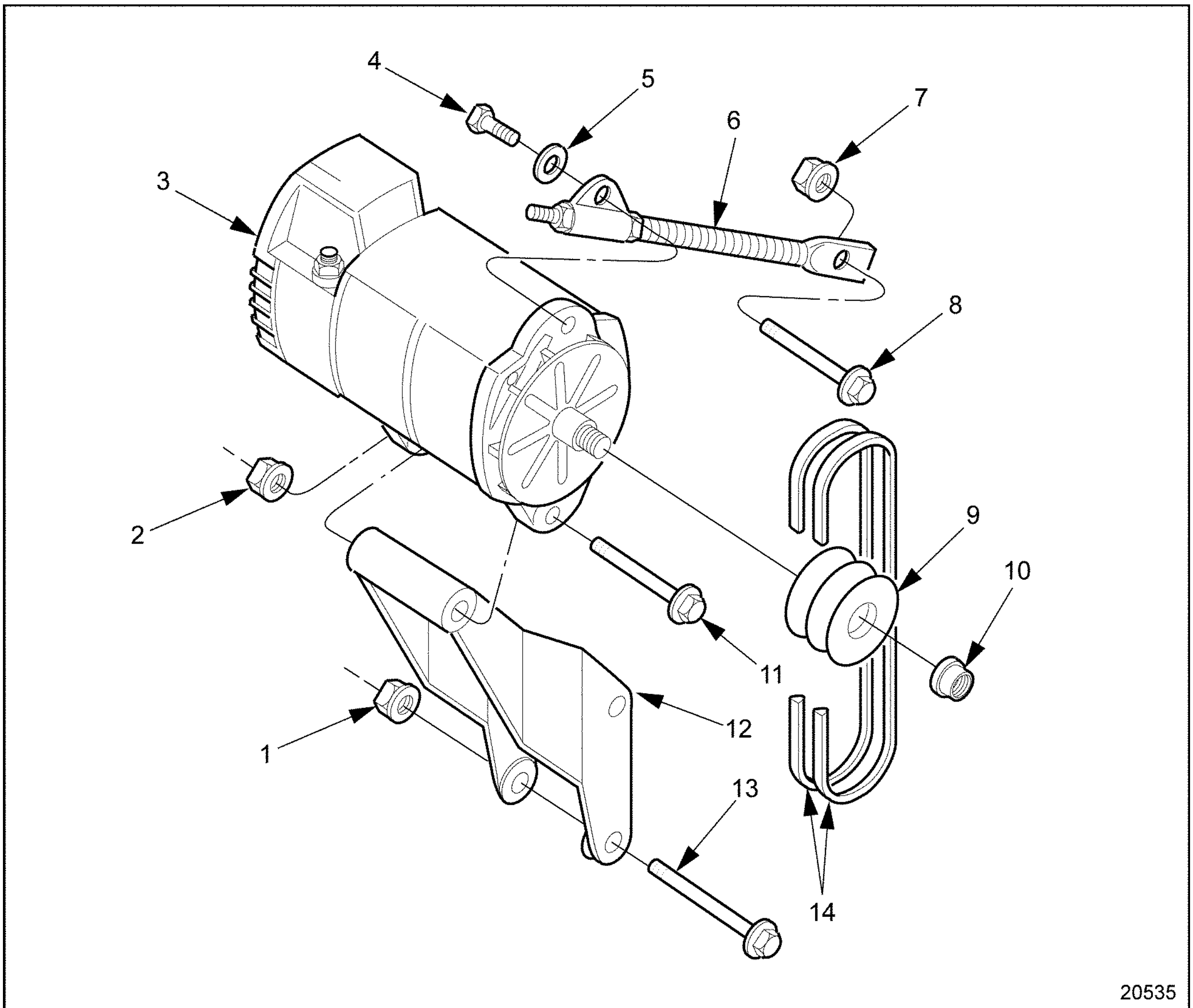
The Series 50G spark ignited high pressure gas engine utilizes the Detroit Diesel Electronic Control (DDEC) system in conjunction with the Gaseous Fuel Injection (GFI) system, specifically tailored for the Series 50 gas engine, to control combustion. The GFI computerized fuel injection system electronically meters fuel according to demand. A combination of Detroit Diesel and GFI sensors are used to dynamically monitor the engine and environment to provide open loop fueling. In addition to assisting with fuel delivery control, DDEC is used to control the spark ignition system, provide engine shutdown protection, and provide additional safety shut downs for the vehicle fuel system. The DDEC system has been modified to provide optimum operation for the Series 50G engine. The Series 50G electronic control system includes the following enhancements:

- The low pressure system controls both spark for the spark plugs and fuel delivery.
- The ECM has been modified for use with the Series 50G. A standard diesel ECM cannot be used with the Series 50G.
- The Series 50G has been modified to incorporate additional engine sensors including:
  - Inlet Air Temperature (used in conjunction with GFI system)
  - Oil Temperature (used in conjunction with GFI system)
  - Knock Sensor
  - Manifold Air Pressure (MAP)
  - Barometric Air Pressure (BAP)
  - Fuel Pressure
  - Fuel Temperature
- The Series 50G design incorporates certain gas components including:
  - Signal Noise Enhancement Filter (SNEF) Module

8.3 BATTERY CHARGING ALTERNATOR

The battery charging alternator provides a source of electrical current for maintaining the storage battery in a charged condition and supplies sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

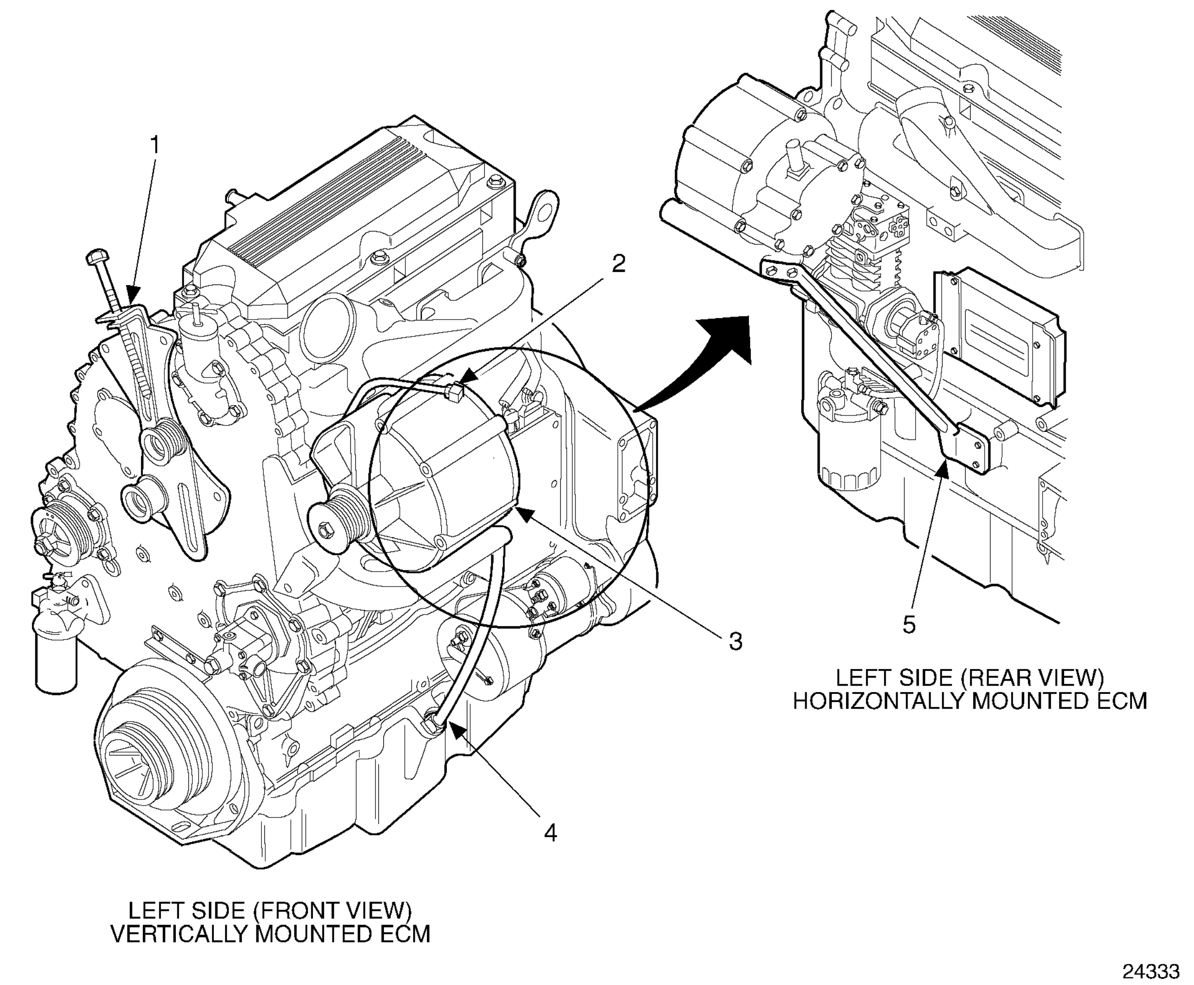
The battery charging circuit consists of an alternator, a voltage regulator, a battery(s) and the connecting wiring. See Figure 8-1, for parts of the battery charging alternator.



1. Nut (2)
2. Nut
3. Alternator
4. Bolt, Alternator-to-Adjusting Rod
5. Washer
6. Alternator Adjusting Rod
7. Nut
8. Bolt, Adjusting Rod-to-Engine
9. Pulley, Alternator Drive
10. Locknut
11. Bolt, Alternator-to-Mounting Bracket
12. Mounting Bracket
13. Bolt, Mounting Bracket-to-Engine (2)
14. Drive Belts

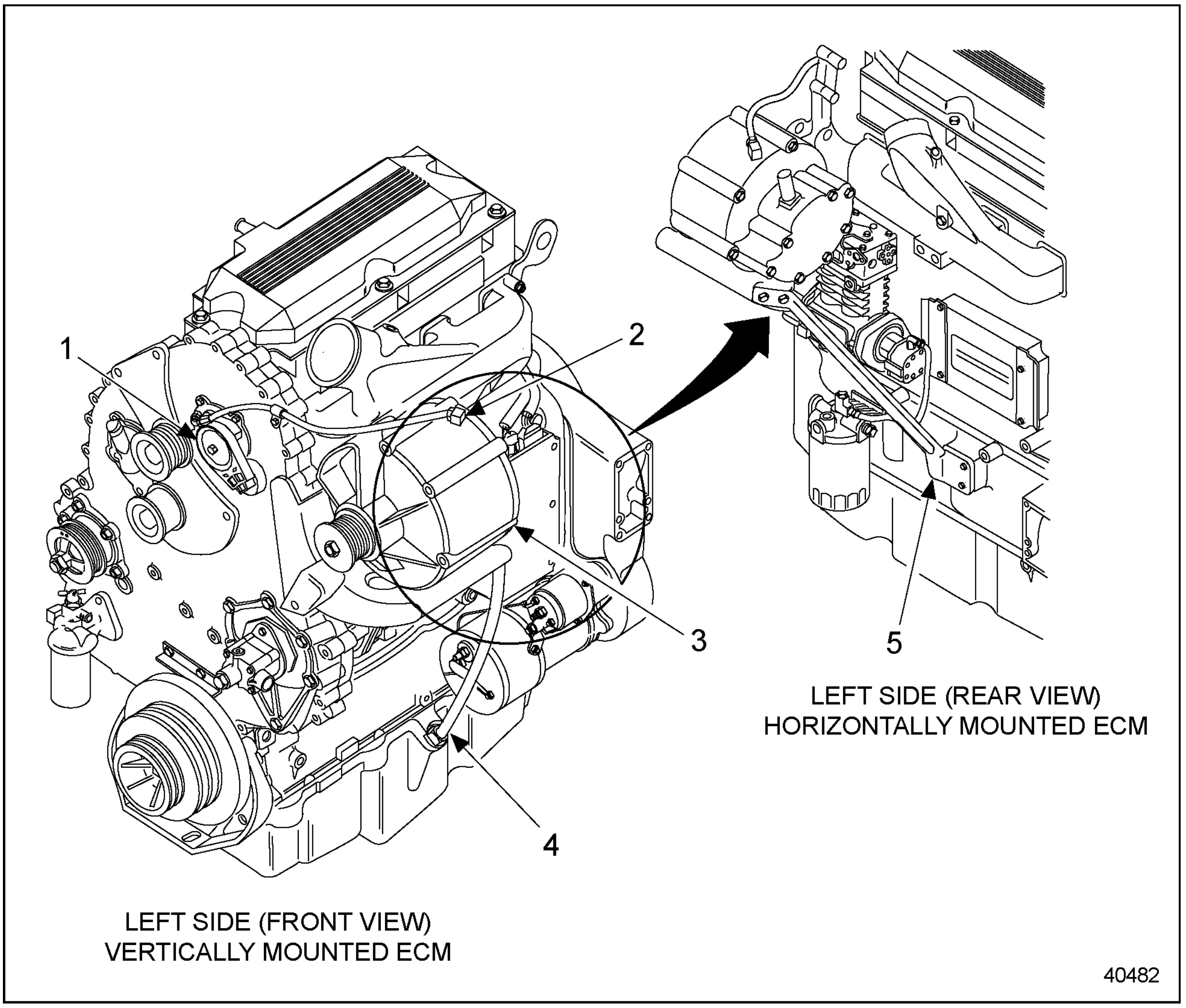
Figure 8-1 Typical Alternator and Related Parts Location

The alternator used on the Series 50 automotive engine is a bracket-mounted, alternating current (AC), self-rectifying unit. See Figure 8-2 for former alternator mounting. See Figure 8-3for current alternator mounting.



1. Tensioner Assembly
2. Vent Hose
3. Alternator
4. Oil Drain Tube
5. Bracket Support

Figure 8-2 Former Series 50 Coach Alternator Mounting



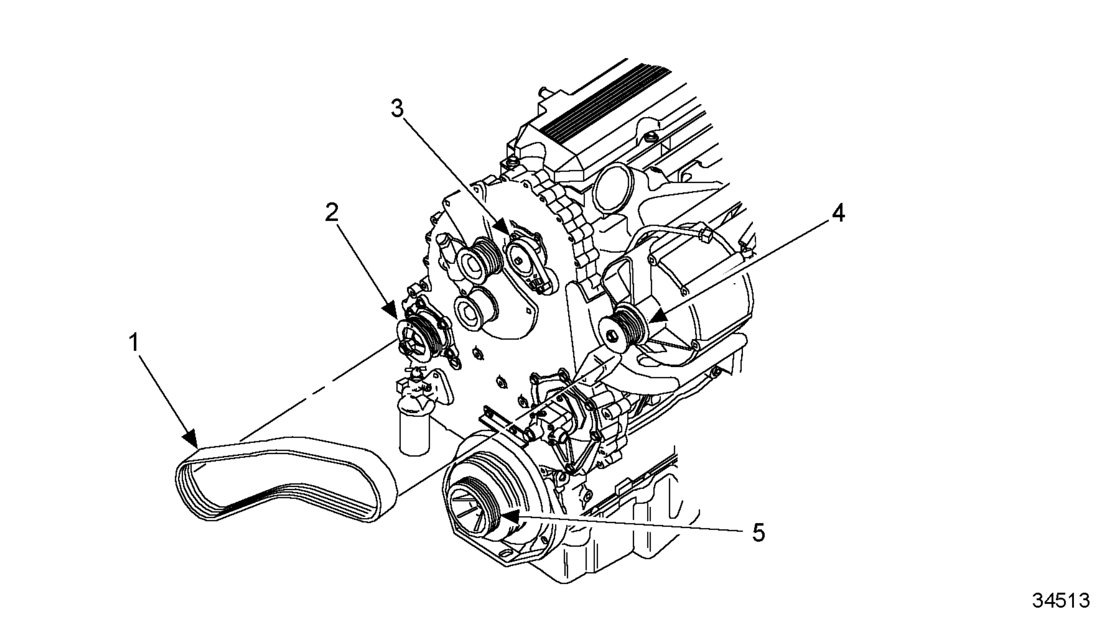
1. Auto Belt Tensioner
2. Vent Hose
3. Alternator
4. Oil Drain Tube
5. Bracket Support

Figure 8-3 Current Series 50 Coach Alternator Mounting

NOTICE:

Mixing an improved tensioner assembly, support plate, or tensioner adjusting bolt with a former tensioner assembly, support plate, or tensioner adjusting bolt may result in alternator drive belt damage and loss of electrical power to the vehicle.

In 1995, the former 50 DN alternator drive system replaced the early 50 DN alternator drive system previously used on Series 50 coach engines. See Figure 8-4. The changes to the drive system took effect with the engine serial numbers listed in Table 8-1.



1. Drive Belt
2. Accessory Drive Pulley
3. Auto Tensioner
4. Alternator Drive Pulley
5. Crankshaft Pulley

Figure 8-4 Alternator Drive System

Change	Engine Serial Number	Build Date
Alternator Pulley	4R-12386	Nov. 27, 1995
Acc. Drive Assembly	4R-12647	Dec. 14, 1995
Tensioner/Support Plate	4R-12853	Dec. 20, 1995

Table 8-1 Effectivity of Improved 50 DN Alternator Drive System Changes

The former 50 DN alternator drive system includes a new tensioner assembly, support plate, tensioner adjusting bolt, alternator pulley, and alternator drive assembly. The top pulley of the tensioner assembly is the same size as the bottom pulley 127 mm (5 in.). All pulleys in the system have front and back flanges to insure proper belt positioning during assembly and improved belt tracking during engine operation.

The former and early tensioner assembly, support plate, and tensioner adjusting bolt are not separately interchangeable on a part-for-part basis and cannot be mixed on an engine.

To simplify installation of the 50 DN alternator drive belt and ensure proper running tension throughout drive belt life, an auto belt tensioner assembly and idler assembly replaced the former tensioner/support plate assembly on December 15, 1997. See Figure 8-3. Use of the auto tensioner eliminates the need for periodic belt tension inspection. Only the current auto belt tensioner assembly and idler assembly are used on engines with 50 DN alternators.

Effective June 2000, the No. 4 size vent hose on the 50DN alternator was replaced by a No. 6 braided hose to improve venting of the alternator and extend alternator life. In addition, the vent line connection point on the engine was moved from a tapped hole in the gear case to a tapped hole in the auto belt tensioner mounting plate.

On engines equipped 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 Series 50 alternator is front mounted and belt driven using the accessory drive pulley. The accessory drive pulley is gear driven by the bull gear. Refer to Section 1.29 for accessory drive information.

8.3.1 Replacement of Alternator

Refer to the OEM guidelines for alternator service procedures.

8.3.2 Cleaning and Removal of Alternator

Precleaning is not necessary.

Remove the alternator as follows:

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

1. Disconnect the cables at the batteries. Tag each lead to ensure correct connection when the alternator is reinstalled.
2. If the alternator has more than the output cable lead, disconnect all other leads from the alternator, and tag each one to ensure correct installation.
3. Remove the alternator output cable.
4. If alternator is oil cooled, disconnect the oil supply, return, and vent lines.
5. Loosen the alternator mounting bolts and adjusting rod nut to allow slack in the drive belt(s). If an auto belt tensioner assembly is installed, use a breaker bar with a 3/4 inch drive to rotate the tensioner pulley upward to relieve belt tension.

CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

6. Remove the drive belt(s).
7. While supporting the alternator, remove the adjusting rod bolt and hardened washer.
8. Loosen and remove the nut and washer at the rear alternator mounting flange.
9. While supporting the alternator, remove the alternator-to-bracket bolt to prevent it from falling.
10. Remove the two woodruff keys, if equipped.
11. Remove and retain the alternator pulley locknut, alternator pulley, and fan from the unit. See Figure 8-1.

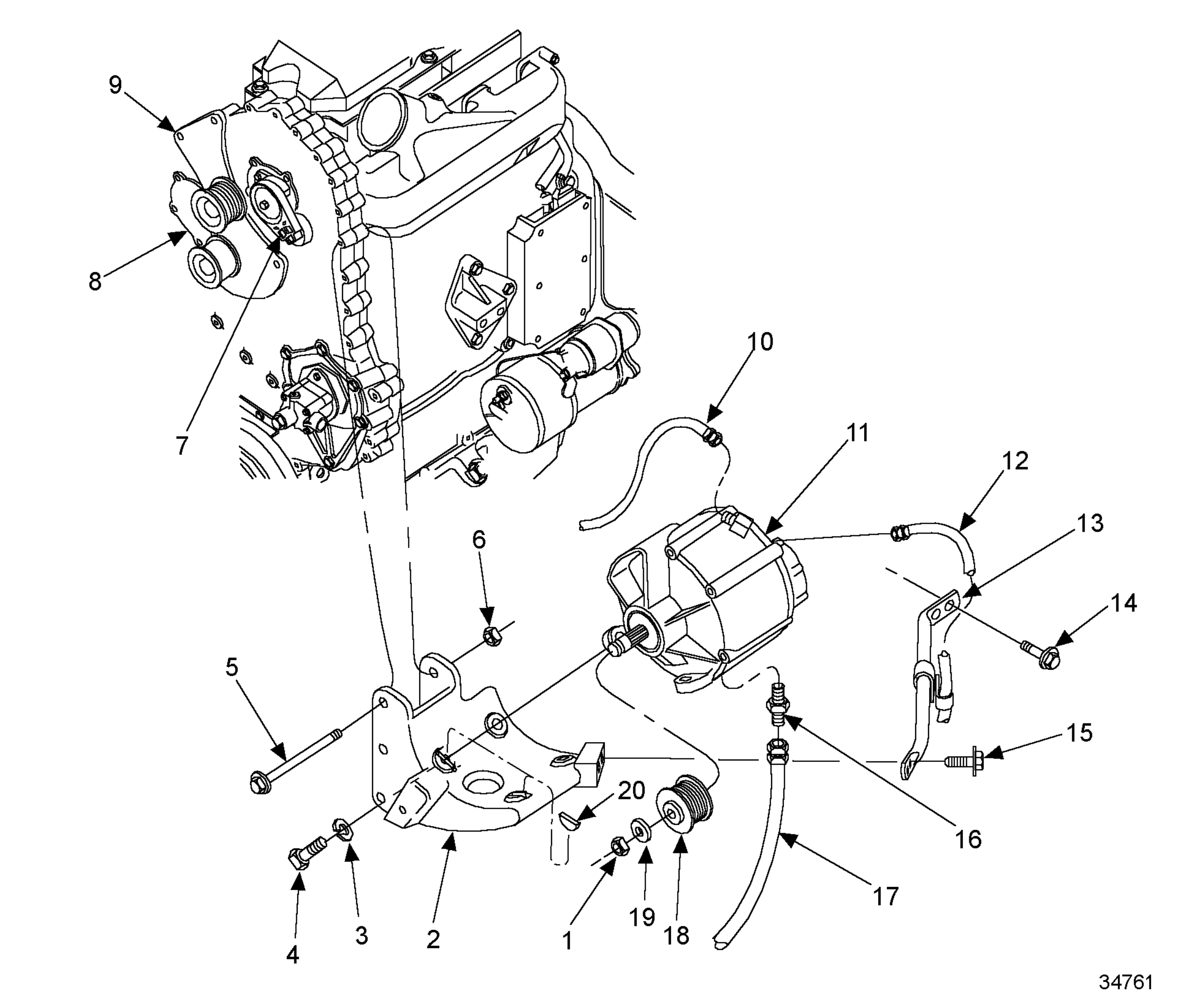
8.3.2.1 Inspection of Alternator

Refer to OEM guidelines for alternator service procedures.

8.3.3 Installation of Alternator

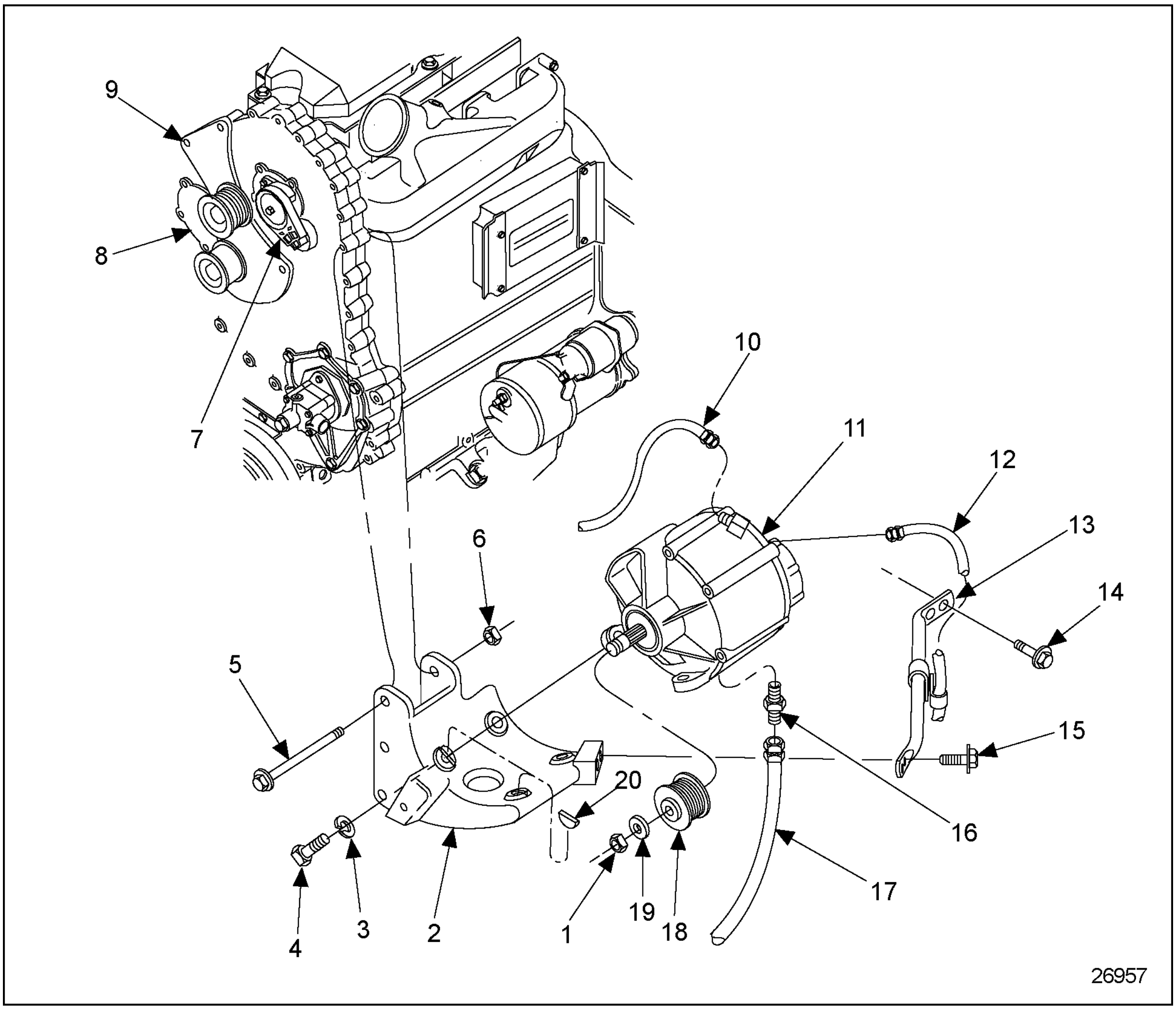
Install alternator as follows:

1. Install alternator mounting bracket to the gear case. See Figure 8-5 (vertical ECM) or see Figure 8-6 (horizontal ECM). Torque the mounting bolts to 58-73 N·m (43-54 lb·ft).



1. Pulley Nut
2. Alternator Mounting Bracket
3. Washer (4)
4. Bolts, Bracket to Alternator (4)
5. Bolt, Bracket to Front Cover (3)
6. Nut (3)
7. Auto Tensioner
8. Idler Assembly
9. Auto Tensioner Mount
10. Alternator Vent Hose
11. Alternator
12. Oil Supply Tube
13. Alternator Support Bracket
14. Bolt, Support to Block (2)
15. Bolt, Bracket Support (2)
16. Oil Drain Tube Connector
17. Oil Drain Tube
18. Alternator Pulley
19. Washer
20. Woodruff Key (2)

Figure 8-5 Series 50 Coach Alternator and Related Parts (Vertical ECM)



1. Pulley Nut
2. Alternator Mounting Bracket
3. Washer (4)
4. Bolts, Bracket to Alternator (4)
5. Bolt, Bracket to Front Cover (3)
6. Nut (3)
7. Auto Tensioner
8. Idler Assembly
9. Auto Tensioner Mount
10. Alternator Vent Hose
11. Alternator
12. Oil Supply Tube
13. Alternator Support Bracket
14. Bolt, Support to Block (2)
15. Bolt, Bracket Support (2)
16. Oil Drain Tube Connector
17. Oil Drain Tube
18. Alternator Pulley
19. Washer
20. Woodruff Key (2)

Figure 8-6 Series 50 Coach Alternator and Related Parts (Horizontal ECM)

2. If a 50 DN alternator is used, install the pulley and lock nut, if removed, to the alternator. If an air cooled alternator is used, install the fan, drive pulley and locknut, if removed, to the alternator. Torque the pulley retaining nut to 315 N·m (225 lb·ft).
3. If the pulley was not removed, check the retaining nut for proper torque. Torque the retaining nut to 315 N·m (225 lb·ft), as necessary.
4. If the pulley was removed during disassembly, install two woodruff keys in mounting brackets.
5. Position the alternator on the mounting bracket, and align the holes in the alternator mounting flanges with those in the bracket support.

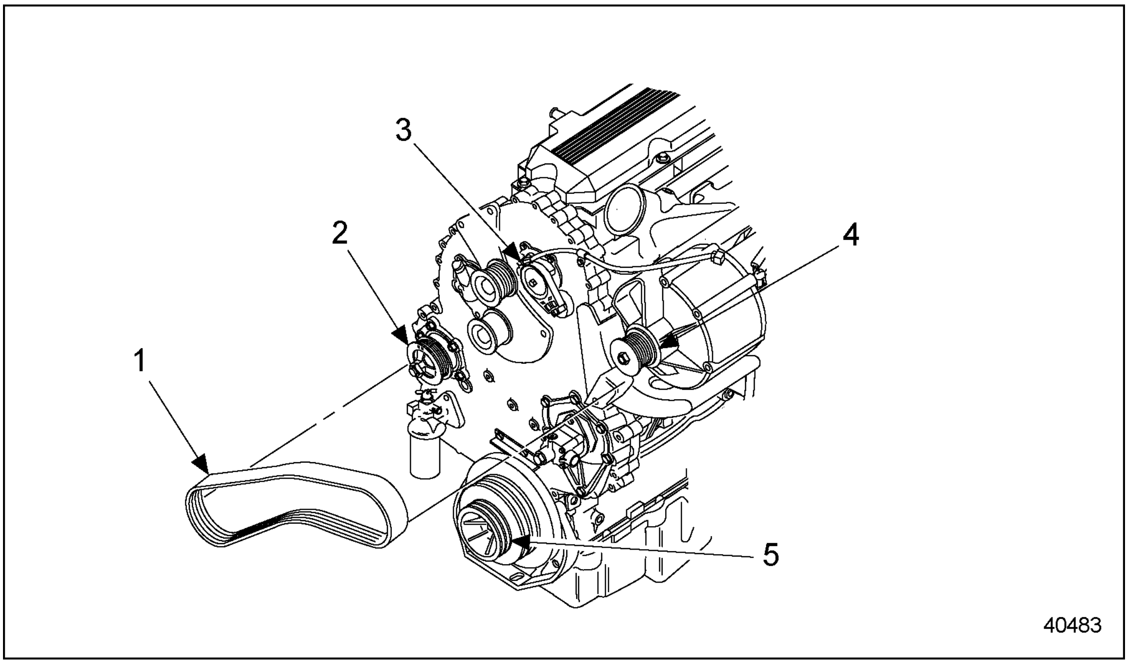
NOTE:
There are two holes in the front alternator end frame mounting flanges. One is threaded and one is not threaded. The threaded hole is positioned up and is used to secure the alternator to the adjusting rod.

6. 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. See Figure 8-1.

NOTICE:
Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup.

7. If alternator is oil cooled, connect the oil supply, return, and vent lines.
8. Install the belt carefully over the crankshaft or accessory drive pulley, the idler pulleys (if installed), and alternator drive pulley on the engine. If an auto belt tensioner is installed, use a breaker bar with a 3/4 inch drive to rotate the tensioner pulley upward for belt

installation. Ensure the grooved and smooth faces of the belt are properly positioned on the pulleys before taking up slack. See Figure 8-7.



1. Drive Belt
2. Accessory Drive Pulley
3. Auto Tensioner
4. Alternator Drive Pulley
5. Crankshaft Pulley

Figure 8-7 Coach Poly-vee Belt Installation

9. If an auto belt tensioner assembly is not installed, adjust the alternator belt tension. For twin belt-driven or single Powerband ® belt-driven alternator refer to Section 8.3.3.1 or for 12-rib poly-vee belt-driven 50 DN alternator refer to Section 8.3.3.2.
10. Torque the alternator-to-mounting bracket bolt and nut and the alternator-to-adjusting rod bracket bolt to 81-95 N·m (60-70 lb·ft).
11. Attach the wires and cables to the alternator. Ensure that each one is correctly installed in the location from which it was removed. Keep all connections clean and tight.

Powerband ® is a registered trademark of the Gates Rubber Company.

8.3.3.1 Checking Belt Tension on a Two-Groove Powerband® Alternator Drive

The recommended tension for new belts is 890 N (200 lb). However, because new belts lose tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 10 to 15 minutes. To check belt tension, use the following procedure:

NOTICE:

Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Tension the new drive belts to 890 N (200 lb) using Kent-Moore® belt tension gage, BT-3386-WE-75-225-2/V-1.1.3-31-R-P, or equivalent.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine from 10 to 15 minutes to allow the belts to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 10 to 15 minutes.
4. Measure belt tension:
   [a] If tension is 667 N (150 lb) or more, no re-tensioning is required.
   [b] If tension is less than 667 N (150 lb), re-tension the belt to 667 N (150 lb).
5. Check belt tension every 100 hours or 7,500 miles (12,000 km). Refer to Section 13.5.7 and re-tension belt to 667 N (150 lb), if necessary.

Kent-Moore ® is a registered trademark of the SPX Corporation.

8.3.3.2 Checking 12-Rib Poly-vee Belt-Driven 50 DN Alternator Belt Tension

The recommended tension for a new 12-rib poly-vee belt is 1558 N (350 lb). However, because a new belt loses tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 30 minutes. To check belt tension, use the following procedure:

NOTICE:
Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup.

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Tension the new poly-vee drive belt to 1558 N (350 lb) using Kent-Moore belt tension gage, J 41251-B, or equivalent. Refer to Section 13.5.7 for poly-vee belt tension gage usage procedure.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

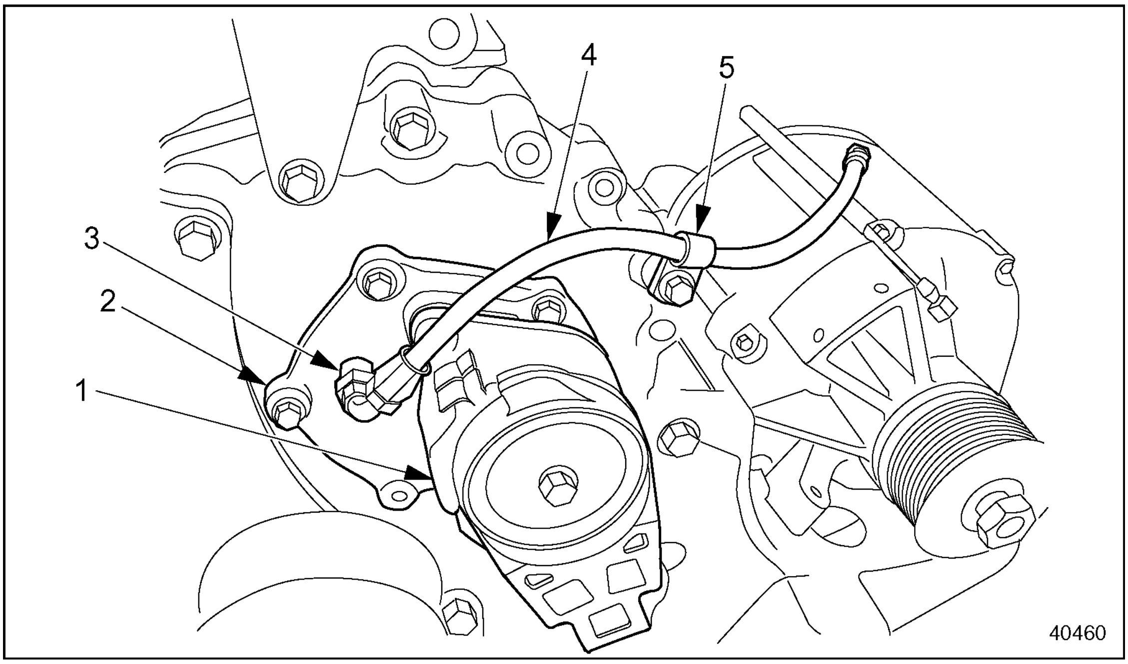
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine for 30 minutes to allow the belts to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 30 minutes.
4. Measure belt tension:
   [a] If tension is 1115 N (250 lb) or more, no tensioning is required.
   [b] If tension is less than 1115 N (250 lb), adjust belt tension to 1115 N (250 lb).
5. Check belt tension every 100 hours or every 7,500 miles (12,000 km), refer to Section 13.5.7 and re-tension to 1115 N (250 lb), if necessary.

Powerband ® is a registered trademark of the Gates Rubber Company. Kent-Moore ® is a registered trademark of the SPX Corporation.

8.3.3.3 50 DN Alternator Vent Line

Delco 50DN alternators are oil cooled and require an oil supply line from a port on the side of the engine block, an oil drain line from the bottom of the alternator to the oil pan or block, and a vent line to keep the oil within the alternator at an acceptable level and avoid overheating. The original vent line was a No. 4 hose connected between the top of the alternator and a tapped hole in the back of the gear case. Effective June 2000, the former vent line was replaced by a No. 6 braided hose connected between the orifice on top of the alternator and a tapped hole in the mounting plate for the auto belt tensioner assembly. See Figure 8-8. The larger diameter hose provides improved venting and helps eliminate the potential for vent line plugging, which could lead to insufficient cooling of alternator components and shortened alternator life.



1. Auto Tensioner Assembly
2. Mounting Plate, Auto Tensioner Assembly
3. Connector, 3/8 in. flared to 1/4 in. NPTF, straight
4. Vent Line, Alternator
5. Clip, Hose

Figure 8-8 Vent Line Installed in Auto Tensioner Mounting Plate

INSTALLATION OF THE IMPROVED VENT LINE

The improved vent line is installed between the alternator case and the drive belt auto-tensioner mounting plate on the gear case cover. Existing Series 50 engines with auto tensioner assemblies and engines with former manual drive belt tensioner assemblies may be modified to accept the improved vent line. Use the following procedures:

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

Installation of Vent Line in Drive Belt Auto Tensioner Assembly Mounting Plate

On engines with current drive belt auto tensioner assemblies, install the improved vent line between the alternator and the tensioner mounting plate as follows:

1. With the engine at ambient temperature and cool to the touch, remove and discard the former alternator vent line. Plug the vent line hole at the back of the gear case with a 1/4 in. NPTF square socket head pipe plug.
2. Remove the former vent fitting from the top of the alternator case.
3. Install the 3/8 in. flared to 1/4 in. NPTF, 90 degree elbow into the top of the alternator case.
4. Refer to section 8.3.2 to remove the alternator drive belt.
5. Remove the drive belt auto tensioner assembly from the mounting plate on the gear case cover.
6. Remove the mounting plate from the gear case cover.

7. Drill a 0.425 in. diameter hole on the left side of the mounting plate and thread with a 1/4 in. NPTF - 4FF tap. See Figure 8-9for hole location.

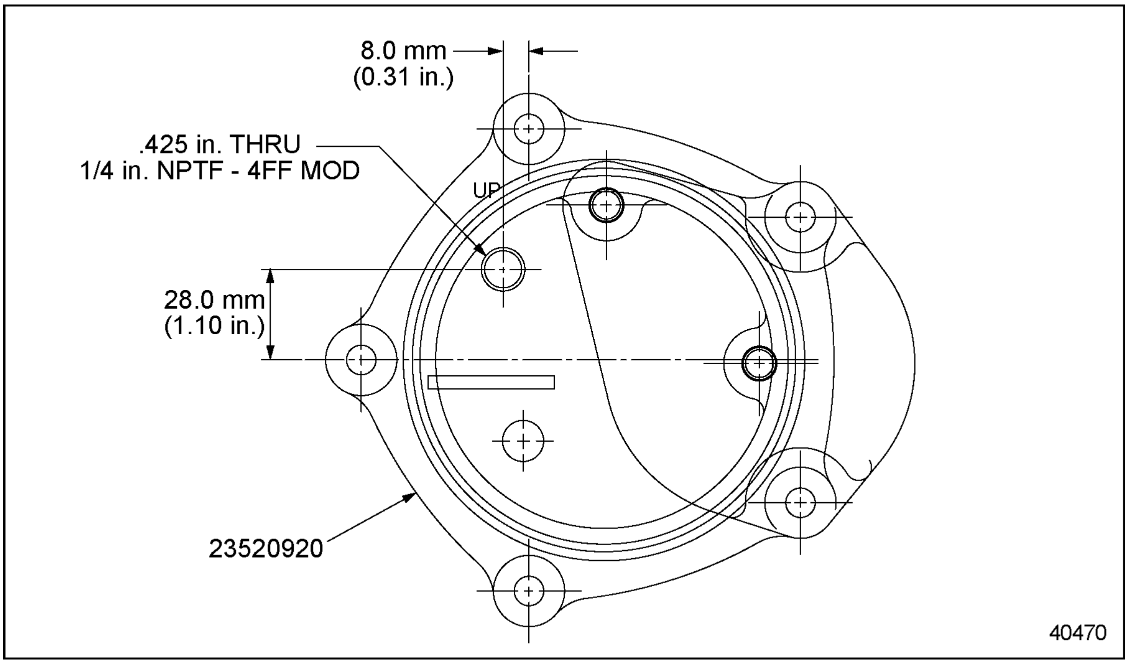


Figure 8-9 Location of Drilled and Tapped Vent Line Hole in Auto Tensioner Mounting Plate

8. Clean the plate carefully to remove all drill chaff.
9. Using a new gasket, install the plate onto the gear case cover.
10. Install the auto tensioner assembly onto the mounting plate.
11. Apply DDC®/Loctite® pipe sealant with Teflon® P/N 23509542, or equivalent, to the 3/8 in. flared to 1/4 in. NPTF straight fitting and install into the mounting plate. Attach the improved vent line and tighten securely.

NOTICE:
Do not drill the engine lifter bracket to install a hose clip, since this will weaken the bracket.

NOTICE:
Do not fasten the hose clip to either of the engine lifter bracket mounting bolts. The hose clip **must**be attached to the bolt on the right side of the lifter bracket to ensure unrestricted air flow through the vent line.

12. To prevent sags and low points, secure the vent line with the hose clip. Remove the gear case cover mounting bolt on the right side of the lifter bracket (bolt No. 12 – see Figure 8-10). Attach the hose clip to the bolt, reinstall, and torque the bolt to 58 –73 N·m (43 – 54 lb·ft).

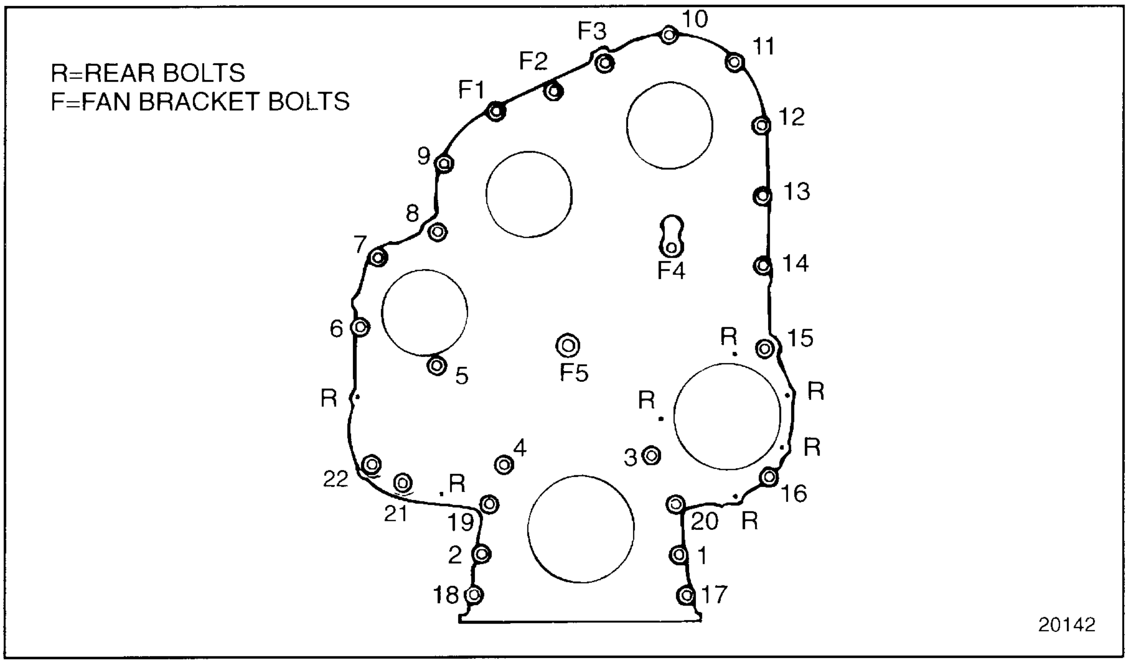


Figure 8-10 Gear Case Cover Mounting Bolt Locations

13. Refer to section 8.3.3 to install the alternator drive belt.
14. Reconnect starting power, start the engine, and check for proper vent line operation.

Installation of Vent Line in Front Camshaft Cover on Engines with Former Manual Belt Tensioner Assembly

On engines equipped with the former manual belt tensioner assembly, the front camshaft cover is situated behind the tensioner assembly, requiring its removal. Install the improved vent line on these engines as follows:

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

1. With the engine at ambient temperature and cool to the touch, remove and discard the former alternator vent line. Plug the vent line hole at the back of the gear case with a 1/4 in. NPTF square socket head pipe plug.
2. Remove the former vent fitting from the top of the alternator case.
3. Install the 3/8 in. flared to 1/4 in. NPTF, 90 degree elbow into the top of the alternator case.
4. Refer to section 8.3.2 to remove the alternator drive belt.
5. Remove the manual belt tensioner assembly from the gear case cover.
6. Remove the front camshaft cover from the gear case cover.

7. The center hole in the cover has a 1/8 in. NPTF thread which must be enlarged. Using a 0.425 in. drill bit, carefully drill out the tapped hole. Thread the hole with a 1/4 in. NPTF - 4FF tap. See Figure 8-11.

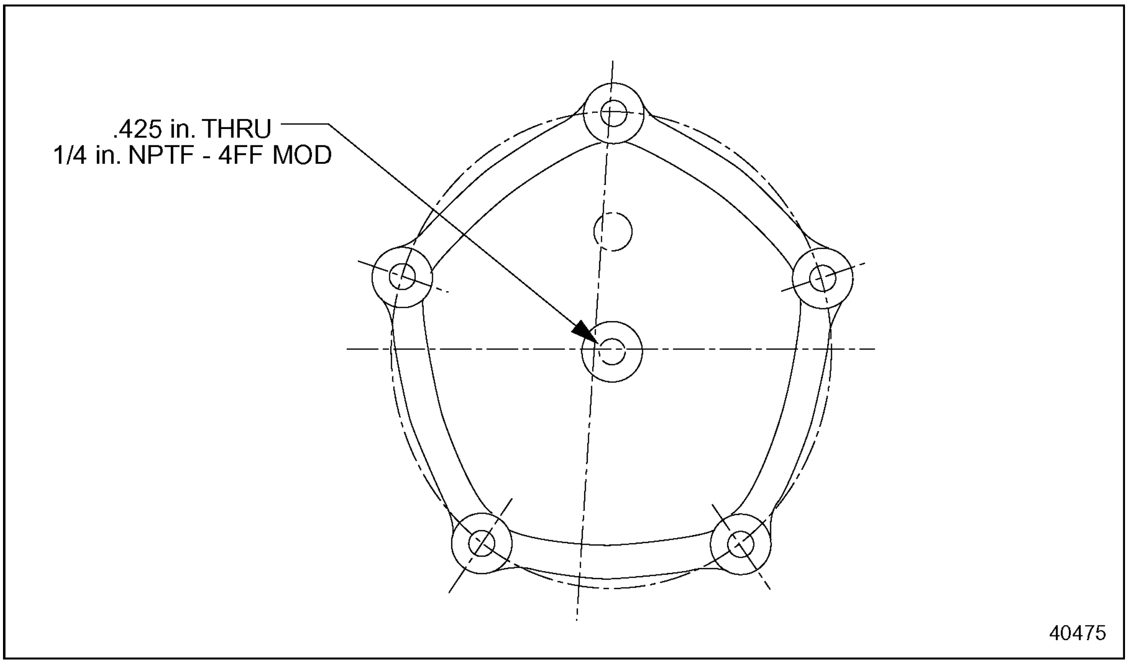


Figure 8-11 Drilled and Tapped Vent Line Hole in Front Camshaft Cover

8. Clean the cover carefully to remove all drill chaff.
9. Using a new gasket, install the front camshaft cover onto the gear case cover.
10. Apply DDC/Loctite pipe sealant with Teflon P/N 23509542, or equivalent, to the 3/8 in. flared to 1/4 in. NPTF straight fitting and install into the cover. Attach the improved vent line and tighten securely.
11. Install the manual belt tensioner assembly.

NOTICE:
Do not drill the engine lifter bracket to install a hose clip, since this will weaken the bracket.

NOTICE:
Do not fasten the hose clip to either of the engine lifter bracket mounting bolts. The hose clip **must**be attached to the bolt on the right side of the lifter bracket to ensure unrestricted air flow through the vent line.

12. To prevent sags and low points, secure the vent line with the hose clip. Remove the gear case cover mounting bolt on the right side of the lifter bracket (bolt No. 12 – see Figure 8-10). Attach the hose clip to the bolt, reinstall, and torque the bolt to 58 –73 N·m (43 – 54 lb·ft).
13. Refer to section 8.3.3of the service manual and install the alternator drive belt.
14. Reconnect starting power, start the engine, and check for proper vent line operation.

8.4 STORAGE BATTERY

The lead-acid storage battery is an electro-chemical device for storing energy and converting chemical energy into electrical energy.

The battery has three major functions:

- ☐ It provides a source of current for starting the engine.
- ☐ It acts as a stabilizer to the voltage in the electrical system.
- ☐ It can, for a limited time, furnish current when the electrical demands exceed the output of the alternator.

CAUTION:

To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:

- ☐ **Flush your skin with water.**
- ☐ **Apply baking soda or lime to help neutralize the acid.**
- ☐ **Flush your eyes with water.**
- ☐ **Get medical attention immediately.**

If you come in contact with 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.

In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer. This information is listed in Table 8-2.

Series 50 Engine	System Voltage	Minimum Battery Rating [SAE Cold Cranking AMPS (CCA) at -17.8°C (0°F)]
8.5 Liter	12V	1875 CCA*
8.5 Liter	24V	950 CCA*

* Recommendation based on the use of Delco-Remy 42MT (or equivalent) cranking motor.

Table 8-2 Electrical Size of Series 50 Replacement Battery

8.4.1 Repair or Replacement of Storage Battery

Refer to the OEM for service procedure.

8.4.2 Cleaning and Removal of Storage Battery

Precleaning may be necessary. Refer to OEM guidelines.

Remove storage battery as follows:

1. Disconnect grounded terminal of the battery.
2. Remove the cable clamps.
3. Remove felt washer.
4. Remove the battery.

8.4.2.1 Inspection of Storage Battery

For storage battery inspection procedure, refer to OEM guidelines.

8.4.3 Installation of Storage Battery

Install the battery as follows:

1. Clean battery carrier, as necessary.
2. Seat the battery level in its carrier.

NOTICE:
Do not draw the hold-down clamps down too tightly or the battery case will become distorted or crack.

3. Tighten the hold-down clamps evenly until snug.
4. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition.
5. Place a new felt washer at the base of each terminal beneath the cable clamps, to make the cable connections as corrosion resistant as possible.
6. Coat the entire connection with a heavy general-purpose grease.

NOTE:
Be sure the ground cable is clean and tight at the engine block or frame.

NOTICE:
Connect the **grounded** terminal of the battery **last** to avoid short circuits, which will damage the battery.

7. Check the polarity to be sure the battery is not reversed with respect to the generating system.
8. Refer to Section 11.1.8 for verification of proper storage battery installation.

8.5 CRANKING MOTOR

The cranking motor is bolted to the flywheel housing. See Figure 8-12.

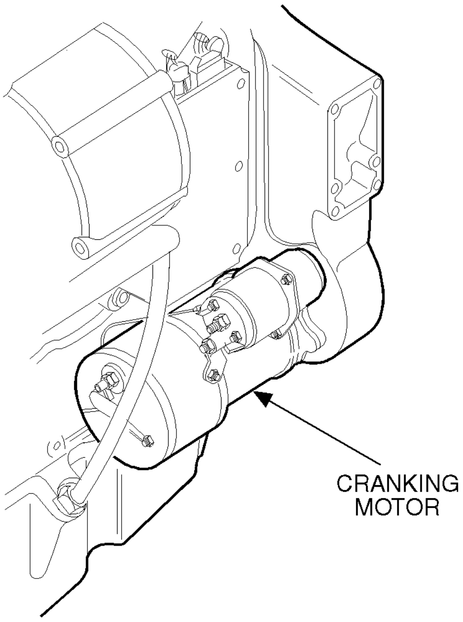


Figure 8-12 Cranking Motor Mounting

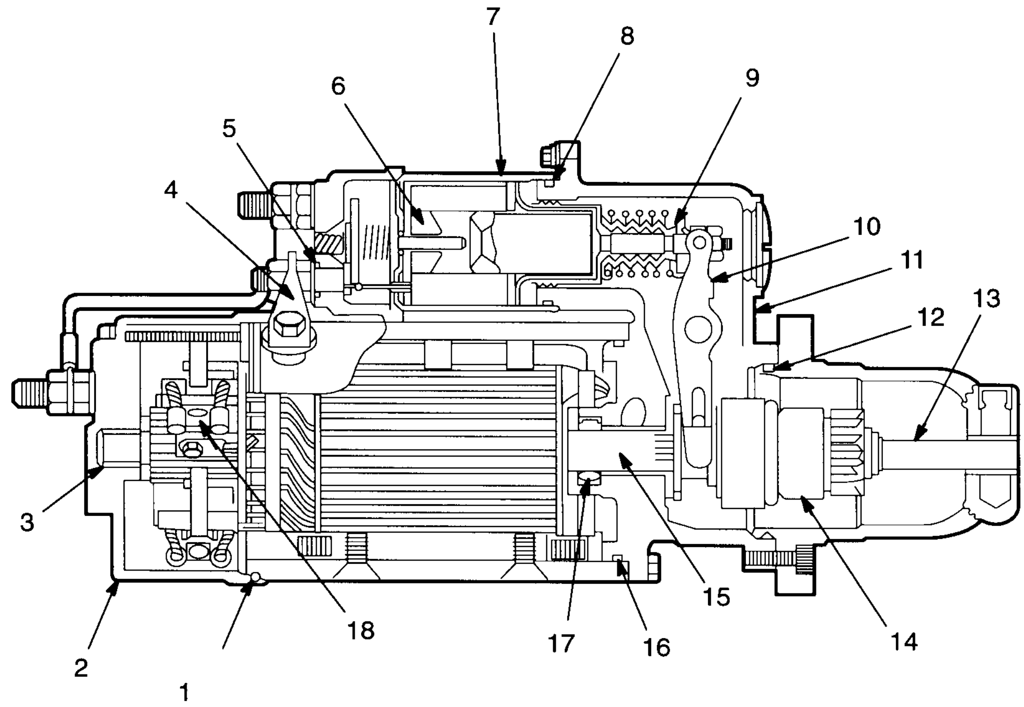
NOTICE:
To prevent excessive overrun and damage to the drive and armature windings, the switch should be opened immediately when the engine starts. A cranking period should not exceed 30 seconds without stopping to allow the motor to cool for at least two minutes.

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 cranking 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.

NOTE:
Some engines may be equipped with air starters. Contact starter manufacturer for operating characteristics and rebuilding procedures.

The 42 MT cranking motor typically used on the Series 50 engine has a nose housing that can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. The commutator end cap can be removed to inspect the brushes, in most cases, without removing the cranking motor from the vehicle.

The cranking motor armature is supported by three sintered bronze bearings located, one each, in the nose and intermediate housings, with one in the commutator end cap. See Figure 8-13.



1. O-ring
2. End Cap (Removal for Inspection)
3. Bronze Bearing
4. Connector Strap
5. Gasket
6. Low Friction Bushing
7. Seamless, One-piece Solenoid Case
8. O-ring
9. Sealing Boot
10. Shift Mechanism (Totally Enclosed)
11. Two-piece Housing
12. O-ring
13. Bronze Bearing
14. Heavy-duty Drive Overrunning Clutch
15. Bronze Bearing
16. O-ring
17. Shaft Seal
18. One-piece Brush

Figure 8-13 Typical Cranking Motor Cross-Section

Sintered bronze bearings used in the current cranking motors have a dull finish, compared to the former machined, cast bronze bearings, which had a shiny finish.

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. For the complete cranking circuit, refer to the vehicle manufacturer's wiring diagram.

A basic cranking circuit is shown in the following illustration. See Figure 8-14.

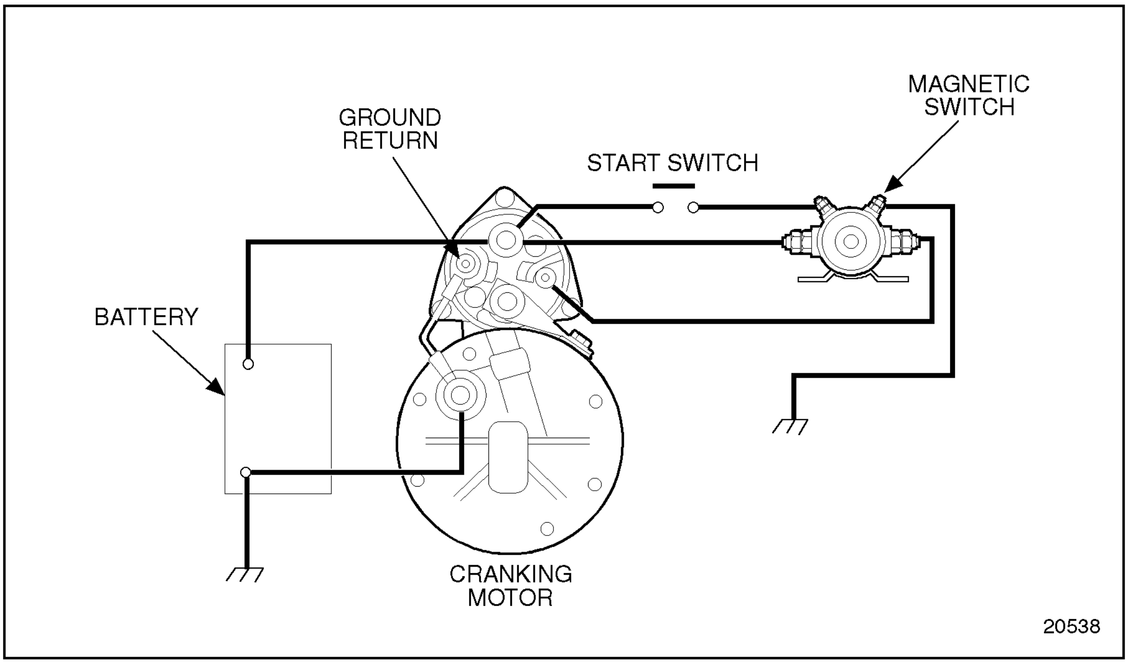


Figure 8-14 Basic Cranking Circuit

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 magnetic switch contacts 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 to close, and the cranking takes place.

8.5.1 Replacement of Cranking Motor

Refer to the OEM guidelines for cranking motor service procedures.

8.5.2 Cleaning and Removal of Cranking Motor

Precleaning is not necessary.

Remove the cranking motor as follows:

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

1. Remove the ground strap or negative cable(s) from the battery(s).
2. Tag each lead to ensure correct connections when the cranking motor is reinstalled.
3. Disconnect the cranking motor cables and solenoid wiring.
4. Support the motor, and remove the three bolts which secure it to the flywheel housing.
5. Pull the motor out to remove it from the flywheel housing.

If the nose housing requires relocation, perform the following steps:

NOTICE:

The solenoid should not be located below the centerline of the cranking motor. Dust, oil, moisture and foreign material can collect and cause solenoid failure.

1. Remove the six socket head screws (1 short and 5 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.
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. Torque the screws to 18-23 N·m (13-17 lb·ft).

8.5.3 Installation of Cranking Motor

Install the cranking motor as follows:

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

1. Support the cranking motor, and install the three bolts that secure it to the flywheel housing.
2. Connect the cranking motor cables and the solenoid wiring.
3. Install the ground strap or negative cable(s) to the battery(s).

4. If aluminum flywheel housing is used, torque the cranking motor attaching bolts to 187-209 N·m (138-154 lb·ft). If a cast iron flywheel housing is used, the cranking motor attaching bolts should be torqued to 245-306 N·m (181-226 lb·ft).
5. If equipped with a 42 MT, install wiring terminal leads to the cranking motor and the solenoid switch.
6. Torque the smaller connections to 1.8-3.4 N·m (16-30 lb·in.). Torque the larger connections to 27-34 N·m (20-25 lb·ft).

NOTE:
Keep all of the electrical connections clean and tight.

7. Refer to Section 11.2 for verification of proper cranking motor installation.

8.6 DDEC III WIRING HARNESS

The DDEC sensor wiring harness is equipped with two metal retaining clips and secured to the engine cylinder block with bolts. A cover and two bolts secure the injector wiring harness to the rear of the cylinder head. See Figure 8-15.

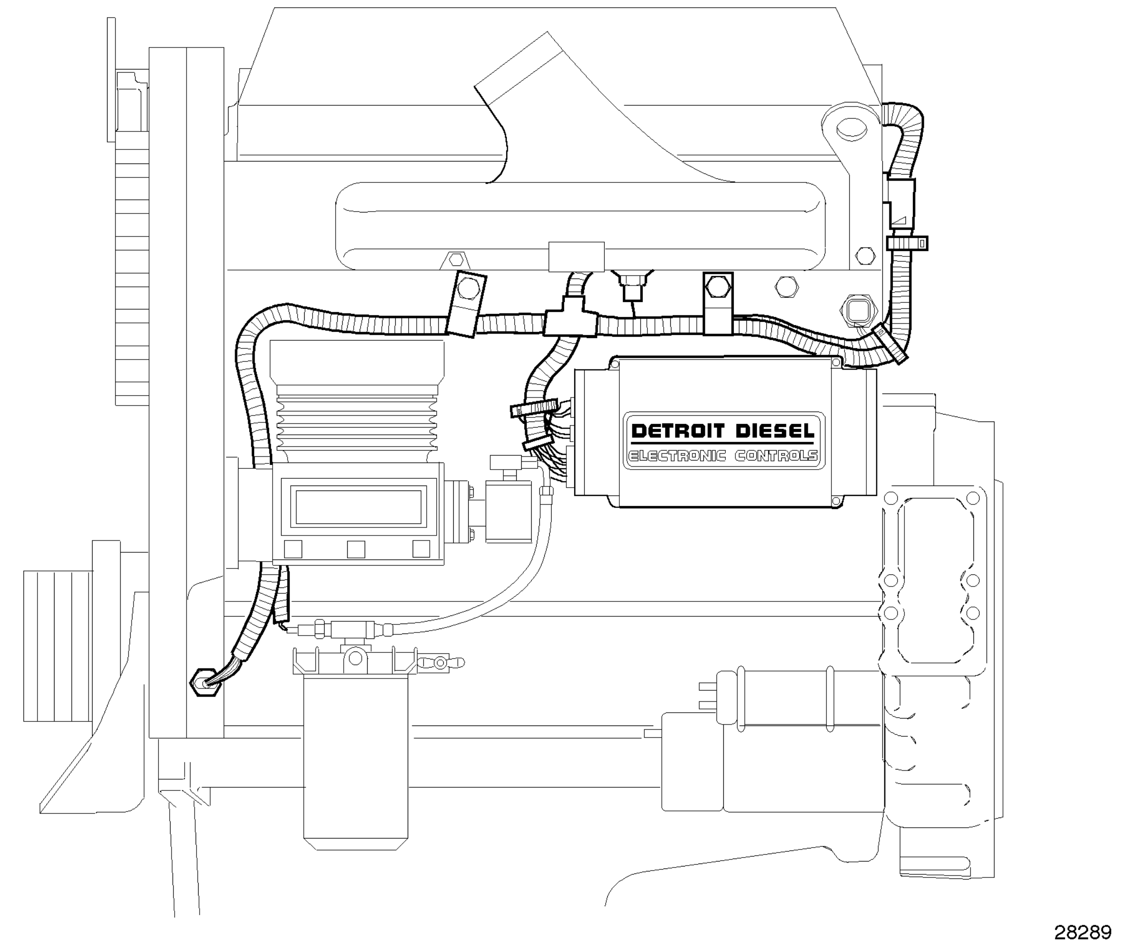


Figure 8-15 Typical DDEC III Wiring Harness

Due to a hardware change made in October of 1995 to the DDEC ® III ECM, a path to ground can arise during ECM powerdown which may allow unintended engine cranking.

Unintended engine cranking can occur if *all*of the following conditions exist:

- ☐ The engine has an ECM manufactured between October of 1995 and September of 1996
- ☐ The engine is equipped with the Optimized Idle ™ feature.

- ☐ The ignition remains turned on while battery power is removed from the ECM during servicing.

NOTE:
This condition will not occur on engines manufactured after September of 1996.

To address this concern and eliminate the potential for unintended engine cranking under the conditions listed above, an Optimized Idle Starter Relay Harness Overlay Service Kit was released for engines with ECM's manufactured between October of 1995 and September of 1996.

8.6.1 Diagnostic Procedures

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, refer to the *DDEC II Troubleshooting Guide, 6SE489* or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497 Basic Knowledge Required.

8.6.2 Repair or Replacement of DDEC III Wiring Harness

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 8-16.

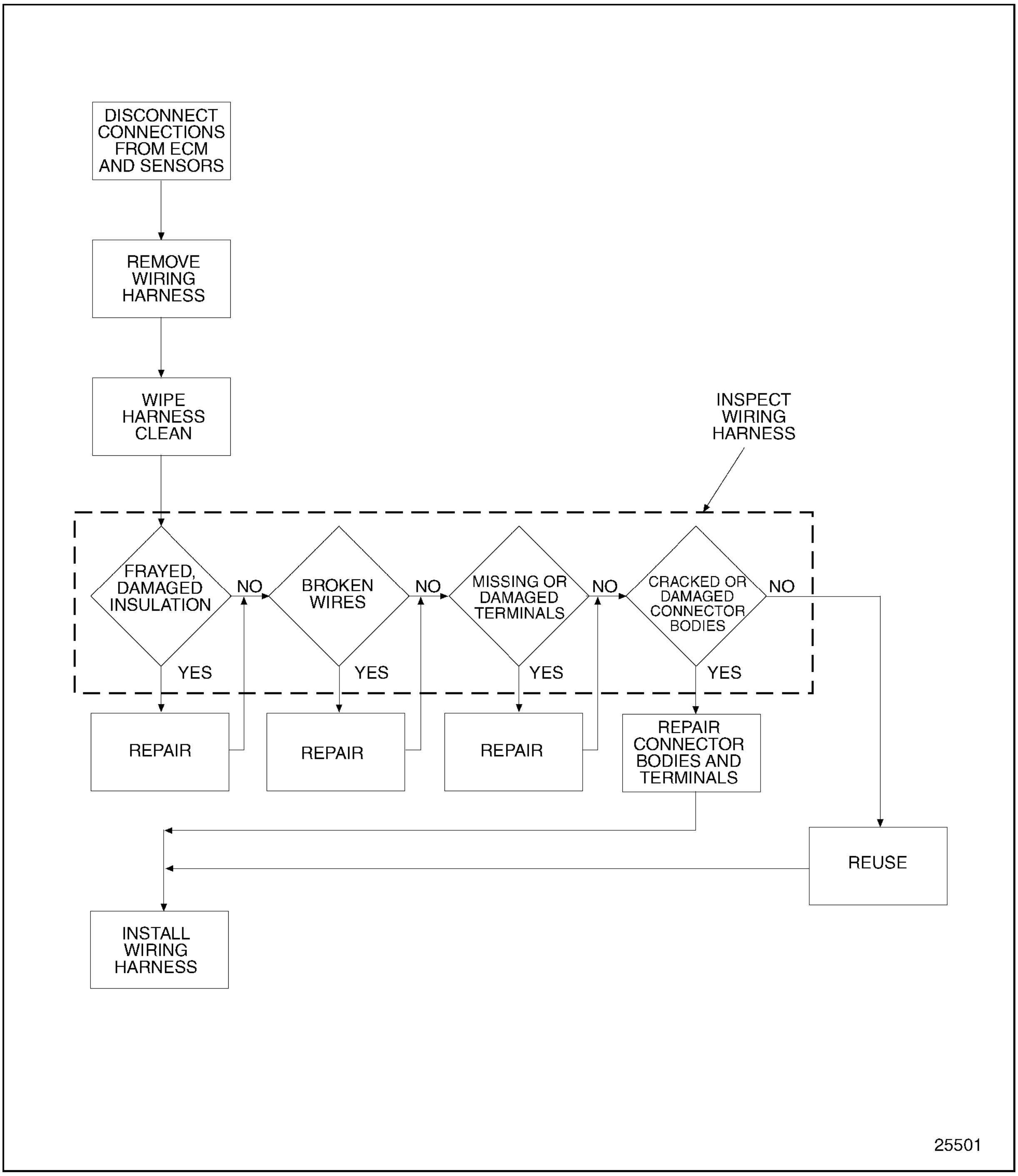
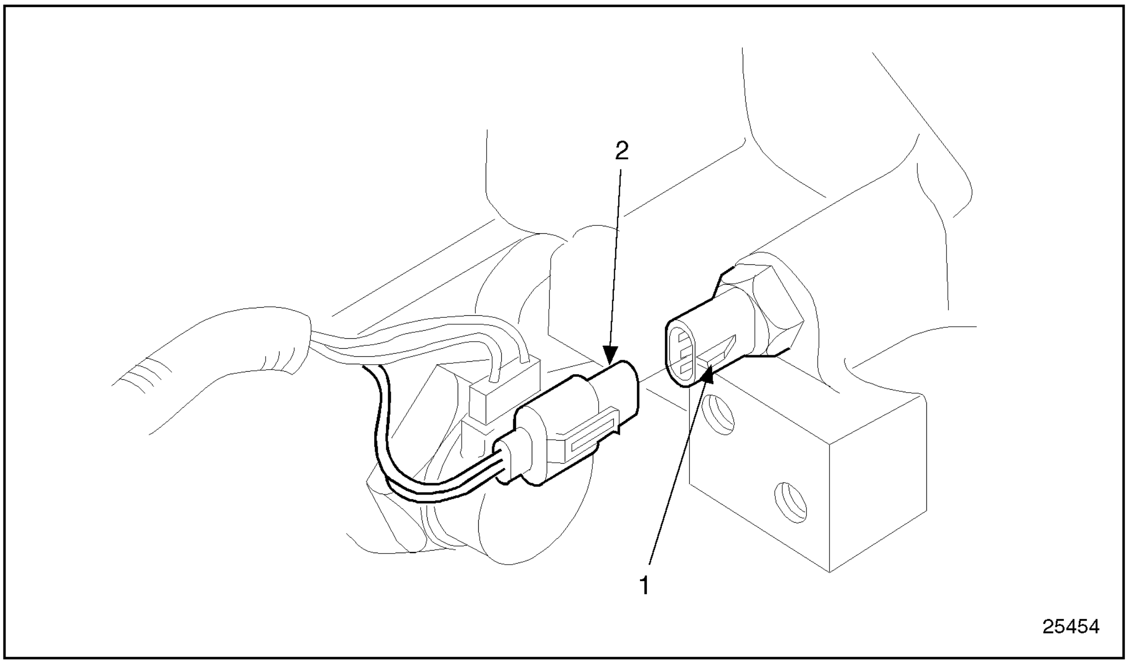


Figure 8-16 Flowchart for Repair or Replacement of ECM Wiring Harness

8.6.3 Removal of DDEC III Wiring Harness

Remove the DDEC III sensor wiring harness as follows:

1. Disengage the locking tang on each individual sensor connector body. See Figure 8-17.



1. Locking Tang
2. Connecting Body

Figure 8-17 Typical Sensor Connector Locking Tang

2. Grasp the connector body and gently pull it from the sensor.
3. Remove the two bolts securing the metal harness clips to the engine.
4. Remove the 30-pin connector from the ECM by loosening the connector attaching bolt. Carefully pull the connector from the ECM and remove the harness from the engine.

8.6.4 Installation of DDEC III Sensor Wiring Harness

Install the DDEC III sensor wiring harness as follows:

1. Install the 30-pin connector to the ECM, and torque the connector body attaching bolt to 0.79-1.47 N·m (7-13 lb·in.).
2. Install the two bolts securing the metal harness clips to the engine. Torque them to 30-38 N·m (22-28 lb·ft).
3. Carefully plug the two-pin and three-pin harness connectors into the appropriate sensors.
4. If the engine ECM is programmed with the Optimized Idle option, a starter relay harness overlay kit may be installed. Refer to Section 8.6.5 and refer to Section 8.6.5.1.

8.6.5 Installation of Starter Relay Harness Overlay Service Kit

Install starter relay harness overlay service kit on an Optimized Idle option-equipped Series 60 engine as follows:

8.6.5.1 Qualifying the ECM for Use with the Starter Relay Harness Overlay Kit

Before installing the starter relay harness overlay service kit, the ECM *must* be qualified for use with the kit and replaced, if necessary. Qualify the ECM for use as follows:

Refer to the DDEC III ECM serial number/model number label located on top of the ECM.

If the second letter of the ECM *serial number*is "D," "E," or "F" and the last three characters of the *model number* are "AO1, ""AO2," "AO3," or "AO4," the ECM *must* be replaced before the kit can be installed. Following is an example of an ECM that must be replaced:

ECM Serial Number S E 600KZM ***/ ECM Model Number*** 6DD2368 A03

If the second letter of the ECM *serial number*is "A" through "C" or any letter from "G" onward *and* the last three characters of the *model number* are "CO1" through "CO3" or "AO5" and later alpha-numeric designations, the ECM *does not* require replacement before the kit can be installed. Following is an example of an ECM that does not require replacement:

ECM Serial Number S C 6005QM **/** ***ECM Model Number*** 6DD2296CO3 or 6DD2296AO5.

A summary of this procedure is listed in Table 8-3.

If Second Letter of ECM Serial Number Is:	And Last 3 Characters of ECM Model Number Are:	Disposition of ECM
" D", " E", or " F"	AO2, AO3, or AO4	Replace ECM
" G" and later letters	AO5 and later alpha-numeric designations	Use ECM

Table 8-3 Qualifying ECM for Use with Optimized Idle Overlay Kit

8.6.6 Preparation of Engine for Installation of Optimized Idle Starter Relay Harness Overlay Kit

Prepare engine for installation of optimized idle starter relay harness overlay kit as follows:

1. Place the transmission in neutral, set the parking brake, stop the engine, block the vehicle wheels, and close the hood/cab.
2. Turn ignition to the *On*position, but do not start the engine.

3. Locate Optimized Idle starter relay. See Figure 8-18.

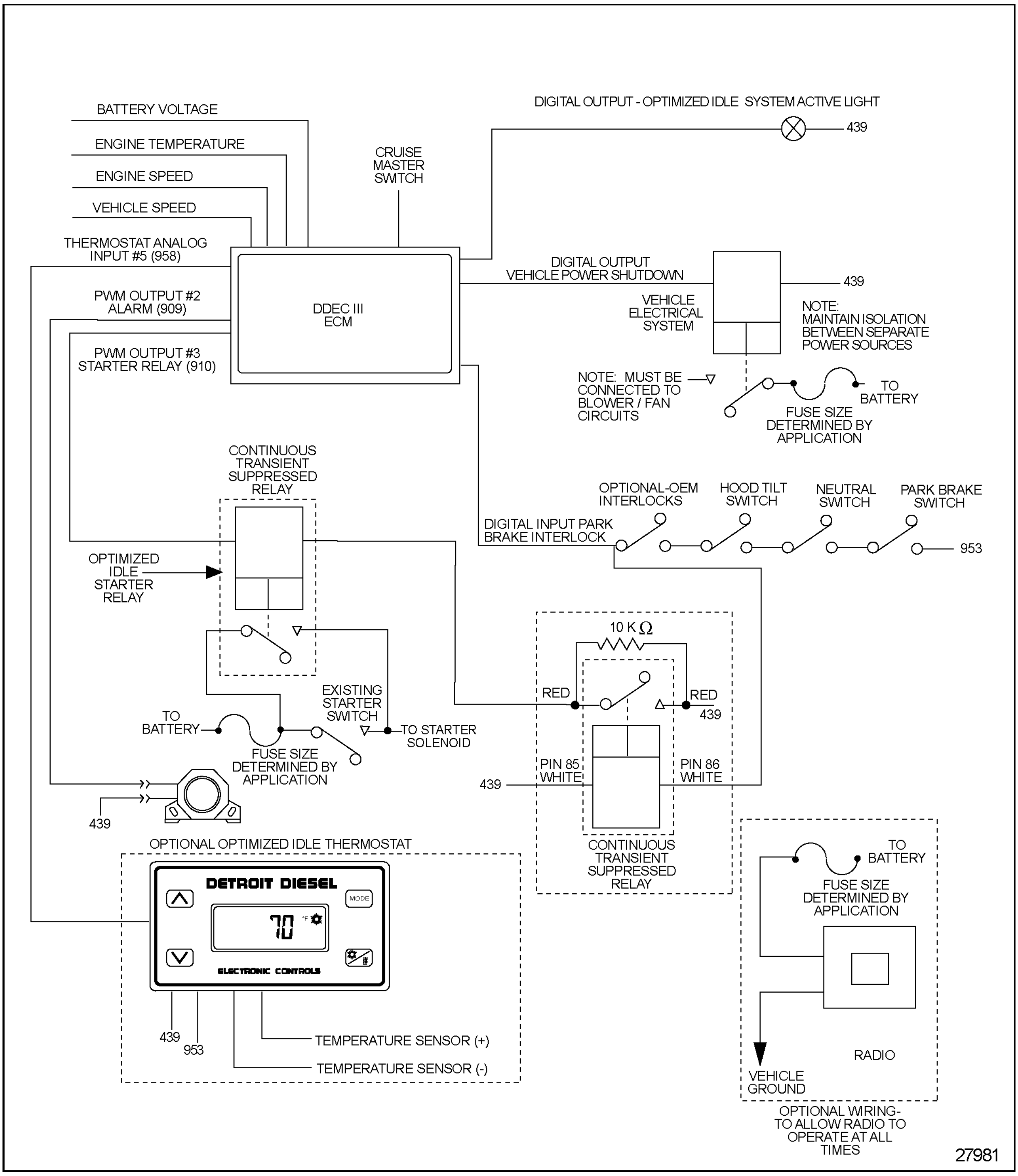


Figure 8-18 Optimized Idle System Overview

4. Remove starter relay from relay block (Note: The *Check Engine Light* will illuminate once the relay is removed from the relay block, and a code 63 [PWM driver #3 Open Circuit] will be logged).

5. Measure the voltage between pin 85 of the relay block and a good ground and note the voltage.
   [a] If the voltage is *less than* 4 VDC, pin 85 is PWM # 3. Mark the wire as "PWM # 3" and mark the wire attached to pin 86 of the relay coil as "Power".
   [b] If the voltage is *greater than* 4 VDC, pin 85 is the power side of the relay. Mark the wire as "power" and mark the wire attached to pin 86 of the relay coil as "PWM # 3".
6. Open the hood/cab.
7. Using the DDR (diagnostic data reader) select "Calibration Configuration," then select ECM inputs and outputs.
8. Arrow through the selections to find the pin position configured for "Park Brake Interlock."
9. Locate the appropriate wire in the 30-pin connector and label it "Park Brake Interlock."
10. Turn off the ignition.

CAUTION:

To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:

- ☐ **Flush your skin with water.**
- ☐ **Apply baking soda or lime to help neutralize the acid.**
- ☐ **Flush your eyes with water.**
- ☐ **Get medical attention immediately.**

11. Remove negative (-) battery cables.

8.6.7 Installation of Optimized Idle Starter Relay Harness Overlay Kit Components

Install optimized idle starter relay harness overlay kit components as follows:

1. Mount relay supplied in kit near Optimized Idle starter relay. See Figure 8-18.
2. Cut the wire labeled "power" approximately 6 in. from the relay block.
3. Route both of the red wires from the overlay harness to the cut wire.
4. Cut off any excess wire and strip the insulation.
5. Splice one of the red wires to the one side of the cut wire.
6. Splice the other red wire to the other side of the cut wire.
7. Splice the pink wire (439) to DDEC wire 439.

8. Route the white wire from the overlay harness through the fire wall to the Optimized Idle park brake interlock input wire.
9. Cut off any excess wire and strip the insulation from the white overlay harness wire.
10. Splice the white wire into the wire labeled "Digital Input", approximately 6 inches from the ECM 30-pin connector.
11. Install conduit on the section of the white wire in the engine compartment.
12. Secure conduit.
13. Close hood/cab.
14. Replace the starter relay into the relay block.

8.6.8 Verify Installation of Service Kit

Verify installation of service kit as follows:

CAUTION:

To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

1. Reconnect the battery negative (-) cables.
2. Turn ignition to "On" position and wait through bulb check. If "Check Engine" light remains on, check the codes. If a code 63 (PWM driver #3 Open Circuit) is logged, refer to the troubleshooting procedure included below. Otherwise, refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Toggle the "Cruise" on/off switch from *off* to *on*. The "Optimized Idle" light should flash.
5. After the engine shuts down, turn the thermostat on by pressing any button. Press *up* or *down* arrow until the heat or cool symbol begins to flash.

    [a] If the engine starts, repairs are complete.

    [b] If the engine does not start, call DDC's Technical Service Department.

8.7 METRI-PACK™ 150 SERIES CONNECTORS

Metri-Pack ™ 150 series connectors are "pull-to-seat" connectors. Each wire must be pushed through the connector prior to crimping the terminal. Cable seals are inserted into the shell of the connector and hold many wires.

Metri-Pack is a trademark of Delphi-Packard.

8.7.1 Repair and Replacement of Metri-Pack 150 Series Connectors

Repairs to Metri-Pack 150 series connectors are not possible. Remove the defective or damaged connector and replace. Refer to Section 8.7.2.

8.7.2 Removal of Metri-Pack 150 Series Connectors

A tang on the terminal locks into a tab molded into the plastic connector to retain the cable assembly. Remove and repair Metri-Pack 150 terminals using the following instructions.

1. Insert the removal tool into the cavity of the connector, placing the tip of the tool between the locking tang of the terminal and the wall of the cavity. See Figure 8-19.

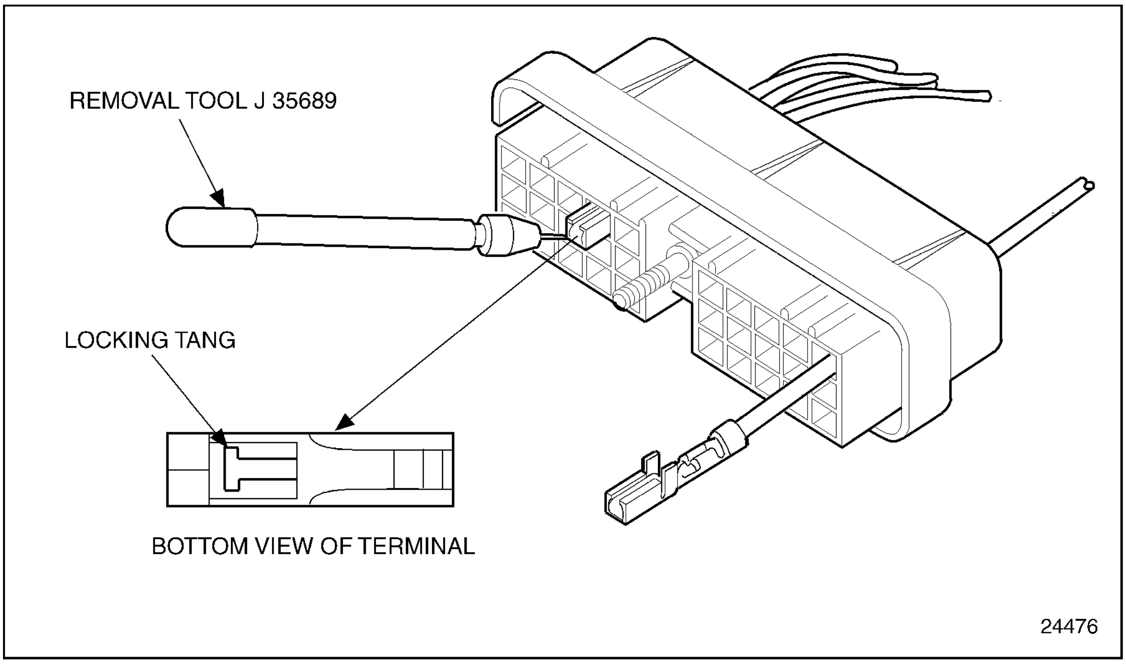


Figure 8-19 Terminal Removal

2. Depress the tang of the terminal to release it from the connector.
3. Push the cable forward through the terminal until the complete crimp is exposed.
4. Cut the cable immediately behind the damaged terminal to repair it.

5. Follow the installation instructions for crimping the terminal and inserting it into the connector.

8.7.3 Installation of Metri-Pack 150 Series Connectors

Metri-Pack 150 connectors are of the "pull-to-seat" type. Each cable must be pushed through the seal and connector prior to crimping the terminal. Cable seals are inserted into the shell of the connector and hold many wires. Use the following instructions for terminal installation:

1. Push the cable through the correct cavity of the seal and connector. See Figure 8-20.

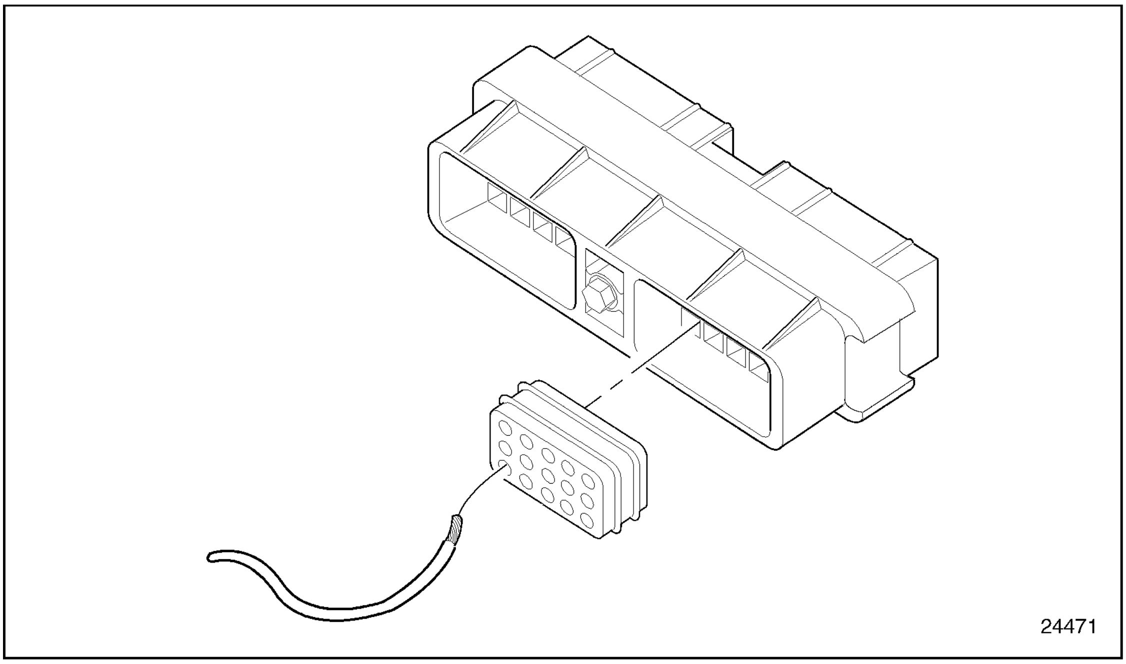


Figure 8-20 Inserting Wire Connector

2. Strip the end of the cable using wire strippers to leave 5.0 mm (0.20 in.) (± 0.5 mm ±0.02 in.) of bare conductor.
3. Squeeze the handles of the crimping tool together firmly to cause the jaws to automatically open.
4. Hold the "wire side" facing you.

5. Insert the terminal until the wire attaching portion of the terminal rests on the 20-22 anvil. Be sure the wire core wings and the insulation wings of the terminal are pointing toward the upper jaw of the crimping tool. See Figure 8-21.

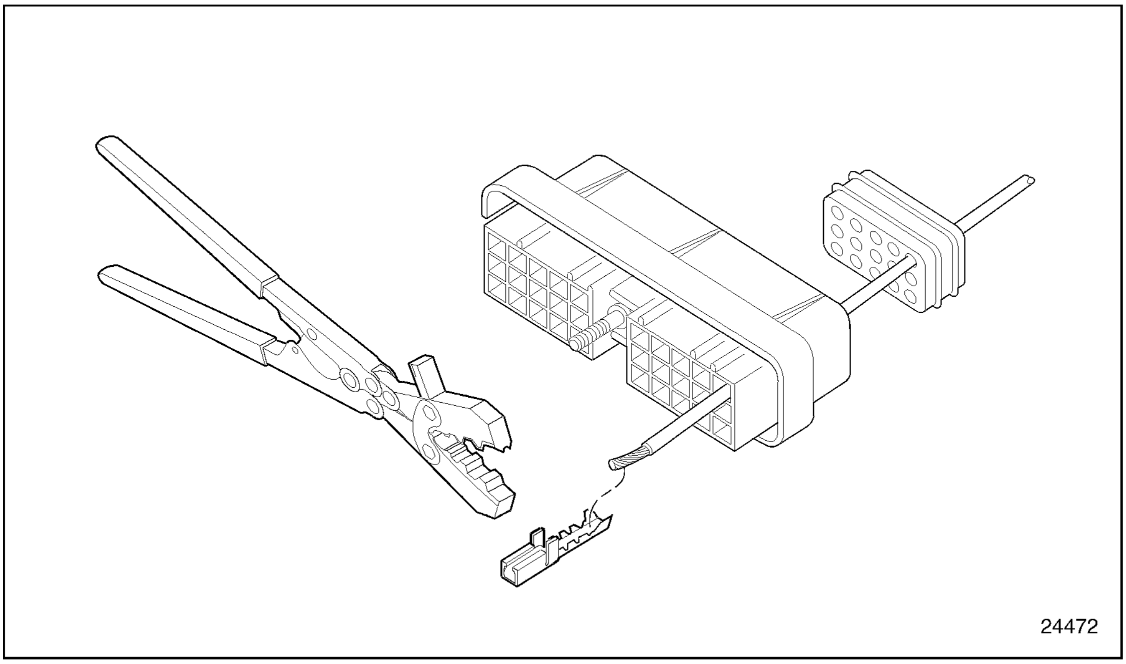


Figure 8-21 Terminal and Crimping Tool Position

6. Insert the cable into the terminal until the stripped portion is positioned in the wire core wings, and the insulation portion ends just forward of the insulation wings. See Figure 8-22.

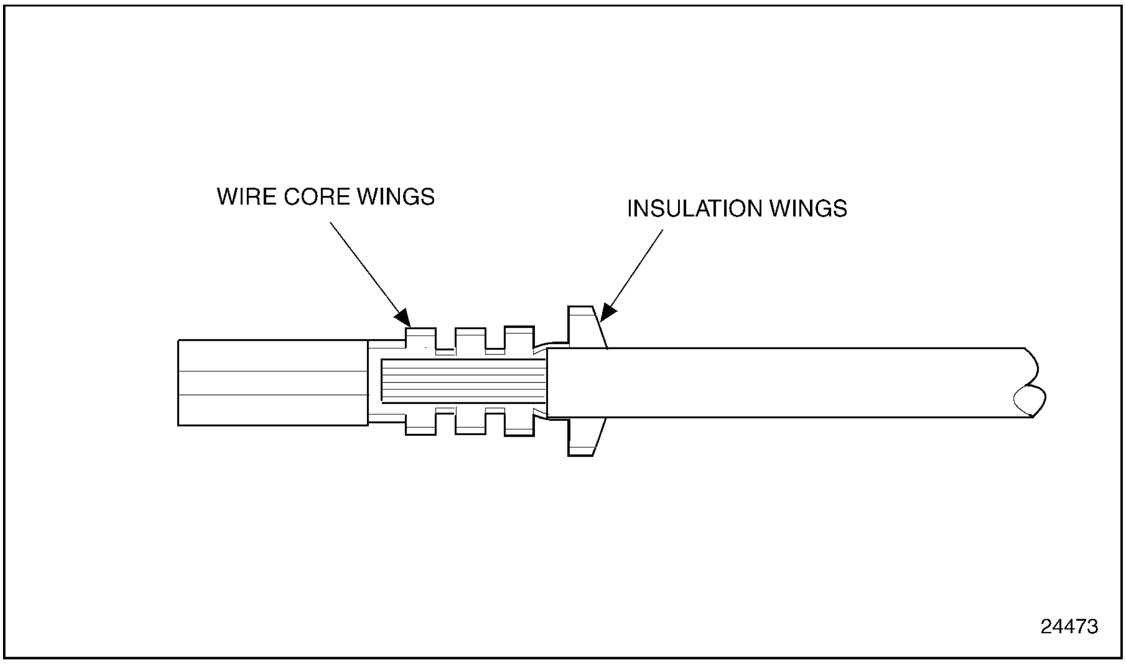


Figure 8-22 Cable to Terminal Alignment

7. Compress the handles of the crimping tool until the ratchet automatically releases and the crimp is complete.

NOTE:
For faster, more efficient crimping operation, a bracket or bench rest may be used to cradle one handle of the tool. The operator can apply the terminals by grasping and actuating only one handle of the tool. See Figure 8-23.

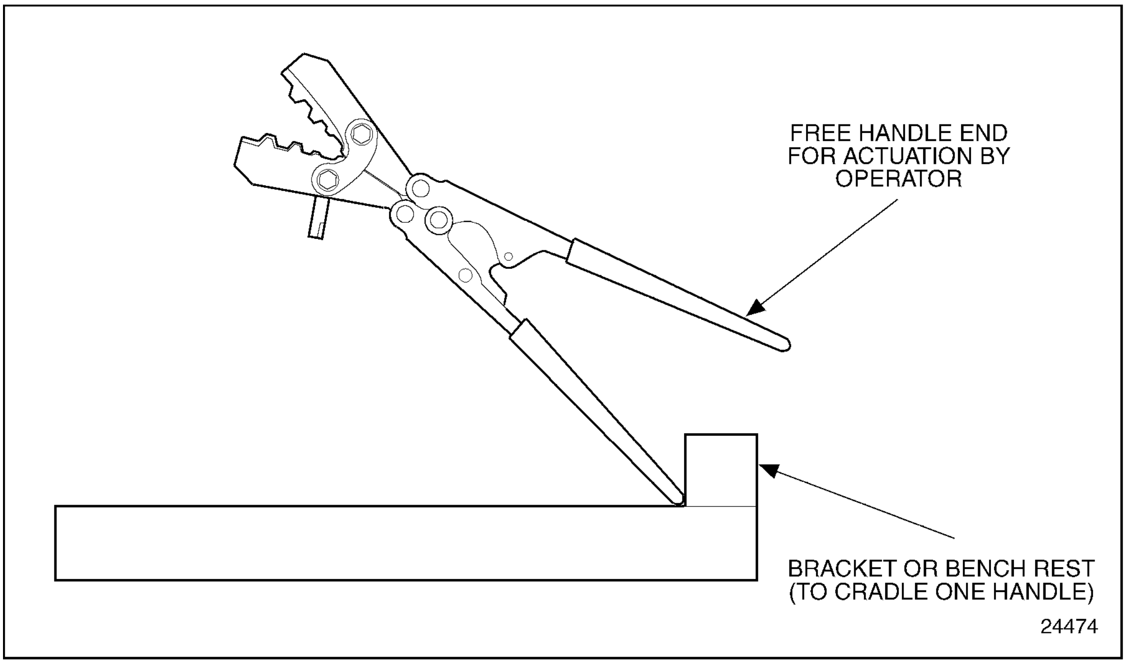


Figure 8-23 Crimping Operation

8. Release the crimping tool with the lock lever located between the handles, in case of jamming.
9. Align the locking tang of the terminal with the lettered side of the connector.

10. Pull the cable back through the connector until a click is heard. See Figure 8-24. Position the seal into the connector.

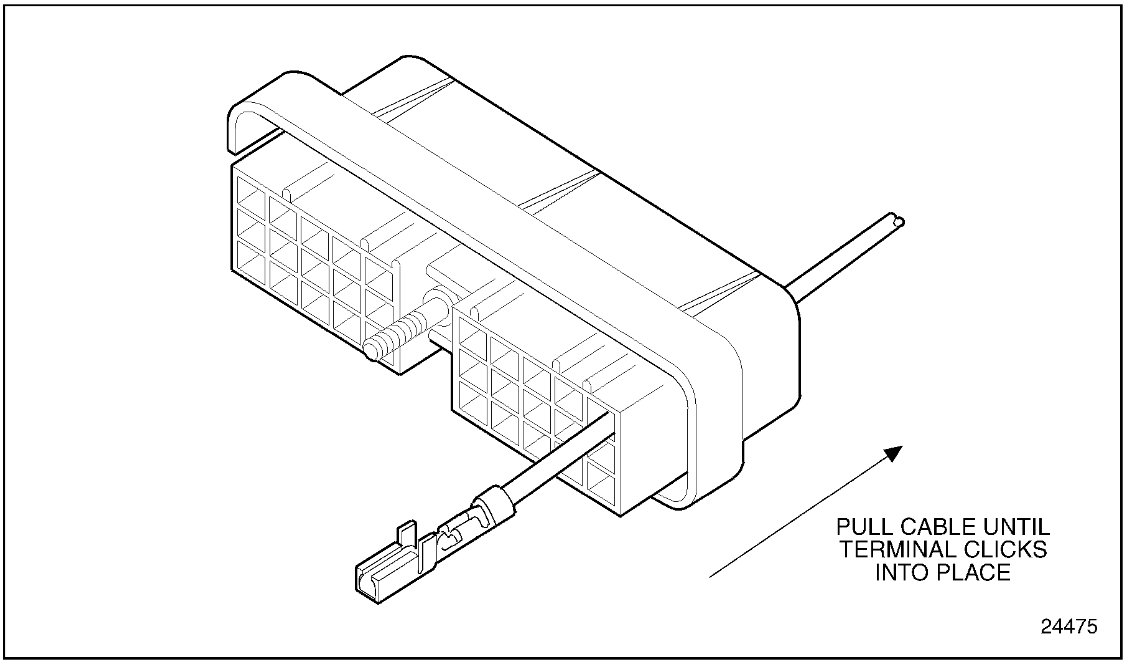


Figure 8-24 Pulling the Terminal to Seat

NOTE:
For ECM 30-pin connectors, put locking tang opposite lettered side.

8.8 MICRO-PACK™ SERIES CONNECTORS

Micro-Pack™ series connectors are push-to-seat connectors. Each wire must be crimped into the terminal before it is inserted into the connector. All terminals require 18 gage GXL wire.

Micro-Pack is a trademark of Delphi-Packard.

8.8.1 Repair and Replacement of Micro-Pack Connectors

Repairs to Micro-Pack connectors are not possible. Remove the defective or damaged connector and replace. Refer to Section 8.8.2.

8.8.2 Removal of Micro-Pack Connectors

To remove the connector:

1. Cut the cable immediately behind the damaged terminal.
2. Install a fresh connector. Refer to Section 8.8.3.

8.8.3 Installation of Micro-Pack Connectors

Micro-Pack series connectors are of the push-to-seat design. The terminal is crimped on the wire before it is inserted into the connector.

Use the following instructions for terminal installation:

NOTICE:
The cable should be stripped of insulation *before* it is inserted through the connector body.

1. Strip the end of the cable using wire strippers to leave 5.0 mm (0.20 in.) (±0.5 mm ±0.02 in.) of bare conductor.
2. Insert the terminal into the locating hole of the crimping tool. Check the gage of the cable to locate the proper hole.

3. Insert the cable into the terminal until the stripped portion is positioned in the cable core wings, and the insulated portion of the cable is in the insulation wings. See Figure 8-25.

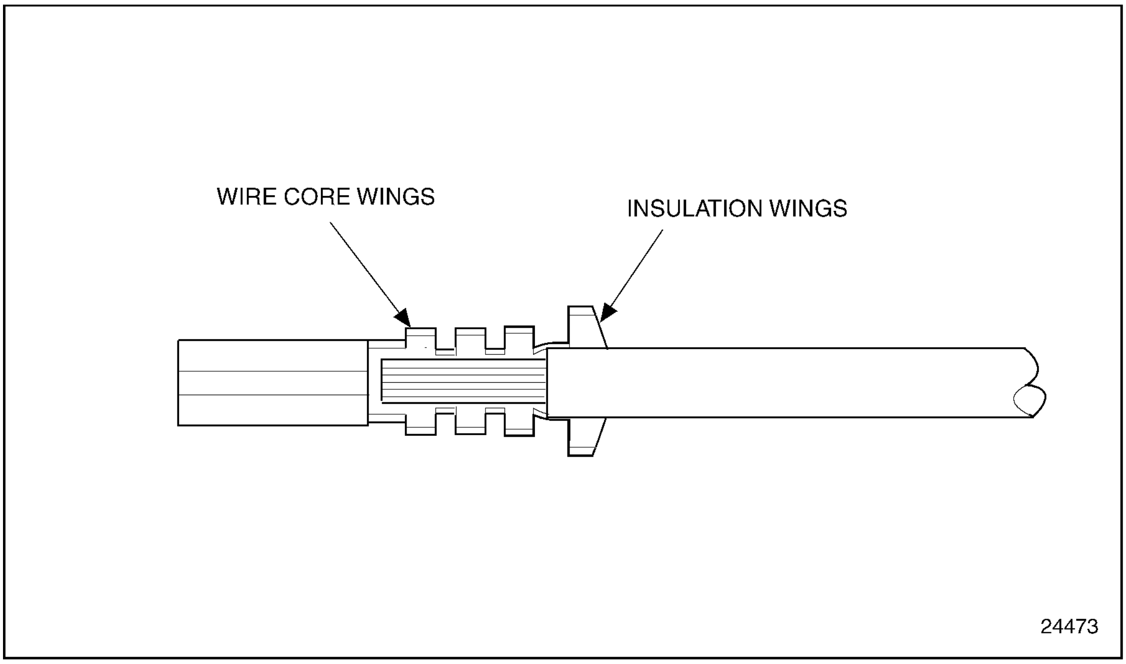


Figure 8-25 Cable to Terminal Alignment

4. Compress the handles of the crimping tool until the crimp is complete.

NOTE:
For faster, more efficient crimping operation, a bracket or bench rest may be used to cradle one handle of the tool. The operator can then apply the terminals by grasping and actuating only one handle of the tool.

5. Release the crimping tool with the lock lever located between the handles, in case of jamming.
6. Push the crimped terminal into the connector until it clicks into place. Gently tug on the cable to make sure it is secure.

8.9 WEATHER PACK™ AND METRI-PACK 280 SERIES CONNECTORS

Weather Pack ™ and Metri-Pack ™ 280 series connectors are push-to-seat. The terminal is crimped onto each wire before it is inserted into the connector. A cable seal is crimped on each wire at the same time the terminal is crimped onto the wire. Weather Pack connectors use a secondary lock on both male and female connector bodies and the lock snaps into place over the cable seals after installation. Some Metri-Pack connectors have secondary locks as well.

Weather Pack and Metri-Pack is a trademark of Delphi-Packard.

8.9.1 Repair and Replacement of Weather Pack and Metri-Pack 280 Series Connectors

Repairs to Weather Pack and Metri-Pack 280 series connectors are not possible. Remove the defective or damaged connector and replace. Refer to Section 8.9.2.

8.9.2 Removal of Weather Pack and Metri-Pack 280 Series Connectors

Two locking tangs are used on the terminals to secure them to the connector body. Use the following instructions for removing terminals from the connector body.

1. Grasp the cable to be removed and push the terminal to the forward position.
2. Insert the removal tool straight into the front of the connector cavity until it rests on the cavity shoulder. See Figure 8-26.

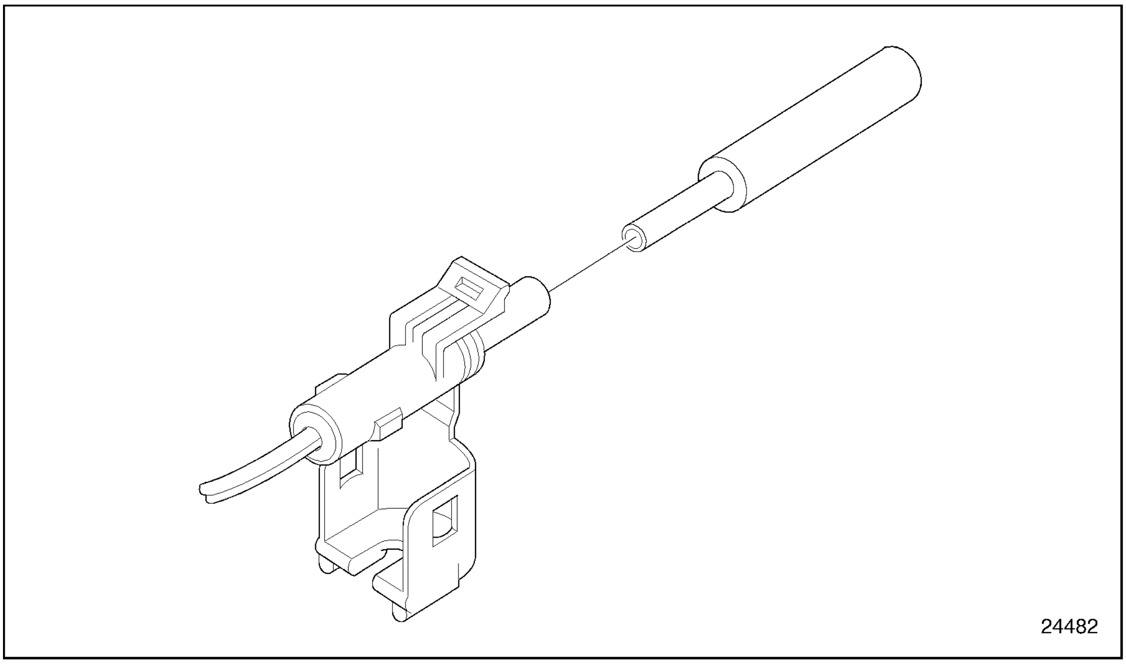


Figure 8-26 Removal Tool Procedure

3. Grasp the cable and push it forward through the connector cavity into the tool while holding the tool securely in place. The tool will depress the locking tangs of the terminal.
4. Pull the cable rearward (back through the connector).
5. Remove the tool from the connector cavity.
6. Cut the wire immediately behind the cable seal.
7. Follow the installation instructions for crimping the terminal and inserting it into the connector.

8.9.3 Installation of Weather Pack and Metri-Pack 280 Series Connectors

Use the following instructions for terminal installation:

1. Slip the cable seal onto the wire.
2. Strip the end of the cable using strippers to leave 5.0 mm 0.20 in. (±0.5 ±0.02 in.) of bare connector.
3. See Figure 8-27 to position the cable seal.

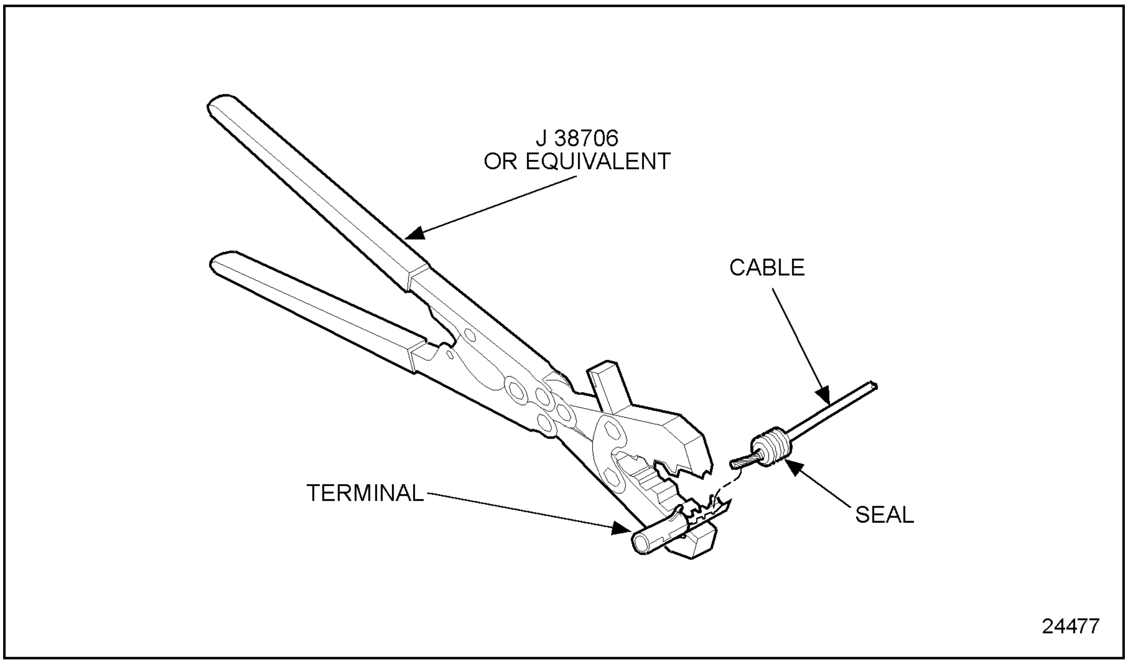


Figure 8-27 Terminal Position

4. Insert the terminal into the locating hole of the crimping tool using the proper hole according to the gage of the cable to be used. See Figure 8-28.
5. Insert the cable into the terminal until the stripped portion is positioned in the cable core wings, and the seal and insulated portion of the cable are in the insulation wings. See Figure 8-28.

6. Compress the handles of the crimping tool until the ratchet automatically releases and the crimp is complete. See Figure 8-28 for a properly crimped terminal.

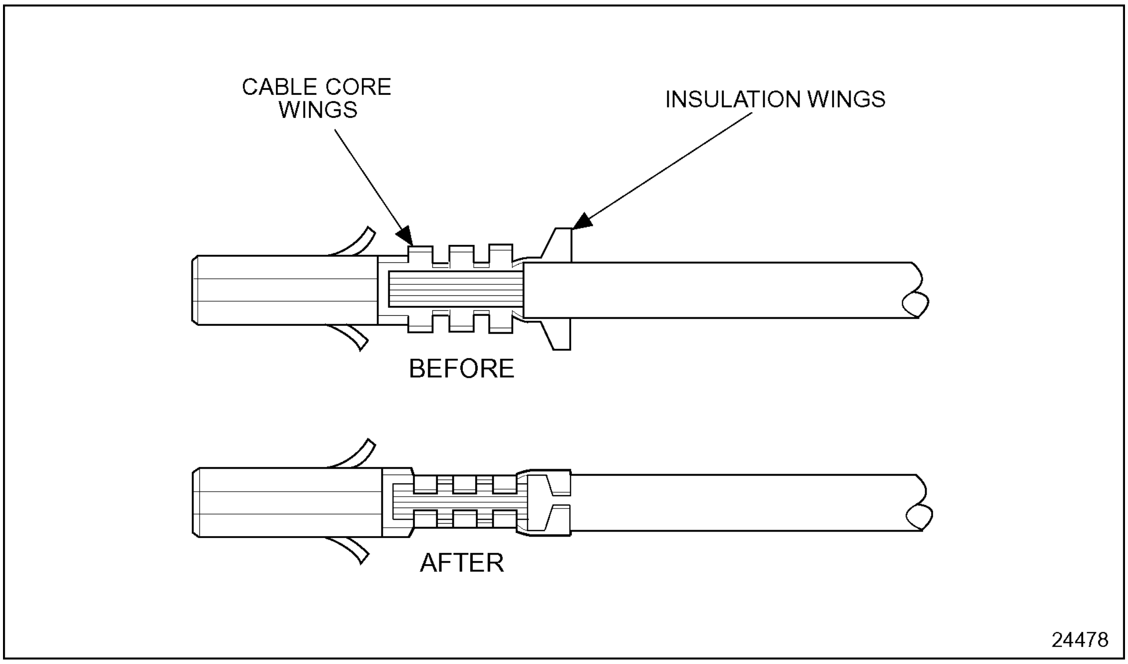


Figure 8-28 Cable and Terminal Position Before and After Crimping

7. Release the crimping tool with the lock lever located between the handles, in case of jamming.

8. Push the crimped terminal into the connector until it clicks into place. Gently tug on the cable to make sure it is secure. See Figure 8-29.

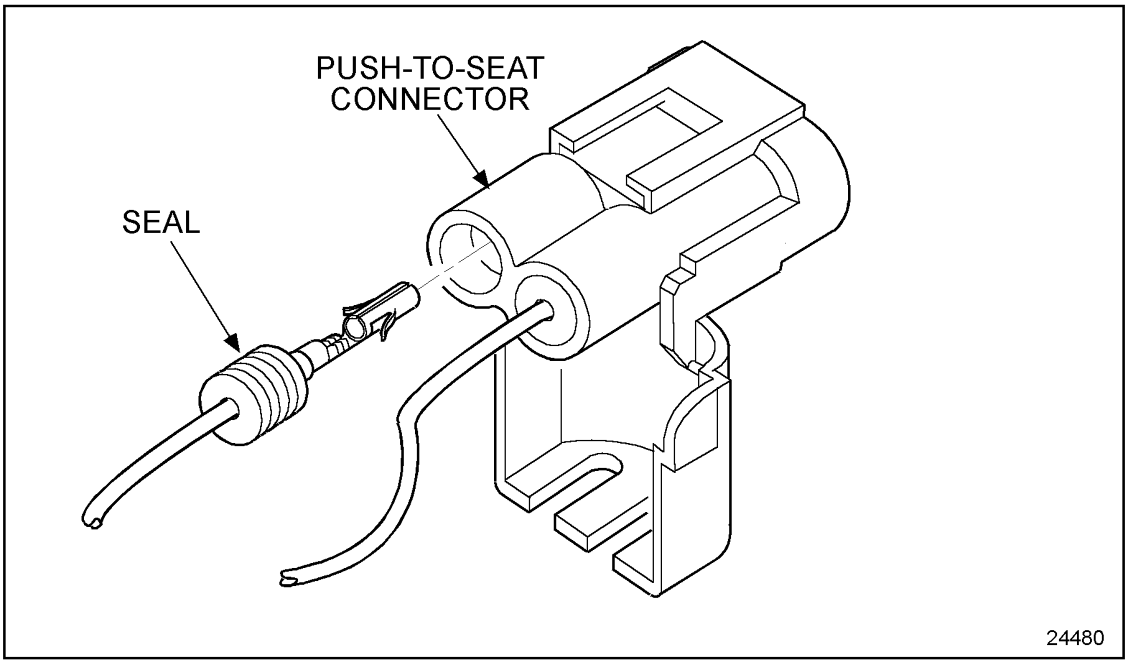


Figure 8-29 Inserting Terminal in Connector

8.10 CONNECTOR TOOLS

Crimp tools and connector removing tools can be purchased from:

Kent-Moore

29784 Little Mack

Roseville, MI 48066-2298

(800) 328-6657

The tools listed in Table 8-4 are used with the connectors associated with the DDEC III Systems.

Connector	Tool	Kent-Moore Part No.
Micro-Pack	Crimp Tool	J 38125-6
Micro-Pack	Removal Tool	J 38125-12
Weather-Pack	Removal Tool	J 36400-5
Metri-Pack 150 Series	Crimp Tool	J 35123
Metri-Pack 150 Series	Removal Tool	J 35689
Metri-Pack 280 Series	Crimp Tool	J 38125-6
Metri-Pack 280 Series	Removal Tool	J 33095

Table 8-4 Terminal Replacement Tools

8.11 SPLICING GUIDELINES

The following are guidelines which may be used for splices. The methods described are not the only acceptable methods. Any method should produce a high quality, tight splice with durable insulation which can be expected to last the life of the vehicle.

The selection of crimpers and splice connectors is optional. Select a high quality crimper equivalent to Kent-Moore tool J 38706 and commercially available splice clips.

8.11.1 Splicing Tools

The following is a list of tools required for splicing wires:

- ☐ Soldering iron
- ☐ Rosin core solder
- ☐ Wire strippers
- ☐ Heat shrink tubing
- ☐ Splice clips
- ☐ Crimp pliers

8.11.2 Straight Leads

To splice straight leads:

1. Locate broken wire
2. Remove insulation as required; be sure exposed wire is clean and not corroded.
3. Slide a sleeve of shrink wrap on the wire long enough to cover the splice and overlap the wire insulation, about $\frac{1}{4}$ inch on both sides.
4. Insert one wire into splice clip (P/N: 0597428 or equivalent) and crimp.

5. Insert the other wire into splice clip and crimp. See Figure 8-30.

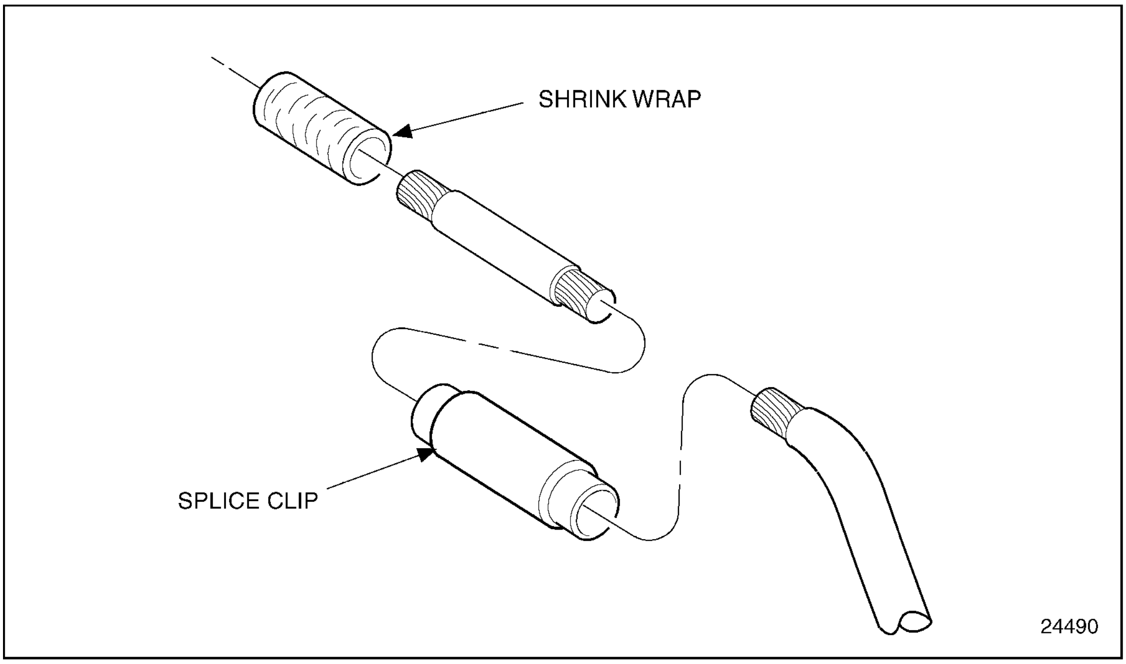


Figure 8-30 Spliced Wire

8.11.3 Solder

Soldering splice connectors is optional. To solder splice connectors:

1. You *must use rosin core solder.*
2. Check the exposed wire before the splice is crimped in its connector. The exposed wire *must* be clean before the splice is crimped.
3. Use a suitable electronic soldering iron to heat the wires. Apply the solder to the heated wire (not to the soldering iron), allowing sufficient solder flow into the splice joint.
4. Pull on connection to assure crimping and soldering integrity.

8.11.4 Shrink Wrap

Shrink wrap is required. Alpha FIT-300, Raychem TAT-125 or any equivalent heat shrink, dual wall, epoxy encapsulating adhesive polyolefin is required. For information on this product contact the companies listed in Table 8-5.

Alpha Wire Corporation	Raychem Corporation, Thermofit Division
711 Lidgerwood Ave.	300 Constitution Drive
P.O. Box 711	Building B
Elizabeth, New Jersey 07207-0711	Menlo Park, CA 94025
1-800-522-5742	415-361-3860

Table 8-5 Addresses

To heat shrink wrap a splice:

1. Select the correct diameter to allow a tight wrap when heated. The heat shrink wrap *must* be long enough to overlap the wire insulation about 6.35 mm (0.25 in.) on both sides of the splice.
2. Heat the shrink wrap with a heat gun; do not concentrate the heat in one location, but play the heat over the entire length of shrink wrap until the joint is complete.

8.11.5 Multiple Broken Wires

To splice multiple broken wires:

1. Stagger the position of each splice. See Figure 8-31.

2. You *must* stagger positions to prevent a large bulge in the harness and to prevent the wires from chafing against each other.

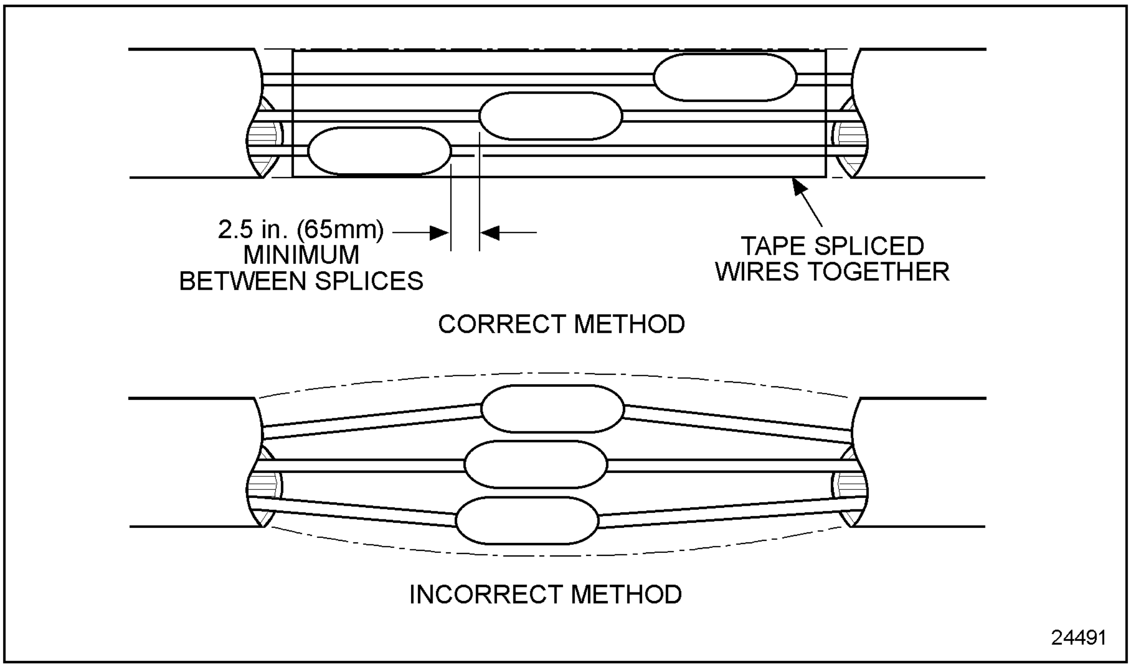


Figure 8-31 Multiple Splices

8.11.6 Three Wire Splice

Three-way splice connectors are commercially available to accommodate three-wire splices. The technique is the same as a single butt splice connector. See Figure 8-32.

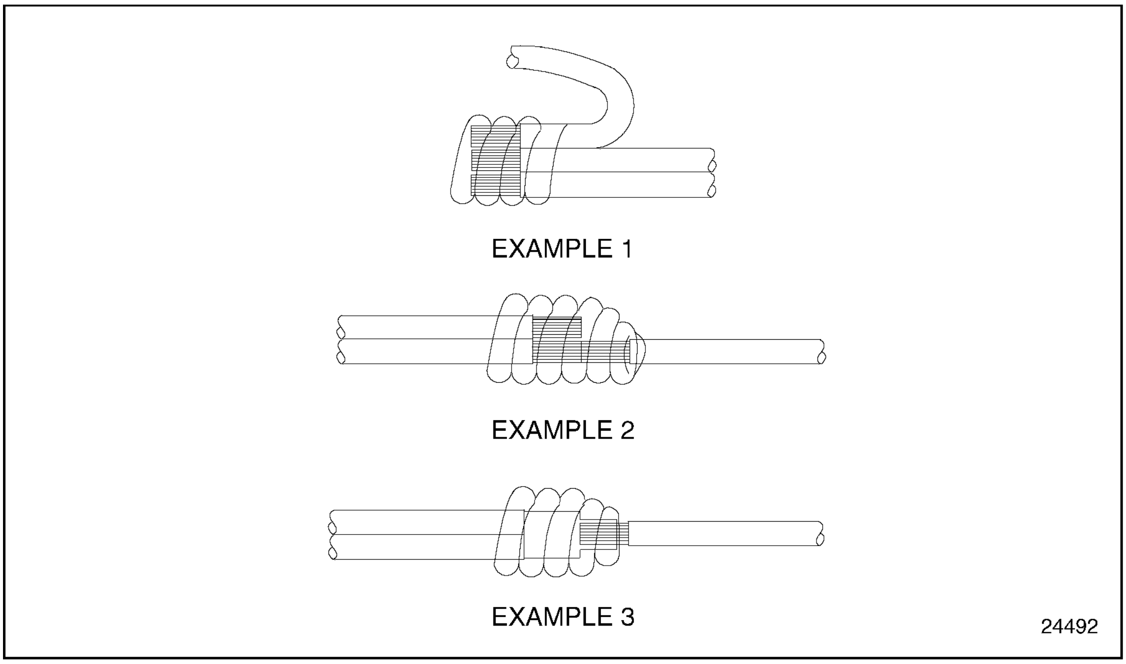


Figure 8-32 Three-Way Splice

8.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

Torque Specification Exceptions - Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 8 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 8-6. Standard (nonmetric) nut and bolt torque specifications are listed in Table 7 in the "General Information" section at the beginning of this manual.

EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS

Exceptions to standard fastener torque specifications are listed in Table 8-6.

Fastener	Torque, N·m	Torque, lb·ft
Bolt, Alternator Mounting Bracket	58-73	43-54
Nut, Drive Pulley	95-108	70-80
Bolt, Alternator-to-Mounting Bracket	81-95	60-70

Table 8-6 Exceptions - Metric Fastener Torque Specifications

9 POWER TAKE-OFF

Section **Page**

9.1 REAR ENGINE POWER TAKE-OFF (REPTO) ASSEMBLY

The REPTO (Rear Engine Power Take Off) is an aluminum SAE #1 flywheel housing mounted against the rear of the cylinder block, it takes the place of a standard flywheel housing. It provides a cover for the flywheel and serves as a support for the cranking motor and the transmission.

The aluminum flywheel housing has an internal idler gear that is driven off the rear of the crankshaft. Those gears drive an output yoke that faces the rear of the vehicle. The output yoke is located at the one o'clock position and has four different yoke configurations. It provides up to 300 hp intermittent and 240 hp continuous PTO power.

A rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing. Refer to section 1.8.

The output yoke and its oil seals can be serviced. If there is any internal failure, the REPTO should be removed and replaced as an assembly.

9.1.1 Repair and Replacement for the Rear Engine Power Take-Off Assembly

The REPTO assembly currently is a nonserviceable component; if there are internal problems with the REPTO it must be replaced as an assembly.

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 9-1.

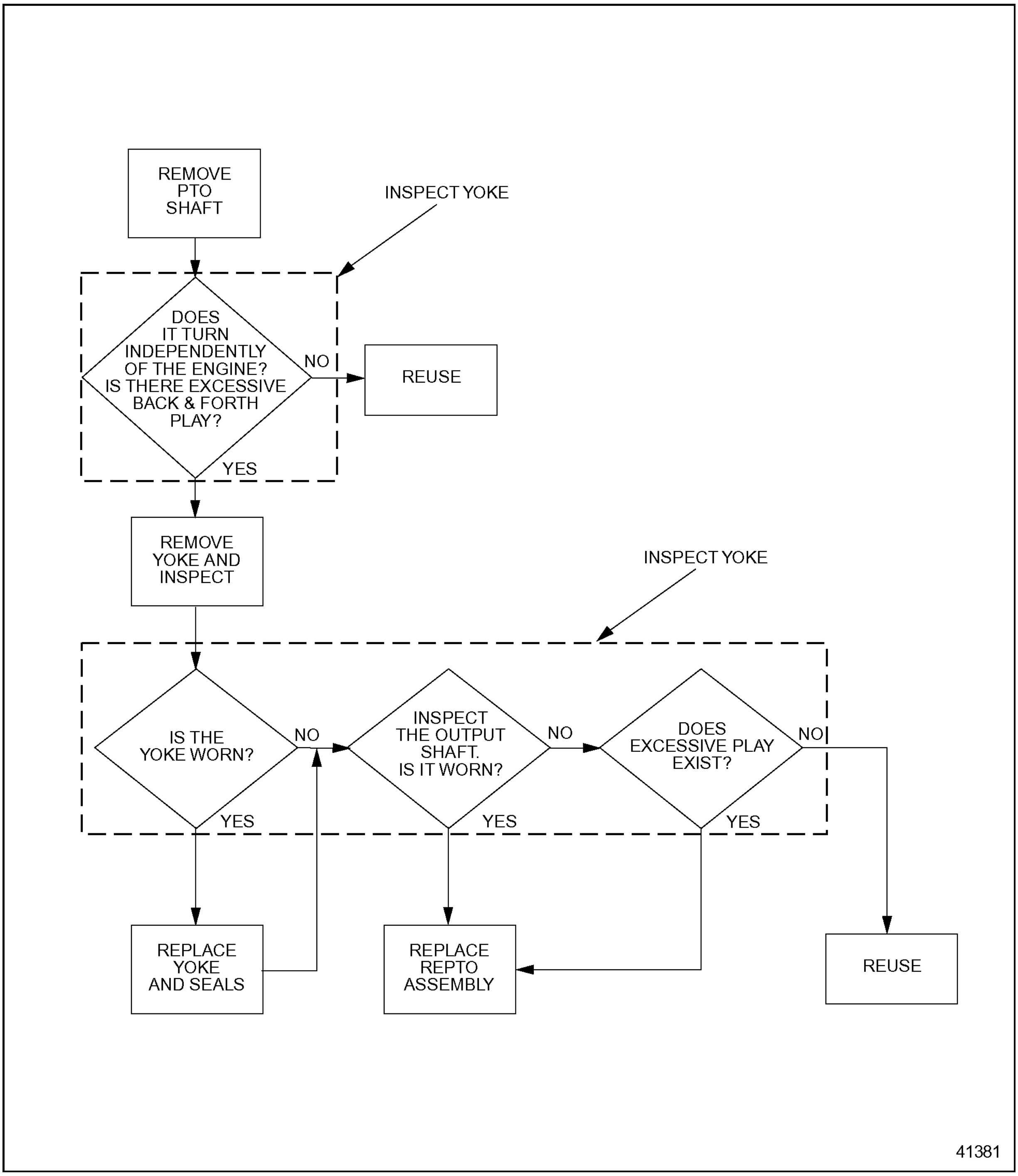


Figure 9-1 Flowchart for Repair or Replacement of REPTO Assembly

9.1.2 Removal of Rear Engine Power Take-off Assembly

Remove the REPTO assembly as follows:

1. Disconnect battery power. Refer to section 8.3.2.
2. Remove cranking motor from the REPTO flywheel housing. Refer to section 8.5.2.
3. Remove transmission and PTO driveshaft and any other parts attached to the housing.
4. Remove the flywheel as follows:
   [a] Remove two adjacent flywheel bolts.
   [b] Insert two flywheel guide studs, J 36235 into the crankshaft. See Figure 9-2.

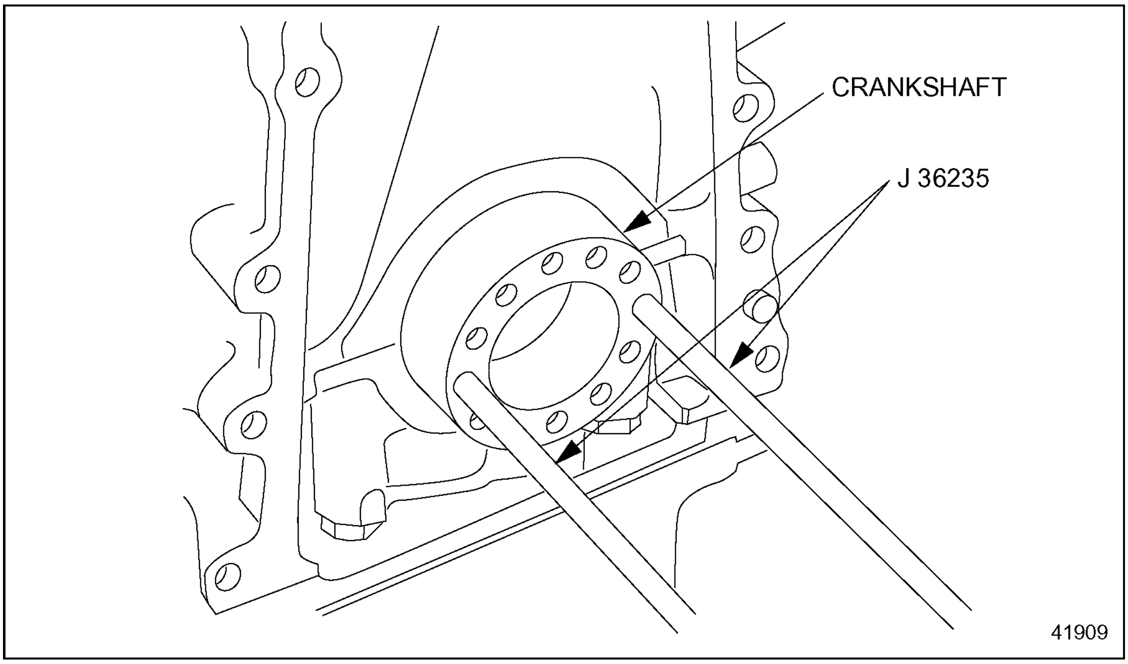


Figure 9-2 Flywheel Guide Studs

   [c] Remove the remaining flywheel bolts.

5. Drain oil pan housing by removing the plug at the bottom of the housing. Remove the oil line from the cooler.

6. Remove three plugs to gain access to bolts securing the housing to the block. See Figure 9-3
7. Remove the three bolts being careful not to drop them into the housing.

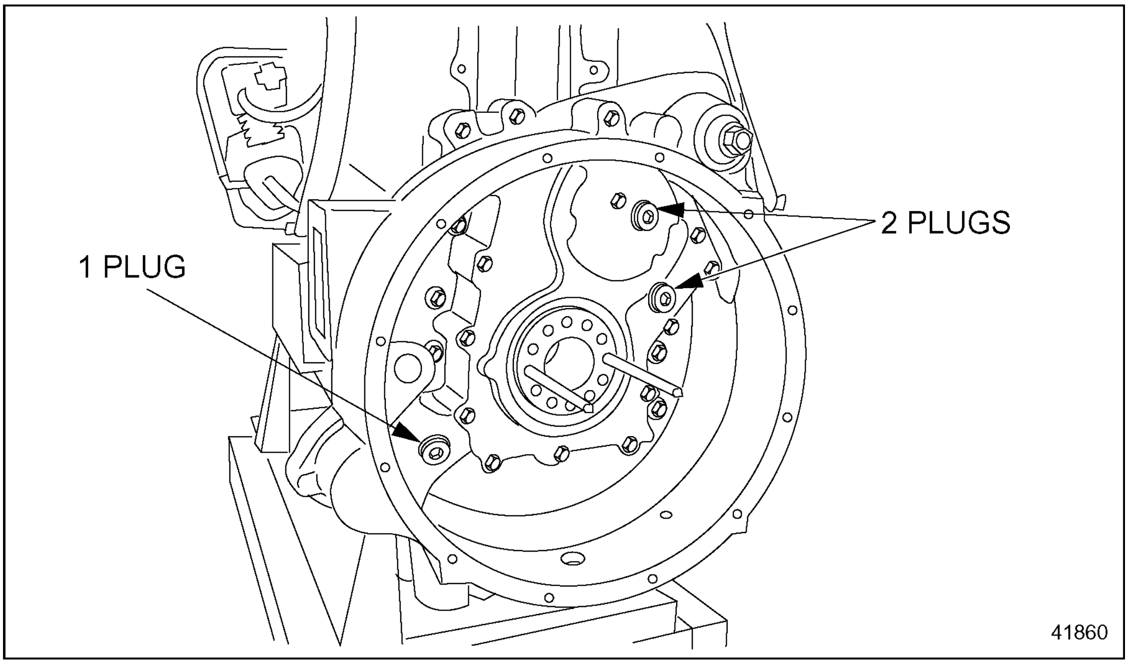


Figure 9-3 Pipe Plugs on the Gear Set Cover Plate

NOTICE:
Do not drop the bolt or washer into the gear set. Engine or REPTO damage will occur.

8. Remove the remaining eight bolts.

CAUTION:
To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

9. Attach a suitable sling or use a floor jack to support the flywheel housing, which weighs about 120 lbs. Gently tap the backside of the flywheel housing with a rubber mallet to loosen it from the block. Remove the housing.
10. Remove any gasket material from the flywheel housing and block at this time. See Figure 9-4.

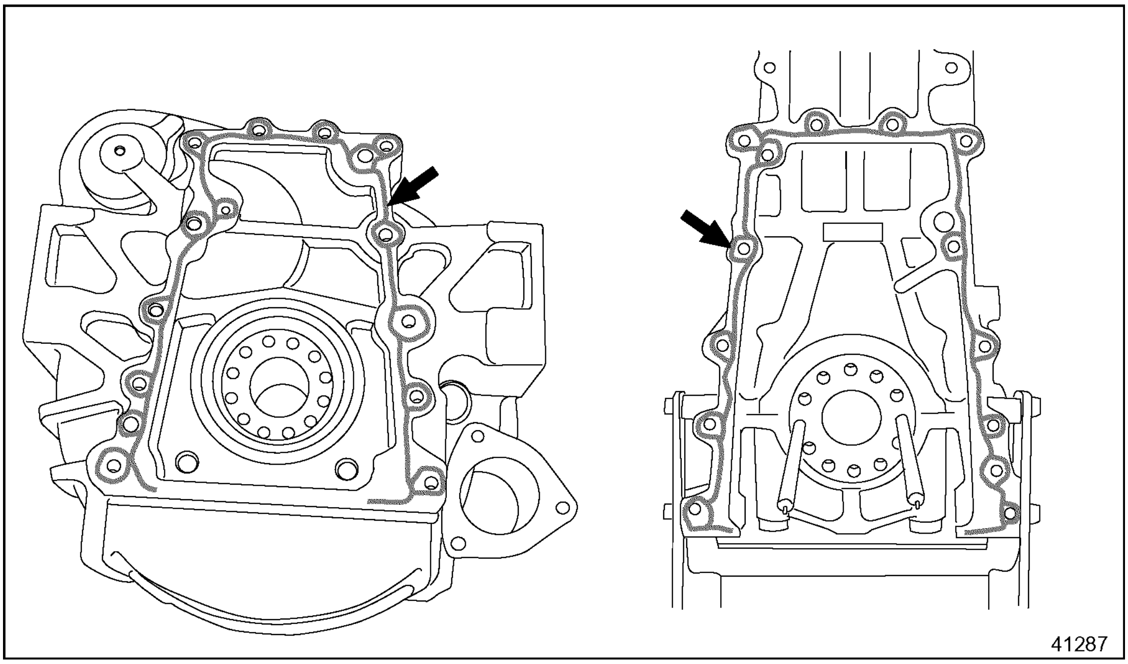


Figure 9-4 Removal of Gasket Material

CAUTION:

To avoid injury from flying sealant. Do not use an impact gun on plugs with white sealant.

11. Remove all sealing material from the block and housing. Refer to Section on “Cleaning” in the “General Information Section”.

9.1.3 Cleaning of Rear Engine Power Take-off Assembly

Clean the REPTO as follows:

1. Clean any residue from the end of the crankshaft and inside wall of the REPTO mounting hub.
2. Clean any residue from the yoke sealing surface, washer and nut.

9.1.3.1 Inspection of Rear Engine Power Take-off Assembly

Inspect the REPTO assembly as follows:

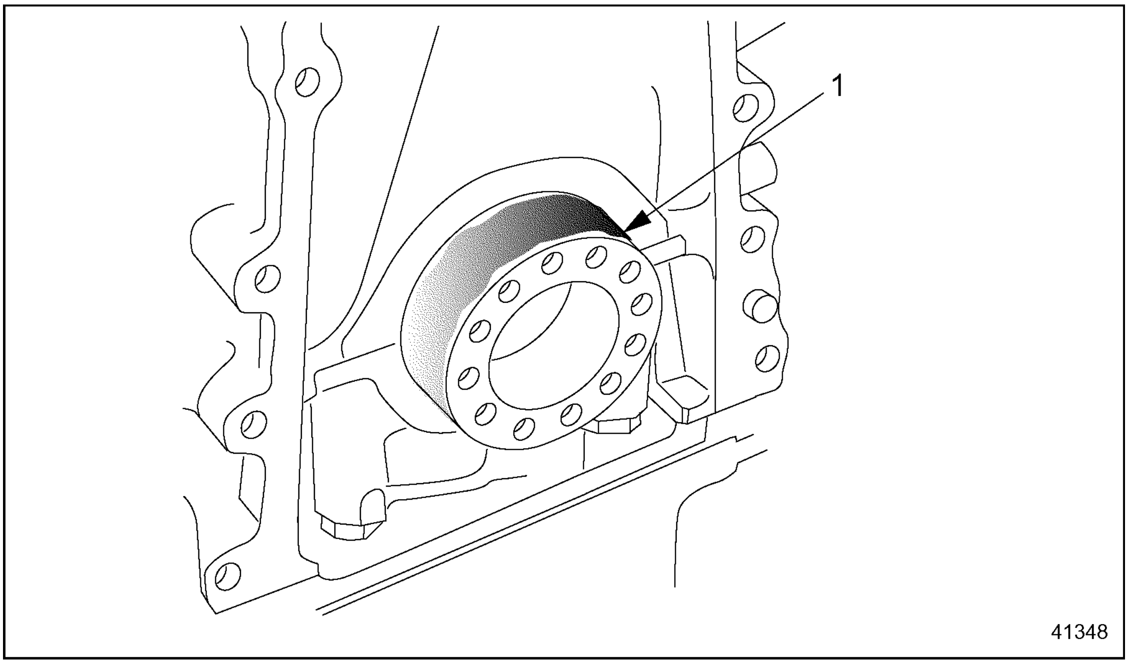
1. Inspect the flywheel. Refer to section1.14.2.1.
2. Inspect flywheel housing for cracks and any other damage.
   [a] If sealing surface is damaged, repair with emery cloth.
   [b] If cracked, repair is not possible.
3. Inspect the crankshaft where the rear oil seal makes contact. Refer to section1.8.
   [a] Check for groove in crankshaft.
   [b] If crankshaft is grooved, install a wear sleeve over the crankshaft end. An oversized I.D. rear oil seal must be used with the rear sleeve. Refer to section 1.8.7.
4. Inspect the bottom of the yoke.
   [a] If burrs are found on the surface of the yoke, replace the component.
   [b] If no damage is found, reuse part.
5. Inspect the rubber yoke seal.
   [a] If any defects are found, replace the seal.
   [b] If no damage is found, reuse the seal.

9.1.4 Installation of Rear Engine Power Take-off Assembly

Install the REPTO as follows:

1. Apply a lubricant like white grease to the end of the crankshaft and inside the wall of the REPTO mounting hub. See Figure 9-5.

NOTE:
If installing a new REPTO housing, ensure that all 11 plastic shipping plugs are removed from the housing.



1. Crankshaft

Figure 9-5 Application of Lubricant

2. If installing a new REPTO housing:

CAUTION:
To avoid injury from flying sealant. Do not use an impact gun on plugs with white sealant.

[a] Install the pipe plug above the cranking motor mount on the REPTO flywheel housing. See Figure 9-6.

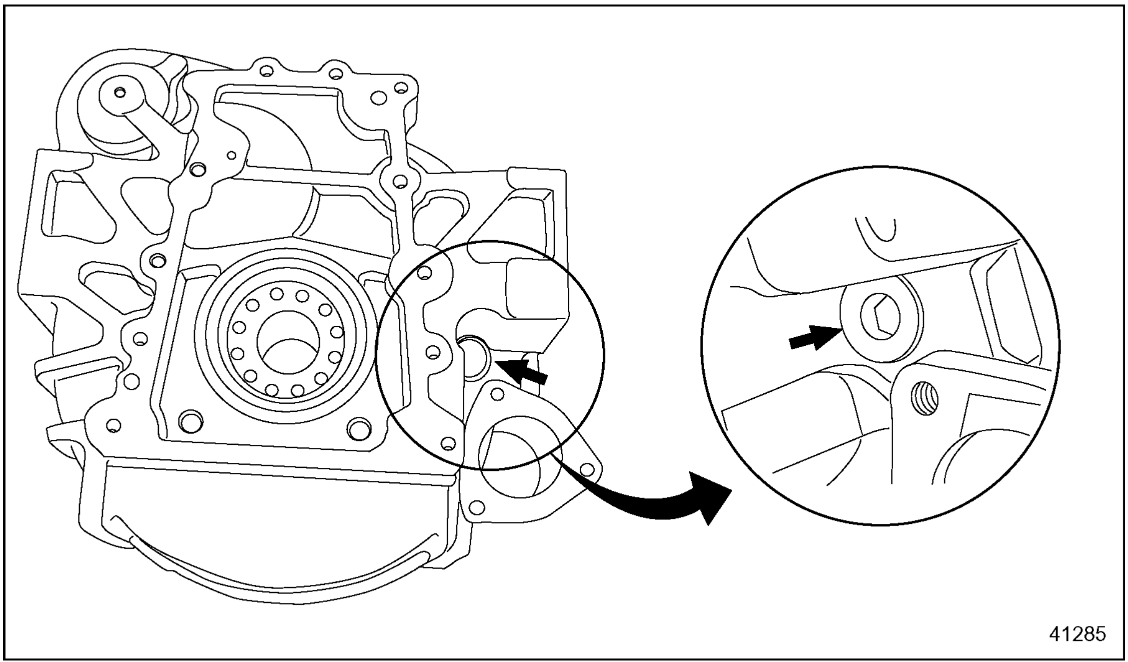


Figure 9-6 Installation of Pipe Plug Above Cranking Motor Mount

[b] Install the bottom pipe plug located in the 6 o'clock position on the REPTO flywheel housing. See Figure 9-7.

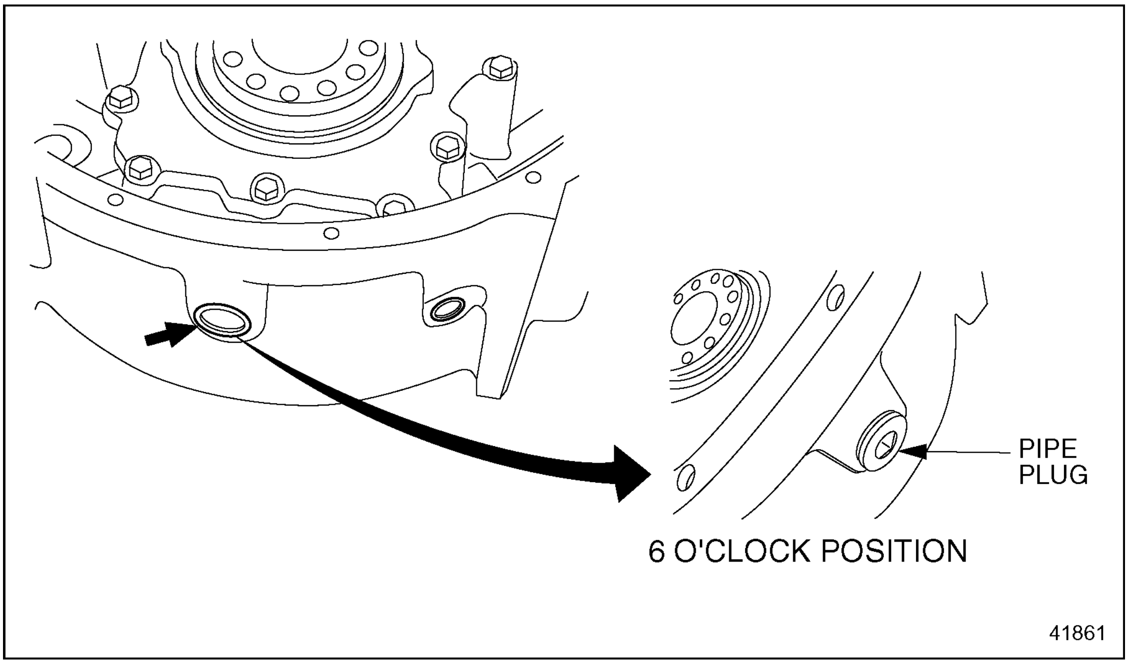
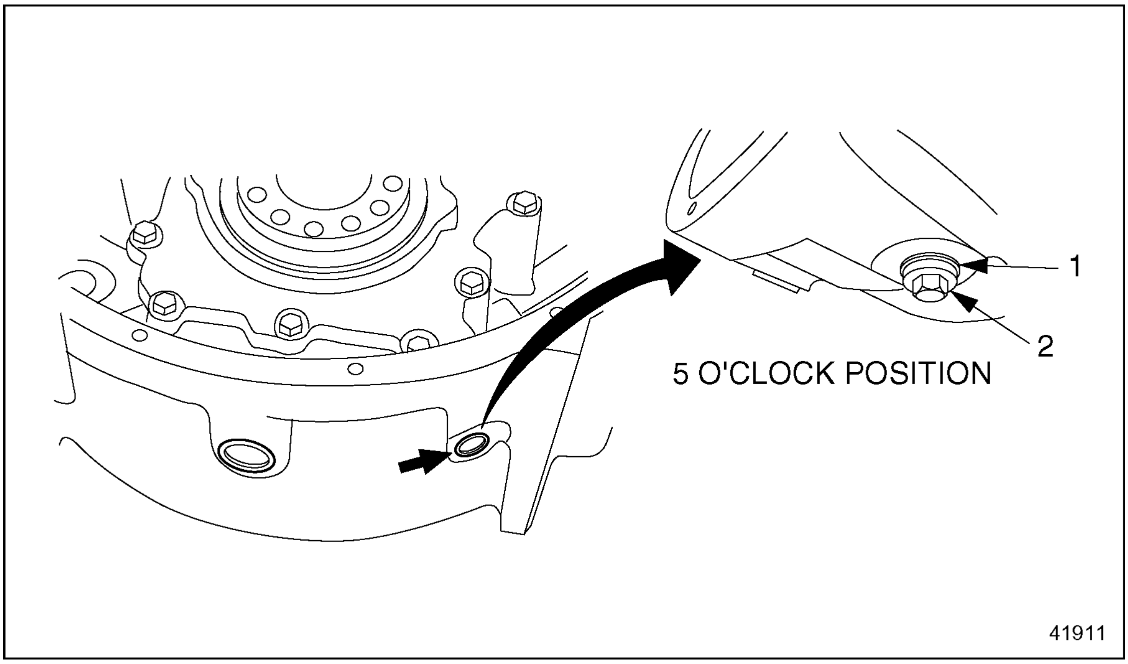


Figure 9-7 Installation of Pipe Plug in the 6 o'clock Position

[c] Install the pipe plug with a copper washer located in the 5 o'clock position on the REPTO flywheel housing. See Figure 9-8.



1. Copper Washer
2. Pipe Plug

Figure 9-8 Installation of Pipe Plug in the 5 o'clock Position

NOTE:
Do not install any plugs in the two holes below the crankshaft on the back lower face (even though they are threaded), they are oil drain holes back to sump. See Figure 9-9.

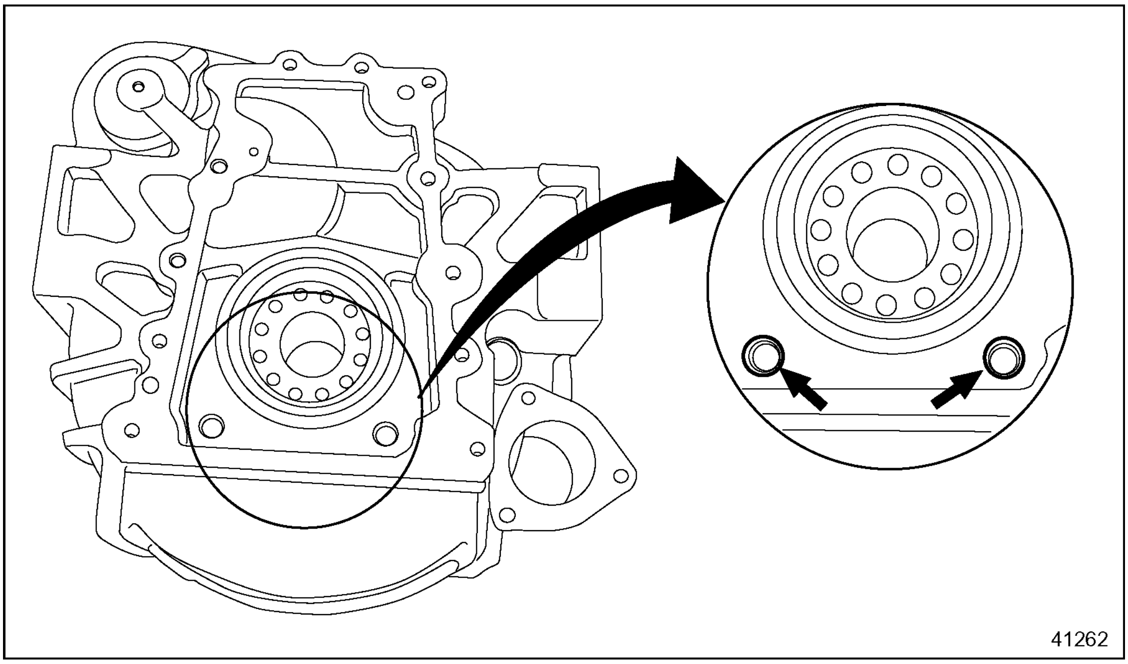


Figure 9-9 No Pipe Plug in these Two Threaded Holes

3. Apply Gasket Eliminator®, Kent-Moore® part number or equivalent PT 7276, to sealing surface of the flywheel housing or the block whichever is easier. See Figure 9-10.

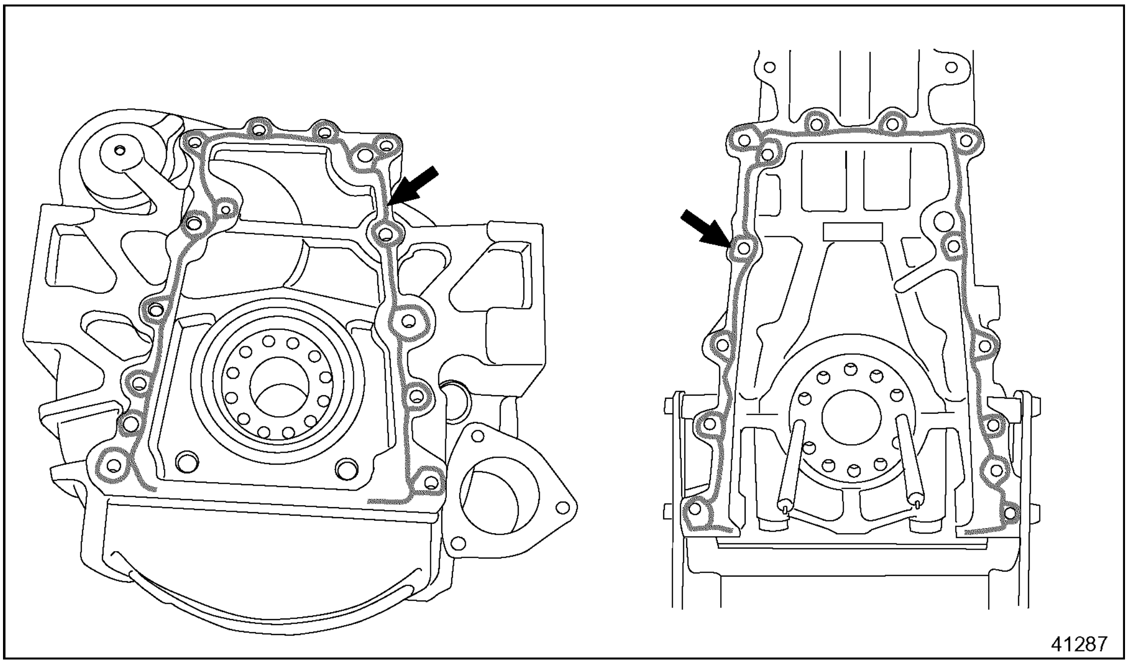
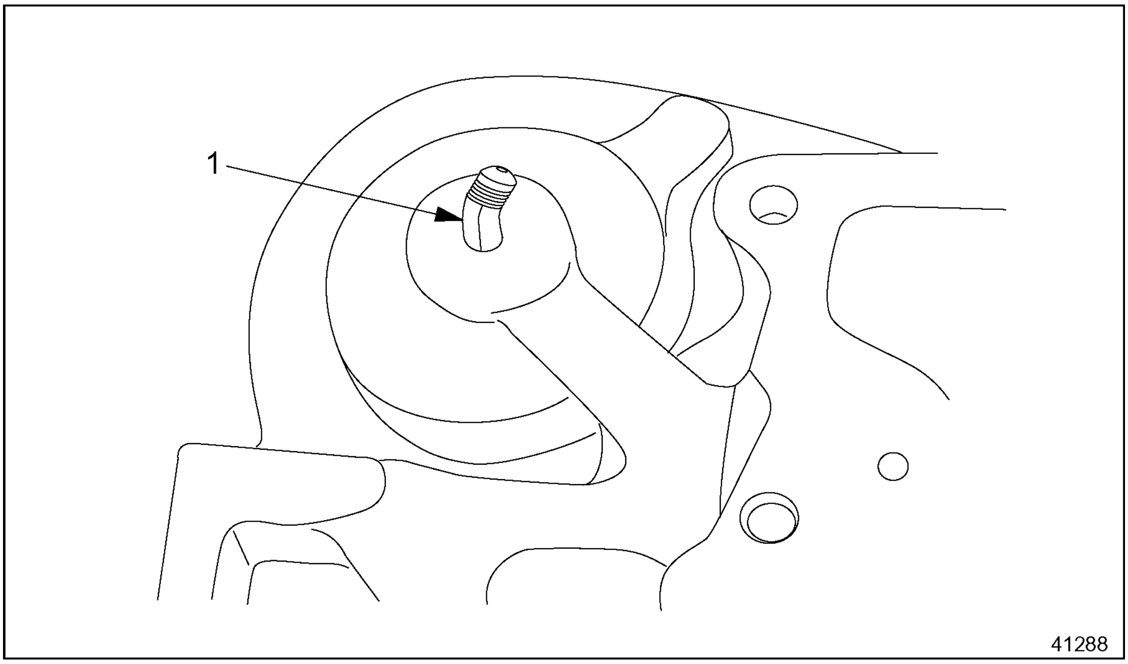


Figure 9-10 Application of Gasket Eliminator®

4. Install oil fitting on back of flywheel housing. See Figure 9-11.



1. Oil Fitting

Figure 9-11 Installation of Oil Fitting

5. Insert two flywheel guide studs, J 36235 into the crankshaft. See Figure 9-12.

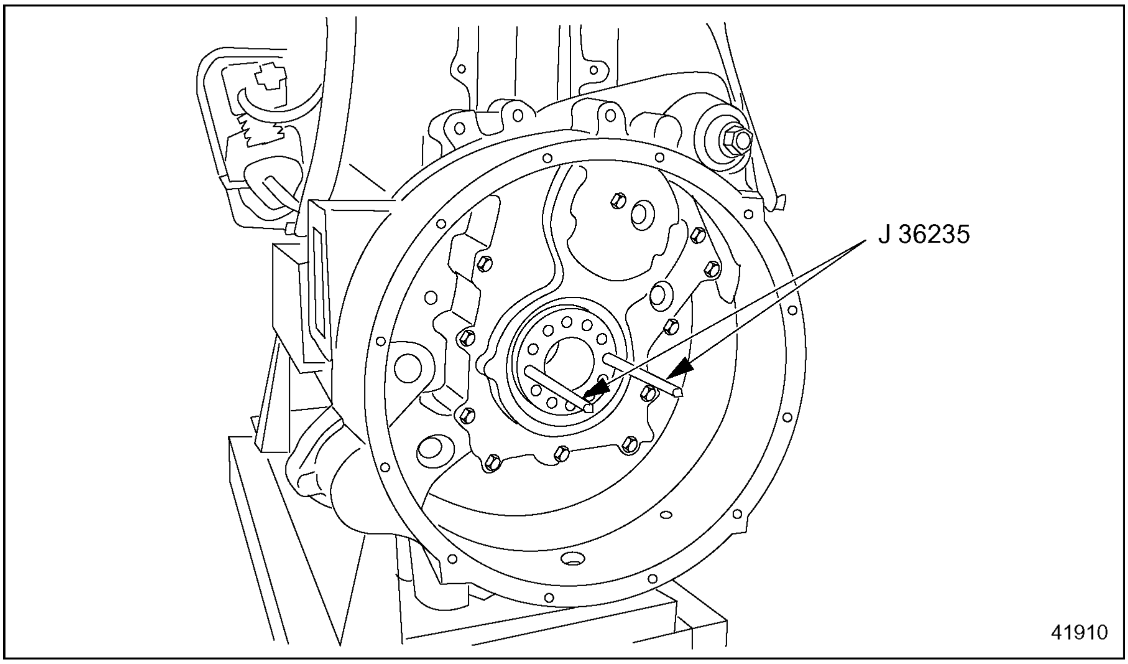
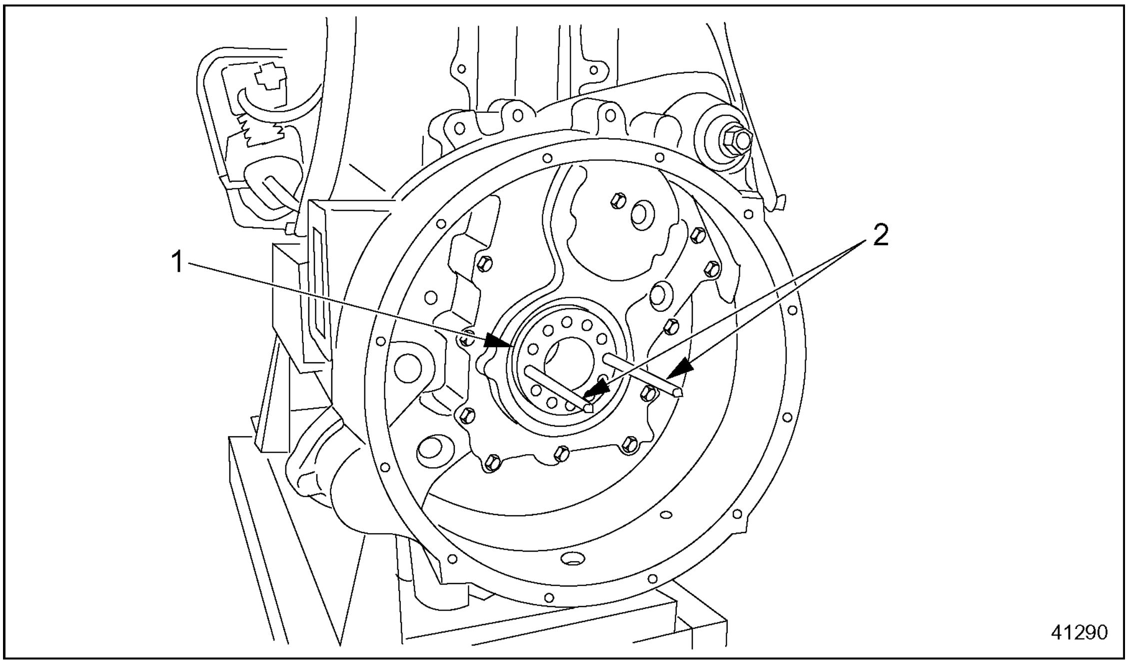


Figure 9-12 Flywheel Guide Studs

CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

6. Use a hoist to carefully slide the REPTO flywheel housing into position onto the guide studs. See Figure 9-13.



1. Crankshaft
2. Guide Studs J 36235

Figure 9-13 Installation of REPTO Flywheel Housing

NOTICE:
Do not drop the bolt or washer into the gear set. Engine or REPTO damage will occur.

7. Using a magnetic socket, install and torque all eleven flywheel housing mounting bolts in sequence to 112–126 N·m (83–93 lb·ft.) for 12 mm bolts or 160–200 N·m (118–148 lb·ft.) for 14 mm bolts. See Figure 9-14.

NOTE:
Ensure that the three bolts behind plugs are not overlooked in this step.

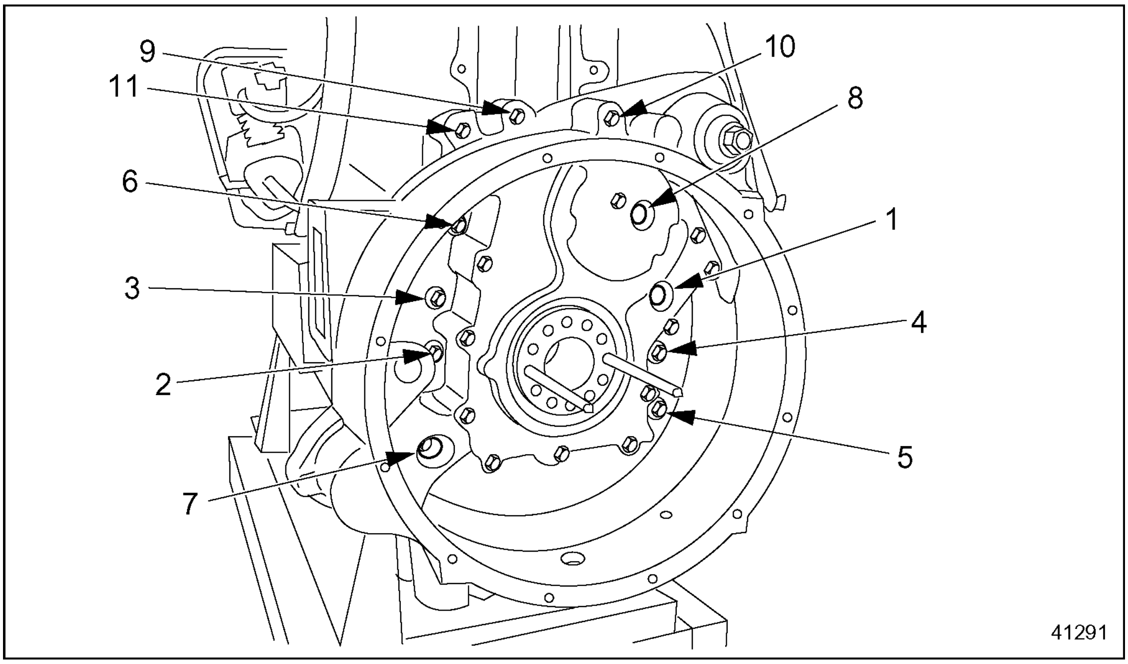


Figure 9-14 Flywheel Housing Bolt Location and Torque Sequence

8. Install the two pipe plugs located on the gear set cover plate and plug next to the cranking motor. See Figure 9-15.

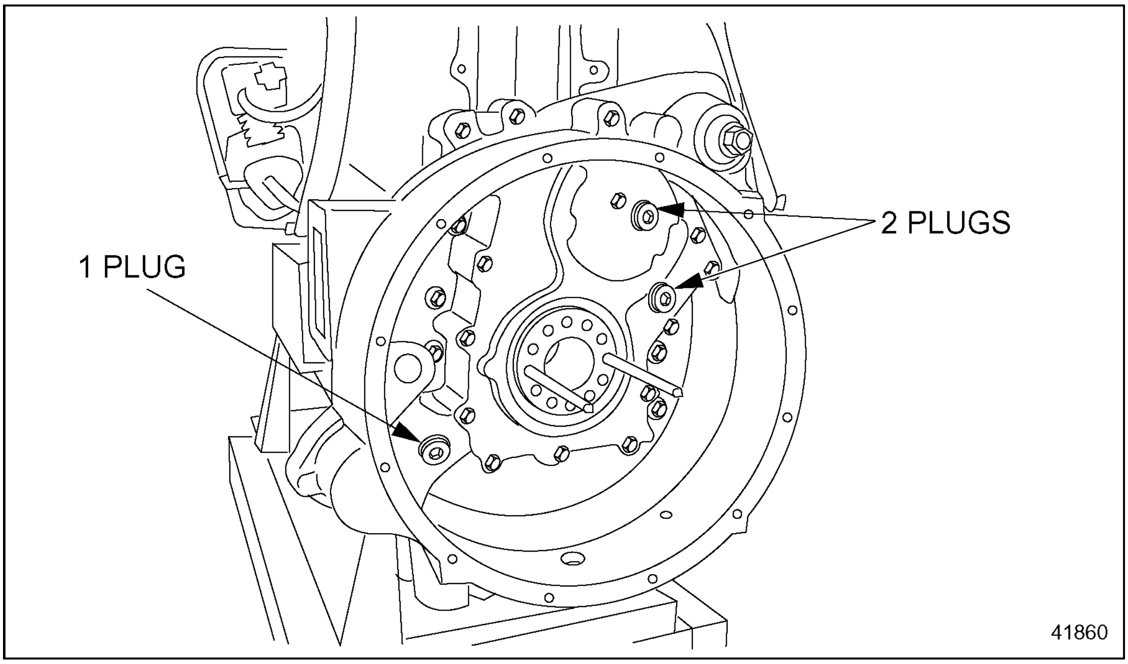


Figure 9-15 Pipe Plugs on the Gear Set Cover Plate

9. Set crankshaft endplay as follows:

NOTICE:
Setting crankshaft end play must be done whenever the REPTO housing is installed to prevent crankshaft from damaging crankshaft thrust washers upon initial engine startup.

[a] Bolt the flywheel to the unit using six flywheel bolts.

[b] Torque the flywheel bolts to 102 N·m (75 ft·lb).

[c] Remove the flywheel. (This is necessary to remove the gap between the crankshaft and REPTO drive hub.)

[d] Attach driver handle, J 8092, onto the setting tool, J 42722–1. See Figure 9-16.

[e] Stack approximately 0.100 in. of shims, J 42722–4, onto the nose of the setting tool. See Figure 9-16.

[f] Add or remove shims until 0.005 in. gap is measured at four points (90 degrees apart) with a feeler gage. See Figure 9-16.

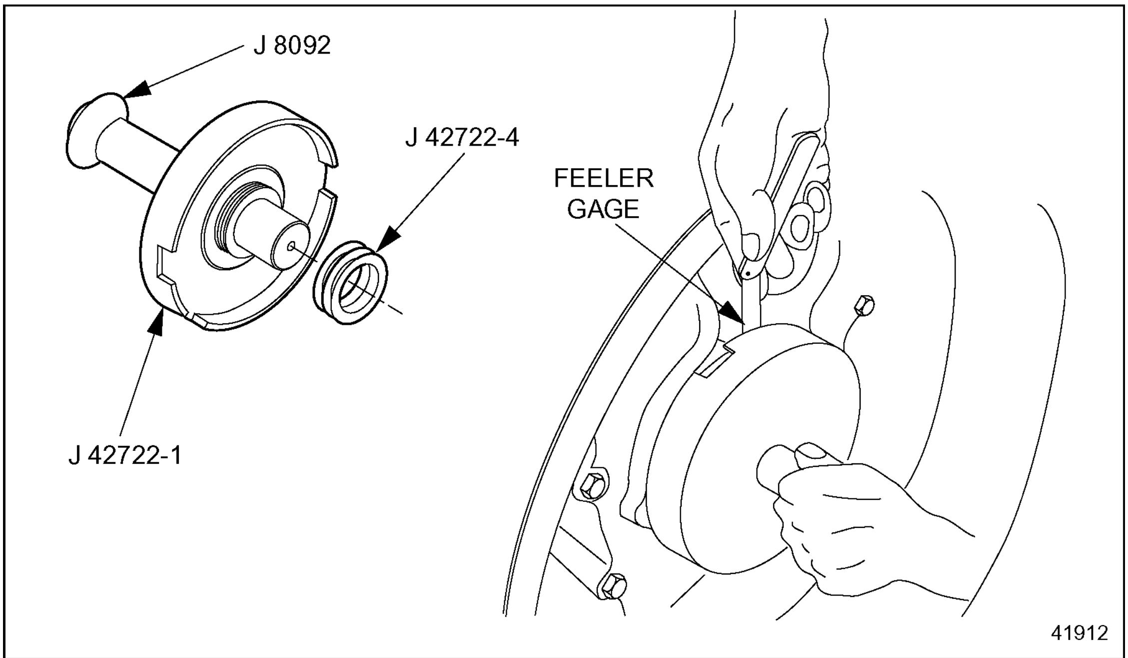


Figure 9-16 Installation of Shims

NOTE:
Tool must be held firmly in place and perpendicular to the housing.

[g] Hold the setting tool firmly against the drive hub; with a large hammer, hit the driver handle two to four times to set the gap between the crank and thrust washer. See Figure 9-17.

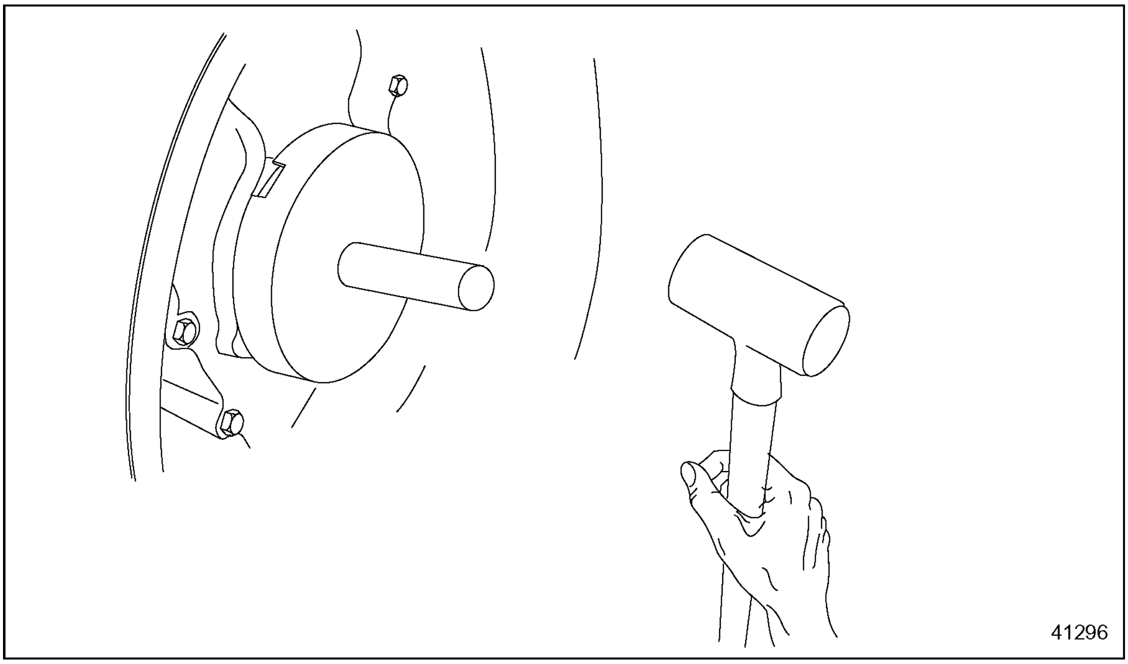


Figure 9-17 Installation of Shims

[h] Remove the tool, ensuring no shims remain stuck to the hub.

10. Bar the engine over from the front of the crankshaft. It should turn slightly harder than without the REPTO housing installed.
11. Install flywheel and torque bolts. Refer to section 1.14.3.

NOTE:
Crankshaft endplay is set and there is no further need to check if this procedure was done correctly.

NOTE:
All cranking motors assembled to the REPTO housings should be installed with a new gasket.

12. Install cranking motor. Refer to section 8.5.3.

NOTICE:
Do not connect to the wrong port. Connecting to the wrong port will allow coolant to be fed to the gears and the engine will fail.

NOTE:
Ensure the oil supply line is connected to the port next to the turbo oil supply line and not to the oil cooler assembly.

13. Install the oil supply line to the brass fitting on the housing and the opened port.
14. Test for REPTO Flywheel Housing Bore Concentricity as follows:
    [a] Attach the base post onto the crankshaft palm.
    [b] Assemble the dial indicators onto the base post.
    [c] Position the dial indicator square with the flywheel housing inside bore of the bell. Ensure the indicator has adequate travel in each direction. See Figure 9-18.

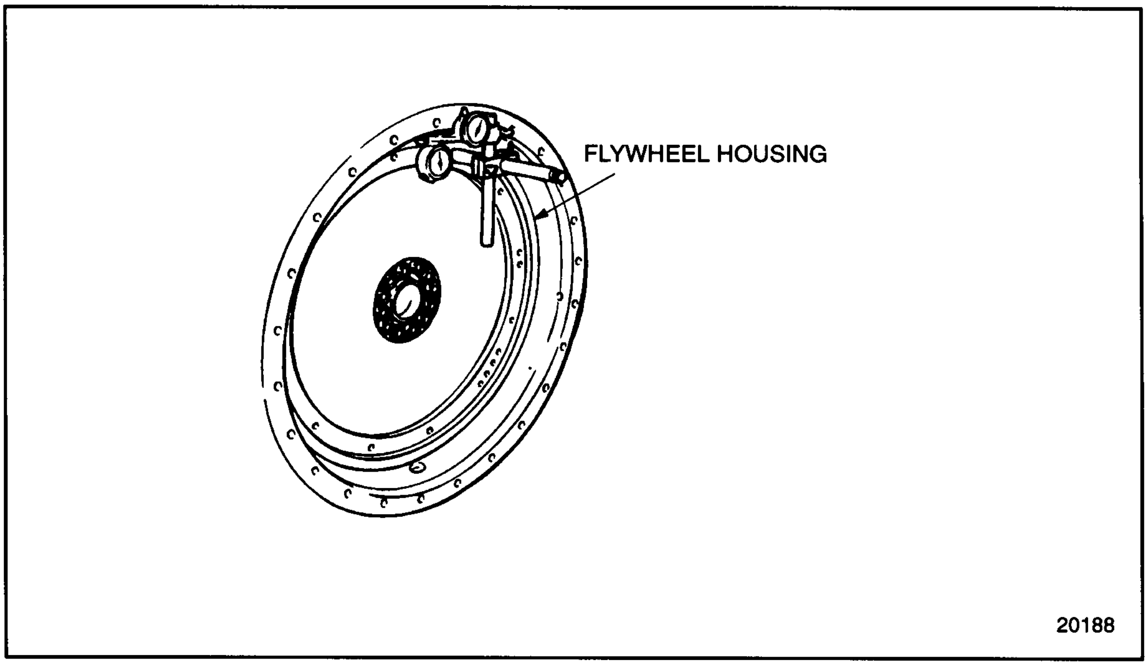


Figure 9-18 Measuring Flywheel Housing Bore Concentricity

    [d] Adjust each dial indicator to read zero at the twelve o'clock position.

[e] Bar the engine and rotate the crankshaft one complete revolution, taking readings at 90 degree intervals (four readings each for the bore). See Figure 9-19.

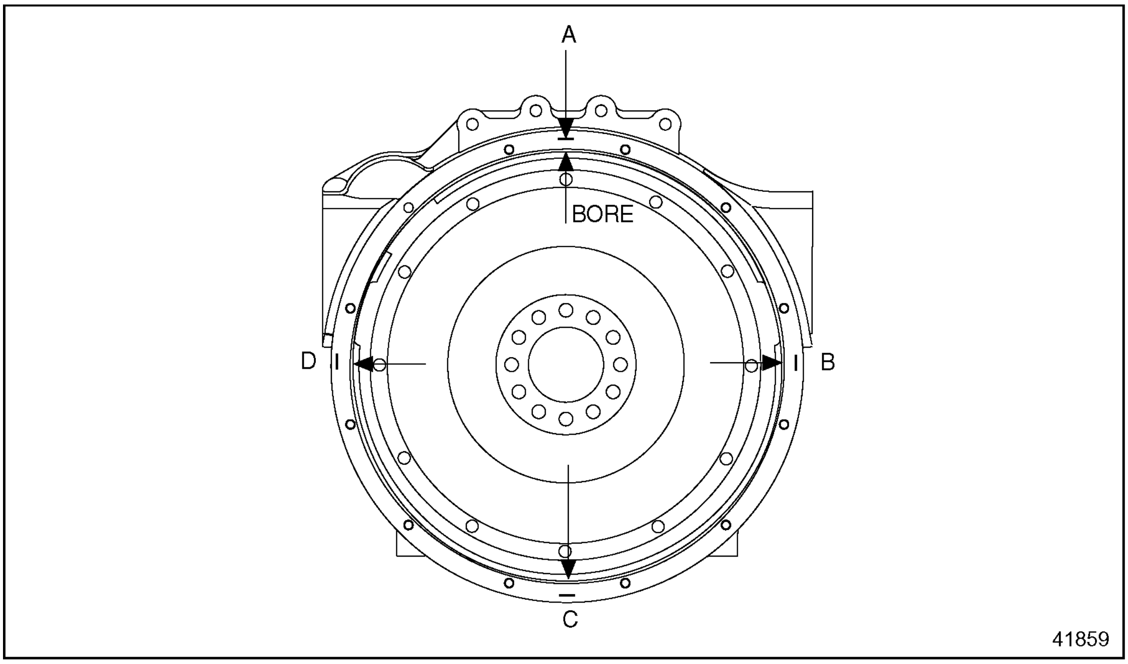


Figure 9-19 Flywheel Housing

[f] Remove the wrench or cranking bar before recording each reading to ensure accuracy.

NOTE:
The maximum total indicator reading must not exceed 0.33 mm (0.013 in.).

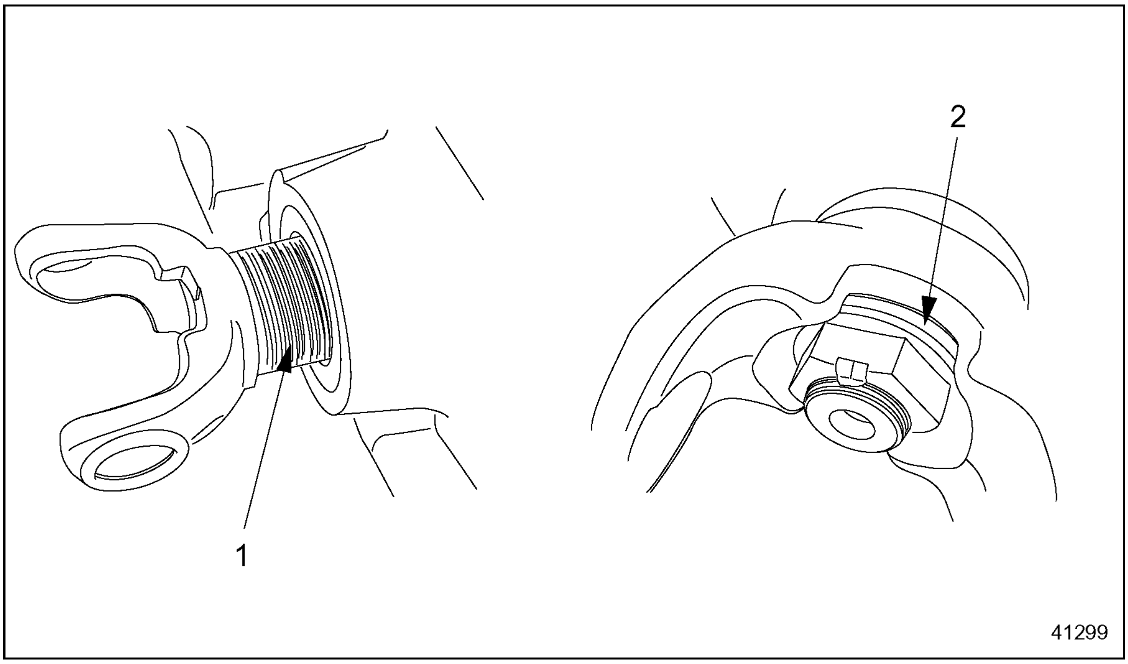
[g] If the run-out exceeds the maximum limits, check for dirt of foreign material between the flywheel housing and the cylinder block or oil pan.

[h] Clean the mating surfaces once again. Refer to section "General Information, Cleaning" in the beginning of this manual.

[i] Install REPTO Flywheel Housing. Refer to section 9.1.4.

[j] Check run-out again.

15. Install transmission. Refer to OEM.
16. Apply lube to the yoke seal surface and slide it onto the PTO spline. See Figure 9-20.
17. Apply Loctite® 565 or equivalent to both sides of the large washer and hand start nut. See Figure 9-20.



1. Yoke
2. Washer

Figure 9-20 Apply Lube to Yoke Seal and Loctite® 565 to Both Sides of Washers

18. Insert a 3/4 in. drive wrench in the front pulley or use J 36375–Aflywheel lock tool in the flywheel housing to stop crank from turning.
19. Install the nut to the spline and torque to 474–542 N·m (350–400 ft lbs).
20. Install oil pan. Refer to section 3.9.3.
21. Fill engine with clean lube oil. Refer to section 5.2.
22. Install engine into vehicle.

CAUTION:

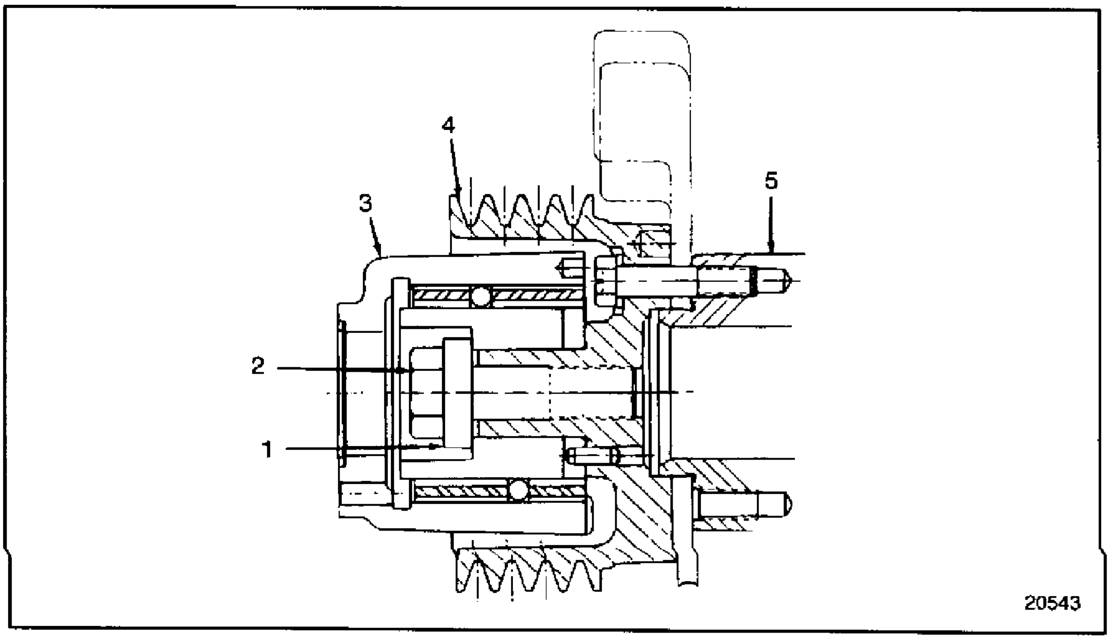
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

23. Start and run engine for verification of proper engine operation.

9.2 FRONT MOUNTED POWER TAKE-OFF

Detroit Diesel Corporation (DDC) has a front mounted PTO for use on the Series 50 engines. See Figure 9-21.



1. Retainer
2. Bolt
3. Hub Assembly
4. Pulley Assembly
5. Crankshaft

Figure 9-21 Front Mounted Power Take-off Components

This PTO is available in two different models, adaptable to Spicer 1310 and Spicer 1350 drive shafts depending on the torque and horsepower requirements. Maximum torque and horsepower for the PTO assemblies are listed in Table 9-1.

Power Take-off Models	Engine Speed	Torque	Horsepower
Spicer 1310	1800 r/min	162.7 N·m (120 lb·ft)	30.6 kW (41 hp)
Spicer 1310	2100 r/min	158.7 N·m (117 lb·ft)	29.8 kW (40 hp)
Spicer 1350	1800 r/min	261.7 N·m (193 lb·ft)	57.4 kW (77 hp)
Spicer 1350	2100 r/min	253.6 N·m (187 lb·ft)	56.0 kW (75 hp)

Table 9-1 Torque and Horsepower for the Front Mounted Power Take-off Assemblies

NOTE:
These torque and horsepower values are the maximum available taken at three degrees shaft angle. Any increase in the shaft angle has a direct negative effect on the amount of available torque and horsepower, as well as shaft life.

Also, any new application must have a "Torsional Analysis" performed by the DDC Engineering Department.

The PTO drive shaft must be purchased through Spicer Universal Joint Division, Dana Corporation.

If a PTO adaptor kit is to be installed on an engine that has been in service it will be necessary to remove the standard pulley configuration and replace it with one of the PTO adaptor kits.

Perform the following steps to install the new PTO assembly:

1. Remove the six bolts that retain the standard crankshaft pulley; refer to Section 1.13.
2. Install the new PTO pulley; refer to Section 9.2.3. Be certain to use the new bolts and washer provided with the PTO adaptor kit.
3. Install the new hub insulator assembly inside the new pulley assembly making certain that the slot on the backside of the hub fits over the dowel in the pulley.
4. Install the new 1 in.-14 x 3.50 in. bolt and retainer after coating the bolt threads and underside of the bolt head with INTERNATIONAL COMPOUND #2®. Torque the bolt to 610 N·m (450 lb·ft).

9.2.1 Repair and Replacement of the Front Mounted Power Take-off Assembly

The front mounted power take-off assembly is a nonserviceable component, tag for remanufacture.

9.2.2 Removal of the Front Mounted Power Take-off

Perform the following steps to remove the PTO assembly:

1. Remove the inspection plug in the bottom of the flywheel housing and install the flywheel lock tool, J 36375–A. See Figure 9-22.

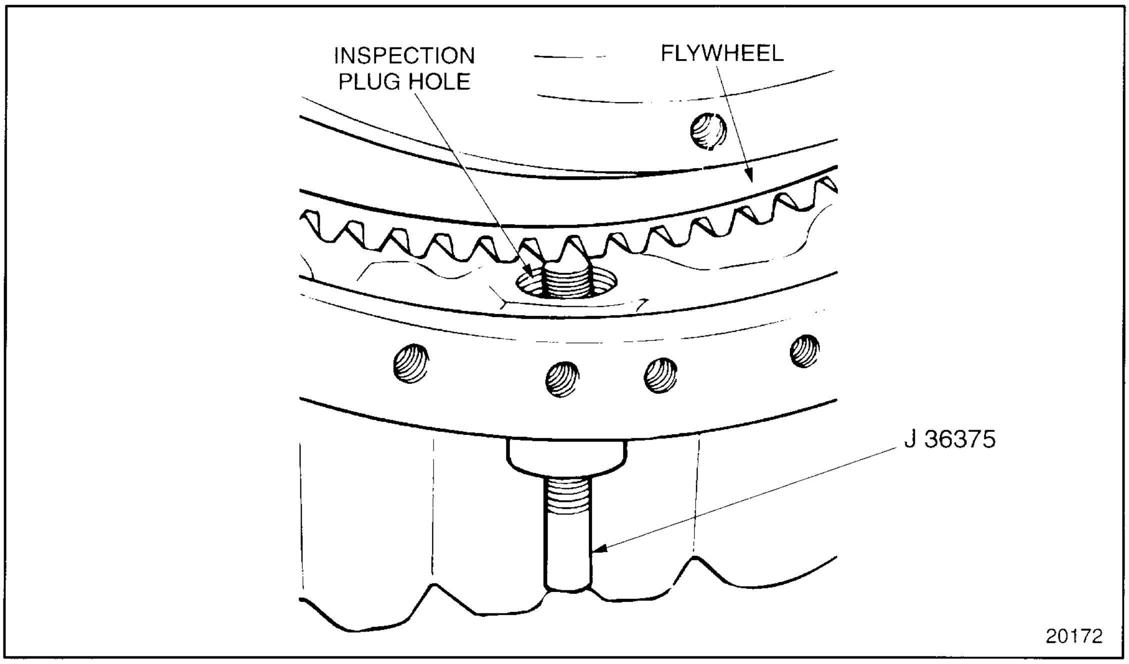


Figure 9-22 Flywheel Lock

2. Thread the center screw of the flywheel lock, J 36375–A, into the flywheel housing until the tip of the tool rests between two teeth of the flywheel ring gear. Tighten the knurled knob finger-tight. See Figure 9-22.

NOTE:
It may be necessary to bar the engine over so that the tool center screw is exactly between two teeth.

3. Remove the PTO hub assembly attaching bolt and retainer.
4. Remove the PTO hub assembly.
5. Remove the crankshaft pulley. Refer to Section 1.13.2.

9.2.2.1 Inspection of the Front Mounted Power Take-off

Visually inspect the PTO hub contact surfaces for galling or burrs. To correct surfaces that have damage, smooth these surfaces with emery cloth or a stone.

9.2.3 Installation of the Front Mounted Power Take-off

Install the PTO assembly as follows:

1. If removed, install flywheel locking tool J 36375–A through the inspection plug hole in the bottom of the flywheel housing. See Figure 9-22.
2. Install the crankshaft pulley. Refer to Section 1.13.3.
3. Install the PTO hub assembly inside of the crankshaft pulley making sure the slot on the backside of the hub fits over the dowel in the pulley.
4. Install the PTO hub assembly attaching bolt and retainer after coating the bolts threads and underside of the bolt head with INTERNATIONAL COMPOUND #2® or equivalent. Torque the bolt to 610 N·m (450 lb·ft).

10 SPECIAL EQUIPMENT

Section **Page**

10.1 AIR COMPRESSOR

The Series 50 air compressor is flange mounted to the air compressor drive assembly, located on the left side of the engine at the rear of the gear case. See Figure 10-1.

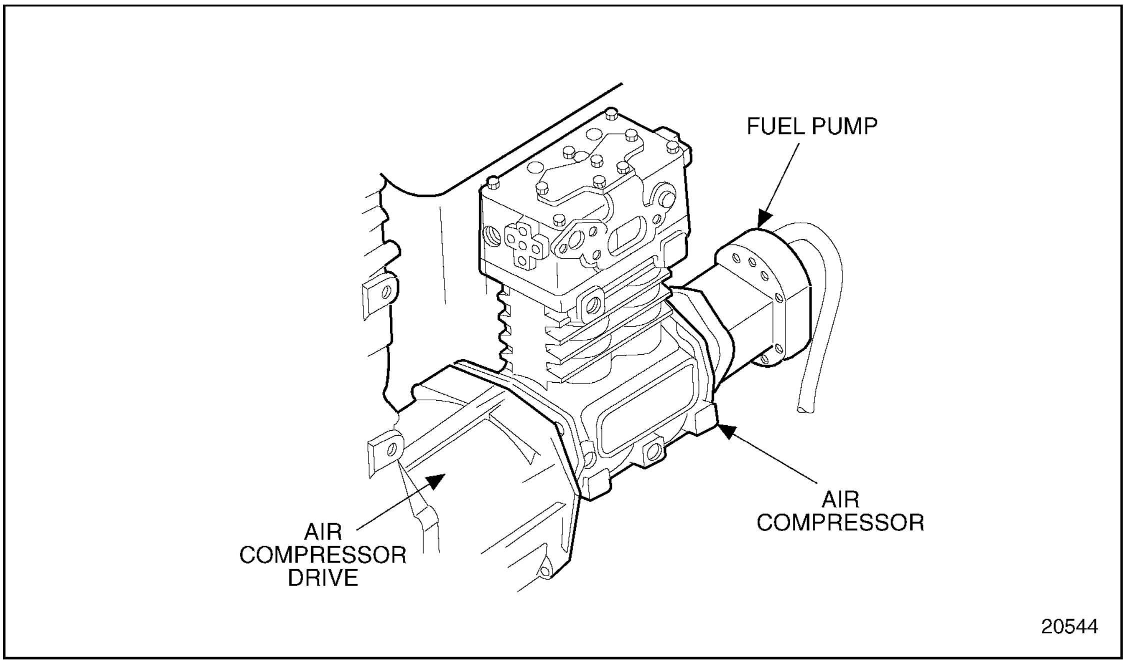


Figure 10-1 Air Compressor Mounting

Detroit Diesel has improved the mounting of the air compressor coolant inlet hose which runs from the cylinder block to the air compressor. The improved mounting eliminates the potential for air compressor coolant hose abrasion caused by rubbing against the cylinder block.

To eliminate abrasion caused by rubbing of the coolant inlet hose against the cylinder block, a new mounting clip (23506443) and bolt (11503454) are now used on all engines with Bendix air compressors.

Original air compressors were flange-mounted to the air compressor drive assembly. See Figure 10-2. Effective with unit serial number 4R6959 built November 22, 1994, adaptorless air compressors replaced the original compressors on the majority of Series 50 engines. Adaptorless compressors are flange-mounted directly to the gear case. See Figure 10-3. Improved cylinder blocks were released concurrent with this change. The adaptorless air compressors can only be used with the improved cylinder blocks. Refer to Section 1.1 for information on the improved cylinder blocks.

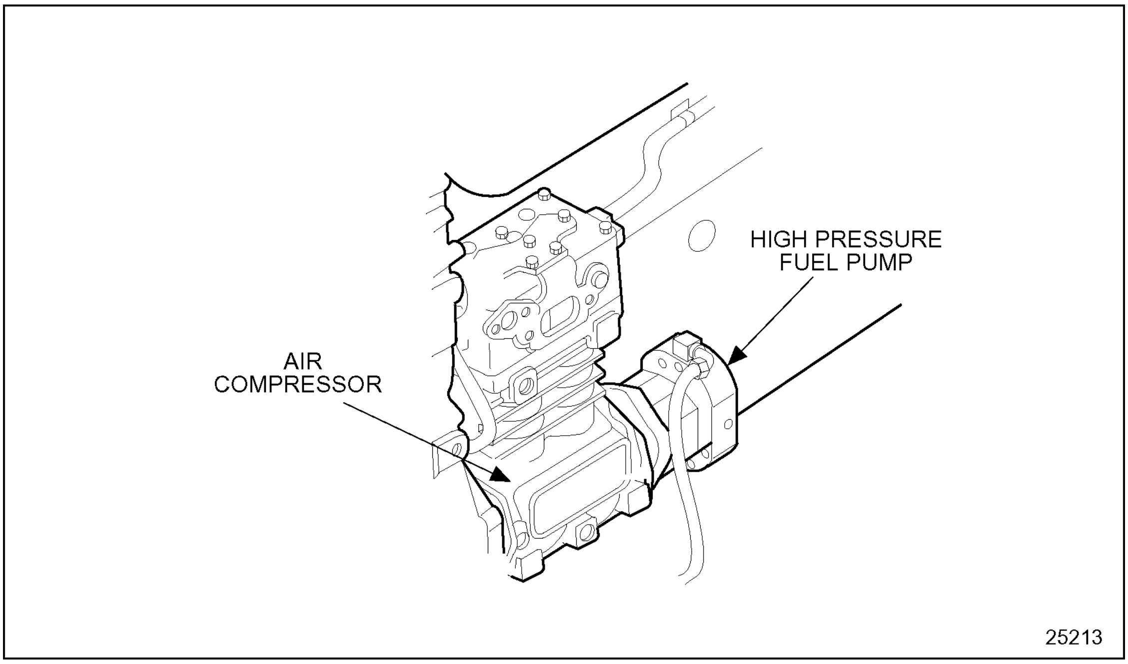


Figure 10-2 Adaptorless Air Compressor Mounting

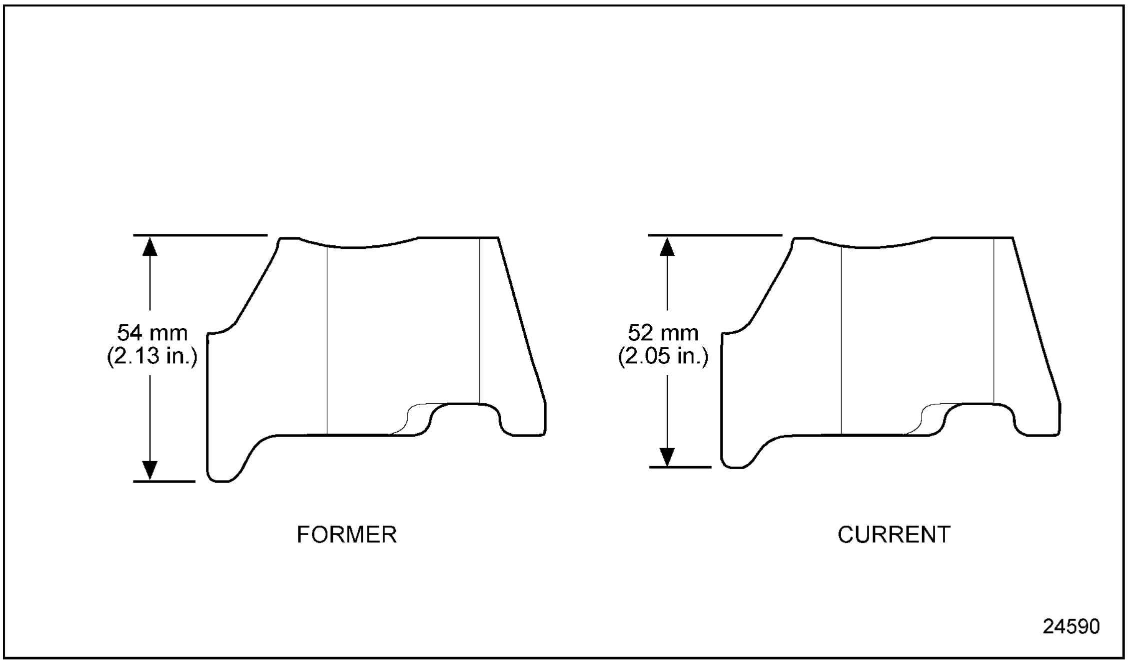


Figure 10-3 Location of Air Compressor Pressure Relief Valve

This air compressor also drives the engine fuel pump which is bolted to the rear end of the compressor. The compressor crankshaft is designed to accept a drive coupling placed between the compressor and fuel pump.

The compressor is driven by the bull gear. The air compressor is water cooled. Engine coolant is fed to the compressor through a flexible hose tapped into the engine block water jacket and connected to the front of the compressor. Coolant returns from the rear of the compressor through a flexible hose to the engine cylinder head. Lubricating oil is supplied to the compressor by a line from the cylinder block oil gallery that connects to the air compressor. Lubricating oil returns to the engine crankcase through the air compressor drive assembly. The Series 50 air compressor is unique compared to the DDC two cycle engines because of its special forged crankshaft, drive hub, and nut.

10.1.1 Replacement of Air Compressor

Detroit Diesel does not service the air compressor. Service of air compressors should be referred to an authorized service center of the original equipment manufacturer.

To replace the air compressor, perform the following procedure. See Figure 10-4.

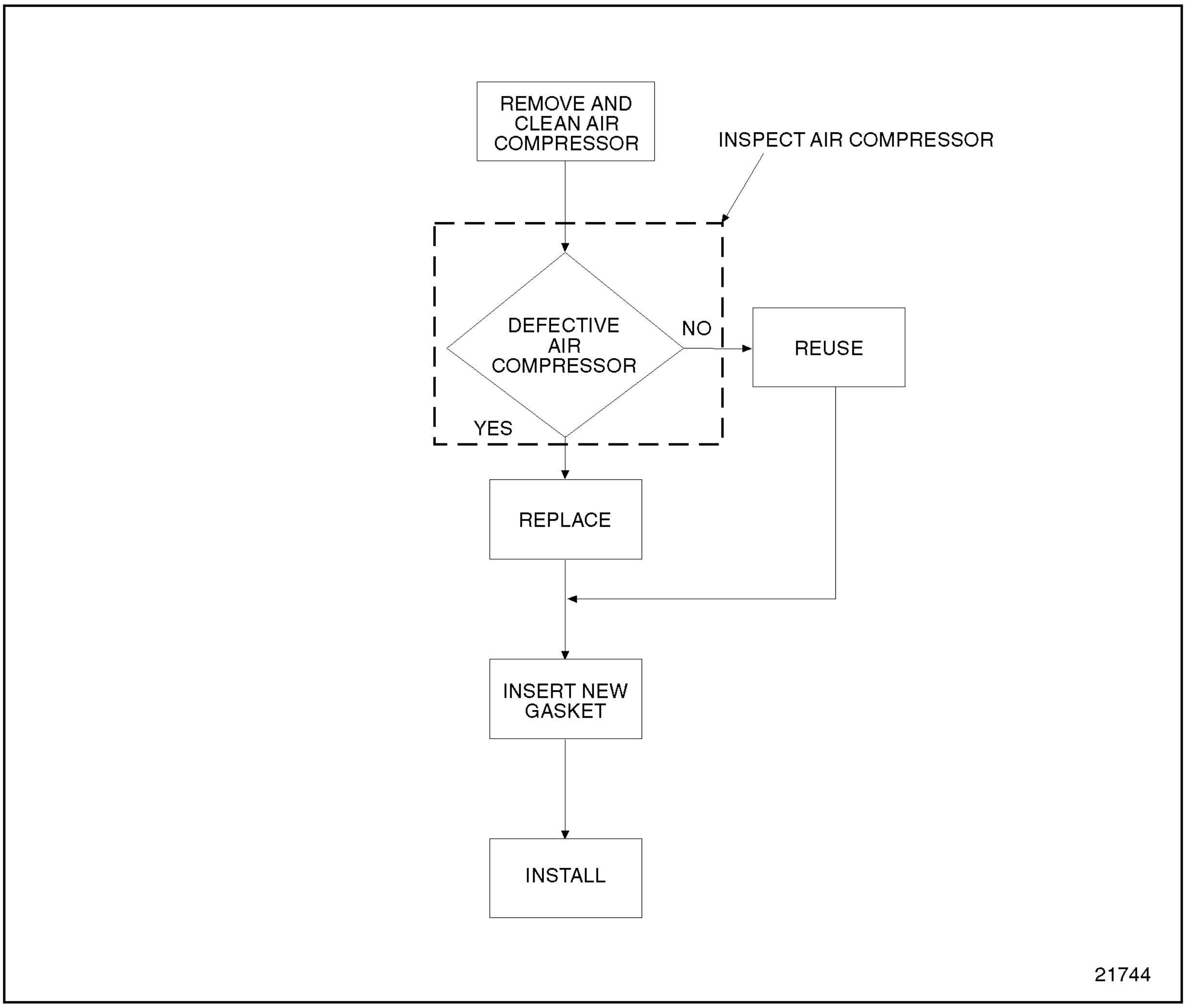


Figure 10-4 Flowchart for Replacement of Air Compressor

10.1.2 Cleaning and Removal of Air Compressor

Pre-cleaning is not necessary.

Remove the air compressor as follow:

1. Disconnect the air lines to and from the compressor.
2. Disconnect the fuel pump lines.
3. Remove the fuel pump and drive coupling. Refer to Section 2.6.2.
4. Drain the cooling system. Refer to Section 13.5.4.
5. Disconnect and remove the coolant supply line hose and clip and return lines at the air compressor.
6. Disconnect the lubricating oil supply line from the compressor.
7. Remove an unused compressor discharge port plug on the top or side of the compressor head, if necessary for installation of a pressure relief valve.
8. Remove the bolts securing the air compressor support bracket from the cylinder block and air compressor.
9. Remove the support bracket.

NOTE:
Due to the cylinder block and compressor configuration, the upper inside air compressor-to-air compressor drive bolt is difficult to reach with standard tools. Compressor wrench, J 35948, will facilitate removal and installation of this bolt.

10. Remove the bolts that secure the air compressor to the air compressor drive assembly.
11. Slide the air compressor rearward to disengage the hub from the coupling.

10.1.3 Inspection of Air Compressor

Refer to OEM guidelines to determine if the air compressor needs to be repaired or replaced.

10.1.4 Installation of Air Compressor

Install the air compressor as follows:

1. Clean all gasket material from the mating surfaces of the air compressor and air compressor drive.
2. Using a new gasket, install the air compressor as follows:
   [a] Adaptor-mounted compressor: mate the internal gear teeth of the drive assembly hub with the external gear teeth of the coupling.
   [b] adaptorless compressor: mate the external gear teeth of the compressor coupling with the bull gear teeth.

3. Install the pressure relief valve into the open discharge port plug. Using a 7/8 in. (Number 14 metric) deep socket, carefully torque the valve to 23-31 N·m (17-23 lb·ft).
4. Align the bolt holes of the two components and install the air compressor-to-air compressor drive bolts.
5. Torque the five bolts and one nut to 58–73 N·m (43–54 lb·ft) using the required torque pattern. See Figure 10-5. Use compressor wrench, J 35948, to tighten the upper-inside bolt.

NOTE:
The shorter bolt is installed in the two o'clock position.

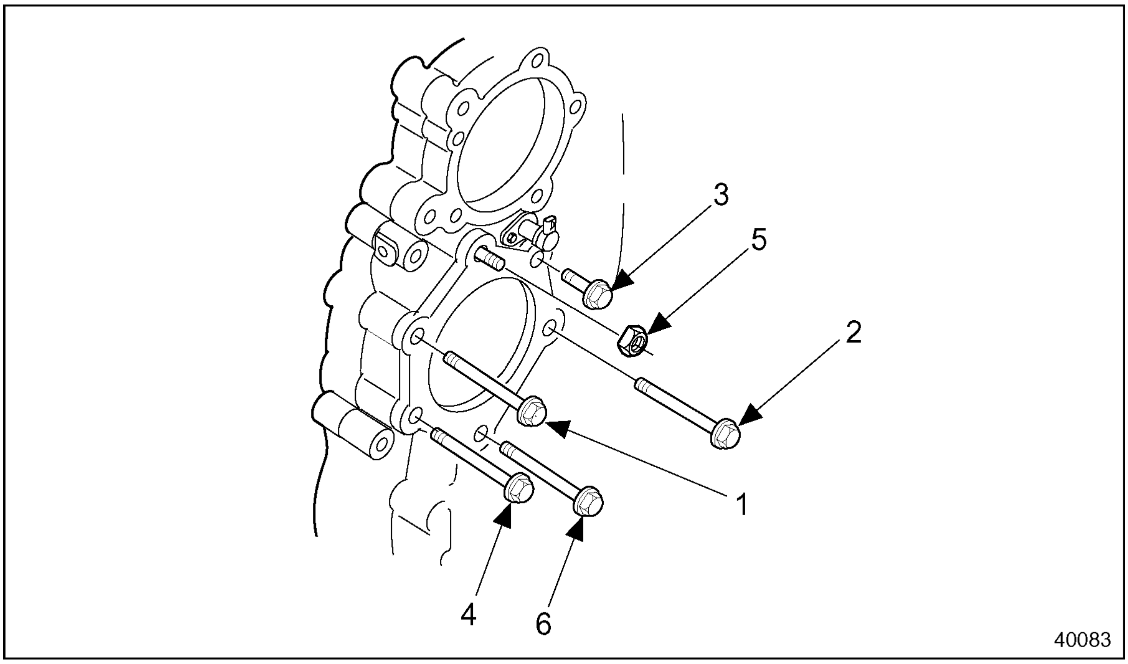


Figure 10-5 Bolt Torque Sequence

6. Install the air compressor support bracket to the compressor and cylinder block. Tighten the support bracket-to-air compressor bolts.
   [a] For 25 mm long bolts use a torque of 41–52 N·m (30–38 lb·ft).
   [b] For 20 mm long bolts use a torque of 30–38 N·m (22–28 lb·ft).
7. Torque the support bracket-to-cylinder block bolts to 58-73 N·m (43-54 lb·ft).
8. If spring type hose clamps are used:
   [a] Install the coolant supply and return lines from the cylinder block and connect to the air compressor using four spring type hose clamps. Torque to 58-73 N·m (43-54 lb·ft).
   [b] Install the supercharger line from the intake manifold and connect to the air compressor using two spring type hose clamps.
9. If a worm screw drive, liner type clamp is used:

[a] Install the coolant supply and return lines from the cylinder block and connect to the air compressor using four worm screw drive clamps. Torque to 58-73 N·m (43-54 lb·ft).

[b] Install the supercharger line from the intake manifold and connect to the air compressor using two worm screw drive type hose clamps.

10. Install the lubricating oil supply line to the compressor.
11. Install the air lines to and from the compressor.
12. If the unit has a compressor driven fuel pump, install the fuel pump. Refer to Section 2.5.6.
13. Refer to Section 13.5.4 to fill the cooling system.

10.2 AIR COMPRESSOR DRIVE HUB

The air compressor crankshaft will turn while removing or tightening the drive hub retaining nut unless some provision is made to hold it. One method is to weld a modified drive coupling to a support or base which can be anchored to the mounting flange of the compressor.

A Series 71 or 92 flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. When positioned, the exterior splines of the coupling mesh with the internal splines of the drive hub and the assembly is secured to the compressor housing. The shaft is then kept from rotating when the nut is loosened or tightened, by the hub and key.

10.2.1 Replacement of Air Compressor Drive Hub

To replace the air compressor drive hub, perform the following procedure. See Figure 10-6.

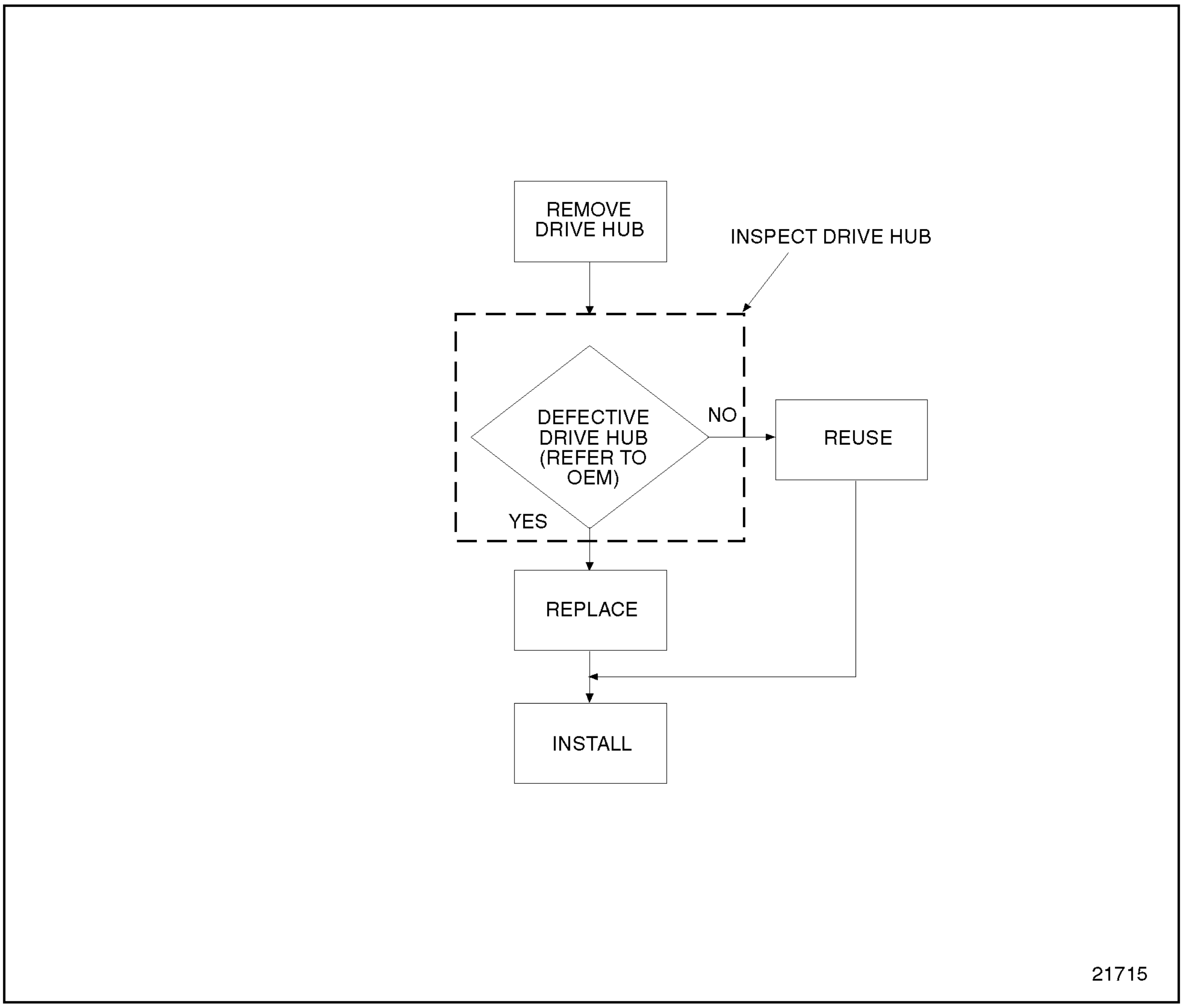


Figure 10-6 Flowchart for Replacement of Air Compressor Drive Hub

10.2.2 Cleaning and Removal of Air Compressor Drive Hub

Precleaning is not necessary.

Refer to Section 10.1.2 for removal of the air compressor.

To keep the shaft from rotating, perform the following:

To properly position the cover and coupling with the drive hub, four collars, 19 mm O.D. and 12.7 mm I.D., 19 mm long (3/4 in. O.D. and 1/2 in. I.D., 3/4 in. long), and two pieces of bar stock 19 mm x 19 mm x 102 mm (3/4 in. x 3/4 in. x 4 in.) must be fabricated and welded to the flywheel housing cover at the positions shown in the next illustration. See Figure 10-7.

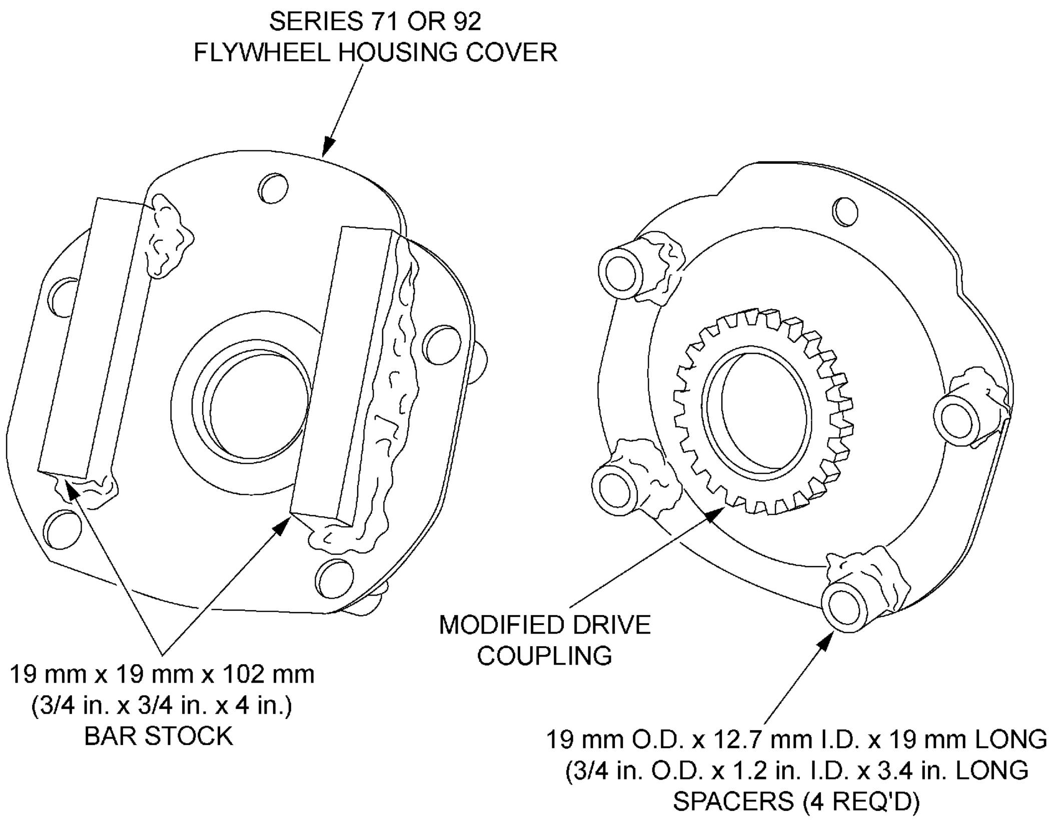


Figure 10-7 Holding Fixture

Position the coupling into the drive hub. Lay the flywheel housing cover over the coupling, center the collars over the compressor housing bolt holes, and tack weld the cover to the coupling.

The diameter of the cover hole must be opened up to the same diameter as the coupling inside diameter to permit access to the drive hub retaining nut. Two bolts will secure the base to the compressor during the operation.

Remove the air compressor drive hub as follows:

1. Install the holding fixture to the flange of the air compressor, engaging the coupling with the internal teeth of the drive hub. Install two bolts to secure the fixture to the compressor. See Figure 10-8.

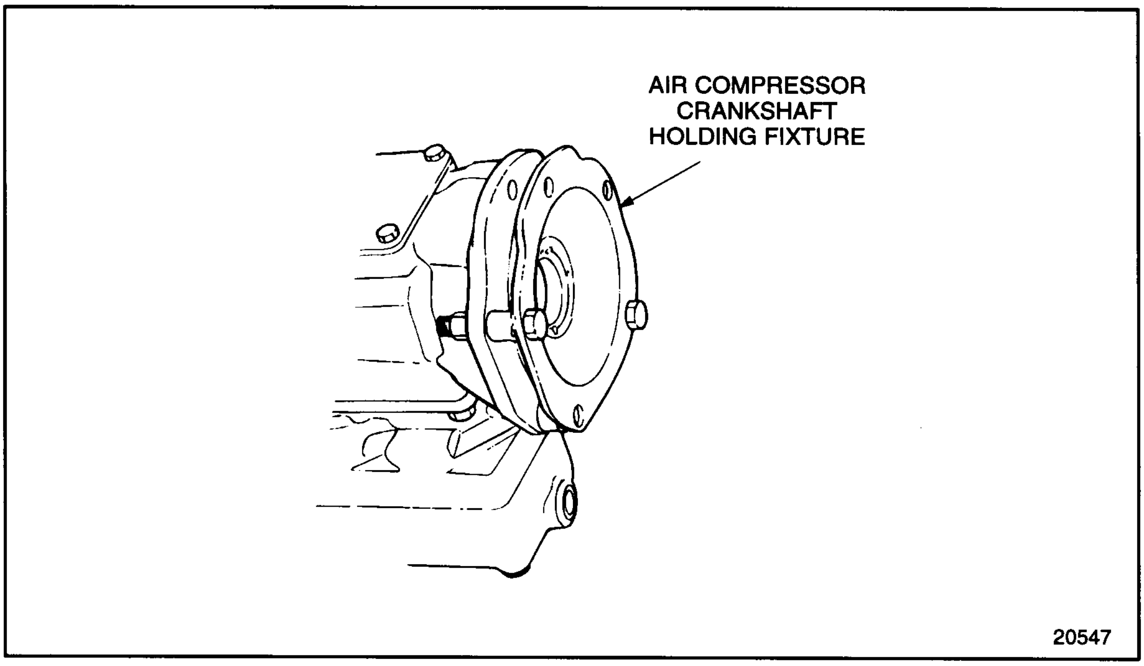


Figure 10-8 Air Compressor Crankshaft Holding Fixture Installation

2. Loosen and remove the drive hub retaining nut.
3. Remove the drive hub from the air compressor by lifting the hub off of the shaft.

10.2.3 Inspection of Air Compressor Drive Hub

Refer to OEM guidelines to determine if the air compressor drive hub needs to be repaired or replaced.

10.2.4 Installation of Air Compressor Drive Hub

Install the air compressor drive hub as follows:

NOTICE:
The drive hub and nut on the Series 50 have a unique configuration. Only the correct part numbers should be used.

1. Install the key to the keyway on the air compressor shaft. Align the keyway in the drive hub with the key in the air compressor crankshaft.
2. Install the hub to the shaft as far as it will go by hand. Do not cock or jam the hub. See Figure 10-9.

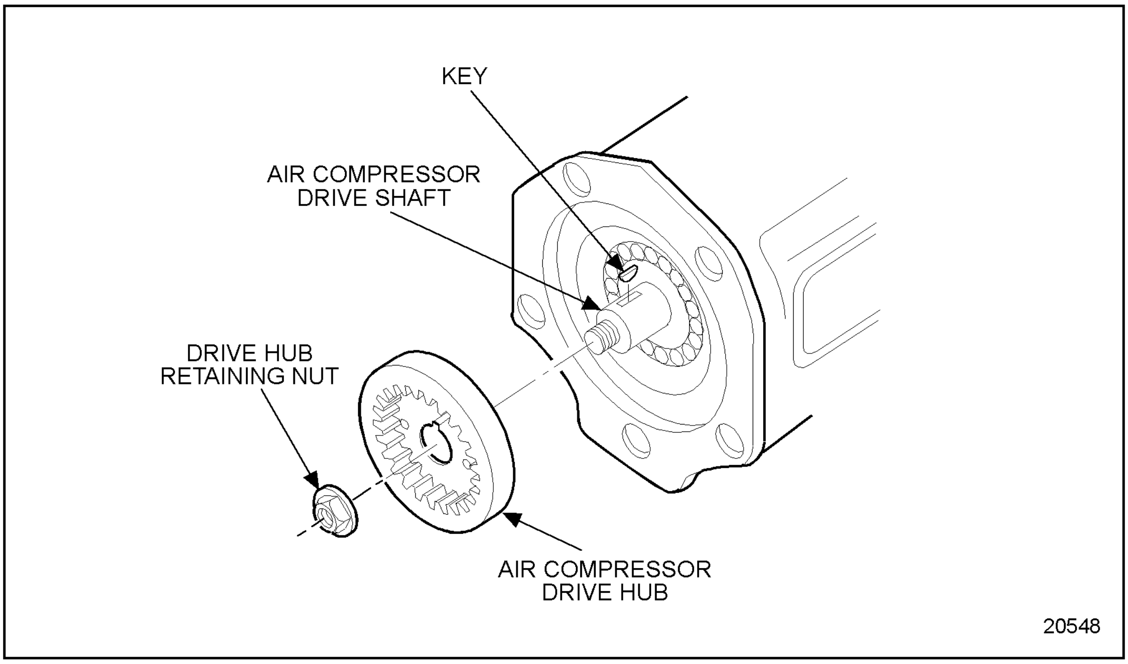


Figure 10-9 Air Compressor Drive Hub Assembly

3. Install the drive holding fixture to the flange of the air compressor, engaging the coupling with the internal teeth of the drive hub. Install two bolts to secure the fixture to the compressor. See Figure 10-8.

4. Torque the air compressor drive hub retaining nut to 298-346 N·m (220-255 lb·ft). See Figure 10-10.

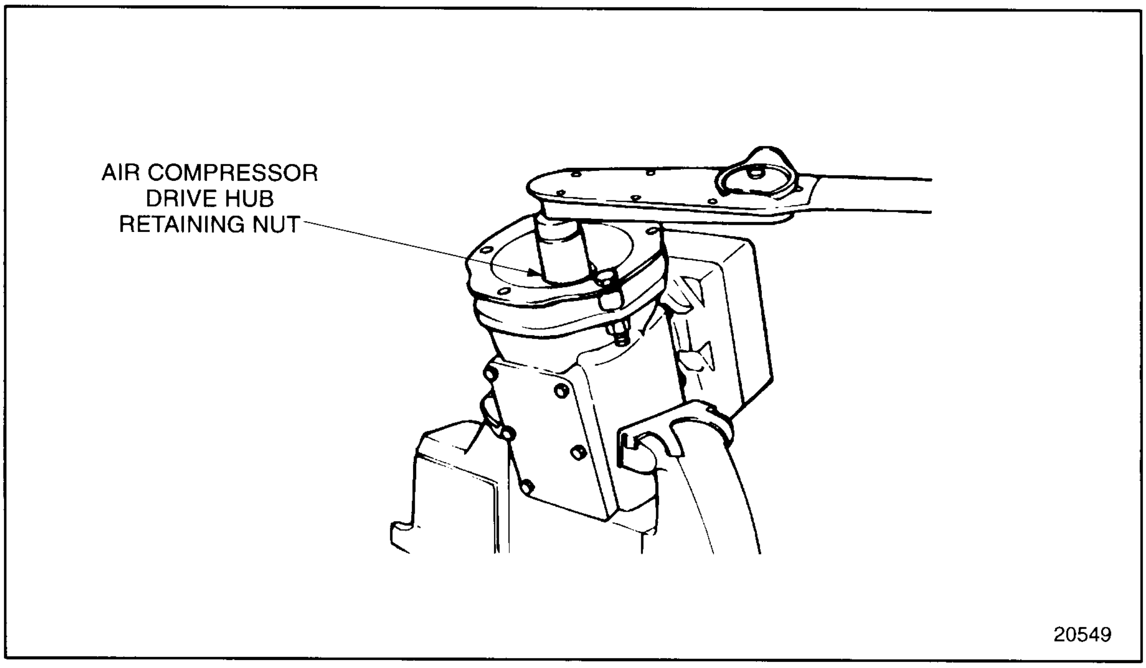
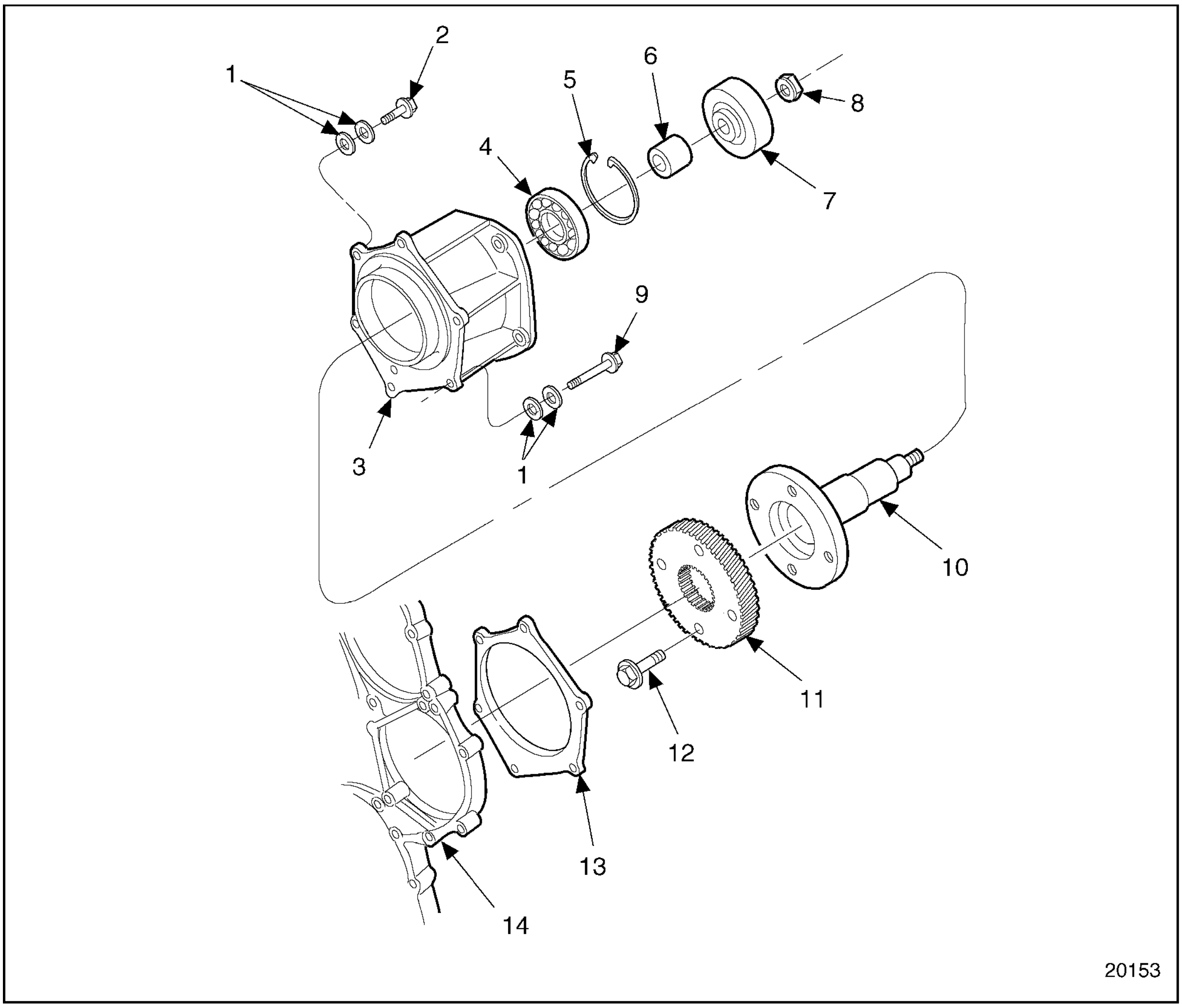


Figure 10-10 Torquing Drive Hub Retaining Nut

5. Loosen the two bolts that retain the holding fixture to the compressor flange, and remove the holding fixture.

10.3 AIR COMPRESSOR DRIVE ASSEMBLY

The air compressor drive assembly mounts to the rear of the gear case on the intake side of the engine. See Figure 10-11.



1. Plain Washers (Shims)
2. Short Bolt, Air Compressor Drive Housing-to-Gear Case (1)
3. Housing, Air Compressor
4. Ball Bearing, Air Compressor Drive
5. Snap Ring
6. Spacer
7. Hub, Air Compressor Drive
8. Flange Nut, Air Compressor Drive Hub
9. Plain Washers (Shims) Long Bolt
10. Shaft, Air Compressor Drive
11. Gear, Air Compressor Drive
12. Bolt, Air Compressor Drive Gear-to-Shaft
13. Gasket, Air Compressor Drive Housing-to-Gear Case
14. Drive Gear Case

Figure 10-11 Air Compressor Drive Detail and Location of Parts

A drive gear meshes with the bull gear and is driven at a ratio of 1.19:1.

The drive gear is bolted to the air compressor drive shaft. A drive hub is installed onto the opposite end of the air compressor drive shaft, and is used to drive the air compressor. On vehicles with power steering, a short splined coupling connects the drive gear to the power steering pump. The coupling is inserted in the splined center of the air compressor drive gear.

Two composition gaskets are used, one to seal the air compressor drive housing to the gear case, and one to seal the air compressor to the drive housing.

10.3.1 Replacement of Air Compressor Drive Assembly

To replace the air compressor drive assembly, perform the following procedure. See Figure 10-12.

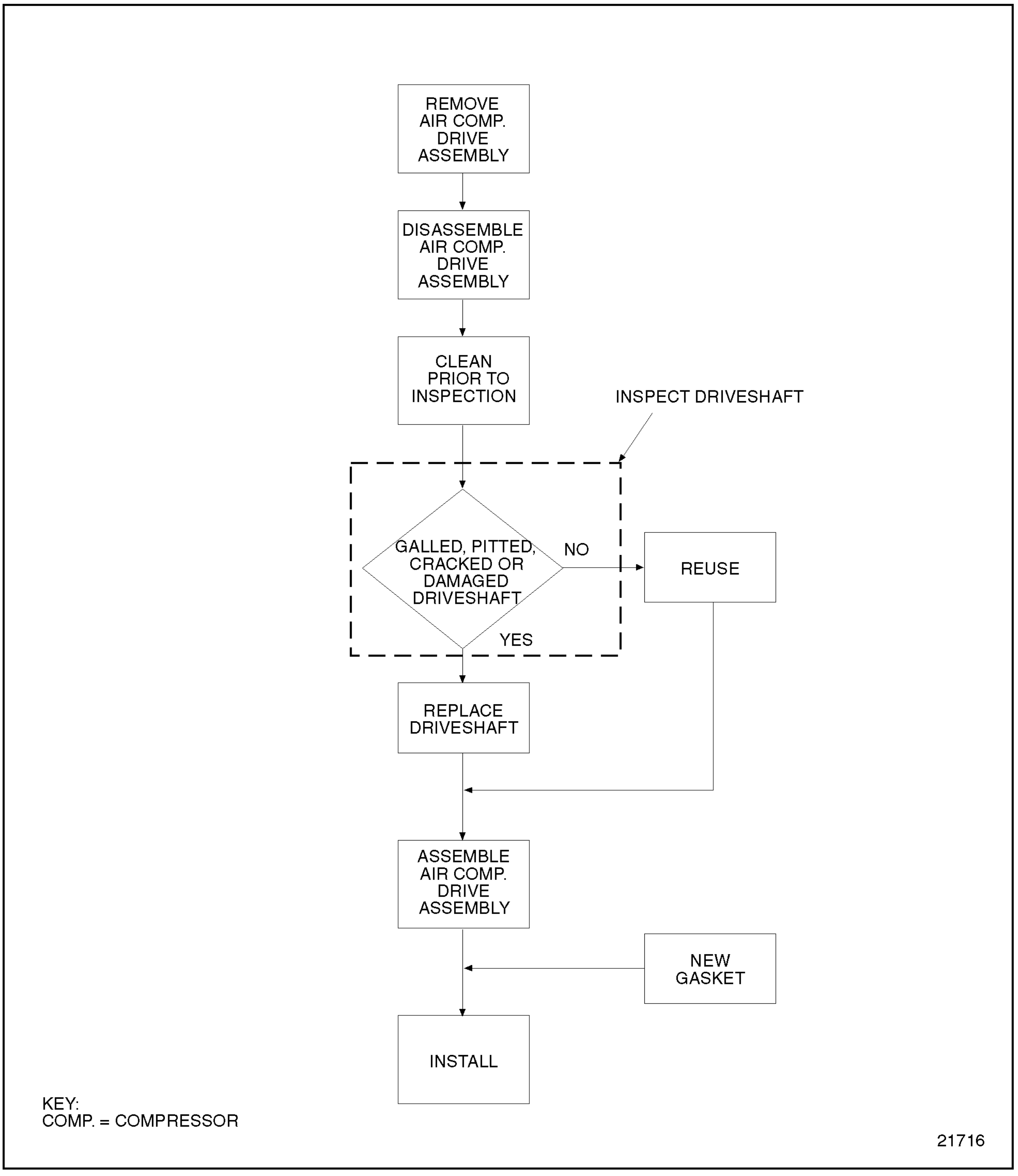


Figure 10-12 Flowchart for Replacement of Air Compressor Drive Assembly

10.3.2 Cleaning and Removal of Air Compressor Drive Assembly

Cleaning is not necessary.

Remove the drive assembly as follows:

1. If equipped, remove the air compressor. Refer to Section 10.1.2.
2. If equipped with power steering, loosen and remove the five bolts securing the power steering pump and cover assembly to the gear case cover.
3. Remove the pump and cover assembly.
4. Remove the power steering drive coupling from the air compressor drive gear.
5. Disconnect the oil supply lines from the "T" fitting, if applicable, at the top of the air compressor drive housing.
6. Remove the six bolts that secure the air compressor drive assembly to the gear case.
7. Remove the assembly by pulling it straight out of the gear case.

NOTE:
The short bolt in the two o'clock position is for installation reference.

10.3.3 Disassembly of Air Compressor Drive Assembly

Disassemble the air compressor drive assembly as follows:

1. Secure the holding fixture, see Figure 10-7, in a suitable vise with the drive coupling facing up. See Figure 10-13.

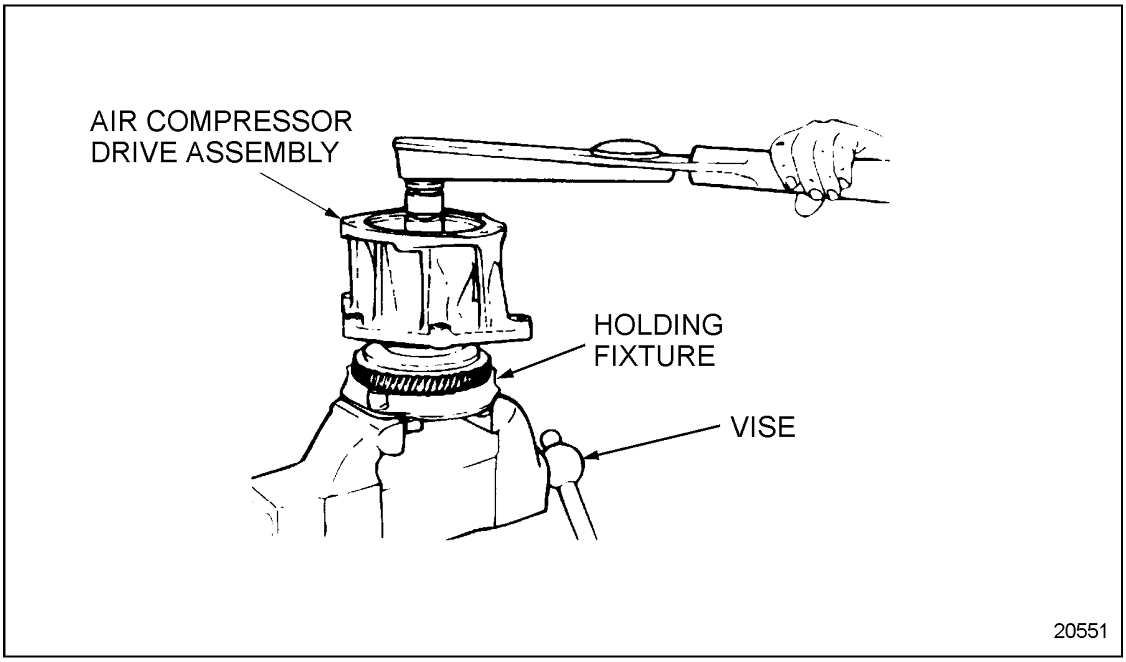


Figure 10-13 Air Compressor Drive Hub Disassembly

2. Position the air compressor drive assembly onto the holding fixture, engaging the internal teeth of the drive gear with the coupling on the holding fixture.
3. Loosen and remove the flanged nut retaining the drive hub to the drive shaft.
4. Remove the drive hub from the air compressor drive assembly.
5. Remove the spacer from the drive shaft (current air compressor drive only).
6. Remove the drive assembly from the holding fixture and place on bench.
7. Remove the four bolts that secure the drive gear to the drive shaft flange and remove gear.
8. Use the air compressor and fan drive service tool set, J 36310-A, for disassembly. See Figure 10-14.

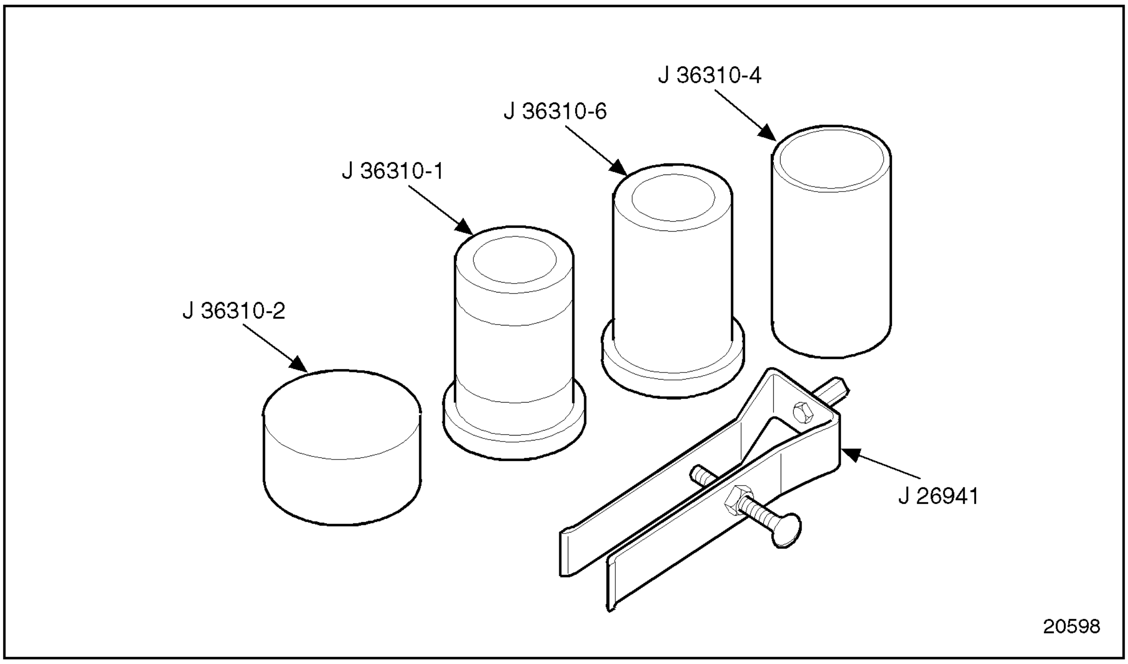


Figure 10-14 Air Compressor and Fan Drive Service Kit Set

9. Support the air compressor drive housing on press plates with the drive hub side facing up.
10. Press the air compressor drive shaft out of the drive housing.

NOTE:
Whenever the drive shaft is removed from the housing, the ball bearing assembly must be replaced.

11. Remove the large snap ring retaining the ball bearing in the air compressor drive hub housing using snap ring pliers. See Figure 10-15.

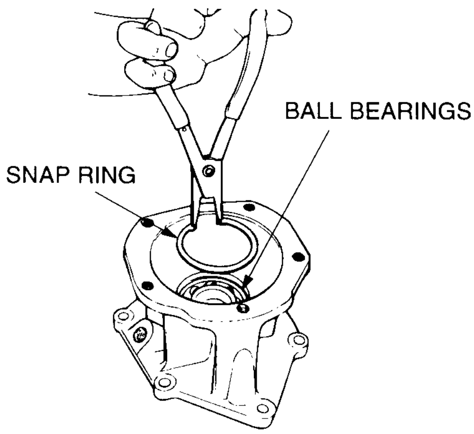


Figure 10-15 Roller Bearing Snap Ring Removal

12. On current design air compressor drive only, turn the air compressor drive housing over and support it on the press bed.
13. Using the narrow end of bearing installer, J 36310-6, part of tool set J 36310–A, against the bearing, press the bearing from the housing.
14. Discard the bearing.

NOTE:
The following steps apply only to the former design air compressor drive.

15. Using the snap ring pliers, turn the drive assembly over, and remove the large snap ring retaining the roller bearing in the air compressor drive housing. See Figure 10-16.

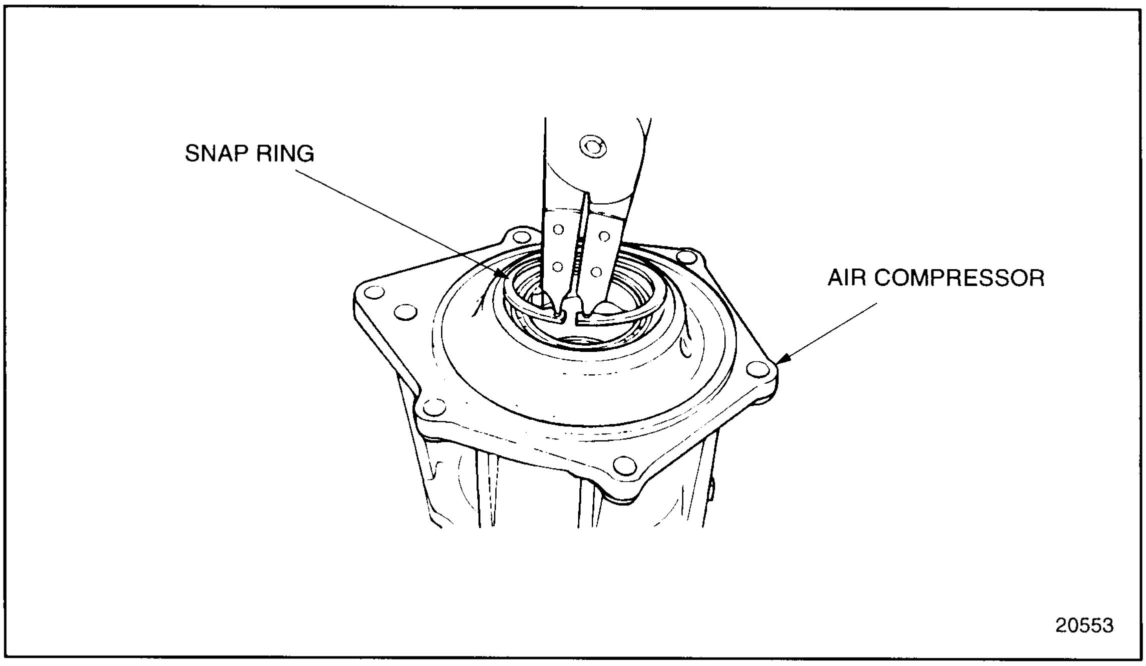
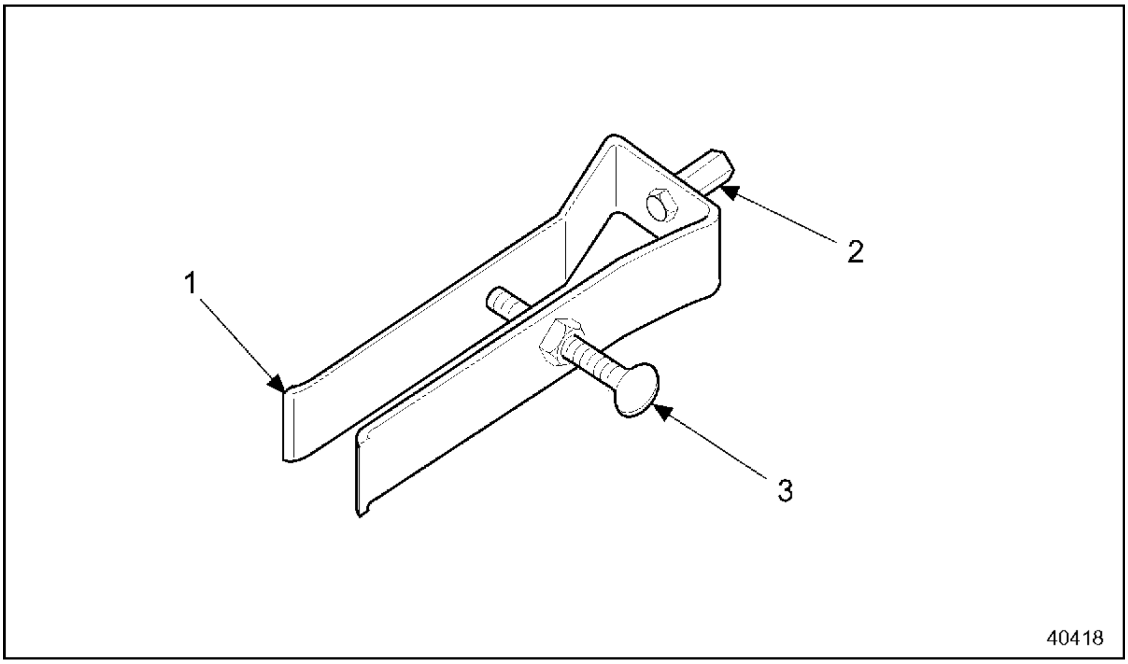


Figure 10-16 Ball Bearing Snap Ring Removal

NOTE:
Whenever the bearings are removed from the housing, the bearing assemblies must be replaced.

16. Install the lip of the bearing remover, J 26941, under the bearing. See Figure 10-17.



1. Lip
2. Slide Hammer Attaching Point
3. Thumb Screw

Figure 10-17 Roller Bearing Remover

17. Tighten the thumb screw on the bearing remover until it is snug against the bearing.
18. Install a suitable slide hammer to the top of the bearing remover. Remove the bearing.
19. Repeat this procedure to remove the other bearing from the housing.

20. Using snap ring pliers, remove the small snap ring retaining the roller bearing inner race on the air compressor drive shaft. See Figure 10-18.

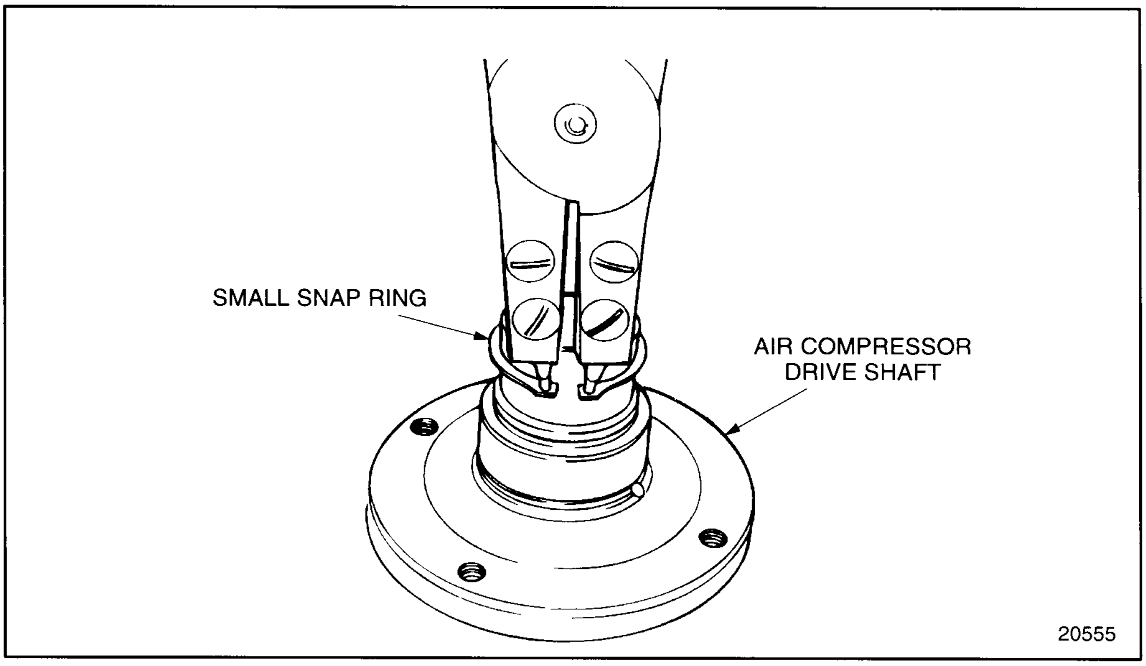


Figure 10-18 Roller Bearing Inner Race Snap Ring Removal

21. Using a punch and hammer, work through the two access holes to drive the roller bearing inner race from the air compressor drive shaft. See Figure 10-19.

NOTE:
Whenever the roller bearing inner race is removed from the shaft, the roller bearing assembly must be replaced.

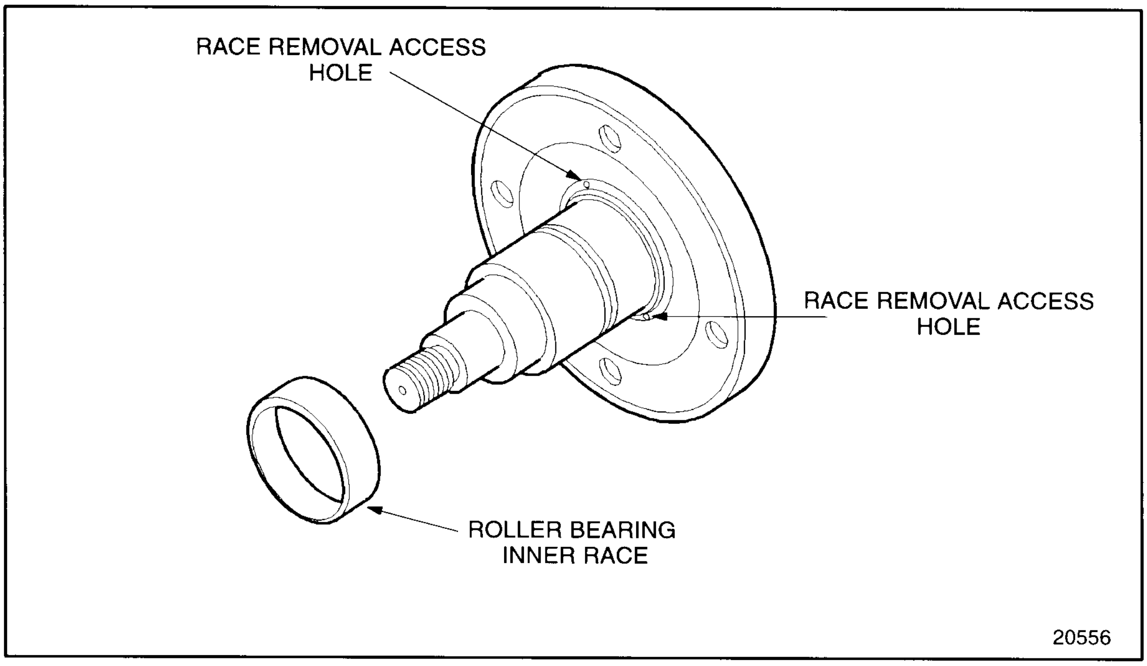


Figure 10-19 Bearing Inner Race Removal

Clean the air compressor drive assembly prior to inspection as follows:

1. Clean all of the parts with clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry with compressed air.

10.3.3.1 Inspection of the Air Compressor Drive Assembly

Inspect the air compressor drive assembly as follows:

1. Inspect the drive shaft for damage.
   [a] Check drive shaft for galling, pitting, cracks, or other damage.

[b] If drive shaft is damaged, replace with new part.

10.3.4 Assembly of Air Compressor Drive Assembly

Assemble the air compressor drive assembly as follows:

1. Turn the housing over.

NOTE:
The bearing identification numbers must face the installer when installing the bearing.

2. Install the ball bearing in the air compressor drive housing using a press and the large end of the ball bearing installer, J 36310-1, part of tool set J 36310–A, for the former design or, J 36310-6, part of tool set J 36310–A, for the current design.
3. Press on the outer race of the bearing only. See Figure 10-20.

NOTE:
Be sure the bearing is fully seated against the shoulder in the housing for the snap ring to be installed.

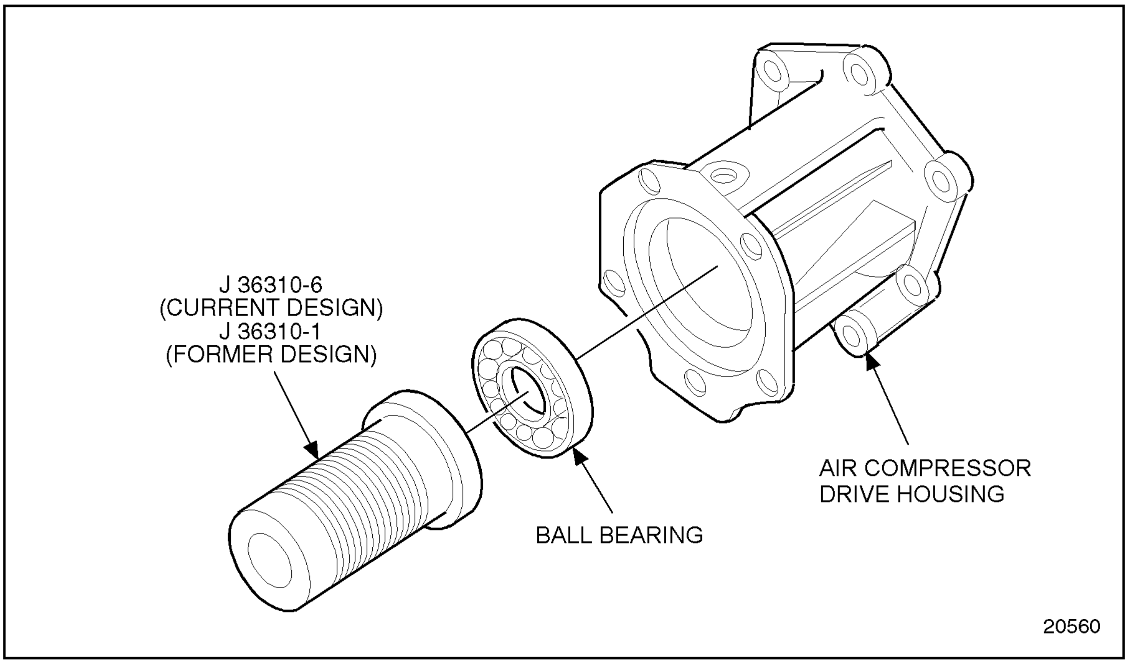


Figure 10-20 Ball Bearing Installation

NOTE:
There is a plastic sleeve in the current design ball bearing which must not be removed when installing the bearing. The sleeve will be pushed out when the drive shaft is installed.

4. Install the snap ring retaining the ball bearing in the housing using snap ring pliers. See Figure 10-21.

NOTE:
Be sure the snap ring is fully seated in its groove in the housing.

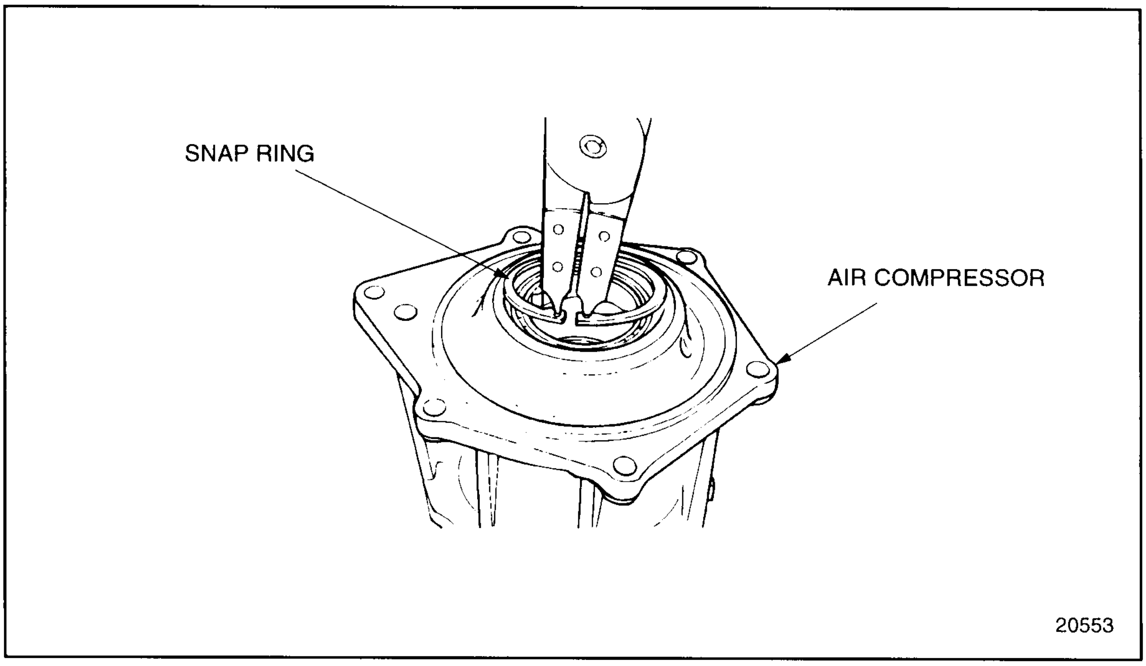


Figure 10-21 Snap Ring Installation

5. Place wide end of ball bearing installer, J 36310-6, part of tool set J 36310–A, on press bed.
6. Place the air compressor drive housing on the bearing installer, making sure that the installer is centered on the bearing inner race.
7. Position the drive shaft in the bearing inner race.
8. Press the drive shaft into the bearing and housing assembly until the shaft shoulder is seated against the bearing inner race.
9. Remove the air compressor drive assembly from the tool.
10. Remove the plastic sleeve from inside of the tool.
11. Discard plastic sleeve.

12. Install the air compressor drive gear to the shaft. See Figure 10-22.

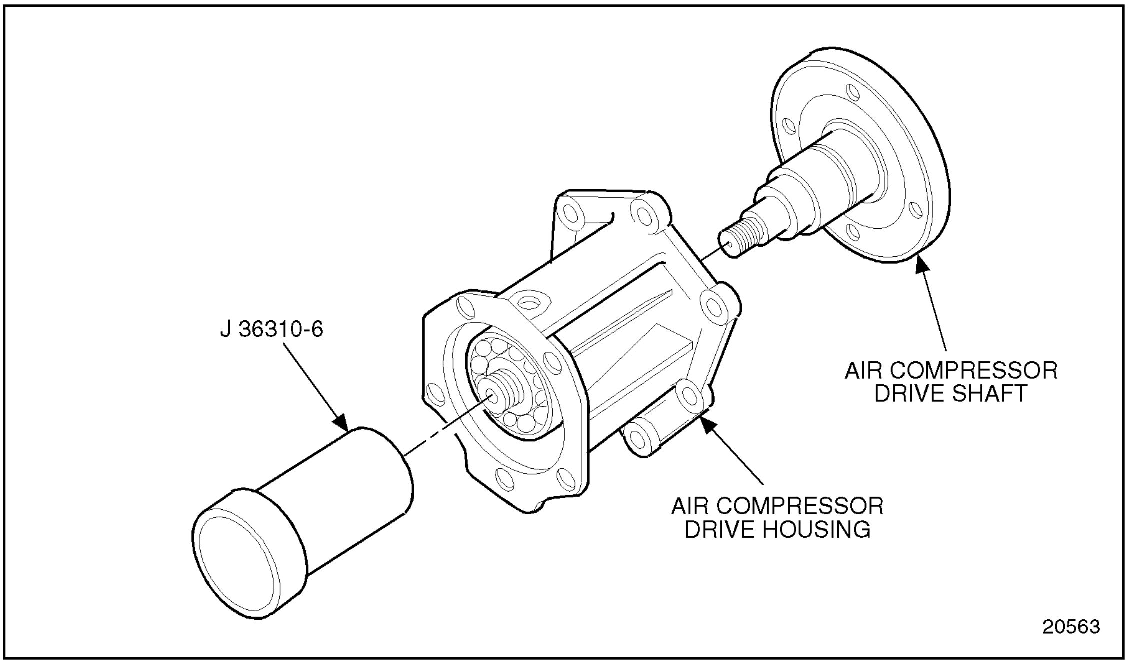


Figure 10-22 Air Compressor Drive Gear Installation

13. Install the four drive gear-to-drive shaft bolts and torque to 58-73 N·m (43-54 lb·ft).
14. Secure the holding fixture, See Figure 10-7, in a suitable vise with the drive coupling positioned up.
15. Position the air compressor drive assembly on the holding fixture, engaging the internal teeth of the drive gear with the coupling on the fixture.
16. Lubricate the ball bearing with clean engine oil.
17. Place the spacer on the drive shaft seating it against bearing inner race.

18. Place the air compressor drive hub on the drive shaft. See Figure 10-23.

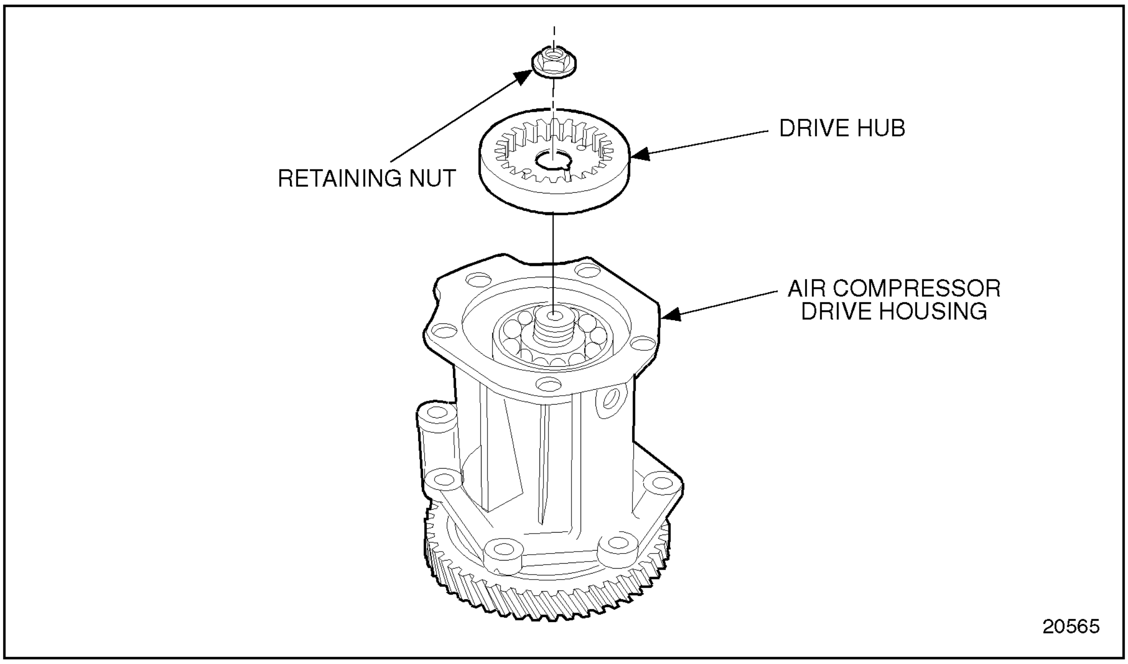


Figure 10-23 Drive Hub Installation

19. Install the flanged nut retaining the drive hub to the drive shaft. Torque the nut to 300-345 N·m (221-255 lb·ft).
20. Remove the drive assembly from the holding fixture and position it on a suitable flat surface with the drive gear facing up.

21. Assemble a dial indicator and magnetic base so that the indicator stem rests on the face of the drive gear just inboard of the drive gear teeth. See Figure 10-24.

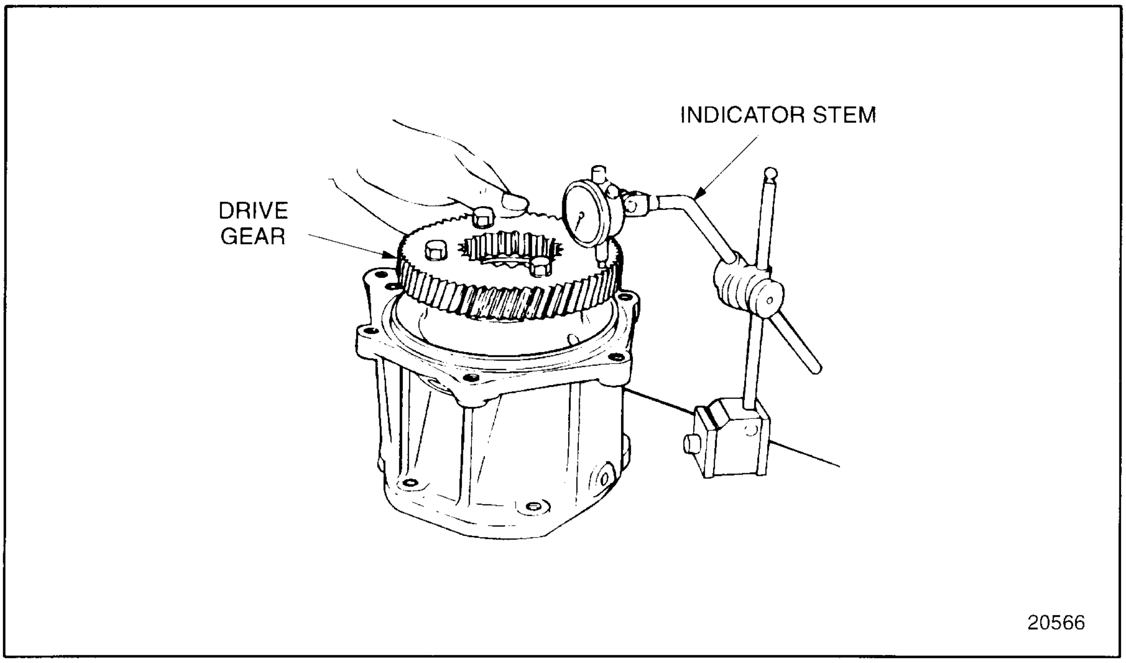


Figure 10-24 Measuring Air Compressor Drive Gear TIR

22. Zero the dial indicator.
23. Rotate the drive gear two full revolutions. As the gear is rotated, the dial indicator may register both to the left and right of zero. The total amount the indicator needle moves to the left and right of zero, added together, gives the total indicated runout (TIR). Maximum allowable TIR is 0.08 mm (0.003 in.).

10.3.5 Installation of Air Compressor Drive Assembly

Install the air compressor drive assembly as follows:

1. Install the air compressor drive assembly to its original position in the gear case, using a new gasket between the housing and gear case.
2. Install the bolts and nut that secure the air compressor drive assembly to the gear case.

3. Using the required torque pattern, torque the five bolts and nut to 58-73 N·m (43-54 lb·ft). See Figure 10-25.

NOTE:
The shorter bolt is installed in the two o'clock position.

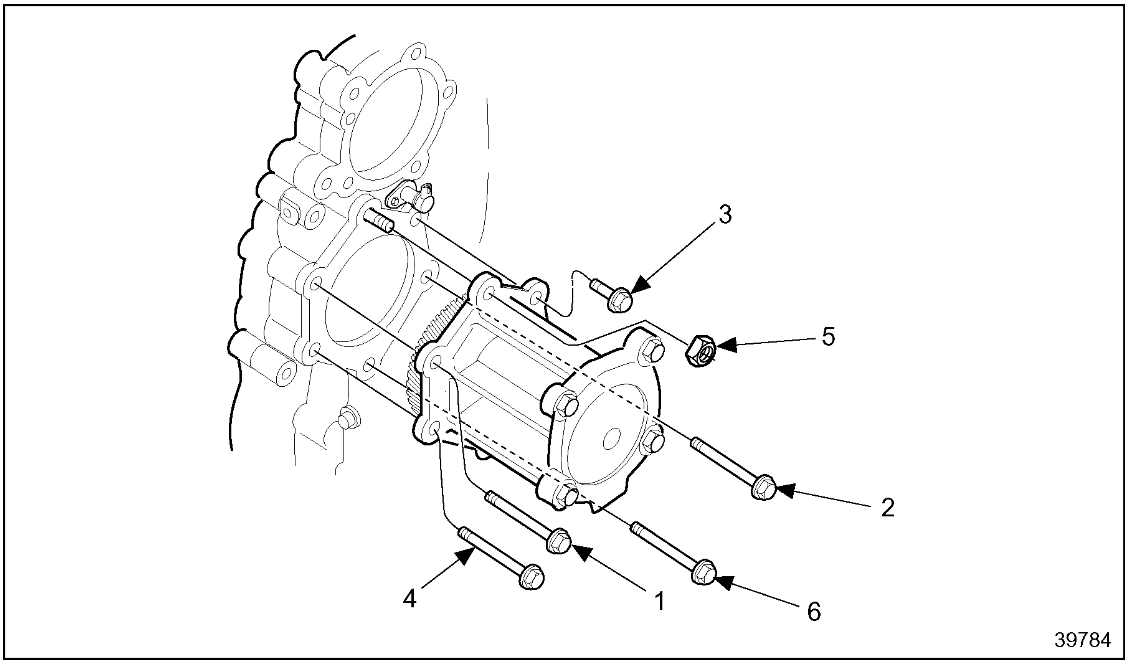


Figure 10-25 Bolt Torque Sequence

4. Measure the bull gear-to-air compressor drive gear lash. Refer to Section 1.21.2.1.
5. Install the access cover. Use a new gasket between the access cover and the gear case cover, and torque the 5 bolts to 30-38 N·m (22-28 lb·ft) in a star-shaped tightening pattern.
6. If the engine is equipped with a power steering pump, install the proper steering drive coupling and power steering pump and cover assembly to the gear case cover. Install a new gasket between the cover and the gear case cover, and torque the 5 bolts to 30-38 N·m (22-28 lb·ft) in a star-shaped tightening pattern.
7. Connect the oil supply line at the "T" fitting, if applicable, at the top of the air compressor drive housing.
8. Install the air compressor. Refer to Section 10.1.4.

NOTE:
For engines used in coach applications, a high strength air compressor supply hose must be installed between the intake manifold and the air compressor inlet. This hose can be identified by the light blue color on the inside of the hose. Flat band spring type hose clamps must be used.

CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

9. Install any other components that were removed for this procedure.

10.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

Specifications are listed in the General Information section at the beginning of the manual. Exceptions are listed below:

Exceptions to Standard Fastener Torque Specifications

Exceptions to Standard Fastener Torque Specifications supporting the Series 50 Engine are listed in Table 10-1.

Fastener	Torque, N · m	Torque, lb · ft.
Pressure relief valve-to-discharge port plug	23-31	17-23
Bolts, air compressor-to-air compressor drive bolts	58-73	43-54
Bolts, support bracket-to-air compressor (25 mm long)	41-52	30-38
Bolts, support bracket-to-air compressor (20 mm long)	30-38	22-28
Bolts, support bracket-to-cylinder block	58-73	43-54

Table 10-1 Exceptions - Metric Fastener Torque Specifications

11 OPERATION AND VERIFICATION

11.1 PREPARATION FOR A FIRST TIME START

Before starting an engine for the first time, carefully read and follow the instructions in this section. Also, refer to Section 13 .

NOTICE:
Attempting to run the engine before studying these instructions may result in serious damage to the engine.

NOTICE:
When preparing to start a new or overhauled engine or an engine that has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see Daily Operations in the Preventive Maintenance Chart. Refer to Section 13.2. Failure to perform required prestart operations may result in engine damage.

11.1.1 Cooling System

Install all of the drain cocks and plugs in the cooling system as instructed below:

1. Open the cooling system vents.
2. Remove the filler cap and fill the cooling system with a coolant specified. Refer to Section 5.4. The coolant level should be within two inches (50 mm) of the filler neck to allow for fluid expansion.
3. Close the vents, if used, after filling the cooling system.

11.1.2 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.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 172 kPa (25 lb/in.^{2}) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use lubricating oil as specified. Refer to Section 5.2. Then, remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the *full* mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with lubricating oil. Refer to Section 13.5.1. 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, rocker arm shafts, camshaft lobes and camshaft follower rollers.

11.1.3 Turbocharger

When a turbocharger is replaced, or if the engine has been in storage, the turbocharger must be prelubricated by pouring oil into the oil supply inlet before the engine is started. Rotate the shaft to coat the bearings with oil.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

CAUTION:

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

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.

Start and run the engine at idle until oil supply pressure has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers 138 kPa (20 lb/in.^{2}) pressure at idle speed.

11.1.4 Air Cleaner

Refer to OEM instructions for the air cleaner, and service accordingly.

11.1.5 Transmission

Check the oil level and, if necessary, fill the transmission case or torque converter to the proper level with the lubricant specified by the manufacturer.

11.1.6 Fuel System

Fill the fuel tank with the fuel specified. Refer to Section 5.1.

If the unit is equipped with a fuel valve, it must be opened. To ensure prompt starting, the fuel system between the pump and fuel return line must be full of 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. Before priming the fuel system, remove and fill both fuel filters with clean fuel oil and reinstall them.

NOTE:
The engine 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.

11.1.7 Drive Belts

Adjust all drive belts as recommended. Refer to Section 13.5.7.

11.1.8 Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of silicone spray or petroleum jelly and the electrolyte must be at the proper level.

A hydrometer reading (corrected for the temperature of the electrolyte) should be 1.265 or higher. If necessary, charge the battery.

11.1.9 Clutch

Disengage the clutch, if the unit is so equipped.

11.2 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 Maintenance-All Applications." Refer to Section 13.2.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

Start an engine equipped with an electric starting motor as follows:

1. Turn the ignition switch to the "ON" position. The yellow check engine and red stop engine lights should both light up. After 6-10 seconds both lights should go out. If both lights fail to go out, refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497 Basic Knowledge Required.

NOTICE:

To prevent serious damage to the cranking motor, if the engine does not start, do not press the starting switch again while the cranking motor is spinning.

2. If the check engine and stop engine lights both go out, press the starting motor switch firmly. If the engine fails to start within 15 seconds, release the starting switch and allow the starting motor to cool for 15 seconds before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

11.3 RUNNING

The following sections cover normal operations.

11.3.1 Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, or the stop engine light (red) comes on, stop the engine and check the lubricating oil system. Refer to the *DDEC II Troubleshooting Guide,* 6SE489, or *DDEC III/IV Single ECM Troubleshooting Guide,* 6SE497 for the appropriate troubleshooting charts.

11.3.2 Warm-up

Make sure area is well-ventilated before starting the engine.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

Run the engine at idle with no-load for approximately five minutes, allowing it to warm-up before applying a load. The engine will idle at a higher speed if the oil is cold when started.

As the engine reaches operating temperature, the electronic control system of the engine will lower the idle speed if not equipped with an automatic transmission.

If the unit is operating in a closed room, start the room ventilating fan or open the windows and doors, as weather conditions permit, so ample air is available for the engine.

11.3.2.1 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.

11.3.3 Engine Temperature

Refer to Section 11.5 for normal operating temperature.

11.3.4 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 lubricating oil specified. Refer to Section 5.2.

11.3.5 Cooling System

Several types of cooling systems are used by vehicle manufacturers. Refer to vehicle owner's manual for specific instructions.

CAUTION:

To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

Remove the radiator cap slowly and check the engine coolant level. The coolant level should be within two inches of the top of the opening. If necessary, add properly inhibited coolant.

11.3.6 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.

11.3.7 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.

11.4 STOPPING

The following should be performed for NORMAL stopping:

1. Release the load and decrease the "engine speed" in the NEUTRAL position.
2. Allow the engine to run at idle with no-load for a few minutes, then turn the key switch to the "OFF" position.

The following should be performed after a NORMAL stop:

1. Fill fuel tank. A full tank will minimize condensation.
2. Check coolant level after the engine has cooled down. Add coolant, if necessary, to bring it to the proper level.
3. Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.
4. Check and, if necessary, add sufficient fluid to bring it to the proper level. Follow manufacturer's recommendations for proper levels.
5. Make a visual check for external leaks in the fuel, lubricating and cooling systems.

11.4.1 Emergency Stopping

To stop the engine, turn the key to the "OFF" position.

11.5 OPERATING CONDITIONS

The typical operating conditions for the Series 50 engine are listed in Table 11-1 and listed in Table 11-2. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Be sure that the readings represent true values and the instruments are accurate before attempting to make corrections to the engine. This data represents rated conditions. Actual data may be influenced by environmental conditions.

Parameter Limits	Operating Conditions at 2100 r/min	Operating Conditions at 1800 r/min
Lubricating oil pressure (at rated speed) -kPa (lb/in.^{2})	345 (50)	345 (50)
Minimum oil pressure for safe operation (idle) kPa (lb/in.^{2})	83 (12)	83 (12)
In gallery oil temperature, maximum - °C (°F)	110 (230)	110 (230)
Oil flow-liters/minute (gallons/minute)	109 (29)	91 (24)
Oil pan capacity: High-liters (quarts)	21 (22)	21 (22)
Oil pan capacity: Low-liters (quarts)	18 (19)	18 (19)
Total engine oil capacity (with filters)-liters (quarts)	28 (26)	28 (26)

Table 11-1 Series 50 Lubrication System Parameters

Air, Fuel and Cooling System Parameter Description	Operating Conditions at 2100 r/min	Operating Conditions at 1800 r/min
Air System		
Air Inlet restriction full load, maximum - kPa (in. H_2O):		
Dirty air cleaner	5.0 (20)	5.0 (20)
Clean air cleaner	3.0 (12)	3.0 (12)
Crankcase pressure full load, maximum-kPa (in. H_2O)	0.75 (3)	0.75 (3)
Exhaust back pressure, maximum-kPa (in. Hg):		
Full load	10.1 (3.0)	10.1 (3.0)
Maximum allowable temperature rise (ambient air to engine inlet) - °C (°F)	16.7 (30)	16.7 (30)
Maximum allowable charge air cooler pressure drop - kPa (in. Hg)	10.1 (3.0)	10.1 (3.0)
Fuel System		
Fuel pressure at secondary filter outlet - kPa (lb/in.^{2})		

Air, Fuel and Cooling System Parameter Description	Operating Conditions at 2100 r/min	Operating Conditions at 1800 r/min
Normal with 2.03 mm (0.080 in.) restriction	577 (75)	577 (75)
Minimum	345 (50)	345 (50)
Fuel spill minimum at no-load - L/min (gal/min):		
Normal with 2.03 mm (0.080 in.) restriction	4.9 (1.3)	4.1 (1.0)
Fuel pump suction at pump inlet, maximum - kPa (in. Hg):		
Clean system	20 (6)	20 (6)
Dirty system	41 (12)	41 (12)
Cooling System		
Coolant temperature normal - °C (°F)	88 (190)	88 (190)
Coolant inlet restriction, maximum - kPa (in. Hg)	0.0 (0.0)	0.0 (0.0)
Coolant flow at full load speed-L/min (gal/min)	341 (90)	276 (73)
Engine coolant capacity - liters (quarts)	17 (16)	17 (16)
Minimum pressure cap - kPa (lb/in.^{2}):	62 (9.0)	62 (9.0)
Maximum top tank temperature - °C (°F)	99 (210)	99 (210)
Minimum top tank temperature - °C (°F)	71 (160)	71 (160)
Thermostats:		
Start to open - °C (°F)	86 (186)	86 (186)
Fully open - °C (°F)	97 (207)	97 (207)

Table 11-2 Series 50 Air System, Fuel System, and Cooling System Parameters

11.6 SERIES 50G OPERATING CONDITIONS

Listed in Table 11-3 are the engine operating conditions specifications.

System	Spec
Fuel System	
Maximum Fuel Inlet Temperature - °F (°C)	140 (60)
Minimum Fuel Inlet Temperature - °F (°C)	32 (0)
Maximum Fuel Inlet Pressure to Metering Valve @ Idle - lb/in^2(kPa)	150 (1034)
Minimum Fuel Inlet Pressure to Metering Valve @ Idle - lb/in^2(kPa)	120 (827)
Fuel Filter, Primary	Coalescing, 1 micron
Fuel Filter, Secondary	Coalescing, 1 micron
Lubrication System	
Oil Pressure at Rated Speed - lb/in^2 (kPa)	50 (345)
Oil Pressure at Low Idle - lb/in^2 (kPa)	12 (83)
In Pan Oil Temperature - °F (° C)	235 (113)
Oil Pan Capacity, High Limit - qt (L)	22 (21)
Oil Pan Capacity, Low Limit - qt (L)	19 (18)
Total Engine Oil Capacity with Filters - qt (L)	28 (26)
Oil Filter, Two Full Flow - microns	28
Cooling System	
Thermostat:	
Start to Open - °F (° C)	186 (86)
Fully Open - °F (° C)	207 (97)
Maximum Water Pump Inlet Restriction - in. Hg (kPa)	0 (0)
Engine Coolant Capacity - gal (L)	17 (117)
Minimum Pressure Cap - lb/in^2 (kPa)	9 (62)
Maximum Coolant Pressure (Exclusive of Pressure Cap) - lb/in^2 (kPa)	10 (69)
Maximum Top Tank Temperature - °F (° C)	210 (99)
Minimum Top Tank Temperature - °F (° C)	160 (71)
Air System	
Maximum Ambient to Turbo Compressor Inlet Temperature Rise - °F (° C)	30 (16.7)
Maximum Air Intake Restriction:	
Dirty Air Cleaner - in. H_2O (kPa)	20 (5)
Clean Air Cleaner - in. H_2O (kPa)	12 (3)

System	Spec
Engine Manifold Pressure - in. Hg (kPa)	38.5 (130)
Maximum Charge Air Cooler System Total Pressure Drop - in. H_2O (kPa)	41 (10.2)
Maximum Ambient to Intake Manifold Temp. - °F (° C)	30.0 (16.7)
Maximum Crankcase Pressure - in. H_2O (kPa)	2 (0.5)
Exhaust System	
Exhaust Flow:	
Rated Speed - ft^3 /min (m^3 /min)	1680 (47.6)
Peak Torque Speed - ft^3 /min (m^3 /min)	1090 (30.9)
Exhaust Temperature:	
Rated Speed - °F (°C)	1110 (600)
Peak Torque Speed - °F (°C)	1065 (575)
Maximum Back Pressure - in. Hg (kPa)	2.4 (8.1)

Table 11-3 Engine Operating Conditions for the Series 50G Engine

11.7 MANIFOLD ABSOLUTE PRESSURE SENSOR (MAP SENSOR) FOR THE SERIES 50G ENGINE

Listed in Table 11-4 are the air inlet pressure diagnostic codes:

Parameter Identification Character (PID): A PID is a single byte character used in J 1587 messages to identify the data byte(s) that follow. PIDs in the range 0-127 identify single byte data, 128-191 identify double byte data, and 192-253 identify data of varying length.

Failure Mode Identifier (FMI): The FMI describes the type of failure detected in the subsystem and identified by the PID. The FMI and the PID combine to form a given diagnostic code defined in J 1587 within PID 194.

DDR Description	Voltage	PID	FMI	Information
AIR INLET PRESSURE	HIGH	106	0	Indicates that the Manifold Absolute Pressure Sensor (MAP) has detected that engine intake manifold pressure has exceeded the recommended operating range.
AIR INLET PRESSURE	HIGH	106	3	Indicates that the Manifold Absolute Pressure Sensor (MAP) input to the ECM has exceeded 95% (normally >4.75 volts) of the sensor supply voltage. This diagnostic condition is typically detected when there is an open sensor return circuit or the sensor signal circuit is shorted to the sensor +5 volt supply.
AIR INLET PRESSURE	LOW	106	4	Indicated that the Manifold Absolute Pressure Sensor (MAP) input to the ECM has dropped below 5% (normally, 0.25 volts) of the sensor supply voltage. This diagnostic condition is typically: - An open sensor signal circuit- An open sensor signal circuit opens sensor +5 volt supply circuit- The sensor signal is shorted to the sensor return circuit or ground- The sensors +5 volt supply is shorted to sensor return circuit or to ground

Table 11-4 Air Inlet Pressure Diagnostic Codes for the Series 50G Engine

Listed in Table 11-5 are the throttle control specifications:

DDR Description	Circuit	SID	FMI	Information
Unrecognized SID or OIL PRS LOW*	OPEN	51	3	Indicates that the Throttle Power function that has been assigned to the ECM Auxiliary Output #3 circuit (S3) is open or is shorted to battery (+). This diagnostic condition is detected when the Throttle Power driver is OFF and the DDEC III ECM measures a high voltage on the circuit output.
Unrecognized SID or OIL PRS LOW*	SHORT TO GROUND	51	4	Indicates that the Throttle Power function that has been assigned to the ECM Auxiliary Output #3 circuit (S3) is shorted to ground. This diagnostic condition is detected when the DDEC III ECM is unsuccessful in turning ON the Throttle Power driver output. The Throttle Power output is a high side driver, which means that the DDEC III ECM supplies battery (+) to the throttle power circuit to turn ON the function.
Unrecognized SID or OIL PRS LOW*	OPEN	52	3	Indicates that the Throttle Power function that has been assigned to the ECM Auxiliary Output #4 circuit (T3) is open or is shorted to battery (+). This diagnostic condition is detected when the Throttle Power driver is OFF and the DDEC III ECM measures a high voltage on the circuit output.
Unrecognized SID or OIL PRS LOW*	SHORT TO GROUND	52	4	Indicates that the Throttle Power function that has been assigned to the ECM Auxiliary Output #4 circuit (T3) is shorted to ground. This diagnostic condition is detected when the DDEC III ECM is unsuccessful in turning ON the Throttle Power driver output. The Throttle Power output is a high side driver, which means that the DDEC III ECM supplies battery (+) to the throttle power circuit to turn ON the function.
PWM DRIVER #2	SHORT TO BATTERY (+)	58	3	Indicates that the PWM DRIVER #2 circuit (Y1) output is shorted to battery (+). This diagnostic condition is detected when the DDEC III ECM is unsuccessful in turning ON the circuit function. NOTE: The DDEC III ECM supplies a switched ground to the PWM DRIVER #2 circuit to turn ON the circuit function.
PWM DRIVER #2	OPEN	58	4	Indicates that the PWM DRIVER #2 circuit (Y1) output is open or is shorted to ground. This diagnostic condition is detected when the PWM DRIVER #2 function is OFF and the DDEC III ECM measures a low voltage on the circuit output.

* All version 1.00 or version 2.00 Prolink 9000 DDR software occurred prior to assignment of natural gas engine throttle control diagnostics. As a result, the DDR, depending upon the version software installed, will display either of the following descriptions when diagnosing natural gas throttle position codes: "Unrecognized SID" or "OIL PRS LOW." Both descriptions are incorrect.

Table 11-5 Throttle Control Specifications for the Series 50G Engine

Listed in Table 11-6 are the throttle control diagnostic codes:

DDR Description	Voltage	PID	FMI	Information
THROTTLE PLATE POS	HIGH	51	3	Indicates that the Throttle Plate Position Sensor input to the ECM has exceeded 95% (normally >4.75 volts) of the sensor supply voltage. This diagnostic condition is typically detected when there is an open sensor return circuit or the sensor signal circuit is shorted to the sensor +5 volt supply.
THROTTLE PLATE POS	LOW	51	4	Indicates that the Throttle Plate Position Sensor input to the ECM has dropped below 5% (normally < 0.25 volts) of the sensor supply voltage. This diagnostic is typically detected when there is: - An open sensor signal circuit- An open sensor +5 volt supply circuit- The sensor signal is shorted to the sensor return circuit or to ground
THROTTLE PLATE POS	HIGH	51	0	Indicates that the Throttle Plate Position Sensor input to the ECM has indicated that the throttle plate has exceeded the recommended operating range.
THROTTLE PLATE POS	LOW	51	1	Indicates that the Throttle Plate Position Sensor input to the ECM has indicated that the throttle plate has dropped below the recommended operating range.

Table 11-6 Throttle Control Diagnostic Codes for the Series 50G Engine

Listed in Table 11-7 are the knock sensor and knock interface module diagnostic codes:

DDR Description	Voltage	PID	FMI	Information
Unrecognized SID	HIGH	67	3	Indicates that the knock sensor input to the ECM has exceeded 95% (normally >4.75 volts) of the sensor supply voltage. This diagnostic is typically detected when there is an open sensor return circuit or the sensor signal circuit is shorted to the sensor +5 volt supply.
Unrecognized SID	LOW	67	4	Indicates that the knock sensor input to the ECM has dropped below 5% (normal < 0.25 volts) of the sensor supply voltage. This diagnostic is typically detected when there is: - An open sensor signal circuit- An open sensor +5 volt supply circuit- The sensor signal is shorted to the sensor return circuit or to ground- The sensor +5 volt supply is shorted to sensor return circuit or to ground
Unrecognized SID	HIGH	67	0	Indicates that the knock interface module has detected that the engine knock level has exceeded the first level of the recommended engine operational level.
Unrecognized SID	MECHAN-ICAL FAULT	67	7	Indicates that the knock interface module has detected that the engine knock level has exceeded the second level of the recommended engine operational range.

Table 11-7 Knock Sensors and Knock Interface Module Diagnostic Codes for the Series 50G Engine

The GFI monitor screen for the Series 50G engine is graphically illustrated; see Figure 11-1.

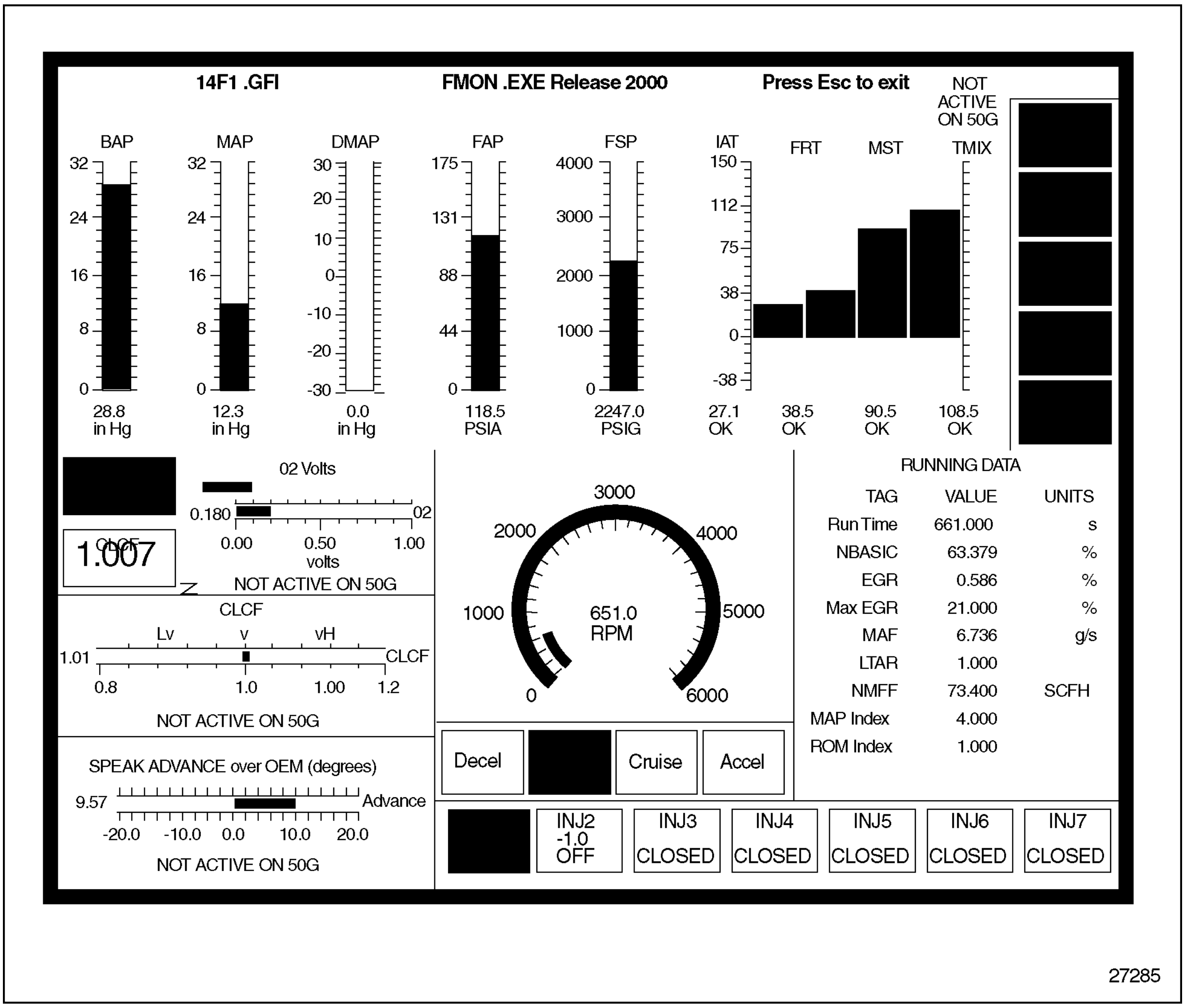


Figure 11-1 GFI Monitor Screen for Series 50G Engine

11.8 ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair that uses replacement piston rings, pistons, or bearings, for example, 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 to determine if the engine will perform to published specifications and to permit a physical inspection for leaks of any kind. It is an excellent method for 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.

NOTICE:
Thermostats are required to control the coolant flow and to help maintain a constant engine temperature. Therefore, be sure that they are in place and fully operative or the engine may overheat during the run-in. Furthermore, a deaeration line must be installed in the uppermost portion of the engine to prevent any overheat problems during 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 5.6°C (10°F) higher than the water inlet temperature. A 5.6°C (10°F) rise across an engine is recommended; however, an 8.3°C (15°F) temperature rise maximum is permitted.

11.8.1 The Basic Engine

A basic engine includes only those components actually necessary 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 Engine Run-In Check. The fan and battery-charging alternator typify accessories not considered on the basic engine.

Since the DDEC system requires a source of electrical power to operate the Electronic Unit Injectors, all DDEC equipment should be connected and operating properly. In addition, a fully charged battery must be connected to the system. Refer to OEM guidelines.

In situations where other than basic engine equipment is used during the test, a proper record of this fact should be made on the Engine Test Report. The effects of additional equipment on engine performance should then be considered when evaluating test results.

11.8.2 Dynamometer Test and Run-in Procedure

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, provisions for engine mounting, the absorption unit, a heat exchanger, and a torque loading and measuring device.

For accurate dynamometer readings during a Series 50 engine run-in, the chassis dynamometer room *must* be properly ventilated. See Figure 11-2.

WARNING:

PERSONAL INJURY

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

40527

Figure 11-2 California Proposition 65 Warning

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb ·ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula, see Figure 11-3.

$$BHP = \frac{T_1 \times RPM}{5250} \qquad kW = \frac{T_2 \times RPM}{9429}$$

WHERE;

BHP	=	BRAKE HORSEPOWER, hp
kW	=	POWER, kW
T_1	=	TORQUE, ft·lb
T_2	=	TORQUE, N·m
RPM	=	ENGINE SPEED, r/min
5250	=	DYNAMOMETER CONSTANT
9429	=	DYNAMOMETER CONSTANT

21483

Figure 11-3 Formulas for Power Developed in the Engine

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 Figure 11-4.

SERIES 50 ENGINE TEST REPORT

Date: ____________________ Unit Number: ____________________
Repair Order Number: ____________________ Model Number: ____________________
PROM I.D.: ____________________ Max. N/L RPM: ____________________
Rated F/L RPM: ____________________
Idle RPM: ____________________

A. PRESTART

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL OIL SYSTEM	3. FILL COOLING SYSTEM

B. START UP AND IDLE FOR 30 SECONDS

START__________ STOP __________ OIL PRESSURE __________ WATER TEMPERATURE __________

C. WARM UP — 5 MINUTES **START** __________ **STOP** __________

RPM MAX. SPEED	LOAD 50%	OIL PRESSURE	WATER TEMPERATURE
1. LUBE OIL LEAKS	2. FUEL OIL LEAKS	3. COOLANT LEAKS	4. LOOSE BOLTS

D. RUN IN — 5 MINUTES **START** __________ **STOP** __________

RPM MAX. SPEED	LOAD 75%	OIL PRESSURE	WATER TEMPERATURE

E. FINAL RUN IN — 20 MINUTES **START** __________ **STOP** __________

RPM MAX. SPEED	LOAD 100%	CRANKCASE PRESSURE AT F/L	EXHAUST BACK PRESSURE AT F/L
LUBE OIL PRESS. AT F/L	LUBE OIL TEMP. AT F/L	FUEL OIL TEMP. AT F/L	FUEL OIL PRESSURE AT F/L
WATER TEMP. AT F/L	TURBO BOOST PRESS. AT F/L	LUBE OIL PRESSURE AT IDLE	IDLE RPM

REMARKS:

OK __________ Reject __________ Dynamometer Operator __________ Date __________

24336

Figure 11-4 Series 50 Engine Test Report Form

11.8.2.1 Instrumentation

Certain instrumentation is necessary so that data required to complete the Engine Test Report may be obtained. The following list contains 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.

- ☐ Oil pressure gage installed in one of the engine main oil galleries (DDEC data can also be used)
- ☐ Water temperature gage installed in the thermostat housing or water outlet manifold
- ☐ Adaptor for connecting a pressure gage or water manometer to the crankcase
- ☐ Fuel pressure gage at the rear of the cylinder head

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in lb/in.^{2}, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Gage reading = (lb/in.^{2}) x 27.7 = inches of water

Gage reading = (lb/in.^{2}) x 2.04 = inches of mercury

NOTICE:
Before starting the run-in or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions; see " Preparation for a First Time Start:" refer to Section 11.1. Failure to follow instructions could result in engine damage.

11.8.2.2 Run-in Procedure

Use the following procedure for preparation of engine run-in. See Figure 11-4 part A.

1. Fill and prime the lubrication system as outlined under Lubrication System, "Preparation for a First Time Start." Refer to Section 11.1.
2. Prime the fuel system as outlined under Fuel System, "Preparation for a First Time Start." Refer to Section 11.1.
3. Make a preliminary valve clearance adjustment before the engine is started. Refer to Section 12.2.
4. Make a preliminary injector timing check before starting the engine. Refer to Section 12.2.
5. Be sure that the turbocharger has been prelubricated by adding oil to the turbocharger oil inlet or by pressurizing the lubrication system.
6. Check to be sure all test stand water valves, fuel valves, etc. are open.
7. Inspect the exhaust system, checking that it is properly connected to the engine.

Use the following procedures for engine run-in:

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine with minimum dynamometer resistance.

NOTICE:

All Series 50 engines should be operated at idle for at least one minute after starting to assure oil supply and pressure to the turbocharger bearings. Inadequate lubrication will result in bearing damage.

2. Set the engine throttle at idle speed; idle for 30 seconds. Record oil pressure and water temperature values on the engine Test Report; see Figure 11-4, Part B. Check all connections to be sure there are no leaks.
3. The Engine Test Report sample, see Figure 11-4, establishes the sequence of events and specifications for the test and run-in. Also, refer to Section 11.5 for *"Operating Conditions",* which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power. 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 Warm-Up - 5 minutes; see Figure 11-4, Part C. Complete leak information.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Run the engine at this speed and load for 5 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length start and stop times, speed, brake horsepower, coolant temperature and lubricating oil pressure on the Engine Test Report; see Figure 11-4, Part D.
5. Run the engine at each speed and rating for the length of time indicated in the Engine Run-In Schedule. During this time, engine performance will improve as new parts begin to seat in.
6. Inspect the engine for fuel oil, lubricating oil and water leaks.
7. Upon completion of the run-in and inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.
8. Record all data requested; see Figure 11-4, Part E.

NOTE:
Allow the engine to idle at least 3 minutes in order for the turbocharger to cool and reduce speed before shutdown.

After all of the tests have been made and the Engine Test Report is completed, see Figure 11-4, Part D., the engine is ready for final test, see Figure 11-4, Part E. 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 five minutes at the same speed and load used for warm-up. If piston rings or bearings have been replaced as a result of problems during the warm-up, the entire run-in must be repeated as though the test and run-in procedure were started anew.

All readings observed during the final run-in should fall within the range specified in the "Operating Conditions", refer to Section 11.5, 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 run-in at full load. It should be recorded and should be within the specified range.
- The lubricating oil pressure should be recorded in kPa or lb/in.^{2} after being taken at engine speeds indicated in the " Operating Conditions," refer to Section 11.5.

☐ Check the crankcase pressure, refer to Section 29.3, while the engine is operating at maximum run-in speed. Attach a manometer to the oil dipstick opening; refer to Section 29.1, calibrated to read inches of water.

The following steps are necessary to complete the final Engine Repair Schedule.

1. Determine the maximum rated brake horsepower and the full-load speed to be used during the final run-in.
2. Apply this load to the dynamometer.
3. The engine should be run at this speed and load for five minutes.

NOTE:
While making the final run-in, the engine should develop 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.

4. All information, see Figure 11-4, Part E, should be recorded.
5. 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.
6. A final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system, (refer to Section 13.5.2) and adding a rust inhibitor to the cooling system (refer to Section 13.5.4).
7. Change the lubricating oil filters.

12 ENGINE TUNE-UP

Section **Page**

12.1 ENGINE TUNE-UP PROCEDURES

The Series 50 engine is equipped with Detroit Diesel Electronic Control system (DDEC). Since DDEC replaces any mechanical governing devices, and the fuel injectors are electronically controlled, it is unnecessary to perform engine speed adjustments.

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

NOTICE:

To prevent possible damage, do not perform engine tune-up procedures or engine repair without first disconnecting the engine cranking motor and/or batteries.

The turbocharger compressor inlet shield, J 26554-A, must be used anytime the engine is operated with the air inlet piping removed. See Figure 12-1.

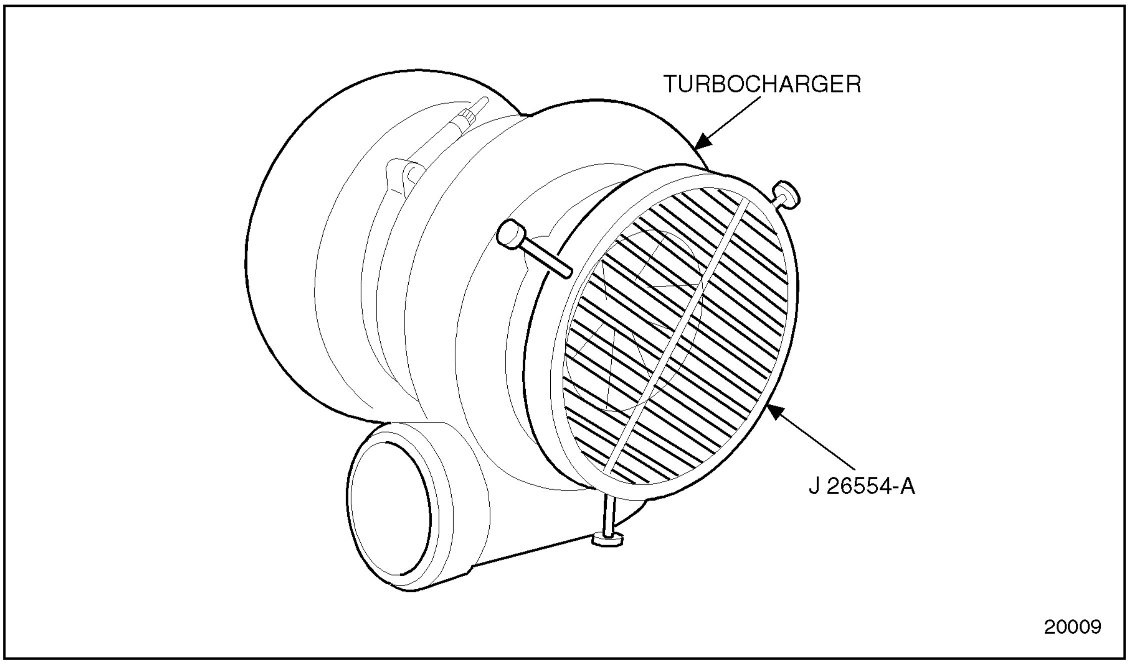


Figure 12-1 Turbocharger Compressor Inlet Shield

The shield helps prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the impeller.

The tune-up procedure for the Series 50 engine consists of intake and exhaust valve clearance adjustments, fuel injector height adjustments, and Jake Brake ® lash adjustments. These adjustments should be made with the engine cold. Refer to Section 12.2.

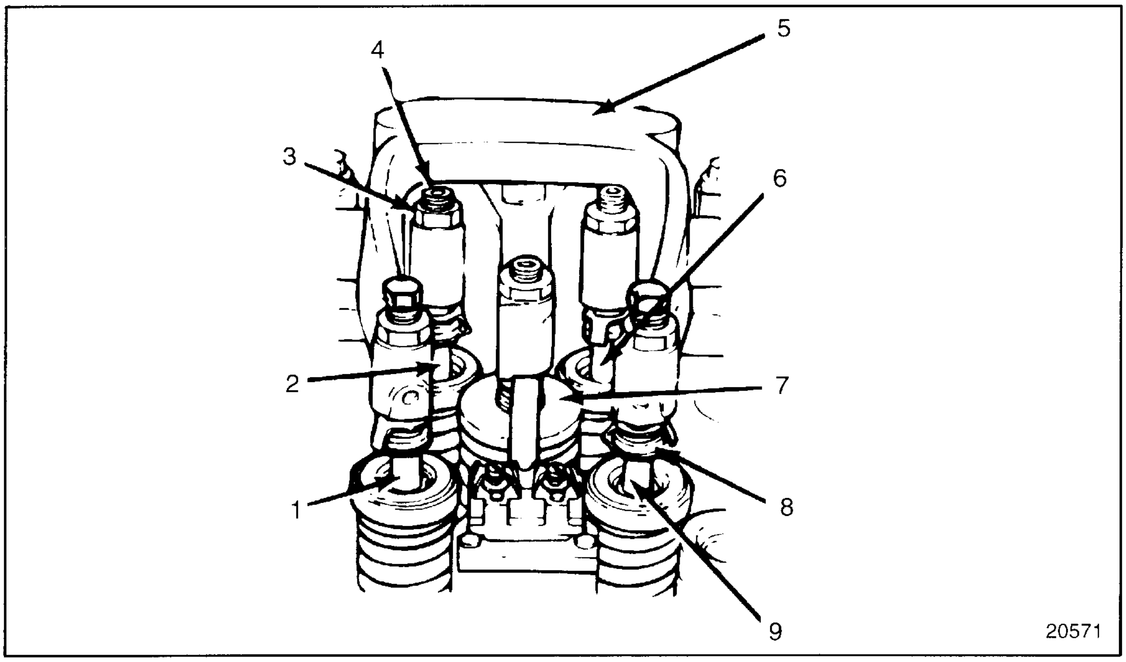
12.2 VALVE LASH, INJECTOR HEIGHT (TIMING) AND JAKE BRAKE ® LASH ADJUSTMENTS

Accurate adjustment of clearance between valve buttons, intake and exhaust valves is important if maximum performance and economy are to be obtained.

Likewise, injector height should be properly maintained.

Intake valve clearance and injector height are adjusted by means of an adjusting set screw and locknut located at the valve (or injector) end of the rocker arm; see Figure 12-2.

NOTE:
On engines equipped with a Jake Brake, measure valve lash and injector height before removing any brake housings. Only remove the brake housings necessary to provide access for adjustment.



1. Exhaust Valve
2. Intake Valve
3. Locknut
4. Adjusting Set Screw
5. Exhaust Rocker Arm Assembly
6. Intake Valve
7. Fuel Injector Follower
8. Valve Button
9. Exhaust Valve

Figure 12-2 Valve and Fuel Injector Rocker Arm Assembly Components

NOTICE:

Ensure the height gage seats on the machined surface with the tip in the pilot hole. Foreign material in the pilot hole or on the machined surface may prevent accurate setting of the injector height.

The fuel injector height is adjusted using the injector height gage, as listed in Table 12-1. On engines equipped with a Jake Brake®, move the handle on the injector height gage to the alternate position, 90° to the shank. A height gage pilot hole is provided in the injector body on the machined surface contacted by the injector clamp near the solenoid. See Figure 12-3.

Component	Setting Dimensions	Tolerance
Fuel Injector Height: DDEC II Models 6047 GUXX	78.2 mm (3.078 in.) Use tool J 35637-A	77.95-78.45 mm (3.068-3.088 in.)
Fuel Injector Height: DDEC III Models 6047 GKXX	78.8 mm (3.103 in.) Use tool J 39697	77.55-79.05 mm (3.053-3.112 in.)
Fuel Injector Height: DDEC IV Model: 6047TKXX	80.3 mm (3.161 in.) Use tool J 42665	80.05-80.55 mm (3.151-3.171 in.)
Fuel Injector Height: DDEC IV Model: 6047MKXX	81.0 mm (3.190 in.)	
Intake Valve Clearance	0.203 mm (0.008 in.)	0.127-0.280 mm (0.005-0.011 in.)
Intake Valve Clearance Natural Gas Models 604XGKGX	0.279 mm (0.011 in.)	0.203-0.356 mm (0.008-0.014 in.)
Intake Valve Clearance Model 604XMKGX	0.267 mm (0.010 in.)	0.253 -0.281 mm (0.009.-0.011 in.)
Exhaust Valve Clearance*-"U" Valves Models 604XGUXX	0.508 mm (0.020 in.)	0.432-0.584 mm (0.017-0.023 in.)
Exhaust Valve Clearance*-"H" Valves Models 604XGKXX	0.660 mm (0.026)	0.584-0.736 mm (0.023-0.029 in.)
Exhaust Valve Clearance*-"J" All Natural Gas Models 604XXXGX	0.914 mm (0.036 in.)	-
Exhaust Valve Clearance **_Nickel-Alloy Valves Models 604XMKXX, 604XTKXX	0.508 mm (0.020 in.)	0.432-0.584 mm (0.017-0.023 in.)

XX Any characters in these positions set to the adjacent column.

* "U", "H", and "J" valves have the letter designation stamped in the recess of the valve head. "H" and "J" valves also have a machined identification ring above the valve lock groove. "U" valves do not.

** After engine serial number 4R37769 the valve is identified by the raised bump in the center of the recess on the combustion face, the deletion of the machined identification ring above the keeper groove and the part number.

Table 12-1 Valve Clearance and Injector Height Settings

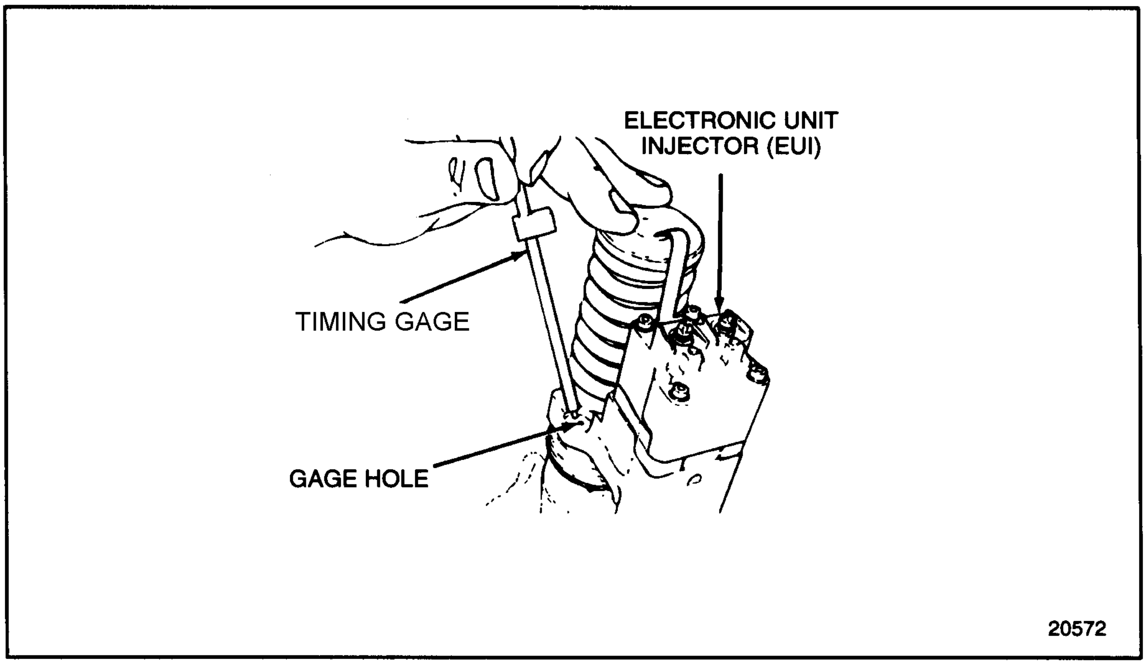
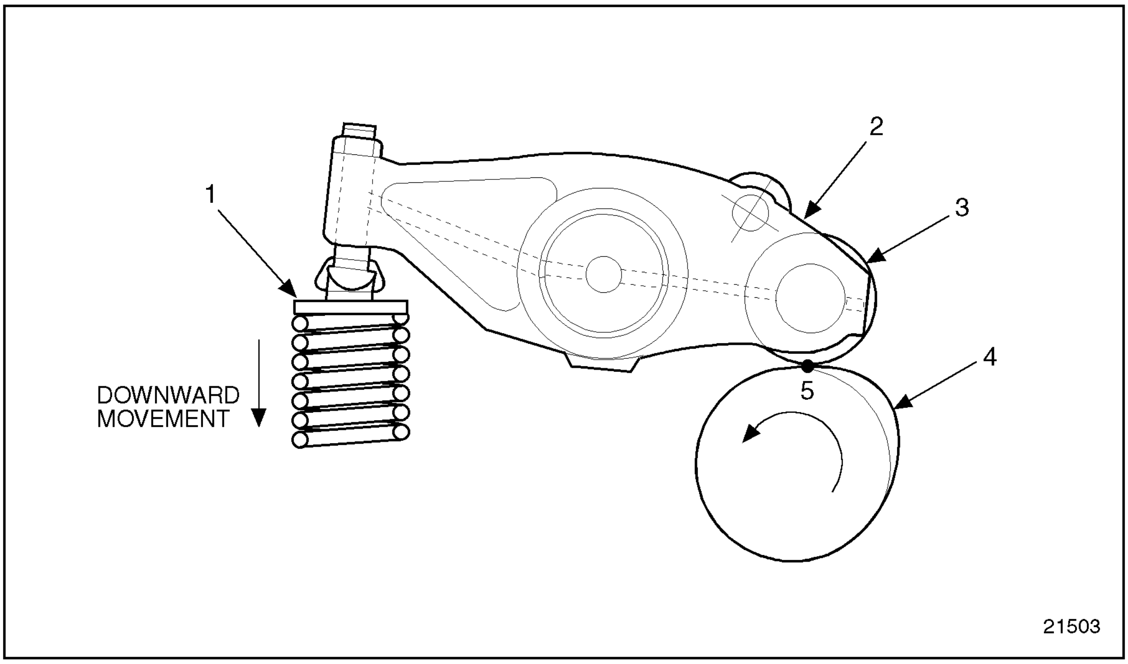


Figure 12-3 Timing Gage

To determine if improper valve clearance, injector height or both are causing the cylinder to misfire, perform the following preliminary step 1through step 3and repeat step 4 through step 12 for each cylinder to determine if worn or damaged lobes or rollers are causing the engine to misfire:

1. Disconnect starting power for engine.
2. Remove the engine valve rocker cover. Refer to Section 1.6.2. .
3. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley.

4. Bar the engine over. Stop engine rotation when any one of the injector followers has just begun its downward stroke; see Figure 12-4.



1. Injector Follower
2. Injector Rocker Arm Assembly
3. Injector Roller
4. Injector Cam Lobe
5. Point on the Camshaft Lobe that first produces downward motion of the injector follower

Figure 12-4 Injector Followers Downward Stroke

5. Using the Timing Circle Chart, see Figure 12-5, locate the cylinder requiring clearance. The timing circle can be started with any cylinder. Ensure that the circle is completed to adjust all valves and injectors.

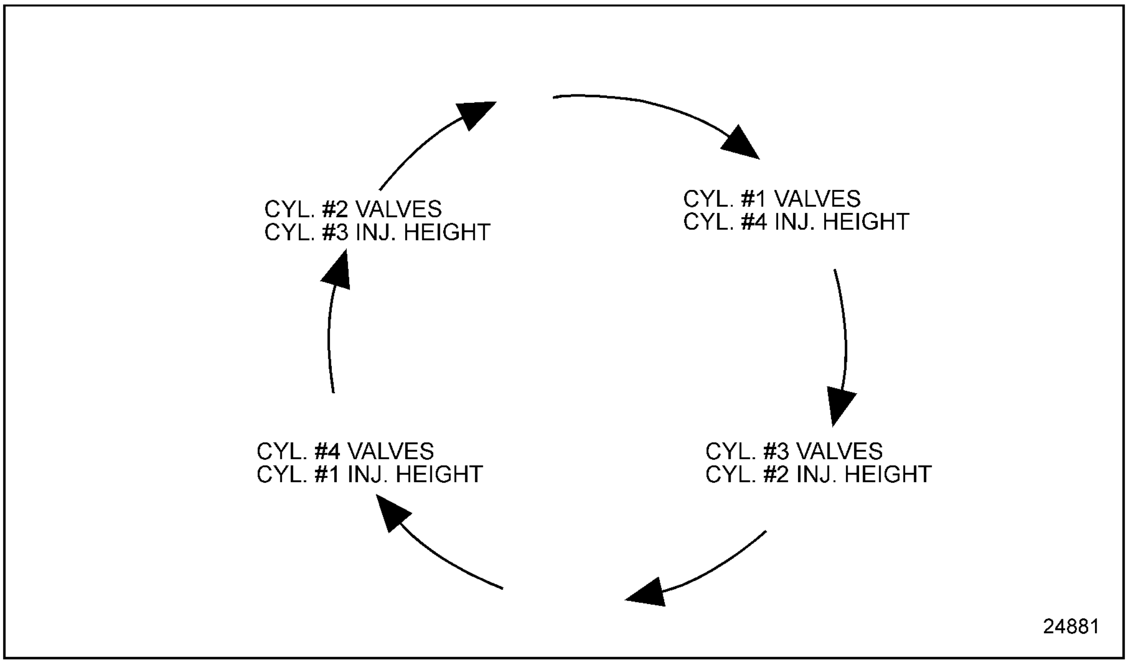
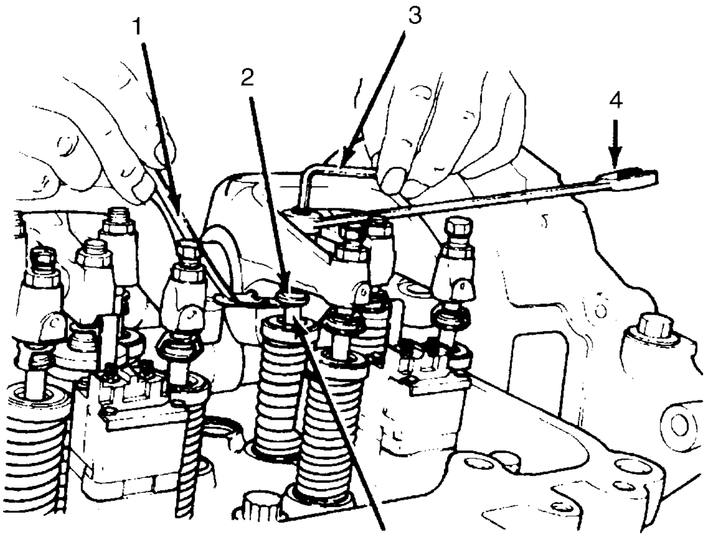


Figure 12-5 Timing Circle Chart

NOTICE:
Never set the valves and injector of the same cylinder at the same time. Doing this will result in engine damage.

6. For diesel applications adjust the intake valves, insert a feeler gage between the tip of the valve stem and the valve button at the end of the rocker arm. See Figure 12-6 and see Table 12-1.
7. For natural gas applications adjust the intake valves, insert a feeler gage between the tip of the valve stem and the valve button at the end of the rocker arm. See Table 12-1.
8. Loosen the locknut, and turn the adjusting set screw until the feeler gage produces an even smooth pull between the valve stem and valve button.



1. Feeler Gage
2. Valve Button
3. Allen Wrench (3/16 in.)
4. Wrench (9/16 in.)
5. Intake Valve Stem

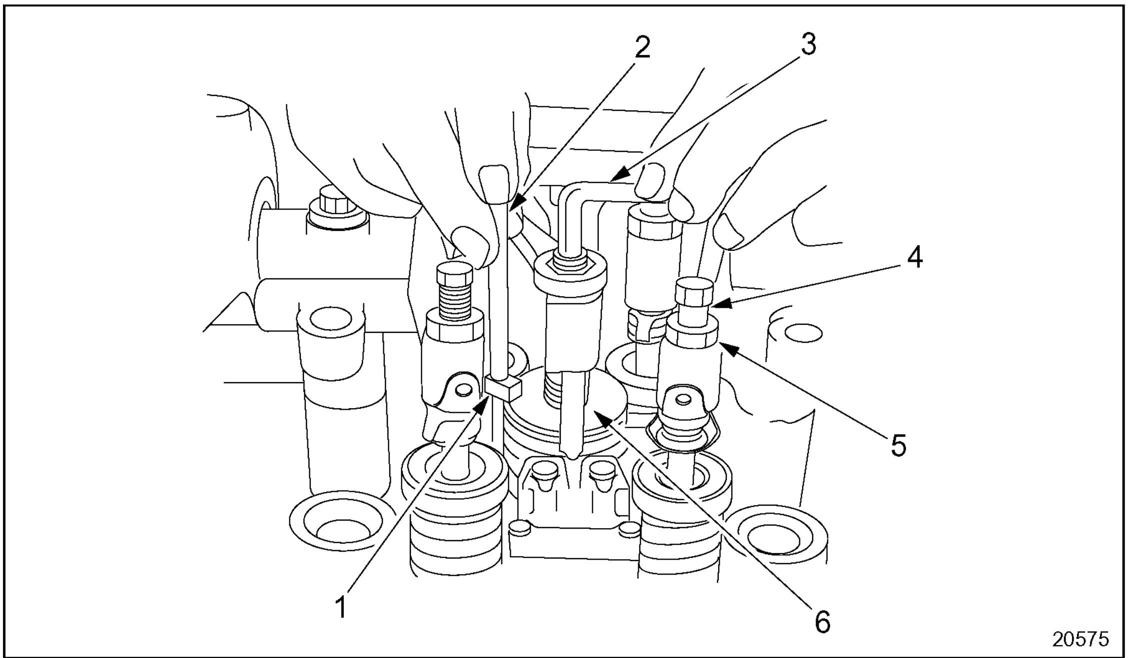
Figure 12-6 Valve Clearance Adjustment

9. Torque the locknut to 41-47 N·m (30-35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.

10. For diesel applications the exhaust valves are adjusted the same way as the intake valves. See Table 12-1. After engine serial number 4R37769 use a 0.5080 mm (0.020 in.) feeler gage. Check option label on valve cover for correct settings. It is normal for tune-up settings to vary, even when using the correct setting procedures. Some items influencing tune-up measurements are different gages, individuals and mechanical variations.

NOTE:
When setting valve lash clearance or injector height, always set them to the dimensions listed in Table 12-1.

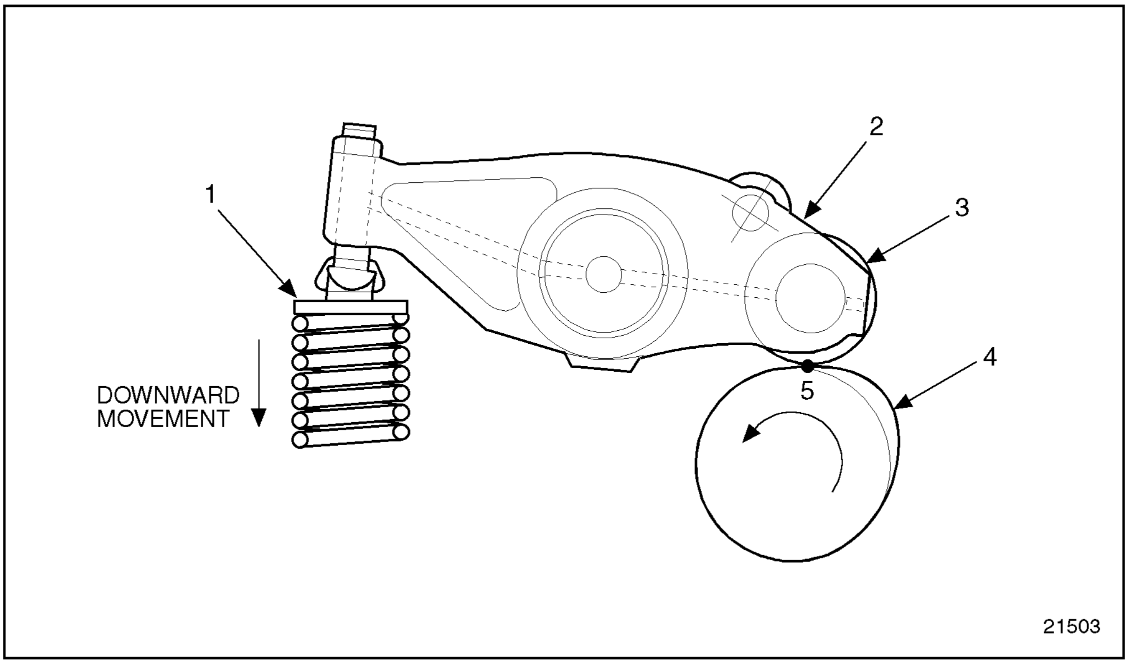
11. For natural gas applications the exhaust valves are adjusted the same way as the intake valves. See Table 12-1.
12. Complete the adjustment of all four valves (two intake, two exhaust) for that cylinder before proceeding to step 13.
13. Refer to the Timing Circle Chart and note the cylinder number in parentheses, directly under the cylinder that just received the valve lash adjustment. See Figure 12-5.
14. Adjust the fuel injector height for the cylinder indicated on the chart in parentheses, see Figure 12-5, by placing the small end of the height gage in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger. See Figure 12-7. Set injectors to the dimensions listed in Table 12-1.



1. Height Gage Flag
2. Height Gage
3. Allen Wrench (3/16 in.)
4. Set Screw
5. Locknut
6. Fuel Injector Follower

Figure 12-7 Fuel Injector Height Adjustment

15. Loosen the fuel injector rocker arm locknut and turn the adjusting set screw until the extended part (flag) of the gage will just pass over the top of the injector follower. An accurate "feel" will be developed. The objective is to adjust all four injectors to the same feel.
16. Torque the locknut to 41-47 N·m (30-35 lb·ft). Check the adjustment with the height gage and, if necessary, readjust the set screw. Remove the height gage.
17. Refer to the Timing Circle Chart. See Figure 12-5 and follow the arrow to the next cylinder in the adjustment sequence.
18. Bar the engine over in the direction of normal rotation until the injector follower of the next cylinder in the adjustment sequence begins its downward motion, see Figure 12-8.



1. Injector Follower
2. Injector Rocker Arm Assembly
3. Injector Roller
4. Injector Cam Lobe
5. Point on the Camshaft Lobe that first produces downward motion of the injector follower

Figure 12-8 Injector Followers Downward Stroke

19. Repeat the valve adjustment and fuel injector height adjustment step 5 through step 17 until all the valves and fuel injectors have been adjusted.
20. If the engine is equipped with Jake Brakes®, adjust Jake brake slave pistons. Refer to Section 1.30.5.1.
21. Replace the engine rocker cover. Refer to Section 1.6.1.
22. Reconnect starting power to the engine.

12.3 ENGINE TUNE-UP PROCEDURES FOR THE SERIES 50G ENGINE

The Series 50G is equipped with Detroit Diesel Electronic Controls (DDEC) and a Gaseous Fuel Injector (GFI) system.

CAUTION:

To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

CAUTION:

To avoid injury from contact with rotating parts when an engine is operating with the air inlet piping removed, install an air inlet screen shield over the turbocharger air inlet. The shield prevents contact with rotating parts.

The tune-up procedure for the Series 50G consists of intake and exhaust valve clearance adjustments and spark plug replacement. These procedures should be performed with the engine cold. See Figure 12-9 for the gas turbocharger compressor inlet shield.

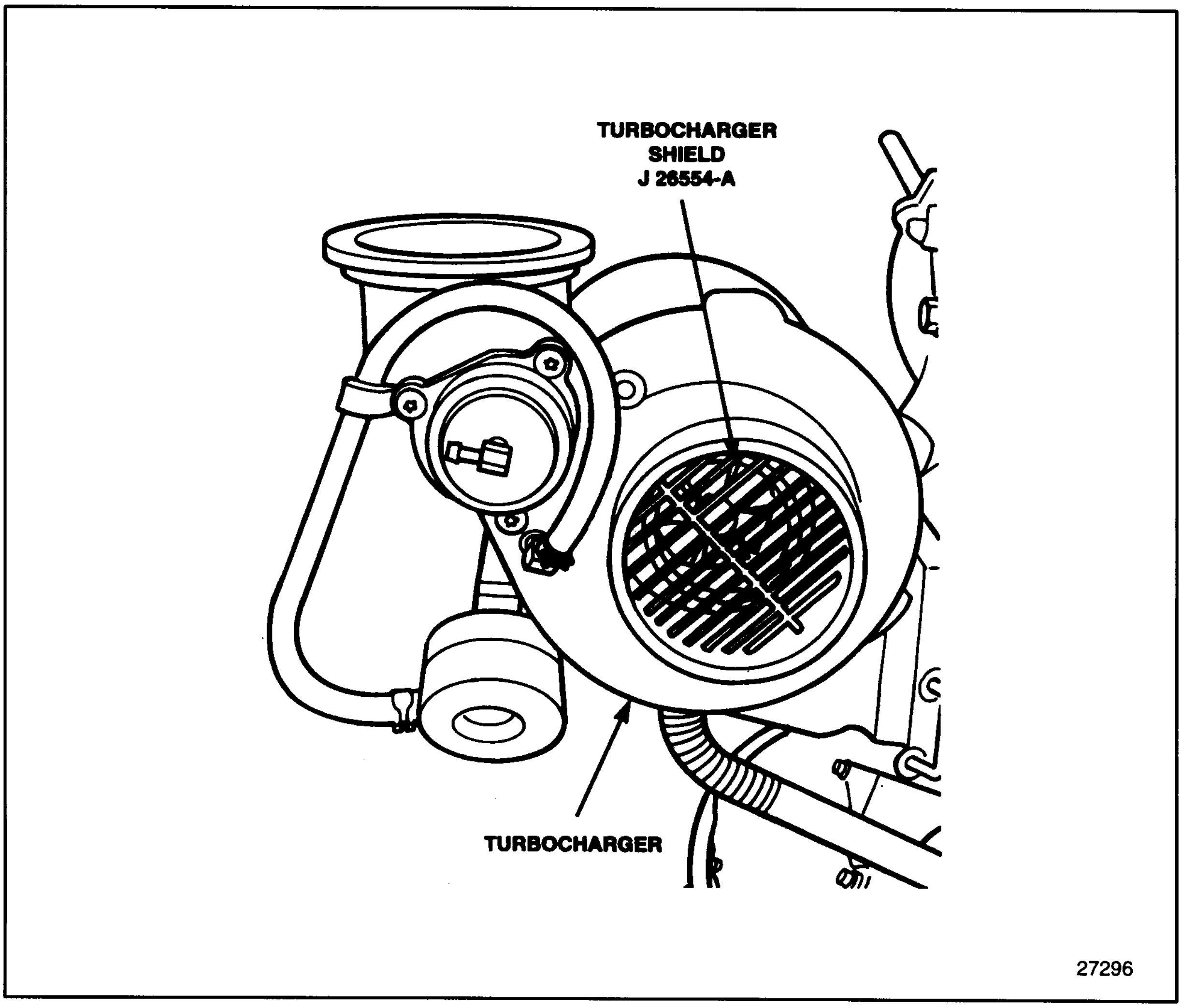


Figure 12-9 Turbocharger Compressor Inlet Shield (Series 50G)

12.4 VALVE LASH FOR THE SERIES 50G ENGINE

Accurate adjustment of the clearance between the valve buttons and the intake and exhaust valves is important if maximum performance and economy are to be obtained.

Intake and exhaust valve clearance are adjusted by an adjusting set screw and locknut located at the valve end of the rocker arm. See Figure 12-10.

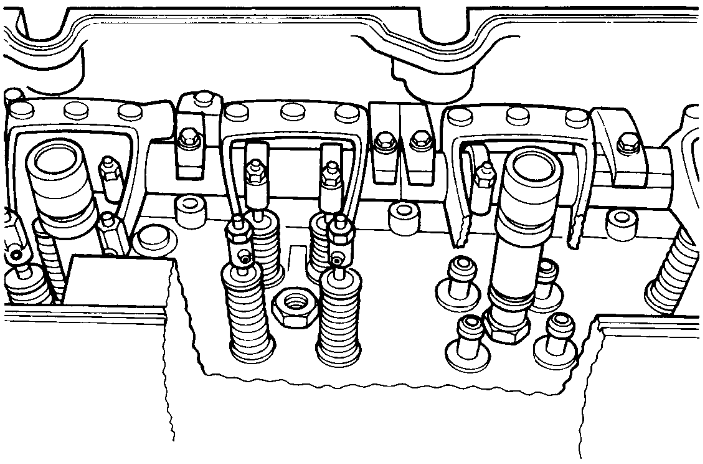


Figure 12-10 Valve and Fuel Injector Height Adjustment Components for the Series 50G Engine

Bar the engine over clockwise until one of the cylinders has the intake and exhaust cam follower rollers on the base circle of the camshaft. Adjust all four valves at this position. Continue barring the engine over until the next cylinder is in position. Follow the timing valve circle chart until all of the valves have been adjusted. See Figure 12-11.

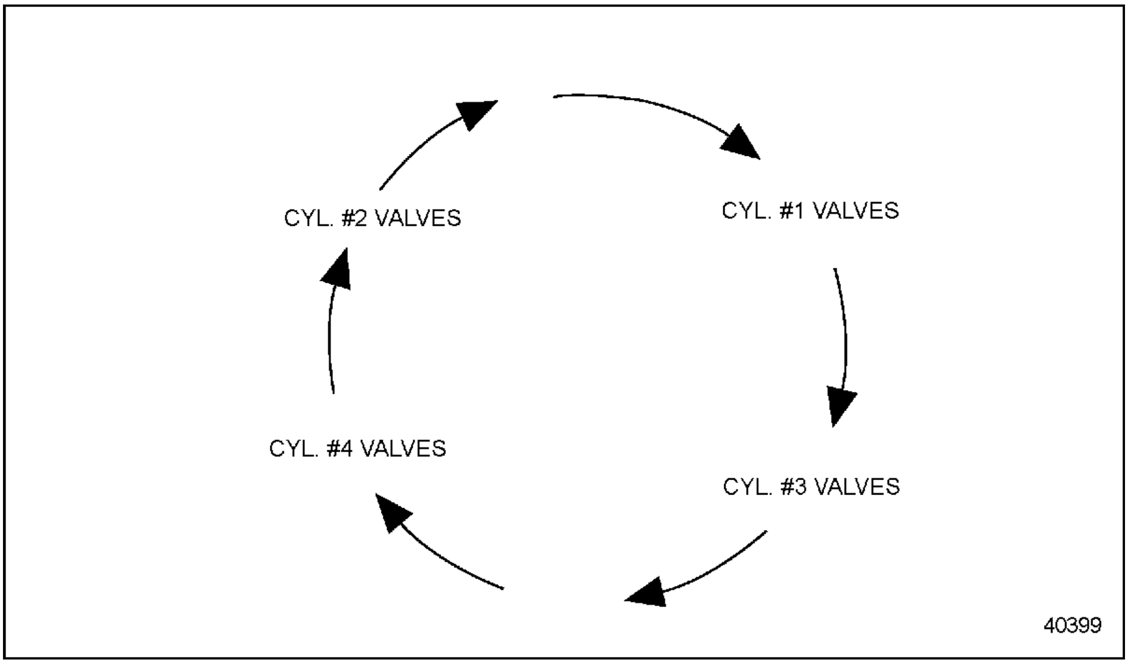


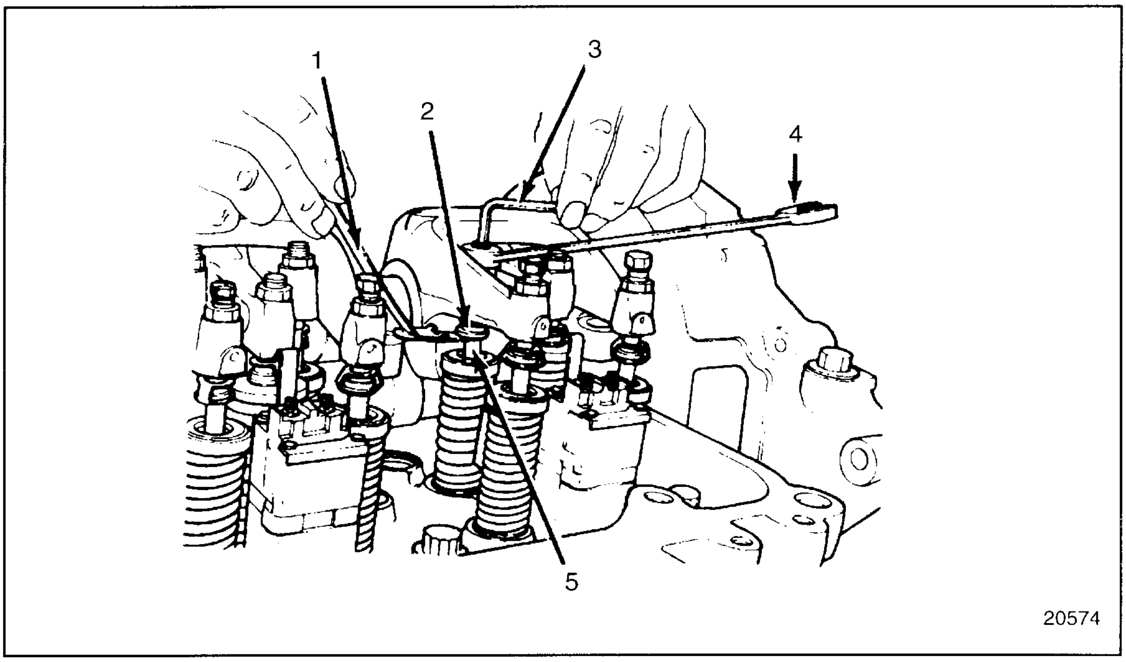
Figure 12-11 Timing Circle Chart for the Series 50G Engine

1. Disconnect starting power for engine.
2. Remove spark plug boots from the connection on the rocker cover.
3. Remove the engine valve rocker cover; refer to Section 1.6.2.
4. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley. Bar the engine over until both the intake and exhaust cam rollers are on the base circle of the camshaft. Stop engine rotation.

NOTE:
The cylinder number.

5. See Figure 12-11 and locate the cylinder. The timing circle can be started with any cylinder. Ensure the circle is completed to set all valves.

6. To adjust the intake valves, insert a feeler gage between the tip of the valve stem and the valve button at the end of the rocker arm. See Figure 12-12 and see Table 12-1



1. Feeler Gage
2. Valve Button
3. Allen Wrench (3/16 in.)
4. Wrench (9/16 in.)
5. Intake Valve Stem

Figure 12-12 Valve Clearance Adjustment Series 50G

7. Loosen the locknut, and turn the adjusting set screw until the feeler gage produces an even or smooth pull between the valve stem and the valve button.
8. Torque the locknut to 41-47 N·m (30-35 lb·ft), and remove the feeler gage. Insert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.
9. The exhaust valves are adjusted the same way as the intake valves. See Table 12-1
10. Complete the adjustment of all four valves (two intake, two exhaust) for that cylinder before proceeding to the next step.
11. See Figure 12-11 and note the cylinder number, in parentheses, directly under the cylinder that just received the valve adjustment.

13 PREVENTIVE MAINTENANCE

Section **Page**

13.1 MAINTENANCE OVERVIEW

The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from the Series 50 Engine. The intervals indicated are time or miles of actual operation.

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 a First Time Start." Refer to Section 11.1.

The daily maintenance of Series 50 engines is the same for all applications. Refer to Section 13.2. Periodic maintenance of Series 50 engines is dependent on the application. For engines installed in stationary and industrial applications, refer to Section 13.4. For engines installed in vehicles, refer to Section 13.3.

13.2 DAILY MAINTENANCE - ALL APPLICATIONS

The following items need to be inspected, serviced, corrected or replaced on a daily basis, as necessary:

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Fuel lines and flexible hoses, refer to Section 13.5.3
- ☐ Cooling system, refer to Section 13.5.4
- ☐ Turbocharger, refer to Section 13.5.5

13.3 MAINTENANCE OF VEHICLE ENGINES

Vehicle engine components must be maintained at various intervals.

13.3.1 6,000 Miles (10,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 6,000 miles (10,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.2 7,500 Miles (12,000 km) Interval Maintenance

Every 7,500 miles (12,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to Section 13.5.6
- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8

13.3.3 12,000 Miles (19,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 12,000 miles (19,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.4 15,000 Miles (24,000 km) or 6 Month Interval Maintenance

The following components must be replaced every 15,000 miles (24,000 km) or 6 months.

- ☐ Air cleaner, refer to Section 13.5.9
- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23

- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.5 18,000 Miles (29,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.6 24,000 Miles (39,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 24,000 miles (39,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.7 30,000 Miles (48,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 30,000 miles (48,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.8 30,000 Miles (48,000 km) or 12 Month Interval Maintenance

Every 30,000 miles (48,000 km) or 12 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Battery charging alternator, refer to Section 13.5.20

Likewise, the following components must be replaced every 30,000 miles (48,000 km) or 12 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.9 36,000 Miles (58,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 36,000 miles (58,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.10 42,000 Miles (68,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 42,000 miles (68,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.11 45,000 Miles (72,000 km) or 18 Month Interval Maintenance

Every 45,000 miles (72,000 km) or 18 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 45,000 miles (72,000 km) or 18 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.12 48,000 Miles (77,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 48,000 miles (77,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.13 54,000 Miles (87,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 54,000 miles (87,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.14 60,000 Miles (97,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 60,000 miles (97,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23

- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.15 60,000 Miles (97,000 km) or 24 Month Interval Maintenance

Every 60,000 miles (97,000 km) or 24 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Cooling system, refer to Section 13.5.4
- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Oil pressure, refer to Section 13.5.19
- ☐ Battery charging alternator, refer to Section 13.5.20
- ☐ Engine and transmission mounts, refer to Section 13.5.21
- ☐ Crankcase pressure, refer to Section 13.5.22
- ☐ Thermostats and seals, refer to Section 13.5.24
- ☐ Crankcase breather, refer to Section 13.5.25
- ☐ Valve lash and injector height, refer to Section 12.2

Likewise, the following components must be replaced every 60,000 miles (97,000 km) or 24 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.16 66,000 Miles (106,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 66,000 miles (106,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23

- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.17 72,000 Miles (116,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 72,000 miles (116,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.18 75,000 Miles (121,000 km) or 30 Month Interval Maintenance

Every 75,000 miles (121,000 km) or 30 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 75,000 miles (121,000 km) or 30 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.19 78,000 Miles (126,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 78,000 miles (126,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.20 84,000 Miles (135,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 84,000 miles (135,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.21 90,000 Miles (145,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 90,000 miles (145,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Alternator and attaching hardware, refer to section 13.5.28
- ☐ Air conditioning and attaching hardware, refer to section 13.5.29
- ☐ Air compressor and attaching hardware, refer to section 13.5.30

13.3.22 90,000 Miles (145,000 km) or 36 Month Interval Maintenance

Every 90,000 miles (145,000 km) or 36 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Battery charging alternator, refer to Section 13.5.20
- ☐ Alternator and attaching hardware, refer to section 13.5.28
- ☐ Air conditioning and attaching hardware, refer to section 13.5.29
- ☐ Air compressor and attaching hardware, refer to section 13.5.30

Likewise, the following components must be replaced every 90,000 miles (145,000 km) or 36 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.23 96,000 Miles (154,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 96,000 miles (154,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.24 102,000 Miles (164,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 102,000 miles (164,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.25 105,000 Miles (169,000 km) or 42 Month Interval Maintenance

Every 105,000 miles (169,000 km) or 42 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 105,000 miles (169,000 km) or 42 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.26 108,000 Miles (174,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 108,000 miles (174,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.27 114,000 Miles (183,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 114,000 miles (183,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.28 120,000 Miles (193,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 120,000 miles (193,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.29 120,000 Miles (193,000 km) or 48 Month Interval Maintenance

Every 120,000 miles (193,000 km) or 48 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Cooling system, refer to Section 13.5.4
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Oil pressure, refer to Section 13.5.19
- ☐ Battery charging alternator, refer to Section 13.5.20
- ☐ Engine and transmission mounts, refer to Section 13.5.21
- ☐ Crankcase pressure, refer to Section 13.5.22
- ☐ Thermostats and seals, refer to Section 13.5.24
- ☐ Crankcase breather, refer to Section 13.5.25

Likewise, the following components must be replaced every 120,000 miles (193,000 km) or 48 months.

- ☐ Drive belts, refer to Section 13.5.7
- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10

- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.30 126,000 Miles (203,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 126,000 miles (203,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.31 132,000 Miles (212,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 132,000 miles (212,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.32 135,000 Miles (217,000 km) or 54 Month Interval Maintenance

Every 135,000 miles (217,000 km) or 54 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 135,000 miles (217,000 km) or 54 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11

- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.33 138,000 Miles (222,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 138,000 miles (222,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.34 144,000 Miles (232,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 144,000 miles (232,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.35 150,000 Miles (241,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

Every 150,000 miles (241,000 km), the following components must be lubricated;

- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.3.36 150,000 Miles (241,000 km) or 60 Month Interval Maintenance

Every 150,000 miles (241,000 km) or 60 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Drive belts, refer to Section 13.5.7
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Battery charging alternator, refer to Section 13.5.20

Likewise, the following components must be replaced every 150,000 miles (241,000 km) or 60 months.

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12
- ☐ Fan hub bearings, refer to Section 13.5.23
- ☐ Idler pulley bearings, refer to Section 13.5.23

NOTE:
If grease fittings are installed on the fan hub and the idler pulley support, the fan hub bearings and fan belt idler pulley bearings **must** be lubricated.

13.4 MAINTENANCE OF ENGINES USED IN STATIONARY AND INDUSTRIAL APPLICATIONS

Engine components used in stationary and industrial applications must be maintained at various intervals.

13.4.1 100 Hours (3,000 miles-4,800 km) Maintenance

Every 100 hours (3,000 miles-4,800 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to Section 13.5.6
- ☐ Drive belts, refer to Section 13.5.7

13.4.2 150 Hours (4,500 miles-7,200 km) Maintenance

Every 150 hours (4,500 miles-7,200 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air cleaner, refer to Section 13.5.9

Likewise, the following components must be replaced every 150 hours (4,500 miles-7,200 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.3 300 Hours (9,000 miles-14,500 km) Maintenance

Every 300 hours (9,000 miles-14,500 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Battery charging alternator, refer to Section 13.5.20

Likewise, the following components must be replaced every 300 hours (9,000 miles-14,500 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.4 450 Hours (13,500 miles-21,700 km) Maintenance

Every 450 hours (13,500 miles-21,700 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 450 hours (13,500 miles-21,700 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.5 600 Hours (18,000 miles-29,000 km) Maintenance

Every 600 hours (18,000 miles-29,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Oil pressure, refer to Section 13.5.19
- ☐ Battery charging alternator, refer to Section 13.5.20
- ☐ Engine and transmission mounts, refer to Section 13.5.21
- ☐ Crankcase pressure, refer to Section 13.5.22
- ☐ Thermostats and seals, refer to Section 13.5.24
- ☐ Crankcase breather, refer to Section 13.5.25

Likewise, the following components must be replaced every 600 hours (18,000 miles-29,000 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.6 750 Hours (22,500 miles-36,000 km) Maintenance

Every 750 hours (22,500 miles-36,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Cooling system, refer to Section 13.5.4
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 750 hours (22,500 miles-36,000 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.7 900 Hours (27,000 miles-43,500 km) Maintenance

Every 900 hours (27,000 miles-43,500 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Battery charging alternator, refer to Section 13.5.20
- ☐ Alternator and attaching hardware, refer to section 13.5.28
- ☐ Air conditioning and attaching hardware, refer to section 13.5.29
- ☐ Air compressor and attaching hardware, refer to section 13.5.30

Likewise, the following components must be replaced every 900 hours (27,000 miles-43,500 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.8 1,050 Hours (31,500 miles-50,700 km) Maintenance

Every 1,050 hours (31,500 miles-50,700 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Fan Hub, refer to Section 13.5.23

Likewise, the following components must be replaced every 1,050 hours (31,500 miles-50,700 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.9 1,200 Hours (36,000 miles-58,000 km) Maintenance

Every 1,200 hours (36,000 miles-58,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Oil pressure, refer to Section 13.5.19
- ☐ Battery charging alternator, refer to Section 13.5.20
- ☐ Engine and transmission mounts, refer to Section 13.5.21
- ☐ Crankcase pressure, refer to Section 13.5.22
- ☐ Thermostats and seals, refer to Section 13.5.24
- ☐ Crankcase breather, refer to Section 13.5.25

Likewise, the following components must be replaced every 1,200 hours (36,000 miles-58,000 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.10 1,350 Hours (40,500 miles-65,000 km) Maintenance

Every 1,350 hours (40,500 miles-65,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16

Likewise, the following components must be replaced every 1,350 hours (40,500 miles-65,000 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

13.4.11 1,500 Hours (45,000 miles-72,000 km) Maintenance

Every 1,500 hours (45,000 miles-72,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to Section 13.5.2
- ☐ Cooling system, refer to Section 13.5.4

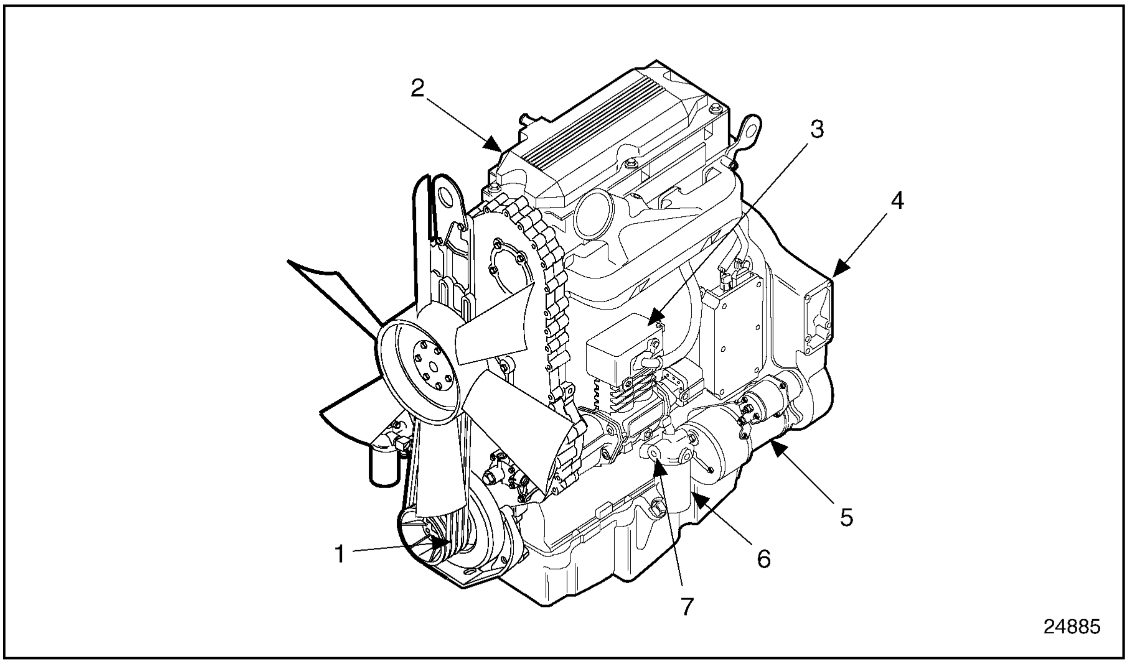
- ☐ Air compressor, refer to Section 13.5.8
- ☐ Air system, refer to Section 13.5.15
- ☐ Exhaust system, refer to Section 13.5.16
- ☐ Engine (steam clean), refer to Section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to Section 13.5.18
- ☐ Battery charging alternator, refer to Section 13.5.20

Likewise, the following components must be replaced every 1500 hours (45,000 miles-72,000 km).

- ☐ Lubricating oil, refer to Section 13.5.1
- ☐ Lubricating oil filter, refer to Section 13.5.10
- ☐ Fuel filter, refer to Section 13.5.11
- ☐ Coolant filter and inhibitor, refer to Section 13.5.12

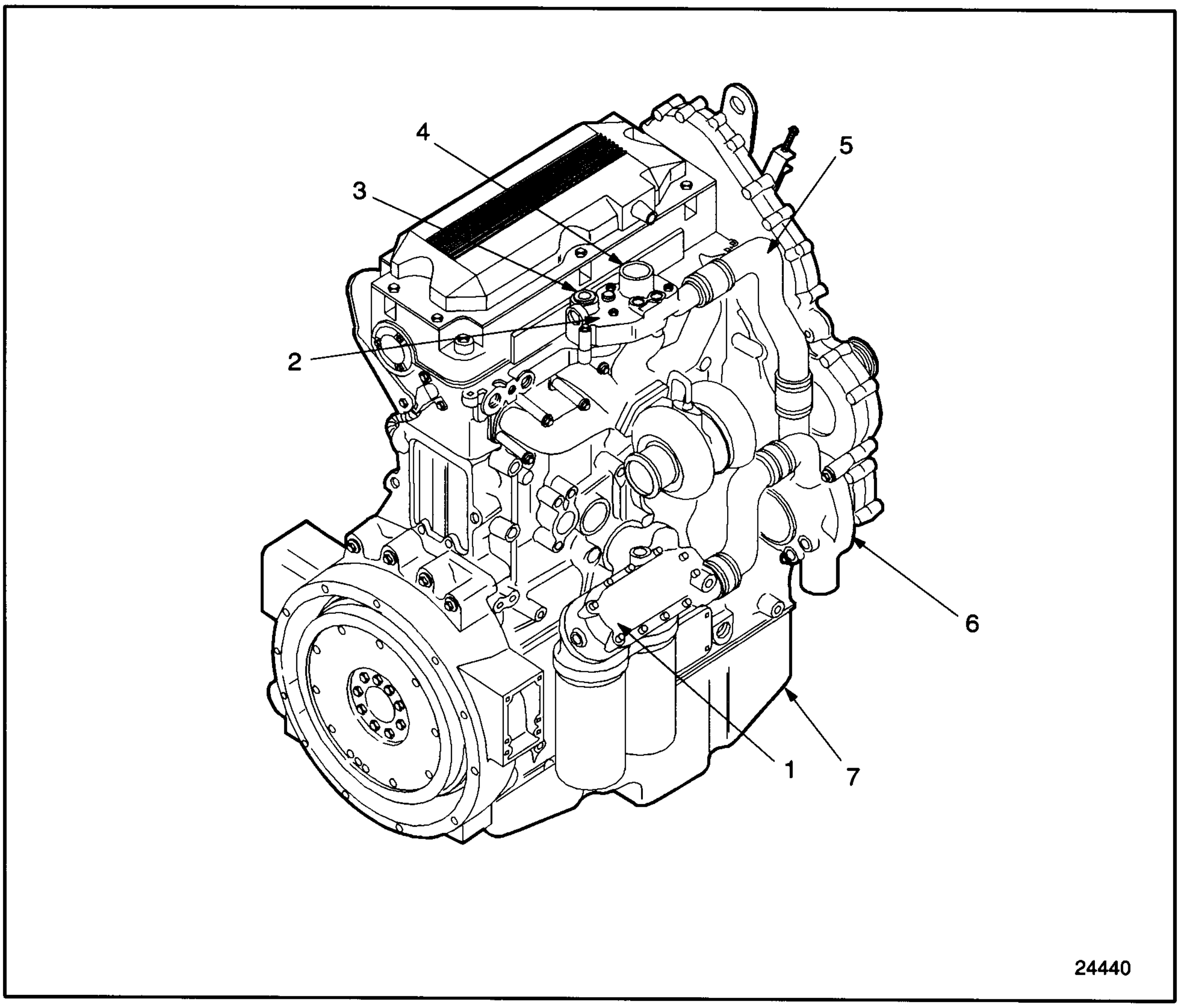
13.5 DESCRIPTION OF MAINTENANCE ITEMS

For locations of components and systems to be maintained, see Figure 13-1, and see Figure 13-2.



1. Drive Belts
2. Rocker Cover
3. Air Compressor
4. Transmission Mounts
5. Cranking Motor
6. Fuel Filter
7. Fuel Filter Fitting

Figure 13-1 Preventive Maintenance Service Items



1. Oil Cooler
2. Thermostat Housing
3. Thermostat Vent
4. Thermostats and Seals
5. Water Bypass Tube
6. Water Pump
7. Oil Pan

Figure 13-2 Preventive Maintenance Service Items

13.5.1 Lubricating Oil

Check the lubricating oil level with the engine stopped and the vehicle on level ground. If the engine has just been stopped and is warm, 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. Refer to Section 5.2.

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 the external oil lines.

Select the proper grade of oil. Refer to Section 5.2.

Change the lubricating oil as follows:

1. Position the vehicle or equipment on level ground.
2. If the engine is cold, run it until it is warm.

NOTE:
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.

NOTICE:
When removing or installing a side plug, hold the flats of the insert with a 2 1/8 in., or larger, open end adjustable wrench to keep it from turning. If the insert is loosened, it may be necessary to remove the oil pan, and retighten the nut to prevent a possible oil leak.

3. Remove drain plug on the bottom of oil pan. Drain lube oil into a suitable container. *Always dispose of used lubrication oil in an environmentally responsible manner, according to EPA and state recommendations.*
4. Coat drain plug(s) with Loctite PT7271 sealant (or equivalent). Install and torque to 45-56 N·m (33-41 lb·ft).

To replace the lube oil filters, perform the following procedure:

1. Remove the spin-on filter cartridges using strap wrench tool J 29917 (or equivalent) and a 1/2 in. drive socket wrench and extension.
2. Dispose of the used oil and filters in an environmentally responsible manner, according to EPA and state recommendations.
3. Clean the filter adaptor with a clean, lint-free cloth.
4. Lightly coat the filter gaskets (seals) with clean engine oil.
5. Start the new filters on the adaptor, and tighten by hand until the gaskets touch the mounting adaptor head. **Tighten full flow filters an additional two-thirds turn by hand.**Add oil as required to bring the level to the "full" mark on the dipstick. Twenty two quarts (21 L) are required when the filters are not changed.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

Start and run the engine for a short period, and check for leaks. After leaks have been corrected, stop the engine long enough for oil to drain back to the crankcase (approximately 20 minutes). Add oil as required to bring the level to the proper mark on the dipstick.

13.5.2 Fuel Tanks

Keep the fuel tank filled to reduce the condensation to a minimum. Select the proper grade of fuel in accordance with the Fuel Specifications. **Refer to Section** 5.1.

Open the drain at the bottom of the fuel tank every 30,000 miles/48,000 km (300 hours for industrial applications), to drain off any water and sediment.

Every 12 months or 60,000 miles/96,000 km (600 hours for industrial applications), whichever comes first, tighten all fuel tank mountings and brackets (refer to OEM maintenance guidelines). At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the flexible fuel lines. Repair or replace the parts as necessary (refer to OEM maintenance guidelines).

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 organizations (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Condensation is particularly prevalent on units that stand idle for extended periods of time. Ambient temperature changes cause condensation in partially filled fuel tanks.

Units in storage are particularly susceptible to microbe growth. The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commercially 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.
- The diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax (or equivalent), treats the fuel itself, and therefore, the entire fuel system.

Any units that will sit idle for extended periods, or any units being stored, 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 (isopropyl alcohol) in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

13.5.3 Fuel Lines and Flexible Hoses

Make a visual check for fuel leaks at all engine-mounted fuel lines and connections, 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. Ensure that hoses are not resting on or touching shafts, couplings, heated surfaces, including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary (refer to OEM maintenance guidelines).

Investigate leaks immediately to determine 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:

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

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 to which it is subjected. With this in mind, all hoses should be thoroughly inspected 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 or after a maximum of five years service.

13.5.4 Cooling System

Check the coolant level daily. Ensure it is within 2 in. (50 mm) of the filler neck or vehicle manufacturer's recommendation. Add coolant, as necessary.

NOTE:
Do not overfill the coolant system.

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.

NOTE:
In order to ensure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system 103-138 kPa (15-20 lb/in.^{2}) using radiator cap and cooling system tester, J 24460-01. Do not exceed 138 kPa (20 lb/in.^{2}). Any measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any internal coolant system leaks.

Clean the cooling system every 24 months using a good radiator cleaning combination 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 the proper anti-freeze/water mixture and pre-charge of inhibitors.

Inspect all of the cooling system hoses at least once every 30,000 miles/48,000 km (300 hours for industrial applications) to ensure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses, if necessary. Refer to OEM maintenance guidelines.

Drain the engine coolant as follows:

1. Allow engine to cool.

CAUTION:

To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

2. Remove drain plugs from the bottom of water pump, at the right rear of the engine, and at the bottom of the thermostat housing.
3. Remove radiator pressure cap.
4. Open valve at bottom of radiator.
5. Collect used antifreeze in a suitable container, and dispose of the solution in an environmentally responsible manner, according to state and federal (EPA) recommendations.

6. Replace all drain plugs, and close any drain valves.
7. Refill the system with proper antifreeze and clean soft water mixture.
8. Purge entrapped air by allowing the engine to warm-up without the pressure cap installed. With the transmission in neutral, increase engine speed above 1000 r/min. Add coolant as required.
9. Allow engine to cool.
10. Install the pressure cap after filling the coolant level to the bottom of the radiator filler neck.

If the cooling system is contaminated, flush the cooling system as follows:

1. Drain the coolant from the engine.
2. Refill with soft clean water.

NOTE:
If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine and operate it for 15 minutes after the thermostats have opened to thoroughly circulate the water.
4. Drain the unit completely.
5. Refill with clean water and operate for 15 minutes after the thermostats have opened.
6. Drain the unit completely.
7. Fill with 50/50 antifreeze/water and precharge of inhibitor.
8. Purge entrapped air by allowing the engine to warm-up without the pressure cap installed. With the transmission in neutral, increase engine speed above 1000 r/min. Add coolant as required.
9. Allow engine to cool.
10. Install the pressure cap after filling the coolant level to the bottom of the radiator filler neck.

13.5.4.1 Test Procedure for DDEC Engines Equipped with Low Coolant Level Sensor (CLS)

The following test procedure is for engine cooling systems that are equipped with a low coolant sensor mounted in the top tank of the radiator. This sensor must be tested annually or every 100,000 miles (160,000 km), whichever comes first.

CAUTION:
To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

1. Allow the engine to cool to ambient temperature.
2. Turn ignition switch on and verify no coolant level sensor codes. **(DO NOT START ENGINE.)**
3. Reduce coolant level below CLS level.
4. Check "stop engine light". It should illuminate within 10 seconds, indicating low coolant level.
   [a] If light illuminates, system is working properly.
   [b] If light does not illuminate, refer to Section 13.5.4.2.
5. Fill coolant to proper level. Refer to Section 13.5.4.

13.5.4.2 Stop Engine Light Did Not Illuminate

If stop engine light did not illuminate, use the following procedure:

1. Check wiring harness and mating connector for damaged wires or pins.
2. Remove and clean sensor. Wash with mild detergent and rinse with clean water.
3. Submerge sensor in container of water up to connector with wiring harness connected.
4. Turn ignition switch on. **(DO NOT START ENGINE.)**
5. Slowly remove sensor from water.
6. The light should illuminate, indicating low coolant level.
7. If light does illuminate, system is working properly.
8. If light still does not illuminate, replace sensor and return it to DDC.

13.5.5 Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks and restrictions to oil flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause. Refer to Section 6.6.1.

13.5.6 Battery

On batteries equipped with charge indicator eyes, periodically check for adequate charge. If batteries are the filler cap type, check the level of the electrolyte every 100 hours or every 7,500 miles (12,000 km). In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. Electrolyte should be maintained in accordance with the battery manufacturer's recommendations. Periodically remove, check and clean battery post terminals and connections. Replace corroded or damaged parts. Refer to Section 8.4.1.

13.5.7 Drive Belts

New standard vee-belts and Powerband ® belts will stretch after the first few hours of operation. Run the engine for 10 to 15 minutes at 1200 r/min to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, battery charging generator or alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 250 miles (400 km) of operation. Thereafter, check the tension of the drive belts every 100 hours or 7,500 miles (12,000 km) and adjust, if necessary. Belts should be neither too tight nor too loose. Belts that are too tight impose excess loads on the crankshaft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. A loose belt will slip and may cause damage to accessory components.

NOTE:
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 0.032 in. (0.81 mm) of their specified center distances.

With a belt tension gage, J 23600 new number BT-3373–F, or equivalent, adjust the belt tension as listed in Table 13-1listed in Table 13-2and .

FAN DRIVE	
Single Belt	**2 or 3 Belt**
355–455 N (80–100 lb)	266–3555 N (60–80 lb)

Table 13-1 Fan Drive Belt Tensions

ALTERNATOR DRIVE		
Belt	**New**	**Used**
Two 1/2 in. V-Groove	556 N (125 lb)	445 N (100 lb)
2–Groove Powerband®	890 N (200 lb)	667 N (150 lb)
12–Rib Poly-V 50 DN Alternator	1,558 N (350 lb)	1,115 N (250 lb)

Table 13-2 Alternator Drive Belt Tensions

If a belt tension gage is not available, adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 12.70-19.05 mm 0.500-0.750 in.).

NOTE:
When installing or adjusting an accessory drive belt, ensure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

NOTE:
Drive belts (vee, Powerband®, and poly-vee) should be replaced every 2,000 hours or 100,000 miles (160,000 km).

A single poly-vee belt is used with the 50 DN Alternator. The 12-rib alternator drive belt tension is set at 1558 N (350 lb) during engine assembly and belt replacement using Kent-Moore belt tension gage, J 41251-B, or equivalent. A new belt loses tension rapidly during the first few minutes of operation. Therefore, it is important to check the tension after 30 minutes of operation. Allow the belt to cool with the engine off for 30 minutes before measuring tension.

- ☐ If the tension on the belt is greater than or equal to 1115 N (250 lb), no further tensioning is required.
- ☐ If the tension on the belt is less than 1115 N (250 lb), tension the belt to 1115 N (250 lb).

Periodic tensioning of the belt is required to maximize belt life. The belt tension should be measured once per month or every 7,500 miles (12,000 km), whichever comes first.

A belt tensioning tool is available from Detroit Diesel, J 41251-B. The gage is calibrated from 779 to 1558 N (175 to 350 lb). The following procedure will describe proper use of the belt tensioning tool:

NOTICE:
Failure to properly orient the drive belt when installing it over the pulleys may result in belt damage at engine startup.

1. Poly-vee belts are very sensitive to undertension. Without a gage and proper tension measurement, the belt tension will probable be too low. Undertension wears belts rapidly and will lead to premature belt failure.
2. Measure the belt tension between the alternator drive pulley and the upper idler pulley, or between the upper idler pulley and the alternator pulley.

NOTICE:
Do not let gage handle snap back after pressing handle when not installed on belt under tension. Broken gear will result.

3. Squeeze gage handles together to fully open the gage. The belt must pass between the hook and the leg pads. The entire belt width must be supported by the hook and leg pads.
4. Release the gage handles quickly to "snap" the gage on the belt. Read tension on the face of the gage. Repeat the measurement 2 or 3 times to ensure accuracy.
5. The support legs on the gage should not contact pulleys or any other engine hardware.
6. Keep gage clean. Dirt will wear out the leg pads.

13.5.7.1 Inspect for Rib Cracking

As a poly-vee belt goes through its natural life, it passes through several phases:

- ☐ After an extended time in service, minor rib cracks may appear, usually one or two cracks per inch of belt. See Figure 13-3. This condition is considered normal.

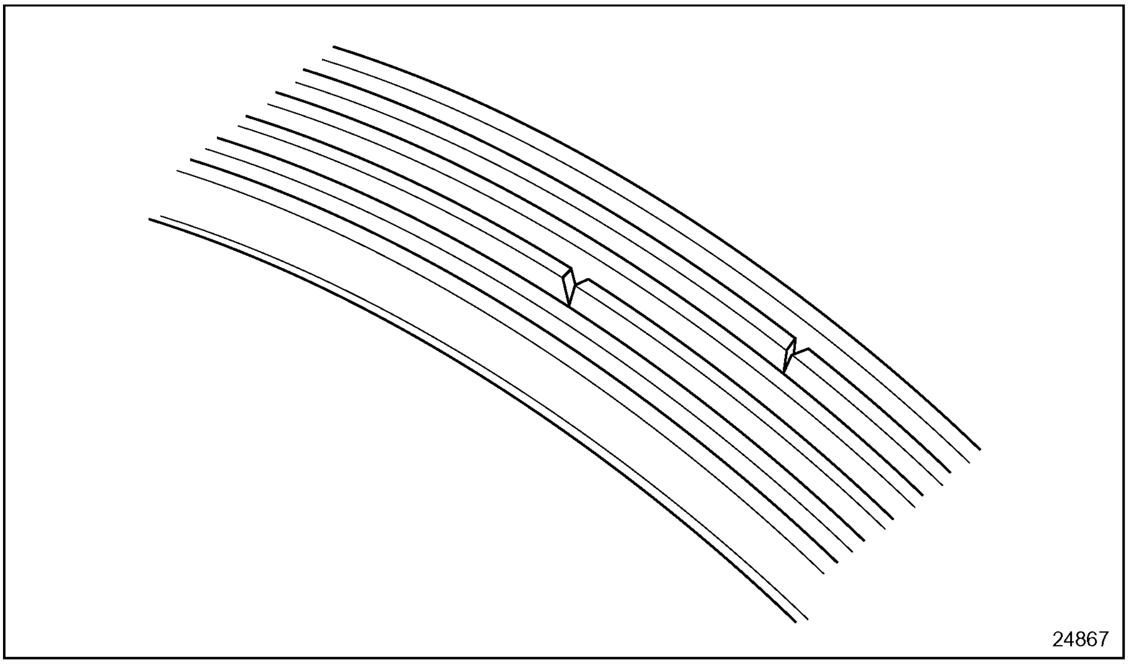


Figure 13-3 Minor Rib Cracking

- A replacement concern occurs when the belt ribs exhibit severe multiple cracking (see Figure 13-4). This leads to "chunking" (breaking away of rib material). see Figure 13-5

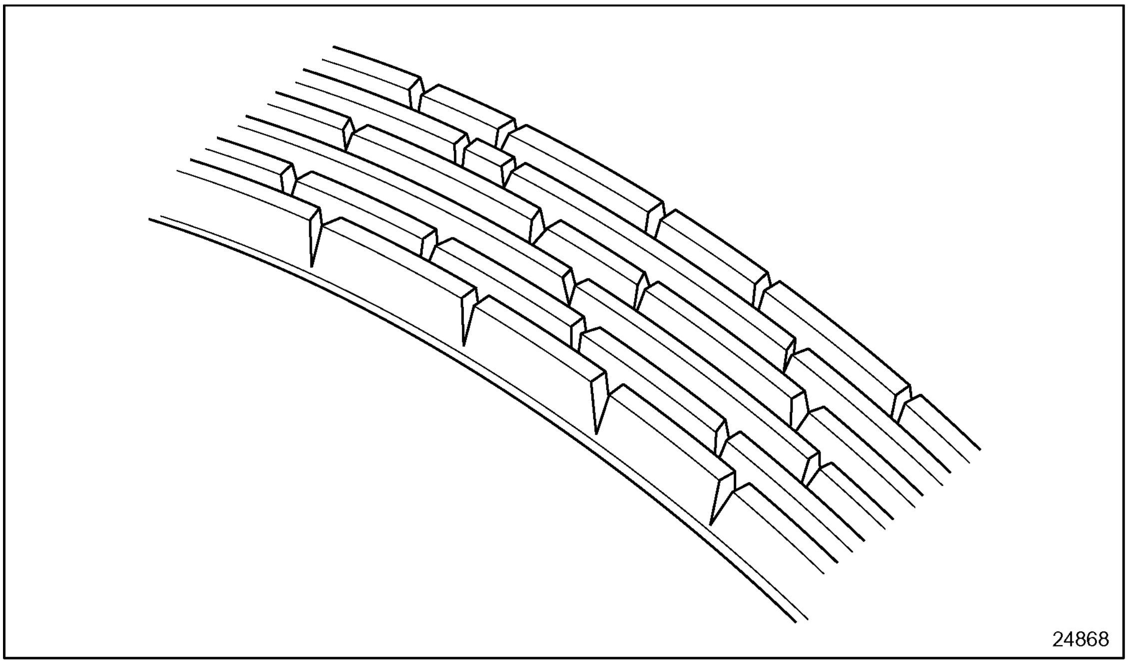


Figure 13-4 Severe Rib Cracking

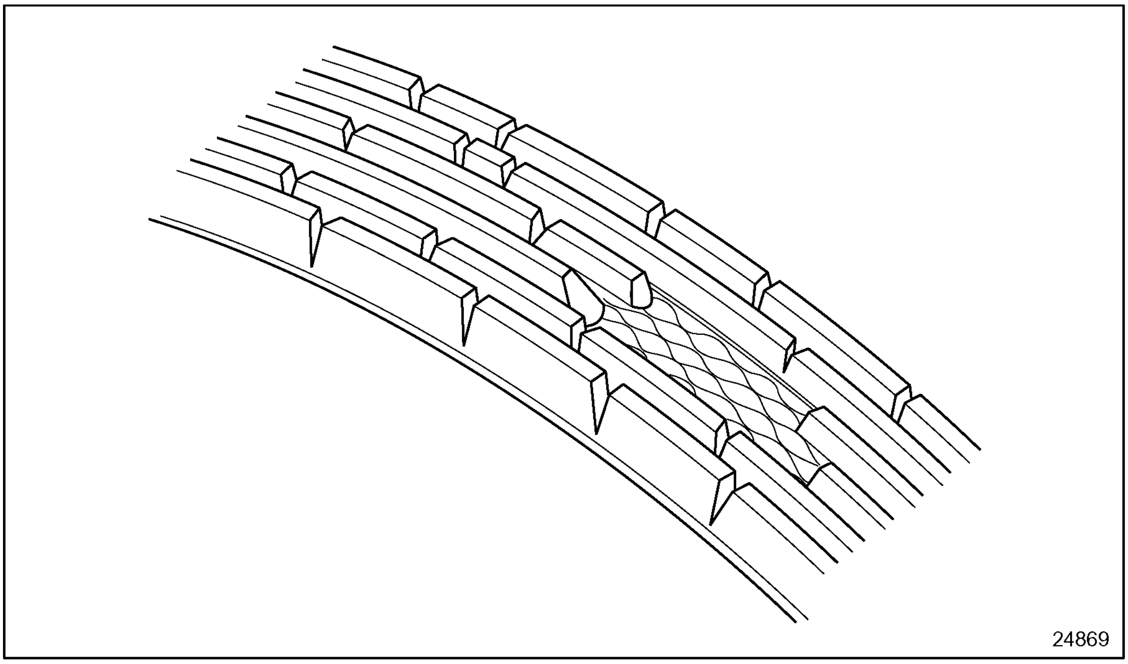


Figure 13-5 Rib Chunking

- When severe cracking or rib "chunking" appears, belt replacement is required.

13.5.7.2 Inspect for Rib Sidewall Glazing

When the ribs appear to have a shiny surface that is hard and brittle, it is usually a symptom of belt slippage. This results from inadequate tension, extreme temperature, or both. Both characteristics will lead to severe cracking and failure, often with little advance warning. If this happens, locate the cause and correct before installing a new belt.

13.5.7.3 Inspect for Belt Wear

Accelerated wear on any part of the belt fabric backing, tensile cord, or rib rubber is a concern and should be investigated. The causes of accelerated wear are:

- ☐ Drive misalignment - For efficient belt performance, misalignment must not exceed 1.59 mm (1/16 in.) for each 305 mm (12.0 in.) of belt span
- ☐ Incorrect belt length
- ☐ Environmental conditions - Temperature, excessive exposure to engine fluids, etc.
- ☐ Abrasive material - Stones, sand, metal shavings, etc.

13.5.7.4 Inspect for Foreign Objects

Premature failure may be caused by the belt coming in contact with a foreign object.

NOTICE:
Any object protruding into the path of the belt drive that contacts the belt will cause damage and failure of the belt.

Prior to installing a new belt, verify removal of any foreign objects protruding into the belt path.

13.5.7.5 Inspect for Noise Vibration

Much effort has gone into the design of each poly-vee belt drive in order to prevent noise vibration. However, field problems occasionally occur. Some causes of noise vibration are:

- ☐ Misalignment - This may cause a chirping noise, especially at or near idle speed.
- ☐ Mounting - Rigid bracketing of accessories is a must for acceptable free belt span vibration.

NOTE:
Some span vibration is to be expected during the range of engine speed and accessory loading.

- ☐ Belt tension - Insufficient belt tension may cause a high - pitched howl (squeal) or rasping sound during engine acceleration or deceleration.

13.5.8 Air Compressor

Remove and clean all air compressor air intake parts every 150 hours or 15,000 miles (24,000 km). Refer to Section 10.1.2. To clean either the hair-type or polyurethane-type compressor air strainer element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until it is dirt-free. Then, dip the element in lubricating oil and squeeze it dry before placing it back in the air strainer.

For replacement of the air strainer element, contact the nearest servicing dealer; replace with the polyurethane element, if available.

Every 12 months or 30,000 miles (48,000 km) [300 hours for industrial applications] tighten the air compressor mounting bolts.

13.5.9 Air Cleaner

Inspect the air cleaner element every 15,000 miles (24,000 km) for vehicle engines, 150 hours for non-vehicle engines, or more often if the engine is operated under severe dust conditions. Replace the element if necessary. Check the gaskets for deterioration and replace, if necessary. If the dry type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean and repair as necessary.

Under no engine operating conditions should the air inlet restriction exceed 20 inches of water (5.0 kPa). A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Dry-type air cleaner elements used in on-highway applications should be discarded and replaced with new elements when the maximum allowable air inlet restriction has been reached. No attempt should be made to clean or reuse on-highway elements after these intervals.

Dry-type elements used in industrial applications should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached, whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations, if any. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

13.5.10 Lubricating Oil Filter

Install new full flow spin-on oil filters at a **maximum** of 15,000 miles (24,000 km) (truck engines) 6,000 miles (10,000 km) (coach engines) or 150 hours (non-vehicle engines) or each time the engine oil is changed, whichever comes first. Install the new filters, turning them until they contact the gasket fully with no side movement, then turn an additional 2/3 turn by hand.

Make a visual inspection of all lubricating oil lines for wear and/or chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

If the engine has not been operated for a prolonged period or the turbocharger has been removed or replaced, prelubricate the turbocharger as outlined under " Assembly of Turbocharger." **Refer to Section** 6.5.6.

Check for oil leaks after starting the engine.

13.5.11 Fuel Filters

Install new fuel filters every six months or 15,000 miles (24,000 km) (truck engines) 6,000 miles (10,000 km) (coach engines) or 150 hours (non-vehicle engines) or when plugging is indicated.

A method of determining when filters are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet fitting and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction should not exceed 20.3 kPa (6 in. Hg) and must not exceed 12 in. Hg (41 kPa) with a dirty system.

At normal operating speeds and with the standard 0.080 in. (2.03 mm) restriction fittings, the fuel pressure at the cylinder head inlet is 345-517 kPa (50-83 lb/in.^{2}). Change the fuel filters whenever the inlet restriction at the fuel pump reaches 41 kPa (12 in. Hg) at normal operating speeds and whenever the fuel pressure at the cylinder head inlet fitting falls to the minimum fuel pressure shown above.

Spin-on type primary and secondary fuel filters are used on Series 50 engines. The spin-on type consists of a shell, element, and gasket unitized into the single cartridge and a filter cover, which includes a threaded sleeve to accept the spin-on filter cartridge. An optional fuel/water separator may be installed in place of the standard primary filter.

Replace spin-on type primary or secondary filter elements as follows:

1. With the engine shut down, place a suitable container under the filter.
2. A fuel shutoff valve may be installed on the discharge side of the secondary fuel filter. If installed, turn the handle on the shutoff valve to the **closed** position (perpendicular to the valve).
3. Using a suitable band type filter wrench, remove the primary and secondary fuel filters. Dispose of the filters in an environmentally responsible manner, according to state and federal (EPA) recommendations.
4. Fill new replacement filters with clean fuel oil, and coat the gaskets lightly with clean fuel oil.

NOTICE:
Overtightening may crack or distort the adaptors.

5. Thread the new filters onto the adaptors until they make full contact with the gasket and no side movement is evident. Then rotate an additional one-half turn **by hand**.
6. Turn the handle on the shutoff valve (if installed) to the **open** position (in line with the valve).

NOTICE:

To improve engine starting, have replacement filters filled with fuel and ready to install immediately after used filters are removed. This will prevent possible siphoning and fuel system aeration.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

7. Start the engine, and check for leaks.

NOTICE:

Under no circumstances should the starting motor and fuel pump be used to prime the fuel filters. Prolonged use of the starting motor and fuel pump to prime the fuel system can result in damage to the starter, fuel pump, and injectors and cause erratic running of the engine because of air in the lines and filters.

[a] If the engine fails to start after filter replacement, the fuel system will require priming with tool J 5956 (or equivalent). Authorized Detroit Diesel service outlets are properly equipped to perform this service.

Replace fuel/water separator as follows:

1. Drain off some fuel by opening the drain valve.
2. Using a strap wrench, remove the element and bowl together. Remove the bowl from the element. The filter and bowl have standard right-hand threads, so turn counterclockwise to remove.
3. Clean the bowl and the O-ring seal.

NOTICE:
To avoid damaging the bowl or the filter, do not use tools when tightening.

4. Apply a light coating of clean fuel or grease to the O-ring seal, spin the bowl onto the new filter, and *tighten by hand*.
5. Apply a light coating of clean fuel or grease to the new O-ring seal on the top of the filter. Spin the filter and bowl assembly onto the filter head, and *tighten by hand*until snug.
6. To eliminate air from the filter, operate the primer pump on the filter head (if equipped) until the fuel purges at the filter assembly.

CAUTION:
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm. □ **Always start and operate an engine in a well ventilated area.** □ **If operating an engine in an enclosed area, vent the exhaust to the outside.** □ **Do not modify or tamper with the exhaust system or emission control system.**

7. Start the engine, and check for leaks. Correct any leaks with the engine off.

13.5.12 Coolant Filter and Water Pump

Inspect the water pump drain hole every 6 months making sure it is open. A small chemical build up or streaking at the drain hole may occur, and this is not an indication of a defective water pump or seal. If coolant does not leak from the drain hole under normal operating conditions, do not replace the water pump. If the cooling system is protected by a coolant filter and conditioner, the element should be changed every 15,000 miles (24,000 km) or 150 hours (industrial applications). Use the proper coolant filter element in accordance with instructions given under coolant specifications. **Refer to Section** 5.4.

13.5.13 Guidelines for Water Pump Replacement

The investigation of engine water pumps returned to the factory has, in many cases, revealed normal weepage from the water pump weep hole. This condition is often misdiagnosed as a water pump seal failure. The diagnostic procedure is used to determine if the engine water pump seal has failed or is functioning normally. Guidelines are also presented for the steps that should be taken prior to water pump replacement.

13.5.13.1 Source of Premature Failure of Water Pump Seals

Water pump seal failures may result from debris or deposits at the seal surface, low coolant levels, improper coolant chemicals or fabrication defects. Fabrication defects are quickly evident at low mileage/engine hours, while failures caused by debris or deposits at the seal surface appear over the service life of the pump. Premature failure of the water pump seal is typically an indication of poor coolant and lubricating oil maintenance.

Improper coolant maintenance can lead to excess supplemental coolant additives (SCA) in the coolant. This can cause excess phosphorus and silicates to precipitate within the cooling system. Deposits can build up between the shaft and the seal, causing a leak path or an abrasive effect on the seal face. Coolant formulated with hard water can also result in excess magnesium and calcium precipitation, with the same effect on the water seal. For additional information on the effects of inadequate cooling system maintenance, see DDC publication, 7SE390, "Cooling System Technicians Guide".

On gear-driven water pumps, oil from the weep hole indicates a failure of the oil seal within the water pump. The normal cause for premature failure of the oil seal is excessive wear debris and soot in the engine oil, which can result from extended oil change intervals. These contaminants act abrasively on the seal-to-shaft interface.

13.5.13.2 Water Pump Seal Assessment

The following steps should be followed to verify leakage prior to removal and replacement of the water pump:

1. When accessible, clean any debris or obstruction from the weep hole, being careful not to disturb the seal. This will help address the nature of the leakage. See Figure 13-6.

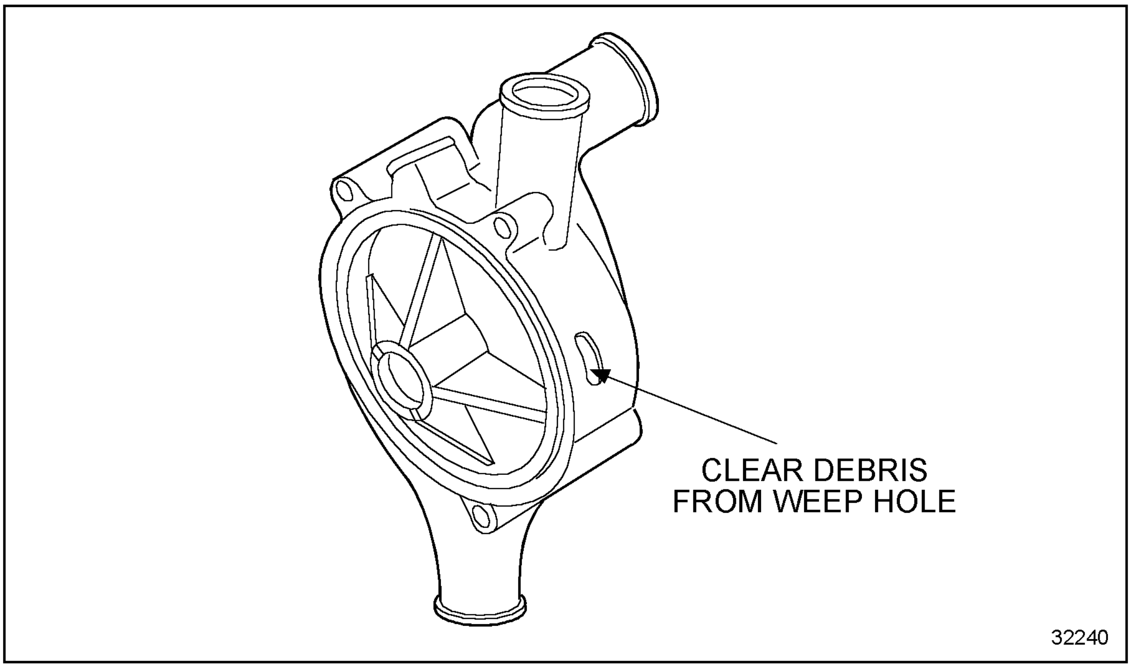


Figure 13-6 Water Pump Weep Hole

2. If no leakage of coolant is observed under operating conditions, the water pump should not be replaced.

NOTE:
Chemical streak trails and seepage are normal, but continuous drip leaks are not.

NOTE:
Weeping is described as a passing of liquid across a sealed surface of about 1-5 drops per day's usage. See Figure 13-7. Seeping describes a greater amount of liquid equal to more than 5 drops per day's usage. Leaking describes a near-constant dripping of liquid. See Figure 13-8.

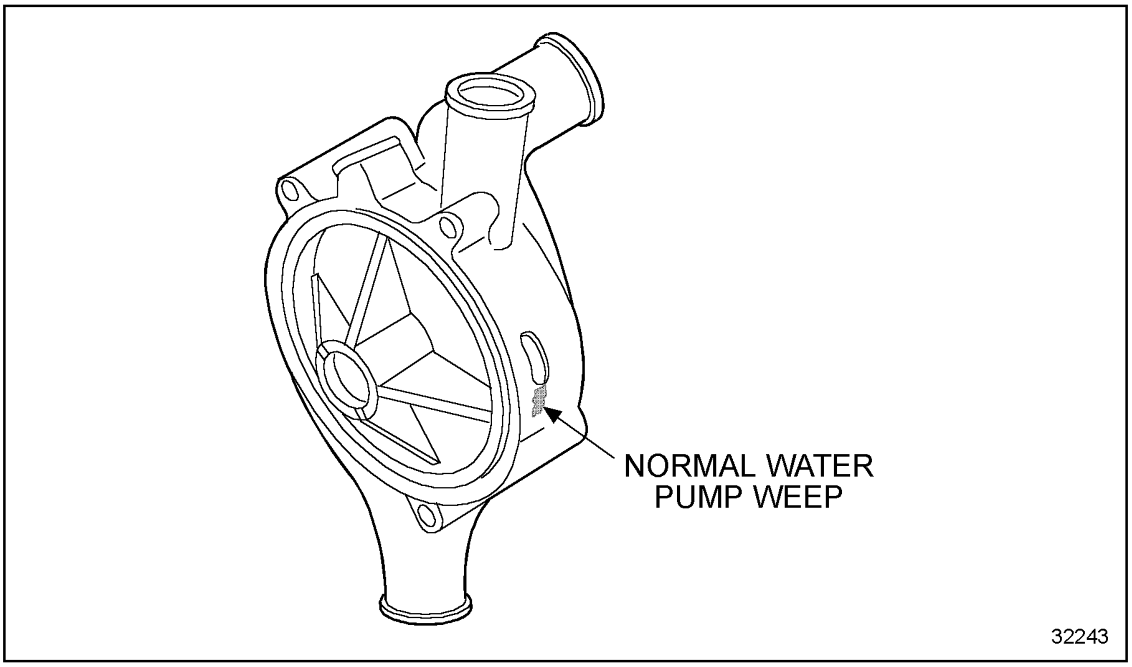


Figure 13-7 Water Pump Showing Normal Weeping

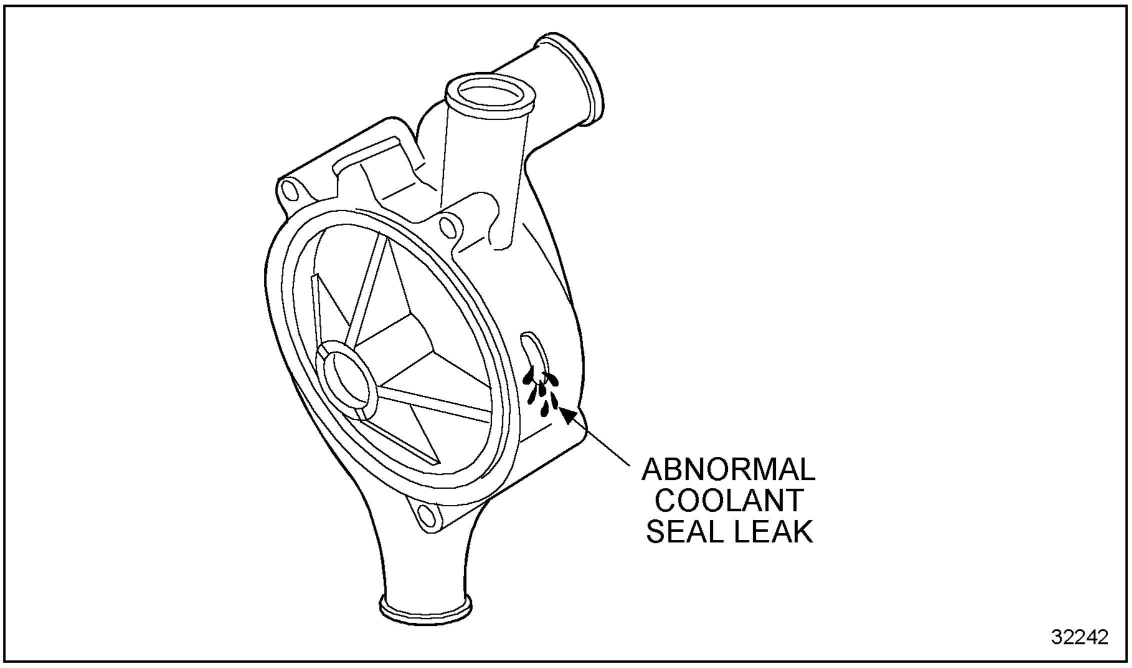


Figure 13-8 Water Pump Showing Abnormal Leaking

NOTE:
Water pumps which exhibit a chemical build-up in the weep hole do not necessarily require replacement. See Figure 13-9. Some weeping is expected as a result of the coolant lubrication of the seal surface.

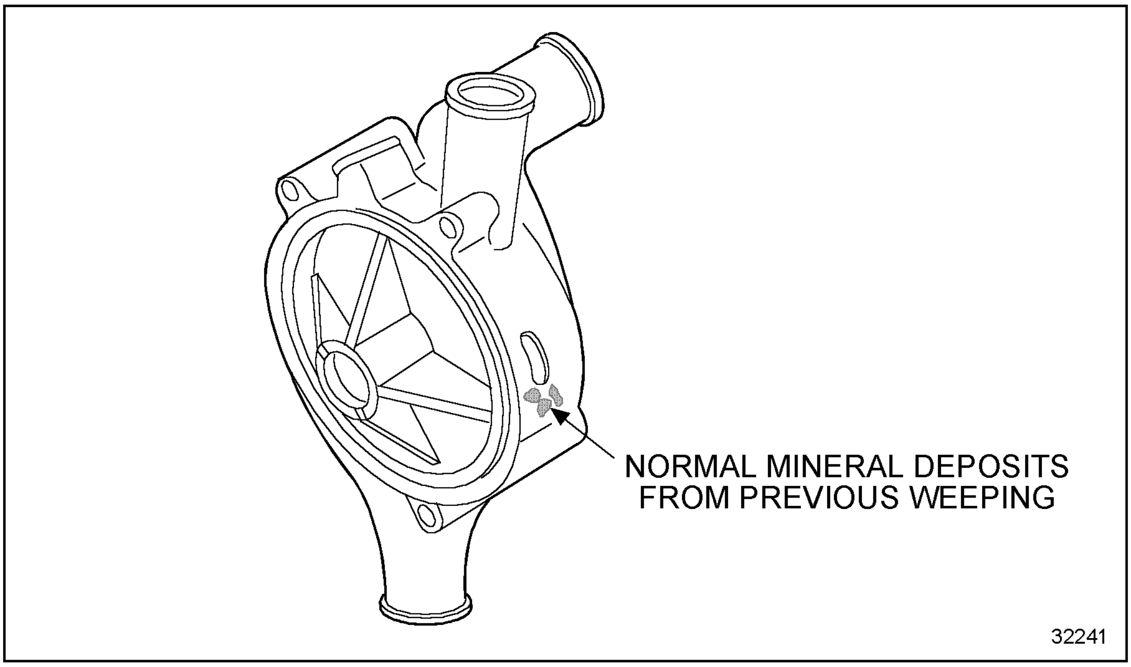


Figure 13-9 Water Pump Showing Normal Mineral Deposits Caused By Weeping

Replace water pump if oil is found coming from the weep hole on gear-driven water pumps. The engine oil must then be tested for excess debris, and replaced if not conforming to specifications.

The SCA inhibitors and glycol concentration must be checked according to the recommended maintenance schedule as described in the Detroit Diesel Service Manual and Operators Guide for that specific engine or DDC Publication, 7SE298.

13.5.13.3 Water Pump Leak Test Summary

Test water pump for leaks as follows:

1. Ensure weep hole is clear.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Run engine and look for coolant leaking from weep hole.

   [a] Do not replace water pump due to chemical streaks.

   [b] Replace the water pump if coolant is leaking or dripping.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Run engine and check for oil leaks from weep hole.

   [a] If oil leak is observed, replace the water pump and conduct an oil analysis per publication, 7SE390, then replace water pump as needed.

4. Test and reformulate the coolant to proper glycol and SCA concentrations per the Service Manual Maintenance schedule as indicated in the engine operators guide or DDC publication, 7SE298.

NOTE:
Failure to adhere to oil and coolant specifications will result in a significant decrease in the service life of the water pump seals, and could invalidate the warranty.

13.5.14 Cranking Motor

Refer to OEM maintenance guidelines.

13.5.15 Air System

It is important with turbocharged engines that all the connections in the air system be checked to ensure they are tight. Check all hoses and ducting for punctures, deterioration or other damage and replace, if necessary.

Refer to OEM maintenance guidelines.

13.5.16 Exhaust System

Check the exhaust manifold retaining bolts and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if so equipped.

Refer to OEM maintenance guidelines.

13.5.17 Engine (Steam Clean)

Refer to OEM maintenance guidelines.

NOTICE:
Do not apply steam or solvent directly on the battery charging generator/alternator, starting motor, DDEC components, sensors, or other electrical components, as damage to electrical equipment may result.

Steam clean the engine and engine compartment.

13.5.18 Radiator

Inspect the exterior of the radiator core every 12 months or 30,000 miles-48,000 km (300 hours for industrial applications) 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.

Refer to OEM maintenance guidelines.

13.5.19 Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the equipment is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 60,000 miles (96,000 km) for vehicle engines or 600 hours for stationary or industrial engines.

Refer to OEM maintenance guidelines.

13.5.20 Battery Charging Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

Refer to OEM maintenance guidelines.

13.5.21 Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 600 hours or 60,000 miles (96,000 km). Tighten or repair as necessary.

Refer to OEM maintenance guidelines.

13.5.22 Crankcase Pressure

Check and record the crankcase pressure every 600 hours-96,000 km (60,000 miles).
Refer to Section 29.3.

13.5.23 Fan Hub

If the fan bearing hub assembly has a grease fitting, use a hand grease gun and lubricate the bearings with two shots of Texaco Premium RB grease, or Mobilgrease HP, or an equivalent lithium-base multi-purpose premium grease at the following intervals as listed in Table 13-3. Care should be taken not to overfill the housing.

Engine Application	Fan Bearing Lubrication Interval
On-highway Truck Engine	15,000 miles (24,000 km)
Transit Coach Engine	6,000 miles (9,600 km)
Non-vehicle Engine	1,050 Hours

Table 13-3 Fan Bearing Lubrication Intervals

NOTICE:

Failure to properly lubricate the fan hub bearing at required intervals my result in fan bearing, spindle damage or both. This could lead to fan malfunction, loosening or both, which could result in serious engine damage.

NOTE:
This is a change from the original recommendation, which required greasing the bearing on vehicle engines every 100,000 miles (160,000 km).

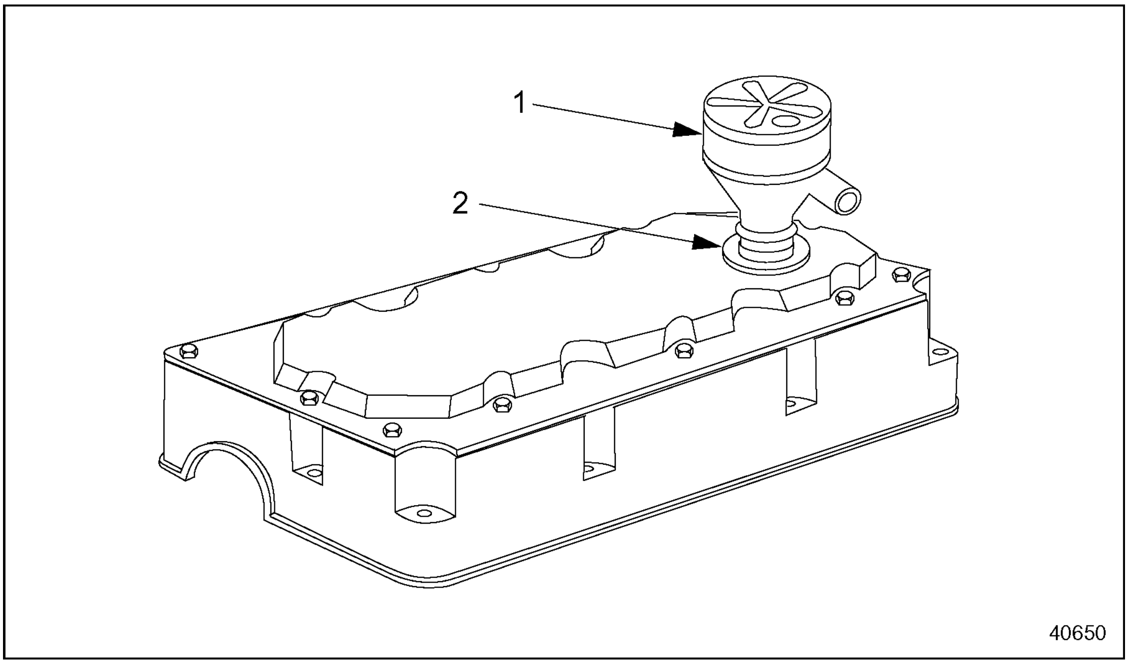
13.5.24 Thermostats and Seals

Inspect the thermostats and seals every 24 months. Refer to Section 4.3.2.1 for thermostat inspection procedures. The thermostats and seals should be replaced every 200,000 miles (240,000 km) for vehicle engines or 4,000 hours for non-vehicle engines.

13.5.25 Crankcase Breather

Remove the internally mounted (in the engine rocker cover) crankcase breather assembly annually (vehicle engines) or every 1,050 hours (non-vehicle engines) and wash the steel mesh pad in clean fuel oil. Refer to Section 1.6.2. This cleaning period may be reduced or lengthened according to the severity of service.

The rocker cover-mounted breather assembly (part number 23512984) and seal ring (part number 23515211) used in the closed crankcase breather system should be *replaced*every 4000 engine operating hours. These parts are not reusable and no attempt should be made to clean or reuse them. See Figure 13-10.



1. Breather
2. Seal

Figure 13-10 Rocker Cover-Mounted Breather Location

13.5.26 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.

The valve lash and injector heights on all Series 50 diesel-fueled engines must be measured and, if necessary, adjusted after the *first* 60,000 miles (96,000 km) or 24 month period, whichever comes first. Once the initial measurements and adjustments have been made, any changes beyond this point should be made only as required to maintain satisfactory engine performance.

Refer to Section 12.2of this service manual for valve lash and injector height measurement and adjustment procedures.

NOTICE:
Failure to measure valve clearances and injector heights at the required initial period and make necessary adjustments may result in gradual degradation of engine performance and reduced fuel combustion efficiency.

The valve lash on Series 50G natural gas-fueled engines should be checked and adjusted as follows:

- ☐ Transit Bus Engines - Check every 36,000 miles (58,000 km) or 12 months, whichever comes first, and adjust if necessary.
- ☐ Generator Set Engines - Check every 1,500 hours of operation or 12 months, whichever comes first, and adjust if necessary.

Refer to Section 12.4of this service manual for valve lash adjustment procedures.

NOTICE:
Failure to measure valve lash at the required intervals and make necessary adjustments may result in gradual degradation of engine performance and reduced fuel combustion efficiency.

13.5.27 Fuel Pro 380/380E Filter Element Replacement

There is no scheduled interval for replacing the element. The element should be replaced when the fuel level in the see-through cover reaches the top of the element.

13.5.28 Alternator and Attaching Hardware

The alternator and attaching hardware should be inspected for cracks, and the securing bolts should retorqued every 90,000 miles for on-highway vehicles, 900 hours for stationary and industrial applications.

13.5.29 Air Conditioning and Attaching Hardware

The air conditioner and attaching hardware should be inspected for cracks, and the securing bolts should retorqued every 90,000 miles for on-highway vehicles, 900 hours for stationary and industrial applications.

13.5.30 Air Compressor and Attaching Hardware

The air compressor and attaching hardware should be inspected for cracks, and the securing bolts should retorqued every 90,000 miles for on-highway vehicles, 900 hours for stationary and industrial applications.

13.6 PREVENTIVE MAINTENANCE FOR THE SERIES 50G ENGINE (CITY TRANSIT COACH)

The following is a list of items that are unique to the Series 50G engine for preventive maintenance (city transit coach):

13.6.1 Coalescing Fuel Filters

Drain coalescing fuel filters daily. Inspect natural gas fuel filter every 6,000 miles (9,600 km). Replace fuel filter if dirt, debris or foreign objects are present “inside” of the fuel filter. Also, replace if fuel filter seal is damaged.

NOTE:
Oil saturation on the outside of the fuel filter is a NORMAL condition of the oil coalescing process.

13.6.2 Valve Lash

Check valve lash. Valve lash should be inspected and adjusted every 60,000 miles as specified.

13.6.3 Closed Crankcase Breather System

The closed crankcase breather filter must be replaced every 6000 miles. The filter is located in the remote mounted crankvent assembly.

13.6.4 Dry Type Air Cleaner

Under no operating condition should the intake restriction exceed 20 inches of water at full load and rated speed. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine. For equivalent restriction limits for lower speed, refer to Detroit Diesel Corporation Engineering Bulletin No. 39, "Air Cleaner Systems for Detroit Diesel Engines".

Inspect the air cleaner element every 12,000 miles (coaches). Inspect the air cleaner more often if the engine is operated under severe dust conditions. Replace the element if necessary. Check the gaskets for deterioration and replace, if necessary. If the dry type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean and repair as necessary.

13.6.5 Engine Lubricating Oil

Change the lubricating oil every 6,000 miles for city transit coaches. (Refer to Engine Requirements - Lubricating Oil, Fuel and Filters - 7SE272).

13.6.6 Engine Lubricating Oil Filters

Change the lubricating oil filters at each oil change 6,000 miles for city transit coaches).

13.6.7 Coolant

Check the coolant level daily before starting the engine. Make sure coolant is up to the proper level. Add coolant as necessary. DO NOT OVERFILL. Check all cooling system lines and hoses for damage, leaks or loose connections. Tighten or replace as necessary. (Refer to Coolant Selections for Detroit Diesel Engines 7SE298). Check for proper inhibitor level at each oil change (15,000 miles) and add as required or 6,000 miles (coaches).

13.6.8 Turbocharger and Wastegate Assembly

Inspect turbocharger mountings, air intake and exhaust ducts, recirculation valve assembly, and wastegate valve assembly, including hoses, for leaks. Check the oil and water inlet and outlet lines and connections for leaks and restrictions to flow. Check for unusual vibrations or noises. If excessive, remove unit from service and have cause corrected.

13.6.9 Turbocharger Compressor Recirculation Valve

Every 18,000 miles, vacuum check the turbocharger compressor recirculation valve for leakage per the service manual. If the valve assembly does not hold the vacuum specified, the valve needs to be disassembled and inspected for defective components.

13.6.10 Thermostat

Check thermostats and seals every 108,000 miles (coach), whichever comes first. Replace the seals and/or thermostat, if necessary.

13.6.11 Spark Plugs

Replace the spark plugs and boot spring assembly every 18,000 miles (coach); refer to Section 15.5 and refer to Section 15.10 for plug information.

13.6.12 Spark Plug Ignition Wires

Inspect spark plug wires at spark plug change interval for cracks and/or deterioration, and for proper routing. Replace wires at 108,000 miles (coach).

13.7 MAINTENANCE OF SERIES 50G ENGINES

Series 50G transit coach components must be maintained at various intervals.

13.7.1 6,000 Miles (10,000 km) Interval Maintenance for Transit Coach

Every 6,000 miles (10,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.2 12,000 Miles (19,000 km) Interval Maintenance for Transit Coach

Every 12,000 miles (19,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.3 18,000 Miles (29,000 km) Interval Maintenance for Transit Coach

Every 18,000 miles (29,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Turbo recirculation valve, refer to Section 13.6.9.
- ☐ Spark plugs, boot-spring assembly, refer to Section 13.6.11.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.4 24,000 Miles (39,000 km) Interval Maintenance for Transit Coach

Every 24,000 miles (39,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.

- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.5 30,000 Miles (48,000 km) Interval Maintenance for Transit Coach

Every 30,000 miles (48,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.6 36,000 Miles (58,000 km) Interval Maintenance for Transit Coach

Every 36,000 miles (58,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Turbo recirculation valve, refer to Section 13.6.9.
- ☐ Spark plugs, boot-spring assembly, refer to Section 13.6.11.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.7 42,000 Miles (68,000 km) Interval Maintenance for Transit Coach

Every 42,000 miles (68,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.8 48,000 Miles (77,000 km) Interval Maintenance for Transit Coach

Every 48,000 miles (77,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.

- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.9 54,000 Miles (87,000 km) Interval Maintenance for Transit Coach

Every 54,000 miles (87,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Turbo recirculation valve, refer to Section 13.6.9.
- ☐ Spark plugs, boot-spring assembly, refer to Section 13.6.11.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.10 60,000 Miles (97,000 km) Interval Maintenance for Transit Coach

Every 60,000 miles (97,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Valve lash, refer to Section 13.6.2.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.11 66,000 Miles (106,000 km) Interval Maintenance for Transit Coach

Every 66,000 miles (106,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.12 72,000 Miles (116,000 km) Interval Maintenance for Transit Coach

Every 72,000 miles (116,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Valve lash, refer to Section 13.6.2.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Turbo recirculation valve, refer to Section 13.6.9.
- ☐ Spark plugs, boot-spring assembly, refer to Section 13.6.11.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.13 78,000 Miles (126,000 km) Interval Maintenance for Transit Coach

Every 78,000 miles (126,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.14 84,000 Miles (135,000 km) Interval Maintenance for Transit Coach

Every 84,000 miles (135,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.15 90,000 Miles (145,000 km) Interval Maintenance for Transit Coach

Every 90,000 miles (145,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.

- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Turbocharger recirculation valve, refer to Section 13.6.9.
- ☐ Spark plugs, boot-spring assembly, refer to Section 13.6.11.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.16 96,000 Miles (154,000 km) Interval Maintenance for Transit Coach

Every 96,000 miles (154,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.17 102,000 Miles (164,000 km) Interval Maintenance for Transit Coach

Every 102,000 miles (164,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.18 108,000 Miles (174,000 km) Interval Maintenance for Transit Coach

Every 108,000 miles (174,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Valve lash, refer to Section 13.6.2.
- ☐ Crankcase breather element, refer to Section 13.6.3.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Turbo recirculation valve, refer to Section 13.6.9.
- ☐ Spark plugs, boot-spring assembly, refer to Section 13.6.11.
- ☐ Thermostat, refer to Section 13.6.10.
- ☐ Spark plug wires, refer to Section 13.6.12.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.19 114,000 Miles (183,000 km) Interval Maintenance for Transit Coach

Every 114,000 miles (183,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.7.20 120,000 Miles (193,000 km) Interval Maintenance for Transit Coach

Every 120,000 miles (193,000 km), the following components must be maintained:

- ☐ Fuel filter, element and seal, refer to Section 13.6.1.
- ☐ Coalescing filters, refer to Section 13.6.1.
- ☐ Engine lubricating oil, refer to Section 13.6.5.
- ☐ Engine lubricating oil filter, refer to Section 13.6.6.
- ☐ Turbocharger and wastegate assembly hoses, refer to Section 13.6.8.
- ☐ Dry type air cleaner, refer to Section 13.6.4.
- ☐ Coolant, refer to Section 13.6.7.
- ☐ Crankvent breather filter replaced, refer to Section 13.6.3.

13.8 MAINTENANCE OF SERIES 50G ENGINES FOR GENERATOR SET

Failure to adjust valve lash or replace spark plug ignition boot and spring assemblies when required may result in inefficient engine operation.

Series 50G genset components must be maintained at various intervals.

13.8.1 Daily Maintenance for Genset

The following components must be maintained daily:

- ☐ Lubricating oil, refer to 11.5
- ☐ Oil pressure, refer to 11.5
- ☐ Turbocharger, refer to 13.5.5
- ☐ Drive belts, refer to 13.5.7
- ☐ Fuel lines and hoses, refer to 13.5.3

13.8.2 250 hrs (or 3 months) Interval Maintenance for Genset

Every 250 hrs (or 3 months) the following components must be replaced:

- ☐ Lubricating oil, refer to 11.5
- ☐ Lube oil filter, refer to 13.5.1

13.8.3 1,000 hrs (or 12 months) Interval Maintenance for Genset

Every 1,000 hrs (or 12 months) the following components must be replaced:

- ☐ Air cleaner, refer to 13.5.9

13.8.4 1,500 hrs (or 12 months) Interval Maintenance for Genset

Every 1,500 hrs (or 12 months) the following components must be replaced:

- ☐ Spark plug boots, refer to Section 15.10
- ☐ Spark plugs, refer to Section 15.10

13.8.5 3,800 hrs (or 24 months) Interval Maintenance for Genset

Every 3,800 hrs (or 24 months) the following must be replaced:

- ☐ Coolant, refer to 13.5.4

13.8.6 250 hrs (or 3 months) Interval Maintenance for Genset

Every 250 hrs (or 3 months), the following components must be maintained:

- ☐ Crankcase breather, refer to 13.5.25
- ☐ Drive belts, refer to 13.5.7

- ☐ Air cleaner, refer to 13.5.9
- ☐ Battery, refer to 13.5.6

13.8.7 500 hrs (or 6 months) Interval Maintenance for Genset

Every 500 hrs (or 6 months), the following components must be maintained:

- ☐ Crankcase pressure, refer to 13.5.22
- ☐ Coolant filter/inhibitor, refer to 13.5.4
- ☐ Charge air cooler, refer to 6.7.1
- ☐ Fan hub, refer to 13.5.23

13.8.8 1,000 hrs (or 12 months) Interval Maintenance for Genset

Every 1,000 hrs (or 12 months), the following components must be maintained:

- ☐ Thermostat, refer to 13.5.24
- ☐ PSV valve, refer to 2.38
- ☐ Fuel lines and hoses, refer to 13.5.3
- ☐ Battery charging alternator, refer to 13.5.20
- ☐ Engine and generator mounts, refer to 13.5.21
- ☐ Radiator, refer to 13.5.18
- ☐ Exhaust system, refer to 13.5.16

13.8.9 1,500 hrs (or 12 months) Interval Maintenance for Genset

Every 1,500 hrs (or 12 months), whichever comes first, the following components must be maintained:

- ☐ Spark plug ignition boot and spring assemblies; inspect, refer to 15.12
- ☐ Intake and exhaust valve lash; refer to 12.4

13.8.10 3,800 hrs (or 24 months) Interval Maintenance for Genset

Every 3,800 hrs (or 24 months), the following components must be maintained:

- ☐ Fuel mixer, refer to 2.39
- ☐ Vibration damper, refer to 1.13.2.1

13.9 LUBRICATING OIL AND FILTER CHANGE INTERVALS FOR GENSET

The following must be maintained at various intervals.

13.9.1 250 hrs (or 12 months) Interval Maintenance (Standby Duty)

Every 250 hrs (or 12 months), the following fluids must be replaced for an engine on standby:

- ☐ Lubricating oil, refer to 11.5

13.9.2 250 hrs (or 3 months) Continuous Duty Interval Maintenance (Continuous Duty)

Every 250 hrs (or 3 months), the following must be replaced for a continuous running engine:

- ☐ Lubricating oil, refer to 11.5

13.10 LUBRICATING OIL AND FILTER CHANGE INTERVALS FOR GENSET (WITH HIGH SULFUR FUELS)

The following fluids must be maintained at various intervals.

NOTICE:
Operation with fuels having total sulfur greater than 32 ppm, on a mass basis, may result in engine damage, and is not recommended by Detroit Diesel Corporation.

13.10.1 200 hrs (or 6 months) Interval Maintenance (Standby Duty)

Every 200 hrs (or 6 months), the following must be replaced for an engine on standby:

Fuel with total sulfur greater than 17 ppm, but less than 24 ppm.

- ☐ Lubricating oil, refer to 11.5

13.10.2 200 hrs (or 3 months) Interval Maintenance (Continuous Duty)

Every 200 hrs (or 3 months), the following must be replaced for a continuous running engine:

Fuel with total sulfur greater than 17 ppm, but less than 24 ppm.

- ☐ Lubricating oil, refer to 11.5

13.10.3 150 hrs (or 3 months) Interval Maintenance (Standby Duty)

Every 150 hrs (or 3 months), the following must be replaced for a engine on standby:

Fuel with total sulfur greater than 24 ppm, but less than 32 ppm.

- ☐ Lubricating oil, refer to 11.5

13.10.4 150 hrs (or 3 months) Interval Maintenance (Standby Duty)

Every 150 hrs (or 3 months), the following must be replaced for a engine on standby:

Fuel with total sulfur greater than 24 ppm, but less than 32 ppm.

- ☐ Lubricating oil, refer to 11.5

13.11 DETECTING INTERNAL FUEL LEAKS

Used lube oil analysis can identify a potential source of engine trouble before it occurs. A program such as the Detroit Diesel Oil Analysis Program is recommended for monitoring crankcase oil in all engines. One of the most serious conditions used oil analysis can uncover is the presence of excessive fuel in the lube oil which should not exceed 2.5% maximum of oil volume, reference Detroit Diesel's Publication 7SE270 “Engine Requirements for Lubricating Oil, Fuel and Filters.” While used oil analysis can uncover the presence of excessive fuel in the lube oil, other methods must be used to determine its source. Three particularly effective tests involve the use of special test fuel containing dye additives , the J 37050-A , (on engine) Injector Pop tester, and the J 34760-A Injector Pop-N-Fixture with the J 34760-147A adaptor.

13.11.1 Prepare Test Fuel

The use of J 28431-BFluorescent dye is effective in fuel leak detection and should be the technician's choice in preparing a test fuel mixture. However, if a “Black light“ or fluorescent dye are not available, red LTO 1140 may be substituted.

Prepare Fluorescent Dye J 28431-B as follows:

- □ Mix 118 ml (four ounces) of fluorescent dye additive with 15.1 liters (four gallons) of diesel fuel in a clean container marked with the words “Test Fuel”.

Prepare Red LTO 1140 as follows:

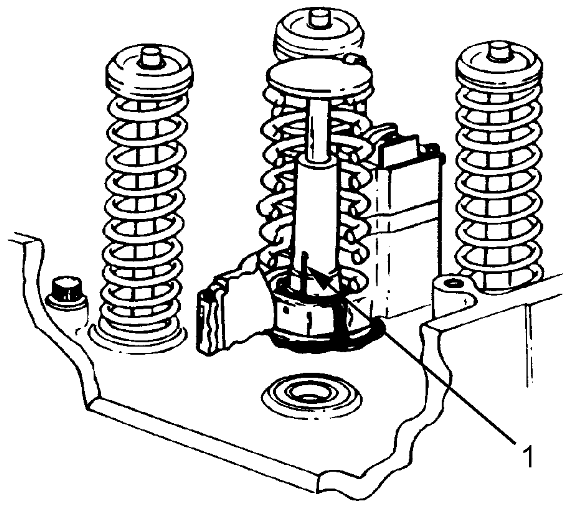
- □ Mix 59 ml (two ounces) of Red LTO 1140 dye additive with 18.9 liters (five gallons) of diesel fuel in a clean container marked with the words “Test Fuel”.

13.11.2 Fuel Leak Tests (Injectors Installed/Engine Off)

To locate a leaking injector the tests below should be completed in the sequence indicated and stopped at a point when the leaking injector is diagnosed. If a leaking injector is found, do not arbitrarily replace more than that injector, as multiple injector malfunctions are rare on the same engine. Multiple injector returns under WARRANTY will require verification by the servicing outlet using the J 34760-A Pop-N-Fixture.

NOTICE:

During fuel pressure testing (engine off, 5 minutes at 50 psi) fuel leakage will be evident at the injector body/plunger spring seat area. See Figure 13-11. Factory tests have shown that accumulation of fuel at each injector, approximately a tablespoon may be evident during these tests. Evidence of fuel in this area is expected, as there is no other place for it to go when the injector cavities are pressurized, forcing fuel between the injector body and plunger.



1. Acceptable Fuel Leakage

Figure 13-11 Acceptable-Fuel Leakage Between Injector Plunger and Body

13.11.3 Fuel Pressure Test

Since there is no known fuel leak tester available in the commercial market today, one must be fabricated. Use the following guidelines to help in fabricating:

- ☐ Although test fuel can be pressurized by variety of methods, Detroit Diesel recommends an air/fuel accumulator design capable of safely withstanding a minimum pressure of 345 kPA (50 psi).
- ☐ The tester should have a capacity of 9.5 liters (2.5 gallons) of test fuel and provide for contamination free storage of the test fuel when not in use.
- ☐ **Regulated** shop air may be used to charge the accumulator tank and maintain a constant test fuel pressure.
- ☐ A shut-off valve should be installed at the accumulator outlet to start and stop pressurization during the test sequence.

CAUTION:

To avoid injury from the sudden release of a high-pressure hose connection, wear a face shield or goggles.

CAUTION:

To avoid injury from tank rupture or a sudden air hose failure, do not use unregulated air pressure or an accumulator tank with an inadequate pressure rating.

Fuel Leak Tester

1. Fill fuel system tester with the fluorescent or red dye fuel mixture approximately 9.5 liters (2.5 gallons).
2. Charge tester (outlet valve closed) with shop air **regulated** at 345 kPA (50 psi) .

Tester hook-up to engine fuel system.

There are two options for fuel tester to engine hook-up as determined by the ease of access.

- ☐ Option 1–Remove the fuel line from the outlet side of the fuel pump and connect the fuel system testers line in this fuel hose fitting. This hook-up location will require the fuel system shut-off valve to remain in the **open** position during testing. About 3.8 liters (1 gallon) of test fuel will be necessary to charge the engine's fuel system from this hook-up location. Test fuel will not harm the engine's fuel filters and may remain in the fuel system at the conclusion of testing.
- ☐ Option 2–Remove the fuel line from the outlet side of the fuel by-pass filter adapter and connect the fuel testers line in this fuel hose fitting. It is recommended that the fuel system shut-off valve be placed in the **closed** position before removing the engine fuel line and remain **closed**until reinstalled. About 1.9 liter (0.5 gallon) of test fuel will be necessary to charge the engine's fuel system from this hook-up location.

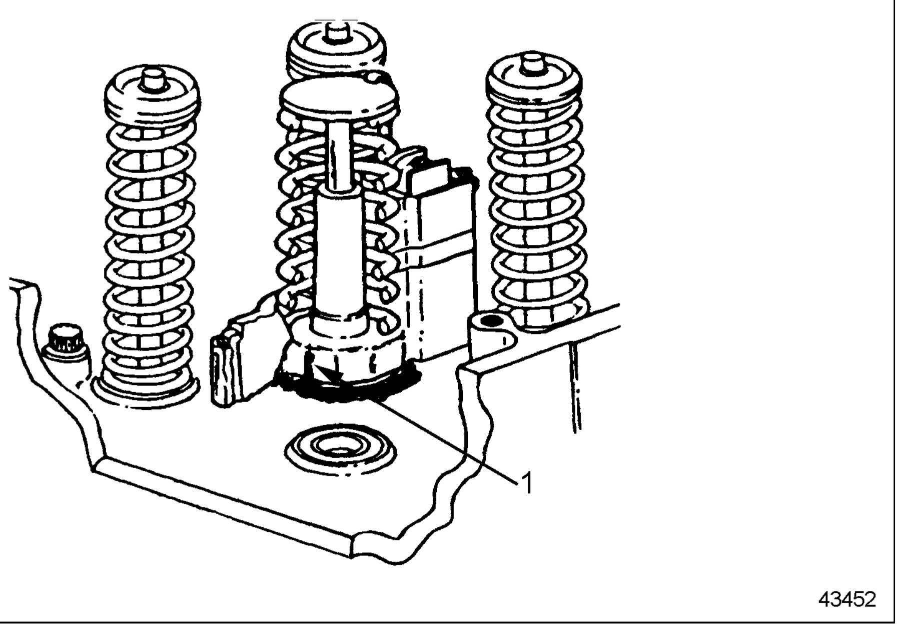
3. Remove rocker cover and disconnect the fuel outlet line at a convenient location between the cylinder head and the fuel tank. Install an appropriate size pipe plug (loose) in the fuel outlet line end and place it in a container to catch the fuel while priming the cylinder head. If equipped, Jake Brakes® should be removed to allow for the visual examination of the injectors during fuel leak testing and if necessary on-engine injector 'Pop' test.
4. Slowly open the fuel tester's shut-off valve and charge the cylinder head fuel galley. When test fuel is flowing from the fuel return line and air has been purged from the system, tighten the pipe plug at the engine fuel outlet line fitting.
5. With the fuel tester shut-off valve completely open and the cylinder head galley pressurized to 345 kPa (50 psi), visually monitor the overhead using a black light for five minutes if the test time goes beyond five minutes it will become more difficult to determine the faulty injector due to expected leakage at the injector plunger/body. Pay special attention to any leaks at the injector body, high and low pressure body

plugs, see Figure 13-12 and see Figure 13-14, injector nut to body and nut to tube seals see Figure 13-13, and stop valve cover see Figure 13-15.

NOTICE:
Injector plunger/body leakage at the follower spring area is normal and expected during this test.

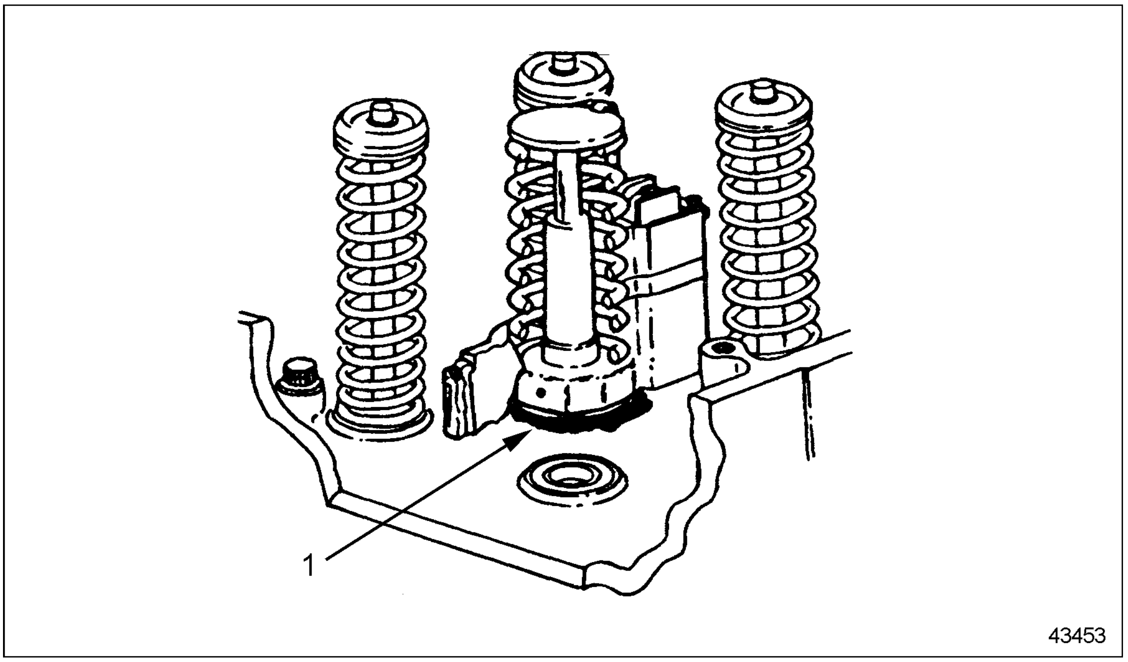
NOTICE:
The figures that follow do not illustrate amount of fuel leakage but rather its origin or location. If injector(s) are removed and reinstalled in the head, the injector nut 'O' ring seals should be replaced with new parts.

NOTICE:
If pressurization testing does not reveal the leaking injector, proceed to section **Injector 'Pop' test (On Engine) with J 37050-A.**



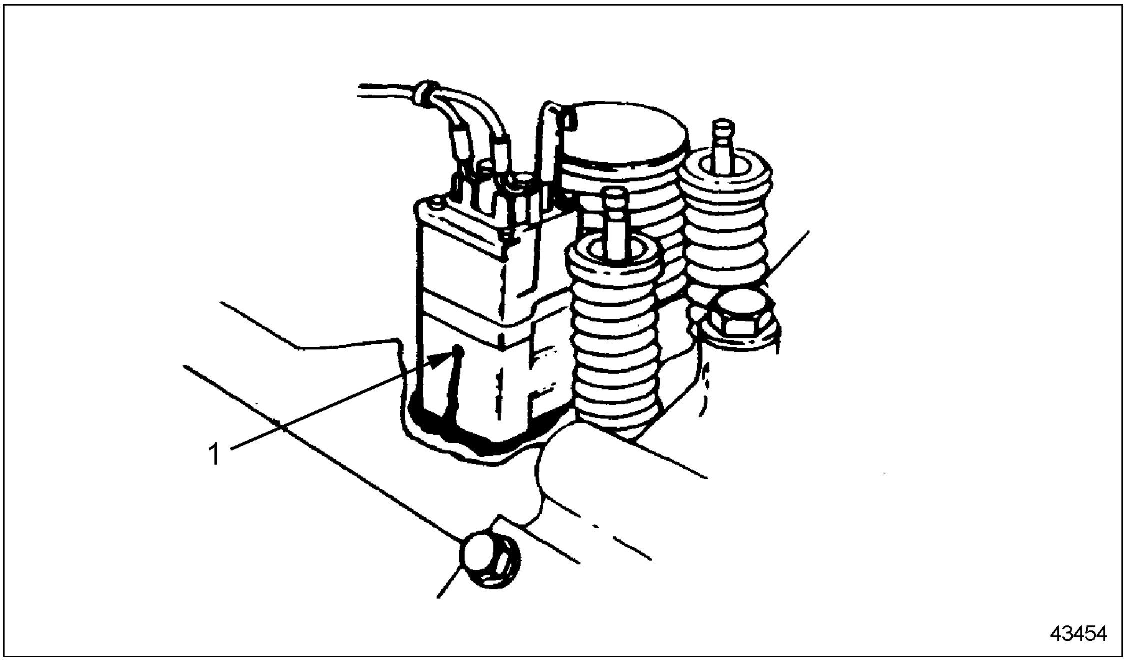
1. Fuel Leakage at low Pressure Body Plug

Figure 13-12 Unacceptable-Fuel Leakage at low Pressure Body Plug



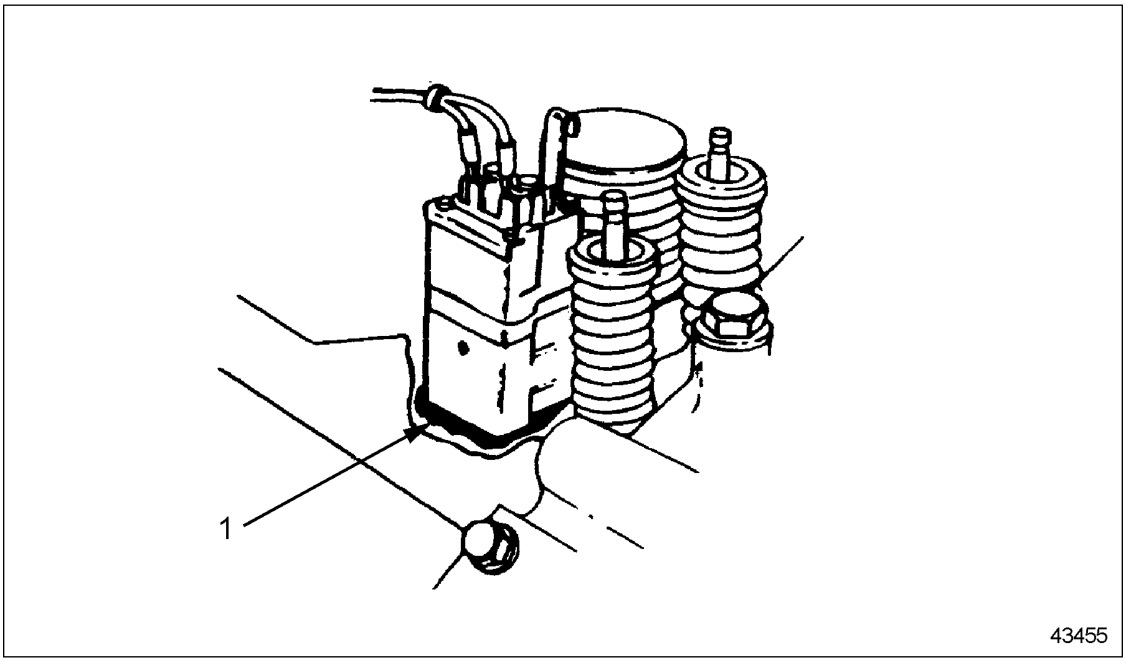
1. Fuel Leakage at Injector Nut-to-Tube 'O' Ring Seal

Figure 13-13 Unacceptable-Fuel Leakage at Injector Nut-to-Tube 'O' Ring Seal



1. Fuel Leakage at High Pressure Body Plug and or Body Crack

Figure 13-14 Unacceptable-Fuel Leakage at High Pressure Body Plug and or Body Crack



1. Fuel Leakage at Injector Stop Valve Cover

Figure 13-15 Unacceptable-Fuel Leakage at Injector Stop Valve Cover

6. Correct the cause of any abnormal fuel leaks.
7. Bleed the pressure from the accumulator tank and remove the pipe plug from the fuel outlet line. Reinstall the fuel outlet line in the engine's fuel system. Disconnect the fuel tester and reinstall the fuel inlet line in the engine's fuel system.
8. Completely open the engine's fuel shut-off valve and assure that all fuel connections are tight. Reinstall the rocker cover and start engine to purge the air from the fuel system. If the engine fails to start, it may be necessary to prime the fuel system.

13.11.4 Injector 'Pop Test (On Engine) With J-37050-A

Perform this test if injector leakage cannot be identified after pressure testing the cylinder head. Energizing and stoking the suspect injector(s) will produce the internal fuel pressures created during engine operation, thus increasing any abnormal fuel leakage. Refer to manufacture's instructions supplied with the J 37050-Atester for set-up procedure.

Perform the following steps for the Injector Pop Test.

1. Wipe down the overhead to remove any test fuel generated from previous testing.
2. Disconnect both 5-way injector harness connectors at the ECM.
3. Connect alligator clips from the tester cable to the EUI. It is not necessary to disconnect the solenoid terminal leads from the EUI engine wiring harness if the 5-way injector harness connectors have been removed from the ECM.

4. Connect power supply clips to the vehicles 12 volt battery. **Red to Positive(+) and Black to Negative(-).**
5. Option 1–Connect remote starter cable to the vehicle starter motor.
6. Option 2–Operate vehicle starter switch from drivers seat in the cab.
7. Depress and hold trigger on tester's pistol grip start button while rotating 'current' control knob clockwise to increase current to the injector solenoid.

NOTICE:
The Letter **'O'** at the left side of the LED amps readout window indicates the injector solenoid is **OPEN, 'C'**indicates **CLOSED**. The pistol grip trigger must be released and depressed for each time the injector solenoid is activated.

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

8. Using the vehicle starter, motor the engine while energizing the injector solenoid. It should only be necessary to cycle the solenoid once or twice to pressurize the injector. Energize only one injector at a time.

NOTICE:
While activating the injector solenoid, cylinder detonation may occur when motoring the engine. This occurrence will not harm the engine. It should be noted again that if the 5-way injector connectors are not disconnected at the ECM, the engine may start.

9. With the vehicle start switch in the **OFF** position or remote starter cable disabled, visually examine each suspect injector for abnormal fuel leakage using a “black light” or look for evidence of red dye if LTO test fuel is used.
10. Repeat the above procedure for each injector being tested.
11. Correct the cause of any abnormal fuel leakage.
12. Refer to **Fuel Leak Tester**, instruction items 7 and 8.

13.11.5 Injector Bench Test with J 34760-A Pop-N-Fixture

If multiple injectors are removed for fuel leakage, each should be bench tested using the J 34760-A Pop-N-Fixture. Fuel leakage may be more easily observed while performing this bench test. Refer to manufacture's instructions supplied with the J 34760-A Pop-N-Fixture for set-up and test procedures.

Wash, wipe down and allow injector to dry before mounting in test fixture. Fuel leakage will be more recognizable by adding fluorescent dye to the fixture's fuel reservoir and using a “black light” to examine the injector during testing.

13.12 CLEANING CONTAMINATED LUBRICATION OIL SYSTEM

When coolant has leaked into the lubrication system, the lubrication system must be thoroughly flushed to avoid or limit damage. Use the flushing procedures outlined below.

13.12.1 Before Flushing

The following steps must be followed before flushing the contaminated lubrication system:

1. Determine the cause of the internal coolant leak, and correct the problem.
2. Thoroughly drain the lubricating oil. Take a representative 6–8 ounce sample of the oil and label it for chemical analysis.
3. Examine the drained oil:
   [a] Follow procedure “A” if the oil is still reasonably fluid, and is typical of the used oil at regular drain intervals.
   [b] Follow procedure “B” if the oil shows a gelling texture.
4. Inspect the main bearing shells.
   [a] If damaged, the engine must be disassembled and checked for any additional damage.
   [b] If not damaged, proceed as follows:
   - Use Procedure A if the oil on the bearing shell(s) is viscous with normal flowing texture.
   - Use Procedure B if the oil on the bearing shell(s) has gelled up, requiring scraping to remove.

13.12.2 Procedure A

Use this procedure if the contaminated lubricating oil is still freely flowing, without gelling. This procedure requires the lubricating oil recommended for normal operation.

CAUTION:

To avoid injury from fire caused by heated lubricating-oil vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if an oil leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves, apron, etc.) to avoid burns.**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Lubricating oil is relatively harmless at ambient temperatures.

1. Remove and discard the oil filter and replace with new filters.
2. Pressure fill the lubricating system to 25 psi (172 kPa) with the lubricating oil recommended for normal operation, ensuring the crankcase is filled to the proper operating level. Refer to section 5.2.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start and run the engine at fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check engine running conditions frequently, especially the oil pressure. Stop immediately if a reading is out of range.
4. Stop the engine and immediately drain the crankcase. Allow enough time to drain all the fluid. Take a second oil sample and label it.
5. Repeat steps 1 through 4.
6. Remove and discard all oil filters and replace with new filters.
7. Replace oil drain plugs and pressure fill the engine to the proper level with the lubricating oil recommended for normal operation.

8. Have the oil samples analyzed for coolant contamination and condition of the engine.

13.12.3 Procedure B

Use this procedure if the contaminated oil exhibits gelling. This procedure requires the lubricating oil recommended for normal operation and the addition of a solvent.

CAUTION:

To avoid injury from fire caused by heated lubricating-oil vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if an oil leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves, apron, etc.) to avoid burns.**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Lubricating oil is relatively harmless at ambient temperatures.

1. Remove and discard all oil filters and replace with new filters.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

2. Mix two parts of the lubricating oil recommended for normal operation with one part of butyl cellosolve. Refer to section 5.2of the service manual for the recommended oil. Pressure fill the engine with this mixture to 25 psi (172 kPa) until the crankcase is filled to the proper operating level.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start and run the engine at fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check engine running conditions frequently, especially oil pressure. Stop immediately if a reading is out of range.
4. Stop the engine and immediately drain the crankcase. Allow enough time to drain all the fluid. Take a second oil sample and label it.
5. Remove and discard all oil filters and replace with new filters.
6. Using fresh charge of the lubricating oil recommended for normal operation, pressure fill the engine via the oil gallery to 25 psi (172 kPa) until the crankcase is filled to the proper operating level.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

7. Start and run the engine at fast idle (1000 to 1200 rpm) for 30 minutes to one hour. Check engine running conditions frequently, especially oil pressure; stop immediately if a reading is out of range.
8. Stop the engine and immediately drain the crankcase. allow enough time to drain all the fluid. Take a third oil sample and label it.
9. Remove and discard all oil filters and replace with new filters.
10. Replace oil drain plugs and pressure fill the engine to the proper level with the lubricating oil recommended for normal operation.

11. Have oil samples analyzed for coolant contamination and condition of the engine.

This procedure should flush all coolant contamination from the lubrication system. However, a thin coating from the coolant may still be evident on certain moving engine parts. This coating should disappear within one or two oil changes, due to the detergent and dispersant additives in the engine oil.

NOTE:
The next oil change should be at one-half the normal oil change interval. Ensure that new filters are installed, and that an oil sample is analyzed for coolant contamination and condition of the engine.

14 ENGINE STORAGE

Section **Page**

14.1 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 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 that 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.

14.1.1 Temporary Storage (30 Days or Less)

To protect an engine for a temporary period of 30 days or less, proceed as follows:

1. Drain the engine crankcase. Refer to Section 13.5.1.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil listed in Table 14-2.
3. Fill the fuel tank with the recommended grade of fuel oil listed in Table 14-3. Operate the engine for two minutes at 1200 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. Refer to OEM guidelines.
5. If freezing weather is expected during the temporary storage period, add an ethylene glycol base antifreeze solution to the cooling system in accordance with the manufacturer's recommendations. Otherwise, the coolant system should be flushed and filled with a good rust inhibitor to prevent rusting of the outside diameter of the cylinder liners. Refer to Section 13.5.4.
6. Remove electrical components. Refer to Section 8.
7. Clean the engine exterior of the engine (except electrical components) with fuel oil.
8. Seal all of the engine openings with a material used for this purpose. The material used for sealing must be waterproof, vapor proof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

14.1.2 Restoring a Temporarily Stored Engine

An engine that was stored in accordance with the DDC guidelines for temporary storage can be returned to service in a short time by removing the seals at the engine openings and by checking the engine coolant, fuel oil, lubricating oil and transmission oil levels. (Refer to Section 14.1.1.)

14.1.3 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. Refer to Section 13.5.4.
2. Flush with clean, soft water. Refer to Section 13.5.4.
3. Refill with clean, soft water and add a rust inhibitor to the cooling system. Refer to Section 5.4.
4. Circulate the coolant by operating the engine until normal operating temperature is reached, listed in Table 14-1.

Cooling System Parameters	Normal Range for 2100 r/min Operation	Normal Range for 1800 r/min Operation
Coolant temperature normal - °C (°F)	88 (190)	88 (190)
Coolant inlet restriction, maximum-kPa (in. Hg)	0.0 (0.0)	0.0 (0.0)
Engine coolant capacity-liters (quarts)	23 (24)	23 (24)
Minimum pressure cap-kPa (lb/in.^{2})	48.3 (7)	48.3 (7)
Maximum top tank temperature- °C (°F)	99 (210)	99 (210)
Minimum top tank temperature- °C (°F)	71 (160)	71 (160)
Thermostats start to open- °C (°F)	88 (190)	88 (190)
Thermostats are fully open- °C (°F)	96 (205)	96 (205)

Table 14-1 Series 50 Operating Conditions

5. Stop the engine.
6. Remove the drain plug to drain the engine crankcase. Refer to Section 13.5.1.
7. Install and tighten the 3/4 in.-14 square, magnetic oil drain plug to 45-56 N·m (33-41 lb·ft) torque.
8. Install new lubricating oil filters. Refer to Section 13.5.1.
9. Fill the crankcase to the proper level with a 30-weight preservative lubricating oil MIL-L-21260C, Grade 2. Refer to Section 13.5.1.
10. Drain the fuel tank. Refer to Section 13.5.2.

11. 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, use a separate, portable supply of recommended fuel.

NOTE:
If engines in vehicles are stored where condensation of water in the fuel tank may be a problem, supplemental additives containing methyl carbitol or butyl cellusolve are effective. Follow the manufacturer's instructions for their use. The use of isopropyl alcohol is no longer recommended due to its negative effect on fuel lubricity.

NOTE:
In environments where microbe growth is a problem, a fungicide such as Biobor JF (or equivalent) may be used. Microbial activity may be confirmed with commercially available test kits. Follow the manufacturer's instructions for treatment. Avoid the use of fungicides containing halogenated compounds, since these may cause fuel system corrosion.

12. Drain the fuel system. Refer to Section 13.5.2.
13. Remove the fuel filters. Refer to Section 2.7.1.
14. Discard the used filters.
15. Fill new filters with No. 1 diesel fuel or pure kerosene.
16. Install new oil filters on the engine. Refer to Section 13.5.1.
17. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine. Ensure the engine fuel system is full.
18. Disconnect the fuel return line and the inlet line at the primary filter and securely plug both to retain the fuel in the engine. Refer to Section 13.5.3.
19. Service the air cleaner. Refer to Section 13.5.9.
20. To prepare the transmission, power take-off and turbocharger:
    [a] Follow the manufacturer's recommendations for prolonged storage to store the transmission.
    [b] Follow the manufacturer's recommendations for prolonged storage to store the power take-off.
    [c] Since turbocharger bearings are pressure lubricated through the external oil line leading from the oil filter adaptor 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.

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.

21. Apply a non-friction rust preventive compound to all exposed engine 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.
22. Drain the engine cooling system. Refer to Section 13.5.4.
23. Drain the preservative oil from the engine crankcase. Reinstall and tighten the 3/4 in.-14 square, magnetic drain plug to 45-56 N·m (33-41 lb·ft) torque.
24. Remove and clean the battery and battery cables with a baking soda-water solution and rinse with fresh water. Do not allow the soda solution to enter the battery.
25. Add distilled water to the electrolyte (if necessary) and fully charge the battery.

NOTICE:
Never store a battery in a place below 0°C (32°F).

26. Store the battery in a cool, dry place. Keep the battery fully charged and check the level and specific gravity of the electrolyte regularly.
27. Insert heavy paper strips between the pulleys and drive belts to prevent sticking.
28. Seal all engine openings including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.
29. 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.
30. 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.

NOTE:
Plastic may be used for indoor storage.

14.1.4 Outdoor Storage (30 Days or Less)

In some cases outdoor storage may be unavoidable.

NOTE:
Outdoor storage of engines is not recommended.

If units must be kept out-of-doors. Refer to Section 14.1.5.

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.

Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

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.

14.1.5 Outdoor Storage (More Than 30 Days)

In some cases outdoor storage may be unavoidable.

NOTE:
Outdoor storage of engines is not recommended.

If units must be kept out-of-doors. Refer to Section 14.1.3.

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.

Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

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.

14.2 RESTORING AN EXTENDED STORAGE ENGINE

Use the following procedure to restore an engine that 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. Remove the plugs from the inlet and outlet fuel lines and connect the lines to their proper position.
3. Wash the exterior of the engine with fuel oil to remove the rust preventive. (Do NOT wash electrical components.)
4. Remove the rust preventive from the flywheel.
5. Remove the paper strips from between the pulleys and drive belts.
6. Fill the crankcase to the proper level, with the recommended grade of lubricating oil listed in Table 14-2. Use a pressure lubricator to insure all bearings and rocker shafts are oiled.

Specification	Recommendation
SAE Viscosity Grade	15W-40
API Classification	CG-4
Military Specification	MIL-L-2104E
HT/HS Viscosity	3.7 cP (minimum)

Table 14-2 Recommended Engine Oil

7. Fill the fuel tank with one of the fuels listed in Table 14-3.

General Fuel Classification	ASTM Test	No. 1 ASTM 1-D	No. 2 ASTM 2-D
Gravity, °API (Not Specified in ASTM D 975)	D 287	40-44	33-37
Flash Point, Minimum- °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 (Not Specified in ASTM D 975)	D 2500	‡	‡
Sulfur Content, Maximum-wt%	D 129	0.05* (0.5 †)	0.05* (0.5 †)
Carbon Residue on 10%, Maximum-wt%,	D 524	0.15	0.35
Accelerated Stability, Total Insolubles, Maximum-mg/100 mL	D 2274	1.5	1.5
Ash, Maximum-wt %	D 482	0.01	0.01
Cetane Number, Minimum (Differs from ASTM D 975)	D 613	45	45
Distillation Temperature, °F (° C)	ASTM Test	No. 1 ASTM 1-D	No. 2 ASTM 2-D
IBP, Typical (Not Specified in ASTM D 975)	D 86	350 (177)	375 (191)
10% Typical (Not Specified in ASTM D 975)	D 86	385 (196)	430 (221)
50% Typical (Not Specified in ASTM D 975)	D 86	425 (218)	510 (256)
90% Maximum (Differs from ASTM D 975)	D 86	500 (260)	625 (329)
End Point, Maximum (Not Specified in ASTM D 975)	D 86	550 (288)	675 (357)
Water & Sediment, Maximum wt%	D 1796	0.05	0.05

* U.S. on-highway requirement

† Nondramatic and off-highway applications only

‡ The cloud point should be 10°F (-12°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by crystals.

Table 14-3 Fuel Oil Selection Chart

8. Close all of the drain cocks and fill the engine cooling system with clean soft water and proper inhibitors. Refer to Section 13.5.4. If the engine is to be exposed to freezing

temperatures, fill the cooling system with an ethylene glycol base antifreeze solution. Refer to Section 5.4.1.1.

9. Install and connect the battery. Ensure that the average specific gravity of the battery is 1.265 or higher. Refer to Section 11.1.8. Charge the battery if necessary.
10. Perform the following:
    - [a] Keep the air cleaner housing tight on the air intake pipe.
    - [b] Ensure the correct filter replacement is used.
    - [c] Keep the air cleaner properly assembled so the joints are strictly air tight.
    - [d] Repair any damage to the air cleaner or related parts immediately.
    - [e] Inspect and clean or replace the air cleaner elements as operating conditions warrant.
    - [f] 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.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

    - [g] If a foam or fabric air cleaner element soaked with sticky dirt-holding substance was previously installed, check for the presence of coated engine components. Remove and clean them with a suitable solvent, as required, and blow dry with compressed air.
11. Follow the manufacturer's recommendations covering the return of the transmission to service.
12. Follow the manufacturer's recommendations covering the return of the power take-off to service.
13. Remove the covers from the turbocharger air inlet and turbine outlet connections. Prelube the turbocharger. Refer to Section 6.5.7.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

14. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause smoky exhaust for a few minutes.

NOTE:
Before subjecting the engine to a load or high speed, it is advisable to allow the engine to reach normal operating temperature. Then, monitor the DDEC Diagnostic Data Link for fault codes.

15 IGNITION SYSTEM

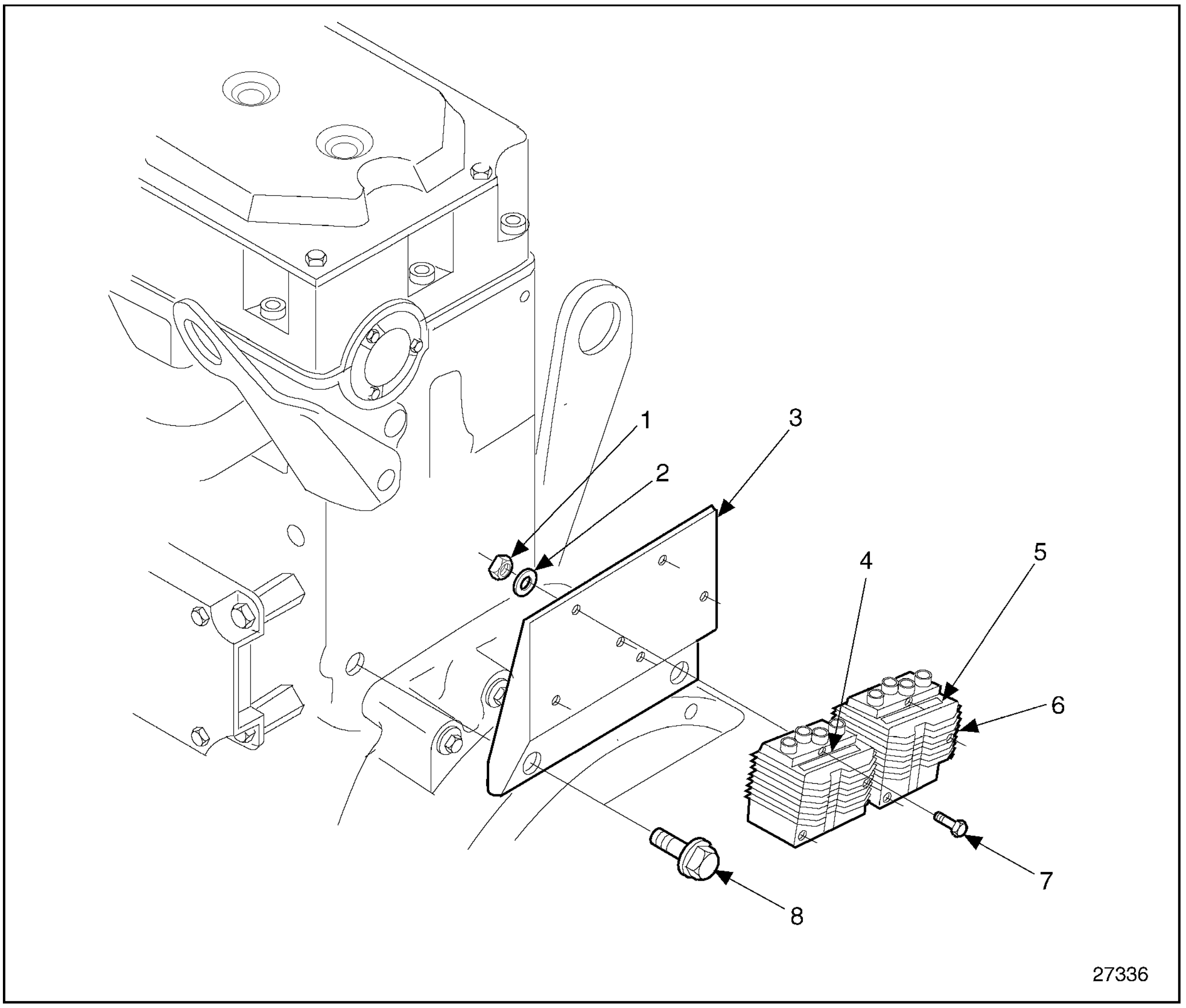
Section **Page**

15.1 OVERVIEW OF IGNITION SYSTEM

The Series 50G engine uses a distributorless ignition system (DIS) to initiate combustion and to control combustion timing. The ECM controls dwell time as a function of supply voltage and ignition timing for all speeds and load conditions. The spark event is controlled based on a magnetic pick-up on the crankshaft so it is not necessary to adjust ignition timing.

15.2 REMOTE MOUNT IGNITION COILS

Series 50G engines produced prior to July 1996 used remote mount ignition coils. This system consists of a coil bracket, two coil packs, an ignition wire harness, an ignition wire bracket, a waste spark harness, an ignition coil harness, and four spark plugs. Each coil mounts to coil bracket by three 1/4 20 x 2.5 in. screws. The coil bracket mounts to the cylinder head by two M12 x 1.75 x 30 metric bolts. See Figure 15-1.



1. Nut
2. Lockwasher (1/4)
3. Ignition Coil Mounting Bracket
4. Left Coil Label
5. Right Coil Label
6. Ignition Coil Pack (2)
7. Bolts (1/4 20 x 2.5 in.)
8. Bolt (M12 x 1.75 x 30 in.)

Figure 15-1 Remote Mount Ignition Coils

15.2.1 Removal of Ignition Coil Bracket

Remove the ignition coil bracket as follows:

1. Unplug the ignition wire harness connectors from the ignition coil packs.
2. Unplug the waste wire harness connectors from the ignition coil packs.
3. Disconnect the ignition coil harness from the ignition coil packs.
4. Remove the two M12 x 1.75 x 30 mounting bolts.
5. Inspect the coil bracket. Refer to Section 15.2.1.1.

15.2.1.1 Inspection of Coil Bracket

Inspect the coil assembly as follows:

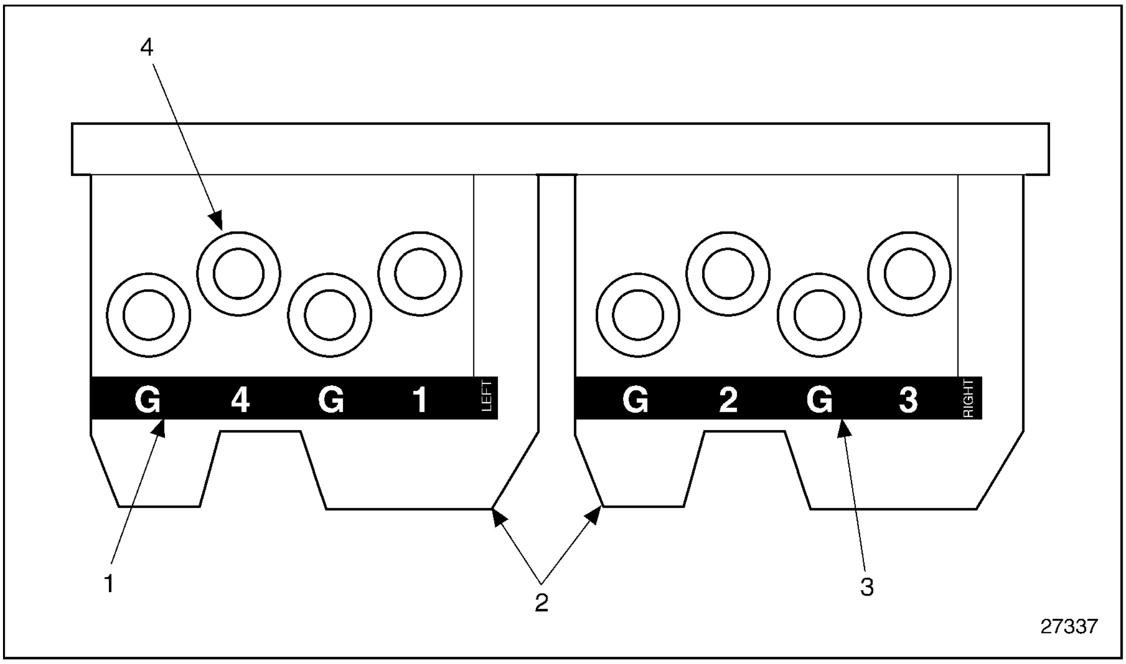
1. Visually check the coils for damage.
   [a] If damage is found. replace coils as necessary. Refer to Section 15.2.2.
   [b] If no damage is found, reuse the coils. Refer to Section 15.2.2.
2. Visually check the coil towers and electrical connectors for dirt, debris, and oil.
   [a] If contamination is found, clean as necessary and apply a light film of dielectric grease on the inside lip of each ignition wire and waste gate wire connector. Reuse component. Refer to Section 15.2.2.
   [b] If no contamination is found, reuse and apply a light film of dielectric grease on the inside lip of each ignition wire and waste gate wire connector. Reuse component. Refer to Section 15.2.2.
3. Visually check the coil bracket for damage.
   [a] If damage is found, replace the bracket. Refer to Section 15.2.2.
   [b] If no damage is found, reuse the bracket. Refer to Section 15.2.2.

15.2.2 Installation of Coil Brackets

Install the coil bracket as follows:

1. Install the bracket to the cylinder head with two M12 x 1.75 x 30 mounting bolts. Torque to 100-126 N·m (74-93 lb·ft). See Figure 15-1.

2. Press the ignition wire harness connectors on the coil towers corresponding to the cylinder positions indicated on the label. See Figure 15-2.



1. Left Label
2. Ignition Coil Packs
3. Right Label
4. Coil Towers

Figure 15-2 Ignition Coil Pack Label Location

NOTE:
Ensure that each connector is fully seated on the coil tower.

3. Press the waste wire harness connectors on the coil towers corresponding to the letter "G" (indicating a ground position). Position the longest lead of the harness on the left most ground tower, and the remaining leads in order of their length.
4. Press the ignition coil harness into the connectors in the ignition coil packs.

15.2.3 Removal of Ignition Coil Pack

Remove the ignition coil pack as follows:

1. Remove the ignition coil bracket. Refer to Section 15.2.1.
2. Remove the three 1/4 20 x 2.5 in. bolts, nuts, and lockwashers per ignition coil packs.

15.2.3.1 Cleaning of Coil Packs

Clean the coil packs as follows:

1. Remove dirt, debris, and oil using clean fuel oil.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry parts with compressed air.
3. Inspect the coil packs. Refer to Section 15.2.3.2.

15.2.3.2 Inspection of Coil Pack

Inspect the coil packs as follows:

1. Visually check the coil packs for damage.
   [a] If damage is found, replace as necessary. Refer to Section 15.2.4.
   [b] If no damage is found, reuse the coil packs. Refer to Section 15.2.4.

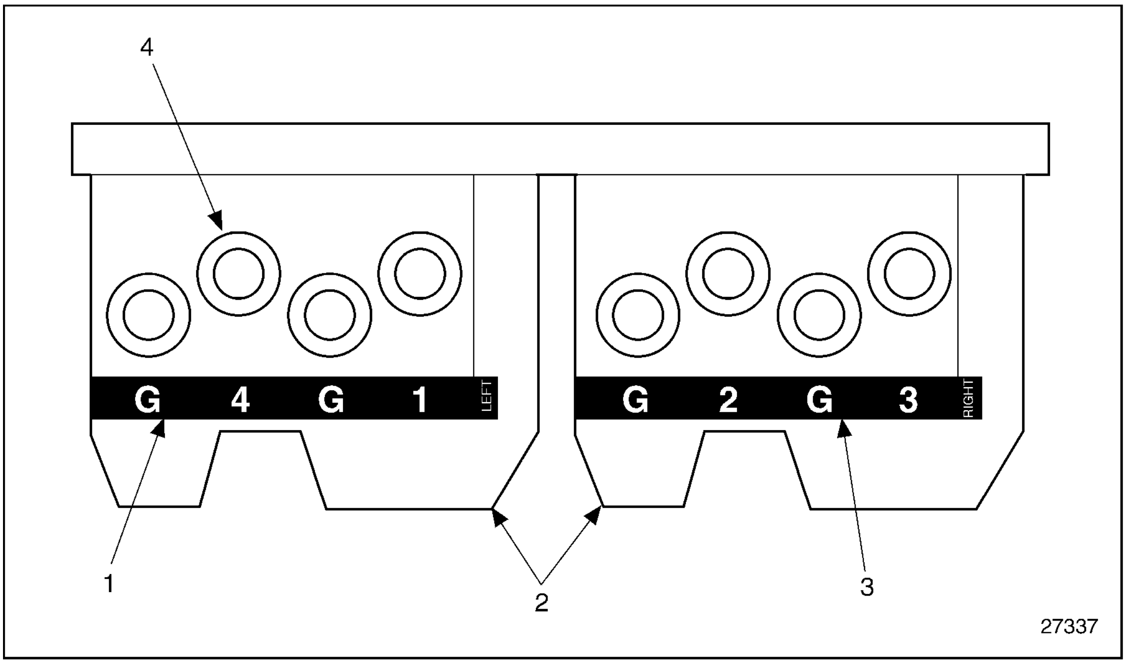
15.2.4 Installation of Coil Packs

Install coil packs as follows:

1. Apply a light film of dielectric grease on the mounting face of the coil pack.
2. Install the ignition coil pack on the coil bracket with three 1/4 20 x 2.5 in. bolts, nuts, and lockwashers per coil pack. Torque bolts to 9-12 N·m (7-9 lb·ft).

3. Install the coil bracket to the cylinder head. Refer to Section 15.2.2.

NOTE:
If a new ignition coil pack is being installed. Attach either a left or right label on the new coil pack corresponding to the position of the coil pack on the engine. See Figure 15-3.



1. Left Label
2. Ignition Coil Packs
3. Right Label
4. Coil Towers

Figure 15-3 Ignition Coil Pack Label Location

15.3 IGNITION WIRE HARNESS

The ignition wire harness conducts high voltage electricity from the ignition coil packs to the spark plugs. Current shunts can occur if any component in the system is damaged, or if the interface between the ignition boot and the spark plug is dirty or oily.

NOTICE:
Do not allow the spark plug wires to contact any engine or vehicle component which would cause rubbing on the insulation during engine operation. Contact with engine or vehicle can cause damage to the spark plug wires.

NOTICE:
Do not allow spark wires to kink during handling. Kinking of spark plug wires can cause damage.

NOTICE:
Do not allow spark plug boot or spark plug wire contact with engine oil. Exposure to engine oil can cause damage.

15.3.1 Removal of Ignition Wire Harness

Remove the ignition wire harness as follows:

1. Pull ignition harness terminals from the ignition coil at the coil towers.
2. Rotate the boot at the rocker cover until the boot slots clear the retainer tangs.
3. Pull the boot straight up and out of the spark plug wells.
4. Inspect the ignition wire harness. Refer to Section 15.3.1.1.

15.3.1.1 Inspection of Ignition Wire Harness

Inspect the ignition wire harness as follows:

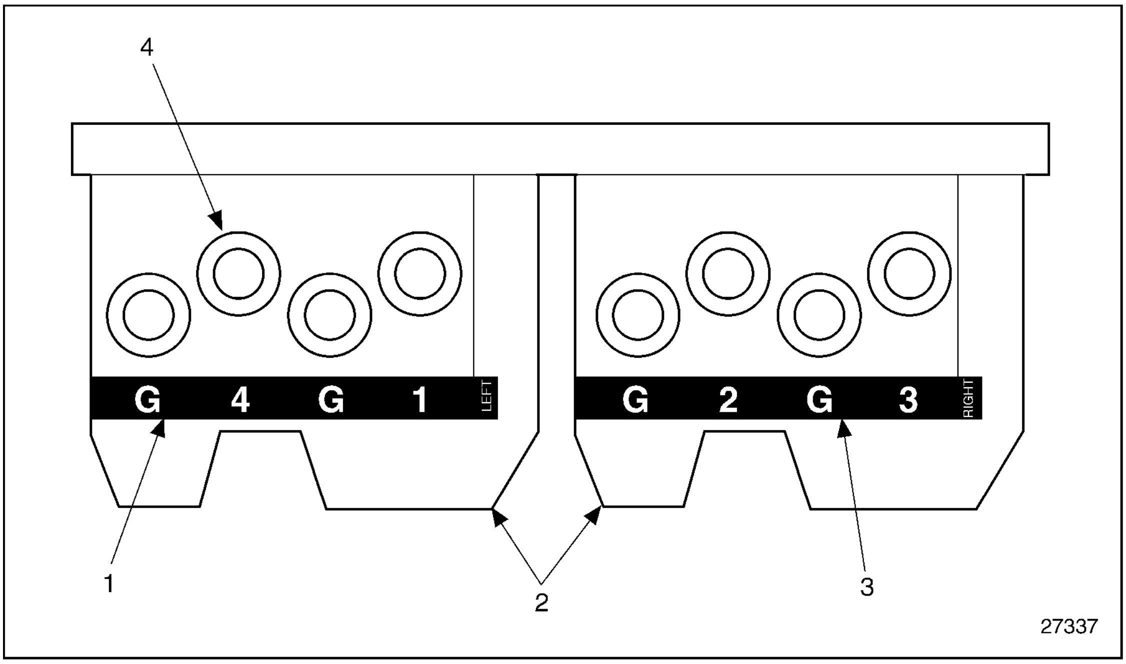
1. Visually check the ignition wire harness for cracks in the insulation or areas where the insulation has been damaged.
   [a] If damage is found, replace as necessary.
   [b] If no damage is found, reuse the ignition wire harness.
2. Visually check the ignition wire harness for dirt, debris, and engine oil.
   [a] If contamination is found, clean as necessary and apply a light coat of dielectric grease to the inside of the ignition boot where it contacts the spark plug. Reuse component. Refer to Section 15.3.2.

[b] If no contamination is found, reuse the ignition wire harness and apply a light coat of dielectric grease to the inside of the ignition boot where it contacts the spark plug. Refer to Section 15.3.2.

15.3.2 Installation of Ignition Wire Harness

Install the ignition wire harness as follows:

1. Insert the spark plug boot onto the spark plug and ensure that the slots clear the retainer tangs.
2. Rotate the spark plug boot into position.
3. Press the ignition wire harness connectors on the coil towers corresponding to the cylinder positions indicated on the label. Ensure that each connector is properly seated on the coil tower. See Figure 15-4.



1. Left Label
2. Ignition Coil Packs
3. Right Label
4. Coil Towers

Figure 15-4 Ignition Wire Harness and Waste Harness Connector Location

15.4 WASTE WIRE HARNESS

The waste wire harness completes the high voltage electrical circuit for each ignition coil by grounding the towers that would otherwise be the waste spark side of an automotive DIS ignition system. The harness is subject to the same damage from contamination, abrasions on the insulation, and mishandling as the ignition wires.

NOTICE:
Do not allow the spark plug wires to contact any engine or vehicle component which would cause rubbing on the insulation during engine operation. Contact with engine or vehicle can cause damage to the spark plug wires.

NOTICE:
Do not allow spark wires to kink during handling. Kinking of spark plug wires can cause damage.

NOTICE:
Do not allow spark plug boot or spark plug wire to come in contact with engine oil. Exposure to engine oil can cause damage.

15.4.1 Removal of Waste Wire Harness

Remove the waste wire harness as follows:

1. Pull the waste wire harness connectors from the ignition coil at the coil towers.
2. Remove the M8 x 1.25 x 14 bolt holding the harness terminal to the cylinder head.
3. Inspect the waste wire harness. Refer to Section 15.4.1.1.

15.4.1.1 Inspection of Waste Wire Harness

Inspect the waste wire harness as follows:

1. Visually check the waste wire harness for cracks in the insulation or areas where the insulation has been damaged.
   [a] If damage is found, replace as necessary.
   [b] If no damage is found, reuse the waste wire harness.
2. Visually check the waste wire harness for dirt, debris, and engine oil.
   [a] If contamination is found, clean as necessary and apply a light coat of dielectric grease to the inside of the ignition wire connector. Refer to Section 15.4.2.
   [b] If no contamination is found, reuse the waste wire harness and apply a light coat of dielectric grease to the inside of each waste wire connector. Refer to Section 15.4.2.

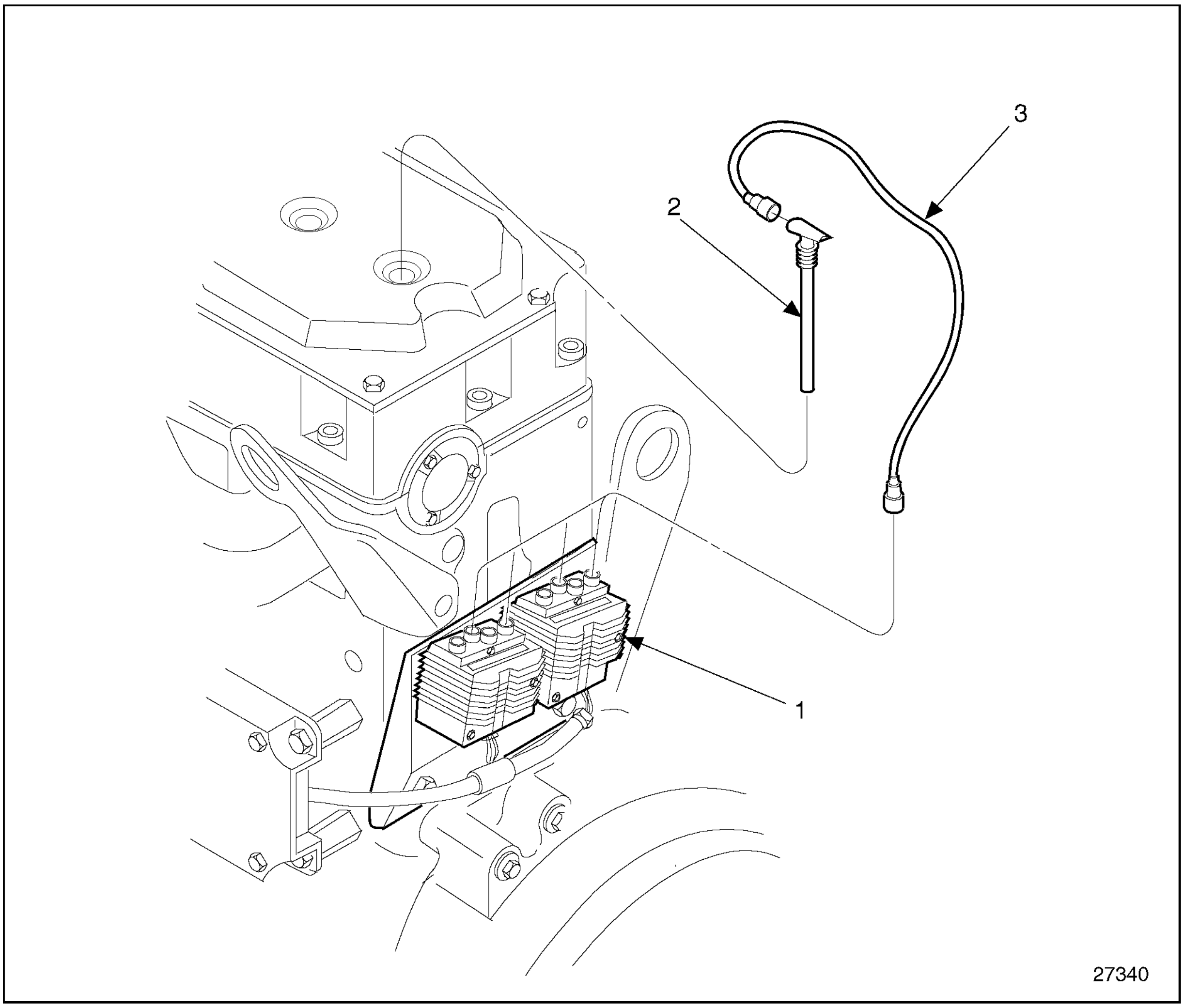
15.4.2 Installation of Waste Wire Harness

Install the waste wire harness as follows:

1. Press the waste wire harness connectors on the coil towers corresponding to the letter "G" (indicating a ground position). Install the longest lead of the harness on the left most ground wire, and the remaining leads in order of their length.
2. Attach the waste wire terminal to the cylinder head with the M8 x 1.25 x 14 bolt. Include the ignition wire bracket if the right side ignition wire routing is used in this installation. Torque the M8 bolt to 30-38 N·m (22-28 lb·ft).

15.5 IGNITION BOOT

The ignition boot can be removed from the ignition wire harness and is serviced separately. See Figure 15-5.



1. Ignition Coil Pack (2)
2. Ignition Boot
3. Ignition Wire

Figure 15-5 Ignition boot

15.5.1 Removal of Ignition Boot

Remove the ignition boot as follows:

NOTE:
Replace the ignition boot if it is torn or softened by heat or oil from the spark plug well.

1. Pull the ignition wire from the boot.
2. Remove ignition boot from ignition wire, if necessary. Discard boot.

15.5.1.1 Inspection of Ignition Boot

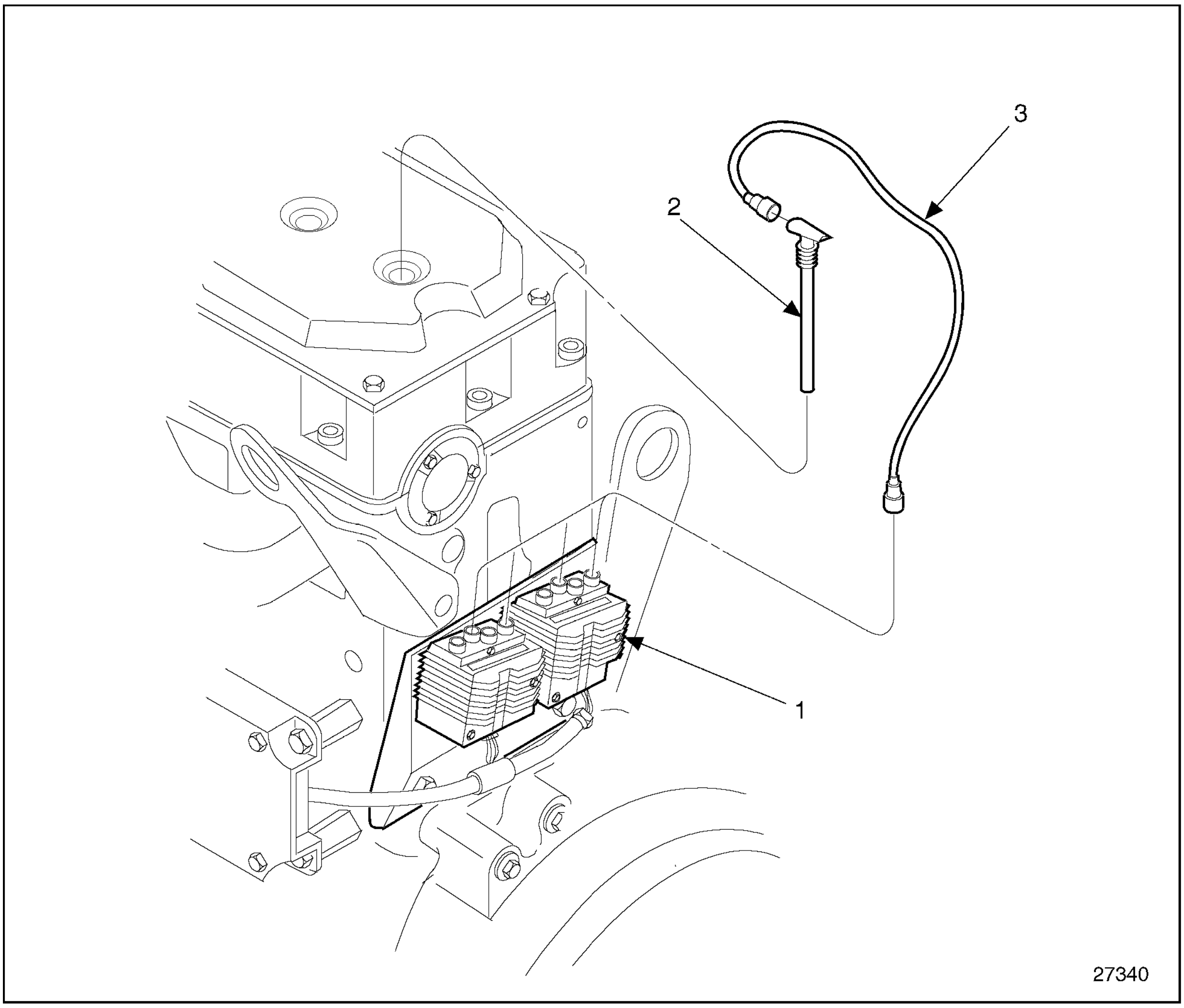
Inspect the ignition boot as follows:

1. Visually check the ignition boot for softened rubber and oil.
   [a] If damage is found, replace ignition boot as required and apply a light coat of dielectric grease to the inside of the ignition boot where it contacts the spark plug. Refer to Section 15.5.2.
   [b] If damage is not found, reuse ignition boot and apply a light coat of dielectric grease to the inside of the ignition boot where it contacts the spark plug. Refer to Section 15.5.2.

15.5.2 Installation of Ignition Boot

Install ignition boot as follows:

1. Install a new ignition boot to the ignition wire. See Figure 15-6.



1. Ignition Coil Pack (2)
2. Ignition Boot
3. Ignition Wire

Figure 15-6 Ignition Boot

NOTE:
The new boot already has a light coating of dielectric grease inside of it.

15.6 IGNITION WIRE AND WASTE WIRE ROUTING

There are two routing patterns for the ignition wire and waste wire harness depending on the installation. Each routing has different coil bracket, ignition wire harness, ignition wire bracket, and ignition boot retainer. One routing has the coil packs vertical and the ignition wires extend over the left side of the engine. The waste wire terminal mounts the cylinder head and points upward with this routing. The other has the coil packs tipped to the right and the ignition wire extends over the right side of the engine. The waste wire terminal mounts the cylinder head pointing downward 45 from the horizontal. See Figure 15-7.

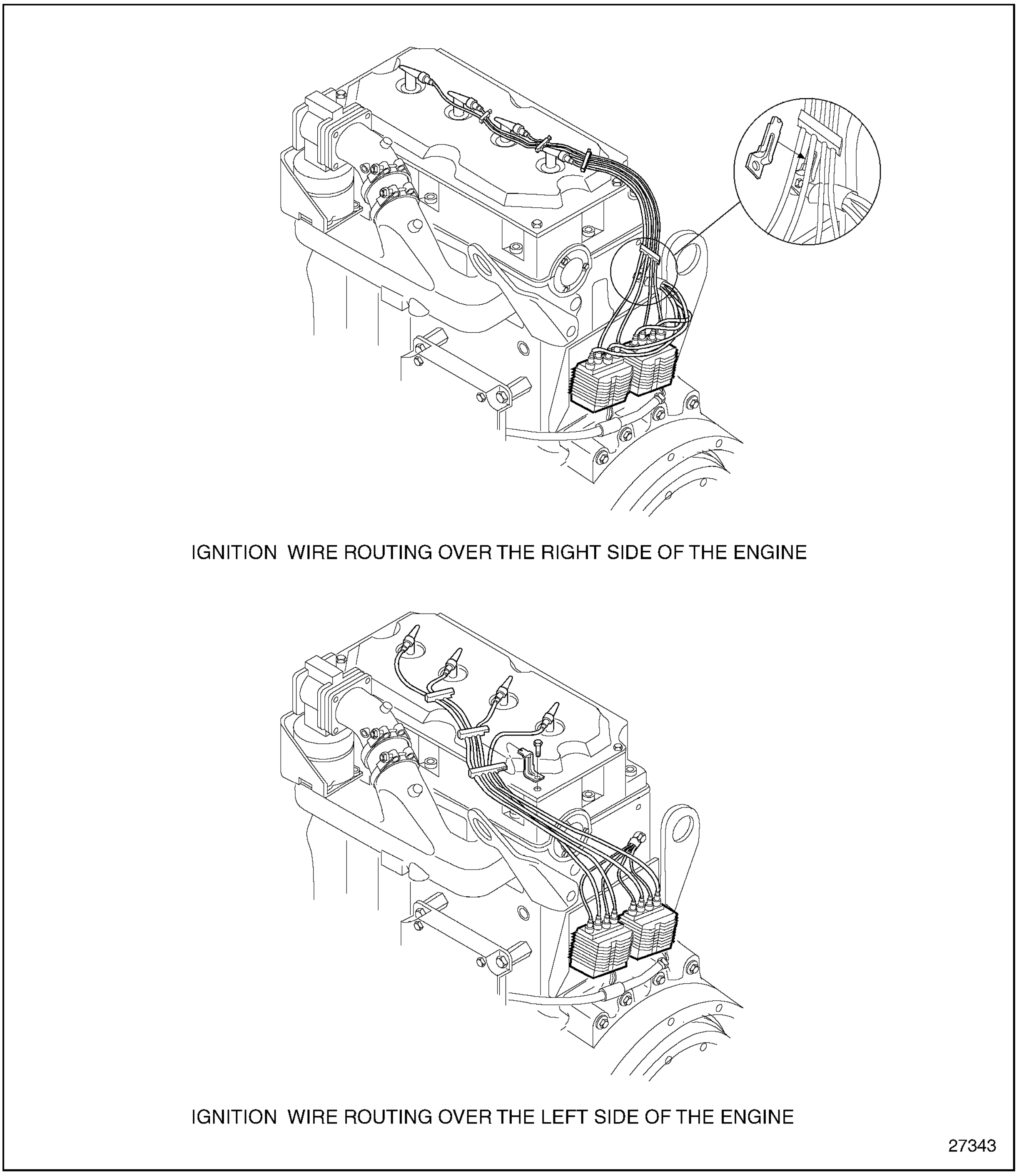


Figure 15-7 Ignition Wire and Waste Wire Routing

15.7 IGNITION WIRE BRACKETS

The ignition wire brackets hold the ignition wires away from the engine and help prevent them from being damaged by abrasion that will occur if they contact other engine components. See Figure 15-8.

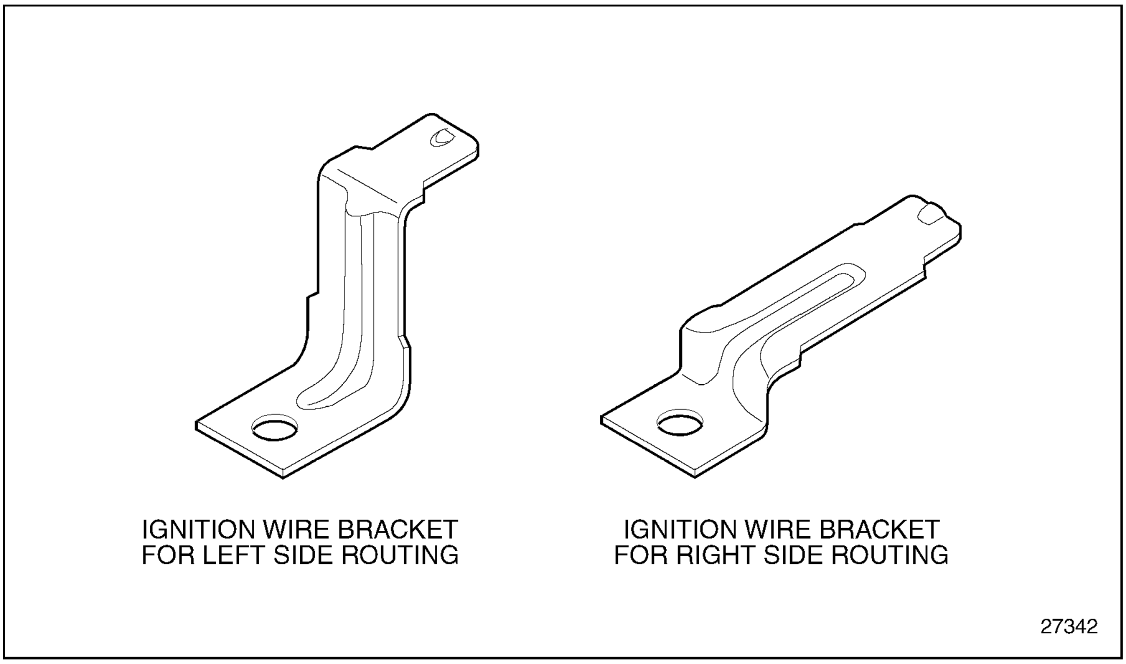


Figure 15-8 Ignition Wire Bracket

The bracket for the routing extending over the left side of the engine mounts to the top left rear corner of the rocker cover using the upper rocker cover mounting bolt. See Figure 15-9.

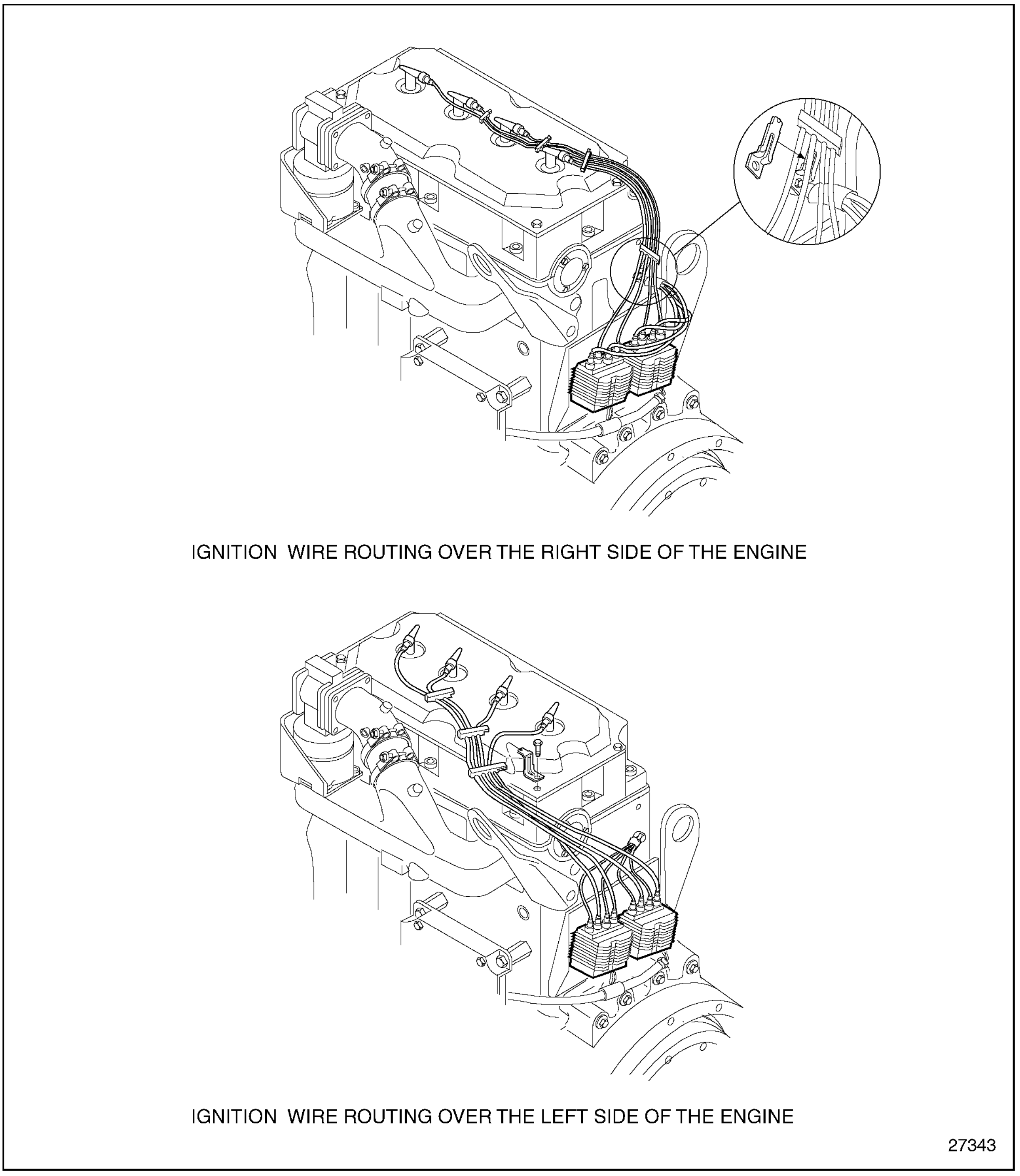


Figure 15-9 Rear Mount Ignition Wire Bracket

The bracket for the routing extending over the right side of the engine mounts to the same bolt on the rear of the cylinder head as the waste wire harness.

15.8 IGNITION BOOT RETAINERS

There are two designs of ignition boot retainers used with the remote ignition coil. See Figure 15-10.

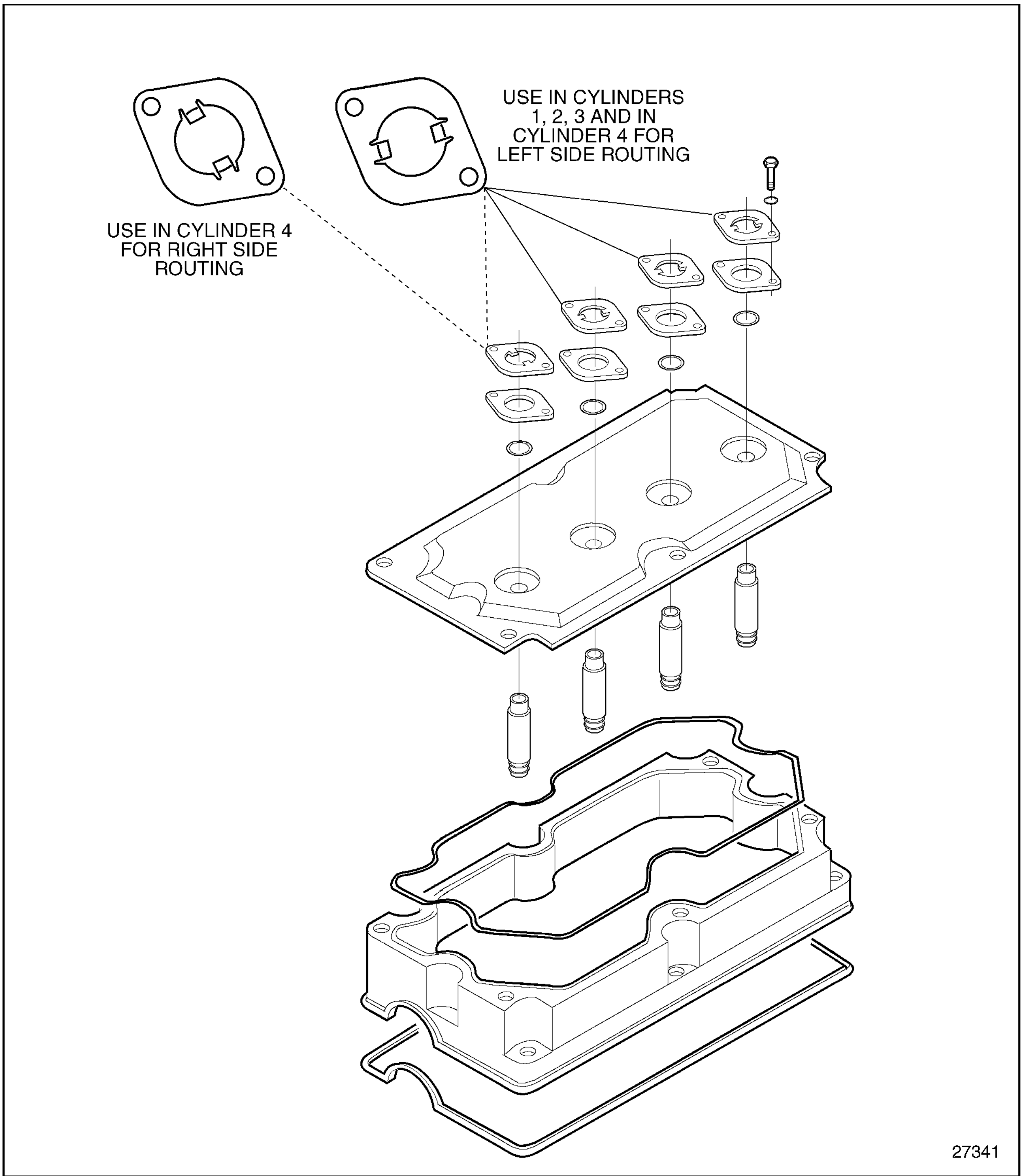


Figure 15-10 Ignition Boot Retainer

15.9 IGNITION COIL HARNESS

The ignition coil harness provides the 12 volt power to the ignition coils and transmits the command signals from the ECM to the coil packs. See Figure 15-11.

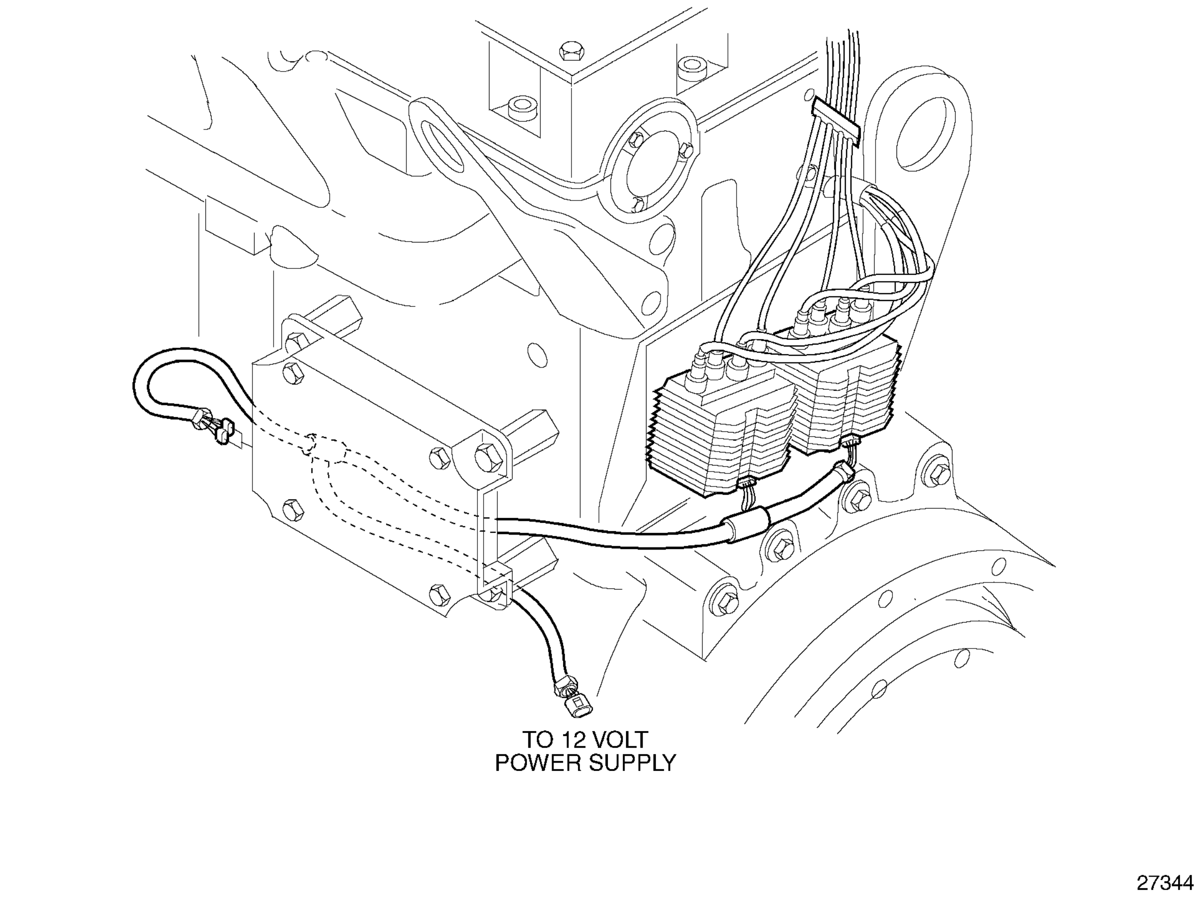


Figure 15-11 Ignition Coil Harness Location

15.9.1 Removal of Ignition Coil Harness

Remove the ignition coil harness as follows:

1. Pull the connectors of the ignition coil harness from the two coil packs.
2. Disconnect the ignition coil harness from the 12 volt power supply. See Figure 15-11.
3. Disconnect the ignition coil harness from the ECM.
4. Unscrew the harness clips from the cylinder block.

15.9.1.1 Cleaning of Ignition Coil Harness

Clean the ignition coil harness as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Remove loose dirt and debris form the connectors on the ignition coil harness, coil packs, 12 volt power supply, and ECM with compressed air.
2. Inspect the ignition coil harness. Refer to Section 15.9.1.2.

15.9.1.2 Inspection of Ignition Coil Harness

Inspect the ignition coil harness as follows:

1. Visually check the coil harness for damage.
   [a] If damage is found, replace as necessary.
   [b] If no damage is found, reuse components.

15.9.2 Installation of Ignition Coil Harness

Install the ignition coil harness as follows:

1. Press the connectors of the ignition coil harness onto the two coil packs.

2. Connect the ignition coil harness to the 12 volt power supply. See Figure 15-12.

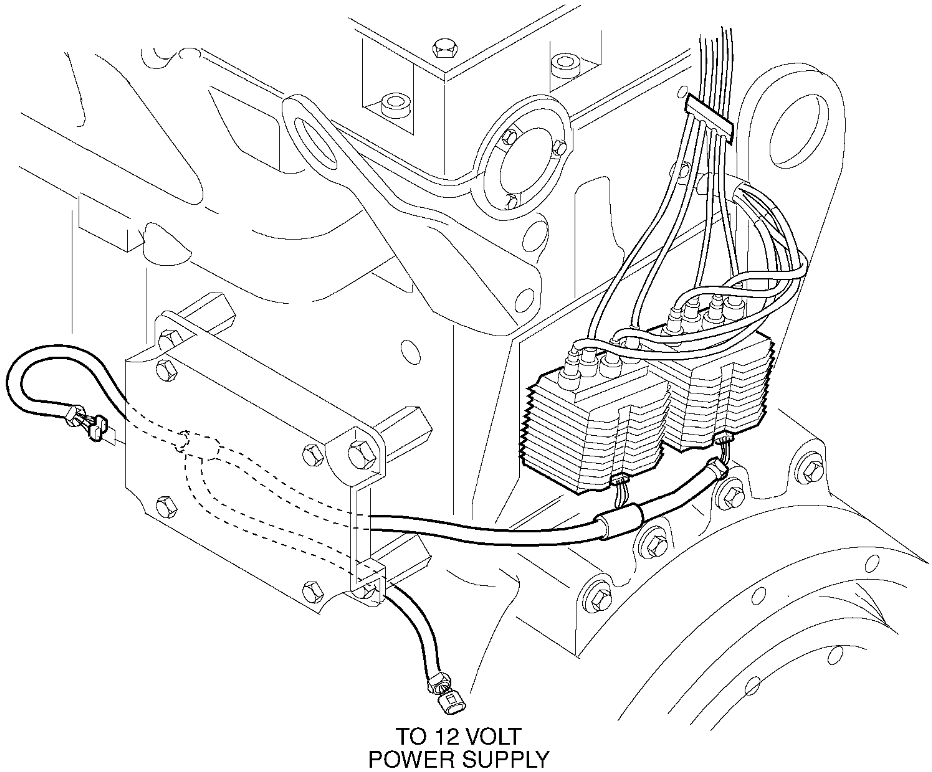


Figure 15-12 Ignition Coil Harness 12 Volt Supply

3. Connect the ignition coil harness to the ECM.
4. Attach the harness clips to the cylinder block.

15.10 SPARK PLUGS

The condition of the spark plug determines the high voltage level and is the single most important component of the ignition system. The size of the electrode gap, conditions of the electrodes, and the amount of deposits on the electrode all affect the life of the plug. The electrodes of the spark plug are made from platinum which will minimize electrode wear.

The spark plug gap can be re-gapped to 0.015 in. if the wear and amount of deposits are low. If either condition is excessive, replace the spark plug with a new one.

15.10.1 Removal of Spark Plug

Remove the spark from the cylinder head as follows:

1. Disconnect the ignition wires from the ignition boots.
2. Remove the ignition boots from the spark plug wells by rotating the boot until the boot slots clear the retainer tangs.
3. Remove the plug using a 5/8 in. thin wall spark plug socket and appropriate extensions.

15.10.1.1 Cleaning of Spark Plug Terminal, Ceramic Insulation, and Socket Area

Clean the spark plug terminal, ceramic insulation, and spark plug socket as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Remove dirt and debris with compressed air.
2. Remove oil and grease deposits.
3. Inspect the spark plug.

15.10.1.2 Inspection of Spark Plug

Inspect the spark plug as follows:

1. Measure the spark plug gap using a 0.381 mm (0.015 in.) feeler gage.
   [a] If the spark plug gap measured is not to specifications, re-gap the plug and use again. Refer to Section 15.10.2.
   [b] If the spark plug gap is within specifications, use the spark plug again. Refer to Section 15.10.2
2. Visually check the spark plugs for excessive deposits and condition of the electrode.

[a] If the spark plug has excessive deposits and electrode wear, replace the spark plug. Refer to Section 15.10.2.

[b] If the spark plug has no deposits nor excessive electrode wear, use the spark plug again. Refer to Section 15.10.2.

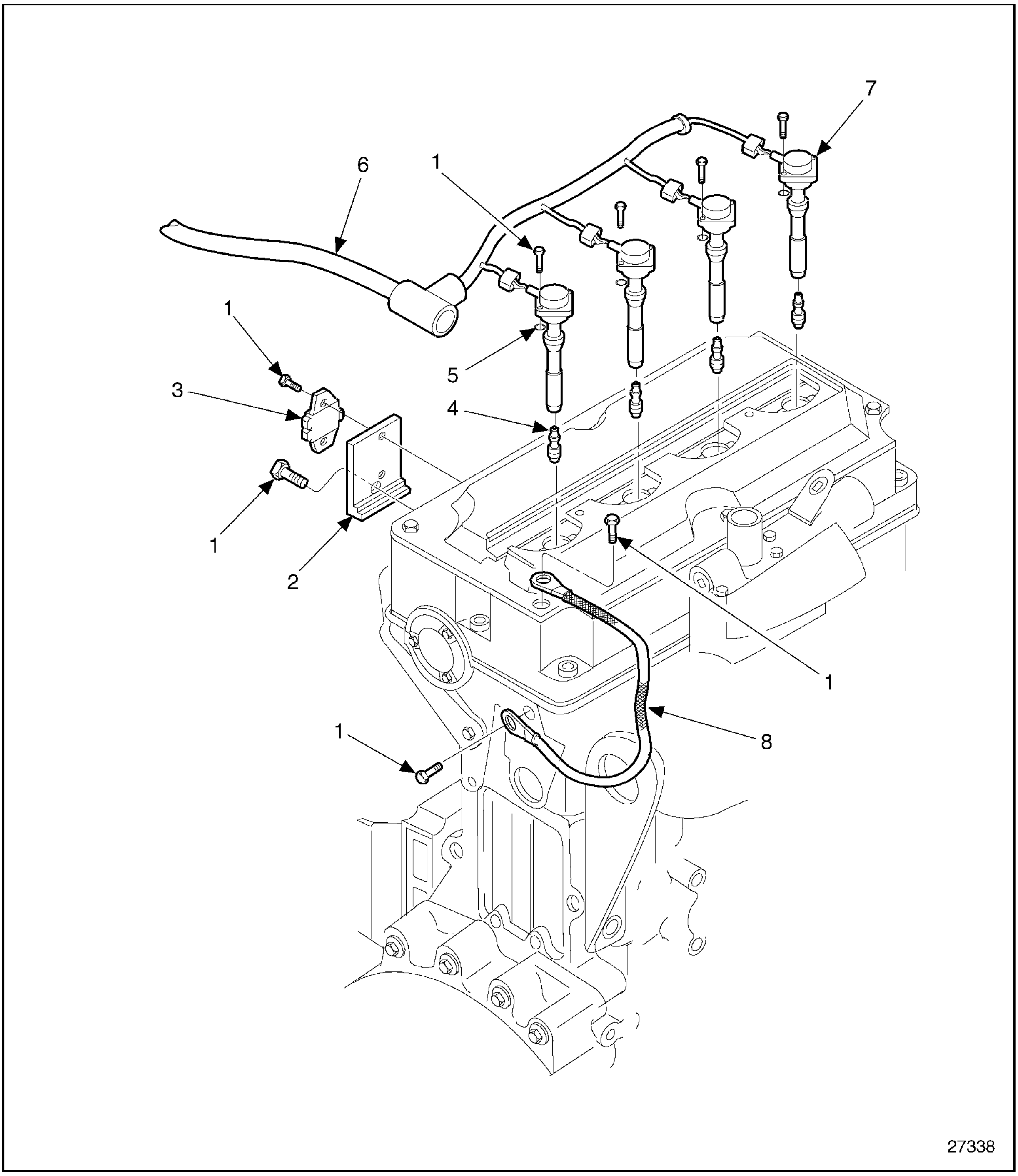
15.10.2 Installation of Spark Plug

Install the spark plug as follows:

1. Install the spark plug using a 5/8 in. thin wall socket and appropriate extensions. Torque the spark plug to 35 - 41 N·m (26-30 lb·ft).
2. Install the ignition boot. Refer to Section 15.5.2.
3. Install the ignition harness. Refer to Section 15.3.2.

15.11 COIL OVER PLUG IGNITION SYSTEM

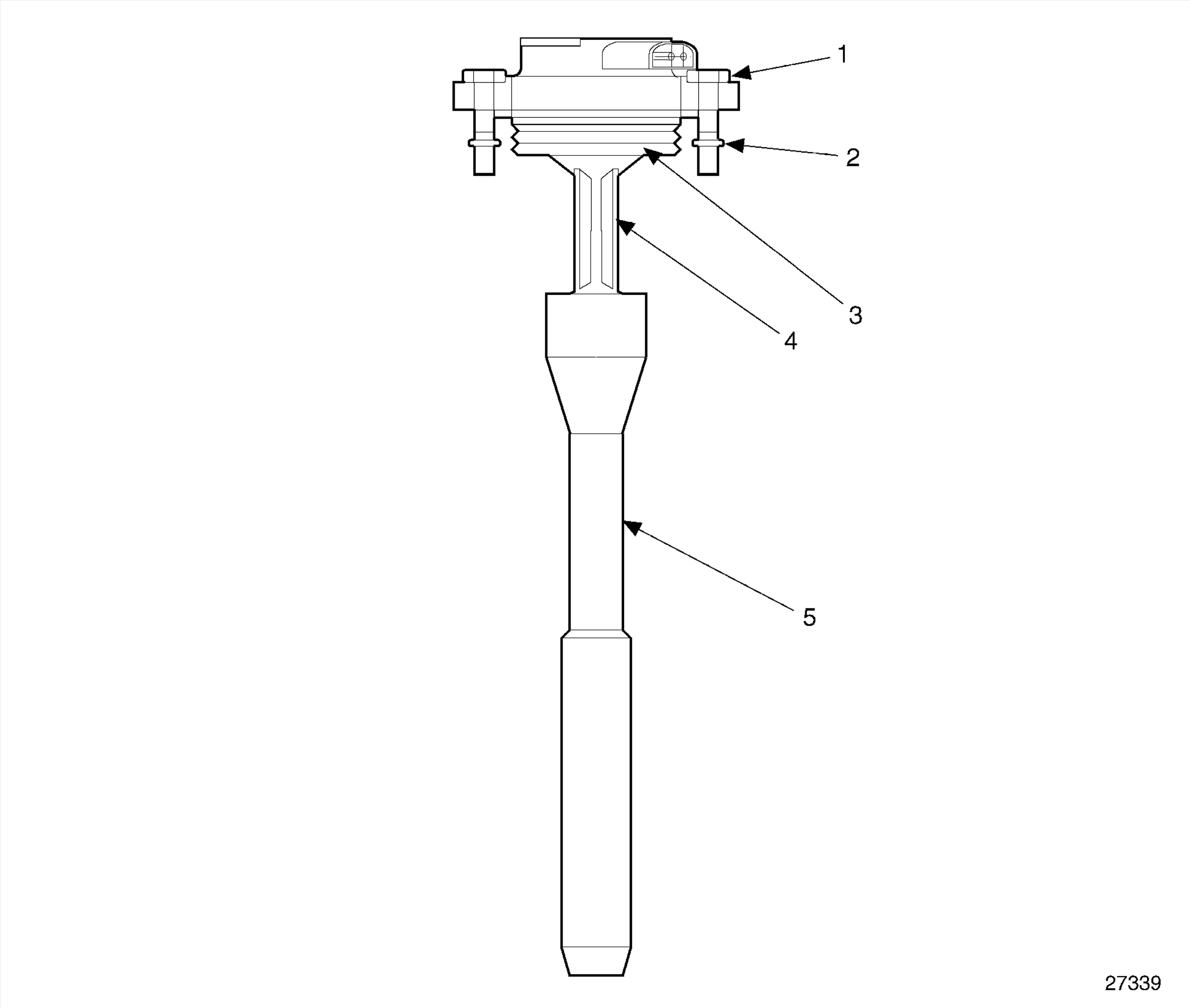
Series 50G engines produced after July 1996 and all genset engines use the coil over plug ignition system. This system consists of four coils, four ignition boots, mounting screws and seals, an ignition module, an igniter module bracket, an ignition coil harness, a ground strap, and four spark plugs. The coils mount in the rocker cover directly above the spark plugs. A coil cover mounts in the rocker cover which protects the coils and shields electromagnetic radiation (EMR) from the environment. See Figure 15-13.



1. Bolt
2. Igniter Module Bracket
3. Igniter Module
4. Spark Plug
5. Seal
6. Igniter Coil Harness
7. Coil and Igniter Boot Assembly
8. Ground Strap

Figure 15-13 Coil Over Plug Ignition System

The ignition coil assembly consists of the ignition coil and integral seal. This is serviced as an assembly, or the seal can be serviced separately. Before the coil can be installed into the engine, it is necessary to attach the boot, mounting screws, and O-rings onto the ignition coil assembly. See Figure 15-14.



1. Bolt, M6 x 1.0 in.
2. Seal Ring (2)
3. Ignition Coil Seal
4. Ignition Coil Assembly
5. Boot and Spring Assembly

Figure 15-14 Ignition Coil Assembly

15.11.1 Removal of Ignition Coil

Remove the ignition coil as follows:

1. Remove the two Phillips screws holding the coil cover in the rocker cover.
2. Remove the low voltage wire harness connectors at each coil to be removed.

3. Unscrew the two M6 x 1.0 bolts that attach the coil to the rocker cover. Pull the coil assembly with the boot, mounting screws, and O-rings out of the spark plug well.
4. Inspect the ignition coil. Refer to Section 15.11.1.1.

15.11.1.1 Inspection of Ignition Coil

Inspect the ignition coil as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Visually check the ignition coil for dirt and debris.
   [a] If dirt and debris are present, clean as necessary and apply a light coat of dielectric grease on the inside of the ignition boot. reuse the ignition coil. Refer to Section 15.11.2.
   [b] If no dirt and debris are present, reuse the ignition coil. Apply a light coat of dielectric grease on the inside of the ignition boot. Refer to Section 15.11.2.
2. Visually check the interface between the boot and spark plug for oil.
   [a] If oil is present, clean as necessary. Apply a light coat of dielectric grease on the inside of the ignition boot. Refer to Section 15.11.2.
   [b] If no oil is present, reuse ignition coil. Apply a light coat of dielectric grease on the inside of the ignition boot. Refer to Section 15.11.2.

15.11.2 Installation of Ignition Coil

Install the ignition coil as follows:

1. Install the ignition coil assembly with the boot, mounting screws, and O-rings into the spark plug well.
2. Guide the mounting bolts through the holes in the rocker cover and screw them into the extension tube. Torque the bolts to 14-16 N·m (10-12 lb·ft).
3. Push the connectors of the low voltage wire harness onto the ignition coils.
4. Put anti-seize compound on the two coil cover mounting screws to aid removal in the future.
5. Install the coil cover on the rocker cover with two Phillips mounting screws.

15.12 IGNITION BOOT ASSEMBLY

The boot assembly consists of the boot and spring and is serviced as an assembly.

15.12.1 Removal of Ignition Boot

Remove the ignition boot as follows:

1. Peel the end back from the coil and pull the two components apart.

15.12.2 Installation of Ignition Boot

Install the ignition boot as follows:

1. Secure the boot over the end of the coil.

NOTE:
Ensure that the boot is all the way on the coil.

15.13 IGNITER MODULE

The igniter module creates a ground path for the ignition coil primary circuit and limits the current to 7.5 amps. A 12 volt power source is supplied to the igniter module along with the command signals from the ECM.

15.13.1 Removal of Igniter Module

Remove the igniter module as follows:

1. Disconnect the ignitor coil harness from the igniter module.
2. Unscrew the two M6 x 1.0 attachment bolts.
3. Inspect the ignitor. Refer to Section 15.13.1.1.

15.13.1.1 Inspection of Igniter Module

Inspect the igniter module as follows:

1. Visually check the back surface of the igniter module, igniter module bracket, and connectors for dirt and debris.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

[a] If dirt and debris are present, clean as necessary with compressed air and reuse. Refer to Section 15.13.2.

[b] If no dirt or debris are present, reuse the igniter module. Refer to Section 15.13.2.

15.13.2 Installation of Igniter Module

Install the igniter module as follows:

1. Install the two M6 x 1.0 mounting screws. Torque to 14-16 N·m (10-12 lb·ft).
2. Press the connectors into the igniter module.

15.14 IGNITER MODULE BRACKET

The igniter module gives off heat and must be mounted on the bracket to keep the internal temperature within acceptable limits. The igniter module bracket is made of aluminum to conduct heat from the igniter module.

15.14.1 Removal of Igniter Module Bracket

Remove the igniter module bracket as follows:

1. Disconnect the ignition coil harness from the igniter module.
2. Remove the igniter module. Refer to Section 15.13.1.
3. Remove the M10 x 1.5 x 30 mounting bolt.
4. Inspect the igniter module bracket.

15.14.1.1 Inspection of Igniter Module Bracket

Inspect the igniter module bracket as follows:

1. Visually check the igniter module bracket for cracks and distortion.
   [a] If damage is found, replace the igniter module bracket.
   [b] If no damage is found, reuse the igniter module bracket.

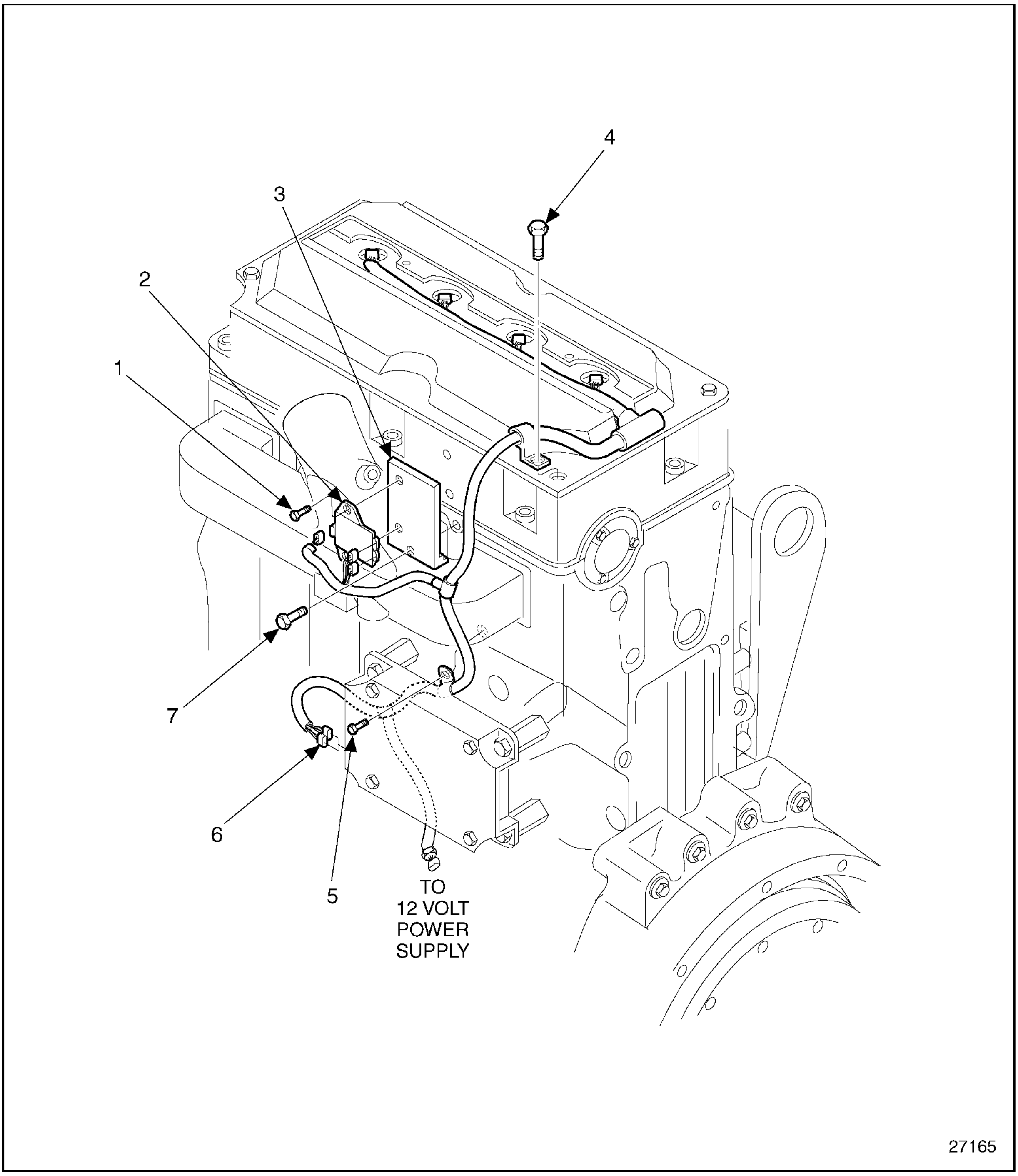
15.14.2 Installation of Igniter Module Bracket

Install the igniter module bracket as follows:

1. Install the bracket to the cylinder head using M10 x 1.5 x 30 mounting bolt. Torque bolt to 58 - 73 N·m (43-54 lb·ft).
2. Press the connectors of the ignition coil harness on the igniter module.

15.15 IGNITION COIL HARNESS

The ignition coil harness provides the 12 volt power to the ignition coils and igniter module, transmits the command signals from the ECM to the igniter module, and the ground circuit from the coils to the igniter module. See Figure 15-15.



1. Bolt
2. Module
3. Bracket
4. Bolt
5. Bolt
6. Harness Connector
7. Bolt

Figure 15-15 Ignition Coil Harness

15.15.1 Removal of Ignition Coil Harness

Remove the ignition coil harness as follows:

1. Remove the two Phillips screws holding the coil cover in the rocker cover. Remove the coil cover.
2. Pull the connectors of the ignition coil harness from the four ignition coils.
3. Pull the connectors from the igniter module.
4. Disconnect the ignition coil harness from the 12 volt power supply.
5. Disconnect the ignition coil harness from the ECM.
6. Unscrew the harness clips from the rocker cover and the cylinder block.
7. Inspect the ignition coil harness. Refer to Section 15.15.1.1.

15.15.1.1 Cleaning of Ignition Coil Harness

Clean the ignition coil harness as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Remove dirt and debris form the connectors on the ignition coil harness, coils, igniter module, 12-volt power supply, and the ECM with compressed air.

15.15.2 Inspection of Ignition Coil Harness

Inspect the ignition coil harness as follows:

1. Visually check the harness for damage.
   [a] If damage is found, replace the ignition coil harness. Refer to Section 15.15.3.
   [b] If no damage is found, reuse the ignition coil harness. Refer to Section 15.15.3.

15.15.3 Installation Ignition Coil Harness

Install the ignition coil harness as follows:

1. Press the connectors of the ignition coil harness onto the four ignition coils.
2. Connect the ignition coil harness to the igniter module.
3. Connect the ignition coil harness to the 12 volt power supply.
4. Connect the ignition coil harness to the ECM.
5. Attach the harness clips to the rocker cover and cylinder block.
6. Add anti-seize compound to the two coil cover mounting screws to aid removal in the future.
7. Install the coil cover on the rocker cover with the two Phillips mounting screws.

15.16 SPARK PLUGS

The condition of the spark plug determines the high voltage level and is the single most important component in the ignition system. The size of the electrode gap, condition of the electrodes, and the amount of deposits on the electrodes all affect the life of the spark plug. The electrodes of the spark plug are made from platinum which will minimize electrode wear.

The spark plug can be regapped to 0.015 in. if the electrode wear and amount of deposits are low. If either of these conditions are excessive, replace the spark plug with a new one.

15.16.1 Removal of Spark Plug

Remove the spark plug from the cylinder head as follows:

1. Remove the ignition coils. Refer to Section 15.11.1.
2. Remove the plug using a 5/8 in. thin wall spark plug socket and appropriate extensions.

15.16.1.1 Cleaning of Spark Plug Terminal, Ceramic Insulation, and Socket Area

Clean the spark plug terminal, ceramic insulation, and spark plug socket as follows:

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

1. Remove dirt and debris with compressed air.
2. Remove oil and grease deposits.
3. Inspect the spark plug.

15.16.1.2 Inspection of Spark Plug

Inspect the spark plug as follows:

1. Measure the spark plug gap using a 0.015 in. feeler gage.
   [a] If the spark plug gap measured is not to specifications, regap the plug and reuse. Refer to Section 15.10.2.
   [b] If the spark plug gap is within specifications, reuse the spark plug. Refer to Section 15.10.2.
2. Visually check the spark plugs for excessive deposits and condition of the electrode.
   [a] If the spark plug has excessive deposits and electrode wear, replace the spark plug. Refer to Section 15.10.2.

[b] If the spark plug has no deposits nor excessive electrode wear, reuse the spark plug. Refer to Section 15.10.2.

15.16.2 Installation of Spark Plug

Install the spark plug as follows:

1. Install the spark plug using a 5/8 in. thin wall socket and appropriate extensions. Torque the spark plug to 35-40 N·m (26-30 lb·ft).
2. Install the ignition boot. Refer to Section 15.5.2.
3. Install the ignition harness. Refer to Section 15.3.2.

16 MISFIRING CYLINDER

Section **Page**

16.1 POOR VEHICLE GROUND

To determine if poor vehicle ground is causing the cylinder to misfire, perform the following steps:

1. Remove alternator belt.

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

2. Start the engine.
3. Run the engine through operating range.
4. Listen for engine misfiring.
   [a] If the engine is still misfiring; refer to Section 16.1.1.
   [b] If the engine is not misfiring, check for aerated fuel; refer to Section 16.2. Shut the engine down.

16.1.1 Negative Lead Repair

Perform the following steps for negative lead repair:

1. Shut down the engine.
2. Remove negative lead(s) at frame ground stud near battery box.
3. Clean ground stud; refer to OEM guidelines.
4. Clean negative lead(s) terminal lugs with low grit sandpaper.
5. Repair any loose or damaged lead(s), using the splice method or rosin core solder; refer to Section 30.1.
6. Install negative lead(s) to frame ground stud; refer to OEM guidelines.

7. Install alternator belt. Torque belt to:
   - [a] If installing a new belt, torque to 170 N·m (25 lb·ft).
   - [b] If installing a used belt, torque to 135 N·m (100 lb·ft).
   - [c] If a belt tension gage is not available, adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 12.70-19.05 mm (0.500-0.750 in.).

NOTE:
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.

NOTE:
Drive belts (V and Poly-V) should be replaced every 2,000 hours or 100,000 miles (160,000 km).

8. Verify negative lead repair; refer to Section 16.1.1.1.

16.1.1.1 Verification of Repair for Negative Lead

Perform the following steps to determine if negative lead repair resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start engine.
2. Run engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.

   [a] If the engine is not misfiring, no further troubleshooting is required. Shut down the engine.

   [b] If the engine is misfiring, check for aerated fuel. Shut down the engine; refer to Section 16.2.

16.2 AERATED FUEL

To determine if aerated fuel is causing the cylinder to misfire, perform the following steps:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Disconnect the fuel line return hose from the fitting located at the fuel tank.
2. Place the opened end of fuel line into a suitable container.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine at 1000 r/min.
5. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are present; refer to Section 16.2.1.
   [b] If air bubbles are not present, check for improper calibration setting. Shut the engine down, refer to Section 16.3.

16.2.1 Aerated Fuel Repair

Perform the following for air in fuel repair:

1. Shut down engine.
2. Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
3. Visually inspect all fuel lines between fuel tank and fuel pump for leaks.
4. Replace any damaged components.
5. Verify repair of fuel lines; refer to Section 16.2.1.1.

16.2.1.1 Test the Engine with Repair for Aerated Fuel

Perform the following to determine if the aerated fuel repair resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start engine.
2. Run engine at 1000 r/min.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, no further troubleshooting is required. Shut down the engine.
   [b] If the engine is misfiring, check for improper injector setting. Shut down the engine; refer to Section 16.3.

16.3 IMPROPER INJECTOR CALIBRATION SETTING (DDEC III ENGINES ONLY)

For troubleshooting DDEC II engines, refer to Section 16.4.

To determine if an improper injector calibration setting is causing the cylinder to misfire, perform the following steps:

1. Remove the valve rocker cover(s); refer to Section 1.6.2.
2. Record the injector calibration code of each injector noting the cylinder number; see Figure 16-1.

NOTE:
Injector calibration and bar codes may be absent from the load plates on first-run production DDEC III injectors 5235575, 5235580, and 5235550. The correct calibration

code for these units is "01". Load plates on current DDEC III injectors include the required calibration or bar code information.

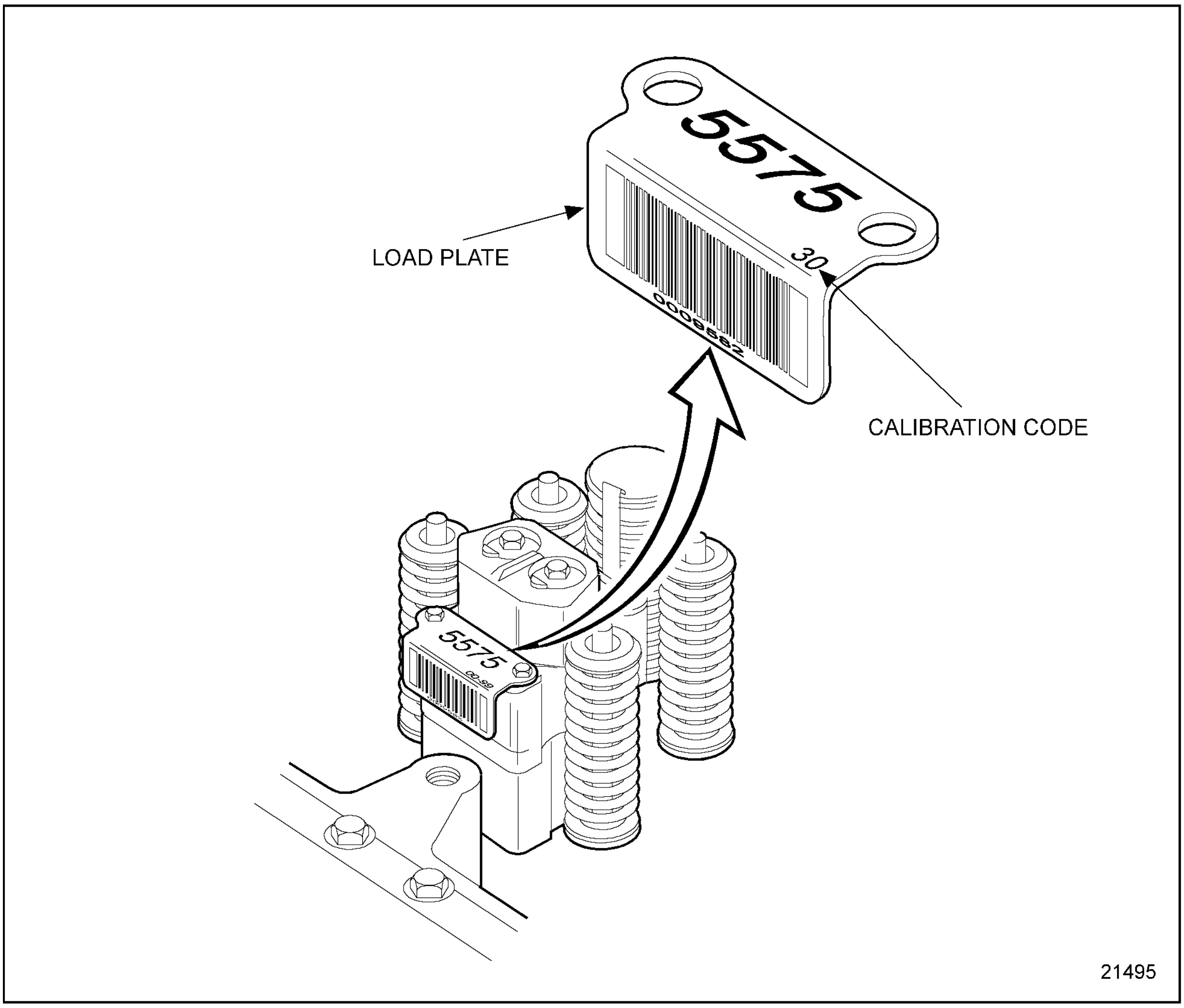


Figure 16-1 Injector Calibration Code

3. Turn vehicle ignition to the *on position*, but do not run engine.
4. Install Display Data Line (DDL) adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.
5. From the Diagnostic Data Reader (DDR) DDEC III Select Menu, scroll to select ENGINE and press the ENTER key.
6. Scroll to select FUEL INJECTOR INFO and press the ENTER key.
7. Scroll to select FUEL INJECTOR CAL and press the ENTER key.
8. Scroll to select FUEL INJECTOR CAL. Select VIEW and press the ENTER key.
9. Compare the calibration code(s) shown on the display with the two digit calibration code(s) on the injector(s).

[a] If the calibration code on the display is different then the calibration code on the suspect injector for that cylinder, the injector setting must be repaired, see Figure 16-1; refer to Section 16.3.1.

[b] If test codes match; refer to Section 16.4.

16.3.1 Improper Injector Setting Repair

Perform the following steps to recalibrate improper injector setting:

NOTICE:
Whenever a DDEC III injector is removed from the engine, it should be reinstalled in its original location to maintain proper cylinder balance. If reinstalled in a different cylinder head location, injector calibration ***must*** be rechecked with the DDR and updated. Failure to observe these steps may result in reduced engine performance.

NOTE:
Injector calibration and bar codes may be absent from the load plates on first-run production DDEC III injectors 5235575, 5235580, and 5235550. The correct calibration code for these units are "01". Load plates on current DDEC III injectors include the required calibration or bar code information.

See Figure 16-1when performing step 1 through step 7.

1. Scroll to select FUNCTION to return to the FUEL INJECTOR CAL menu on the DDR.
2. Scroll to select FUEL INJECTOR CAL. Select UPDATE and press the ENTER key.
3. Type the four-digit "Update Injector Calibration" password for the DDR and press the ENTER key. If this feature is not password protected, type "0000" and press the ENTER key.
4. A message will appear telling you to use the scroll keys to select the cylinder (requiring changes) or select TYPE # enter the numerical keys to change the CAL (calibration value).

NOTE:
An asterisk (*) will highlight the first cylinder number on the list.

5. Scroll to the cylinder requiring change and type in the required two-digit injector calibration code number. Press the ENTER key.

NOTE:
The ENTER key must be pressed before the DDR will allow selection of another cylinder number.

6. Repeat step 5, until all changes have been made.
7. Scroll to select FUNCTION and press the ENTER key.

8. Scroll to select YES and press the ENTER key to reprogram the ECM with the revised injector calibration codes.
9. Turn the ignition to the *off position* and wait a minimum of five seconds before starting the engine.
10. Disconnect the DDR; refer to OEM guidelines.
11. Verify repaired injector settings, refer to Section 16.3.1.1.

16.3.1.1 Verification of Repair for Improper Injector Setting

Perform the following to determine if the proper injector setting adjustment resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the valve rocker cover(s); refer to Section 1.6.6.

CAUTION:

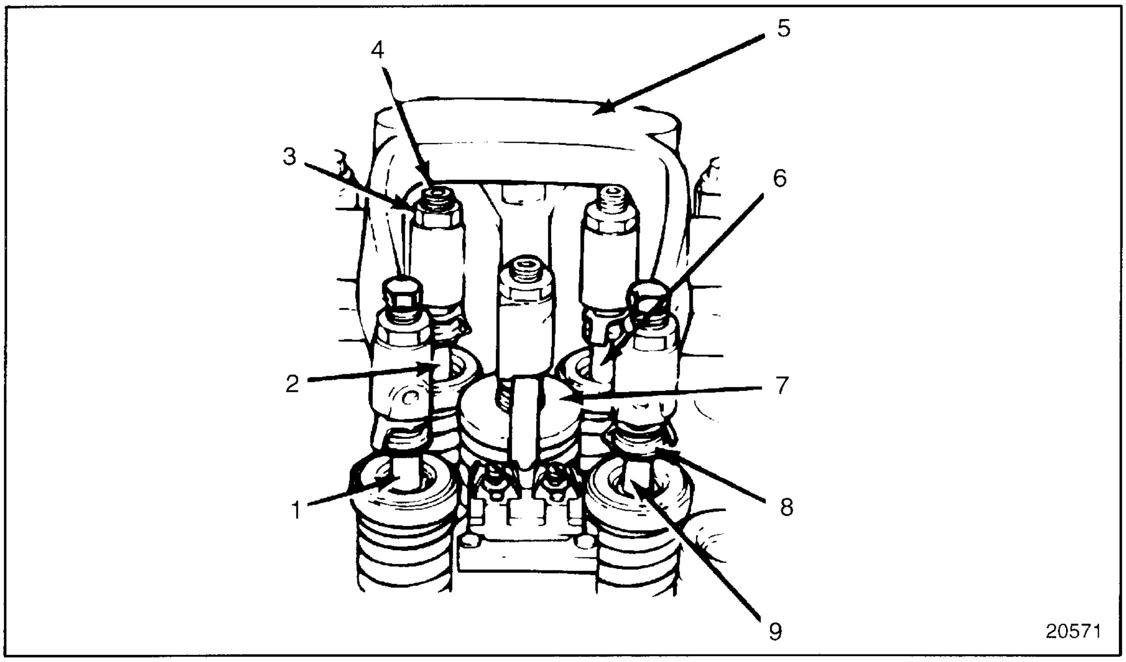
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start the engine.
3. Run the engine at 1000 r/min.
4. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, no further troubleshooting is required. Shut the engine down.
   [b] If the engine is misfiring, check for improper valve clearance and injector height and damaged or worn camshaft lobes and rollers; refer to Section 16.4. Shut the engine down.

16.4 IMPROPER VALVE CLEARANCE OR INJECTOR HEIGHT, WORN OR DAMAGED CAMSHAFT LOBES AND ROLLERS

Intake valve clearance and injector height are adjusted by means of an adjusting set screw and locknut located at the valve (or injector) end of the rocker arm; see Figure 16-2.



1. Exhaust Valve
2. Intake Valve
3. Locknut
4. Adjusting Set Screw
5. Exhaust Rocker Arm Assembly
6. Intake Valve
7. Fuel Injector Follower
8. Valve Button
9. Exhaust Valve

Figure 16-2 Valve and Fuel Injector Height Adjustment Components

NOTE:
On engines equipped with a Jake Brake, measure valve lash and injector height before removing any brake housings. Only remove the brake housings necessary to provide access for adjustment.

NOTICE:
Be sure the height gage seats on the machined surface with the tip in the pilot hole. Foreign material in the pilot hole or on the machined surface may prevent accurate setting of the injector height.

The injector height is adjusted using the injector height gage, J 39697 (DDEC III) or J 35637-A(DDEC II). On engines equipped with a Jake Brake, move the handle on the injector height gage to the alternate position, 90° to the shank. A height gage pilot hole is provided in the fuel injector body on the machined surface contacted by the injector clamp near the solenoid; see Figure 16-3.

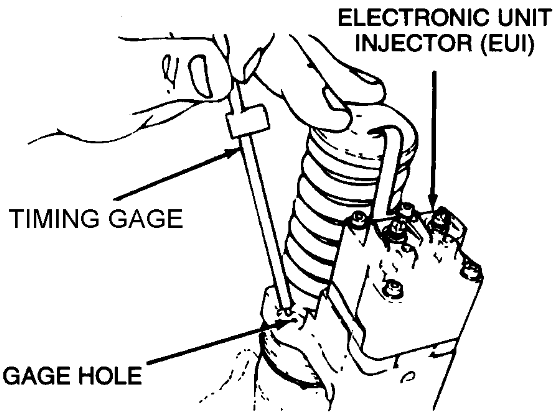
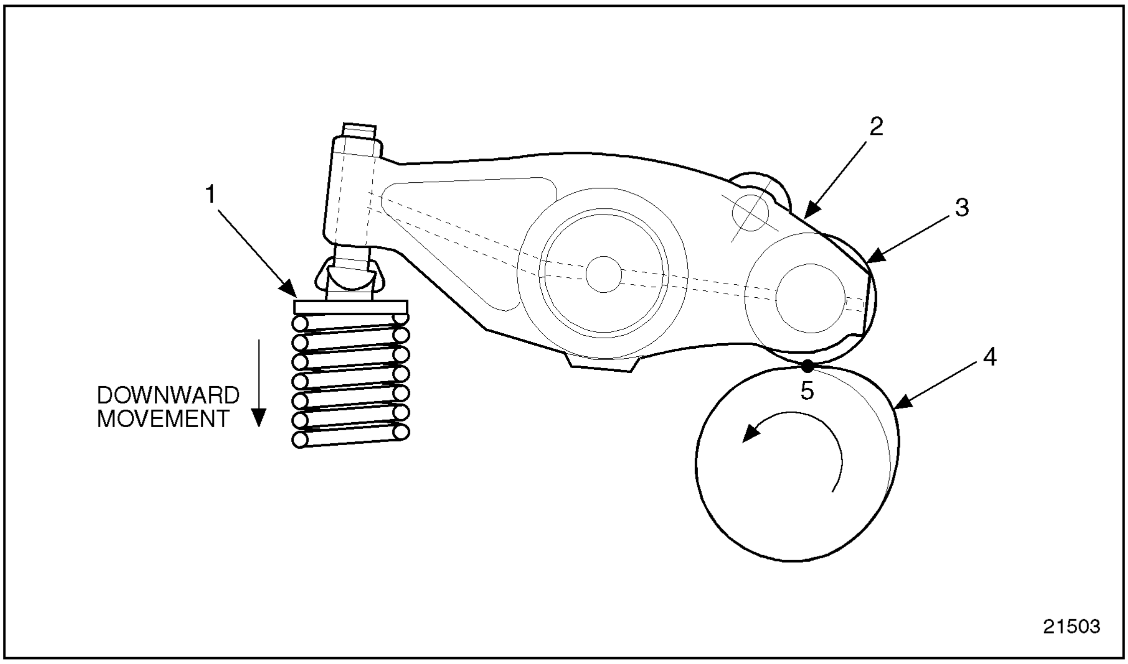


Figure 16-3 Timing Gage

To determine if improper valve clearance, injector height or both are causing the cylinder to misfire, perform the following preliminary step 1through step 3and repeat step 4 through step 9 for each cylinder to determine if worn or damaged lobes or rollers are causing the engine to misfire:

1. Disconnect starting power for engine.
2. Remove valve rocker cover(s); refer to Section 1.6.2.
3. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley.

4. Bar the engine over and inspect camshaft and rollers for wear or damage. Stop engine rotation when any one of the injector followers has just begun its downward stroke; see Figure 16-4.



1. Injector Follower
2. Injector Rocker Arm Assembly
3. Injector Roller
4. Injector Cam Lobe
5. Point on the Camshaft Lobe that First Produces Downward Motion of the Injector Follower

Figure 16-4 Injector Followers Downward Stroke

[a] If damage is found on the camshaft lobes or rollers, stop this procedure and replace damaged components as necessary; refer to Section 1.22.2l. Once complete, refer to Section 16.4.1.1.

[b] If no damage was found to camshaft or rollers, continue with task.

5. Using timing chart, see Figure 16-5, determine if the intake valve clearances are acceptable (listed in Table 16-1), by inserting a feeler gage between the tip of the intake valve stem and the button; see Figure 16-6.

[a] If the intake valve stem clearance is between 0.127-0.280 mm (0.005-0.011 in.); refer to step 6.

[b] If the intake valve stem clearance is not between 0.127-0.280 mm (0.005-0.011 in.), reset the intake valve(s) to 0.203 mm (0.008 in.), refer to Section 16.4.1, step 1.

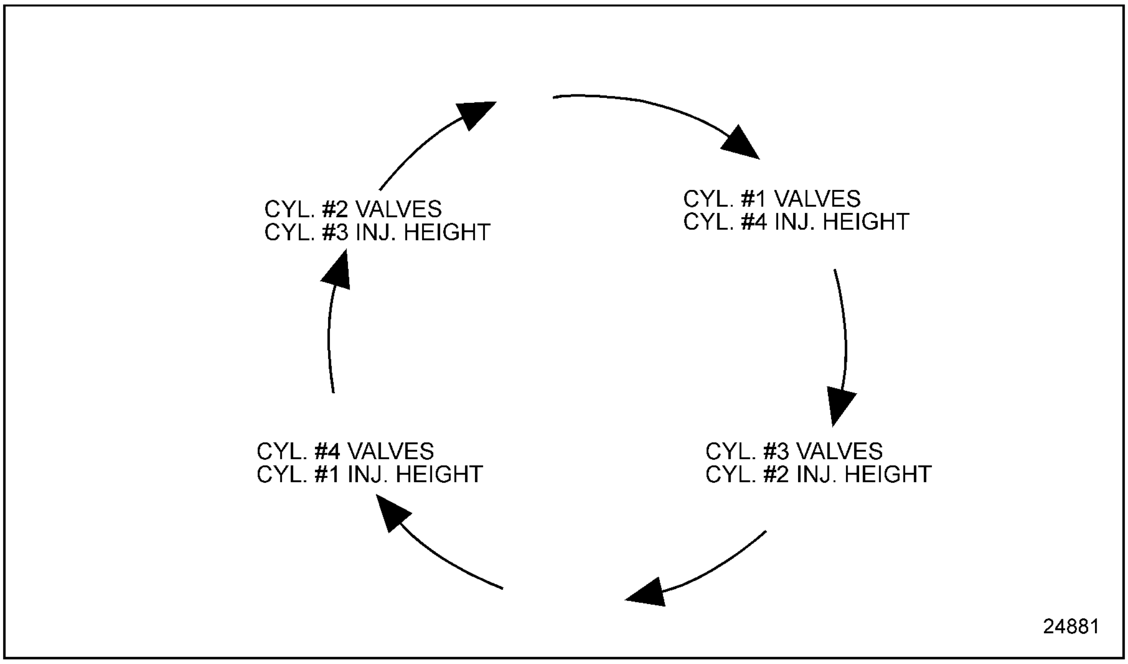
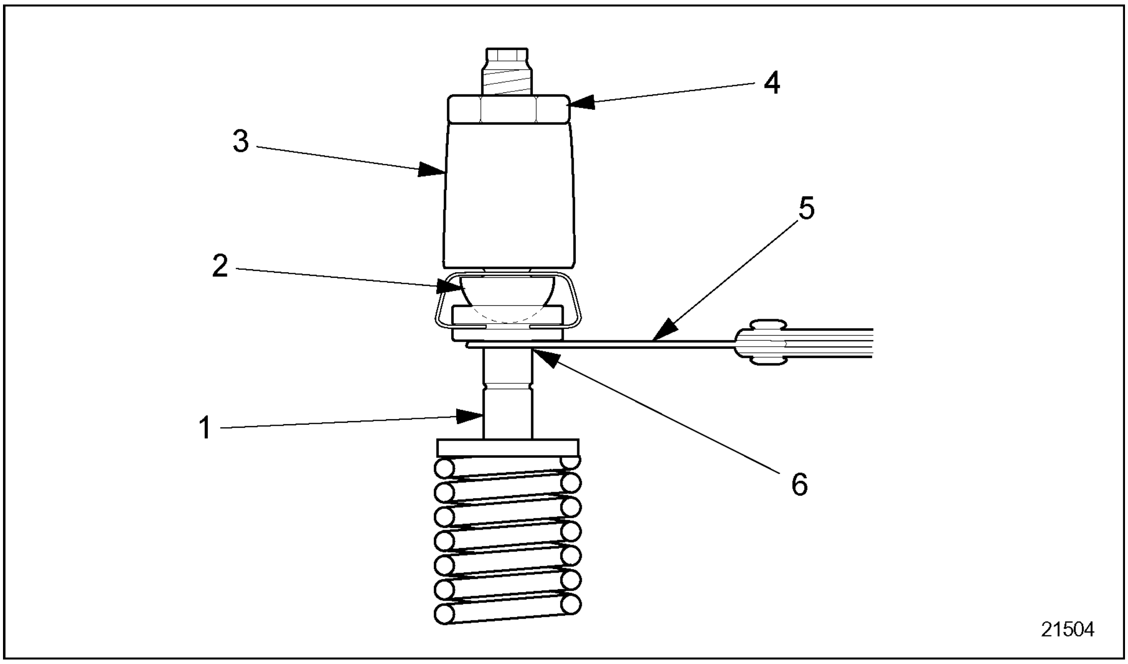


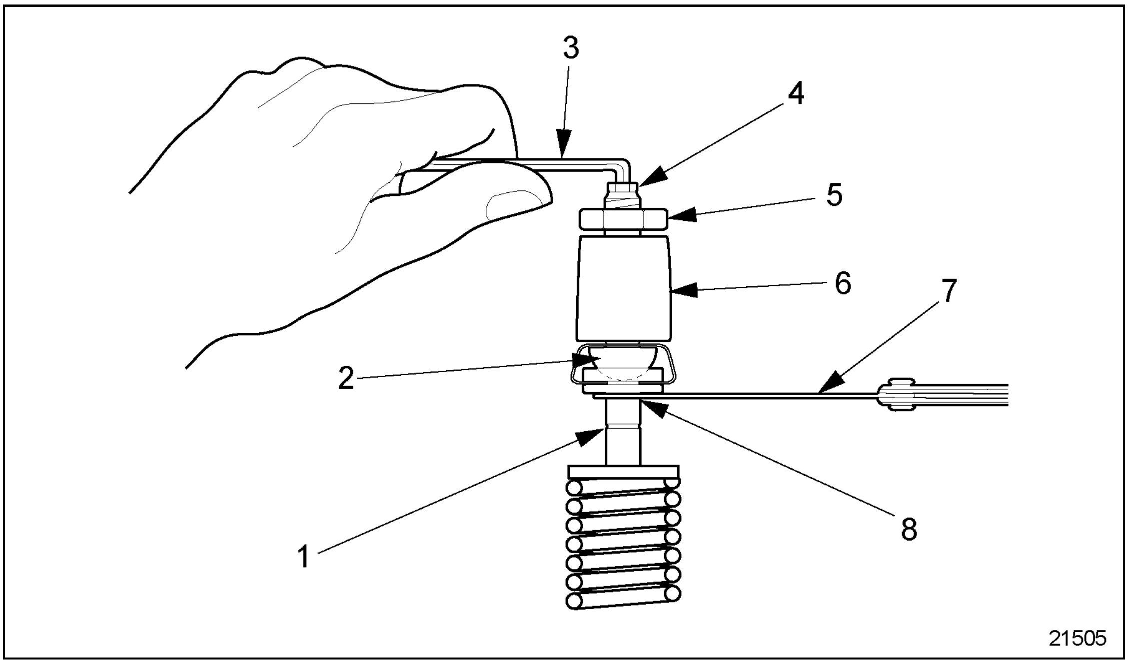
Figure 16-5 Timing Circle Chart



1. Intake Valve
2. Valve Button
3. Intake Rocker Arm Assembly
4. Locknut
5. Feeler Gage
6. Tip of Intake Valve

Figure 16-6 Intake Valve Clearance

6. Using timing chart, see Figure 16-5, determine if the exhaust valve clearances are acceptable, (listed in Table 16-1) by inserting a feeler gage between the tip of the exhaust valve stem and the button; see Figure 16-7.
   - [a] For exhaust valves with a machined groove between the rotator and tip, the exhaust valve stem clearance should be between 0.584-0.736 mm (0.023-0.029 in.). If the exhaust valve stem clearance is between 0.584-0.736 mm (0.023-0.029 in.), proceed to step 7 For exhaust valves without a machined groove between the rotator and tip, the exhaust valve stem clearance should be between 0.432-0.584 mm (0.017-0.023 in.). If the exhaust valve stem clearance is between 0.432-0.584 mm (0.017-0.023 in.), perform to step 7 (for DDEC III) or step 8 (for DDEC II).
   - [b] If the exhaust valve stem clearance is not between 0.584-0.736 mm (0.023-0.029 in.) for exhaust valves with a machined groove between the rotator and tip, reset the valve(s) to 0.660 mm (0.026 in.); refer to step 7(for DDEC III) or step 8 (for DDEC II).
   - [c] If the exhaust valve stem clearance is not between 0.432-0.584 mm (0.017-0.023 in.) for exhaust valves without a machined groove between the rotator and tip, reset the valve(s) to 0.508 mm (0.020 in.); refer to Section 16.4.1, step 2.



1. Location of Identification Groove
2. Valve Button
3. Allen Wrench
4. Adjusting Screw
5. Locknut
6. Exhaust Rocker Arm Assembly
7. Feeler Gage
8. Tip of Exhaust Valve

Figure 16-7 Exhaust Valve Clearance

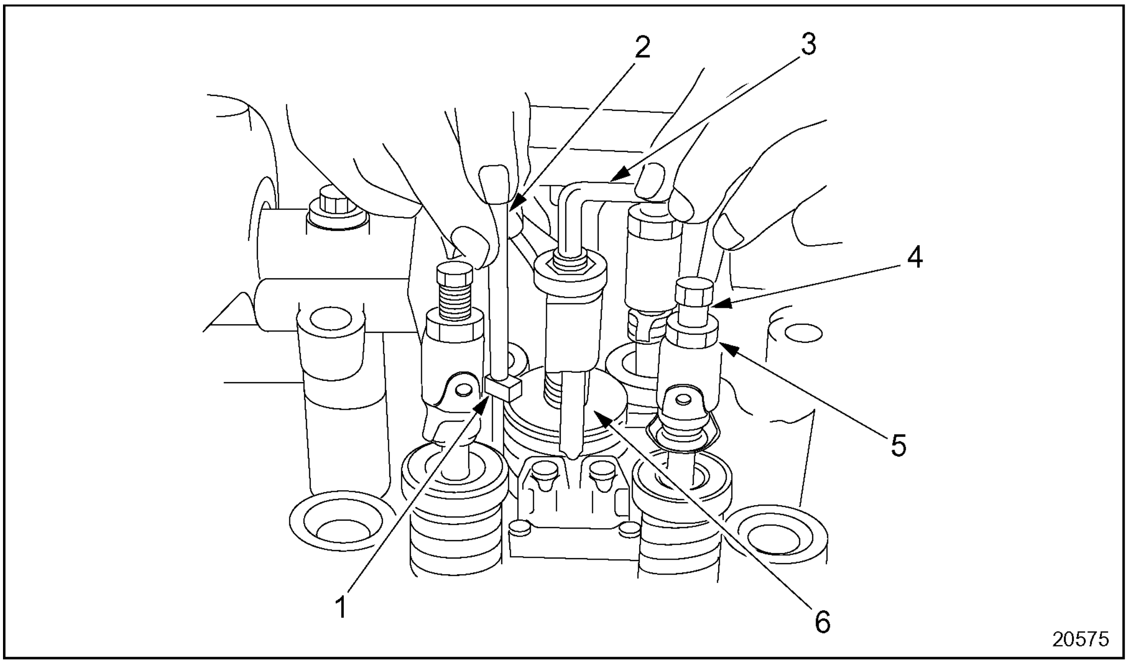
Settings and Models	Acceptable Range	Recommended Setting
Injector Heights DDEC II (6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063WU00, 6063GU00, 6067WU60, 6067GU60, 6063WU60, 6063W41, 6063GU41, 6063G00, 6063GU60, 6063WU00 and 6067GU91)	78.2 mm (3.078 in.)	78.2 mm (3.078 in.)
Injector Heights DDEC III (6067WK60, 6067WK28, 6067GK60, 6067GK28, 6063WK60, 6063WK28, 6063GK05 6063GK60, 6067GK40, 6067WK40, 6063GK32, 6063WK00 and 6063GK28)	78.8 mm (3.102 in.)	78.8 mm (3.102 in.)
Intake Valve Clearance	0.127-0.280 mm (0.005.-0.011 in.)	0.203 mm (0.008 in.)
Exhaust Valve Clearance "U" (6067GT40, 6067WT40, 6067WU40, 6067GU40, 6063WU00, 6063GU00)	0.432 -0.054 mm (0.017-0.023 in.)	0.508 mm (0.020 in.)
Exhaust Valve Clearance "H" (6067WU60, 6067GU60, 6067WK60, 6067GK60, 6067GK28, 6067WK28 6067GU91, 6063WU60, 6063GK05, 6063GK32, 6063GK60, 6063GU41, 6063GU60, 6063WK32, 6063WK60, 6063WU00, 6063WU41, 6063GU00, 6067GK40, 6067WK40, 6063WK28 AND 6063GK28)	0.584-0.736 mm (0.023-0.029 in.)	0.660 mm (0.026 in.)

Table 16-1 Valve Clearance and Injector Height Settings

7. If troubleshooting a DDEC III engine, place the small end of J 39697 in the hole provided in the injector body, with the flat of the gage toward the fuel injector plunger; see Figure 16-3.

   [a] If the tool is flush against the follower, the injector height is acceptable ; refer to step 9, see Figure 16-8.

[b] If the tool is not flush, adjust injector height; refer to Section 16.4.1, step 3.



1. Height Gage Flag
2. Height Gage
3. 3/16 in. Allen Wrench
4. Adjusting Screw
5. Locknut
6. Fuel Injector Follower

Figure 16-8 Fuel Injector Adjustment

8. If troubleshooting a DDEC II engine, place the small end of J 35637-A in the hole provided in the injector body, with the flat of the gage toward the fuel injector plunger.
   [a] If the tool is flush against the follower, the injector height is acceptable ; refer to step 9, see Figure 16-8.
   [b] If the tool is not flush, adjust injector height; refer to Section 16.4.1, step 3.
9. Bar the engine over, clockwise, until the fuel injector for the next cylinder begins its downward stroke; see Figure 16-5. Repeat steps 5 through step 8and repeat until all six fuel injectors and sets of valves have been checked and reset as necessary. When all cylinders have been checked, refer to Section 16.4.1, step 4

16.4.1 Improper Valve Clearance or Injector Height Repair

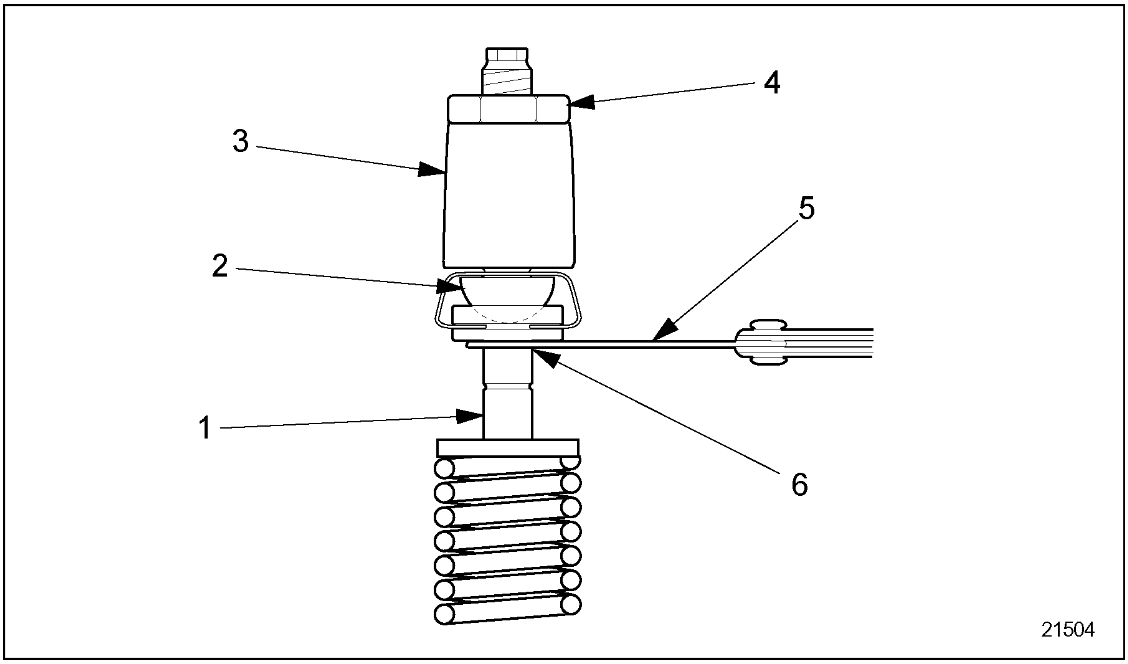
Perform the following steps to repair improper fuel injector height, intake valve clearance, and exhaust valve clearance.

NOTE:
Using the steps below, it will be necessary to bar the engine over only two complete revolutions. Three cylinders will be adjusted for valves, and three cylinders will be adjusted for injectors on each revolution.

If required, remove Jake Brake housing necessary to provide access for repair; refer to Section 1.30.2.

NOTICE:
Never set the valves and injector of the same cylinder at the same time. Doing this will result in engine damage.

1. Adjust the intake valve clearances as follows:
   [a] Insert a 0.203 mm (0.008 in.) feeler gauge between the tip of one valve stem and the valve button; see Figure 16-9.



1. Intake Valve
2. Valve Button
3. Injector Rocker Arm Assembly
4. Locknut
5. Feeler Gage
6. Tip of Intake Valve

Figure 16-9 Measurement of Intake Valve Clearance

[b] Loosen the locknut, and turn the adjusting set screw until the feeler gage produces a snug, smooth pull between the intake valve stem and valve button; see Figure 16-9.

[c] Torque the locknut to 41-47 N·m (30-35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.

2. Perform the following steps to adjust the exhaust valve clearances:

   [a] Insert a 0.660 mm (0.026 in.) feeler gage for valves with a machined groove between the tip of the valve stem and the valve button. Insert a 0.508 mm (0.020 in.) feeler gage for valves without machined groove; see Figure 16-7.

   [b] Loosen the locknut, and turn the adjusting set screw until the feeler gage produces a snug, smooth pull between the exhaust valve stem and the valve button.

   [c] Torque the locknut to 41-47 N·m (30-35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.

3. Perform the following steps to adjust fuel injector heights.

   [a] For DDEC III engines, place the small end of the height gage, J 39697, in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger; see Figure 16-3 and proceed to step 3[c].

   [b] For DDEC II engines place the small end of the height gage, J 35637-A, in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger.

   [c] Loosen the locknut and turn the adjusting set screw until the extended part (flag) of the gage will just pass over the top of the injector follower. A snug feel is recommended. The objective is to adjust all six injectors to the same feel, see Figure 16-9.

   [d] Torque the locknut to 41-47 N·m (30-35 lb·ft).

   [e] Check the adjustment with the height gage, J 39697 (DDEC III engines) J 35637-A (DDEC II engines), and if necessary, readjust the set screw.

4. Install the valve rocker cover(s); refer to Section 1.6.6.
5. Install Jake Brakes, if removed. Refer to Section 1.30.5.
6. Reconnect starting power to the engine.
7. Verify improper clearance repair or injector height setting repair; refer to Section 16.4.1.1.

16.4.1.1 Verification of Repair for Improper Valve Clearance or Injector Height Setting

Perform the following to determine if valve clearance or injector height adjustment resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine at 1000 r/min.
3. Listen for misfiring cylinder.
   [a] If the engine is not misfiring, shut down the engine. No further troubleshooting is required.
   [b] If the engine is misfiring, shut down the engine and check for faulty fuel injector; refer to Section 16.5.

16.5 FAULTY FUEL INJECTOR

To determine if a faulty fuel injector is causing the cylinder to misfire, perform the following steps:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install DDL adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start the engine.
3. From the DDEC III Select Menu, scroll to select ENGINE and press the ENTER key.
4. Scroll to FUEL INJECTOR INFO (CUTOUT) and press the ENTER key.
5. Scroll to select NEW TEST and press the ENTER key.
6. Scroll to select RPM SETTING FOR CCO TEST NORMAL and scroll to select 1000 and press the ENTER key.
7. Scroll to select AUTO and press the ENTER key. Wait for END OF TEST.

NOTE:
If an injector cannot be cutout, an ERROR message will appear. Press FUNC to exit the cylinder cutout function, press the FUNC key.

8. Scroll the list to review the results of the cylinder cutout test. To find suspect injectors, look for a cylinder with a value that is within 0.2° of the NO CUTOUT PULSE WIDTH, by comparing the CUTOUT PULSE WIDTH values to the NO CUTOUT PULSE WIDTH values.
   [a] If any CUTOUT PULSE WIDTH values are within 0.2° of the NO CUTOUT PULSE WIDTH, shut down the engine and refer to Section 16.5.1.

[b] If any CUTOUT PULSE WIDTH values are not within 0.2° of the NO CUTOUT PULSE WIDTH, shut down the engine and refer to Section 16.6.

16.5.1 Faulty Fuel Injector Repair

Perform the following steps for faulty fuel injector assembly(s):

1. Remove and replace injector assembly(s) whose values are within 0.2° of the NO CUTOUT PULSE WIDTH; refer to Section 2.3.2.
2. Verify replaced injector assembly(s), refer to Section 16.5.1.1.

16.5.1.1 Verification of Repair for Faulty Fuel Injector

Perform the following to determine if the replaced fuel injector(s) resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.

   [a] If the engine is not misfiring, shut down the engine. No further troubleshooting is required.

   [b] If the engine is misfiring, shut down the engine and check for a faulty electronic control module (ECM); refer to Section 16.7.

16.6 FAULTY ELECTRONIC CONTROL MODULE

To determine if a faulty electronic control module (ECM) is causing the cylinder to misfire, perform the following:

1. Remove the ECM connector hold-down screws securing the five or six wire harness connection.

NOTE:
Carefully disengage the lock tab on the power harness and injector harness connectors when removing.

2. Remove the thru-bolts holding the ECM to the engine; refer to Section 2.11.2.
3. Remove the ECM from the engine and tag the ECM for core return.
4. Obtain a new reprogrammed ECM for the engine being troubleshooted.
5. Inspect the ECM isolators for any damage, refer to Section 2.11.2. Replace if necessary, refer to Section 16.6.1.
6. Install the ECM to the engine using thru-bolts; refer to Section 2.11.3.
7. Torque the ECM thru-bolts to 23-27 N·m (17-20 lb·ft).
8. Torque the ECM connector hold-down screws to 24-30 N·m (21-26 lb· in.).
9. Verify ECM repair, refer to Section 16.6.1.1.

16.6.1 Faulty ECM Repair

Return tagged cores to designated repair facilities. Contact Detroit Diesel Technical Service Group. Refer to Section 16.6.1.1 for verification of ECM replacement.

16.6.1.1 Verification of Repair for Faulty ECM

Perform the following to determine if the new ECM resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.

    [a] If the engine is not misfiring, shut down the engine. No further troubleshooting is required.

    [b] If the engine is misfiring, shut down the engine and check for worn or damaged valves and cylinder kits; refer to Section 16.7.

16.7 WORN OR DAMAGED VALVE OR CYLINDER KIT

Loss of compression in Series 50 engines may result from a variety of sources, including worn or broken fire or compression rings, holes in pistons, leaky valves, scored or worn cylinder walls, leaky or broken gaskets and cracked cylinder heads or cylinder liners. The detection and elimination of the cause or causes of cylinder pressure losses is vital to engine life and efficient operation. To assist the mechanic in effectively measuring the loss of cylinder pressure, and locating the source of abnormal leaks in individual cylinders, the following test procedure has been developed.

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to Section 10.1.2.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run vehicle to full load and rated speed.
6. Attach a manometer calibrated to read in. H_2O, to the oil dipstick opening; refer to Section 29.1.
7. Measure and record crankcase pressure.
8. Shut down engine.
9. Remove the vehicle from the chassis dynamometer.
10. Review the crankcase pressure test results.

    [a] If the crankcase pressure was greater than 3 in. H_2O (0.75 kPa); refer to Section 16.7.1.

[b] If the crankcase pressure was less than 3 in. H_2O (0.75 kPa); refer to Section 29.2.

11. Compare the cylinder compression test results to specifications.
    [a] If cylinder pressure is below specifications, refer to Section 16.7.1.
    [b] If cylinder pressure is within specification, call Detroit Diesel Technical Service Group.

16.7.1 Worn or Damaged Valve or Cylinder Kit Repair

Perform the following steps for worn or damaged valve or cylinder kit:

1. Remove cylinder head; refer to Section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to Section 1.2.3 for repair and replacement procedures.
3. Inspect for worn or damaged cylinder kit components:
    [a] Inspect cylinder liner for damage, refer to Section 1.20.1.
    [b] Inspect piston and piston rings for damage, refer to Section 1.18.1.
4. Verification of repairs made to cylinder valve(s) or cylinder kit components is required; refer to Section 16.7.1.1.

16.7.1.1 Verification of Repair for Worn or Damaged Valve or Cylinder Kit

Perform the following to determine if the repaired valve or cylinder kit resolved the misfiring cylinder condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed up to the occurrence of the misfiring.
3. Listen for misfiring cylinder.

    [a] If the engine is not misfiring, no further troubleshooting is required. Shut the engine down.

    [b] If the engine is misfiring, call Detroit Diesel Technical Service Group. Shut the engine down.

17 STARTING DIFFICULTY (ENGINE ROTATES)

Section | Page

17.1 EMPTY FUEL TANK

To determine if an empty fuel tank is causing starting difficulty, perform the following:

1. Determine the amount of fuel in fuel tank; refer to OEM guidelines.
   [a] If fuel is at recommended level, check for a weak battery; refer to Section 17.3.
   [b] If fuel is below recommended level; refer to Section 17.1.1.

17.1.1 Low Fuel Level Resolution

Perform the following steps to resolve low fuel level:

1. Fill fuel tank to full; refer to OEM guidelines.
2. Verify fuel tank refill; refer to Section 17.1.1.1.

17.1.1.1 Test Engine with Filled Tank

Perform the following steps to determine if a filled fuel tank resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check the ECM wiring harness; refer to Section 17.2.

17.2 ELECTRONIC CONTROL MODULE WIRING HARNESS

To determine if the electronic control module (ECM) wire harness is causing starting difficulty, perform the following:

1. Turn the ignition switch to the on position.
2. Install the Diagnostic Data Link (DDL) adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.
3. Determine if ECM data is being received by the DDR; refer to OEM guidelines.
   [a] If no data is being received by the DDR, check for intermittent code or a fault and no codes.
   [b] If data is being received by the DDR, check vehicle circuit breakers or fuses; refer to Section 17.2.1.

17.2.1 Vehicle Circuit Breakers or Fuses Check

To determine if the vehicle circuit breakers is causing starting difficulty, perform the following:

1. Visually check ECM circuit breakers or fuses and determine if circuit breaker(s) or fuse(s) are tripped or blown; refer to OEM guidelines.
   [a] If circuit breakers are being shorted, determine cause and repair or replace as necessary; refer to OEM guidelines.
   [b] If circuit breakers are not being shorted, measure the voltage at the ECM power harness; refer to Section 17.2.2.

17.2.2 ECM Power Harness Voltage Test

To determine if the electronic control module power harness is causing circuit breakers to be tripped or blown, perform the following:

1. Turn ignition off, if required.

2. Disconnect the 5-way power harness connector, see Figure 17-1.

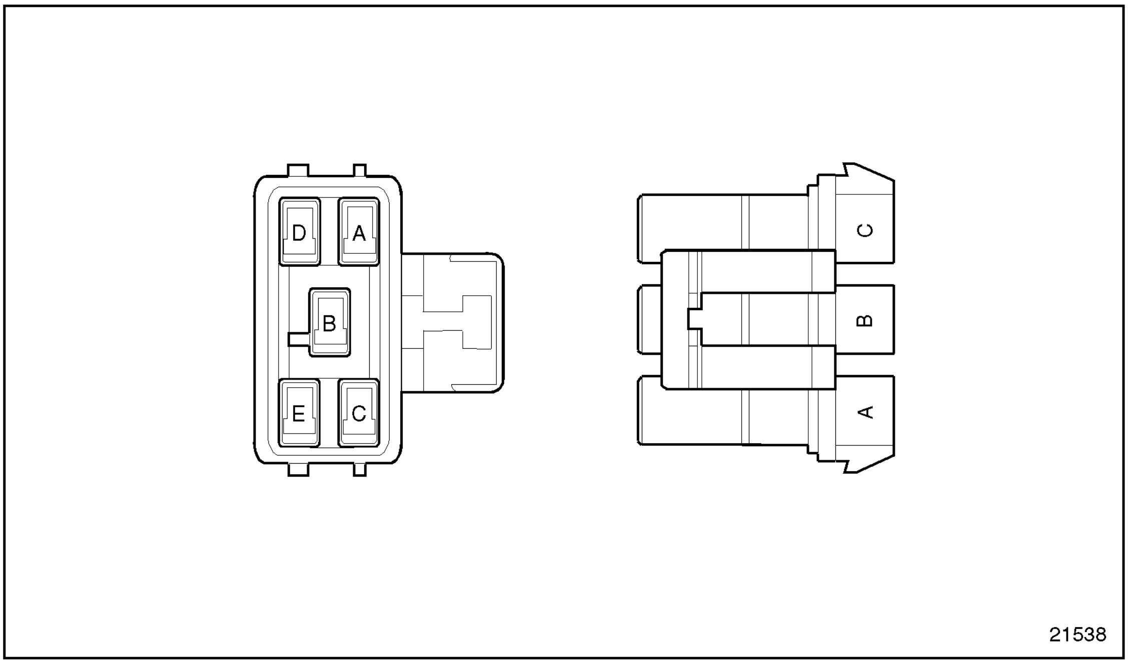


Figure 17-1 5-Way ECM Power Connector

3. Measure and record voltage from socket "A" (red lead) of 5-way power harness connector to a good ground (black lead).
4. Measure and record voltage from socket "C" (red lead) to a good ground (black lead).
5. Review the measured voltage readings.
   [a] If the voltage measured is less than 10 volts, inspect and repair power harness; refer to Section 17.2.3.
   [b] If the voltage measured is greater than 10 volts, check for low battery voltage; refer to Section 17.3.

17.2.3 Power Harness Repair

Perform the following steps to repair power harness:

1. To repair damage to the power harness; refer to Section 30.1.
2. Verify repair of the power harness; refer to Section 17.2.3.1.

17.2.3.1 Test Engine with Repaired Power Harness

Perform the following to determine if the repair resolved starter difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check for low battery voltage; refer to Section 17.3.

17.3 LOW BATTERY VOLTAGE

To determine if a weak battery is causing starting difficulty, perform the following steps:

CAUTION:

To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

1. Measure the battery voltage; refer to OEM guidelines.
   - [a] If voltage is between 10.5-14 volts (21-26 volts for a 24 volt system), check the terminals; refer to Section 17.4.
   - [b] If voltage is less than 10.5 volts (21 volts for a 24 volt system), replacement is necessary; refer to Section 17.3.1.

17.3.1 Battery Replacement

Perform the following steps for battery repair:

1. Remove and replace the battery; refer to OEM guidelines.
2. Verify battery replacement; refer to Section 17.3.1.1.

17.3.1.1 Test Engine With Replaced Battery

Perform the following to determine if the battery replacement resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check the terminals; refer to Section 17.4.

17.4 CORRODED OR DAMAGED BATTERY TERMINALS

To determine if corroded or damaged terminals is causing starting difficulty:

1. Visually inspect terminals for corrosion or damage.
   [a] If corrosion or damage is not found, check the magnetic switch; refer to Section 17.5.
   [b] If corrosion or damage is found, repair is necessary; refer to Section 17.4.1.

17.4.1 Corroded or Damaged Battery Terminal Repair

Perform the following to repair corroded or damaged battery terminals:

1. Repair or replace any corroded or damaged terminals; refer to OEM guidelines.
2. Verify repair of corroded or damaged terminals; refer to Section 17.4.1.1.

17.4.1.1 Test with Repaired Battery Terminals

Perform the following to determine if the repair resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check the magnetic switch; refer to Section 17.5.

17.5 DEFECTIVE MAGNETIC SWITCH

To determine if a defective magnetic switch is causing starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start engine.

CAUTION:

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Clamp a heavy gauge battery jumper cable between the two large studs of the magnetic switch. see Figure 17-2.

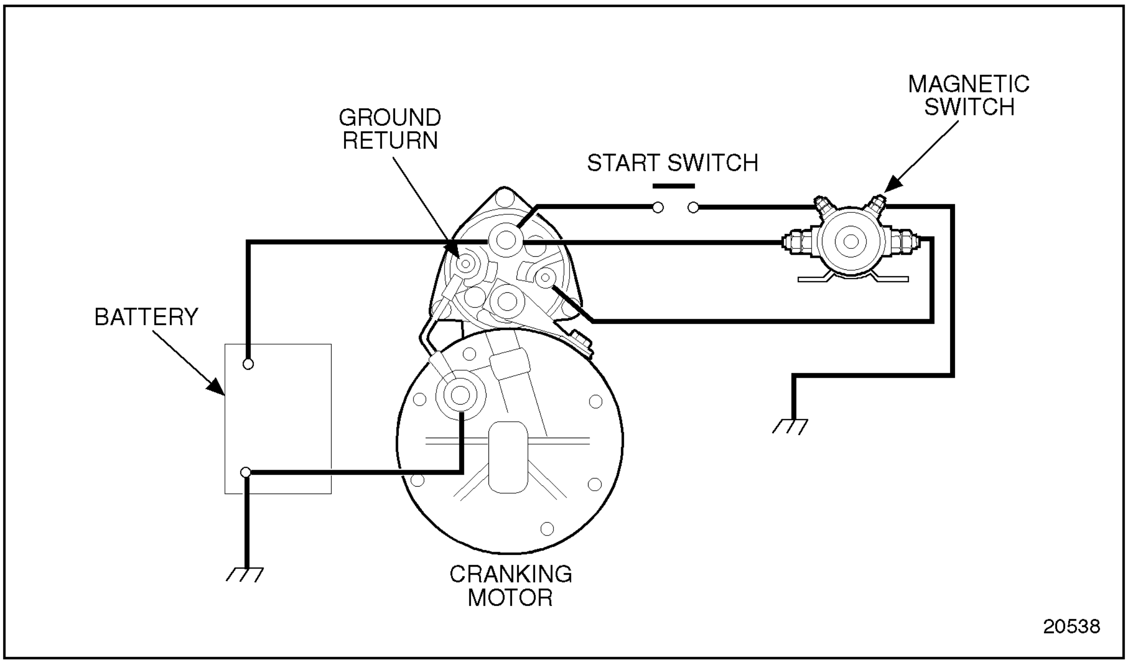


Figure 17-2 Basic Cranking Circuit

3. Remove the jumper cable to shut down the engine.
   [a] If the engine cranked with the jumper cable in place, the magnetic switch must be replaced; refer to Section 17.5.1.
   [b] If the engine did not crank with the jumper cable in place, check the starter; refer to Section 17.6.

17.5.1 Magnetic Switch Replacement

Perform the following for magnetic switch replacement:

1. Replace the magnetic switch; refer to OEM guidelines.
2. Verify magnetic switch replacement; refer to Section 17.5.1.1.

17.5.1.1 Test Engine with Replaced Magnetic Switch

Perform the following to determine if the magnetic switch replacement resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

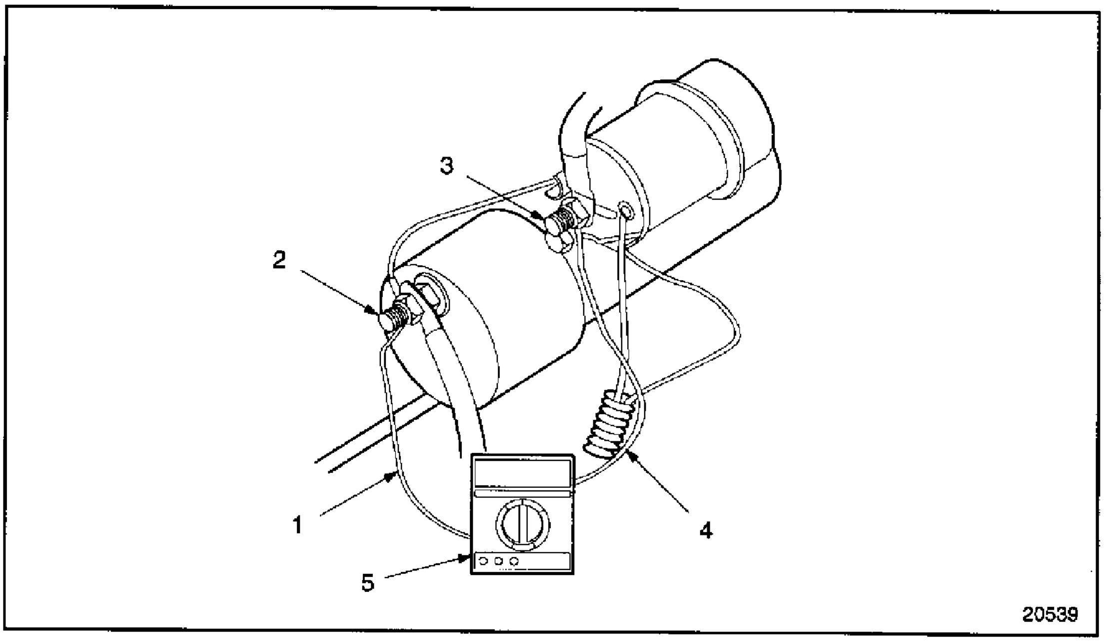
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check the starter; refer to Section 17.6.

17.6 DEFECTIVE STARTER

To determine if a defective starter is causing starting difficulty, perform the following steps:

1. Place the red lead of a voltmeter to the solenoid "BAT" terminal, see Figure 17-3.



1. Black Voltmeter Lead
2. Starter Ground Terminal Lug
3. Red Voltmeter Lead
4. Harness Tube
5. Volt Ohm Meter

Figure 17-3 Cranking Motor Available Voltage Test

2. Place the black voltmeter lead to the starter ground terminal, see Figure 17-2.
3. Engage the starter switch.
4. View the voltage reading on the meter.
   [a] If the voltage is less than 12 volts while cranking the engine, replacement is necessary; refer to Section 17.6.1.
   [b] If the voltage is greater than 12 volts while cranking the engine, check the cranking speed; refer to Section 17.7.

17.6.1 Starter Replacement

Perform the following for starter replacement:

1. Replace the starter; refer to Section 8.5.2.
2. Verify replacement of starter; refer to Section 17.6.1.1.

17.6.1.1 Test Engine with Replaced Starter

Perform the following to determine if the replaced starter resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.

   [b] If the engine fails to start and run, check the cranking speed; refer to Section 17.7.

17.7 LOW CRANKING SPEED

To determine if low cranking speed is causing starting difficulty, perform the following steps:

1. Install a tachometer to the engine and record engine revolution while cranking the engine; refer to OEM for guidelines.
   [a] If the cranking speed is greater than 100 r/min, check the fuel supply valve; refer to Section 17.8.
   [b] If the cranking speed is less than 100 r/min; refer to Section 17.7.1.

17.7.1 Low Cranking Speed Repair

Perform the following for low cranking speed repair:

1. Drain the engine oil. Refer to Section 13.5.1.
2. Remove oil filter(s); refer to Section 3.5.2.
3. Install new oil filter(s); refer to Section 3.5.3.
4. Refill the lubrication system with new oil; refer to Section 13.5.1.
5. Verify low cranking speed repair; refer to Section 17.7.1.1.

17.7.1.1 Test Engine with Replaced Oil

Perform the following to determine if the replaced oil resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check the fuel supply valve; refer to Section 17.8.

17.8 FUEL SUPPLY VALVE

To determine if the fuel supply valve is causing starting difficulty, perform the following steps:

1. Check that fuel supply valve is open; refer to OEM guidelines.
   [a] If the fuel supply valve is closed, repair is necessary; refer to Section 17.8.1.
   [b] If the fuel supply valve is open, check the fuel filters; refer to Section 17.9.

17.8.1 Fuel Supply Valve Repair

Perform the following for fuel supply valve repair:

1. Open the closed valve; refer to Section 2.8.2.
2. Prime the fuel system; refer to Section 2.7.1.
3. Verify fuel supply valve repair; refer to Section 17.8.1.1.

17.8.1.1 Test Engine with Fuel Supply Valve Open

Perform the following to determine if opening the fuel supply valve resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, check the fuel filters; refer to Section 17.9.

17.9 PLUGGED FUEL FILTER(S)

To determine if a plugged fuel filters is causing starting difficulty, perform the following steps:

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

1. Disconnect the fuel line return hose from the fitting located at the fuel tank.
2. Place the opened end of fuel line into a five gallon container.

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine at 1000 r/min.
5. Clock fuel rate for one minute.
6. Measure the amount of fuel flowed into the container.
   [a] If the fuel flow is greater than 1 gal/min, check for air in fuel; refer to Section 17.11. Shut down the engine.
   [b] If the fuel flow is less than 1 gal/min, replace the fuel filters; refer to Section 17.9.1. Shut down the engine.

17.9.1 Plugged Fuel Filter(s) Replacement

Perform the following steps to replace fuel filter(s):

1. Replace the fuel filter; refer to Section 2.7.1.
2. Test the engine to determine if starting has been improved; refer to Section 17.9.1.1.

17.9.1.1 Test Engine with Replaced Fuel Filters

Perform the following to determine if the replaced fuel filters resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.

   [b] If the engine fails to start and run, check the fuel pump; refer to Section 17.10.

17.10 FUEL PUMP

To determine if the fuel pump is causing starting difficulty, perform the following steps:

1. Insert a piece of wire through the pump flange drain hole, see Figure 17-4.

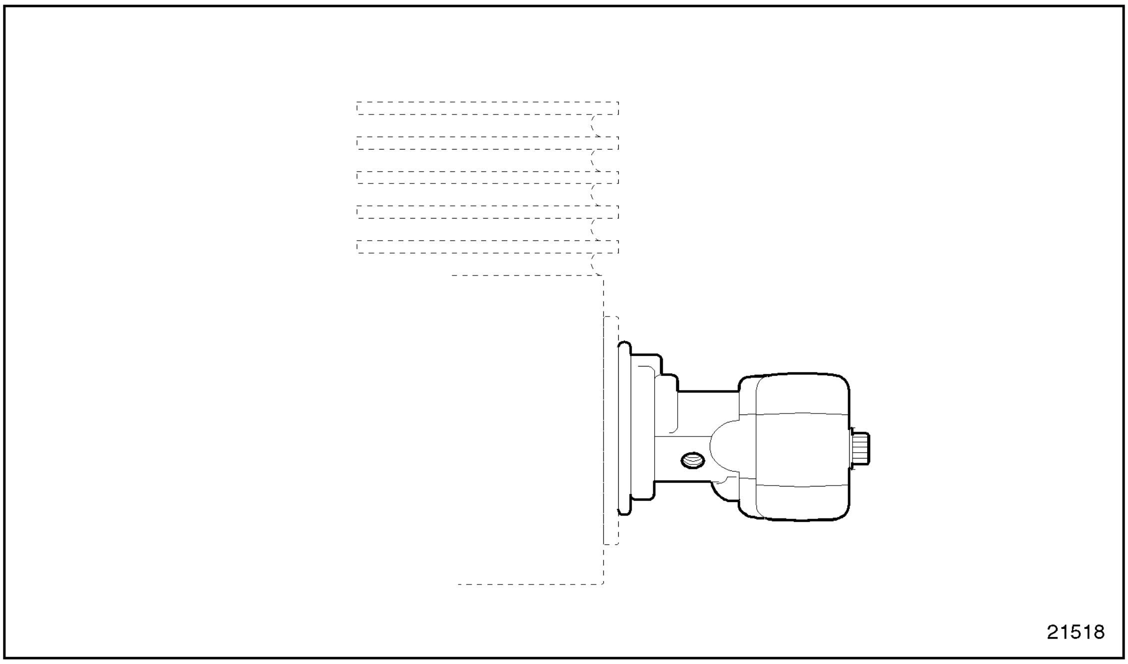


Figure 17-4 Fuel Pump Flange Drain Hole Location

2. Crank the engine momentarily and feel for wire vibration.
   [a] If the wire did not vibrate, determine if the drive hub or coupling should be replaced; refer to Section 17.10.1.
   [b] If the wire did vibrate, check for aerated fuel; refer to Section 17.11.

17.10.1 Drive Hubs and Coupling Replacement

Perform the following for drive hub or coupling replacement:

1. Replace the drive hub or coupling; refer to Section 2.6. Shut the engine down.
2. Test the engine to determine if starting has been improved; refer to Section 17.10.1.1.

17.10.1.1 Engine Test with Replaced Drive Hubs or Replaced Coupling

Perform the following to determine if replaced drive hubs or coupling resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required.
   [b] If the engine fails to start and run, check for air in fuel; refer to Section 17.11.

17.11 AERATED FUEL

To determine if aerated fuel is causing starting difficulty, perform the following steps:

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

1. Disconnect the fuel line return hose from the fitting located at the fuel tank; refer to OEM guidelines.
2. Place the opened end of the fuel line into a suitable container.

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine at 1000 r/min.
5. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are present, repair is necessary; refer to Section 17.11.1.
   [b] If air bubbles are not present, check for a restrictive air filter. Shut down the engine; refer to Section 17.12.

17.11.1 Aerated Fuel Resolution

Perform the following for aerated fuel resolution:

1. Shut down engine.
2. Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
3. Visually inspect all fuel lines between fuel tank and fuel pump for leaks.
4. Replace damaged components as required; refer to OEM guidelines.

5. Verify aerated fuel resolution; refer to Section 17.11.1.1.

17.11.1.1 Test Engine with Aerated Fuel Resolution

Perform the following to determine if aerated fuel resolution resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.

   [b] If the engine fails to start and run, check the air filter; refer to Section 17.12.

17.12 RESTRICTIVE AIR FILTER

To determine if a restrictive air filter is causing starting difficulty, perform the following steps:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Remove the air filter element; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

2. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run; refer to Section 17.12.1.

17.12.1 Air Filter Replacement

Perform the following steps for air filter replacement:

1. Visually inspect the air filter for clogging and replace as necessary; refer to OEM guidelines.
2. Visually inspect gaskets for deterioration and replace as necessary; refer to OEM guidelines.
3. Visually inspect air inlets for restrictions and clean as necessary; refer to OEM guidelines.
4. Verify air filter replacement; refer to Section 17.12.1.1.

17.12.1.1 Test Engine with Replaced Air Filter

Perform the following to determine if the replaced air filter resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.

   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.

   [b] If the engine fails to start and run, check compression; refer to Section 17.13.

17.13 LOW COMPRESSION

To determine if low compression is causing starting difficulty, perform the following steps:

1. Perform a cylinder compression test; refer to Section 29.2.
2. Compare cylinder compression test results to specifications.
   [a] If cylinder pressure is below specifications; refer to Section 17.13.1.
   [b] If cylinder pressure is within specifications, call Detroit Diesel Technical Service Group.

17.13.1 Low Compression Repair

Perform the following steps for low compression repair:

1. Remove cylinder head; refer to Section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to Section 1.2.3.
3. Replace damaged valves; refer to Section 1.4.2.
4. Inspect for worn or damaged cylinder kit components:
   [a] Inspect cylinder liner for damage, refer to Section 1.20.1.
   [b] Inspect piston and piston rings for damage, refer to Section 1.18.1.
5. Verify repairs made to cylinder head valve(s) or cylinder kit components; refer to Section 17.13.1.1.

17.13.1.1 Test Engine with Repaired Cylinder Head Valve(s), and Cylinder Kit

Perform the following steps to determine if the cylinder head valve and cylinder kit repair resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start and run, call the Detroit Diesel Technical Service Group.

18 NO START (ENGINE WILL NOT ROTATE)

Section **Page**

18.1 DISCHARGED BATTERY

To determine if a discharged battery is causing the engine not to start, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Measure and record the voltage at the battery terminals; refer to OEM guidelines.
   [a] If the voltage recorded is below OEM specifications and the engine failed to start, replacement is necessary; refer to Section 18.1.1.
   [b] If the voltage recorded is at recommended OEM specifications and the engine failed to start, check the magnetic switch; refer to Section 18.2.

18.1.1 Discharged Battery Resolution

Perform the following for battery replacement:

1. Replace the battery; refer to OEM guidelines.
2. Verify replacement of the battery; refer to Section 18.1.1.1.

18.1.1.1 Test Engine with New Battery

Perform the following to determine if the new battery resolved the no start condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start or run, check the magnetic switch; refer to Section 18.2.

18.2 DEFECTIVE MAGNETIC SWITCH

To determine if a defective magnetic switch is causing no start:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start engine.

CAUTION:

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

2. Clamp a heavy gage battery jumper cable between the two large studs of the magnetic switch; see Figure 18-1.

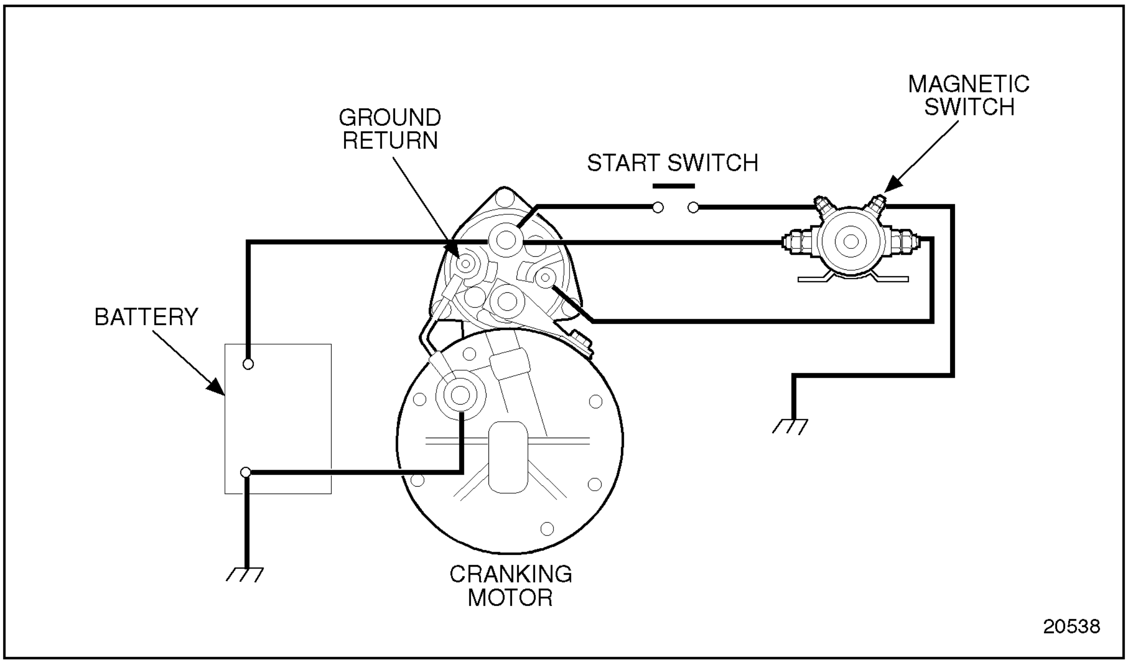


Figure 18-1 Basic Cranking Circuit

3. Remove the jumper cable to shut down the engine.
   [a] If the engine cranked with the jumper cable in place, the magnetic switch must be replaced; refer to Section 18.2.1.
   [b] If the engine did not crank with the jumper cable in place, check the starter; refer to Section 18.3.

18.2.1 Magnetic Switch Replacement

Perform the following for magnetic switch replacement:

1. Replace the magnetic switch; refer to OEM guidelines.
2. Perform verification of magnetic switch replacement; refer to Section 18.2.1.1.

18.2.1.1 Test Engine with New Magnetic Switch

Perform the following to determine if the magnetic switch replacement resolved the no start condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

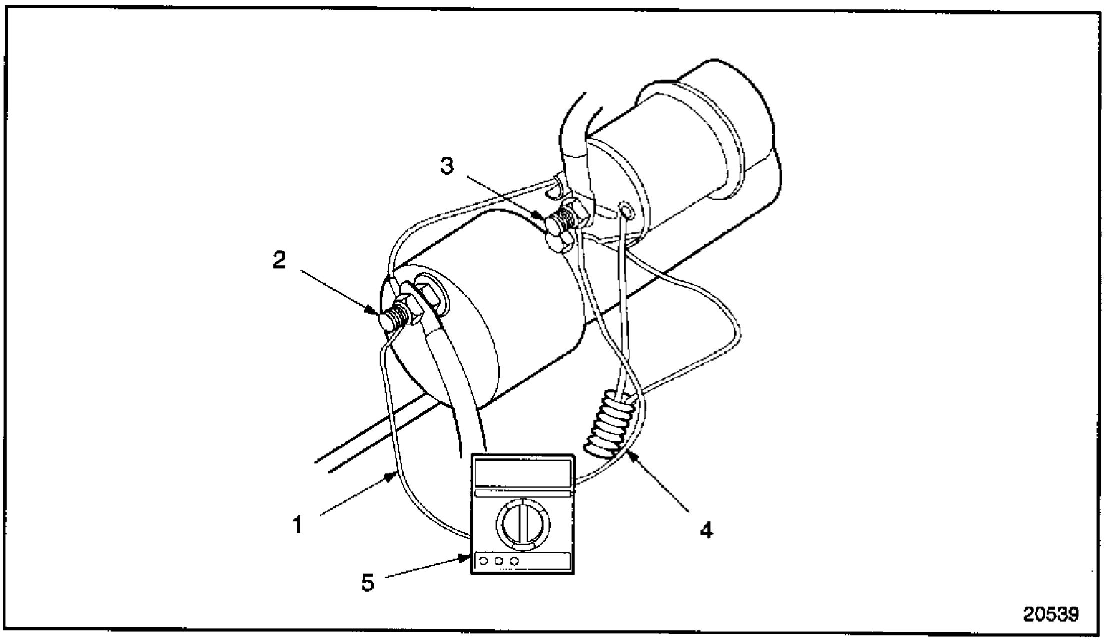
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start or run, check the starter; refer to Section 18.3.

18.3 DEFECTIVE STARTER

To determine if a defective starter is causing no start, perform the following steps:

1. Place the red lead of a voltmeter to the solenoid "BAT" terminal; see Figure 18-2.



1. Black Voltmeter Lead
2. Starter Ground Terminal Lug
3. Red Voltmeter Lead
4. Harness Tube
5. Volt Ohm Meter

Figure 18-2 Cranking Motor Available Voltage Test

2. Place the black voltmeter lead to the starter ground terminal; see Figure 18-1.
3. Engage the starter switch.
4. View the voltage reading on the meter.
   [a] If the voltage is less than specification while cranking the engine, starter replacement is necessary; refer to Section 18.3.1.
   [b] If the voltage is to specification while attempting to crank the engine, check for internal damage; refer to Section 18.4.

18.3.1 Starter Replacement

Perform the following for starter replacement:

1. Replace the starter; refer to Section 8.5.1.
2. Verify replacement of starter; refer to Section 18.3.1.1.

18.3.1.1 Test Engine with New Starter

Perform the following to determine if the new starter resolved no start condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start or run, check for internal engine damage; refer to Section 18.4.

18.4 INTERNAL ENGINE DAMAGE

To determine if internal engine damage is causing no start condition, perform the following steps:

1. Install a 3/4 in. breaker bar or ratchet and attempt to bar the engine over by hand.
2. Determine severity of internal engine damage.
   [a] If the engine rotates freely, check the electronic control module wiring harness; refer to Section 17.2.
   [b] If the engine binds and will not rotate freely, replace crankshaft bearings, or cylinder liners; refer to Section 18.4.1.

18.4.1 Internal Engine Damage Replacement

Perform the following for crankshaft bearings, and cylinder liners replacement:

1. Replace the crankshaft bearings; refer to Section 1.9.1.
2. Replace the cylinder liners; refer to Section 1.20.2.
3. Verify replacement of components; refer to Section 18.4.1.1.

18.4.1.1 Test Engine with Replaced Components

Perform the following to determine if the new components resolved no start condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Attempt to start and run the engine.
   [a] If the engine starts and runs, no further troubleshooting is required. Shut the engine down.
   [b] If the engine fails to start or run, call the Detroit Diesel Technical Service Group.

19 EXCESSIVE OIL CONSUMPTION

Section **Page**

19.1 MISCALIBRATED DIPSTICK

To determine if an overfilled crankcase is causing excessive oil consumption, perform the following:

1. Ensure vehicle is parked on level ground.
2. Perform a universal dipstick calibration check; refer to Section 3.8.
   [a] If the calibration check indicates that the oil level is off by more than 2 mm (0.079 in.), contact your Detroit Diesel regional support office.
   [b] Check for oil leaks; refer to Section 19.2.

19.2 EXTERNAL OIL LEAKS

To determine if oil leaks are causing excessive oil consumption, perform the following:

> **CAUTION:**
>
> **To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.**

1. Steam clean the engine.

> **CAUTION:**
>
> **Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.**
>
> - **Always start and operate an engine in a well ventilated area.**
> - **If operating an engine in an enclosed area, vent the exhaust to the outside.**
> - **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine to operating temperature 88°C (190°F).
3. Check for leaks at oil lines, connections, mating joints, seals, and gaskets.
   [a] If no oil leaks are found, shut down the engine and check for a leaking oil cooler core; refer to Section 19.3.
   [b] If oil leaks are found, shut down the engine; refer to Section 19.2.1.

19.2.1 Engine Oil Leak Repair

Perform the following steps, as necessary, to resolve engine oil leaks:

1. Repair or replace components leaking oil; refer to Section 3.
2. Verify repairs made to correct oil leaks; refer to Section 19.2.1.1.

19.2.1.1 Test Engine with Repairs Made to Correct Oil Leaks

Perform the following steps to determine if the repairs resolved the oil leaks:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine to operating temperature 88°C (190°F).
2. Shut down the engine.
3. Check the engine for oil leaks.
   [a] If no oil leaks are observed, check for a leaking oil cooler core; refer to Section 19.3.
   [b] If leaking; repeat Section 19.2.1.

19.3 LEAKING OIL COOLER CORE

To determine if a leaking oil cooler core is causing excessive oil consumption, perform the following:

1. Check for oil in the engine coolant or radiator.
   [a] If oil is present in either the engine coolant or radiator; refer to step 2.
   [b] If no oil is present in either the engine coolant or radiator, check for a defective air compressor; refer to Section 19.4.
2. Remove the oil cooler core and housing; refer to Section 3.7.2.
3. Clean both the oil side and water side of oil cooler core; refer to Section 3.7.2.
4. Perform an oil cooler core pressure test; refer to Section 3.7.2.1.
5. Visually check to see if air bubbles are rising to the surface of the water within the container.
   [a] If air bubbles are present; refer to Section 19.3.1.
   [b] If no air bubbles are present, complete lube oil consumption report; refer to Section 19.4.

19.3.1 Oil Cooler Core Replacement

Perform the following for oil cooler core replacement:

1. Replace and install a new oil cooler core; refer to Section 3.7.3.
2. Verify replacement of oil cooler core; refer to Section 19.3.1.1.

19.3.1.1 Test Engine with New Oil Cooler Core

Perform the following steps to determine if the replaced oil cooler core reduced oil consumption:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine to operating temperature 88°C (190°F).
2. Shut down the engine.
3. Check the engine coolant for the presence of oil.
   [a] If no oil is present in the coolant, shut down the engine, no further troubleshooting is required.
   [b] If oil is present in the coolant; refer to Section 19.3.1.2.

19.3.1.2 Test Engine for Reduced Oil Consumption

Perform a lube oil consumption report; refer to Section 29.5.

1. Review the oil consumption report.
   [a] If the oil consumption report data is within specifications, check for defective air compressor. Refer to Section 19.4.
   [b] If the oil consumption report data is not within specifications, call Detroit Diesel Technical Service Group.

19.4 DEFECTIVE AIR COMPRESSOR

To determine if a defective air compressor is causing excessive oil consumption, perform the following:

1. Perform a crankcase pressure test and record the test results; refer to Section 29.3 in this manual.
2. Disconnect the air outlet line from the air compressor; see Figure 19-1; refer to Section 10.1.2.

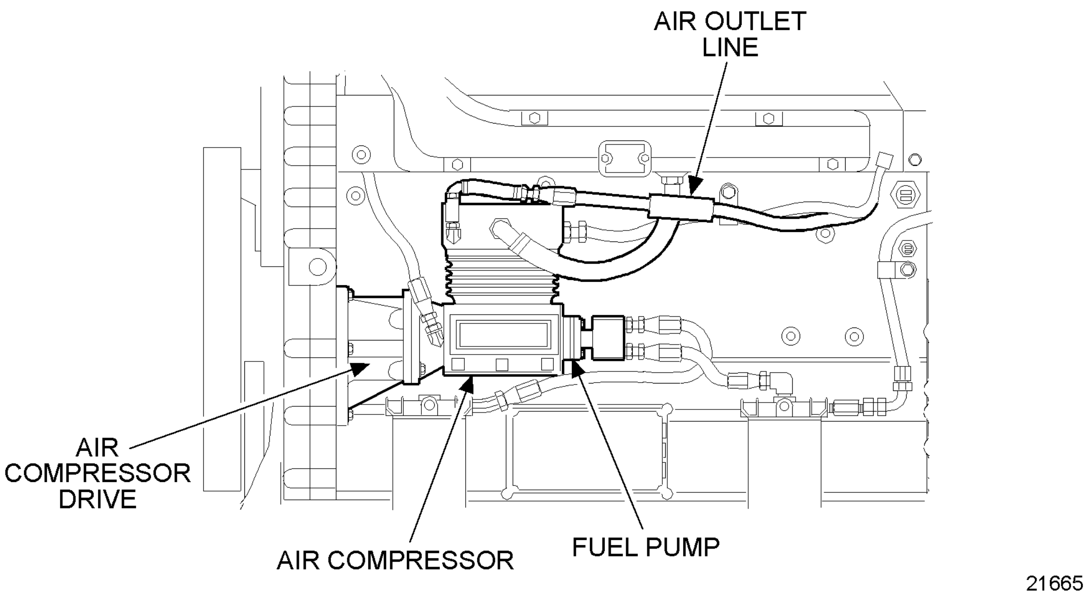


Figure 19-1 Air Compressor Air Outlet Line

3. Repeat step 1 and record the test results.
4. Compare the results of test one with test two.
   [a] If the engine crankcase pressure remained the same, check the turbocharger; refer to Section 19.5.
   [b] If the engine crankcase pressure decreased, repair the air compressor; refer to Section 19.4.1.

19.4.1 Air Compressor Repair

Perform the following steps to repair the defective air compressor:

1. Remove the air compressor from the engine; refer to Section 10.1.2.
2. Disassemble and repair the air compressor; refer to OEM guidelines.
3. Install the repaired air compressor to the engine; refer to Section 10.1.4.

4. Verify repair of the air compressor; refer to Section 19.4.1.1.

19.4.1.1 Test Engine with Repaired Air Compressor

Perform the following steps to determine if the repaired air compressor resolved the excessive crankcase pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure exceeds 3 in. H_2O (0.75 kPa); refer to Section 19.5. Shut the engine down.
   [b] If the engine crankcase pressure is within 3 in. H_2O (0.75 kPa), shut down the engine; no further troubleshooting is required.

19.5 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive oil consumption, perform the following:

1. Remove the turbocharger drain line connected to the crankcase and place the drain line into a suitable container.
2. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure is less than 3 in. H_2O (0.75 kPa), replace the turbocharger; refer to Section 19.5.1.
   [b] If the engine crankcase pressure is 3 in. H_2O (0.75 kPa) or less, check for worn or damaged valve and cylinder kit; refer to Section 19.6.

19.5.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove the defective turbocharger from the engine; refer to Section 6.5.2.
2. Tag removed turbocharger for remanufacture.
3. Install a new turbocharger to the engine; refer to Section 6.5.7.
4. Verify replacement of new turbocharger; refer to Section 19.5.1.1.

19.5.1.1 Test Engine with New Turbocharger

Perform the following steps to determine if a new turbocharger resolved the excessive crankcase pressure:

1. Remove the turbocharger drain line connected to the crankcase and place the drain line into a suitable container.
2. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure is greater than 3 in. H_2O (0.75 kPa), check for worn or damaged valve or cylinder kit; refer to Section 19.6.
   [b] If the engine crankcase pressure is 3 in. H_2O (0.75 kPa) or less, no further troubleshooting is required.

19.6 WORN OR DAMAGED VALVE OR CYLINDER KIT

A loss of cylinder pressure can cause increased oil consumption. The detection and elimination of cylinder pressure losses is vital to engine life and efficient operation. To assist the mechanic in effectively measuring the loss of cylinder pressure, and locating the source of abnormal leaks in individual cylinders, the following test procedure has been developed.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor, refer to Section 10.1.2.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run vehicle to full load and rated speed.
6. Attach a manometer, refer to Section 29.1, calibrated to read in inches of mercury, to the oil dipstick opening. Measure and record the crankcase pressure; refer to Section 29.3.
7. Shut down engine.
8. Remove the vehicle from the chassis dynamometer.
9. Review the crankcase pressure test results.
   [a] If the crankcase pressure exceeds 3 in. H_2O (0.75 kPa), repair worn or damaged valve(s) or cylinder kit; refer to Section 19.6.1.
   [b] If the crankcase pressure was less than or equal to 3 in. H_2O (0.75 kPa), perform cylinder compression test; refer to Section 29.2.
10. Compare the cylinder compression test results to specifications.

[a] If the cylinder compression is below specifications, repair worn or damaged valve(s) or cylinder kit; refer to Section 19.6.1

[b] If the cylinder compression is within specification, call Detroit Diesel Technical Service Group.

19.6.1 Worn or Damaged Valve(s) or Cylinder Kit(s) Repair

Perform the following steps to repair worn or damaged valve(s) and cylinder kit(s):

1. Remove cylinder head; refer to Section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to Section 1.2.3.
3. Inspect for worn or damaged cylinder kit components:
   [a] Inspect cylinder liner for damage, refer to Section 1.20.1.
   [b] Inspect piston and piston rings for damage, refer to Section 1.17.3.1.
4. Perform an oil consumption test report; refer to Section 19.6.1.1.

19.6.1.1 Test Engine for Reduced Oil Consumption

Perform a lube oil consumption report; refer to Section 29.5.

1. Review the oil consumption report.
   [a] If the oil consumption report data is within specifications, check for defective air compressor. Refer to Section 19.4.
   [b] If the oil consumption report data is not within specifications, call Detroit Diesel Technical Service Group.

20 EXCESSIVE CRANKCASE PRESSURE

Section Page

20.1 OBSTRUCTION OR DAMAGE TO ROCKER COVER BREATHER

To determine if an obstructed or damaged breather is causing excessive crankcase pressure, perform the following:

1. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure is less than 3 in. H_2O (0.75 kPa), check the air compressor; refer to Section 20.2.
   [b] If the engine crankcase pressure is greater than 3 in. H_2O (0.75 kPa), replace wire mesh element; refer to Section 20.1.1.

20.1.1 Rocker Cover Breather Resolution

Perform the following steps to replace wire mesh element replacement:

1. Remove the valve rocker cover(s); refer to Section 1.6.2.
2. Remove the wire mesh form the rocker cover; refer to Section 1.6.3.
3. Install a new wire mesh element to the rocker cover; refer to Section 1.6.6.
4. Install the rocker cover to the engine; refer to Section 1.6.7.
5. Verify replacement of wire mesh element; refer to Section 20.1.1.1.

20.1.1.1 Test Engine with New Wire Mesh Element

Perform the following steps to determine if the new wire mesh element resolved the excessive crankcase pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure is less than 3 in. H_2O (0.75 kPa), no further troubleshooting is required. Shut the engine down.

   [b] If the engine crankcase pressure is greater than 3 in. H_2O (0.75 kPa), check the air compressor; refer to Section 20.2.

20.2 DEFECTIVE AIR COMPRESSOR

To determine if a defective air compressor is causing excessive crankcase pressure, perform the following:

1. Perform a crankcase pressure test and record the test results; refer to Section 29.3.
2. Disconnect the air outlet line from the air compressor; see Figure 20-1; refer to Section 10.1.2.

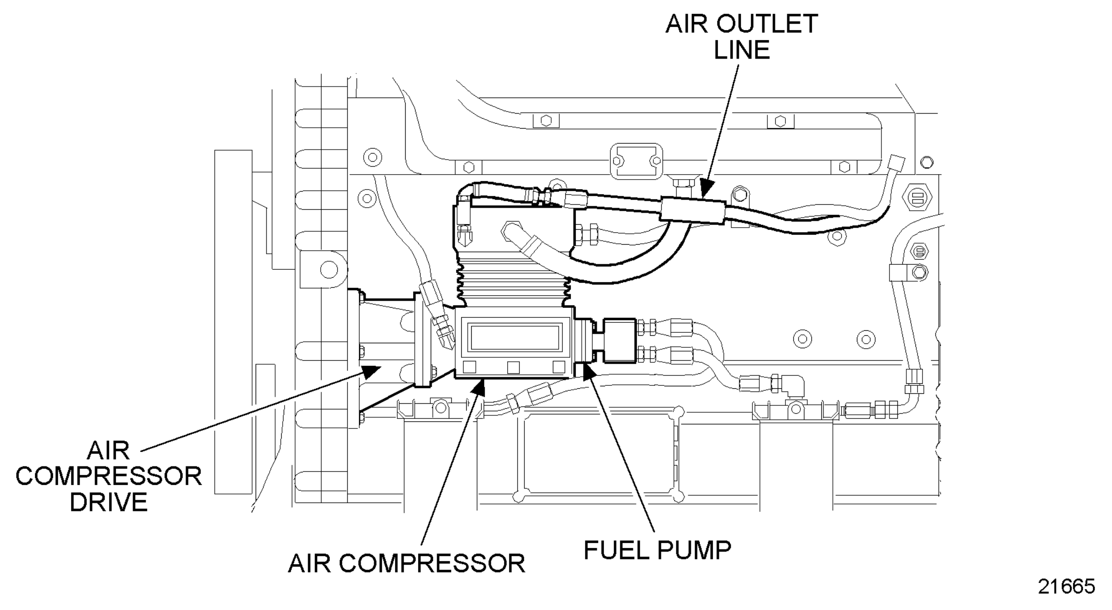


Figure 20-1 Air Compressor Air Outlet Line

3. Repeat step 1 and record the test results.
4. Compare the results of test one with test two.
   [a] If the engine crankcase pressure remained the same, check the turbocharger; refer to Section 20.3.
   [b] If the engine crankcase pressure decreased, repair the air compressor; refer to Section 20.2.1.

20.2.1 Air Compressor Repair

Perform the following steps to repair the defective air compressor:

1. Remove the air compressor from the engine; refer to Section 10.1.2.
2. Disassemble and repair the air compressor; refer to Section 10.1.3.
3. Install the repaired air compressor to the engine; refer to Section 10.1.4.

4. Verify repair of the air compressor; refer to Section 20.2.1.1.

20.2.1.1 Test Engine with Repaired Air Compressor

Perform the following steps to determine if a repaired air compressor resolved the excessive crankcase pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure is within 3 in. H_2O (0.75 kPa), no further troubleshooting is required. Shut the engine down.
   [b] If the engine crankcase pressure is not within 3 in. H_2O (0.75 kPa). Shut the engine down, refer to Section 20.3.

20.3 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive crankcase pressure, perform the following:

NOTICE:
Ensure that the engine is not allowed to operate longer than necessary to perform the crankcase pressure test. A complete loss of crankcase oil will severely damage the engine.

1. Remove the turbocharger outlet line connected to the crankcase and place the drain line into a suitable container; refer to Section 6.5.2.
2. Perform a crankcase pressure test; refer to Section 29.3.
   [a] If the engine crankcase pressure is less than 3 in. H_2O (0.75 kPa), replace the turbocharger; refer to Section 20.3.1.
   [b] If the engine crankcase pressure indicates no change, check for a worn or damaged valve or cylinder kit; refer to Section 20.4.

20.3.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove defective turbocharger from the engine; refer to Section 6.5.2.
2. Tag removed turbocharger for remanufacture.
3. Install a replacement turbocharger to the engine; refer to Section 6.5.7
4. Verify replacement of new turbocharger; refer to Section 20.3.1.1.

20.3.1.1 Test Engine with New Turbocharger

Perform the following steps to determine if a new turbocharger resolved the excessive crankcase pressure:

1. Perform a crankcase pressure test, refer to Section 29.3.
   [a] If the engine crankcase pressure is 3 in. H_2O (0.75 kPa), no further troubleshooting is required. Shut the engine down.
   [b] If the engine crankcase pressure is greater than 3 in. H_2O (0.75 kPa), check for a worn or damaged valve or cylinder kit; refer to Section 20.4.

20.4 WORN OR DAMAGED VALVE OR CYLINDER KIT

To determine if a worn or damaged cylinder kit is causing excessive crankcase pressure, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to Section 10.1.2.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run the vehicle to full load and rated speed.
6. Attach a manometer, refer to Section 29.1, calibrated to read in inches of water, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down the engine.
9. Remove the vehicle from the chassis dynamometer.
10. Review the crankcase pressure test.
    [a] If the crankcase pressure was greater than 3 in. H_2O (0.75 kPa); refer to Section 20.4.1.
    [b] If the crankcase pressure was less than 3 in. H_2O (0.75 kPa); perform a cylinder compression test; refer to Section 29.2.
11. Compare the cylinder compression test results to specifications.

[a] If cylinder pressure is below specifications, (listed in Table 29-2, refer to Section 29.2); refer to Section 20.4.1.

[b] If cylinder pressure is within specifications, (listed in Table 29-2, refer to Section 29.2), call Detroit Diesel Technical Service Group.

20.4.1 Worn or Damaged Valve or Cylinder Kit Repair

Perform the following steps for worn or damaged valve or cylinder kit:

1. Remove the cylinder head; refer to Section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to Section 1.2.3.
3. Inspect for worn or damaged cylinder kit components:
   [a] Inspect cylinder liner for damage, refer to Section 1.20.1.
   [b] Inspect piston and piston rings for damage, refer to Section 1.18.1.
4. Verify repair to cylinder valve(s) or cylinder kit components; refer to Section 20.4.1.1.

20.4.1.1 Test Engine with Repairs Made to Correct Worn or Damaged Valve or Cylinder Kit

Perform the following to determine if the repaired valve or cylinder kit resolved the excessive crankcase pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Move the vehicle requiring test to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to Section 10.1.2.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run the vehicle to full load and rated speed.
6. Attach a manometer, refer to Section 29.1, calibrated to read in inches of water, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down the engine.
9. Remove the vehicle from the chassis dynamometer.
10. Compare the cylinder pressure test results to specifications.

    [a] If cylinder pressure is within specifications, (listed in Table 29-2, refer to Section 29.2), no further troubleshooting is required.

    [b] If cylinder pressure is not within specifications, (listed in Table 29-2, refer to Section 29.2), call Detroit Diesel Technical Service Group.

21 EXCESSIVE EXHAUST SMOKE (BLACK OR GRAY)

Section **Page**

21.1 IMPROPER GRADE OF FUEL OIL

To determine if an improper grade of fuel oil is causing excessive black or gray smoke, perform the following:

1. Acquire a fuel oil sample from the vehicle fuel tank(s).
2. Submit fuel oil sample for an ASTM test analysis.
   [a] If the fuel oil meets specifications, (refer to Section 29.6), check for a restrictive air cleaner; refer to Section 21.2.
   [b] If the fuel oil did not meet specifications, (refer to Section 29.6), resolve improper grade of fuel; refer to Section 21.1.1.

21.1.1 Improper Grade of Fuel Resolution

Perform the following steps to resolve the improper grade of fuel oil:

1. Drain the fuel oil tanks, refer to OEM guidelines, and dispose of properly.
2. Refill the fuel oil tanks with new fuel oil having a cetane number greater than 40.
3. Verify fuel oil resolution; refer to Section 21.1.1.1.

21.1.1.1 Test the Engine with New Fuel Oil

Perform the following steps to determine if the fuel oil refill resolved the excessive exhaust smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.

    [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut the engine down.

    [b] If the engine exhaust smoke is excessively black or gray, shut the engine down. Check the air filter; refer to Section 21.2.

21.2 RESTRICTED AIR CLEANER ELEMENT

To determine if a restrictive air cleaner is causing excessive black or gray smoke, perform the following:

1. Remove the air filter element from the air cleaner container; refer to OEM guidelines.
2. Visually inspect the air cleaner element for damage or clogging.
   [a] If no damage or clogging is found, check the charge air cooler; refer to Section 21.3.
   [b] If damage or clogging is found; refer to Section 21.2.1.

21.2.1 Air Filter Element Replacement

Perform the following to replace the air filter element:

1. Remove and replace the damaged or clogged air filter element; refer to OEM guidelines.
2. Verify air filter element replacement; refer to Section 21.2.1.1.

21.2.1.1 Test the Engine with Replaced Air Filter Element

Perform the following to determine if the new filter element resolved excessive exhaust smoke:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessively black or gray, shut the engine down. Check the charge air cooler; refer to Section 21.3.

21.3 RESTRICTED OR CRACKED CHARGE AIR COOLER

To determine if a charge air cooler is causing excessive exhaust smoke, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

NOTICE:

To avoid engine damage, follow the installation instructions provided with the air-to-air charge air cooler test kit.

1. Attach a WK93 air-to-air charge air cooler test kit; refer to OEM guidelines.
2. Disconnect the air inlet hose from the outlet side of the turbocharger compressor housing; refer to Section 6.5.2.
3. Attach the air-to-air cooler test kit adaptor plug to fit into the hose at the compressor connector; refer to OEM guidelines.
4. Attach an air pressure hose to the air chuck at the regulator and gradually pressurize the air inlet system to a pressure of 25 lb/in.^{2} (177 kPa).
5. Apply a water and soap solution to each hose connection, across the face of the charge air cooler.
6. Apply a water and soap solution to the air intake manifold and cylinder head mating surface area.
7. Visually inspect all joints for air leaks and all charge air cooler welded surfaces for stress cracks.
   [a] If air leaks are present around the joints, replace the charge air cooler; refer to Section 21.3.1.

[b] If any leaks are present around the air intake manifold, repair the air intake manifold; refer to Section 21.3.2.

[c] If no leaks are present, check for a faulty exhaust system; refer to Section 21.4.

21.3.1 Charge Air Cooler Replacement

Perform the following steps to replace the charge air cooler:

1. Replace the charge air cooler, refer to OEM guidelines.
2. Verify replacement of the charge air cooler; refer to Section 21.3.2.1.

21.3.2 Air Intake Manifold Repair

Perform the following steps to repair the air intake manifold:

1. Remove the air intake manifold; refer to Section 6.3.4.
2. Inspect the air intake manifold; refer to Section 6.3.4.1.
3. Install the air intake manifold; refer to Section 6.3.5.
4. Verify repair of the air intake manifold; refer to Section 21.3.2.1.

21.3.2.1 Test the Engine with Replaced Charge Air Cooler and Air Intake Manifold

To determine if the replaced charge air cooler and air intake manifold resolved the excessive exhaust smoke condition, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessively black or gray, shut the engine down. Check the faulty exhaust system; refer to Section 21.4.

21.4 FAULTY EXHAUST SYSTEM

To determine if a faulty exhaust system is causing excessive exhaust smoke, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Drill an 11/32 in. hole in the exhaust pipe, 5 to 12 in. (approximately 127 to 305 mm) from the turbocharger exhaust outlet.

NOTE:
The tapped hole must be in a comparatively straight area of the turbocharger exhaust outlet.

2. Tap the hole to accommodate an 1/8 in. pipe plug.
3. Connect a manometer to the tapped hole; refer to Section 29.1.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Start and run the engine.
5. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
6. Run the engine speed to full load.
   [a] If the exhaust back pressure at full load is less than 3.0 in. Hg (10.1 kPa), check the fuel injectors; refer to Section 21.5. Shut the engine down.
   [b] If the exhaust back pressure at full load is 3.0 in. Hg (10.1 kPa) or greater, refer to Section 21.4.1. Shut the engine down.

21.4.1 Engine Exhaust System Resolution

Perform the following steps to resolve the engine exhaust system:

1. Visually inspect the engine exhaust system; refer to OEM guidelines.
2. Repair and replace defective exhaust system components; refer to OEM guidelines.
3. Verify exhaust system resolution; refer to Section 21.4.1.1.

21.4.1.1 Test the Engine with Replaced Exhaust System

Perform the following steps to determine if replaced engine exhaust system components resolved excessive exhaust smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.
   [b] If the engine exhaust emission is excessively black or gray, shut the engine down. Check the fuel injectors; refer to Section 21.5.

21.5 FAULTY FUEL INJECTOR

To determine if a faulty fuel injector is causing the cylinder to misfire, perform the following steps:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install DDL adaptor to the data cable and plug the adaptor into the DDL connector in the vehicle; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine at no-load.
3. From the DDEC III Select Menu, scroll to select ENGINE and press the ENTER key.
4. Scroll to FUEL INJECTOR INFO (CUTOUT) and press the ENTER key.
5. Scroll to select NEW TEST and press the ENTER key.
6. Scroll to select RPM SETTING FOR CCO TEST NORMAL and scroll to select 1000 and press the ENTER key.
7. Scroll to select AUTO and press the ENTER key. Wait for END OF TEST.

NOTE:
If an injector cannot be cutout, an ERROR message will appear. Press FUNC to exit the cylinder cutout function, press the FUNC key.

8. Scroll the list to review the results of the cylinder cutout test. To find suspect injectors, look for a cylinder with a value that is within 0.2° of the NO CUTOUT PULSE WIDTH, by comparing the CUTOUT PULSE WIDTH values to the NO CUTOUT PULSE WIDTH values.
   [a] If any CUTOUT PULSE WIDTH values are within 0.2° of the NO CUTOUT PULSE WIDTH, shut down the engine; refer to Section 21.5.1.

[b] If any CUTOUT PULSE WIDTH values are not within 0.2° of the NO CUTOUT PULSE WIDTH, shut down the engine; check the turbocharger, refer to Section 21.6.

21.5.1 Faulty Fuel Injector Repair

Perform the following steps for faulty fuel injector assembly(s):

1. Remove and replace injector assembly(s) whose values are within 0.2° of the NO CUTOUT PULSE WIDTH; refer to Section 2.3.2.
2. Verify replaced injector assembly(s); refer to Section 21.5.1.1.

21.5.1.1 Verification of Repair for Faulty Fuel Injector

Perform the following to determine if the replaced fuel injector(s) resolved the excessive exhaust smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed to full load.
3. Visually inspect the exhaust for excessive smoke.

[a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

[b] If the engine exhaust emission is excessive; shut the engine down. Refer to Section 21.6.

21.6 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive exhaust smoke, perform the following:

1. Remove the turbocharger outlet line connected to the crankcase and place the drain line into a suitable container; refer to Section 6.5.2.
2. Perform a crankcase pressure test, refer to Section 29.3.
   [a] If the engine crankcase pressure is greater than 3 in. H_2O, replace the turbocharger; refer to Section 21.6.1.
   [b] If the engine crankcase pressure is 3 in. H_2O, call the Detroit Diesel Technical Service Group.

21.6.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove defective turbocharger from the engine; refer to Section 6.5.2.
2. Tag removed turbocharger for remanufacture.
3. Install a new turbocharger to the engine; refer to Section 6.5.7.
4. Verify replacement of new turbocharger; refer to Section 21.6.1.1.

21.6.1.1 Test Engine with Replaced Turbocharger

Perform the following steps to determine if a replaced turbocharger resolved the excessive exhaust smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine speed to full load.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect the exhaust for excessive smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessive; call the Detroit Diesel Technical Service Group. Shut the engine down.

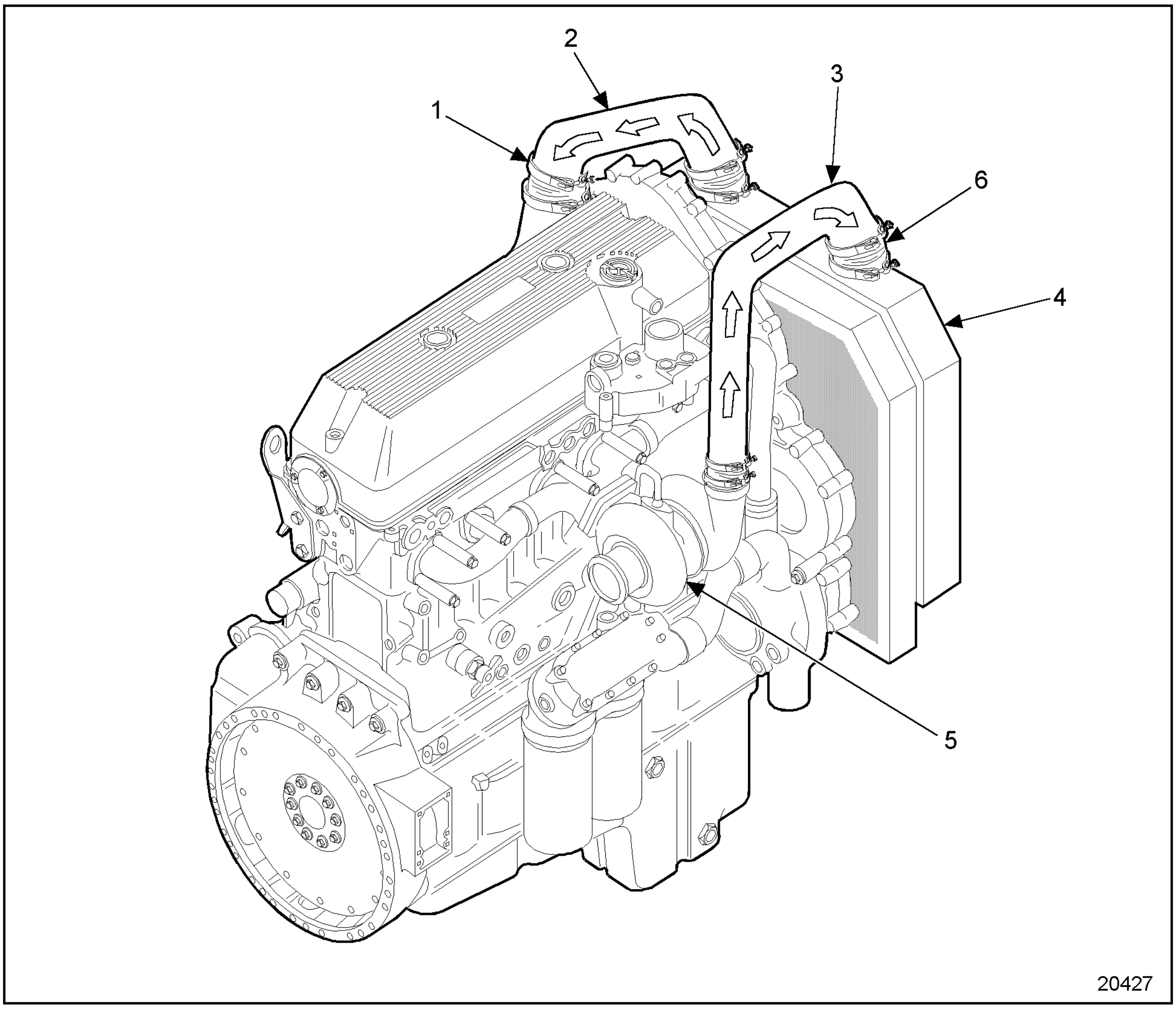
22 EXCESSIVE BLUE SMOKE

Section **Page**

22.1 DEFECTIVE TURBOCHARGER

To determine if a defective turbocharger is causing excessive exhaust smoke, perform the following:

1. Remove the charge air cooler outlet duct connected between the turbocharger and charge air cooler; see Figure 22-1.



1. Flexible Coupling
2. Charge Air Cooler Outlet Duct
3. Charge Air Cooler Inlet Duct
4. Charge Air Cooler
5. Turbocharger
6. Coupling Hose Clamp

Figure 22-1 Charge Air Cooler and Related Parts

2. Visually inspect the charge air cooler outlet duct.

   [a] If excessive engine lube oil is present; refer to Section 22.1.1.

[b] If no engine lube oil is present, check for worn or damaged valve or cylinder kit; refer to Section 22.2.

22.1.1 Turbocharger Replacement

Perform the following steps to replace a defective turbocharger:

1. Remove defective turbocharger from the engine; refer to Section 6.5.2.
2. Tag removed turbocharger for remanufacture.
3. Install a replacement turbocharger to the engine; refer to Section 6.5.7.
4. Verify replacement of new turbocharger; refer to Section 22.1.1.1.

22.1.1.1 Test Engine with Replaced Turbocharger

Perform the following steps to determine if a replaced turbocharger resolved the excessive exhaust smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive smoke.

   [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust smoke is excessively black or gray, check for worn or damaged valve or cylinder kit; refer to Section 22.2.

22.2 WORN OR DAMAGED VALVE OR CYLINDER KIT

To determine if a worn or damaged cylinder kit is causing excessive crankcase pressure, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Move the vehicle requiring testing to the chassis dynamometer; refer to OEM guidelines.
2. Disconnect air compressor; refer to Section 10.1.2.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start the engine.
4. Run the engine and bring the engine coolant temperature to normal operating range.
5. Run the vehicle to full load and rated speed.
6. Attach a manometer, refer to Section 29.1, calibrated to read in inches of water, to the oil dipstick opening.
7. Measure and record crankcase pressure.
8. Shut down the engine.
9. Remove the vehicle form the chassis dynamometer.
10. Review the crankcase pressure test.
    [a] If the crankcase pressure was greater than 3 in. H_2O (0.75 kPa); refer to Section 22.2.1.
    [b] If the crankcase pressure was less than 3 in. H_2O (0.75 kPa), perform a cylinder compression test; refer to Section 29.2.
11. Compare the cylinder compression test results to specifications.

[a] If cylinder pressure is below specifications, (listed in Table 29-2, refer to Section 29.2) refer to Section 22.2.1.

[b] If cylinder pressure is within specifications, (listed in Table 29-2, refer to Section 29.2) call Detroit Diesel Technical Service Group.

22.2.1 Worn or Damaged Valve or Cylinder Kit Repair

Perform the following steps for worn or damaged valve or cylinder kit:

1. Remove the cylinder head; refer to Section 1.2.2.
2. Inspect the cylinder head for worn or damaged valves; refer to Section 1.2.3.
3. Inspect for worn or damaged cylinder kit components:
   [a] Inspect cylinder liner for damage, refer to Section 1.20.1.
   [b] Inspect piston and piston rings for damage, refer to Section 1.18.1.
4. Verify repair to cylinder valve(s) or cylinder kit components; refer to Section 22.2.1.1.

22.2.1.1 Test Engine with Repairs Made to Correct Worn or Damaged Valve or Cylinder Kit

Perform the following to determine if the repaired valve or cylinder kit resolved the excessive crankcase pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start the engine.
2. Run the engine and bring the engine coolant temperature to normal operating range, 88-96°C (190-210°F).
3. Run the vehicle to full load and rated speed.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut the engine down.
   [b] If the engine exhaust smoke is excessively black or gray, call the Detroit Diesel Technical Service Group. Shut the engine down.

23 EXCESSIVE WHITE SMOKE

Section **Page**

23.1 IMPROPER GRADE OF FUEL

To determine if an improper grade of fuel oil is causing excessive white smoke, perform the following:

1. Acquire a fuel oil sample from the vehicle fuel tank(s).
2. Submit fuel oil sample for an ASTM test analysis.
   [a] If the fuel oil meets specifications, (listed in Table 29-4, refer to Section 29.6) check the fuel pump; refer to Section 23.2.
   [b] If the fuel oil did not meet specifications, (listed in Table 29-4, refer to Section 29.6) resolve improper grade of fuel; refer to Section 23.1.1.

23.1.1 Improper Grade of Fuel Resolution

Perform the following steps to resolve the improper grade of fuel oil:

1. Drain the fuel oil tank(s), refer to OEM guidelines, and dispose of properly.
2. Refill the fuel oil tanks with new fuel oil having a cetane number greater than 40.
3. Verify fuel oil resolution; refer to Section 23.1.1.1.

23.1.1.1 Test the Engine with New Fuel Oil

Perform the following steps to determine if the new fuel oil refill resolved the excessive white smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive smoke.
   [a] If the engine exhaust smoke emission appears normal, no further troubleshooting is required. Shut the engine down.
   [b] If the engine exhaust smoke is excessively white, shut the engine down. Check the fuel pump; refer to Section 23.2.

23.2 DEFECTIVE FUEL PUMP

To determine if the fuel pump is causing excessive white smoke, perform the following steps:

1. Insert a piece of wire through the fuel pump flange drain hole; see Figure 23-1.

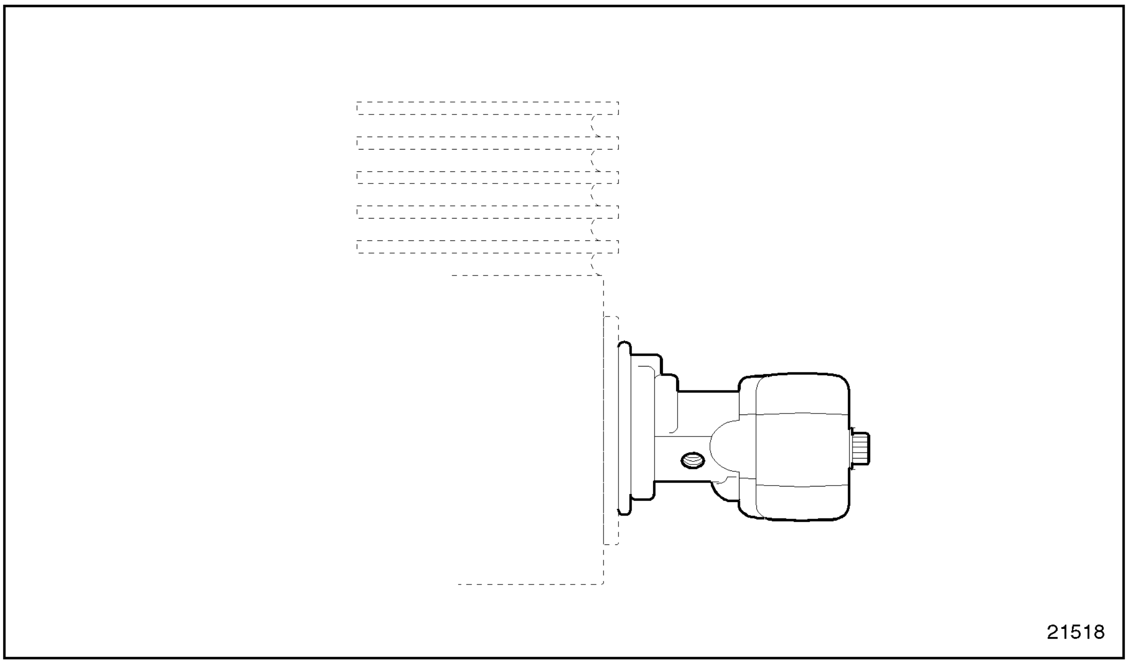


Figure 23-1 Fuel Pump Flange Drain Hole Location

2. Crank the engine momentarily and feel for wire vibration.
   [a] If the wire did not vibrate; refer to Section 23.2.1.
   [b] If the wire did vibrate, check for aerated fuel; refer to Section 23.3.

23.2.1 Drive Hubs and Coupling Replacement

Perform the following for drive hubs or coupling replacement:

1. Replace the drive hubs or coupling; refer to Section 2.6.
2. Verify the drive hubs and coupling replacement; refer to Section 23.2.1.1.

23.2.1.1 Engine Test with Replaced Drive Hubs or Replaced Coupling

Perform the following to determine if replaced drive hubs and coupling resolved excessive white smoke:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive white smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessively white, shut the engine down. Check for aerated fuel; refer to Section 23.3.

23.3 AERATED FUEL

To determine if aerated fuel is causing excessive white smoke, perform the following steps:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Disconnect the fuel line return hose from the fitting located at the fuel tank; refer to OEM guidelines.
2. Place the open end of the fuel line into a suitable container.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Start and run the engine.
4. Operate the engine at 1000 r/min.
5. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are present, shut down engine; refer to Section 23.3.1.
   [b] If air bubbles are not present, shut down engine, check for improper injector calibration setting; refer to Section 23.4.

23.3.1 Aerated Fuel Resolution

Perform the following to resolve aerated fuel:

1. Tighten all fuel line connections between fuel tank and fuel pump; refer to OEM guidelines.
2. Visually inspect all fuel lines between fuel tank and fuel pump for leaks.
3. Repair damaged components as required; refer to OEM guidelines.
4. Verify aerated fuel resolution; refer to Section 23.3.1.1.

23.3.1.1 Test Engine with Aerated Fuel Resolution

Perform the following to determine if aerated fuel resolution resolved excessive white smoke condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive white smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

[b] If the engine exhaust emission is excessively white, shut the engine down. Check for improper injector calibration setting; refer to Section 23.4.

23.4 IMPROPER INJECTOR CALIBRATION SETTING (DDEC III ENGINES ONLY)

To determine if an improper injector calibration setting is causing excessive white smoke, perform the following:

1. Check for improper injector calibration setting (DDEC III engine only); refer to Section 16.3.
2. Check for improper injector setting repair; refer to Section 16.3.1.
3. Verify injector setting repair; refer to Section 23.4.1.

23.4.1 Test Engine with Corrected Injector Setting

Perform the following to determine if injector setting repair resolved excessive white smoke:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive white smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessively white, shut the engine down. Check for improper valve clearance or injector height, worn or damaged camshaft lobes and rollers; refer to Section 23.5.

23.5 IMPROPER VALVE CLEARANCE OR INJECTOR HEIGHT, WORN OR DAMAGED CAMSHAFT LOBES AND ROLLERS

To determine if an improper valve clearance or injector height, worn or damaged camshaft lobes and rollers is causing excessive white smoke, perform the following:

1. Check for improper valve clearance or injector height, worn or damaged camshaft lobes and rollers; refer to Section 16.4.
2. Check for improper valve clearance or injector height repair; refer to Section 16.4.1.
3. Verify valve clearance or injector height, worn or damaged camshaft lobes and rollers repair; refer to Section 23.5.1.

23.5.1 Test Engine with Corrected Valve Clearance or Injector Height, Worn or Damaged Camshaft Lobes and Rollers

Perform the following to determine if the valve clearance or injector height, worn or damaged camshaft lobes and rollers repair resolved excessive white smoke:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive white smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessively white, shut the engine down. Check for faulty fuel injector; refer to Section 23.6.

23.6 FAULTY FUEL INJECTOR

To determine if a faulty fuel injector is causing excessive white smoke, perform the following:

1. Check for faulty fuel injector; refer to Section 16.5.
2. Check for faulty fuel injector repair; refer to Section 16.5.1.
3. Verify fuel injector repair; refer to Section 23.6.1.

23.6.1 Test the Engine with Repaired Fuel Injector

Perform the following to determine if the fuel injector repair resolved excessive white smoke:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive white smoke.

    [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

    [b] If the engine exhaust emission is excessively white, shut the engine down. Check for faulty electronic control module; refer to Section 23.7.

23.7 FAULTY ELECTRONIC CONTROL MODULE

To determine if a faulty electronic control module is causing excessive white smoke, perform the following:

1. Check for faulty electronic control module; refer to Section 16.6.
2. Check for faulty ECM repair; refer to Section 16.6.1.
3. Verify ECM repair; refer to Section 23.7.1.

23.7.1 Test Engine with Repair to the Electronic Control Unit

Perform the following to determine if the ECM repair resolved excessive white smoke:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

3. Visually inspect exhaust for excessive white smoke.

   [a] If the engine exhaust emission appears normal, no further troubleshooting is required. Shut the engine down.

   [b] If the engine exhaust emission is excessively white, shut the engine down. Call Detroit Diesel Technical Service Group.

24 ROUGH RUNNING OR STALLING

Section **Page**

24.1 LOW BATTERY VOLTAGE

To determine if a weak battery is causing rough running or stalling, perform the following steps:

CAUTION:

To avoid injury from battery explosion or contact with battery acid, work in a well-ventilated area, wear protective clothing, and avoid sparks or flames near the battery. Always establish correct polarity before connecting cables to the battery or battery circuit. If you come in contact with battery acid:

- **Flush your skin with water.**
- **Apply baking soda or lime to help neutralize the acid.**
- **Flush your eyes with water.**
- **Get medical attention immediately.**

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Measure the battery voltage; refer to OEM guidelines.
   [a] If the battery voltage is greater than 10.5 volts, refer to Section 24.2.
   [b] If the battery voltage is less than 10.5 volts, replace the battery; refer to Section 24.1.1.

24.1.1 Battery Replacement

Perform the following steps for battery replacement:

1. Remove and replace the battery; refer to OEM guidelines.
2. Verify battery replacement; refer to Section 24.1.1.1.

24.1.1.1 Test Engine with Replaced Battery

Perform the following to determine if the battery replacement resolved difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut the engine down.
   [b] If the engine is running rough or stalling, shut the engine down. Check for aerated fuel oil; refer to Section 24.2.

24.2 AERATED FUEL OIL

To determine if aerated fuel is causing rough running or stalling, perform the following steps:

1. Test for aerated fuel; refer to Section 23.3.
2. Aerated fuel resolution; refer to Section 23.3.1.
3. Verify aerated fuel resolution; refer to Section 24.2.1.

24.2.1 Test Engine with Aerated Fuel Resolution

Perform the following to determine if the aerated fuel resolution resolved rough running or stalling condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).

   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut the engine down.

   [b] If the engine is running rough or stalling, shut the engine down. Check for insufficient fuel oil flow; refer to Section 24.3.

24.3 INSUFFICIENT FUEL OIL FLOW

To determine if insufficient fuel oil flow is causing rough running or stalling, do the following:

1. Perform a fuel oil flow test; refer to Section 29.7.
2. Analyze the fuel oil flow test results.
   [a] If the fuel oil rate is 246 L/hr (65 gal/hr), refer to Section 24.4.
   [b] If the fuel oil rate is less than 246 L/hr (65 gal/hr), resolve the insufficient fuel oil flow; refer to Section 24.3.1.

24.3.1 Insufficient Fuel Oil Flow Resolution

Perform the following steps to resolve the insufficient fuel oil flow:

1. Replace the fuel filter(s); refer to Section 13.5.11.

NOTE:
Always fill the filter(s) with clean fuel oil before installing. Turn the filter(s) until they contact the gasket fully. Then, turn them an additional two-thirds by hand.

2. Inspect the fuel lines for restrictions due to pinching, kinking or other damage. If damage is found, repair as necessary; refer to OEM guidelines.
3. Inspect the cylinder head for a correct restricted fitting. If an incorrect fitting is found, replace with a new fitting; refer to Section 1.2.2.
4. Inspect the fuel return check valve for restrictive movement; refer to Section 2.8.2.
5. Inspect the fuel pump drive assembly. If damage is found, repair as necessary; refer to Section 2.5.2.
6. Verify repairs done to correct insufficient fuel oil flow; refer to Section 24.3.1.1.

24.3.1.1 Test the Engine with Resolved Fuel Oil Flow

Perform the following steps to determine if the fuel oil flow resolution resolved rough running or stalling:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut the engine down.
   [b] If the engine is running rough or stalling, shut the engine down. Check for high fuel oil temperature return; refer to Section 24.4.

24.4 HIGH FUEL OIL TEMPERATURE RETURN

To determine if high fuel oil temperature return is causing rough running or stalling, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 24-1; refer to OEM guidelines.

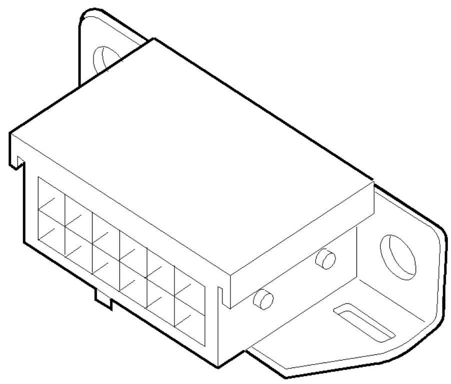


Figure 24-1 Typical Display Data Line Adaptor

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine.
3. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the return fuel oil temperature is less than or equal to 60°C (140°F), refer to Section 24.5.
   [b] If the return fuel oil temperature is greater than 60°C (140°F), resolve the high fuel oil temperature; refer to Section 24.4.1.

24.4.1 High Fuel Oil Temperature Resolution

Perform the following steps to resolve high fuel oil temperature:

1. Remove and replace fuel oil filter(s); refer to Section 2.7.
2. Inspect check valve for any restricted fitting; refer to Section 2.8.2.
3. Replace both the restrictive fitting or check valve; refer to Section 2.8.4.
4. Verify fuel oil filter(s) replacement; refer to Section 24.4.1.1.

24.4.1.1 Test the Engine with Replaced Oil Filters

Perform the following steps to determine if the replaced oil filter(s) resolved the rough running or stalling condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut the engine down.
   [b] If the engine is running rough or stalling, shut the engine down. Check for improper injector calibration setting; refer to Section 24.5.

24.5 IMPROPER INJECTOR CALIBRATION SETTING (DDEC III ENGINES ONLY)

To determine if improper injector calibration setting (DDEC III engines only) is causing rough running or stalling, perform the following:

1. Test for improper injector setting; refer to Section 16.3.
2. Compare the calibration code(s) shown on the Diagnostic Data Reader display with the two digit calibration code(s) on the injector(s).

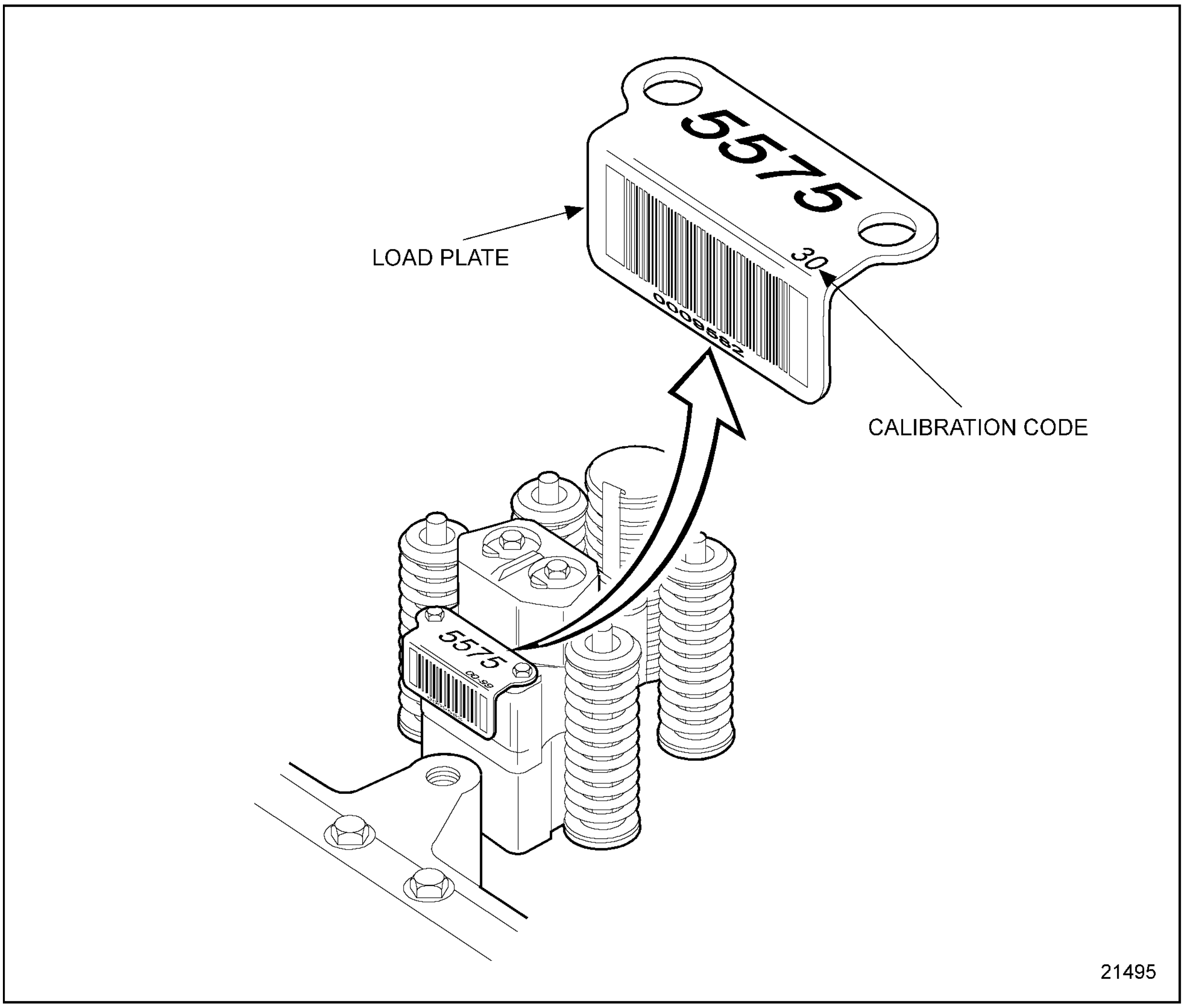


Figure 24-2 Injector Calibration Code

[a] If the calibration codes match, refer to Section 24.6.

[b] If the calibration code on the display is different then the calibration code on the suspect injector for that cylinder, the injector setting must be reset, see Figure 24-2; refer to Section 24.5.1.

24.5.1 Improper Injector Setting Repair

Perform the following steps to recalibrate improper injector setting:

1. Reset incorrect injector setting; refer to Section 16.3.1.
2. Verify injector setting repair; refer to Section 24.5.1.1.

24.5.1.1 Test the Engine with Corrected Injector Setting

Perform the following to determine if the corrected injector setting resolved rough running or stalling:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut the engine down.
   [b] If the engine is running rough or stalling, shut the engine down. Check for low compression pressure; refer to Section 24.6.

24.6 LOW COMPRESSION PRESSURE

To determine if low compression pressure is causing rough running or stalling, perform the following:

1. Perform a cylinder compression test; refer to Section 29.2.
2. Compare cylinder compression test results to specifications.
   [a] If cylinder pressure is within specifications (listed in Table 29-2, refer to Section 29.2), call Detroit Diesel Technical Service Group.
   [b] If cylinder pressure is below specifications (listed in Table 29-2, refer to Section 29.2), refer to Section 24.6.1.

24.6.1 Low Compression Repair

Perform the following steps for low compression repair:

1. Perform low compression repair; refer to Section 17.13.1.
2. Verify cylinder head valve and cylinder kit repair; refer to Section 24.6.1.1.

24.6.1.1 Test Engine with Repaired Cylinder Head Valve(s), and Cylinder Kit

Perform the following steps to determine if the cylinder head valve and cylinder kit repair resolved starting difficulty:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88-96°C (190-210°F).
   [a] If the engine is not running rough or stalling, no further troubleshooting is required. Shut the engine down.
   [b] If the engine is running rough or stalling, shut the engine down. Call Detroit Diesel Technical Service Group.

25 LACK OF POWER

25.1 AERATED FUEL

To determine if aerated fuel is causing lack of power, perform the following steps:

1. Test for aerated fuel; refer to Section 23.3.
2. Visually check to see if air bubbles are rising to the surface of the fuel within the container.
   [a] If air bubbles are not present, shut down engine, check for high fuel pressure; refer to Section 25.2.
   [b] If air bubbles are present, shut down engine; refer to Section 25.1.1.

25.1.1 Aerated Fuel Resolution

Perform the following to resolve aerated fuel:

1. Perform aerated fuel repair; refer to Section 23.3.1.
2. Verify aerated fuel resolution; refer to Section 25.1.1.1.

25.1.1.1 Test the Engine with Aerated Fuel Resolution

Perform the following to determine if aerated fuel resolution resolved lack of power condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.
   [b] If lack of power occurred during the test drive, shut the engine down. Check for high fuel pressure; refer to Section 25.2.

25.2 HIGH FUEL PRESSURE

To determine if high fuel pressure is causing lack of power, perform the following steps:

1. Remove either the fuel pressure sensor (FPS) or fuel temperature sensor (FTS) fitting from the secondary filter, if equipped; see Figure 25-1 for FPS, and see Figure 25-2 for FTS.

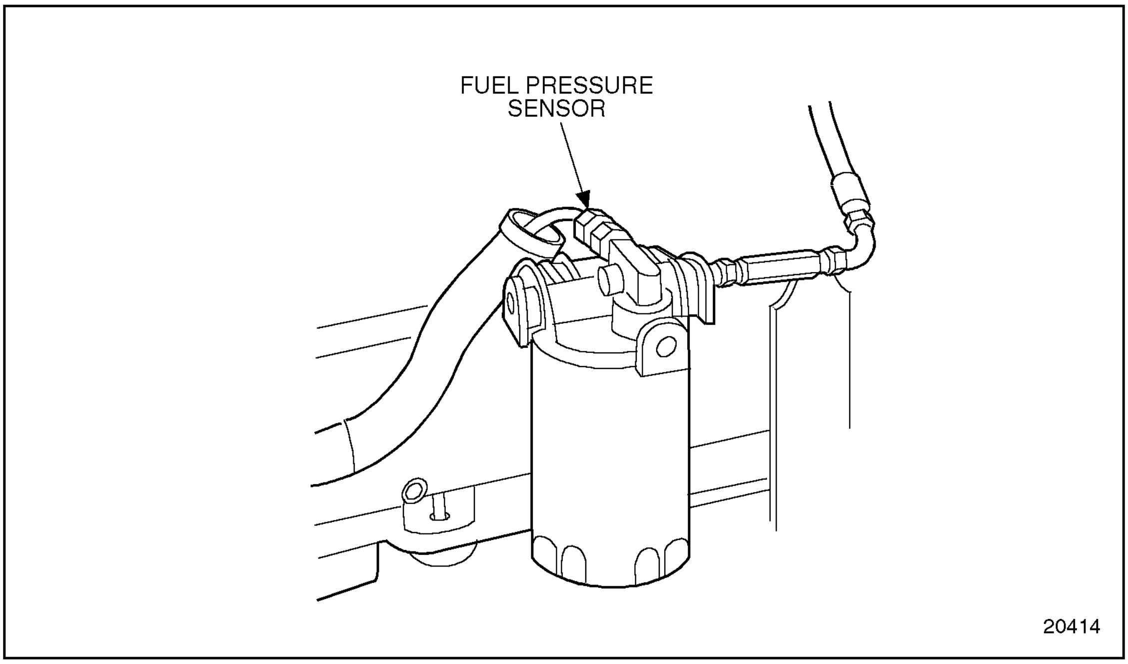


Figure 25-1 Engine Fuel Pressure Sensor

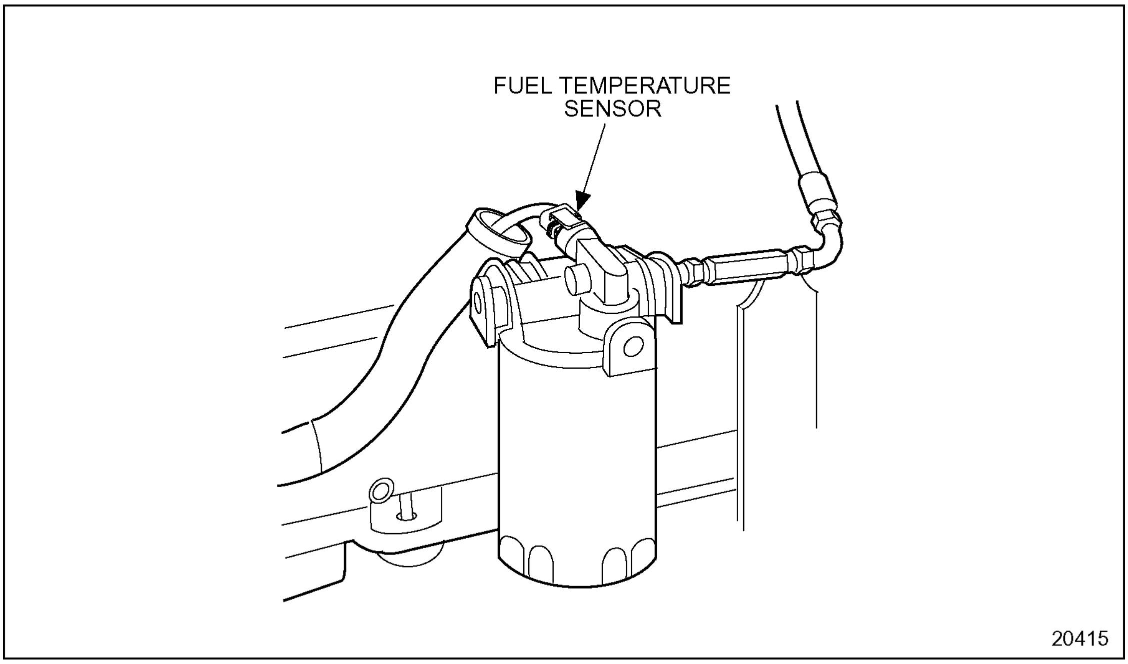


Figure 25-2 Engine Fuel Temperature Sensor

2. Install a tee fitting between the secondary filter and fuel outlet line.

3. Attach a calibrated gauge capable of reading 0-100 lb·in.^{2} to the tee fitting.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

4. Start and run the engine to the speeds, listed in Table 25-1, and record the fuel pressure:

Engine Speed	Fuel Pressure
600 r/min	103-151 kPa (15-22 lb/in.^{2})
1200-1300 r/min	207-310 kPa (30-45 lb/in.^{2})
1800-2100 r/min	448-483 kPa (65-70 lb/in.^{2})

Table 25-1 Fuel Pressure at Various Speeds

5. Shut down the engine.
6. Remove the tee fitting and calibrated gauge from the secondary filter.
7. Reinstall the FTS, refer to Section 2.24.3 or FPS sensors, refer to Section 2.23.3; whichever was removed.
8. Analyze the measured fuel pressure readings.
   [a] If the fuel oil pressure is within specification, listed in Table 25-1, check for high fuel oil temperature return; refer to Section 25.3.
   [b] If the fuel oil pressure is greater than specifications, listed in Table 25-1, refer to Section 25.2.1.

25.2.1 Restricted Fitting and Check Valve Replacement

Perform the following steps to replace the restricted fitting and check valve.

1. Remove the restricted fitting; refer to Section 2.8.2.
2. Install a new restricted fitting; refer to Section 2.8.4.
3. Remove the check valve; refer to OEM guidelines.
4. Install a new check valve; refer to OEM guidelines.
5. Verify check valve and restricted fitting replacement; refer to Section 25.2.1.1.

25.2.1.1 Test the Engine with Replaced Check Valve and Restricted Fitting

Perform the following to determine if the replaced check valve and restricted fitting resolved lack of power condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine at idle with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
3. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.
   [b] If lack of power occurred during the test drive, shut the engine down. Check for high fuel oil temperature return; refer to Section 25.3.

25.3 HIGH FUEL OIL TEMPERATURE RETURN

To determine if high fuel oil temperature return is causing lack of power, perform the following:

1. Test for high fuel oil temperature return; refer to Section 24.4.
2. Analyze the high fuel oil temperature test results.
   [a] If the return fuel oil temperature is less than or equal to 60°C (140°F), check for air cleaner restriction; refer to Section 25.4.
   [b] If the return fuel oil temperature is greater than 60°C (140°F), resolve the high fuel oil temperature return condition; refer to Section 25.3.1.

25.3.1 High Fuel Oil Temperature Resolution

Perform the following steps to resolve high fuel oil temperature return:

1. Remove and replace fuel oil filter(s); refer to Section 2.7.1.
2. Inspect the check valve for a restricted fitting, replace if necessary; refer to Section 2.8.2.
3. Verify high fuel oil temperature repair; refer to Section 25.3.1.1.

25.3.1.1 Test the Engine with Resolved High Fuel Oil Temperature

Perform the following steps to determine if high fuel oil temperature repairs resolved lack of power condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.
   [b] If lack of power occurred during the test drive, shut the engine down. Check for a restricted air cleaner element; refer to Section 25.4.

25.4 RESTRICTED AIR CLEANER ELEMENT

To determine if a restricted air cleaner element is causing lack of power, perform the following:

1. Remove the air filter element from the air cleaner container; refer to OEM guidelines.
2. Visually inspect the air cleaner element for damage or clogging.
   [a] If no damage or clogging is found, check the charge air cooler; refer to Section 25.5.
   [b] If damage or clogging is found; refer to Section 25.4.1.

25.4.1 Air Filter Element Replacement

Perform the following to replace the air filter element:

1. Remove and replace the damaged or clogged air filter element; refer to OEM guidelines.
2. Verify air filter element replacement; refer to Section 25.4.1.1.

25.4.1.1 Test the Engine with Replaced Air Filter Element

Perform the following to determine if the new filter element resolved lack of power:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.

[b] If lack of power occurred during the test drive, shut the engine down. Check the charge air cooler; refer to Section 25.5.

25.5 RESTRICTED OR CRACKED CHARGE AIR COOLER OR LEAKING INTAKE MANIFOLD

To determine if a restricted or cracked charge air cooler or leaking manifold is causing lack of power, perform the following:

1. Test the charge air cooler; refer to Section 21.3.
2. Visually inspect all joints for air leaks and all charge air cooler welded surfaces for stress cracks.
   [a] If charge air cooler leaks are present around the joints, replace the charge air cooler; refer to Section 25.5.1.
   [b] If the intake manifold leaks, repair intake manifold; refer to Section 25.5.2.
   [c] If neither charge air cooler nor intake manifold leaked, check the exhaust system; refer to Section 25.6.

25.5.1 Charge Air Cooler Replacement

Perform the following steps to replace the charge air cooler:

1. Remove and replace the charge air cooler; refer to OEM guidelines.
2. If the intake manifold doesn't leak, verify replacement of the charge air cooler; refer to Section 25.5.2.1.
3. If the intake manifold leaks, repair intake manifold; refer to Section 25.5.2.

25.5.2 Air Intake Manifold Repair

Perform the following steps to repair the air intake manifold:

1. Remove the air intake manifold; refer to Section 6.3.4.
2. Inspect the air intake manifold; refer to Section 6.3.4.1.
3. Install the air intake manifold; refer to Section 6.3.5.
4. Verify repair of the intake manifold; refer to Section 25.5.2.1.

25.5.2.1 Test the Engine with Replaced Charge Air Cooler and Air Intake Manifold

To determine if the repairs resolved the lack of power condition, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.

   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.

   [b] If lack of power occurred during the test drive, shut the engine down. Check the exhaust system; refer to Section 25.6.

25.6 FAULTY EXHAUST SYSTEM

To determine if a faulty exhaust system is causing lack of power, perform the following:

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Test the exhaust system; refer to Section 21.4.
2. Run the engine speed to full load.
   [a] If the exhaust back pressure at full load is less than 3.0 in. Hg (10.1 kPa), check for high inlet air temperature; refer to Section 25.7.
   [b] If the exhaust back pressure at full load is 3.0 in. Hg (10.1 kPa) or greater, refer to Section 25.6.1.

25.6.1 Engine Exhaust System Resolution

Perform the following steps to resolve the engine exhaust system:

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Visually inspect the engine exhaust system; refer to OEM guidelines.
2. Repair or replace defective exhaust system components; refer to OEM guidelines.
3. Verify exhaust system resolution; refer to Section 25.6.1.1.

25.6.1.1 Test the Engine with Replaced Exhaust System

Perform the following steps to determine if replaced engine exhaust system components resolved lack of power condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.
   [b] If lack of power occurred during the test drive, shut the engine down. Check for high inlet air temperature; refer to Section 25.7.

25.7 HIGH INLET AIR TEMPERATURE

To determine if high inlet air temperature is causing lack of power, perform the following:

1. Test the radiator fan, fan drive, or fan shroud for proper operation or configuration; refer to OEM guidelines.
   [a] If the radiator fan, fan drive, or fan shroud pass OEM test, check high altitude operation; refer to Section 25.8.
   [b] If the radiator fan, drive or shroud did not operate correctly; refer to Section 25.7.1.

25.7.1 Radiator Fan, Drive and Shroud Replacement

Perform the following steps to replace the radiator fan, drive, and or shroud:

1. Remove and replace the radiator fan, drive, and or shroud; refer to OEM guidelines.
2. Verify replacement; refer to Section 25.7.1.1.

25.7.1.1 Test the Engine with Radiator Fan, Fan Drive, or Fan Shroud Replacement

Perform the following steps to determine if replaced radiator fan, fan drive, or fan shroud resolved lack of power condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.

   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.

   [b] If lack of power occurred during the test drive, shut the engine down. Check high altitude operation; refer to Section 25.8.

25.8 HIGH ALTITUDE OPERATION

To determine if high altitude operation is causing lack of power, see Figure 25-3:

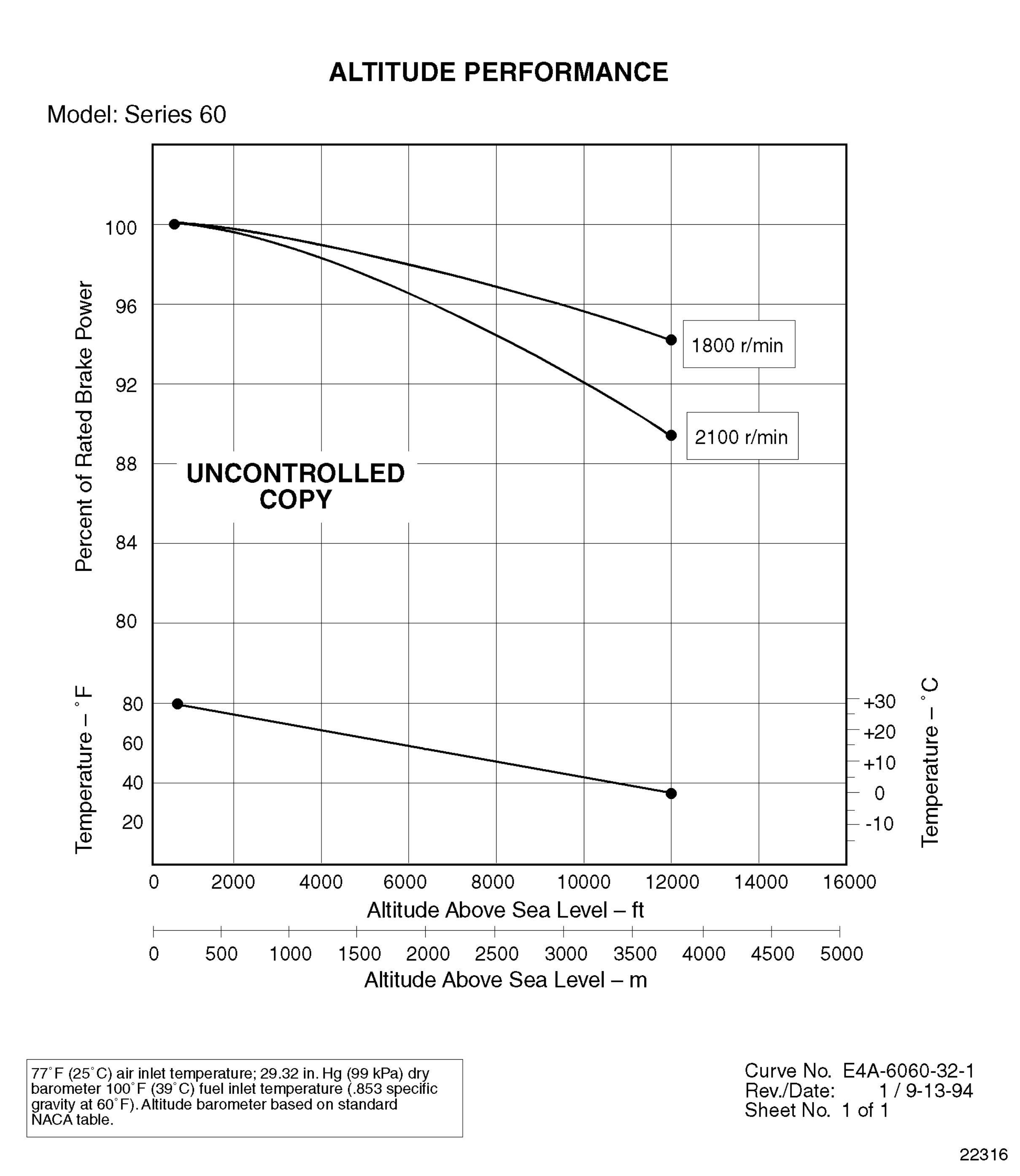


Figure 25-3 Altitude Performance Curves

1. Based on the altitude curve data, see Figure 25-3, decide if high altitude is causing the lack of power.
   [a] If your vehicle is operating above sea level, a loss of power will be encountered, no further troubleshooting is required.
   [b] If your vehicle is operating at or below sea level, and there is a lack of power; refer to Section 25.9.

25.9 INCORRECT CAMSHAFT TIMING

To determine if incorrect camshaft timing is causing lack of power, perform the following:

1. Check the camshaft timing; refer to Section 1.22.6.1.
   [a] If the dial indicator reading is within 0.173-0.215 in., no further troubleshooting is required.
   [b] If the dial indicator reading is not within 0.173-0.215 in., check engine timing; refer to Section 25.9.1.

25.9.1 Engine Timing Resolution

Perform the following steps to resolve incorrect engine timing:

1. Perform an engine gear train timing check; refer to Section 1.21.2.1.
2. Verify engine timing resolution; refer to Section 25.9.1.1.

25.9.1.1 Test Engine with Correct Timing

Perform the following steps to determine if corrected engine timing resolved lack of power condition:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Test drive the vehicle to ensure lack of power has been resolved.
   [a] If no lack of power occurred during the test drive, no further troubleshooting is required. Shut the engine down.
   [b] If lack of power occurred during the test drive, shut the engine down. Call the Detroit Diesel Technical Service Group.

26 LOW OIL PRESSURE

26.1 IMPROPER ENGINE OIL LEVEL

To determine if improper engine oil level is causing low oil pressure, perform the following steps:

1. Ensure that the vehicle is parked on level ground.
2. Check the engine oil level; refer to Section 13.5.1.
   [a] If the engine oil level is correct, check lubricating oil viscosity, refer to Section 26.2.
   [b] If the engine oil level is incorrect, refer to Section 26.1.1.

26.1.1 Low Engine Oil Level Resolution

Perform the following steps for low engine oil level:

1. Fill engine oil pan to correct level; refer to Section 13.5.1.
2. Verify low engine oil resolution; refer to Section 26.1.1.1.

26.1.1.1 Test for Proper Engine Oil Level

Perform the following to determine if properly filled oil pan resolved low oil pressure:

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

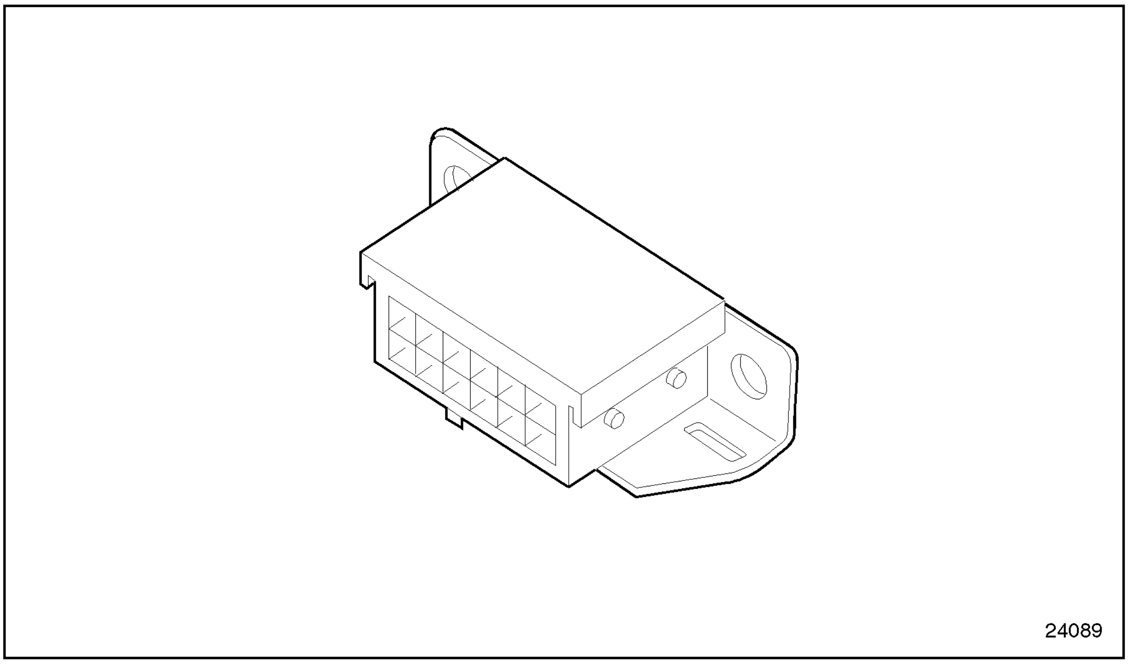


Figure 26-1 Typical Display Data Line Adaptor

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and vary engine speed between 1800-2100 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. Check lubricating oil viscosity; refer to Section 26.2.

26.2 IMPROPER LUBRICATING OIL VISCOSITY

To determine if improper lubricating oil viscosity is causing low oil pressure, perform the following:

1. Acquire a lubricating oil sample from the engine oil pan.
2. Submit oil sample for an ASTM test analysis.
   [a] If engine oil sample meets ASTM specifications, listed in Table 29-2 (refer to Section 29.2), check to determine if lubricating oil is diluted with fuel or coolant; refer to Section 26.3.
   [b] If engine oil sample did not meet ASTM specifications, listed in Table 29-2 (refer to Section 29.2), refer to Section 26.2.1.

26.2.1 Lubricating Oil Replacement

Perform the following steps to replace engine oil:

1. Drain and refill engine with new lubricating oil; refer to Section 13.5.1.
2. Verify lubricating oil replacement, refer to Section 26.2.1.1.

26.2.1.1 Test Engine with Replaced Lubricating Oil

Perform the following to determine if replaced lubricating oil resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates oil pressure greater than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. Check the lubricating oil for fuel and water dilution; refer to Section 26.3.

26.3 LUBRICATING OIL DILUTED WITH FUEL OIL OR ENGINE COOLANT

To determine if lubricating oil is diluted with fuel oil or engine coolant is causing low oil pressure, perform the following:

1. Acquire a lubricating oil sample from the engine oil pan.
2. Visually examine lubricating oil sample for presence of engine coolant or fuel oil.
   - [a] If coolant or fuel oil are not present, check for a faulty oil pressure gage sensor, refer to Section 26.4.
   - [b] If water or fuel oil are present, refer to Section 26.3.1.

NOTE:
Blockage of the engine water pump weep hole can allow coolant that has leaked past a faulty water pump oil seal to enter the lubricating oil. Inspect the weep hole for blockage.

26.3.1 Contaminated Lubricating Oil Resolution

Perform the following steps to resolve contaminated lubricating oil:

1. Drain engine oil pan, refer to Section 13.5.1.
2. Refill engine crankcase with new oil; refer to Section 13.5.1.
3. Verify lubricating oil replacement; refer to Section 26.3.1.1.

26.3.1.1 Test Replaced Lubricating Oil

Perform the following to determine if replaced lubricating oil resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. Check for faulty oil pressure gage sensor; refer to Section 26.4.

26.4 FAULTY OIL PRESSURE GAGE SENSOR

To determine if a faulty oil pressure gage sensor is causing low oil pressure, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and vary the engine speed between 1800-2100 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates oil pressure greater than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR, check oil pressure gage sensor line for obstruction; refer to Section 26.5.

   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine; refer to Section 26.4.1.

26.4.1 Oil Pressure Gage Sensor Replacement

Perform the following steps to replace the oil pressure gage sensor:

1. Remove and replace the oil pressure gage sensor; refer to OEM guidelines.
2. Verify replaced oil pressure gage sensor; refer to Section 26.4.1.1.

26.4.1.1 Test the Engine with Replaced Oil Pressure Gage Sensor

Perform the following to determine if replaced oil pressure gage sensor resolved low oil pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run engine speed at 1800 r/min.
2. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates oil pressure greater than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   [b] If the DDR indicates oil pressure less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. Check oil pressure gage sensor line for obstruction; refer to Section 26.5.

26.5 OIL PRESSURE GAGE LINE OBSTRUCTED

To determine if an oil pressure gage line obstruction is causing low oil pressure, perform the following:

1. Disconnect oil gage line from oil pressure gage; refer to OEM guidelines.
2. Visually inspect oil gage line for obstructions.
   - [a] If no obstructions are found; check to determine if rocker arm shaft plugs are missing; refer to Section 26.6.
   - [b] If obstructions are found; refer to Section 26.5.1.

26.5.1 Obstructed Oil Pressure Gage Line Repair

Perform the following steps to resolve oil pressure gage line obstructions:

1. Remove oil pressure gage line; refer to OEM guidelines.
2. Clean oil gage line by soaking in cleaning solution for 5 minutes.

CAUTION:
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Blow out oil gage line of residue contamination with compressed air.
4. Install cleaned oil gage line; refer to OEM guidelines.
5. Verify oil gage line repair; refer to Section 26.5.1.1.

26.5.1.1 Test the Engine with Repaired Oil Gage Line

Perform the following to determine if replaced oil pressure gage resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates 241 kPa (35 lb/in.^{2}) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}) at 1800 r/min, shut down the engine and disconnect the DDR. Check for missing or damaged rocker arm shaft plugs; refer to Section 26.6.

26.6 ROCKER ARM SHAFT PLUGS MISSING (NEW OR REBUILT ENGINES ONLY)

If engine is not new or has not been rebuilt, refer to Section 26.7.

To determine if a missing rocker arm shaft plugs are causing low oil pressure, perform the following:

1. Remove the rocker arm cover; refer to Section 1.6.2.
2. Visually inspect the rocker arm shaft for missing or leaking shaft plugs.
   [a] If the shaft plugs are present and are not leaking, check the oil cooler for restriction; refer to Section 26.7.
   [b] If the shaft plugs are missing; refer to Section 26.6.2.
   [c] If the shaft plugs are leaking, refer to Section 26.6.1.

26.6.1 Leaking Rocker Arm Shaft Plug Repair

Perform the following steps to repair leaking rocker arm shaft plugs:

1. Remove damaged shaft plugs; refer to Section 1.3.
2. Inspect rocker arm shaft for damage; refer to Section 1.3.3.1. If damage is found, replace the rocker arm shaft; refer to Section 1.3.2.
3. Install new shaft plugs; refer to Section 1.3.4.

NOTE:
Shaft plug **must** be installed 1.0-1.3 mm (0.040-0.050 in.) below surface using J 36236.

4. Install rocker arm cover; refer to Section 1.6.7.
5. Verify repair made to the rocker shaft plugs; refer to Section 26.6.2.1.

26.6.2 Missing Rocker Arm Shaft Plug Repair

Perform the following steps to repair missing rocker arm shaft plugs:

1. Inspect rocker arm shaft for damage; refer to Section 1.3.3.1. If damage is found, replace the rocker arm shaft; refer to Section 1.3.2.
2. Install new shaft plugs; refer to Section 1.3.4.

NOTE:
Shaft plug **must** be installed 1.0-1.3 mm (0.040-0.050 in.) below surface using J 36236.

3. Install rocker arm cover; refer to Section 1.6.7.
4. Verify repair made to the rocker shaft plugs; refer to Section 26.6.2.1.

26.6.2.1 Test Engine with Repaired Rocker Shaft Plugs

Perform the following to determine if repaired rocker shaft plugs resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:
Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm. □ **Always start and operate an engine in a well ventilated area.** □ **If operating an engine in an enclosed area, vent the exhaust to the outside.** □ **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates 241 kPa (35 lb/in.^{2}) at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}) at 1800 r/min, shut down the engine and disconnect the DDR. Check the oil cooler for restriction; refer to Section 26.7.

26.7 RESTRICTED OIL COOLER

To determine if a restricted oil cooler is causing low oil pressure, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine at 1800 r/min.
3. Run the engine at 1800 r/min with a no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88°-96°C (190°-210°F).
   [a] If the DDR is indicating a lubricating oil temperature less than or equal to 110°C (230°F), no further troubleshooting is required, check pressure regulator valve; refer to Section 26.8. Shut down the engine and disconnect the DDR.
   [b] If the DDR is indicating a lubricating oil temperature greater than 110°C (230°F), repair oil cooler; refer to Section 26.7.1. Shut down the engine.

26.7.1 Oil Cooler Repair

Perform the following steps to repair the oil cooler:

1. Remove and repair oil cooler; refer to Section 3.7.1.
2. Clean the oil cooler; refer to Section 3.7.2.
3. Inspect the oil cooler for damage; refer to Section 3.7.2.1.
4. Install repaired oil cooler; refer to Section 3.7.3.
5. Verify repair of oil cooler; refer to Section 26.7.1.1.

26.7.1.1 Test Engine with Repaired Oil Cooler

Perform the following to determine if oil cooler repair resolved low oil pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

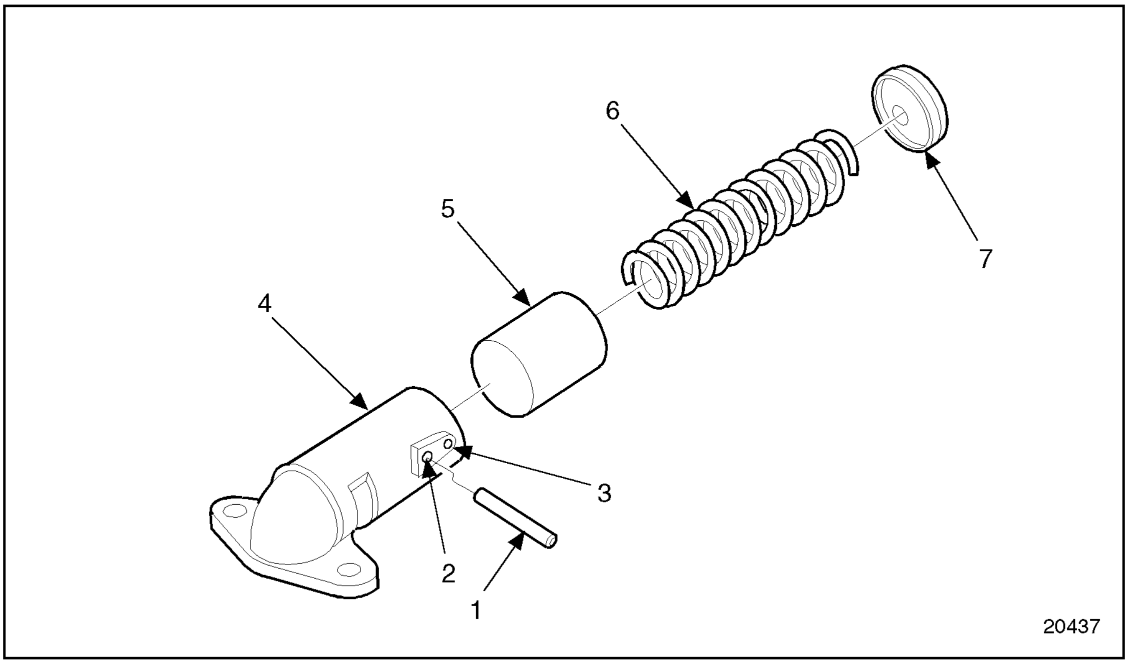
- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine at 1800 r/min.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, 88°-96°C (190°-210°F).
   [a] If the DDR is indicating a lubricating oil temperature less than or equal to 110°C (230°F) at 1800 r/min, disconnect the DDR and shut down the engine. No further troubleshooting is required.
   [b] If the DDR is indicating a lubricating oil temperature greater than 110°C (230°F) at 1800 r/min, shut down the engine and disconnect the DDR. Check pressure regulator valve; refer to Section 26.8.

26.8 NONFUNCTIONAL OR STICKING OIL PRESSURE REGULATOR VALVE

To determine if a nonfunctional or sticking regulator valve is causing low oil pressure, perform the following:

1. Remove the oil pressure regulator; refer to Section 3.3.2 in 6SE450 service manual.
2. Inspect the oil pressure regulator; refer to Section 3.3.3.1.
   [a] If the regulator valve moves freely in the valve body, no further troubleshooting is required; see Figure 26-2. Reinstall the oil pressure regulator assembly; refer to Section 3.3.5, check the bypass valve; refer to Section 26.9.
   [b] If the regulator valve will not move freely in the valve body, refer to Section 26.8.1.



1. Pin
2. Pressure Relief Valve Pin Location
3. Pressure Regulator Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

Figure 26-2 Oil Pressure Regulator

26.8.1 Oil Pressure Regulator Valve Repair

Perform the following steps to repair the oil pressure regulator valve:

1. Disassemble the pressure regulator valve and replace damaged components; refer to Section 3.3.3.
2. Assemble the pressure regulator valve; refer to Section 3.3.4.

3. Verify repair of the regulator valve; refer to Section 26.8.1.1.

26.8.1.1 Test Engine with Repaired Oil Pressure Regulator Valve

Perform the following to determine if repaired oil pressure regulator valve resolved low oil pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR; check bypass valve; refer to Section 26.9.

26.9 DEFECTIVE BYPASS VALVE

To determine if a defective bypass valve is causing low oil pressure, perform the following:

1. Remove the oil filter adaptor; refer to Section 3.6.2.
2. Inspect the oil filter adaptor; refer to Section 3.6.2.1.
   [a] If no damage is found with the oil filter adaptor components. Reinstall the oil filter adaptor; refer to Section 3.6.4, check pressure relief valve; refer to Section 26.10.
   [b] If damage is found with the oil filter adaptor components; refer to Section 26.9.1.

26.9.1 Oil Filter Adaptor Repair

Perform the following steps to repair the oil filter adaptor:

1. Disassemble the oil filter adaptor; refer to Section 3.6.2.
2. Inspect oil filter adaptor, refer to Section 3.6.2.1.
3. Assemble the oil filter adaptor; refer to Section 3.6.3.

NOTE:
Always replace the copper washer whenever the adaptor plug is removed.

4. Install repaired oil filter adaptor; refer to Section 3.6.4.
5. Verify repairs made to the oil filter adaptor; refer to Section 26.9.1.1.

26.9.1.1 Test Engine with Repaired Oil Filter Adaptor

Perform the following to determine if repaired oil pressure regulator valve resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and vary the engine speed between 1800 -2100 r/min.
3. Visually examine the DDR for oil pressure reading.

[a] If the DDR indicates 241 kPa (35 lb/in.^{2}), shut down the engine and disconnect the DDR. No further troubleshooting is required.

[b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}), shut down the engine and disconnect the DDR, check pressure relief valve; refer to Section 26.10.

26.10 DEFECTIVE PRESSURE RELIEF VALVE

To determine if a defective pressure relief valve is causing low oil pressure, perform the following:

1. Remove the pressure relief valve; refer to Section 3.4.2.
2. Inspect the oil pressure relief valve; refer to Section 3.4.3.1.
   [a] If the regulator valve moves freely in the valve body. Reinstall the oil pressure relief valve; refer to Section 3.4.5, check the pickup tube and screen assembly for defects; refer to Section 26.11.
   [b] If the regulator valve will not move freely in the valve body, refer to Section 26.10.1.

26.10.1 Pressure Relief Valve Repair

Perform the following steps to repair the pressure relief valve:

1. Disassemble the pressure relief valve and replace damaged components; refer to Section 3.4.1.
2. Assemble and install the pressure regulator valve; refer to Section 3.4.4.
3. Verify repair of the regulator valve; refer to Section 26.10.1.1.

26.10.1.1 Test Engine with Repaired Relief Valve

Perform the following to determine if repaired relief valve resolved low oil pressure:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800-2100 r/min.
3. Visually examine the DDR for oil pressure reading.
   - [a] If the DDR indicates 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   - [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR, check pickup tube and screen assembly; refer to Section 26.11.

26.11 DEFECTIVE PICKUP SCREEN TUBE AND SCREEN ASSEMBLY

To determine if a defective pickup screen tube or screen assembly is causing low oil pressure, perform the following:

1. Remove pickup screen tube and screen assembly; refer to Section 3.2.1.
2. Visually inspect pickup screen tube and screen assembly; refer to Section 3.2.3.1.
   [a] If no stress cracks, twisted screen tube, or cracked flange gaskets are found, check crankshaft main bearings; refer to Section 26.12.
   [b] If stress cracks, twisted screen tube, or cracked flange gaskets are found; refer to Section 26.11.1.

26.11.1 Pickup Screen Tube and Screen Assembly Repair

Perform the following steps to repair the pickup screen tube and screen assembly:

1. Replace all damaged components identified during inspection.
2. Verify repairs to pickup screen tube and screen assembly; refer to Section 26.11.1.1.

26.11.1.1 Test Engine with Repaired Pickup Screen Tube and Screen Assembly

Perform the following to determine if repaired relief valve resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.

   [a] If the DDR indicates 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.

   [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR, check crankshaft main bearings; refer to Section 26.12.

26.12 DEFECTIVE CRANKSHAFT MAIN BEARING SHELLS

To determine if defective crankshaft main bearing shells are causing low oil pressure, perform the following:

1. Check main bearing to crankshaft journal clearances; refer to Section ADDITIONAL INFORMATION.
   [a] If main bearing shell-to-journal clearance is within 0.040-0.151 mm (0.0016-0.006 in.), check oil pump assembly; refer to Section 26.13.
   [b] If main bearing shell-to-journal clearance is not within 0.040-0.151 mm (0.0016-0.006 in.); refer to Section 26.12.1.

26.12.1 Crankshaft Main Bearing Shell Repair

Perform the following steps to repair crankshaft main bearing shells:

1. Remove and replace defective crankshaft main bearing shells; refer to Section 1.9.2.
2. Verify crankshaft main bearing shells repair: refer to Section 26.12.1.1.

26.12.1.1 Test Engine with New Crankshaft Main Bearing Shells

Perform the following to determine if repaired relief valve resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run engine between 1800 r/min.
3. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. Check the oil pump assembly; refer to Section 26.13.

26.13 DEFECTIVE OIL PUMP ASSEMBLY

To determine if a defective oil pump is causing low oil pressure, perform the following:

1. Remove the oil pump assembly; refer to Section 3.2.2.
2. Manually rotate the oil pump drive gear.
   [a] If the drive gear rotates freely in the pump housing, call Detroit Diesel Technical Service Group.
   [b] If the drive gear did not rotate freely; refer to Section 26.13.1.

26.13.1 Oil Pump Assembly Repair

Perform the following steps to repair the oil pump assembly:

1. Disassemble the oil pump assembly and replace worn or damaged components as required; refer to Section 3.2.3.
2. Reassemble the oil pump; refer to Section 3.2.4.
3. Verify oil pump repair; refer to Section 26.13.1.1.

26.13.1.1 Test Engine with Repaired Oil Pump Assembly

Perform the following to determine if repaired relief valve resolved low oil pressure:

CAUTION:
To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install the Diagnostic Data Reader to the vehicles Display Data Line Adaptor, see Figure 26-1; refer to OEM guidelines.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine speed at 1800 r/min.
3. Visually examine the DDR for oil pressure reading.
   [a] If the DDR indicates 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR. No further troubleshooting is required.
   [b] If the DDR indicates less than 241 kPa (35 lb/in.^{2}), at 1800 r/min, shut down the engine and disconnect the DDR; call Detroit Diesel Technical Service Group.

27 HIGH ENGINE COOLANT TEMPERATURE

Section **Page**

27.1 IMPROPER ENGINE COOLANT LEVEL

To determine if improper engine coolant level is causing high engine coolant temperature, perform the following:

1. Visually inspect the radiator coolant level; refer to OEM guidelines.
   [a] If the radiator coolant level is within 2.0 in. (approximately 0.50 mm) of the radiator filler neck, check insufficient radiator air circulation; refer to Section 27.2.
   [b] If the radiator coolant level is not within 2.0 in. of the radiator filler neck, refer to Section 27.1.1.

27.1.1 Improper Coolant Level Resolution

Perform the following steps to resolve improper coolant level:

1. Fill coolant system to correct level; refer to Section 13.5.4.
2. Verify coolant level resolution; refer to Section 27.1.1.1.

27.1.1.1 Test Engine with Proper Coolant Level

Perform the following to determine if proper coolant level resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), check for insufficient radiator air circulation; refer to Section 27.2.

27.2 INSUFFICIENT RADIATOR AIR CIRCULATION

To determine if insufficient radiator air circulation is causing high engine coolant temperature, perform the following:

1. Visually examine the radiator and radiator shrouding.
   [a] If the radiator is absent of clogging, debris, and dirt, check the pressure control cap; refer to Section 27.3.
   [b] If the radiator has excessive clogging, debris, or dirt; refer to Section 27.2.1.
   [c] If the radiator shrouding is not damaged, incorrectly positioned, or inadequate, check the pressure control cap; refer to Section 27.3.
   [d] If the radiator shrouding is damaged, incorrectly positioned, or inadequate; refer to Section 27.2.2.

27.2.1 Exterior Radiator Repair

Perform the following for exterior radiator repair:

1. Clean the exterior radiator of all clogging, debris, or excessive dirt; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to Section 27.2.2.1.

27.2.2 Radiator Shroud Repair

Perform the following for radiator shroud repair:

1. Repair or replace damaged radiator shrouding; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to Section 27.2.2.1.

27.2.2.1 Test Engine with Repaired Exterior Radiator and Shrouding

Perform the following to determine if exterior radiator and shrouding repair resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check the pressure control cap; refer to Section 27.3.

27.3 FAULTY PRESSURE CONTROL CAP

To determine if a faulty pressure control cap is causing high engine coolant temperature, perform the following:

1. Perform coolant pressure control cap tests; refer to Section 4.4.2.1.
   [a] If the cooling system pressure is less than or equal to 48.3 kPa (7 lb/in.^{2}), check the coolant hoses; refer to Section 27.4.
   [b] If the cooling system pressure is greater than 48.3 kPa (7 lb/in.^{2}), refer to Section 27.3.1.

27.3.1 Pressure Control Cap Resolution

Perform the following steps to resolve faulty pressure control cap:

1. Remove and replace pressure control cap; refer to Section 4.4.2.
2. Install a new pressure control cap; refer to Section 4.4.3.
3. Verify pressure control repair; refer to Section 27.3.1.1.

27.3.1.1 Test Engine with Replaced Pressure Control Cap

Perform the following to determine if exterior radiator repair resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is normal, no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not normal, shut the engine down. Check coolant hoses; refer to Section 27.4.

27.4 DEFECTIVE COOLANT HOSES

To determine if defective coolant hoses is causing high engine coolant temperature, perform the following:

1. Visually examine cooling system hoses; refer to OEM guidelines.
   [a] If cooling system hoses are not soft, deteriorated, or collapsed, check the fan belts; refer to Section 27.5.
   [b] If cooling system hoses are soft, deteriorated, or collapsed; refer to Section 27.4.1.

27.4.1 Coolant System Hoses Replacement

Perform the following steps to resolve worn or damaged coolant system hoses:

1. Remove and replace damaged or worn coolant hoses as necessary; refer to OEM guidelines.
2. Install new coolant hoses as necessary; refer to OEM guidelines.
3. Verify replaced coolant system hoses; refer to Section 27.4.1.1.

27.4.1.1 Test Engine with Replaced Coolant Hoses

Perform the following to determine if the new coolant hoses resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range, and visually examine replaced hoses for any leaks.
   [a] If the engine coolant temperature is 88-96°C (190-210°F) and no leaks are found, no further troubleshooting is required.
   [b] If the engine coolant temperature is 88-96°C (190-210°F) and leaks are found, repair leaks; refer to Section 27.4.1.
   [c] If the engine coolant temperature is not 88-96°C (190-210°F) and no leaks are found, check fan belts; refer to Section 27.5.
3. Shut down the engine.

27.5 FAN BELTS ARE INCORRECTLY ADJUSTED

To determine if misadjusted fan belts are causing high engine coolant temperature, perform the following:

1. Test fan belt(s) tension; refer to Section 13.5.7.
2. Compare tension to belt specifications listed in Table 27-1.

Single Belt	2 or 3 Belts
80-100 lbs (356-445 N)	60-80 lbs (267-356 N)

Table 27-1 Fan Belt Tension

[a] If the belt(s) tension is within specification, check the thermo-modulated fan; refer to Section 27.6.

[b] If the belt(s) tension is not within specification, refer to Section 27.5.1.

27.5.1 Belt Tension Resolution

Perform the following steps to resolve incorrect belt tension:

1. Readjust belt(s) tension as necessary; refer to Section 13.5.7.
2. Verify belt tension resolution; refer to Section 27.5.1.1.

27.5.1.1 Test Engine with Correct Belt Tension

Perform the following to determine if exterior radiator repair resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check thermo-modulated fan; refer to Section 27.6.

27.6 INOPERATIVE THERMO-MODULATED FAN

To determine if an inoperative thermo-modulated fan is causing high engine coolant temperature, perform the following:

1. Test the thermo-modulated fan; refer to OEM guidelines.
   [a] If the thermo-modulated fan is functioning correctly, check thermostats; refer to Section 27.7.
   [b] If the thermo-modulated fan is not functioning correctly; refer to Section 27.6.1.

27.6.1 Thermo-Modulated Fan Replacement

Perform the following steps to replace inoperative thermo-modulated fan:

1. Replace inoperative thermo-modulated fan; refer to OEM guidelines.
2. Verify thermo-modulated fan replacement; refer to Section 27.6.1.1.

27.6.1.1 Test Engine with Replaced Thermo-Modulated Fan

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check thermostats; refer to Section 27.7.

27.7 FAULTY THERMOSTATS

To determine if faulty thermostats are causing high engine coolant temperature, perform the following:

1. Remove thermostat from the thermostat housing; refer to Section 4.3.2.
2. Inspect thermostat for correct operation; refer to Section 4.3.2.1.
   [a] If thermostat opened at 97°C (207°F), check water pump; refer to Section 27.8.
   [b] If thermostat did not open at 97°C (207°F), refer to Section 27.7.1.

27.7.1 Thermostat Replacement

Perform the following steps to replace thermostats:

1. Install new thermostat; refer to Section 4.3.4.
2. Verify replaced thermostat; refer to Section 27.7.1.1.

27.7.1.1 Test Engine with New Thermostat

Perform the following to determine if thermostat replacement resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check water pump; refer to Section 27.8.

27.8 FAULTY WATER PUMP

To determine if a faulty water pump is causing high engine coolant temperature, perform the following:

1. Remove the water pump (gear case mounted); refer to Section 4.2.2.
2. Turn the water pump over and install J 35687, water pump impeller slip and lash tester, into the tapped holes provided in the impeller; see Figure 27-1.

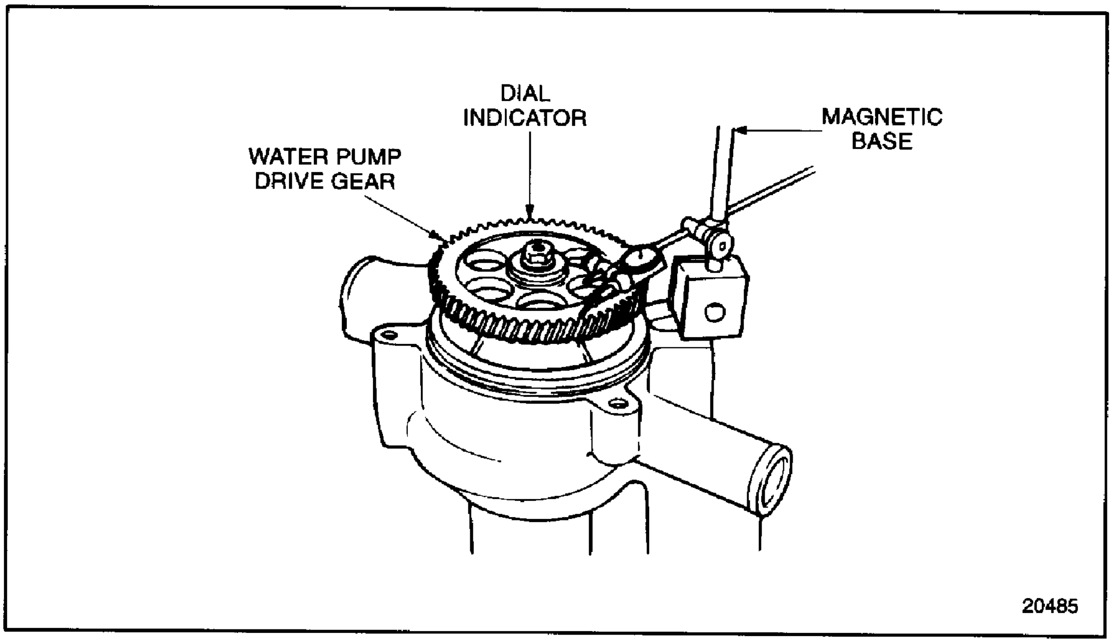


Figure 27-1 Measuring Water Pump Drive Gear Run-Out

3. Clamp the water pump drive gear in a vise, with the impeller facing up. Use soft jaws to prevent damage to the gear teeth.
4. Using a 1/2 in. drive torque wrench in the hole provided in the center of the slip-lash tester, apply 68 N·m (50 lb·ft) torque in either direction. The impeller must withstand 68 N·m (50 lb·ft) torque without slipping.
   [a] If the torque 68 N·m (50 lb·ft) is satisfied without the impeller slipping, check combustion gases in coolant; refer to Section 27.9.
   [b] If the torque 68 N·m (50 lb·ft) is not satisfied and the impeller is slipping; refer to Section 27.8.1.

27.8.1 Water Pump Impeller Replacement

Perform the following steps to replace water pump impeller:

1. Disassemble the water pump and replace worn or damaged impeller; refer to Section 4.2.3 for (gear case mounted).

2. Reassemble the water pump with new components as necessary; refer to Section 4.2.4 for (gear case mounted).

27.8.1.1 Test Engine with Repaired Water Pump

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.

   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.

   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check combustion gases in coolant; refer to Section 27.9.

27.9 COMBUSTION GASES IN COOLANT

To determine if combustion gases in coolant is causing high engine coolant temperature, perform the following:

1. Perform a cylinder compression test; refer to Section 29.2.
   [a] If test results are to specifications, listed in Table 29-2; check radiator coolant flow; refer to Section 27.10.
   [b] If test results are not to specifications, listed in Table 29-2; refer to Section 27.9.1.

27.9.1 Cylinder Head Gasket Replacement

Perform the following steps to replace cylinder head gasket:

1. Remove and replace cylinder head gasket; refer to Section 1.2.2.
2. Verify new cylinder head gasket replacement; refer to Section 27.9.1.1.

27.9.1.1 Test Engine with Replaced Cylinder Head Gasket

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check radiator coolant flow; refer to Section 27.10.

27.10 ABNORMAL RADIATOR COOLANT FLOW

To determine if abnormal radiator coolant flow is causing high engine coolant temperature, perform the following:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Install a sight glass with string (both ends) to the radiator outlet hose near radiator and before fill and heater return lines; see Figure 27-2.

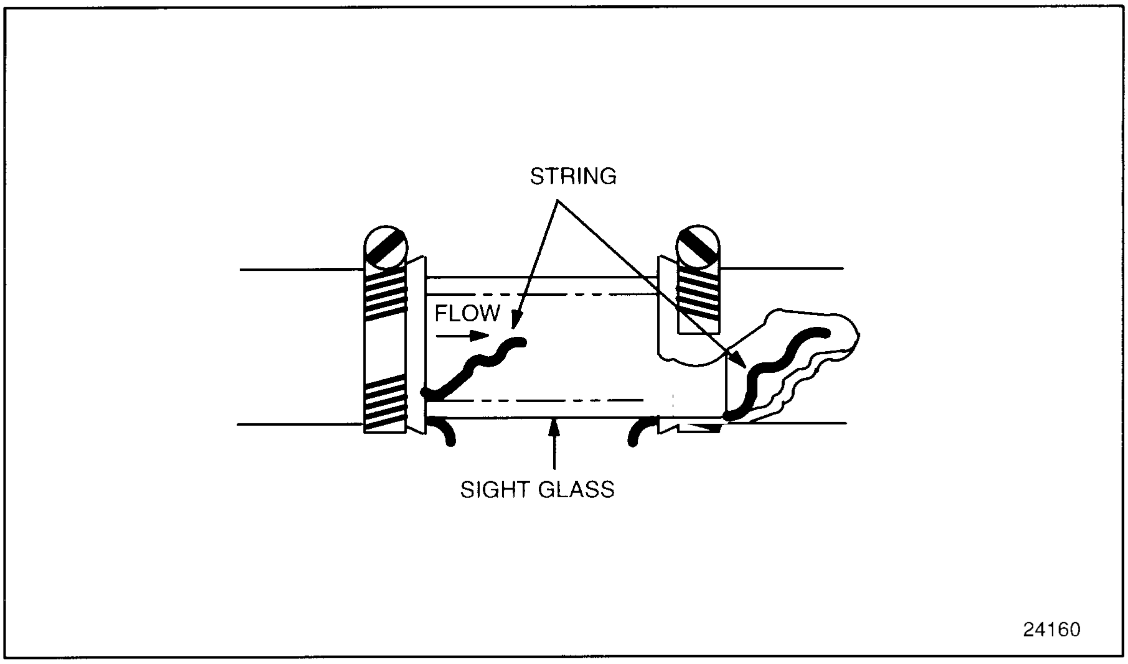


Figure 27-2 Radiator Flow Check

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine at full load.
3. Observe the string for flow and direction as well as the fill and bleed lines. Continue observation while varying the engine speed between 1800-2100 r/min.
   [a] If coolant flow is not observed in the sight glass an imbalance is not present, call Detroit Diesel Technical Service Group. Shut the engine down.
   [b] If coolant flow is observed in the sight glass an imbalance exists; refer to Section 27.10.1. Shut the engine down.

27.10.1 Abnormal Radiator Coolant Flow Resolution

Perform the following steps, as necessary, to resolve abnormal radiator coolant flow:

1. Correct bleed line size; refer to OEM guidelines.
2. Correct fill line size or connector fitting size; refer to OEM guidelines.
3. Correct restrictive top tank opening; refer to OEM guidelines.
4. Correct location of standpipe; refer to OEM guidelines.
5. Verify repairs made to correct abnormal radiator coolant flow; refer to Section 27.10.1.1.

27.10.1.1 Test Engine with Resolved Radiator Coolant Flow

Perform the following to determine if thermo-modulated fan replacement resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Call Detroit Diesel Technical Service Group.

28 LOW COOLANT TEMPERATURE

Section **Page**

28.1 FAULTY THERMOSTATS

To determine if faulty thermostats are causing low engine coolant temperature, perform the following:

1. Remove thermostat from the thermostat housing; refer to Section 4.3.2.
2. Inspect thermostat for correct operation; refer to Section 4.3.2.1.
   [a] If thermostat opened at 97°C (207°F), check insufficient radiator air circulation; refer to Section 28.2.
   [b] If thermostat did not open at 97°C (207°F), refer to Section 28.1.1.

28.1.1 Thermostat Replacement

Perform the following steps to replace thermostats:

1. Install new thermostat; refer to Section 4.3.4.
2. Verify replaced thermostat; refer to Section 28.1.1.1.

28.1.1.1 Test Engine with New Thermostat

Perform the following to determine if thermostat replacement resolved low engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Check insufficient radiator air circulation; refer to Section 28.2.

28.2 INSUFFICIENT RADIATOR AIR CIRCULATION

To determine if insufficient radiator air circulation is causing high engine coolant temperature, perform the following:

1. Visually examine the radiator and radiator shrouding.
   [a] If the radiator has excessive clogging, debris, or dirt; refer to Section 28.2.1.
   [b] If the radiator shrouding is not damaged, incorrectly positioned, or inadequate, and if the radiator is absent of clogging, debris, and dirt, call Detroit Diesel Technical Service Group.
   [c] If the radiator shrouding is damaged, incorrectly positioned, or inadequate; refer to Section 28.2.2.

28.2.1 Exterior Radiator Repair

Perform the following for exterior radiator repair:

1. Clean the exterior radiator of all clogging, debris, or excessive dirt; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to Section 27.2.2.1.

28.2.2 Radiator Shroud Repair

Perform the following for radiator shroud repair:

1. Repair or replace damaged radiator shrouding; refer to OEM guidelines.
2. Verify exterior radiator repair; refer to Section 27.2.2.1.

28.2.2.1 Test Engine with Repaired Exterior Radiator and Shrouding

Perform the following to determine if exterior radiator and shrouding repair resolved high engine coolant temperature:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine.
2. Run the engine through its operating range with no-load for approximately 5 minutes, allowing the engine coolant to reach normal operating range.
   [a] If the engine coolant temperature is 88-96°C (190-210°F), no further troubleshooting is required. Shut the engine down.
   [b] If the engine coolant temperature is not 88-96°C (190-210°F), shut the engine down. Call Detroit Diesel Technical Service Group.

29 COMMON TESTS

29.1 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 from that of a column of water. Mercury does not wet the inside surface: therefore, the top of the column is convex (shape). Water wets the surface and therefore is concave. A mercury column is read by sighting horizontally between the top of the convex mercury surface and the scale, see Figure 29-1.

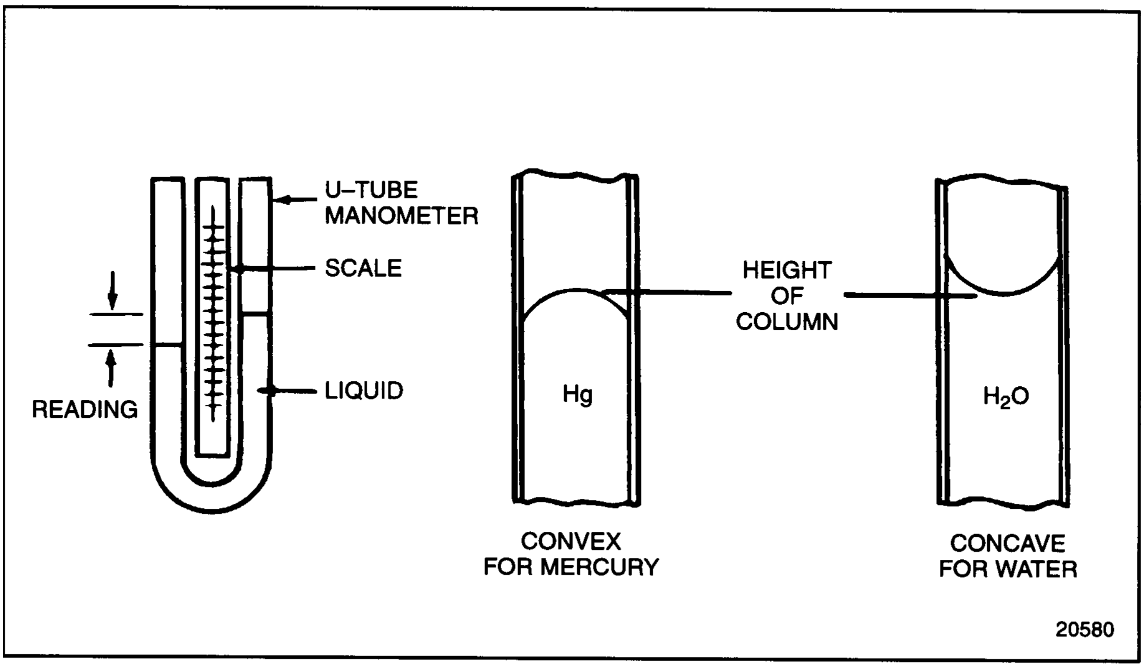


Figure 29-1 Comparison of Column Height for Mercury and Water Manometers

A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one volume 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.

Listed in Table 29-1 are manometer readings which can be converted into other units of measure.

Pressure Conversions
1 in. H_2O = 0.0735 in. Hg
1 in. H_2O = 0.0361 in. lb/in.^{2}
1 in. Hg = 13.61 in. H^2 O
1 in. Hg = 0.4912 lb/in.^{2}
1 lb/in.^{2}= 27.700 in. H^2 O
1 lb/in.^{2}= 2.036 in. Hg
1 lb/in.^{2}= 6.895 kPa
1 kPa = 0.145 lb/in.^{2}

Table 29-1 Pressure Conversion Chart

29.2 CYLINDER COMPRESSION TEST

The following tool is to be used when performing the cylinder compression test, J 6692-B. See Figure 29-2.

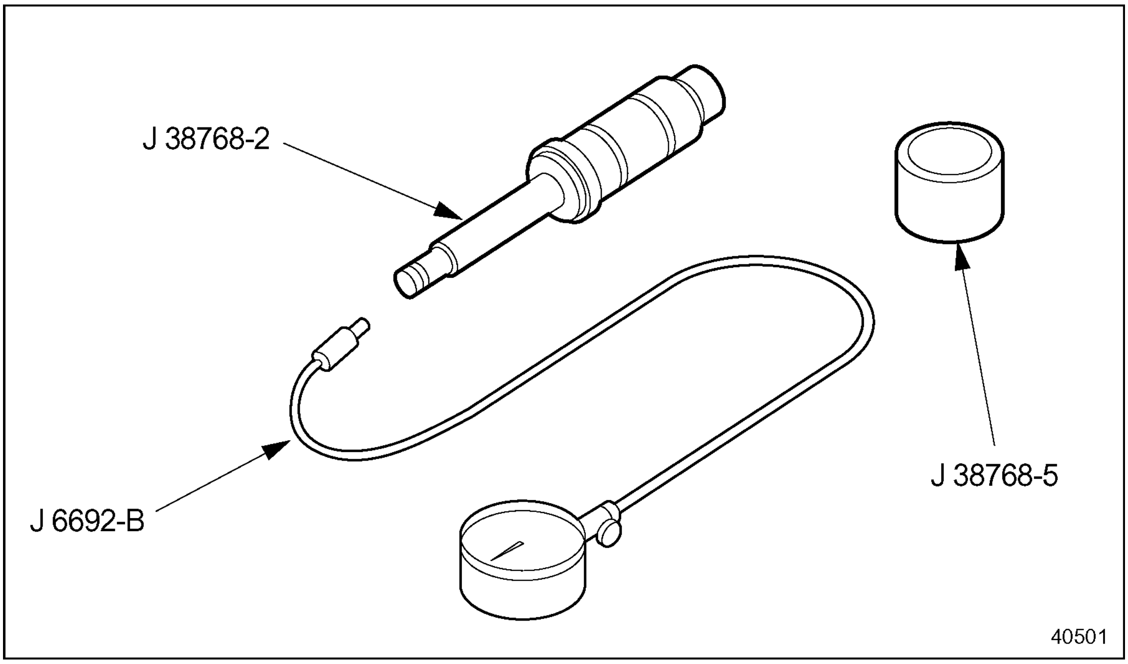


Figure 29-2 Cylinder Compression Test Tool

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Run engine until normal operating temperature is reached and shut down the engine.
2. Clean and remove the rocker cover. Refer to Section 1.6.2.

NOTE:
If cover is two-piece design, it is not necessary to remove bottom.

CAUTION:

To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

NOTICE:

All the fuel must be removed from the cylinder head before removing an injector to prevent the fuel from entering the cylinder and causing hydrostatic lock or wash down.

3. Remove the inlet and outlet lines from the fuel fittings at the rear of the cylinder head. Blow low compressed air into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head.
4. Remove the two rocker shaft through bolts and one nut from the front rocker shaft assembly and lift the rocker shaft assembly off the engine. Refer to Section 1.3.2.

NOTICE:

Turning the screws too far will damage the threads in the injector solenoid housing.

5. Loosen the injector wire terminal screws two (2) 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.
6. Remove the injector hold down crabs.

NOTICE:

Extreme care should be used when handling the injectors to avoid costly damage by dropping or otherwise mishandling. When replacing the injectors, always replace the injector O-rings.

7. Remove the three injectors from the cylinder head. Refer to Section 2.3.2.

8. Place three compression test adaptors J 38768 into the injectors holes. See Figure 29-3.

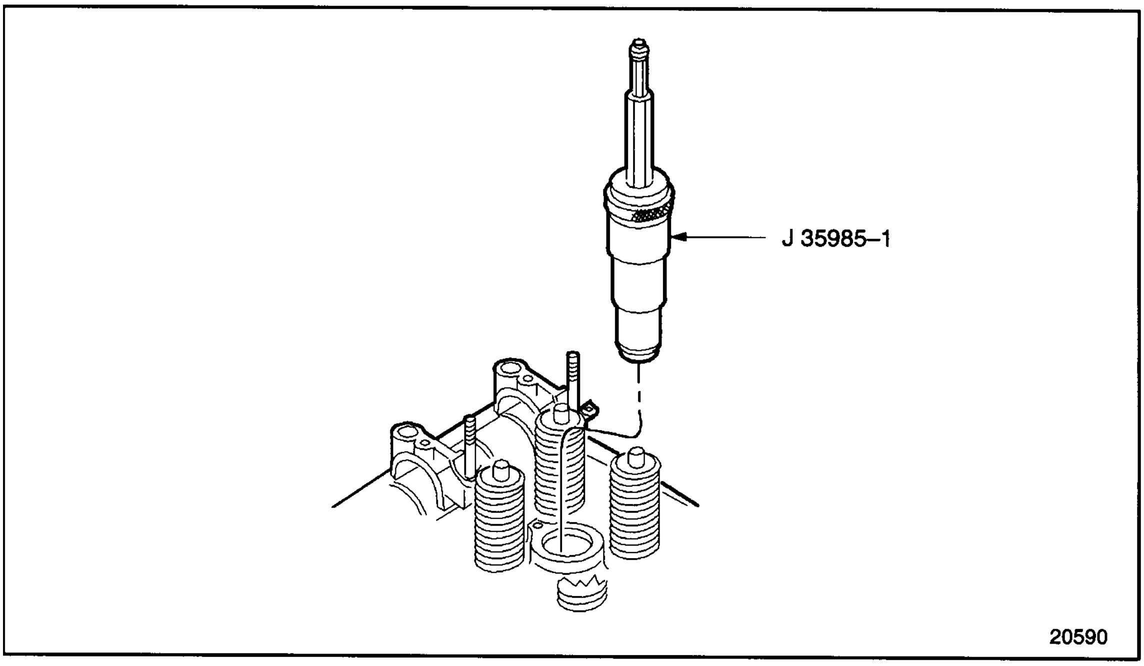


Figure 29-3 Test Adaptor

9. Install the injector hold down crabs and torque the hold down bolts to 58-66 N·m (43-49 lb·ft). See Figure 29-4.

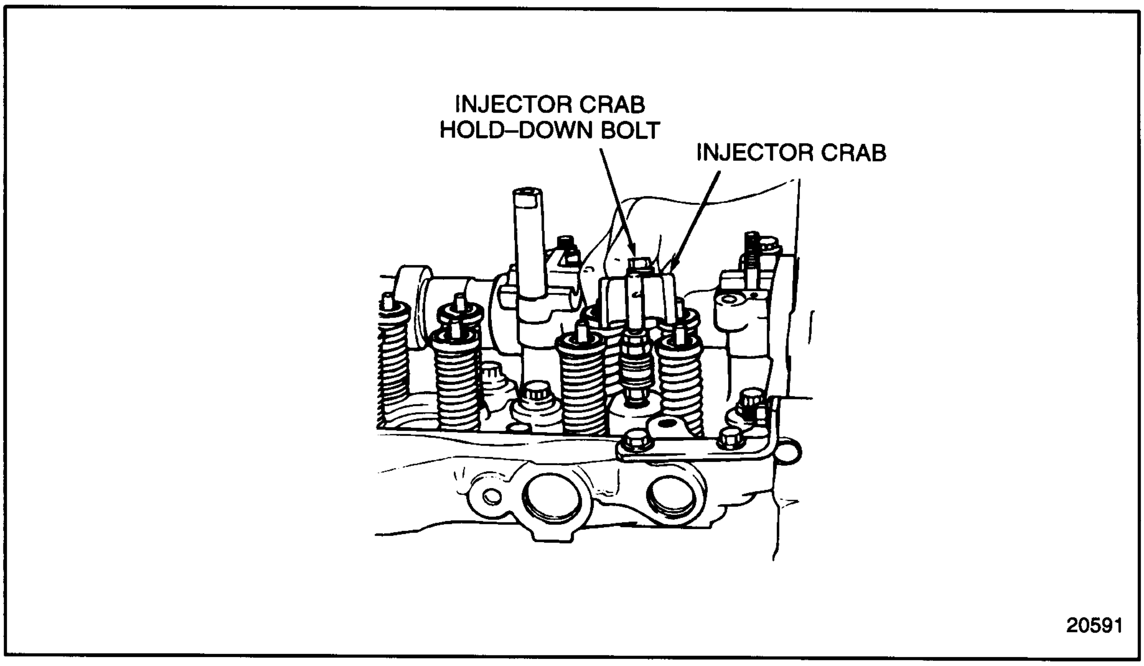


Figure 29-4 Injector Hold Down Crabs

10. Remove the rocker arm assemblies from rocker arm shaft. Refer to Section 1.3.2.
11. Remove the three injector rockers and replace with oil control sleeves J 38768-5 part of J 38768 .
12. Install rocker arm assemblies with sleeves and in place back on rocker arm shaft.
13. Install rocker arm shaft assembly on head. If engine is equipped with Jake Brake, you must use non-Jake Brake rocker arm bolts. Torque the two bolts and the nut to 102-109 N·m (75-80 lb·ft). Refer to Section 1.3.4.
14. Prime the fuel system. Refer to Section 13.5.3.
15. Disconnect the gray connector (injector drive) from the ECM for the A-bank injectors.

NOTE:
To avoid excessive oil splash, place the bottom half of a two-piece design rocker cover, with head to cover gasket installed, on the cylinder head. Install a few bolts and tighten.

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

16. Start engine and run until coolant out temperature reaches 38°C (100°F).

17. Attach cylinder compression gauge J 6692-B to first adaptor. See Figure 29-5.

NOTE:
Cylinder compression gauge J 6692-A part of J 6692-B can be upgraded to J 6692-B by ordering J 6692-18 part of J 6692-B.

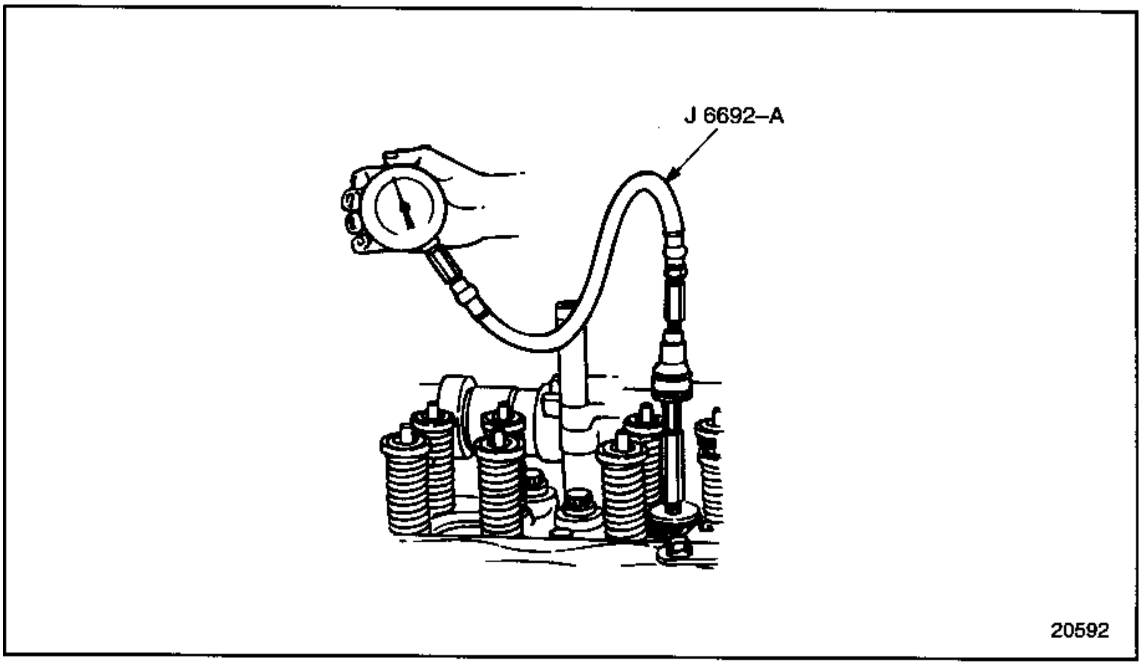


Figure 29-5 Cylinder Leakage Tester

18. Push pressure relief valve at gauge several times until highest compression reading is reached. Series 50 engine specification is 3103-3792 kPa (450-550 lb/in^2) with no two cylinders differing by more than 276 kPa (40 lb/in.^{2}).

NOTE:
If compression readings are below specifications listed in Table 29-2, you will need to repeat step 17 several times to be certain.

19. To determine proper cylinder compression, compare the test results to those listed in Table 29-2.

Altitude, ft	Atmospheric Pressure/lb/in.^{2} (kPa)	12 L Compression Pressure ± 50 /lb/in.^{2} (345 kPa)	11.1 L Compression Pressure ± 50 /lb/in.^{2} (345 kPa)
0	14.7 (101)	539 (3716)	587 (4047)
1000	14.17 (98)	519 (3579)	566 (3903)
2000	13.66 (94)	501 (3304)	545 (3758)
3000	13.17 (91)	483 (3330)	526 (3627)
4000	12.69 (88)	465 (3206)	507 (3496)
5000	12.22 (84)	448 (3089)	488 (3365)
6000	11.77 (81)	431 (2972)	470 (3241)
7000	11.34 (78)	416 (2868)	453 (3123)
8000	10.9 (75)	399 (2751)	435 (2300)
9000	10.5 (72)	385 (2655)	419 (2889)
10000	10.1 (70)	370 (2551)	403 (2779)

Table 29-2 Compression Pressures at Various Altitudes

20. Disconnect the gray connector (injector drive) from the ECM for the B-bank injectors in step 15 Then repeat steps 2 through step 17for the three rear cylinders.

29.3 CRANKCASE PRESSURE TEST (GOVERNED SPEED NO LOAD)

Perform the following steps to perform pressure test:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Attach a manometer, calibrated to read in. H_2O, to the oil dipstick opening.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine.
3. Operate the engine at maximum run-in speed.
4. Record the results.
5. Shut down the engine.
6. Remove the manometer from the oil dipstick opening.

29.4 CRANKCASE PRESSURE TEST (DYNAMIC)

If practical, the use of a chassis dynamometer to obtain full load will provide the most accurate results.

CAUTION:

To avoid injury from loss of vehicle/vessel control, the operator of a DDEC equipped engine must not attempt to use or read the Diagnostic Data Reader when the vehicle/vessel is moving.

1. Using the test kit 23518757, thread the adaptor tube onto the sensor body and push the rubber hose onto the adaptor. This should be done ***without*** lubricating the hose or the adaptor tube.
2. The sensor pigtail can be left disconnected to ease installation onto the engine. To test an engine, remove the dipstick and push the sensor assembly into the dipstick tube. Ensure there is a good seal between the sensor and the dipstick tube.
3. Connect the pigtail to the back of the sensor and route it to the oil pressure sensor wiring harness, avoiding hot exhaust components. Be sure to secure the extra cable away from moving parts.
4. Unplug the wiring harness from the oil pressure sensor on the left rear of the block and plug the crankcase pressure sensor cable into the oil pressure sensor wiring.
5. Plug a DDR into the vehicle connector and prepare for a key-triggered snapshot.
6. Drive the vehicle to get it up to operating temperature. Then, a passenger can trigger a snapshot while the desired speed and load are maintained.

NOTE:
Optimum reading will be at peak torque, 100% load.

7. Print the snapshot including r/min, % Load, Oil Temperature, Coolant Temperature and Turbo Boost Pressure.

8. Once the snapshot is printed, it can be compared to those listed in Table 29-3 to determine the status of the engine.

Oil Pressure (lb in.)	Reading (kPa)	Crankcase Pressure (in. H_2 0)	Oil Pressure (lb in.)	Reading (kPa)	Crankcase Pressure (in. H_2 0)
30.0	207	0.00	45.0	310	7.18
31.0	214	0.47	46.0	317	7.66
32.0	221	0.95	47.0	324	8.14
33.0	228	1.43	48.0	331	8.62
34.0	234	1.91	49.0	338	9.10
35.0	241	2039	50.0	345	9.58
36.0	248	2.87	51.0	352	10.06
37.0	255	3.35	52.0	359	10.54
38.0	262	3.83	53.0	365	11.02
39.0	269	4.31	54.0	372	11.50
40.0	276	4.79	55.0	379	11.98
41.0	283	5.27	56.0	386	12.46
42.0	290	5.75	57.0	393	12.94
43.0	296	6.23	58.0	400	13.40
44.0	303	6.70			

Table 29-3 Crankcase Pressure Comparison vs. Oil Pressure

29.5 LUBE OIL CONSUMPTION REPORT

Perform the following test to determine the cause of excessive oil consumption:

1. Operate vehicle for 5,000 miles, 500 hours, or one oil change period, whichever occurs first.
2. Fill out lube oil consumption report, Form #DA-94.
   [a] If engine consumed 7 qts or less of oil, oil consumption is within normal range. No further troubleshooting is required.

   [b] If engine consumes more than 7 qts of oil, call Detroit Diesel Technical Service Group.

29.6 DIESEL FUEL 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. Detroit Diesel engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (grades 1-D and 2-D) have provide satisfactory performance. The ASTM D 975 specification, however, does not in itself adequately define the fuel characteristics necessary for assurance of fuel quality. The properties listed in Table 29-4, "Diesel Fuel Specifications," will provide optimum engine performance or refer to 7SE270, *Engine Requirements - Lubricating Oil, Fuel, and Filters*.

General Fuel Classification	ASTM Test	Number 1ASTM-1-D	Number 2ASTM 2-D
Gravity, °API #	D 287	40-44	34-38
Cetane number, minimum *	D 613	45	45
Cetane number, minimum *	D 4737	40	40
Ash. wt %, maximum	D 482	0.01	0.01

* Differs from ASTM D 975

Table 29-4 Diesel Fuel Specifications

29.7 FUEL OIL FLOW TEST

Perform the following test to check for proper fuel oil flow:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

1. Disconnect the fuel return hose from the fitting at the fuel tank, refer to OEM guidelines, and hold the open end in an approved container.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- ☐ **Always start and operate an engine in a well ventilated area.**
- ☐ **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- ☐ **Do not modify or tamper with the exhaust system or emission control system.**

2. Start and run the engine at maximum no-load and measure the fuel flow. Nominal fuel return spill with the standard 2.03 mm (0.080 in.) restricted fitting is 246 L/hr (65 gal/hr).

   [a] If the fuel flow rate is 246 L/hr (65 gal/hr), no further testing is required.

   [b] If the fuel flow rate is less than 246 L/hr (65 gal/hr), resolve the low fuel rate; refer to Section 29.7.1.

29.7.1 Low Fuel Rate Resolution

Perform the following steps to resolve the low fuel oil rate:

1. Replace the fuel filters; refer to Section 2.7.1.
2. Visually inspect fuel oil lines for pinching, kinking, and other damage. Repair or replace as necessary; refer to OEM guidelines.
3. Remove and visually inspect the check valve for a correct restricted fitting. Replace if necessary; refer to Section 2.8.2.
4. Verify low fuel oil rate resolution; refer to Section 29.7.1.1.

29.7.1.1 Test the Engine with Replaced Fuel Oil Filters, Check Valve, and Fuel Oil Line Connections

Perform the following steps to determine if the low fuel rate resolution resolved the improper fuel oil flow rate:

CAUTION:

To avoid injury before starting and running the engine, ensure the vehicle is parked on a level surface, parking brake is set, and the wheels are blocked.

CAUTION:

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

- **Always start and operate an engine in a well ventilated area.**
- **If operating an engine in an enclosed area, vent the exhaust to the outside.**
- **Do not modify or tamper with the exhaust system or emission control system.**

1. Start and run the engine at maximum no-load and measure the fuel flow. Nominal fuel return spill with the standard 2.03 mm (0.080 in.) restricted fitting is 246 L/hr (65 gal/hr).

   [a] If the fuel flow rate is 246 L/hr (65 gal/hr), no further testing is required.

   [b] If the fuel flow rate is less than 246 L/hr (65 gal/hr); call the Detroit Diesel Technical Service Group.

29.8 LUBRICATING OIL CRITERIA

Typical properties for required engine oil lubricant is listed in Table 29-5.

Viscosity Grade API Service Viscosity	15W - 40 (CG 4)
Kinematic, cSt 100°C (212°F)	12.5 - 16.3
Kinematic, cSt 40°C (104°F)	95 - 115
HT/HS, cP 150°C (302°F)	3.7 min
Viscosity Index	130
Pour Point °C, maximum	-23 (-9)
Flash Point °C, minimum	215 (419)
Sulfated Ash, % mass	2.0 maximum
Total Base Number	Above 6.0
Zinc, parts/million	Above 700 parts/million

Table 29-5 Typical Properties for Required Lubricant

30 COMMON REPAIRS

Section **Page**

30.1 LEAD REPAIR

Perform the following steps for straight leads using the splice method:

1. To repair straight leads using the splice method:
   [a] Locate broken wire.
   [b] Remove insulation as required: be sure exposed wire is clean and not corroded.
   [c] Slide a sleeve of shrink wrap on the wire long enough to cover the splice and overlap the wire insulation.
2. To repair leads using solder is an optional method:

CAUTION:

To avoid injury, always wear adequate safety equipment.

   [a] You *must* use rosin core solder.
   [b] Check the exposed wire before the splice is crimped in its connector. The exposed wire *must*be clean before splice is crimped.
   [c] Use a suitable electronic soldering iron to heat the wires. Apply the solder to the heated wire (not the soldering iron) allowing sufficient solder flow into the splice joint.
   [d] Pull on connection to assure crimping and soldering integrity.

INDEX

A

B

C

D

E

F

I

J

K

L

M

N

O

S

T

V

W