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SERIES 92®
Service Manual

Detroit Diesel®
Series 92 Engine

DETROIT DIESEL CORPORATION

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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.

⚠ 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, industrial, generator set, and marine applications of the Detroit Diesel Series 92 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.

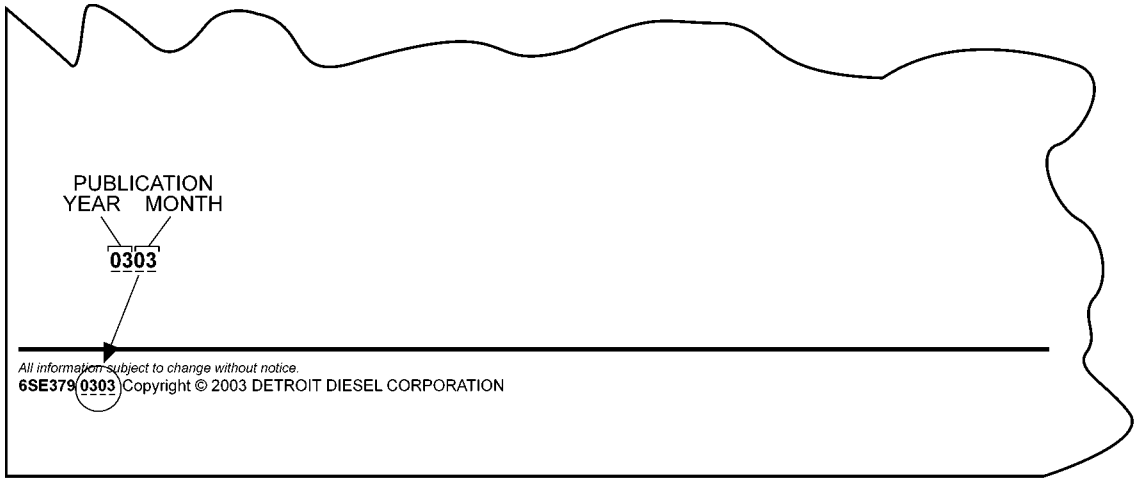
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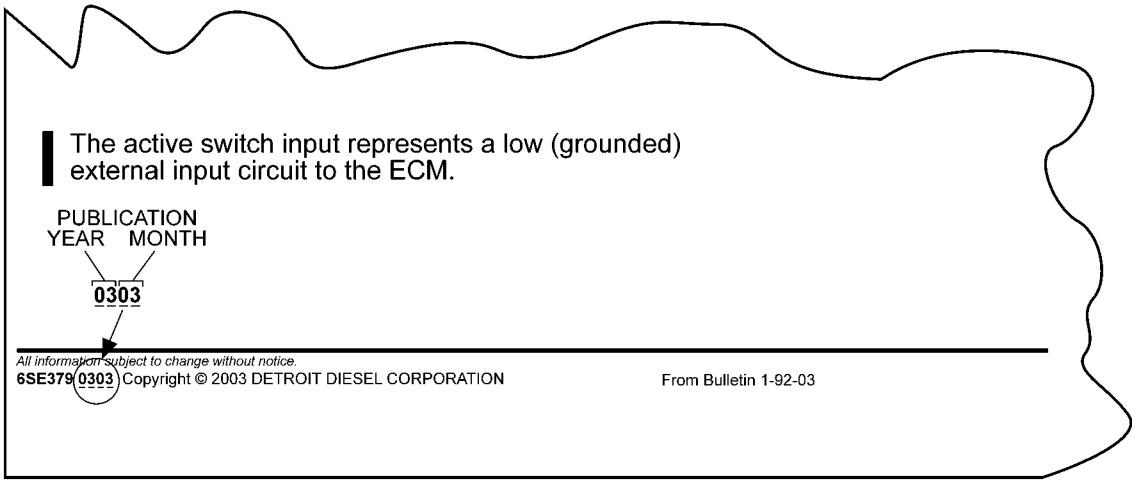
REVISION NOTIFICATION

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

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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.**

Please note this caution and remember:

- Always start and operate the engine in a well ventilated area.
- If in an enclosed area, vent the exhaust to the outside.
- Do not modify or tamper with the exhaust system.For accurate dynamometer readings during a engine run-in, the chassis dynamometer room must be properly ventilated.

⚠ 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.**

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SCOPE AND USE OF THIS MANUAL

This manual covers the basic V-92 diesel engines built by the Detroit Diesel Corporation. Complete instructions on operation, adjustment (tune-up), preventive maintenance, and lubrication and repair (including complete overhaul) are covered. Basic maintenance and overhaul procedures are common to all V-92 engines and apply to all engine models.

The manual is divided into numbered sections. The first section covers the engine (less major assemblies). The following sections cover a complete system such as the fuel system, lubrication system or air system. Each section is divided into subsections containing complete maintenance and operating instructions for a specific subassembly on the engine. Each section begins with a table of contents. Pages and illustrations are numbered consecutively within each section.

Information can be located 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 subassemblies within the major section is listed immediately following the section title.

SAFETY PRECAUTIONS

The following safety measures are essential when working on the Series 92 engine.

Please note this caution and remember:

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

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, ensure lifting device is fastened securely. Ensure that 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.

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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.

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⚠ 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.**

⚠ 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.

Work Place

Organize your work area, and keep it clean. A fall could result in a serious injury. Eliminate the possibility of a fall by:

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

After servicing or adjusting the engine:

- Install all safety devices, guards, or shields.
- Ensure that all tools and service equipment are removed from the engine.

Clothing

Wear safe work clothes that fit and are in good condition. Work shoes are sturdy and rough-soled. Bare feet, sandals, or sneakers are not acceptable foot wear when adjusting and/or servicing an engine. Do not wear the following when working on an engine:

⚠ 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.

- ☐ Rings
- ☐ Wrist watches
- ☐ Loose fitting clothing
- ☐ Any of these items could catch on moving parts causing serious injury.

Power Tools

Do not use defective portable power tools. Check for frayed cords prior to using the tool. Ensure that all electric tools are grounded. Defective electrical equipment and improper use of electrical equipment can cause severe injury.

⚠ CAUTION:

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

Air

Recommendations regarding the use of compressed air are indicated throughout the manual with the following:

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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.

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}). Wear safety glasses or goggles. Use proper shielding to protect everyone in the work area.

Fluids and Pressure

Be extremely careful when dealing with fluids under pressure.

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.

Fluids under pressure can penetrate the skin. These fluids can infect a minor cut or opening in the skin. If injured, see a doctor immediately.

Fuel

Keep the hose and nozzle or the funnel and container in contact with the metal of the fuel tank when refueling to avoid the possibility of an electric spark igniting the fuel.

The following cautions should be followed when filling a fuel tank:

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CAUTION:

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

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.

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.

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CAUTION:

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

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. Ensure the correct type of extinguisher is used for the situation.

Cleaning Agent

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

Working on a Running Engine

When working on a running engine, 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:

To avoid injury from hot surfaces, allow engine to cool before removing any component. Wear protective gloves.

CAUTION:

To avoid injury, use care when working around moving belts and rotating parts on the engine.

Start Attempts

Observe the following caution when working with mineral spirits or mineral spirit-based solvents.

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⚠ 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.**

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

FLUOROELASTOMER (VITON) CAUTION

Observe the following caution when handling fluoroelastomer.

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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.

Under normal design conditions, fluoroelastomer (Viton®) parts, such as O-rings and seals, are perfectly safe to handle. They may become hazardous, however, if these components are subjected to temperatures 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 it contacts bare skin, it may cause severe burns, sometimes with symptoms delayed for several hours.

SERVICE PARTS AVAILABILITY

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

CLEARANCE AND TORQUE SPECIFICATIONS

Refer to section ADDITIONAL INFORMATION for a listing of new part clearances and used part wear limits. The appropriate use of information from the limits column requires service personnel to exercise good judgment. The wear limits recorded, in general, apply only to those parts most frequently replaced during engine overhaul. For additional information, refer to repair or replace in this chapter.

THE TWO CYCLE PRINCIPLE FOR DIESEL ENGINES

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively. See Figure 1.

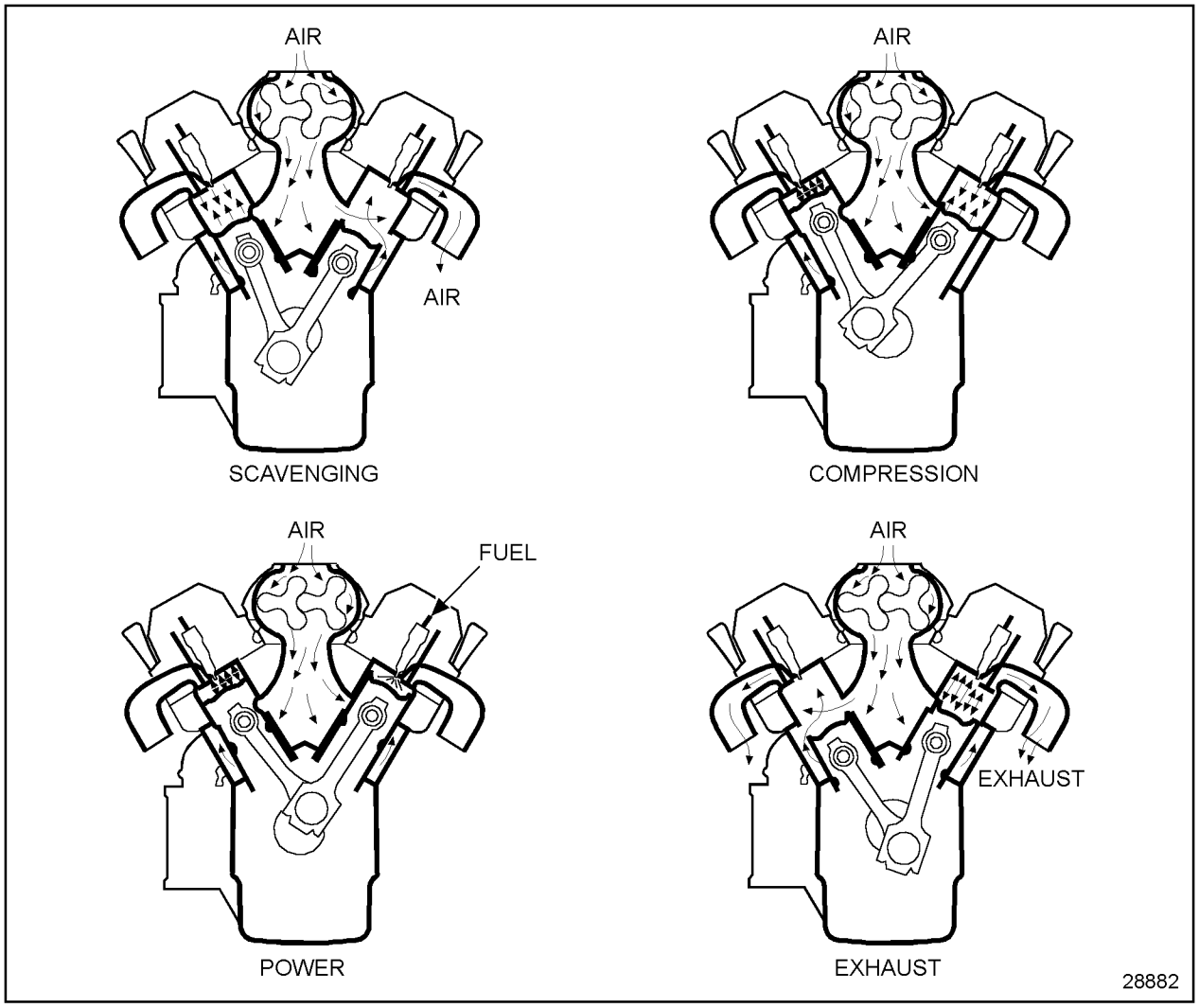


Figure 1 The Two-Stroke Cylinder Engine

Scavenging

A blower forces air into the cylinders to expel the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit air from the blower into the cylinder as soon as the rim of the piston uncovers the ports.

The unidirectional air flow toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

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Compression

As the piston continues on the upward stroke, the exhaust valves close, and the charge of fresh air is compressed.

Power

Shortly before the piston reaches its highest position, the unit fuel injector sprays the required amount of fuel into the combustion chamber. The intense heat generated during the high air compression immediately ignites the fine fuel spray. The combustion continues until the injected fuel has been burned.

Exhaust

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about half way down, allowing the burned gases to escape into the exhaust manifold. Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is once again swept with clean scavenging air. This entire combustion cycle is completed in each cylinder for each crankshaft revolution, in other words, in two strokes. Hence, it is a "two-stroke cycle".

GENERAL DESCRIPTION

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

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

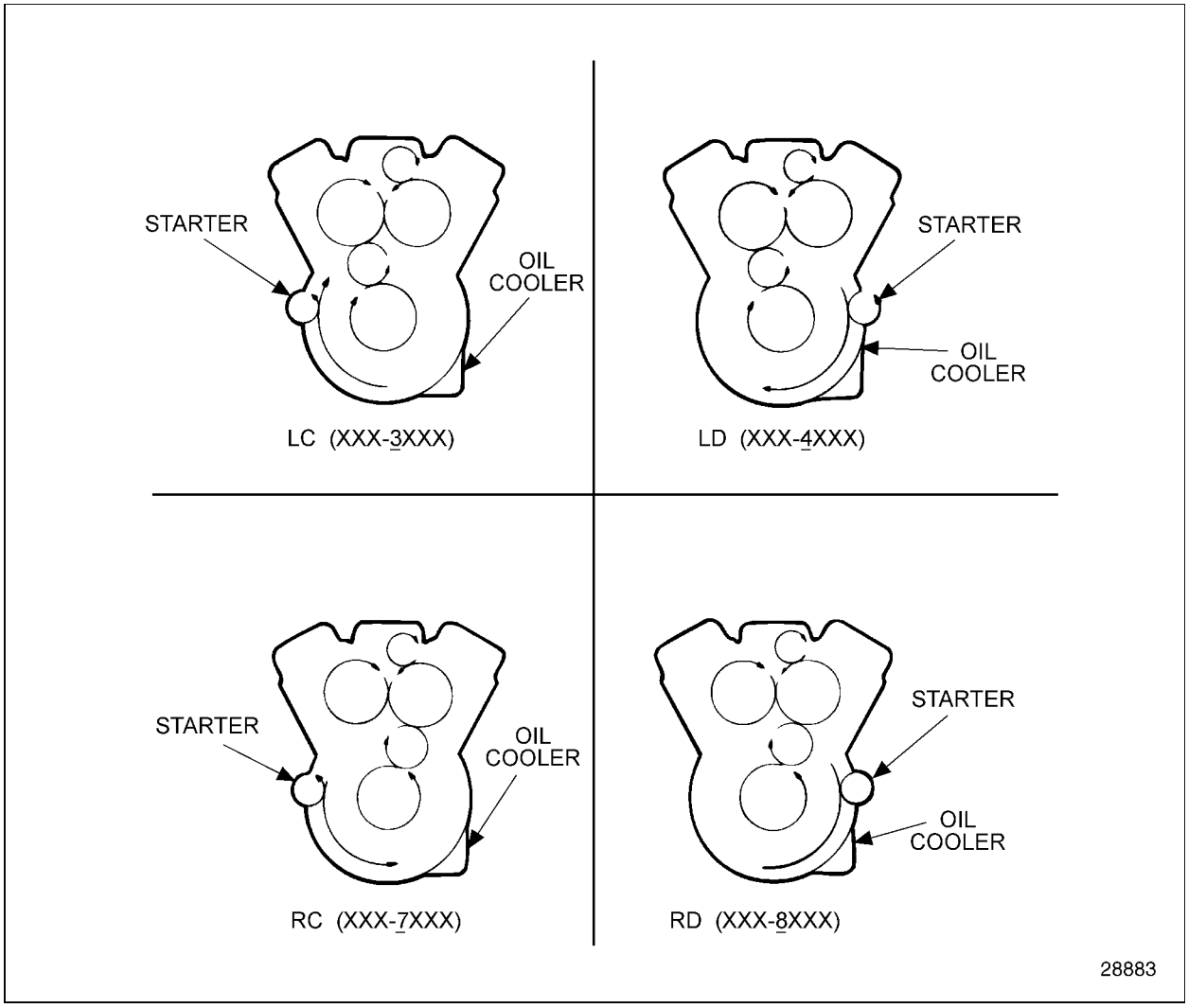


Figure 2 Views From Rear of Engine

See Figure 2 for the meaning of each digit in the model numbering system. The letter L or R indicates left or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C, or D designates the location of the starter and oil cooler as viewed from the rear of the engine.

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

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

Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed system, by the radiator or heat exchanger. Engine temperature is controlled by thermostats that regulate the flow of the coolant within the cooling system.

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

A blower that pumps air into the engine cylinders via the air box and cylinder liner ports supplies air for scavenging and combustion. All air entering the blower passes through an air cleaner.

An electric starting system starts the engine. A storage battery energizes the electric starting motor. A battery-charging generator, with a suitable voltage regulator or an alternator keeps the battery charged.

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

DDEC DIAGNOSTIC READER CAUTION

⚠ 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.

Diagnosis of the engine or electronics system of a DDEC-equipped vehicle, vessel, or wheeled machine, must be done by someone other than the driver or operator. The operator must maintain control of the moving vehicle, vessel, or wheeled machine while the assistant performs the diagnosis.

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DDEC I

DDEC I controls the timing and amount of fuel injected into each cylinder. The system also monitors several engine functions using various sensors that send electrical signals to the main Electronic Control Module (ECM). See Figure 3. The ECM uses this information to send a command pulse to the Electronic Distributor Unit (EDU). The EDU functions as the high current switching unit for actuation of 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.

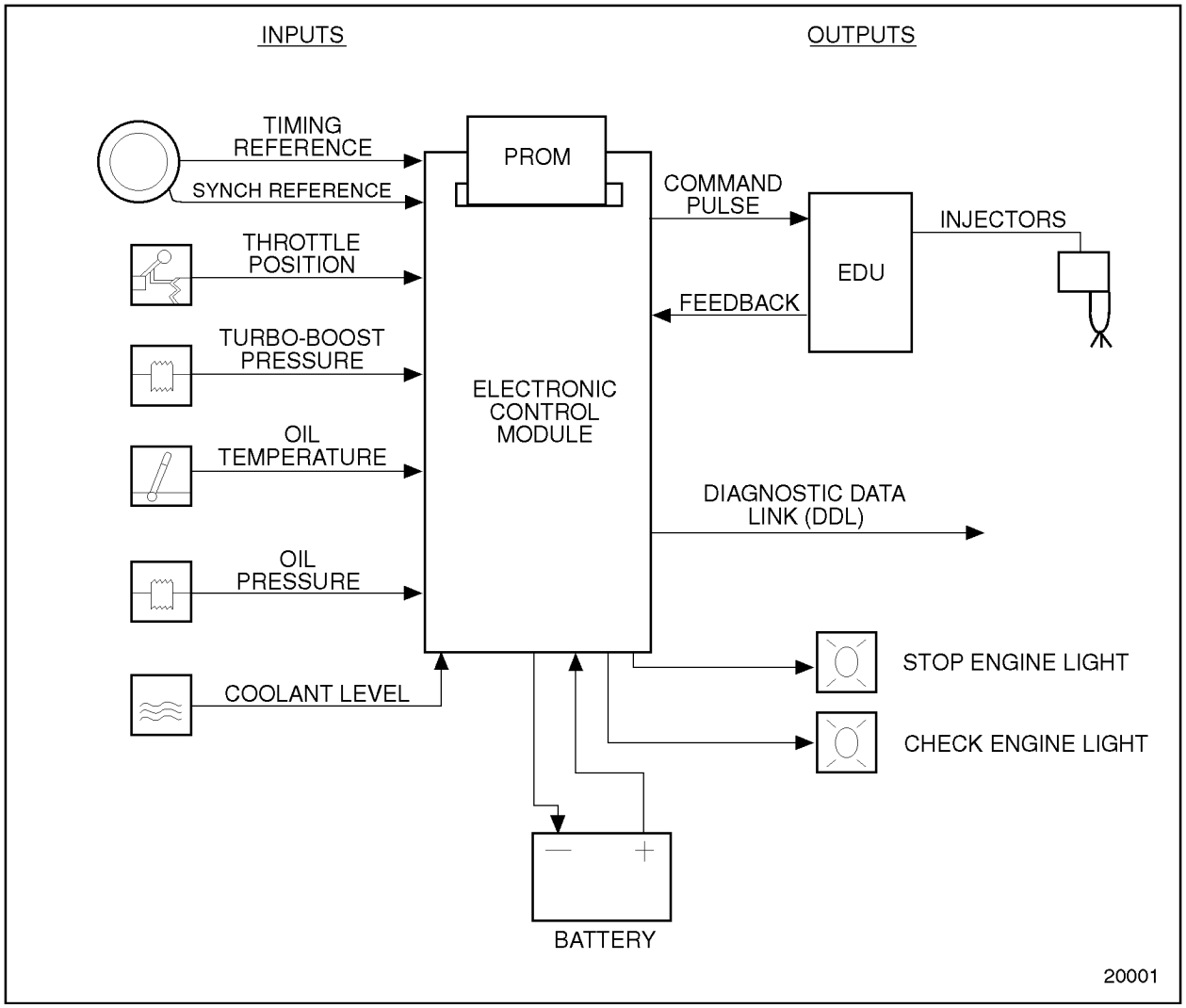


Figure 3 DECC I

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DDEC II

DDEC II also controls the timing and amount of fuel injected into each cylinder. The system also monitors several engine sensors that send electrical signals to the main ECM. See Figure 4. Unlike DDEC I, the DDEC II ECM uses this information to actuate the EUI solenoids. DDEC II incorporates all control electronics into one engine mounted ECM instead of the ECM and EDU that are required in DDEC I. 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.

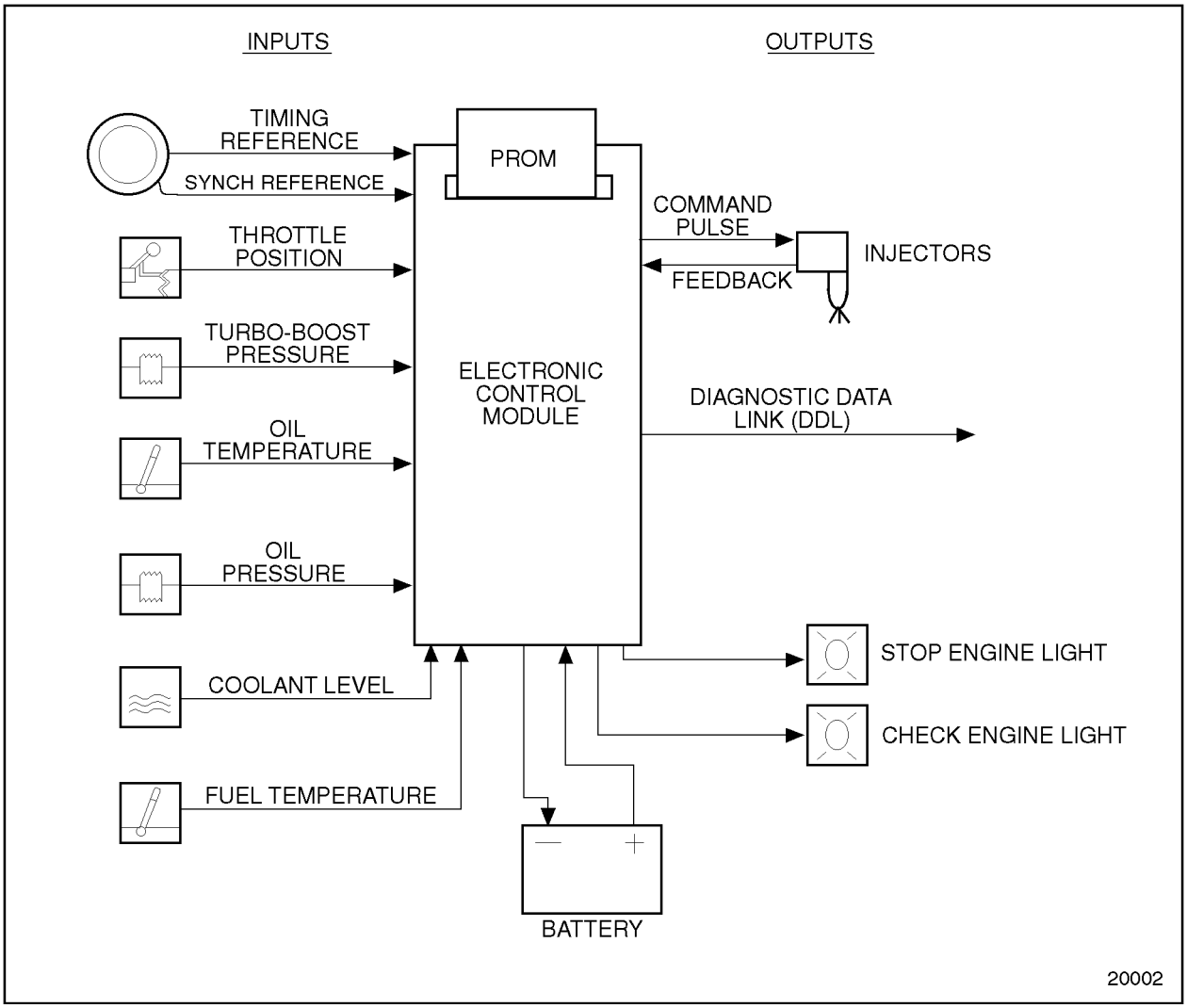


Figure 4 DECC II

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.

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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 5.

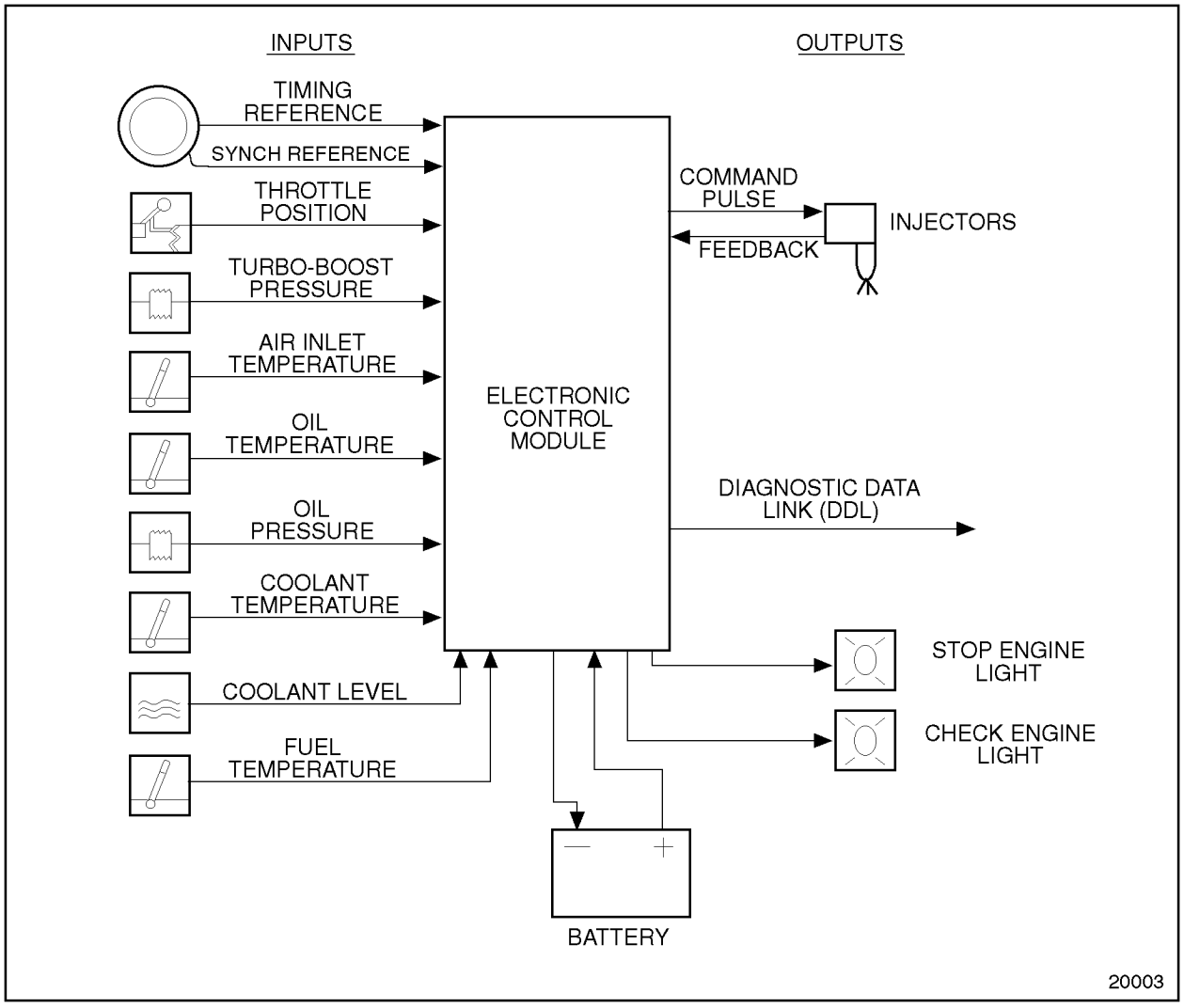


Figure 5 DECC III

Portable equipment facilitates access to DDEC III's diagnostic capabilities. 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 92 Engine are listed in Table 1. See Figure 6 for the cylinder designation and firing order.

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Engine	2 Cycle	2 Cycle	2 Cycle	2 Cycle
Number of Cylinders	6	8	12	16
Bore (inches)	4.84	4.84	4.84	4.84
Bore (mm)	123	123	123	123
Stroke (inches)	5	5	5	5
Stroke (mm)	127	127	127	127
Comp. Ratio (Nominal) (Turbo. Engines)	17 to 1	17 to 1	17 to 1	17 to 1
Comp. Ratio (Nominal) (N/A Engines)	19 to 1	19 to 1	19 to 1	19 to 1
Comp. Ratio (Nominal) (High Output-DDEC)	15 to 1	15 to 1	15 to 1	15 to 1
Comp. Ratio (Nominal) (Special-DDEC)	18 to 1	18 to 1	-	-
Total Displacement - (cubic inches)	552	736	1104	1472
Total Displacement - (liters)	9.05	12.07	18.10	24.14
Number of Main Bearings	4	5	7	10

Table 1 General Specifications for the Series 92 Engine

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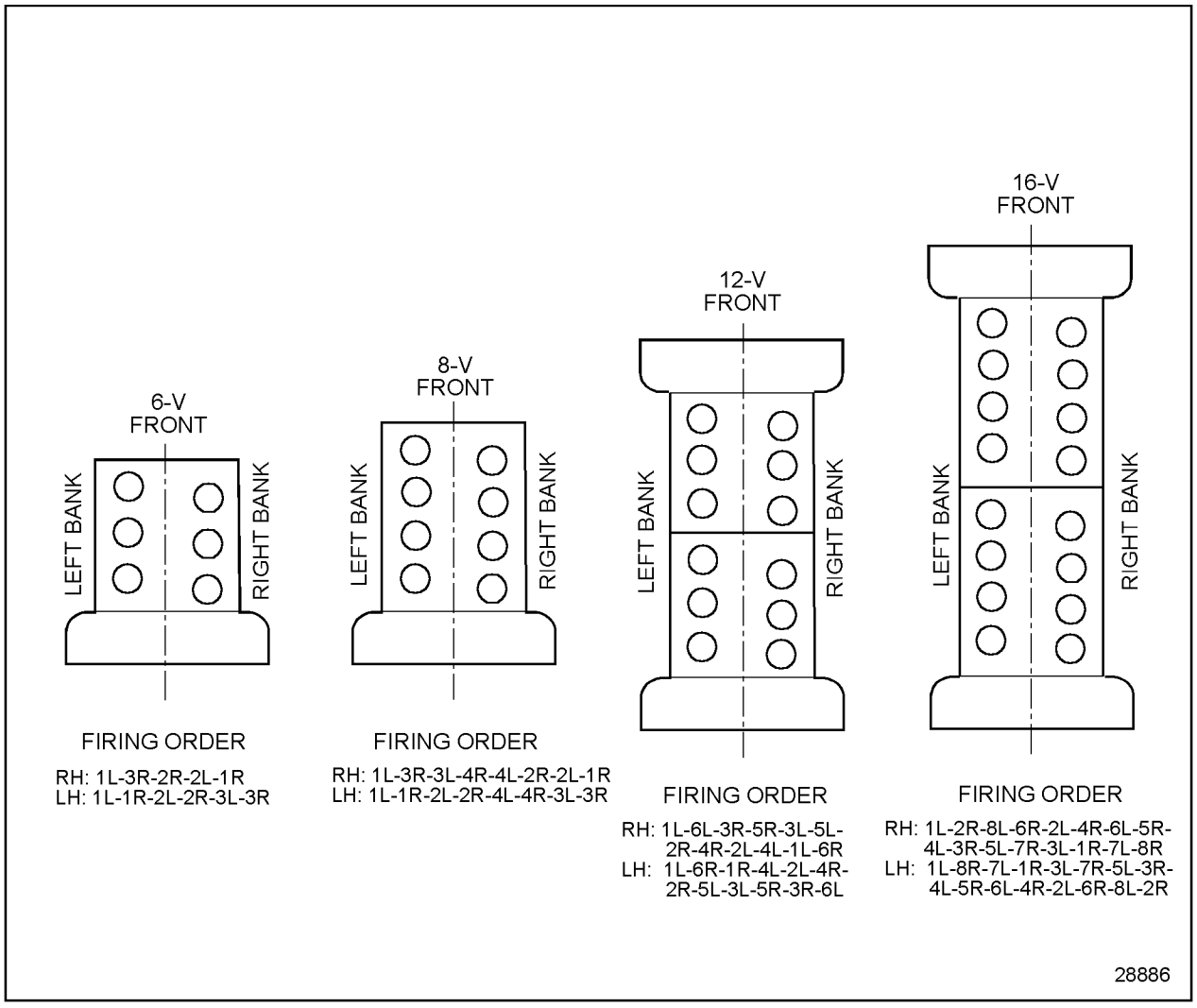


Figure 6 V-92 Engine Cylinder Designation and Firing Order

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ENGINE MODEL, SERIAL NUMBER AND OPTION LABEL

The engine serial number and model number are stamped on the cylinder block in the following locations (as viewed from the flywheel end): the right side, upper front corner of current 6V and 8V cylinder blocks. See Figure 7.

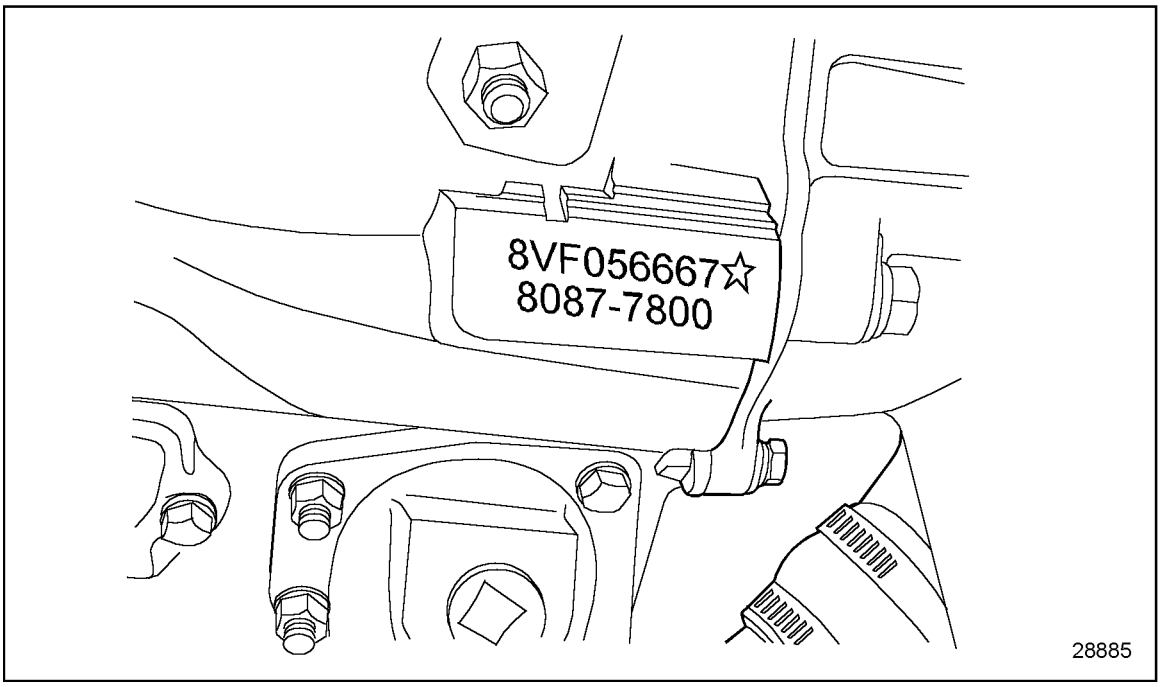
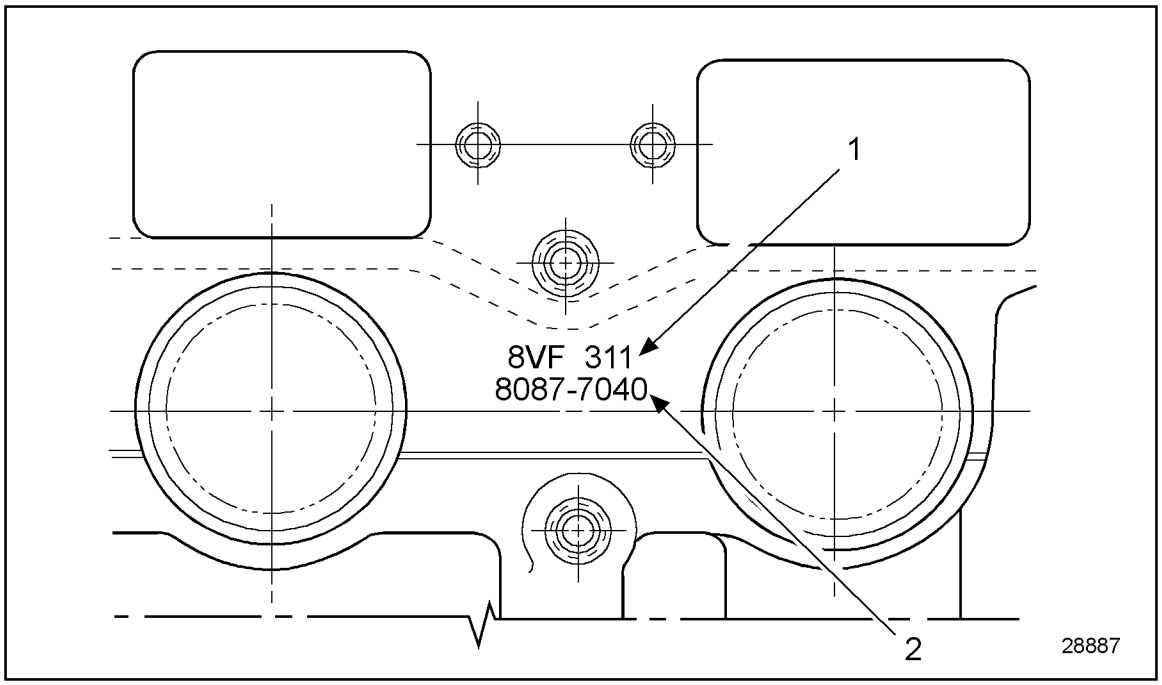


Figure 7 Location of Engine Model Number and Serial Number

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On former 6V and 8V blocks and current 12V and 16V blocks the engine serial number and model number is stamped on the right side, upper rear corner. See Figure 8.



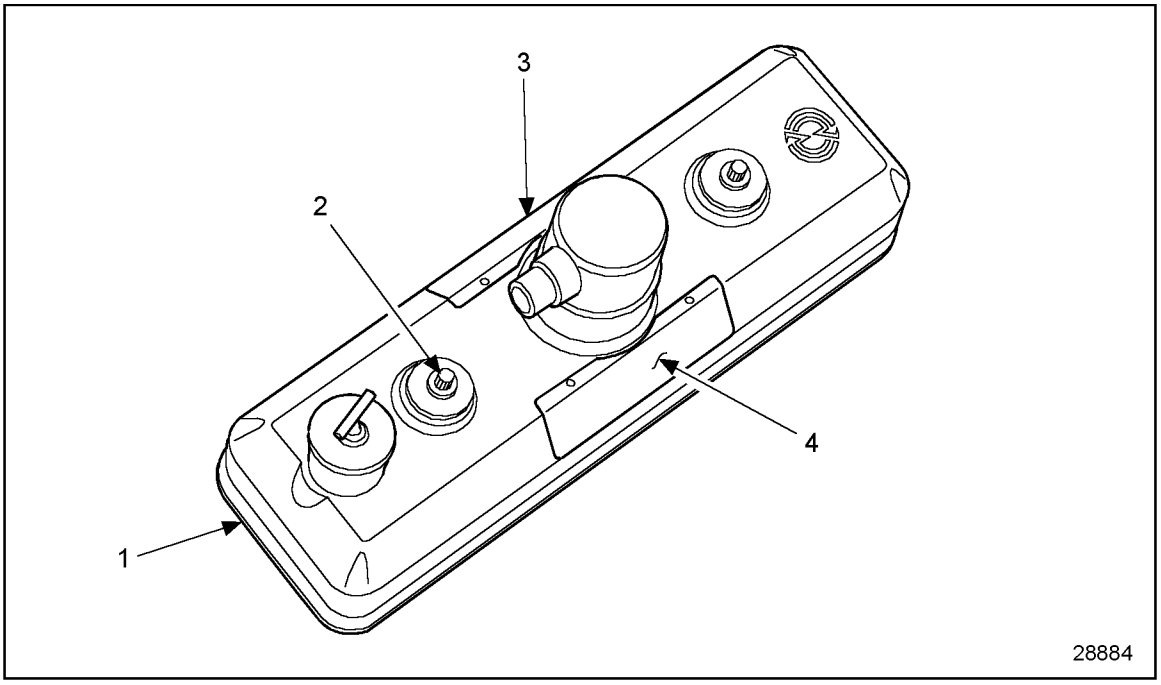
1. Serial Number
2. Model Number

Figure 8 Typical Engine Serial Number and Model Number as Stamped on Cylinder Block

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Option Plate (Metal Labels)

An option plate, attached to one of the valve rocker covers, carries the engine serial number and model number and lists any optional equipment used on the engine. See Figure 9.



1. Rocker Cover
2. Hold Down Bolt
3. Option Plate
4. Smoke Emission Plate

Figure 9 Location of Option Plates

On-highway vehicle engines also carry an exhaust emission certification label next to the option plate. It is separate from the option plate and is mounted permanently in the option plate retainer. The current label includes information relating to an engine family for the maximum fuel injector size and maximum speed. Due to Federal regulations, the exhaust emission plate should not be removed from the rocker cover. Refer to section 12.1.3 for further information regarding emission regulations.

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

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

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

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Option Plate (Paper Labels)

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

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

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

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

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

REPAIR AND REPLACE

In many cases, a service technician 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 added expense. Crankshafts, cylinder liners and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, thereby saving the expense of a new part. Exchange assemblies, such as injectors, fuel pumps, water pumps and blowers, are also desirable service items.

Various factors, such as the type of engine operation, hours in service and next overhaul period, must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble-free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of this manual.

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DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, water and fuel. On engines cooled by a heat exchanger, the fresh water system and raw water system must both be drained. Lubricating oil should also be drained from any transmission attached to the engine.

⚠ CAUTION:

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

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. 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, blocks, or parts dollies.

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. After each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is necessary before it can be satisfactorily inspected.

The cleaning procedure used for all ordinary cast iron parts is outlined under Clean Cylinder Block. Refer to section 1.1. Any special cleaning procedures will be mentioned in the text, wherever required.

Steam Cleaning

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

Tank Cleaning

A tank of sufficient size to accommodate the largest part requiring cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 82-90°C (180-200°F).

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NOTICE:
The Series 92 engine is equipped with various sensors and other electronic components that 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.

Fill the tank with a commercial heavy-duty alkaline cleaner heated to 82-90°C (180-200°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 grease and dirt.

Rinsing Bath

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

Drying

Parts may be dried with compressed air. The heat from the hot tanks will frequently completely dry the parts without using compressed air.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in the engine.

INSPECTION

Parts inspection is used to determine whether parts should be reused or replaced. Although the engine overhaul specifications given throughout this manual will help determine which parts should be replaced, considerable judgment must be exercised by the inspector.

The factors determining whether worn parts (in good condition otherwise) may be reused are the clearance between the mating parts and the wear rate on each of the parts. If the current wear rate will maintain clearances within the specified maximum limit until the next engine overhaul, the used parts may be reinstalled. Wear rate is determined by dividing the wear amount by the hours operated.

Many service replacement parts are available in various undersize, oversize, or standard sizes. Service kits for reconditioning certain parts, and service sets, which include all parts necessary to complete a particular repair job, are also available.

A thorough discussion of proper measurement and inspection procedures lies outside the scope of this manual. Nonetheless, every shop should be equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers.

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

ASSEMBLY

After cleaning and inspection, the engine should be reassembled using new parts when necessary.

Using proper equipment and tools makes the job progress faster and produces better results. Likewise, a suitable working space with adequate lighting must be provided.

Keep the working space, equipment, tools, engine assemblies, and parts clean at all times. If possible, the assembly area should be located away from the disassembly and cleaning areas.

After removal and cleaning, store parts and subassemblies where they will be kept clean. If there is any question about the cleanliness of such parts, they should be recleaned.

During assembly, consult the *"Torque Specification Table"* at the end of each section for proper bolt, nut, and stud torques.

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

Many universal sealers are commercially available. Detroit Diesel Corporation recommends that Loctite® 567 pipe sealer with Teflon®, or equivalent, be used in some instances. Certain plugs, fittings and fasteners available from the Parts Distribution Center already have a sealer applied to the threads. This precoating will not be adversely affected when pipe sealer with Teflon is also applied.

NOTE:
Loctite 567 must not be confused with International Compound No. 2, which is used as a lubricant before tightening certain bolts. Use International Compound No. 2 only when the manual specifically instructs.

FABRICATING, ALTERING, REMOVING AND DISPOSING OF GASKETS

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

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

1. Unless it is known otherwise, treat all gasket material as though it contains asbestos.
2. When cutting strips or blocks from sheets (blanking), hand cut with scissors, knife, or paper cutter. Avoid creating dust.
3. Form outside dimensions with a punch die, or hand cut with scissors, knife or compass.
4. For internal hubs, use a punch die, hand cut with scissors, knife or compass, or punch by hand with a ball-peen hammer or ball bearing.

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

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

ENGLISH TO METRIC CONVERSION

Listed in Table 2 are the English to metric conversions.

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	$Centimeters^2(cm^2)$
$Foot^2(ft^2)$	0.0929	$Meters^2(m^2)$
$Yard^2(yd^2)$	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)

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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 3.6×10^6	Joules (J = one W/s)
Multiply Light	**By**	**To get equivalent number of:**
Foot candle (fc)	1.0764	Lumens/meter^2(lm/m^2)
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 2 English to Metric Conversion Table

DECIMAL AND METRIC EQUIVALENTS

Listed in Table 3 are the decimal to metric equivalents.

Fractions of an inch	Decimal (in.)	Metric (mm)	Fractions of an inch	Decimal (in.)	Metric (mm)
1/64	0.015625	0.39688	33/64	0.515625	13.09687
1/32	0.03125	0.79375	17/32	0.53125	13.49375
3/64	0.046875	1.19062	35/64	0.546875	13.89062
1/16	0.0625	1.58750	9/16	0.5625	14.28750
5/64	0.078125	1.98437	37/64	0.578125	14.68437
3/32	0.09375	2.38125	19/32	0.59375	15.08125
7/64	0.109375	2.77812	39/64	0.609375	15.47812
1/8	0.125	3.175	5/8	0.625	15.87500
9/64	0.140625	3.57187	41/64	0.640625	16.27187
5/32	0.15625	3.96875	21/32	0.65625	16.66875
11/64	0.171875	4.36562	43/64	0.671875	17.06562
3/16	0.1875	4.76250	11/16	0.6875	17.46250
13/64	0.203125	5.15937	45/64	0.703125	17.85937
7/32	0.21875	5.55625	23/32	0.71875	18.25625
15/64	0.234375	5.95312	47/64	0.734375	18.65312
1/4	0.250	6.35000	3/4	0.750	19.05000
17/64	0.265625	6.74687	49/64	0.765625	19.44687
9/32	0.28125	7.14375	25/32	0.78125	19.84375
19/64	0.296875	7.54062	51/64	0.796875	20.24062
5/16	0.3125	7.93750	13/16	0.8125	20.63750
21/64	0.328125	8.33437	53/64	0.828125	21.03437
11/32	0.34375	8.73125	27/32	0.84375	21.43125
23/64	0.359375	9.12812	55/64	0.859375	21.82812
3/8	0.375	9.52500	7/8	0.875	22.22500
25/64	0.390625	9.92187	57/64	0.890625	22.62187
13/32	0.40625	10.31875	29/32	0.90625	23.01875
27/64	0.421875	10.71562	59/64	0.921875	23.41562
7/16	0.4375	11.11250	15/16	0.9375	23.81250
29/64	0.453125	11.50937	61/64	0.953125	24.20937
15/32	0.46875	11.90625	31/32	0.96875	24.60625
31/64	0.484375	12.30312	63/64	0.984375	25.00312
1/2	0.500	12.70000	1	1.00	25.40000

Table 3 Conversion Chart - Customary and Metric Units

SPECIFICATIONS

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

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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 4. The proper torque specifications for metric nuts and bolts are listed in Table 5.

Nut and Bolt Size, in.	260M or Better Torque	280M or Better Torque
10-24	5-7 N·m (4-5 lb·ft)	-
1/4 in.-20	7-9 N·m (5-7 lb·ft)	10-12 N·m (7-9 lb·ft)
1/4 in.-28	8-11 N·m (6-8 lb·ft)	11-14 N·m (8-10 lb·ft)
5/16 in.-18	14-18 N·m (10-13 lb·ft)	18-23 N·m (13-17 lb·ft)
5/16 in.-24	15-19 N·m (11-14 lb·ft)	20-26 N·m (15-19 lb·ft)
3/8 in.-16	31-35 N·m (23-26 lb·ft)	41-47 N·m (30-35 lb·ft)
3/8 in.-24	35-40 N·m (26-29 lb·ft)	47-53 N·m (35-39 lb·ft)
7/16 in.-14	47-51 N·m (35-38 lb·ft)	62-68 N·m (46-50 lb·ft)
7/16 in.-20	58-62 N·m (43-46 lb·ft)	77-83 N·m (57-61 lb·ft)
1/2 in.-13	72-76 N·m (53-56 lb·ft)	96-102 N·m (71-75 lb·ft)
1/2 in.-20	84-95 N·m (62-70 lb·ft)	112-126 N·m (83-93 lb·ft)
9/16 in.-12	92-102 N·m (68-75 lb·ft)	122-136 N·m (90-100 lb·ft)
9/16 in.-18	109-119 N·m (80-88 lb·ft)	145-159 N·m (107-117 lb·ft)
5/8 in.-11	140-149 N·m (103-110 lb·ft)	186-199 N·m (137-147 lb·ft)
5/8 in.-18	171-181 N·m (126-134 lb·ft)	228-241 N·m (168-178 lb·ft)
3/4 in.-10	244-254 N·m (180-188 lb·ft)	325-339 N·m (240-250 lb·ft)
3/4 in.-16	295-305 N·m (218-225 lb·ft)	393-407 N·m (290-300 lb·ft)
7/8 in.-9	417-427 N·m (308-315 lb·ft)	556-569 N·m (410-420 lb·ft)
7/8 in.-14	483-494 N·m (356-364 lb·ft)	644-657 N·m (475-485 lb·ft)
1 in.-8	590-600 N·m (435-443 lb·ft)	789-799 N·m (580-590 lb·ft)
1 in.-14	697-705 N·m (514-521 lb·ft)	928-942 N·m (685-695 lb·ft)

Table 4 Standard (Customary) Fastener Torque Specifications

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

Table 5 Class 10.9 Torque Specifications for Metric Fasteners

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Torque Specification - Pipe Plugs

Standard pipe plug torque specifications supporting the Series 92 engine are listed in Table 6.

Thread Size, NPTF*	Torque Specifications	Torque Specifications
1/8 in.	14-16 N·m	10-12 lb·ft
1/4 in.	19-22 N·m	14-16 lb·ft
3/8 in.	24-30 N·m	18-22 lb·ft
1/2 in.	31-37 N·m	23-27 lb·ft
3/4 in.	45-50 N·m	33-37 lb·ft
1 in.	102-115 N·m	75-85 lb·ft
1-1/4 in.	129-143 N·m	95-105 lb·ft
1-1/2 in.	150-177 N·m	110-130 lb·ft

* Use sealant such as Pipe Plug Sealant with Teflon, PT Loctite 567 or equivalent on all uncoated pipe plugs.

Table 6 Standard Pipe Plug Torque Specifications

Stud torque specifications are listed in Table 7.

Application	Torque Specifications	Torque Specifications
Exhaust Manifold Stud	34-54 N·m	25-40 lb·ft
Water Manifold Cover Stud	14-34 N·m	10-25 lb·ft

Table 7 Stud Torque Specifications

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1 ENGINE

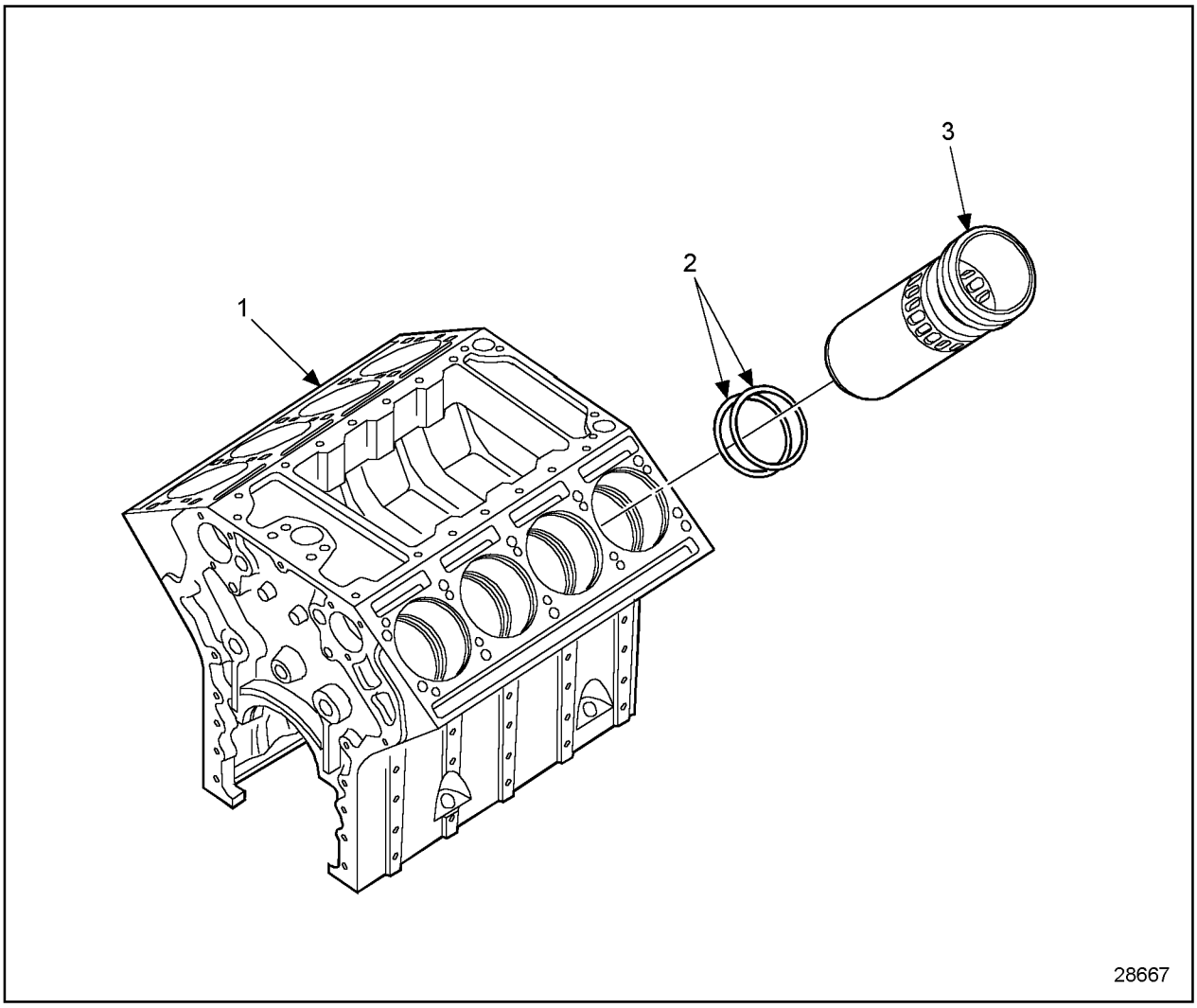
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1.1 CYLINDER BLOCK

The cylinder block is the engine's main structure. See Figure 1-1. Transverse webs provide rigidity and strength and ensure the block bore and bearings align under load.



1. Cylinder Block
2. Seal Rings
3. Cylinder Liner

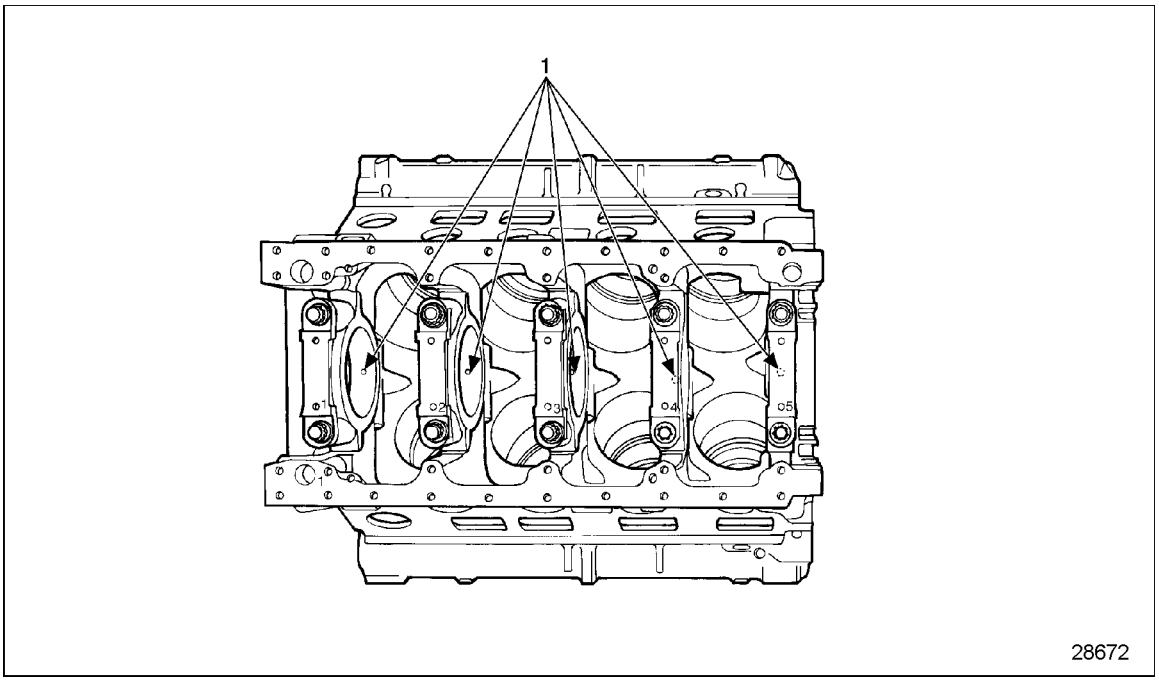
Figure 1-1 Cylinder Block (8V-92 Engine)

The cylinder block is a wet type above the cylinder liner ports and a dry type below the cylinder liner ports. Two seal rings, compressed between the cylinder liner and the block grooves, seal the water jacket and air box.

An air box conducts the air from the blower to the cylinders. Air box openings on each side of the block permit piston and compression ring inspection through the air inlet ports in the cylinder liners. The air box openings in the cylinder block assembly are approximately 1 7/8 in. x 3 1/8 in. and are shielded with cast covers. For additional information on the air box drains, Refer to section ADDITIONAL INFORMATION.

The camshaft bores are on the inner side of each cylinder bank near the top of the block.

The upper halves of the main bearing supports are integrally cast with the block. See Figure 1-2. The main bearing bores are line-bored with the bearing caps intact to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving engine parts, eliminating the need for external piping.



1. Location of Drilled Oil Passages

Figure 1-2 Location of Drilled Oil Passages

The top surface of each cylinder bank is grooved to accommodate a block-to-head oil seal ring. All counterbored oil and water holes in the cylinder block use the same size seal rings.

A flange at the upper end of the cylinder liner retains each liner in the block. The liner flange rests on an insert located in the block bore counterbore.

An individual compression gasket is used at each cylinder. When the cylinder heads are installed, the compression gaskets form a tight seal between the heads and the cylinder block.

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1.1.1 Repair or Replacement of Cylinder Block

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-3.

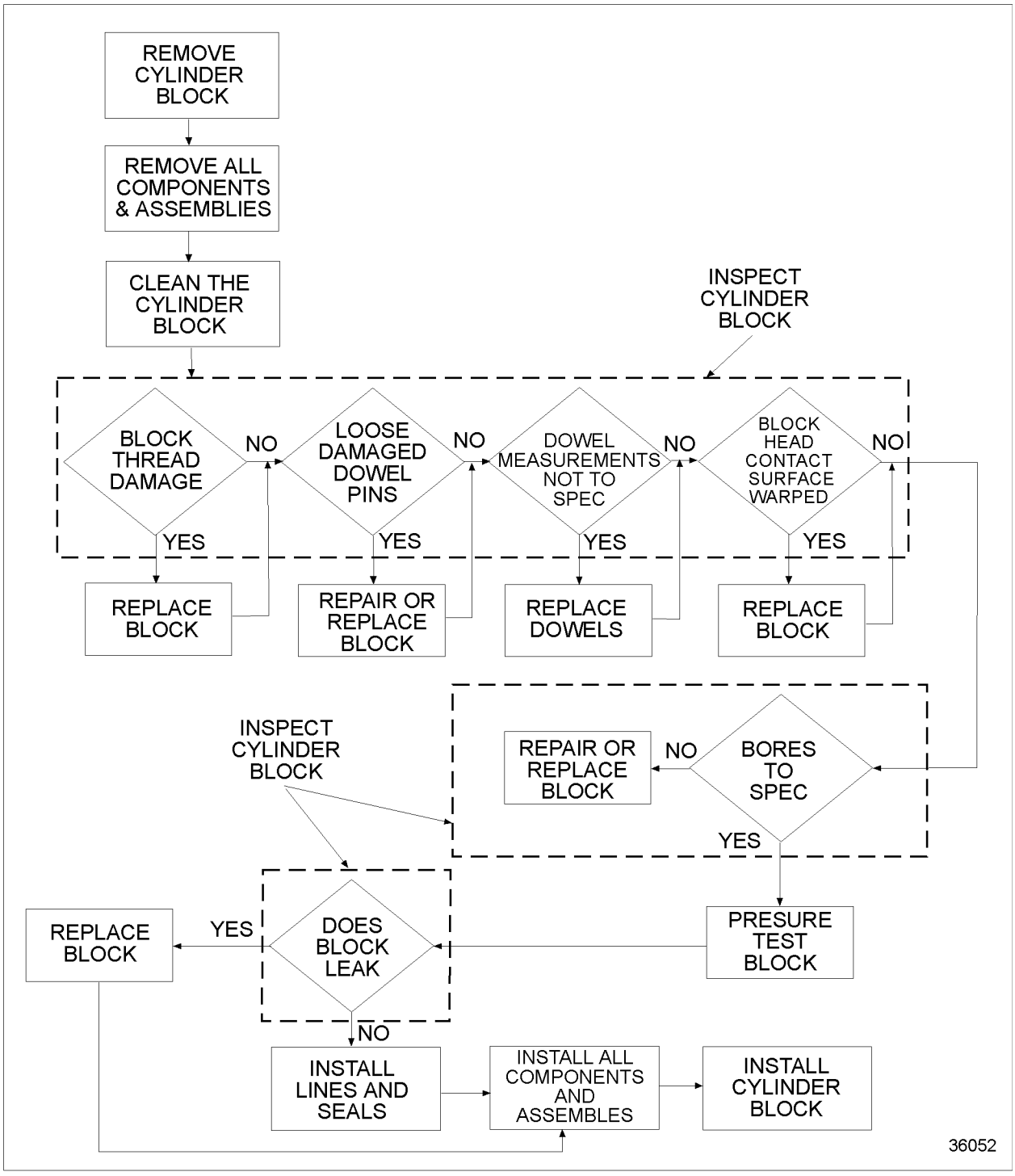
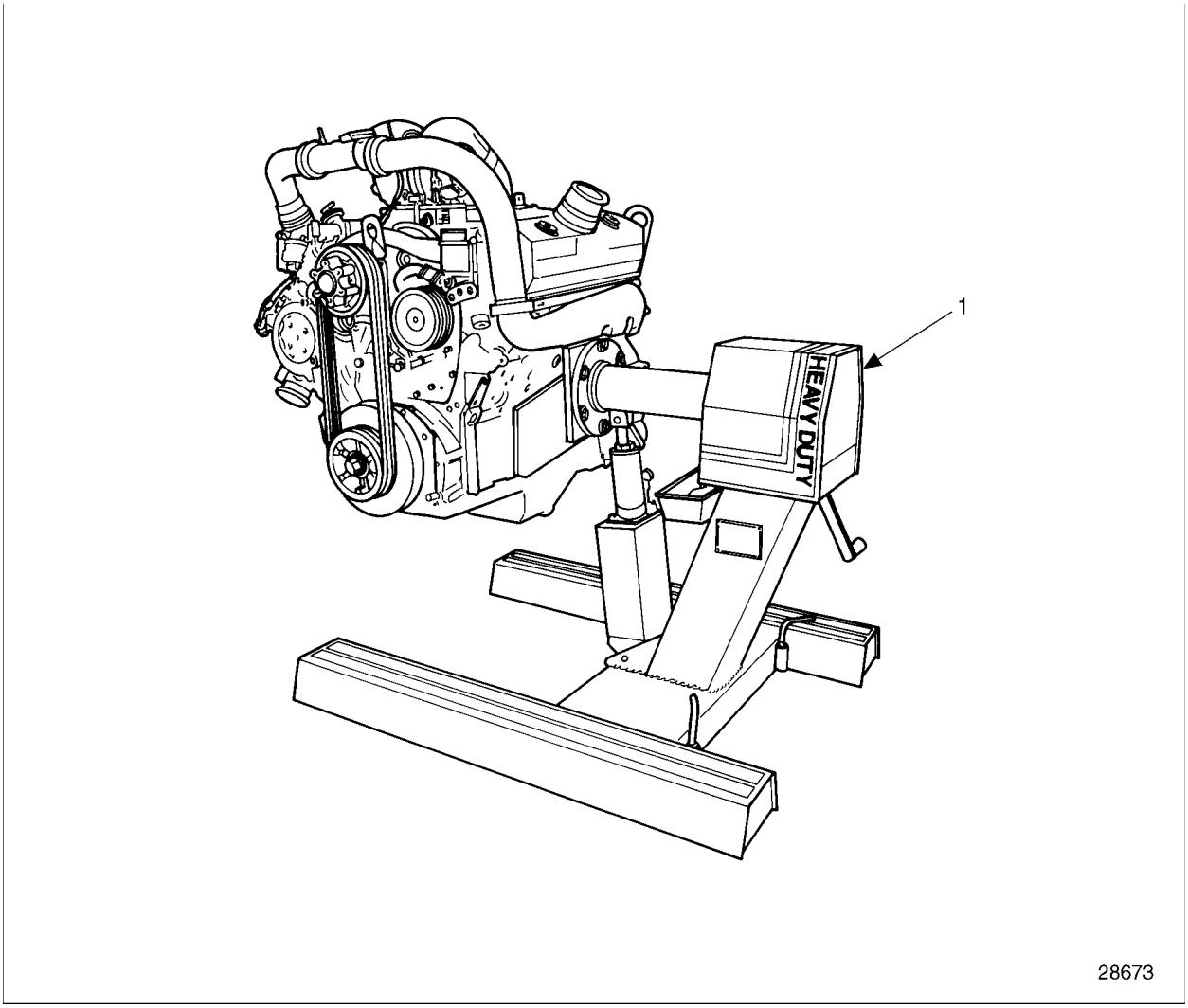


Figure 1-3 Flowchart for Repair or Replacement of Cylinder Block

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1.1.2 Removal of Cylinder Block

The hydraulically operated overhaul stand provides a convenient support when stripping a cylinder block. See Figure 1-4. Once the engine is mounted in an upright position, it may be turned on its side, rotated in either a 90 degree or 180 degree direction, locked in place, and turned back to either end or the oil pan side up.



1. Engine Overhaul Stand

Figure 1-4 Hydraulic Engine Overhaul Stand

NOTE:
Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the transmission or other driven mechanism.

Details of this procedure will vary from one application to another. However, the following steps are necessary when removing the engine:

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⚠ CAUTION:

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

1. Drain the cooling system. Refer to section 13.12.3.
2. Drain the lubricating oil. Refer to section 13.5.2.
3. Disconnect the fuel lines. Refer to section 2.21.2.
4. Remove the air cleaner and mounting brackets. Refer to section 6.2.
5. Remove the turbocharger. Refer to section 6.6.2.
6. Disconnect the exhaust piping, and remove the exhaust manifolds. Refer to section 7.2.2.
7. Disconnect the throttle controls. Refer to section 12.17.
8. Disconnect and remove the starting motor. Refer to section 8.2.2.
9. Disconnect and remove battery-charging alternator. 8.1.2.
10. Remove the air compressor, if used. Refer to section 10.1.
11. Remove the radiator. Refer to section 4.6.2.
12. Remove the fan guard. Refer to section 4.6.2.
13. Remove the air box drain tubes and fittings. Refer to section ADDITIONAL INFORMATION.
14. Remove the air box covers. Refer to section ADDITIONAL INFORMATION.

NOTE:
Early Series 92 vehicle engines built without the air box drain check valve and engines built with drain tubes routed to the crankcase via the dipstick adaptor should be updated with the current open air box drain system. Refer to section ADDITIONAL INFORMATION for inspection of the air box drains.

15. Disconnect any other lubricating oil lines, fuel lines, or electrical connections.
16. Separate the engine from the transmission or other driven mechanism.
17. Remove the engine mounting bolts.

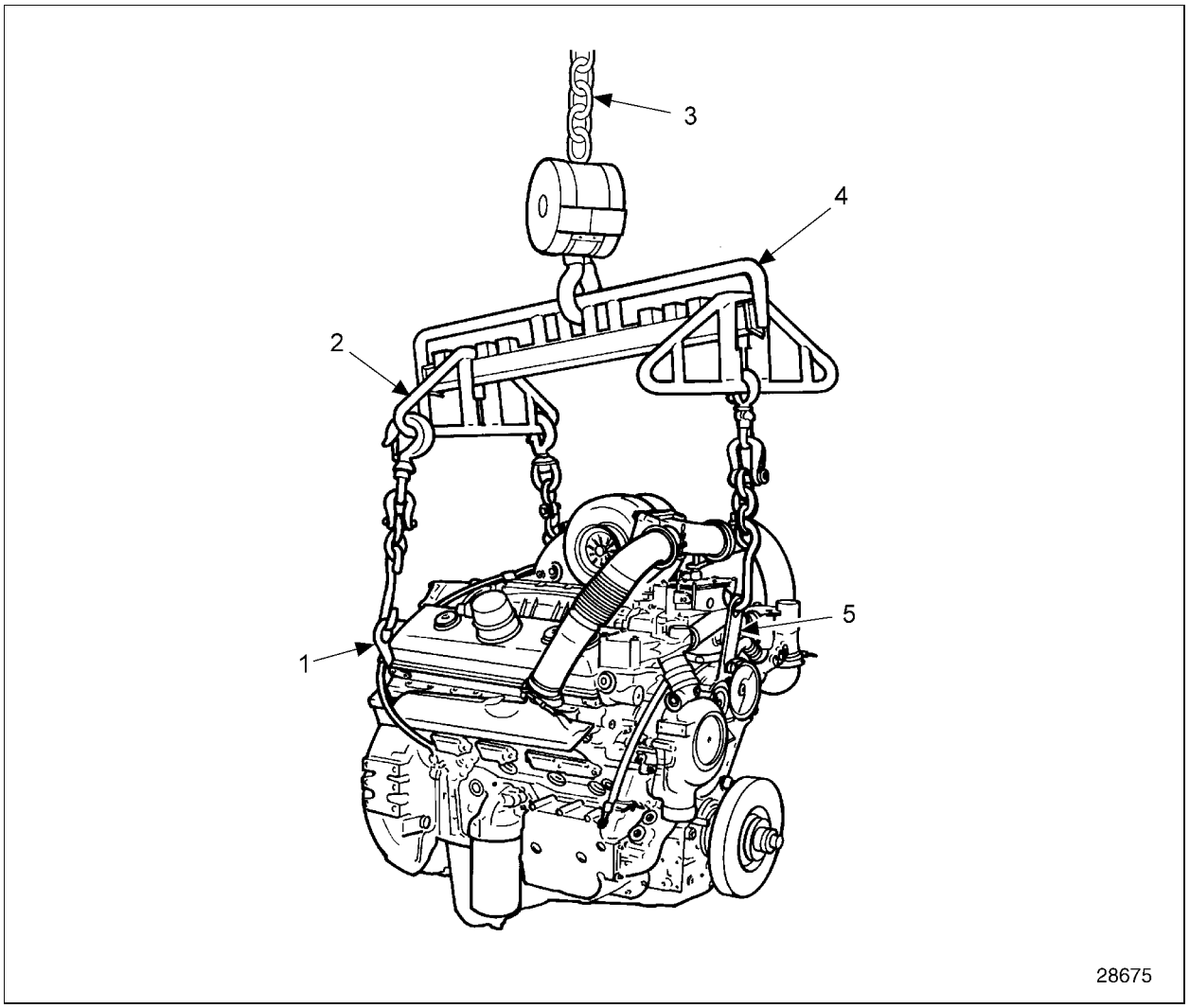
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CAUTION:

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.

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18. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base. See Figure 1-5.



1. Rear Engine Lifter Brackets
2. Lifting Sling (2)
3. Chain Hoist
4. Spreader Bars
5. Front Engine Lifter Bracket

Figure 1-5 Spreader Bar with Sling and Chain

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⚠ CAUTION:

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

NOTICE:

Detroit Diesel recommends replacing the former welded brackets with the current hot stamped brackets whenever bracket removal is required. Failure to follow these recommendations may lead to component damage.

NOTE:
Front support brackets on 8V-92 engines are now hot-stamped to final form in one step, eliminating the welding operation formerly required at the bottom outside corner of the brackets. See Figure 1-6. Former and current design brackets are completely interchangeable, and only the current design will be serviced. Because of the improved engine support that results from this change, Detroit Diesel recommends replacing the former welded brackets with the current hot-stamped brackets whenever bracket removal is required.

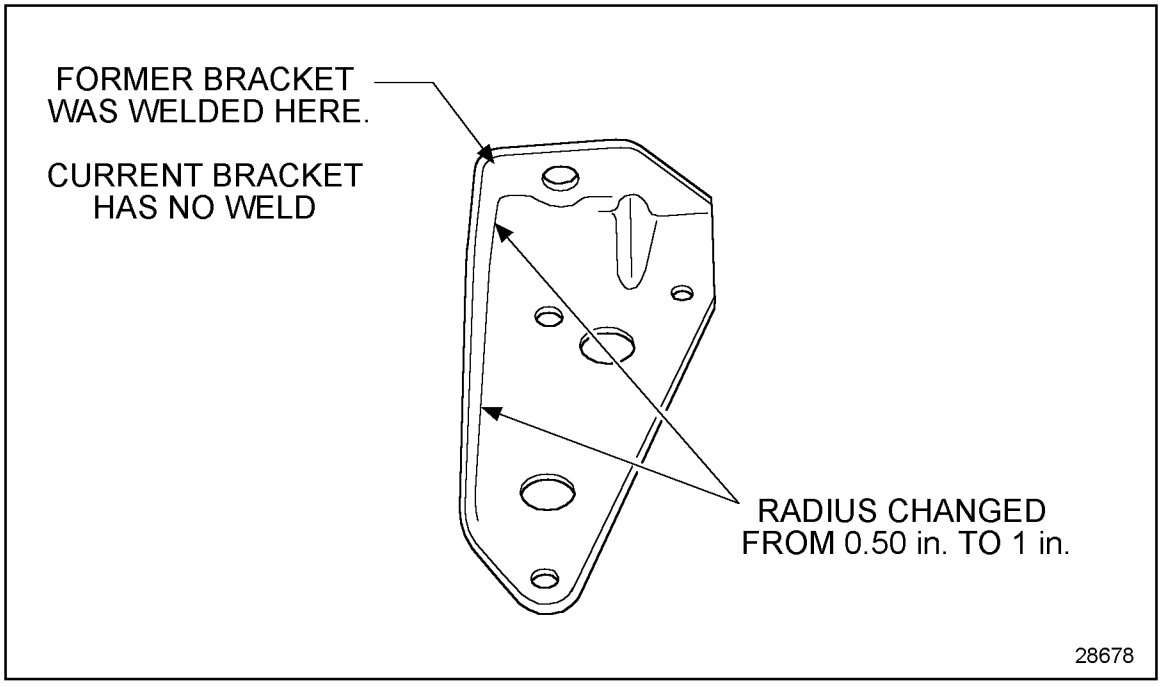


Figure 1-6 Engine Front Support Bracket

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⚠ CAUTION:

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

19. Mount the engine securely to the overhaul stand using grade 8 bolts.

NOTE:
For 6V and 8V engines, use overhaul stand J 29109 with adaptor J 33850. For 12V and 16V engines, use overhaul stand J 9389-04 and adaptor J 8650.

20. With the engine mounted on an overhaul stand, remove all of the remaining subassemblies and parts from the cylinder block.

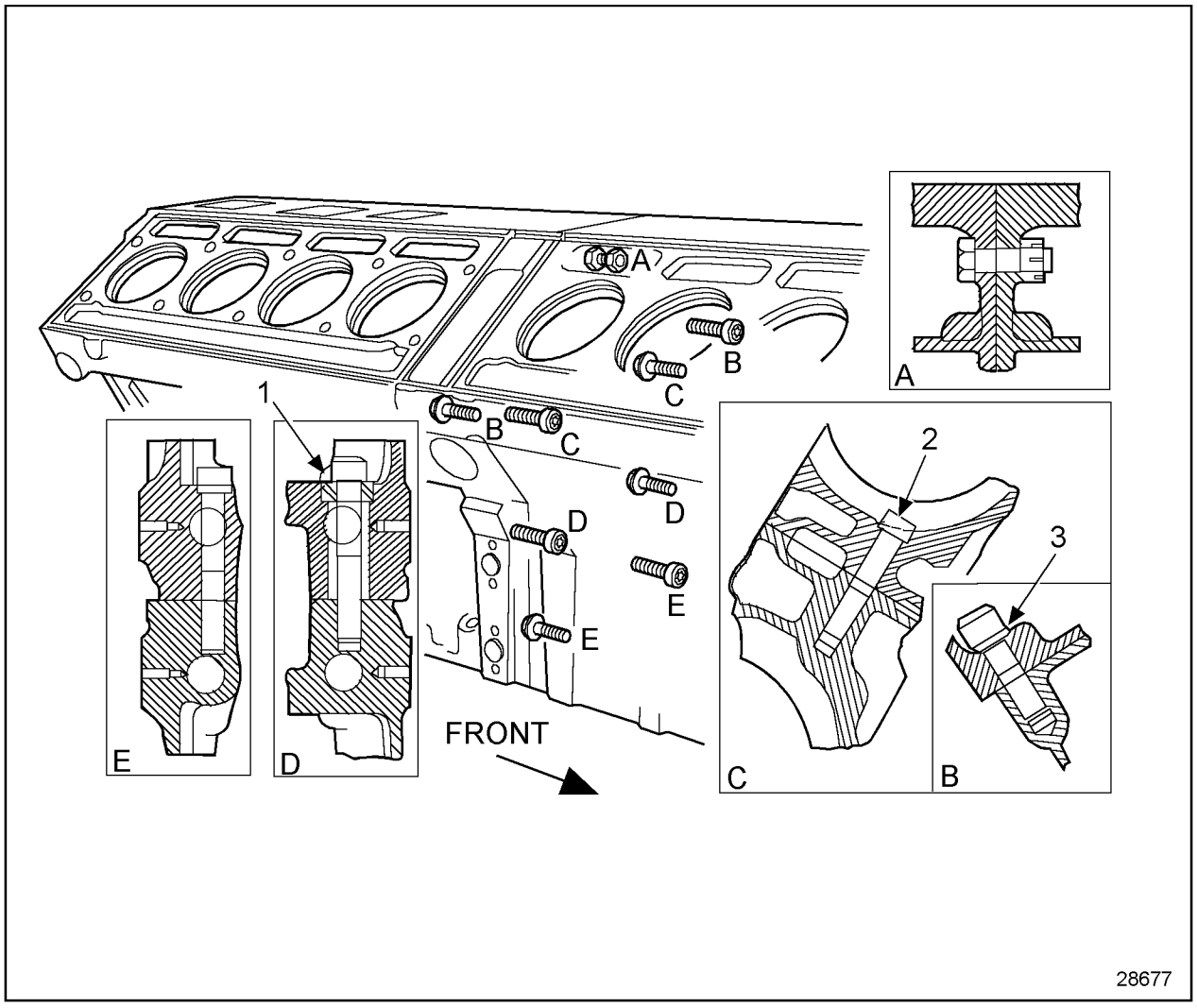
NOTE:
A water inlet adaptor plug and gasket replaces the rear (flywheel housing end) core hole plug in the cylinder block air box floor on engines with an aftercooler. Refer to section 6.8.

21. Refer to section 1.1.3 for disassembly of the cylinder block.

1.1.3 Disassembly of Cylinder Block (12V and 16V Engines)

Disassemble 12V and 16V cylinder blocks as follows:

1. Remove the two "B" bolts and special washers from the oil drain back cavity. See Figure 1-7.



1. Spacer
2. Liner Bore ID
3. Washer

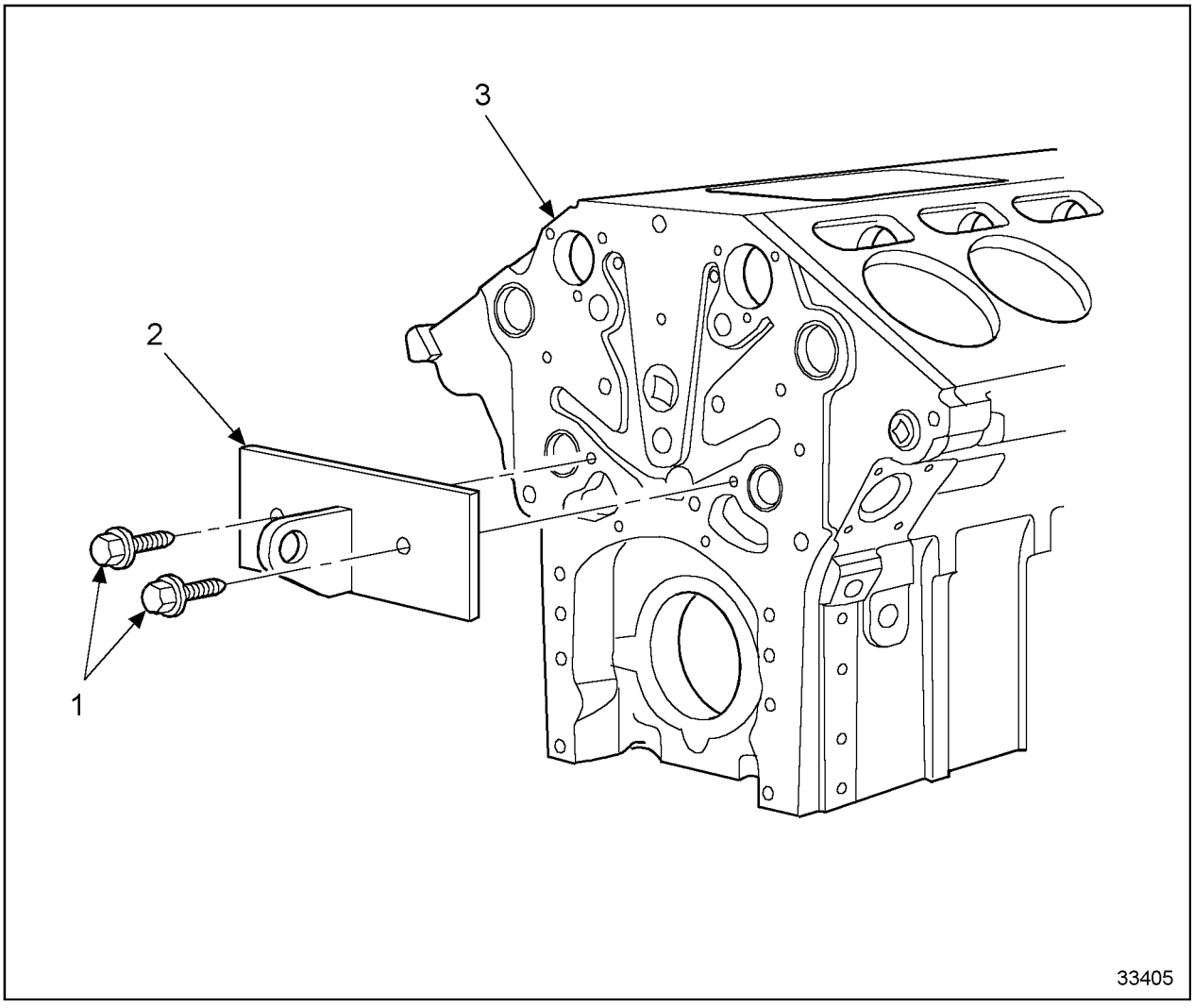
Figure 1-7 Separation of Cylinder Blocks

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CAUTION:

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

2. Attach a suitable lifting bracket to the end of the front cylinder block with two 1/2 in.-13 X 2 in. bolts and two 3/8 in.-16 X 2 in. bolts. See Figure 1-8.



1. Bolts
2. Cylinder Block Lifting Brackets
3. Cylinder Block

Figure 1-8 Cylinder Block Lifting Bracket

CAUTION:

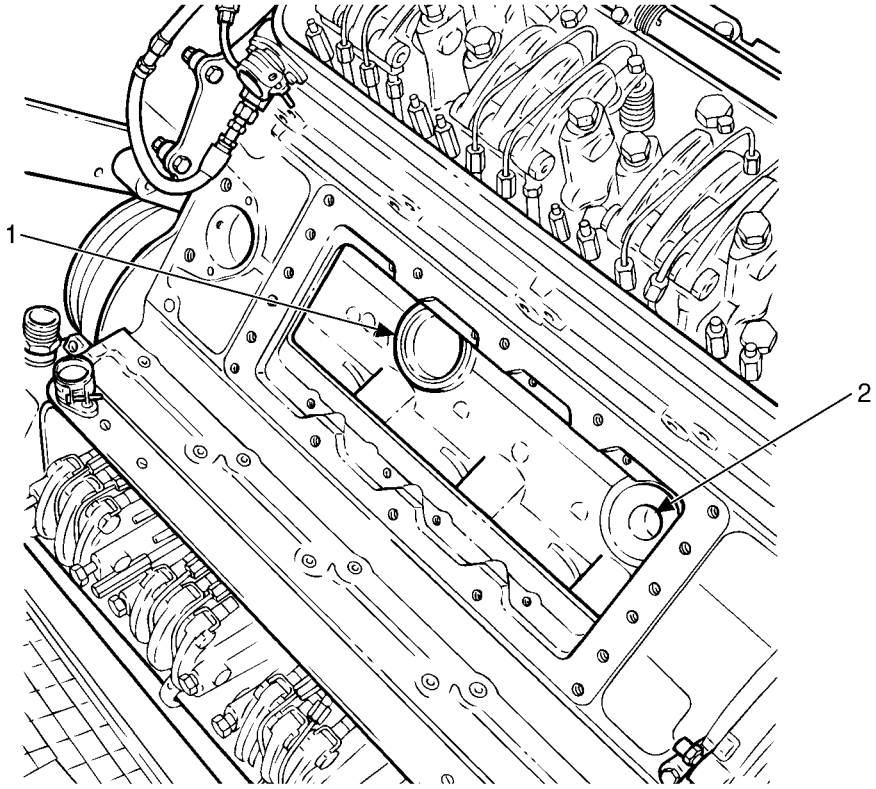
To avoid injury from a falling engine, an adequate lifting device with a spreader bar and sling should be used to lift the engine. The sling and spreader bar should be adjusted so the lifting hooks are vertical to prevent bending the lifter brackets. To ensure proper weight distribution, all provided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

3. Attach a chain hoist to the lifting bracket. Lift the cylinder blocks into a vertical position, and rest the end of the rear cylinder block on a clean, flat surface.
4. Remove the seven remaining bolts A, C, D, and E securing the two cylinder blocks together. See Figure 1-7.
5. Remove the two spacers used on the two "D" bolts. See Figure 1-7.

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6. Lift the front cylinder block off the rear cylinder block, and remove the seal strip from the groove in the rear block.

NOTE:
On aftercooled engines, it will be necessary to remove the 2 1/2 in. plug in the rear core hole in the bottom of the air box and the 2 1/4 in. plug in the top deck of the block in front of the blower mounting pad. See Figure 1-9.



1. Rear Water Inlet Adaptor Plug 2 1/2 in.
2. Front Water Inlet Adaptor Plug 2 1/4 in.

Figure 1-9 Location of Front and Rear Air Box Cup Plugs

7. Refer to section 1.1.4 for cleaning of the cylinder block.

1.1.4 Cleaning of Cylinder Block

Prior to inspection, thoroughly clean the cylinder block as follows:

1. Scrape all gasket material from the cylinder block.
2. Remove all oil gallery plugs and core hole plugs (except the cup plugs) to allow the cleaning solution to contact the inside of the oil and water passages.

NOTE:
If a core hole plug is difficult to remove, hold a 3/4 in. drift against the plug. Give it a few sharp blows with a one pound hammer. With a 1/2 in. flexible handle and a short extension placed in the plug countersink hole, turn the plug slightly to tighten. Turn it in the opposite direction, and back the plug out.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

3. Agitate the cylinder block in a hot bath of commercial heavy-duty alkaline cleaner solution to remove grease.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

4. Rinse the block in hot water, or steam clean it to remove the alkaline cleaner solution.
5. If the water jackets are heavily scaled, proceed as follows:
   [a] Agitate the block in a bath of inhibited phosphoric acid.
   [b] Allow the block to remain in the acid bath until the bubbling stops (approximately 30 minutes).
   [c] Lift the block, drain it, and immerse it in the same acid solution for 10 minutes.
   [d] Repeat step 5[c] until all scale is removed.
   [e] Rinse the block in clean hot water to remove the acid solution.

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⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

[f] Immerse the block in an alkaline bath to neutralize any acid remaining on the casting.

[g] 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.

6. Dry the cylinder block with compressed air.
7. Thoroughly clean all water passages, oil galleries, and air box drain openings.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

8. Coat the air box core plug threads and the gaskets with clean engine oil.
9. Clean the cup plug holes, and apply Loctite 567 pipe sealant with Teflon, or equivalent, to the outer diameter of the plugs.
10. Refer to section 1.1.4.3 for inspection of cylinder block.

1.1.4.1 Pressure Test Cylinder Block (Immersion Method)

Use this method when a large water tank is available and the cylinder block is completely stripped of all parts.

1. Make a steel plate of 1/2 in. stock to cover each cylinder bank of the block. The plates will adequately seal the top surface of the block when used with new cylinder line compression gaskets and water hole seal rings.
2. Use water hole cover plates and gaskets to seal the water openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line to pressurize the water jackets.
3. The seal ring grooves in the cylinder bores must be clean. Install new seal rings in the grooves above the air inlet ports.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Apply clean engine oil to the seal rings.

NOTICE:

Install the inner inserts with care to prevent the seal rings from being rolled or damaged.

5. Place liner inserts in the cylinder block counterbores. Slide the cylinder liners into the block.
6. Install new compression gaskets and water hole seal rings in the block counterbores.
7. Secure the plates to the block with 11/16 in.-11 bolts and flat washers. Tighten the bolts to 330-352 N·m (250-260 lb·ft) torque.
8. Bolt steel plates and suitable rubber gaskets to the water inlet and outlet holes, making them airtight.
9. Drill and tap one cover plate to provide a connection for an air line.
10. Seal the aftercooler water inlet adaptor plug in the air box floor.
11. Immerse the block for 20 minutes in a tank of water heated to 82°-93°C (180°-200°F).

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.

12. Apply 276 kPa (40 lb/in.^{2}) air pressure to the water jackets.
13. Visually inspect for bubbles indicating cracks in the block.
    [a] If cracks are detected, replace the block. Refer to section 1.1.6 and refer to section 1.1.7.
    [b] If no cracks are detected, proceed with inspection.
14. After completing the pressure test, remove the block from the water tank.

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⚠ 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.

15. Remove the plates, gaskets, liners, and inserts. Blow out all passages in the block with 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.

16. Dry the cylinder liners and inserts with compressed air, and coat them with oil to prevent rust.
17. Refer to section 1.1.5 for assembly procedure.

1.1.4.2 Pressure Test Cylinder Block (Leak-Marker)

Use this method when a large water tank is unavailable or when the block is not completely stripped.

The following must be removed before performing this test:

- ☐ Cylinder heads, refer to section 1.3.
- ☐ Blower, refer to section 6.5.
- ☐ Oil cooler, refer to section 3.7.
- ☐ Air box covers, refer to section ADDITIONAL INFORMATION.
- ☐ Oil pan, refer to section 3.11.

Perform the following to pressure test:

1. Make a steel plate of 1/2 in. stock to cover each cylinder bank of the block. The plates will adequately seal the top surface of the block when used with new cylinder line compression gaskets and water hole seal rings.
2. Use water hole cover plates and gaskets to seal the water openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line to pressurize the water jackets.

NOTICE:

Do not use methoxypropanol- based antifreeze. It will destroy the water seals.

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

3. Before attaching the last sealing plate, fill the water jacket with a mixture of water and one gallon ethylene glycol based antifreeze. The antifreeze will penetrate small cracks, and its color will mark their presence.
4. Install the remaining sealing plate, and tighten securely.

⚠ 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. Apply 276 kPa (40 lb/in.^{2}) air pressure to the water jacket. Maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks.
6. Visually inspect cylinder bores, air box, oil passages, crankcase, and block exterior.
   [a] If the water and antifreeze mixture is visible, the block is cracked and must be replaced. Refer to section 1.1.5.
   [b] If no water and antifreeze mixture is visible, proceed with block inspection.
7. Remove the plates, and drain the water jacket.
8. Remove the liners and seal rings.

⚠ 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.

9. Blow out all of the passages in the block with compressed air.

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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. Dry the cylinder liners and inserts with compressed air, and coat them with oil to prevent rust. Refer to section 1.1.5.

1.1.4.3 Inspection of Cylinder Block

Inspect the cylinder block as follows:

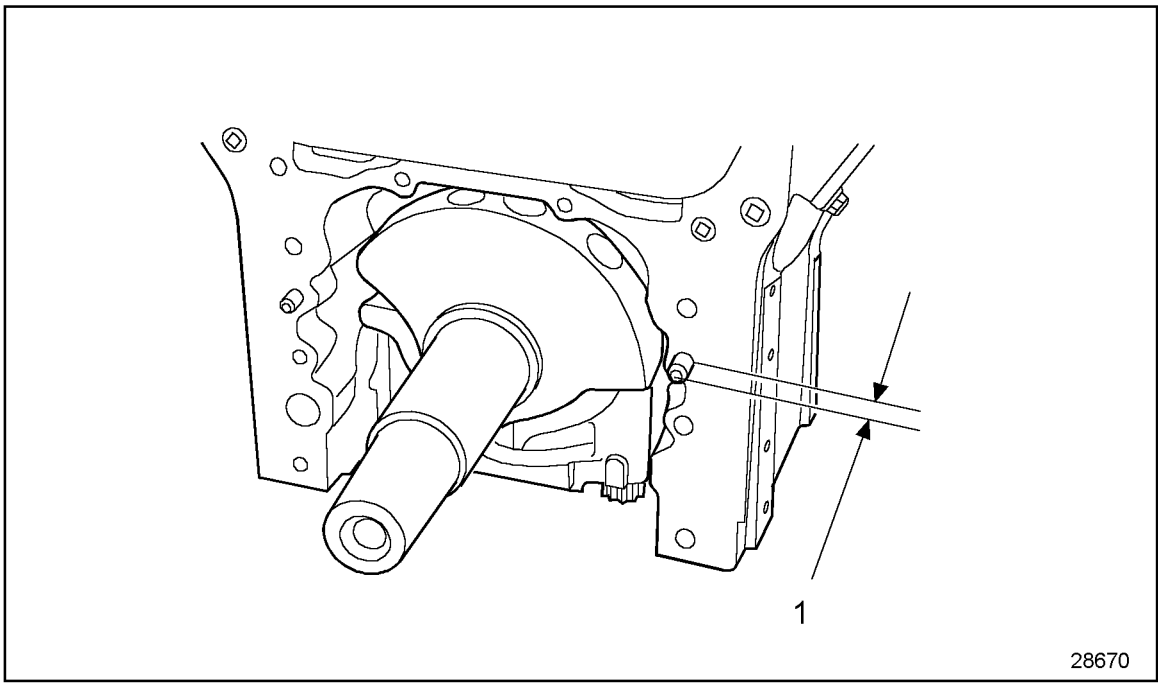
1. Visually inspect all machined surfaces for nicks or burrs.
   [a] If surfaces are nicked or burred, smooth them with a stone.
   [b] If surfaces are free of nicks and burrs, proceed with inspection.
2. Visually inspect tapped holes for thread damage.
   [a] If threads are damaged, re-tap the holes or install helical thread inserts.

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

   [b] If threads are cracked, replace block.
   [c] If threads are undamaged, proceed with inspection.
3. Visually inspect the block for loose or damaged dowel pins.
   [a] If dowel pins are loose, tighten them.
   [b] If dowel pins are damaged, replace them.
   [c] If dowel pins are neither loose or damaged, proceed with inspection.

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4. Measure dowel extension from the ends of the cylinder block. See Figure 1-10.



1. Measure Dowel Extension Here

Figure 1-10 Measuring Dowel Extension

[a] If on 6V and 8V engines, dowels do not extend 16.00 mm (0.630 in.) from the ends of the cylinder block, the dowels must be replaced.

[b] If on 12V and 16V engines, dowels do not extend 22.35 mm (0.880 in.) from ends of the cylinder block, the dowels must be replaced.

[c] If dowels extend the appropriate distance from the cylinder block, proceed with inspection.

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5. Measure the extension of the dowels used to retain the crankshaft thrust washers from the bearing cap surface. See Figure 1-11.

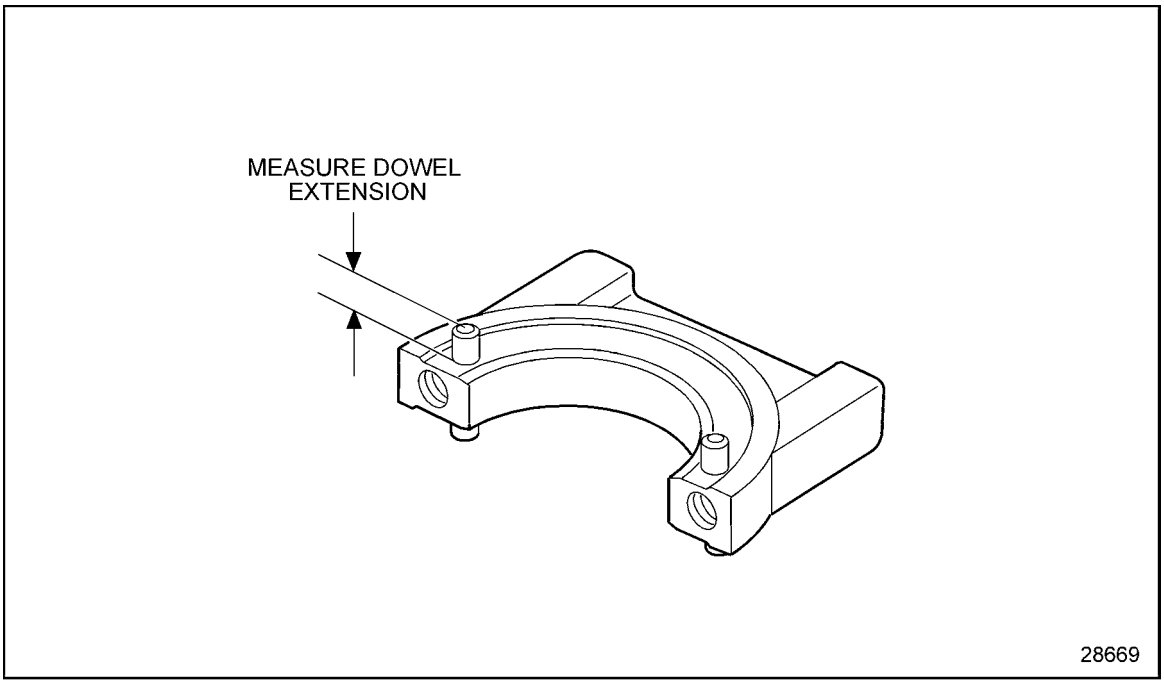


Figure 1-11 Measurement of Bearing Cap Thrust Washer Dowel Extension

[a] If the dowels do not extend 2.79-3.05 mm (0.110-0.120 in.) from the surface of the bearing cap, the dowels must be replaced.

[b] If the dowels extend the appropriate distance from the bearing cap surface, proceed with inspection.

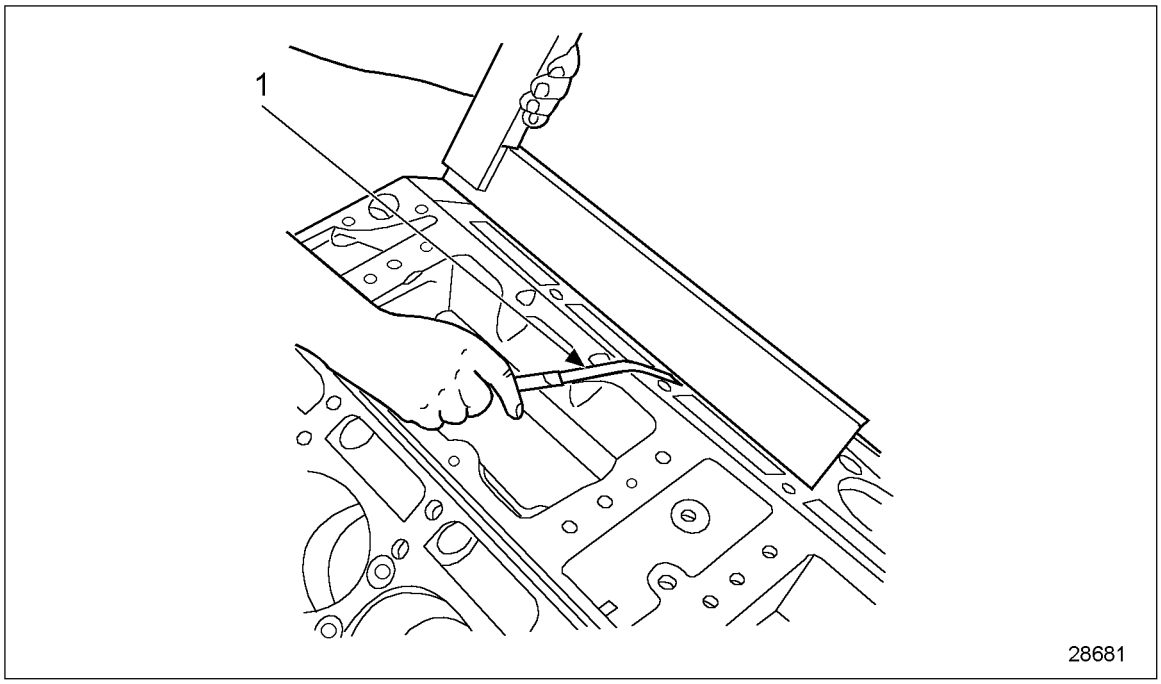
6. Inspect the dowel pins in the rear main bearing cap for looseness or damage.

[a] If pins are loose or damaged, they must be replaced.

NOTE:
Stepped dowel pins are used to replace damaged or loose pins. Prior to installation, the holes in the bearing cap must be bored with a No. 11-4.851 mm (0.1910 in.) or No. 12-4.801 mm (0.1890 in.) drill.

[b] If pins are neither loose or damaged, proceed with inspection.

7. Using a straight edge and feeler gage, check the cylinder block head contact surfaces for flatness. See Figure 1-12.



1. Feeler Gage

Figure 1-12 Measurement of Cylinder Block Head Contact Surfaces

[a] On 6V and 12V engines, if the cylinder head deck surfaces vary more than 0.08 mm (0.003 in.) transversely, and 0.15 mm (0.006) longitudinally, the block must be replaced. Refer to section 1.1.5 and refer to section 1.1.6.

[b] On 8V and 16V engines, if the cylinder head deck surfaces vary more than 0.08 mm (0.003 in.) transversely, and 0.18 mm (0.007 in.) longitudinally, the block must be replaced. Refer to section 1.1.5 and refer to section 1.1.6.

[c] If measurements fall within specifications, proceed with inspection.

8. Measure the distance from the centerline of the crankshaft to the top of the cylinder head surface.

[a] If the distance is less than 411.07 mm (16.184 in.) or more than 411.20 mm (16.189 in.), replace the block. Refer to section 1.1.5 and refer to section 1.1.6.

[b] If the measurement falls within specifications, proceed with inspection.

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9. Clean the counterbore and check counterbore depth. See Figure 1-13.

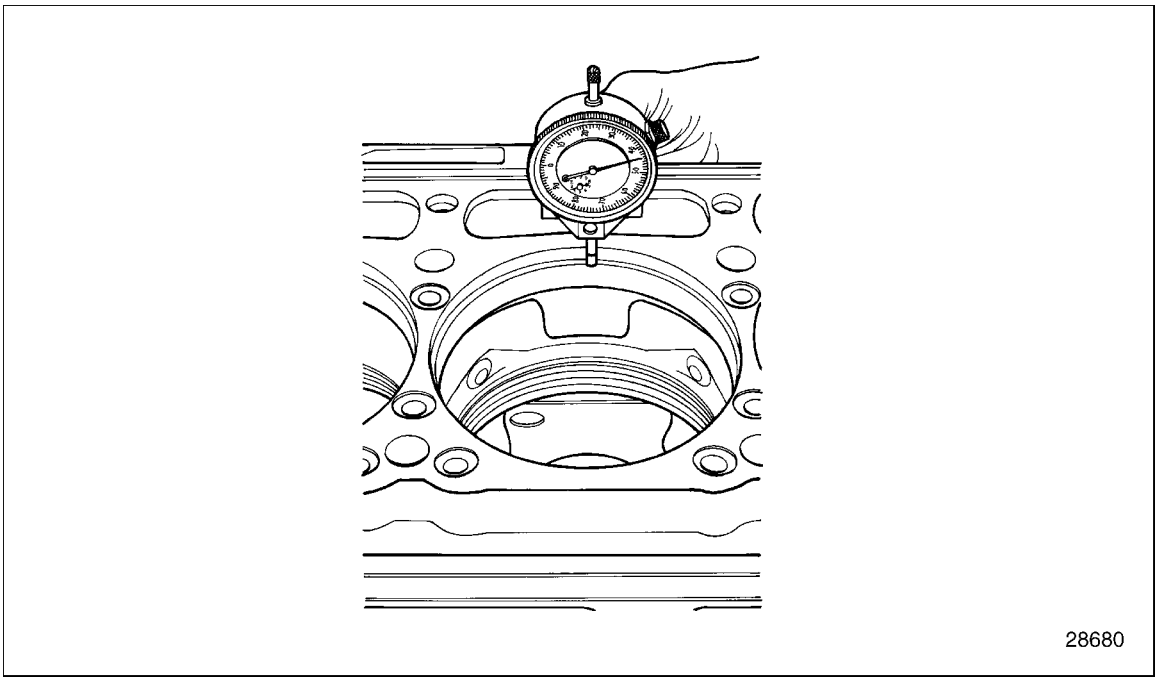


Figure 1-13 Measurement of Cylinder Liner Counter Bores

[a] If the measurement does not fall between 12.078 mm (0.4755 in.) and 12.116 mm (0.4770 in.) and varies more than 0.038 mm (0.0015 in.) throughout the entire circumference, replace the cylinder block. Refer to section 1.1.5 and refer to section 1.1.6.

[b] If there is over a 0.038 mm (0.0015 in.) difference between any two adjacent cylinder counterbores, when measured along the cylinder longitudinal centerline, the cylinder block must be replaced. Refer to section 1.1.5 and refer to section 1.1.6.

[c] If the counterbore measurements are within specifications, proceed with inspection.

10. Inspect the cylinder head retaining bolt holes for damaged threads.

[a] If the threads are damaged, use a tap to "clean-up" the threads. If necessary, install a helical thread insert. Refer to section 1.1.4.4 for inspection of the main bearing bore.

[b] If threads are undamaged, proceed with inspection. Refer to section 1.1.4.4 for inspection of the main bearing bore.

1.1.4.4 Inspection of Main Bearing Bore

Inspect the main bearing bores as follows:

1. Check the main bearing bore diameter. The specified bore diameter is 122.22-122.25 mm (4.812-4.813 in.).

[a] If the diameters for each bore does not fall within these limits, the cylinder block must be replaced. Refer to section 1.1.6 and refer to section 1.1.7.

[b] If the diameter for each bore falls within these limits, proceed with inspection.

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

2. Check the main bearing bores for misalignment.

[a] If bores are misaligned more than 0.03 mm (0.001 in.) overall, or 0.013 mm 0(.0005 in.) between adjacent bores, the block must be line-bored or discarded. Refer to section ADDITIONAL INFORMATION for line boring procedure and refer to section 1.1.4.5 to continue inspection.

[b] If bores are aligned, proceed with inspection, refer to section 1.1.4.5.

1.1.4.5 Inspection of Block Bore

Inspect the block bores as follows:

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NOTICE:
Cylinder block bore measurements should be made with the block flat on the floor. The main bearing caps should be in place, and the bolts torqued to 312-325 N·m (230-240 lb·ft). Failure to follow the torque specifications may result in damage to the cylinder block.

1. Measure each cylinder bore on a 90 degree axis using cylinder bore gage J 5347-B. See Figure 1-14.

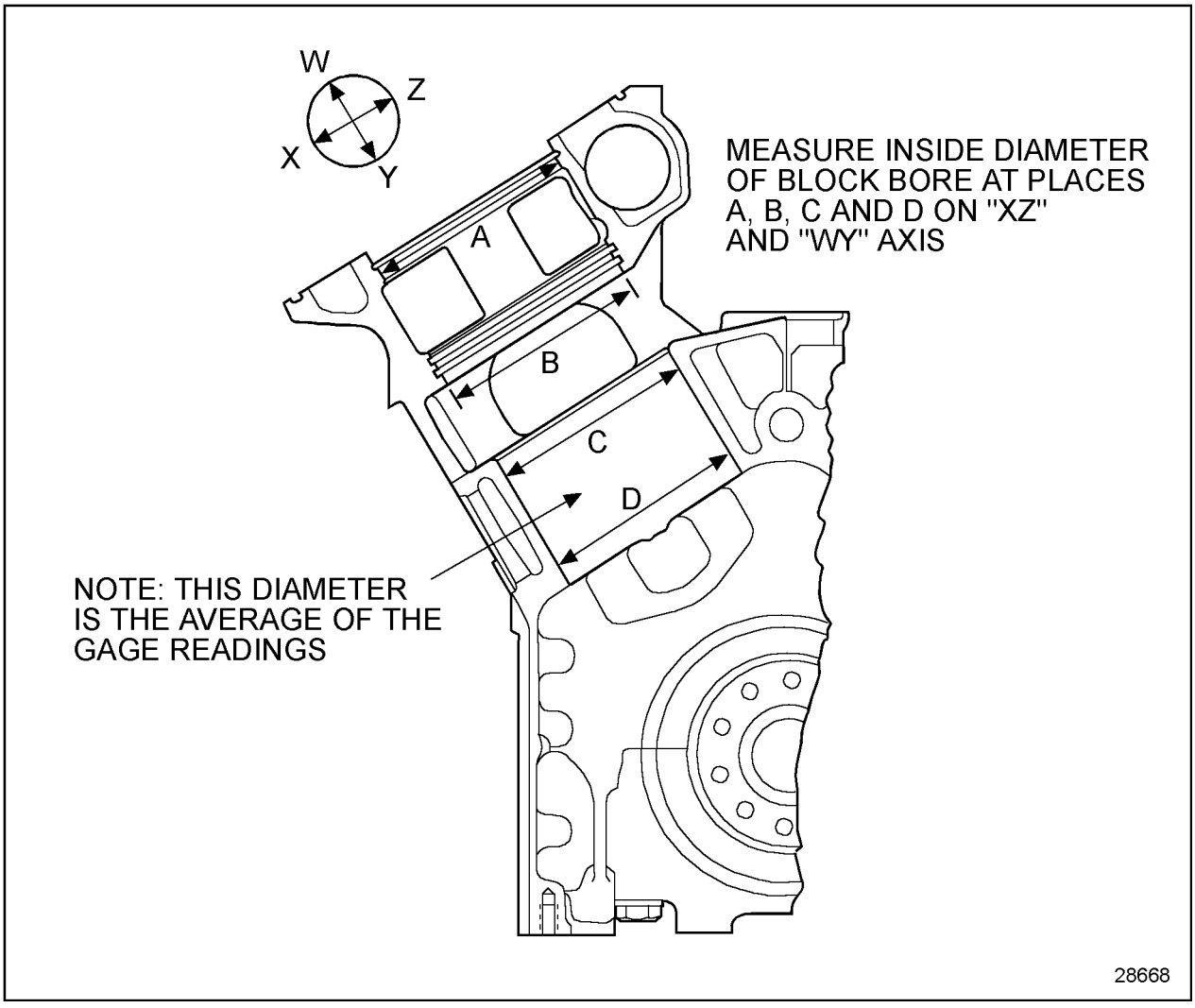


Figure 1-14 Measurement of Cylinder Block Bore

NOTE:
Dial bore gage setting master tool J 23059-01 may be used for setting the cylinder bore gage.

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[a] At position A, diameter must not exceed 136.195 mm (5.3620 in.), if new, or 136.233 mm (5.3635 in.), if used.

[b] At position B, diameter must not exceed 135.598 mm (5.3385 in.), if new, or 135.623 mm (5.3395 in.) if used.

[c] At position C, diameter must not exceed 132.524 mm (5.2175 in.), if new, or 132.550 mm (5.2185 in.), if used.

[d] At position D, diameter must not exceed 132.537 mm (5.2180 in.) if new, or 132.550 mm (5.2185 in.), if used.

[e] If measurements do not fall within specifications, replace the block. Refer to section 1.1.5.

[f] If measurements fall within specifications, proceed with block bore inspection.

2. Measure the taper and out-of-roundness.

[a] If the taper and out-of-roundness exceeds 0.025 mm (0.0010 in.), the block must be replaced. Refer to section 1.1.5.

[b] If the taper and out-of-roundness falls within specifications, proceed with inspection.

3. Clean and inspect the seal ring grooves in the cylinder block bores.

[a] If grooves and lands are pitted or eroded, or if the grooves above the air inlet ports are excessively eroded, replace the block. Refer to section 1.1.5.

[b] If grooves and lands are neither pitted nor eroded, refer to section 1.1.4.1 or refer to section 1.1.4.2 for pressure test.

1.1.5 Assembly of Cylinder Block (12V and 16V Engines)

Assemble the 12V and 16V 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.

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

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⚠ 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.

For assembly of the 6V and 8V engine refer to section 1.1.6.

1. Lift the cylinder block assembly with a chain hoist. Place the cylinder block on a clean, flat surface with the seal strip groove in the front end facing up.
2. Apply a thin coat of Lubriplate®, or equivalent, in the seal strip and seal ring grooves. Place a new seal strip in the groove.
3. Place two new seal rings in the seal ring grooves.
4. Place one new seal ring in the main oil gallery seal ring groove. The seal strip must lay flat in the groove.
5. Apply a thin coat of Lubriplate, or equivalent, on the exposed flat surface of the seal strip. Remove any excess Lubriplate from the cylinder block.

⚠ CAUTION:

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

6. Mount the cylinder block on the overhaul stand.
7. If a new service replacement block is used:
   - ☐ Stamp the engine serial number and model number on the right-hand side of the cylinder block.
   - ☐ Stamp the position number on the main bearing caps.
   - ☐ Stamp the No. 1 bearing position on the oil pan mounting flange.
8. Use a suitable non-hardening sealant on the threads of the plugs and drain cocks.
9. Install all of the required cylinder block plugs and drain cocks.

NOTE:
Effective with engines built from and after February 16, 1998, the 1 in. diameter holes in the front left-bank of 6V, 8V, 12V, and 16V cylinder blocks have been eliminated. This area is now cast solid to provide enhanced coolant flow to the upper cylinder areas of the engine. On blocks built prior to the foregoing date, the 1 in. diameter cup plugs used to seal this area have been or should be replaced by 1-1/4 in. long solid rubber service plugs. When properly installed, the solid plugs provide an inside coolant passage

configuration similar to that in the improved blocks, resulting in enhanced upper cylinder cooling. For this reason, only the solid plugs should be installed in this area when assembling or servicing former blocks. Cup plugs should no linger be used. Apply Loctite 620 or equivalent anaerobic sealant to the O.D. of the plugs, then install plugs in the block until they bottom in the holes. Refer to section ADDITIONAL INFORMATION for installation of new block plugs and cylinder block plugging instructions.

10. Install the necessary plugs and dowels. Refer to section ADDITIONAL INFORMATION, cylinder block plugging instructions.
11. Install and tighten the 2 1/2 in.-16 plugs to 312-366 N·m (230-270 lb·ft) torque using plug installer J 23019.
12. Install the plugs flush with or below the surface of the block.

NOTE:
The plug, that blocks the oil cooler adaptor inlet from the adaptor outlet, must be installed in the vertical passage.

13. Install subassemblies and parts on the block.

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.

14. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.
15. Dismount the block from the lifting device.
16. Run the dynamometer test. Refer to section 11.6 for run-in procedures.
17. Lift the cylinder block approximately four feet off the floor to position the front cylinder block over the rear cylinder block, horizontally and parallel.

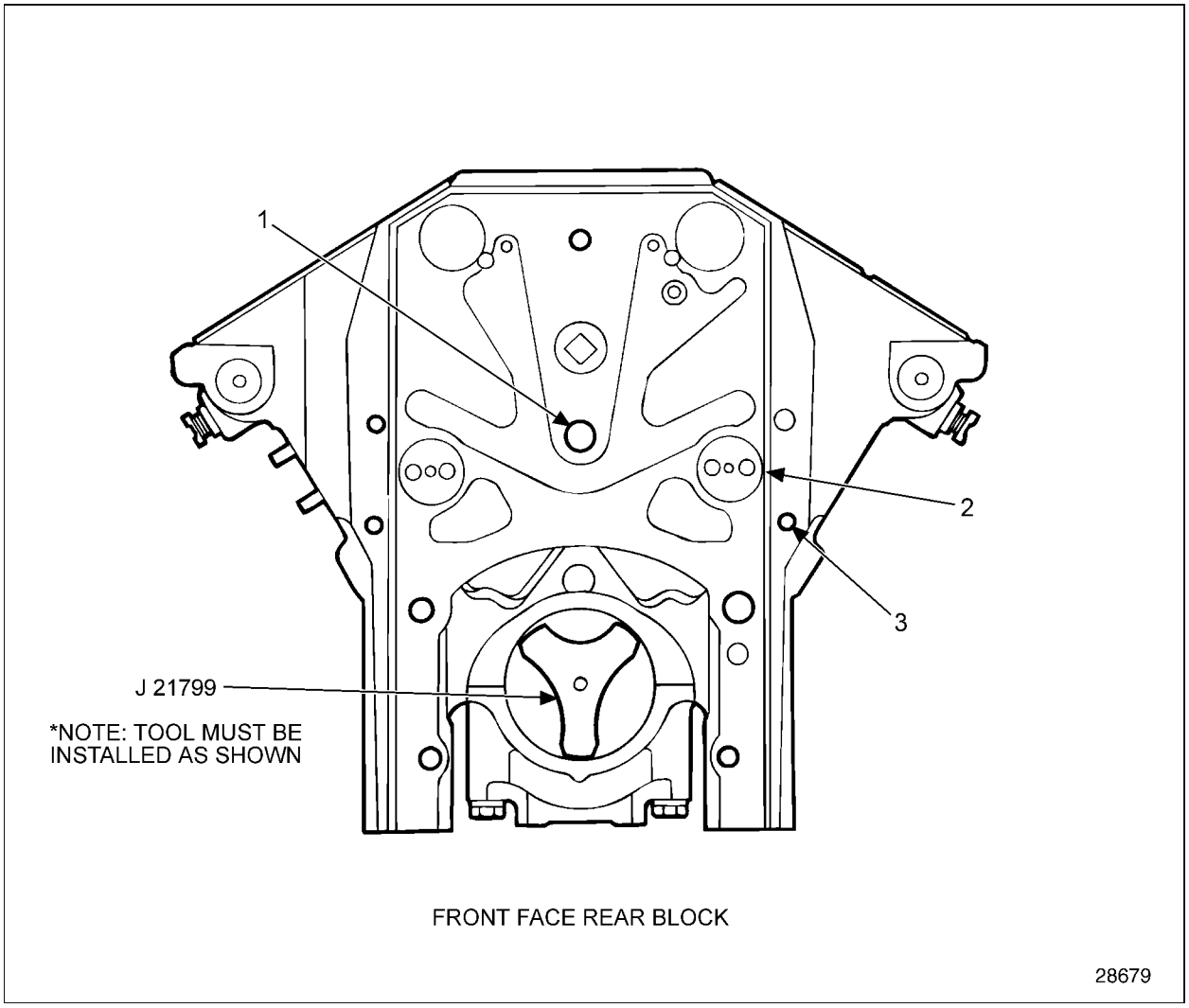
NOTICE:

Do not slide the faces against each other. This may dislodge or twist the block seal strip or oil gallery seal ring.

18. Lower the front block against the rear block. Position the front cylinder block as close to the final alignment as possible before lowering it on the rear cylinder block.
19. Place a suitable wooden block, approximately 3 in. thick, across the number 7 (12V), or 8 (16V), main bearing cap as a support for the alignment tool.

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20. Place the triangular cylinder block alignment tool J 21799 in the main bearing bore. See Figure 1-15 for contact point locations. Rest the lower end of the tool on the wood block.

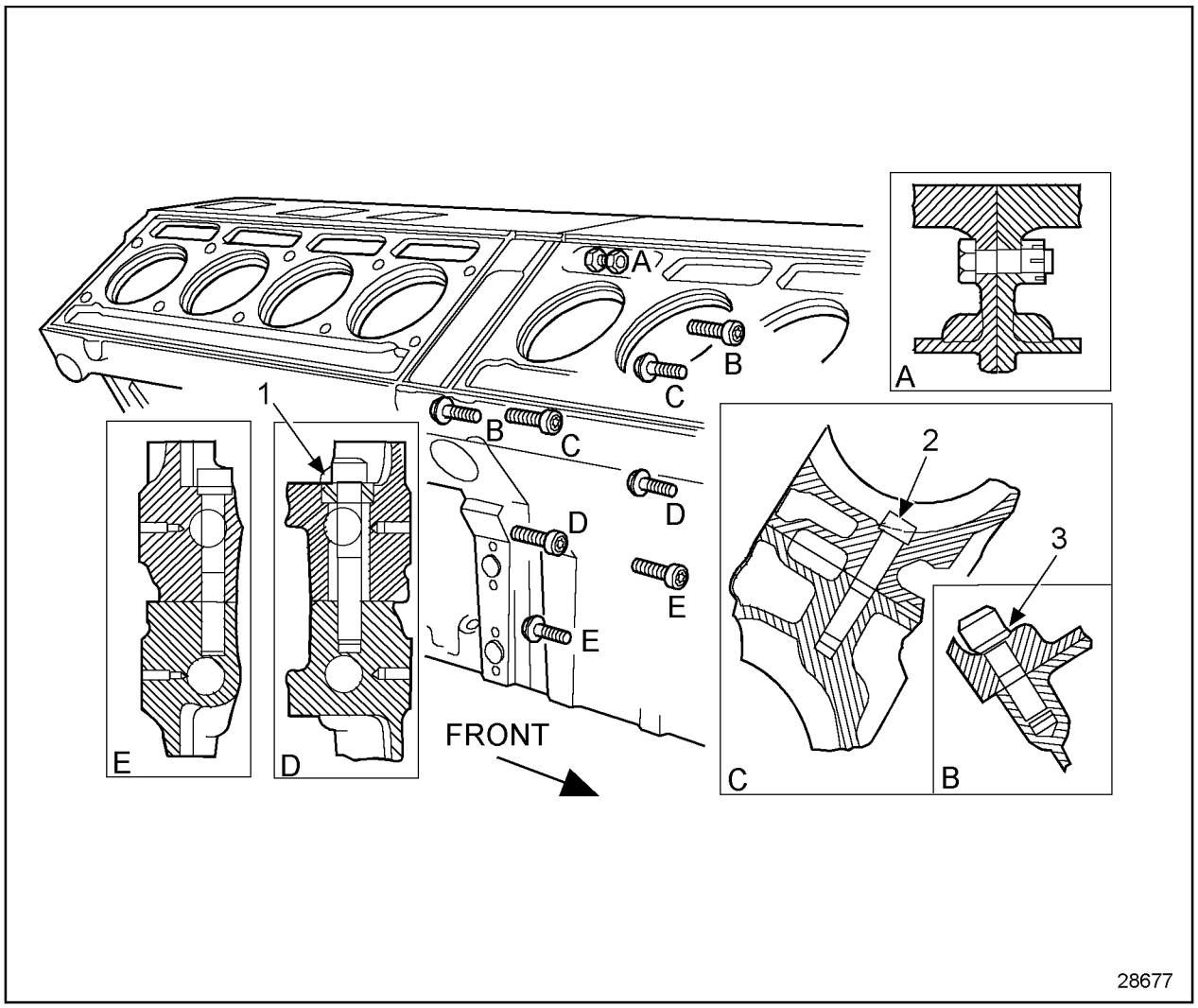


1. Seal Ring
2. Special Plug
3. Seal Ring

Figure 1-15 Position of Cylinder Block Alignment Tool

21. Install the number 4, 5, and 6 (12V), or 5, 6, and 7 (16V), crankshaft main bearing caps in their original positions. Tighten the bolts to 312-325 N·m (230-240 lb·ft) torque.
22. Lubricate the threads and the contact face of the cylinder block attaching bolts A, C, D, and E with a small amount of International Compound No. 2, or equivalent.

23. Place a spacer on each "D" bolt, as shown in inset "D". See Figure 1-16.



1. Spacer
2. Liner Bore ID
3. Washer

Figure 1-16 Separation of Cylinder Liner Blocks

NOTE:
Do not tighten the bolts at this time.

24. If it is necessary to shift the front cylinder block when installing the attaching bolts, use a soft hammer to tap at points "A" and "B". See Figure 1-16.
25. Move a dial indicator across the bottom faces (oil pan rail) of the cylinder blocks. The mismatch, if any, between the bottom faces of the two blocks must be equal on both sides of the cylinder block assembly within 0.05 mm (0.002 in.).
26. If it is necessary to shift the front cylinder block when checking the alignment, tap at points "A" and "B" with a soft hammer to align the blocks.

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27. Tighten the four "C" and "D" bolts to 217-231 N·m (160-170 lb·ft) torque.
28. Tighten the two "E" bolts to 217-231 N·m (160-170 lb·ft) torque.
29. Tighten the "A" bolt nut to 224-238 N·m (160-175 lb·ft) torque.
30. Repeat the cylinder block alignment check. If the alignment is unsatisfactory, loosen all of the attaching bolts, realign the blocks, and retighten the attaching bolts.
31. When cylinder block is aligned, cut the excess block seal strip lengths flush with the bottom face of the block.
32. Remove the cylinder block alignment tool J 21799 and the wood block.

⚠ 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.

33. Lift the cylinder block assembly with a chain hoist, and place it horizontally on a clean, flat surface.
34. Install the "B" bolts and washers. Use power universal socket J 25451-4A and hex bit J 25451-5 from set J 25451-B.

NOTICE:

Do not use socket J 25451-4A from set J 25451-B when torquing these bolts. Damage to the socket could occur.

35. Tighten bolts to 325-339 N·m (240-250 lb·ft) torque, using wrench J 25451-7 from set J 25451-B. Refer to section 1.1.7 for installation of engine.

1.1.6 Assembly of Cylinder Block (6V and 8V Engines)

Assemble 6V and 8V engines as follows:

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CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

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.

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

CAUTION:

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

1. Mount the cylinder block on the overhaul stand.
2. If a new service replacement block is used:
   - Stamp the engine serial number and model number on the right-hand side of the cylinder block.
   - Stamp the position number on the main bearing caps.
   - Stamp the No. 1 bearing position on the oil pan mounting flange.
3. Use a suitable non-hardening sealant on the surface of the block.
4. Install all of the required cylinder block plugs and drain cocks.

NOTE:
Effective with engines built from and after February 16, 1998, the 1 in. diameter holes in the front left-bank of 6V, 8V, 12V, and 16V cylinder blocks have been eliminated. This area is now cast solid to provide enhanced coolant flow to the upper cylinder areas of the engine. On blocks built prior to the foregoing date, the 1 in. diameter cup plugs used to seal this area have been or should be replaced by 1-1/4 in. long solid rubber service plugs. When properly installed, the solid plugs provide an inside coolant passage configuration similar to that in the improved blocks, resulting in enhanced upper cylinder cooling. For this reason, only the solid plugs should be installed in this area when assembling or servicing former blocks. Cup plugs should no linger be used. Apply Loctite 620 or equivalent anaerobic sealant to the O.D. of the plugs, then install plugs in

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the block until they bottom in the holes. Refer to section ADDITIONAL INFORMATION for installation of new block plugs and cylinder block plugging instructions.

5. Install the necessary plugs and dowels. Refer to section ADDITIONAL INFORMATION, cylinder block plugging instructions.
6. Use a suitable non-hardening sealant on the threads of the plugs and drain cocks.
7. Install the plugs flush with or below the surfaces of the block.

NOTE:
The plug, that blocks the oil cooler adaptor inlet from the adaptor outlet, must be installed in the vertical passage.

8. Use tool J 33420 to install the 1 in. plug in the oil gallery to a 86.4 mm (3.40 in.) depth.
9. Use tool J 34650 to install the sealant-coated 1/8 in.-27 pipe plugs.
10. Install a stepped dowel pin to replace loose pins in the rear main bearing cap.
11. Remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.
12. Install assemblies and parts.

⚠ 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.

13. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand. Refer to section 11.6 for run-in procedures.

⚠ CAUTION:

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

14. Dismount the block from the lifting device.
15. Use the dynamometer to run the engine.
16. Run the dynamometer test. Refer to section 1.1.7 for installation of engine.

1.1.7 Installation of Engine

Install the engine as follows:

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.

1. Use a spreader bar with a suitable sling and adequate chain hoist to replace the engine in its base.
2. Replace the engine mounting bolts.
3. Connect the engine to the transmission or other driven mechanisms.
4. Connect lubricating oil lines.
5. Connect the fuel lines.
6. Connect the electrical connections.
7. Attach the air box covers. Refer to section ADDITIONAL INFORMATION.

NOTE:
DDC recommends retrofitting existing 6V inline coach engines with the new air box covers and drains because of the significant drainage improvement. Refer to section ADDITIONAL INFORMATION.

NOTE:
To ensure efficient air box drainage, install air box covers with the drilled drain openings down and the slot in the large cover facing inboard. Install check valves at an angle of 30 degrees to 45 degrees. Do not install check valves horizontally. Refer to section ADDITIONAL INFORMATION.

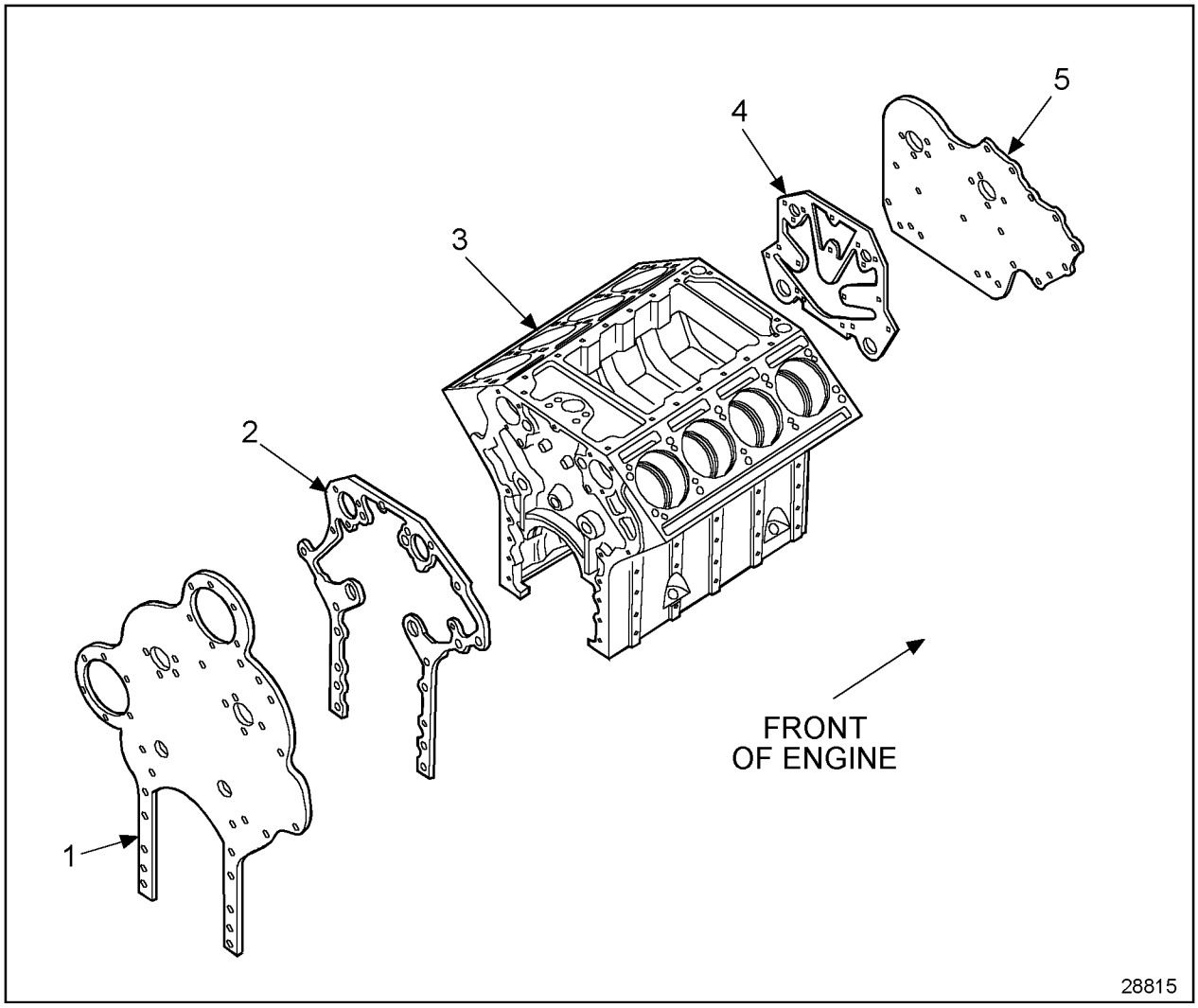
8. Attach the air box drain tubes and fittings. Refer to section ADDITIONAL INFORMATION.
9. Attach the radiator, fan guard, and other related cooling system parts. Refer to section 4.6.3.
10. Attach the air compressor, if used. Refer to section 10.1.
11. Connect the starting motor, battery-charging alternator, and other related electrical system parts. Refer to section 8.1.3 and refer to section 8.2.3.
12. Connect the throttle controls.
13. Connect the exhaust piping, and the exhaust manifolds. Refer to section 7.2.3.

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14. Install the turbocharger, if used. Refer to section 6.6.5.
15. Replace the air cleaner and mounting brackets. Refer to section 6.2.3.
16. Connect the fuel lines. Refer to section 2.21.5.
17. Fill lubricating system with the recommended grade of oil and viscosity. Refer to section 5.2 and refer to section 13.5.1.
18. Fill the cooling system with the specified antifreeze. Refer to section 5.3 and refer to section 13.12.2.
19. Refer to section 11.6 for the run-in procedures.

1.2 CYLINDER BLOCK END PLATES

Flat steel plates bolted to each end of the cylinder block provide a support for the flywheel housing at the rear and a balance weight cover at the front of the engine. See Figure 1-17. The rear end plate has a 3 in. diameter breather hole for crankcase ventilation. Gaskets are used between the block and each end plate. On current engines, the left-bank accessory drive mounting hole in the rear end plate is omitted, unless an accessory drive is specified.



1. Rear End Plate
2. Rear End Plate Gasket
3. Cylinder Block
4. Front End Plate Gasket
5. Front End Plate

Figure 1-17 Cylinder Block Front and Rear End Plates (8V Engine)

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1.2.1 Repair or Replacement of Cylinder Block End Plate

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-18.

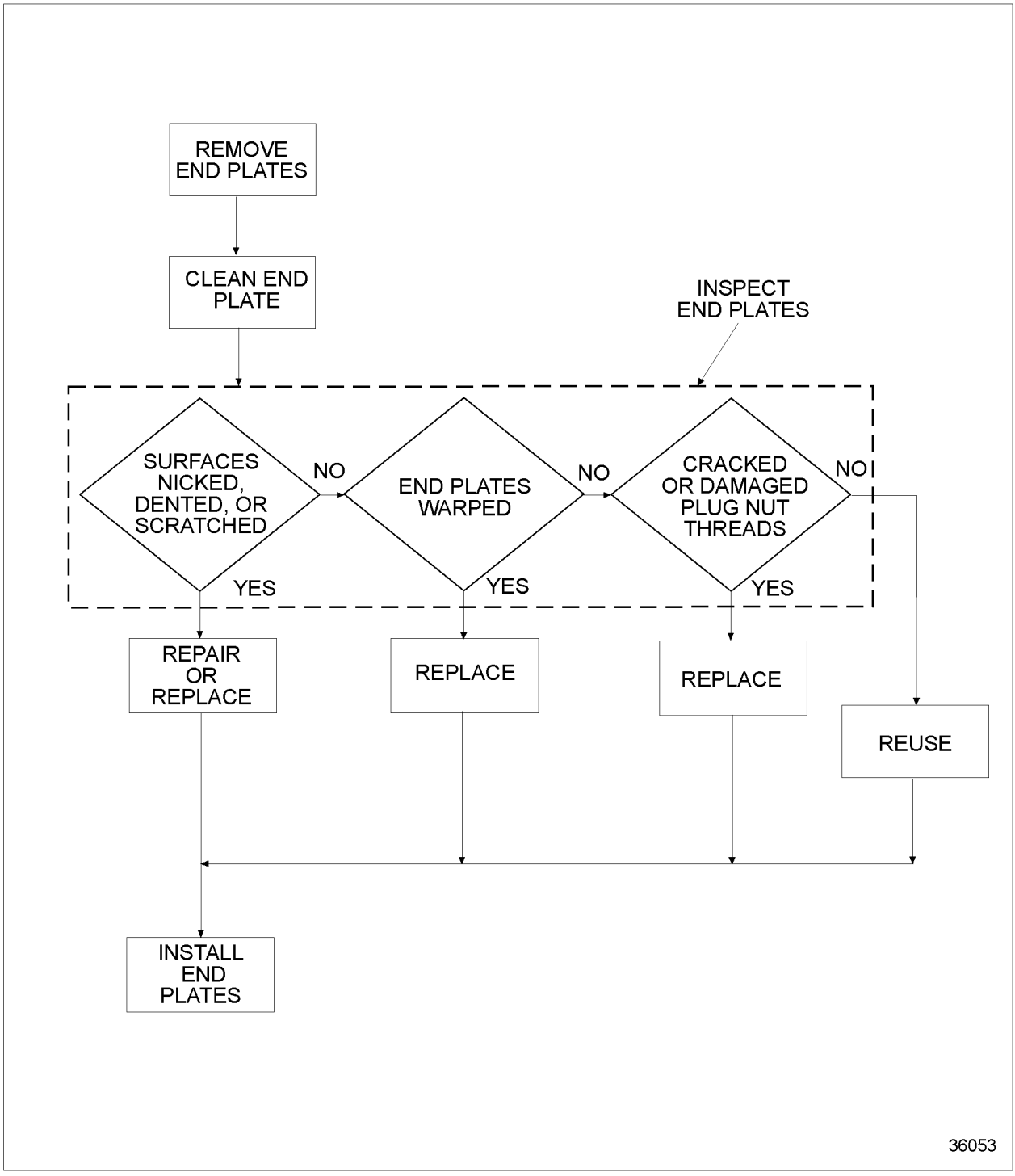
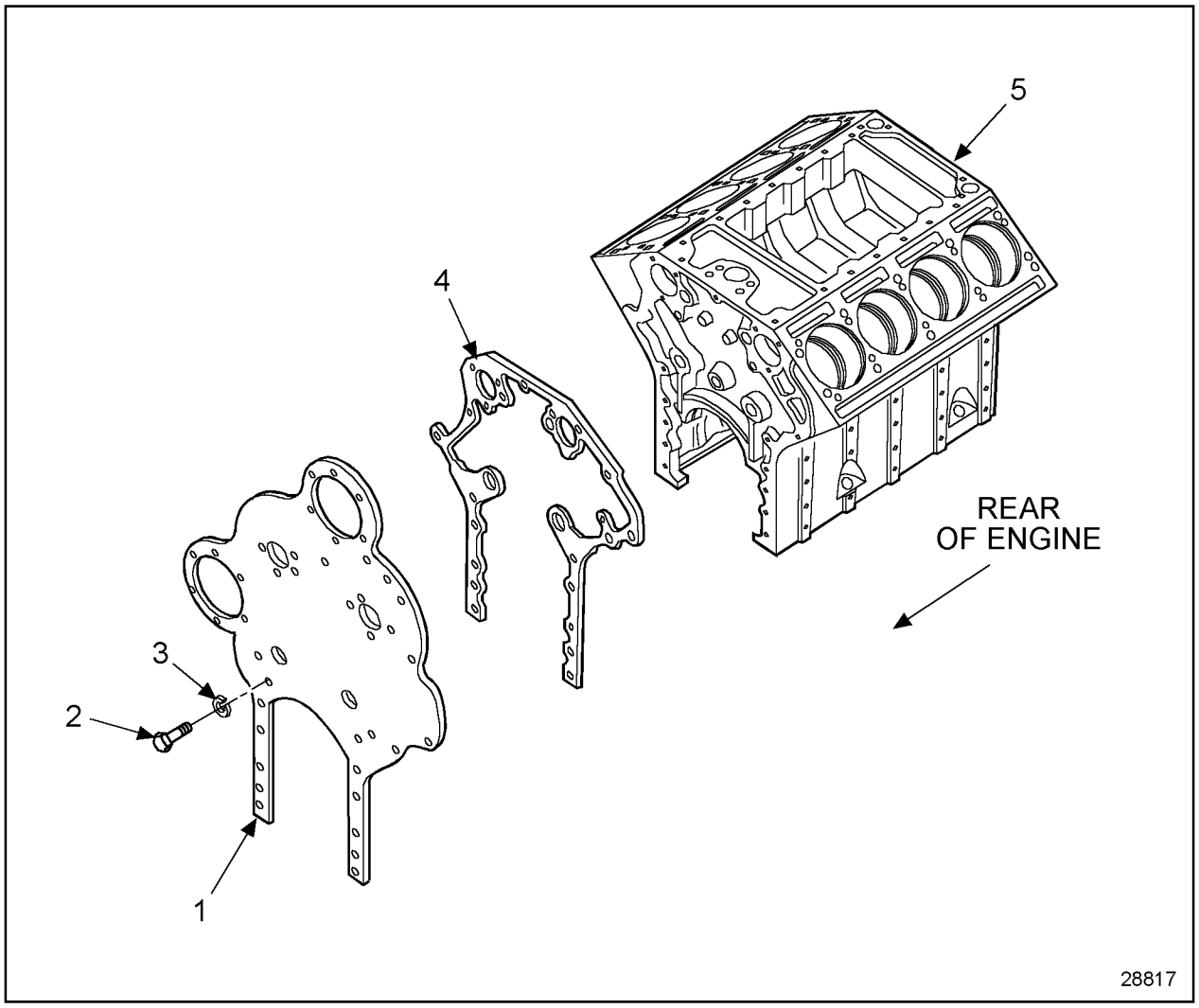


Figure 1-18 Flowchart for Repair or Replacement of Cylinder Block End Plates

1.2.2 Removal of Cylinder Block Rear End Plate

Remove the cylinder block rear end plates as follows:

1. Remove the 5/8 in.-11 x 1 in. bolt on the right rear side of the rear end plate. See Figure 1-19.



1. Rear End Plate
2. Rear End Plate Bolt
3. Washer
4. Rear End Plate Gasket
5. Cylinder Block

Figure 1-19 Cylinder Block Rear End Plate

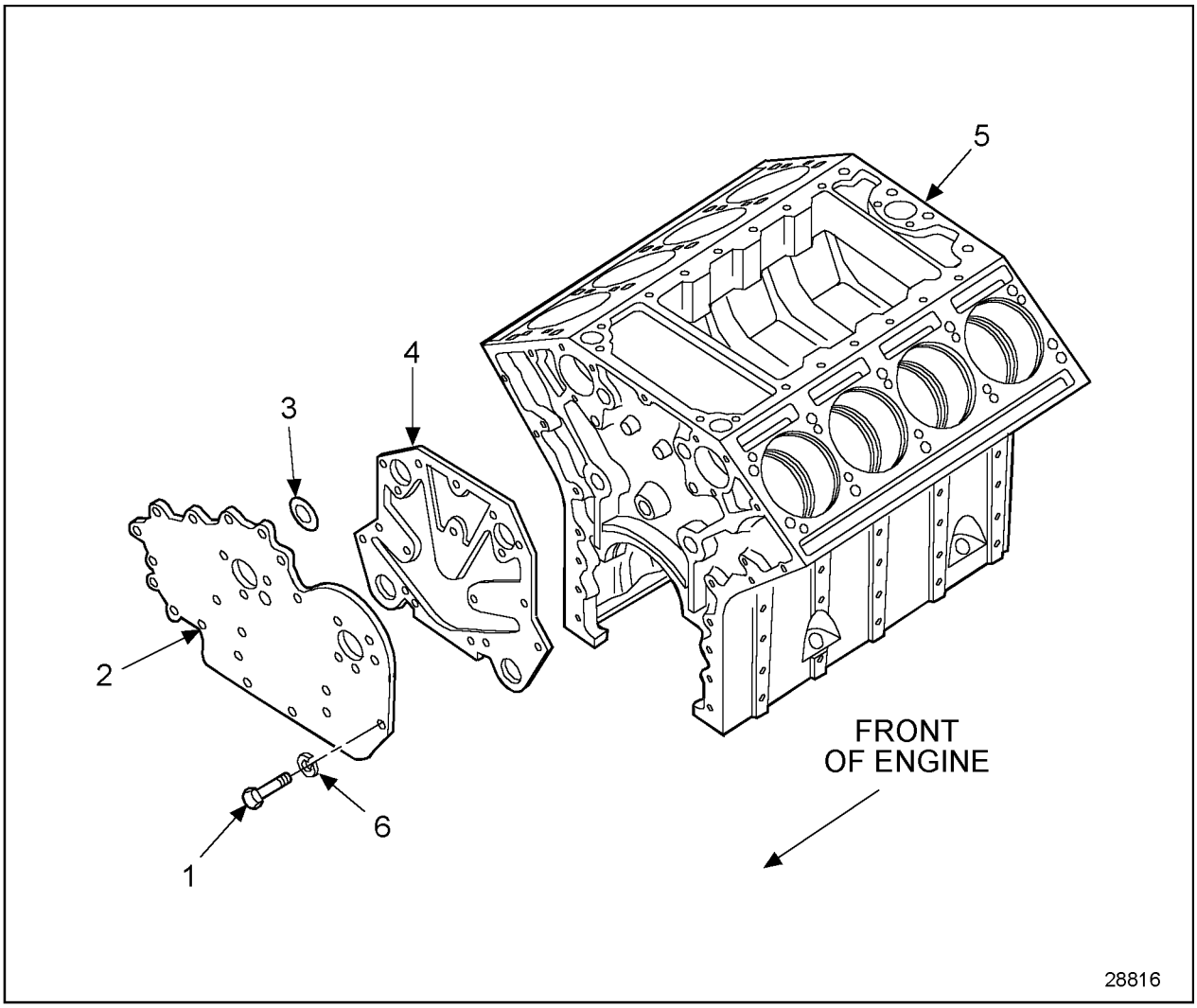
2. Remove the bolts and lock washers retaining the rear end plate to the cylinder block.
3. Remove and discard gaskets. Refer to section 1.2.3.

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1.2.3 Removal of Cylinder Block Front End Plate

Remove the front end plate as follows:

1. Remove the bolts and lock washers retaining the front end plate to the cylinder block. See Figure 1-20.



1. Front End Plate Bolt
2. Front End Plate
3. Small Round Gasket
4. Front End Plate Gasket
5. Cylinder Block
6. Lock Washer

Figure 1-20 Cylinder Block Front End Plate

2. Remove and discard the gaskets. Refer to section 1.2.3.1.
3. Refer to section 1.2.3.1 for cleaning of cylinder block end plate.

1.2.3.1 Cleaning of Cylinder Block End Plate

Prior to inspection, clean the end plates as follows:

1. All of the old gasket material must be removed from both surfaces of the end plate and the cylinder block.

⚠ 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. Immerse the end plates in a hot bath of commercial heavy-duty alkaline cleaner solution.

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

3. Rinse them in hot water, or steam clean to remove the alkaline cleaner solution.
4. Refer to section 1.2.3.2 for inspection of cylinder block end plate.

1.2.3.2 Inspection of Cylinder Block End Plate

Inspect the cylinder block end plates as follows:

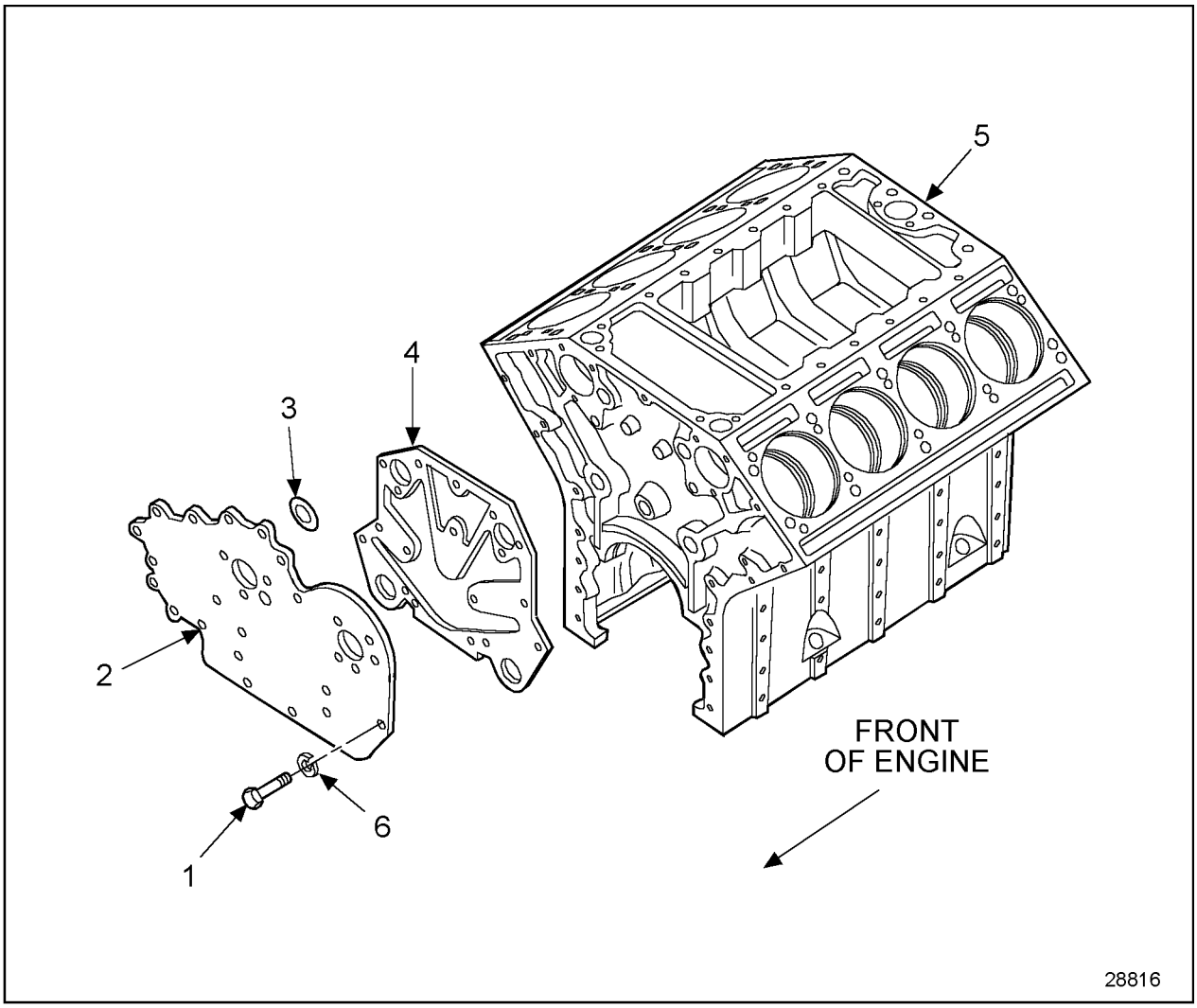
1. Inspect both surfaces of each end plate for nicks, dents, scratches, or score marks.
   [a] If nicked, dented, scratched, or scored, clean with crocus cloth.
   [b] If excessively nicked, dented, scratched, or scored, replace the end plates. Refer to section 1.2.4.
   [c] If the end plates are not nicked, dented, scratched, or scored, proceed with inspection.
2. Check the end plates for warpage.
   [a] If warped, replace the end plates. Refer to section 1.2.4.
   [b] If the end plates are not warped, proceed with inspection.
3. Check the plug nuts in the end plates for cracks or damaged threads.
   [a] If cracked or threads are damaged, replace the plug nuts. Refer to section 1.2.4 to continue installation.
   [b] If not cracked or damaged, reuse the plug nuts. Refer to section 1.2.4 for installation of cylinder block front end plate.

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1.2.4 Installation of Cylinder Block Front End Plate

Install the front end plate as follows:

1. Affix new gaskets to the ends of the cylinder block. Attach the small round gasket to the corner at the front end of the cylinder block. See Figure 1-21.



1. Front End Plate Bolt
2. Front End Plate
3. Small Round Gasket
4. Front End Plate Gasket
5. Cylinder Block
6. Lock Washer

Figure 1-21 Cylinder Block Front End Plate

2. Attach the front end plate to the cylinder block with bolts and lock washers. Finger-tighten the bolts.

3. Insert the right-bank camshaft end bearing through the SMALL bearing bore in the end plate and into the block bore to accurately align the end plate with the cylinder block.

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

4. With the bearing in place, tighten the 1/2 in.-13 end plate-to-cylinder block bolts to 96-102 N·m (71-75 lb·ft) torque. Tighten the 3⁄8 in.-16 bolts to 41-47 N·m (30-35 lb·ft) torque.
5. Remove the camshaft bearing that served as a pilot while attaching the front end plate. Refer to section 1.2.5 for installation of cylinder block rear end plate.

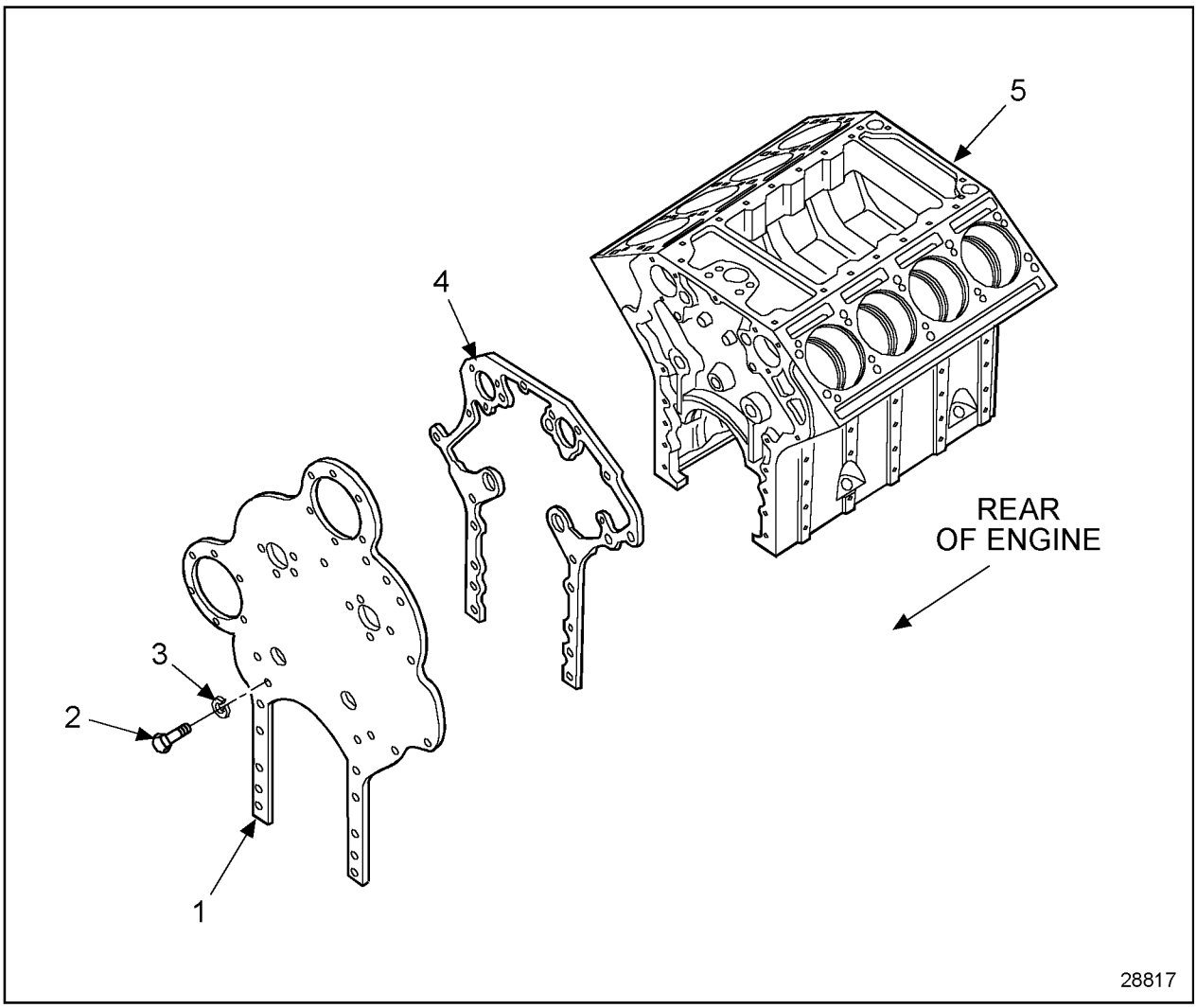
1.2.5 Installation of Cylinder Block Rear End Plate

Install the rear end plate as follows:

NOTE:
Prior to installing the end plate, attach the small cover (if used) to the cylinder block side of the rear end plate with two bolts and copper washers. Use a new gasket between the cover and the end plate.

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1. Affix new gaskets to the ends of the cylinder block. See Figure 1-22.



1. Rear End Plate
2. Rear End Plate Bolt
3. Washer
4. Rear End Plate Gasket
5. Cylinder Block

Figure 1-22 Cylinder Block Rear End Plate

2. Attach the rear end plate to the cylinder block with bolts and lock washers. Finger-tighten the bolts.
3. Insert the right-bank camshaft end bearing through the SMALL bearing bore in the end plate and into the block bore to accurately align the end plate with the cylinder block.

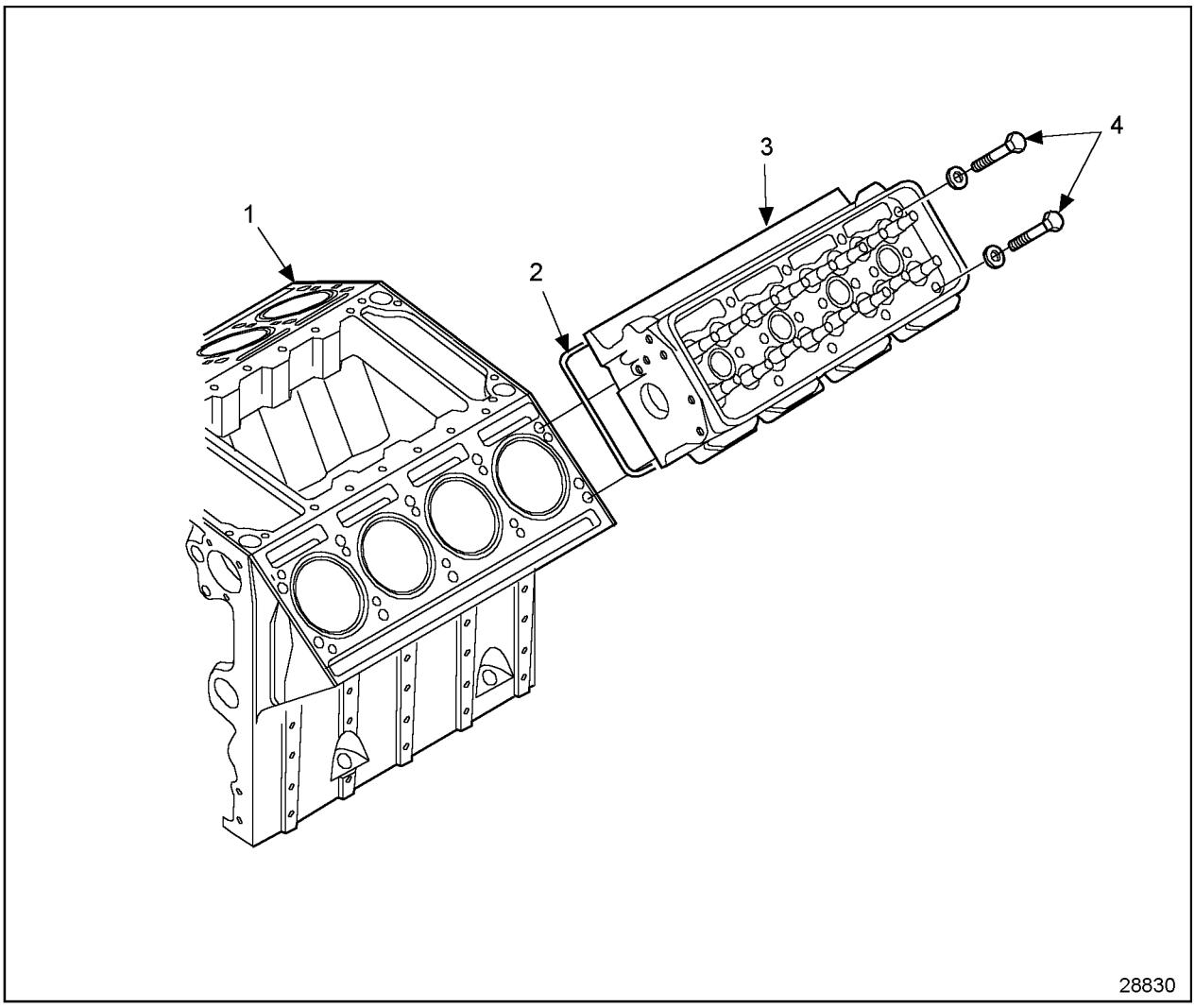
NOTE:
The holes in the front and rear end plates for the camshaft end bearings are not the same size. The smaller hole is accurately machined for alignment purposes and is always located on the engine's right side, as viewed from the rear.

4. With the bearing in place, tighten the 1/2 in.-13 end plate-to-cylinder block bolts to 96-102 N·m (71-75 lb·ft) torque. Tighten the 3⁄8 in.-16 bolts to 41-47 N·m (30-35 lb·ft) torque. Remove the camshaft bearing that served as a pilot while the front end plate was being attached. Remove the camshaft bearing that served as a pilot while the front end plate was being attached.
5. Install the 5/8 in.-11 X 1 in. bolt on the right rear side of the end plate. Tighten it to 140-149 N·m (103-110 lb·ft) torque.
6. Trim off any excess gasket material.

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1.3 CYLINDER HEAD

The cylinder head is a one-piece casting. Special 11/16 in.-11 bolts and hardened washers or special 11/16 in.-11 washer faced bolts hold the cylinder head securely on each cylinder block bank. See Figure 1-23.



1. Cylinder Block
2. Cylinder Head Gasket
3. Cylinder Head Assembly
4. Cylinder Head Bolts

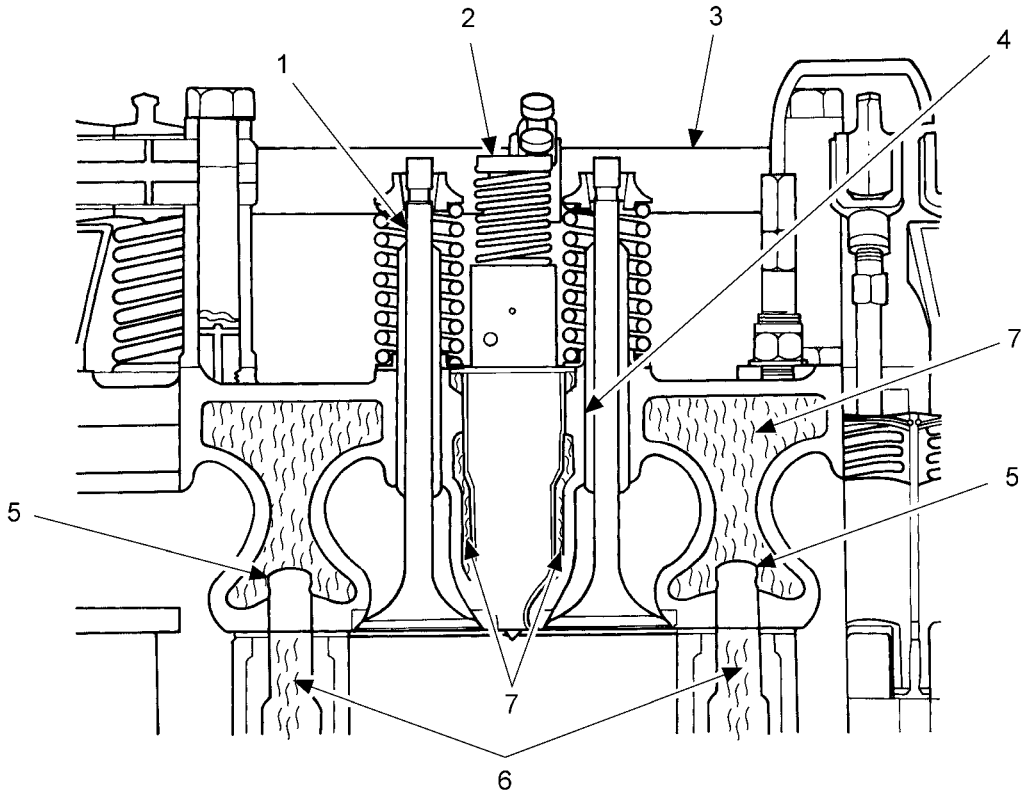
Figure 1-23 Cylinder Head

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

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate valve seating under varying temperatures and prolong cylinder head life.

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To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube that passes through the water space in the cylinder head. See Figure 1-24. The lower end of the injector tube is pressed into the cylinder head and flared. The upper end is flanged and sealed with a seal ring. The upper and lower ends of the injector tube prevent water and compression leaks.



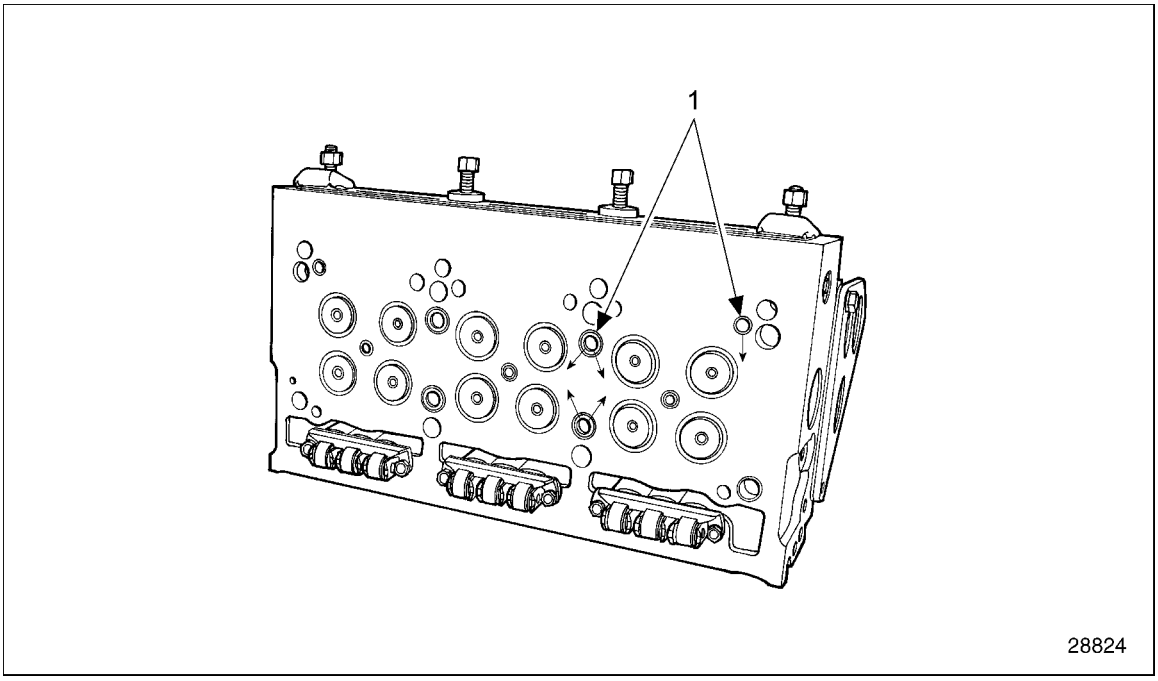
1. Exhaust Valve
2. Fuel Injector
3. Rack
4. Injector Tube
5. Nozzles
6. Water Passage (Block to Head)
7. Water Passage Around Fuel Injector Tube and Through Cylinder Head

Figure 1-24 Coolant Passages Around Exhaust Valves and Fuel Injectors

The exhaust passages from each cylinder exhaust valve lead through a single port to the exhaust manifold. Engine coolant surrounds the exhaust passages and the injector tubes.

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Water nozzles pressed into the water inlet ports in the cylinder head further ensure cooling. See Figure 1-25. The nozzles direct high velocity engine coolant toward the cylinder head sections that are subjected to the greatest heat.

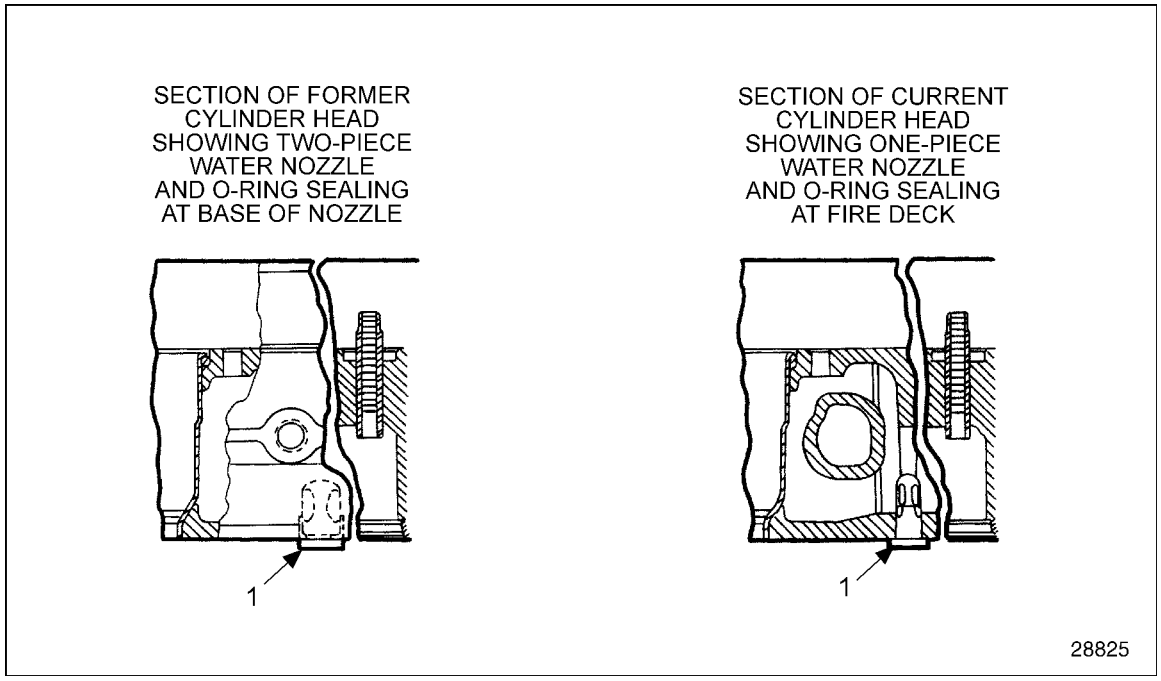


1. Water Nozzles

Figure 1-25 Cylinder Head Water Nozzles

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New cylinder heads with small diameter, one-piece, double-jet water nozzles are being used on Series 92 Engines, effective with serial numbers 6VF-72972, 8VF-65910 and 16VF-4322. See Figure 1-26. Water nozzle hole diameters have been reduced from 20.62 to 13.72 mm (0.812 to 0.540 in.), leaving more material between nozzle holes and bolt holes to improve nozzle-to-head sealing.



1. Seal

Figure 1-26 Former and Current Water Nozzle Installation

The fuel inlet and outlet manifolds are integrally cast into the cylinder head. Tapped holes are provided for fuel line connection at various points along each manifold. Water flow is entirely internal on the 6V and 8V end outlet cylinder heads. On 12V and 16V engines, a water manifold is attached to each cylinder head.

To seal compression between the cylinder head and the cylinder liner, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the cylinder head and cylinder block are sealed with the same size silicone seal rings that fit into counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block.

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

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NOTICE:
The cylinder head firedeck will overheat and crack if the coolant does not cover the firedeck surface.

The engine operating temperature should be maintained within the operating range. The cooling system should be inspected daily and kept full at all times. Refer to section 13.7.2.

Abnormal operating conditions or improper maintenance can cause cracks in the cylinder head. If cracking occurs, correct the cause to avoid recurring failure.

Unsuitable water in the cooling system forms lime and scale deposits and prevents proper cooling. Refer to section 5.3.1.7 and refer to section 5.3.1.8 for engine coolant recommendations.

Loose or improperly seated injector tubes cause compression leaks in the cooling system and engine coolant loss. The tubes must be tight to properly seat. Refer to section 2.4.3.

A melted fuse plug insert indicates that the engine has overheated, possibly damaging the cylinder head. If the fuse plug insert has melted, *both* cylinder heads must be removed and inspected. All water nozzles and injector hole tubes should be replaced and the proper fuse plugs installed before cylinder heads are reused.

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

Other conditions that may result in cylinder head cracks are listed below:

- Leaking injectors causing excess fuel to enter the cylinders.
- Slipping fan belts reduce air flow, causing the engine to overheat.
- Dirt on the radiator core reduces air flow and slows the heat transfer.
- Inoperative radiator caps result in coolant loss.

1.3.1 Repair or Replacement of Cylinder Head

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-27.

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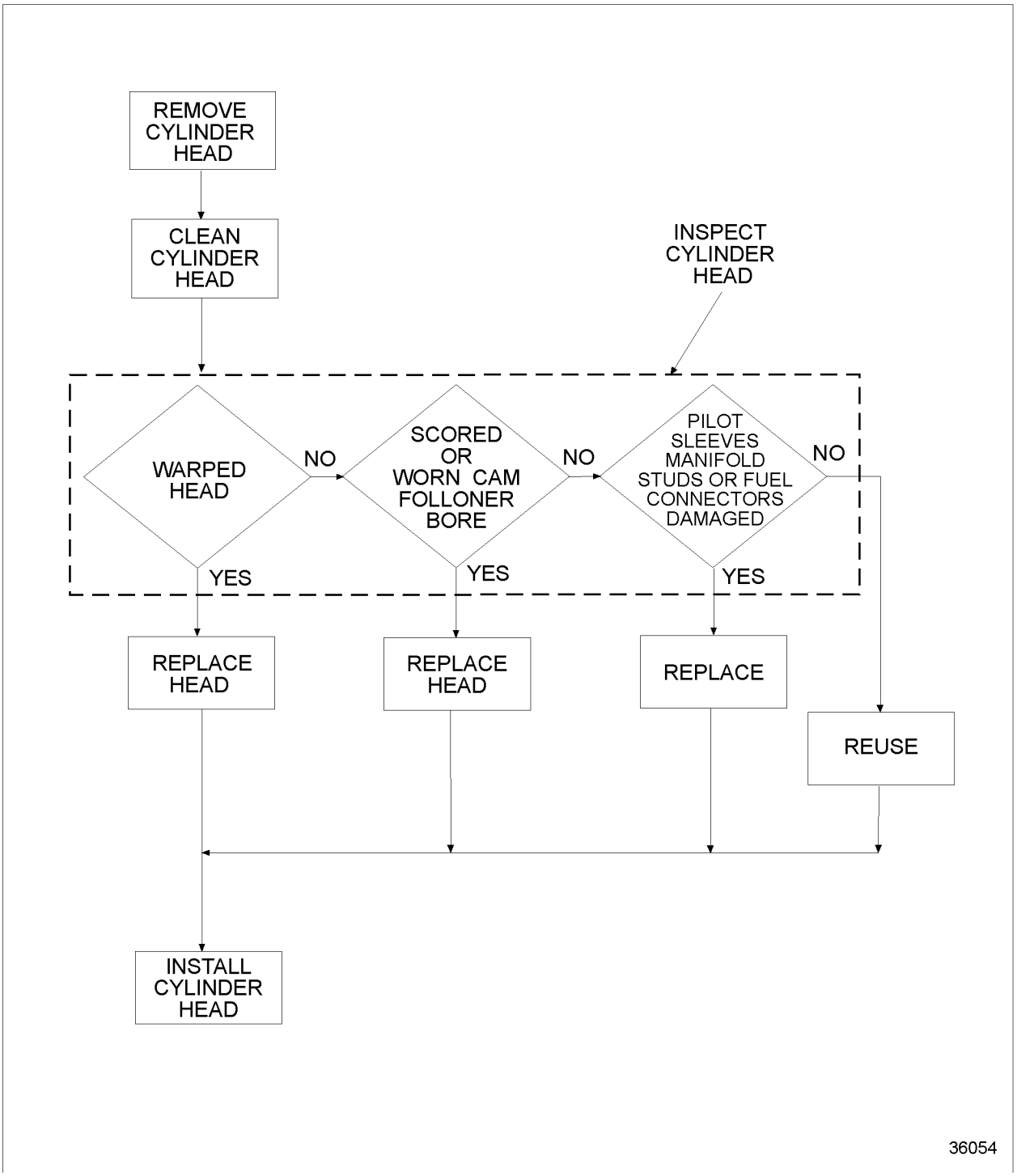


Figure 1-27 Flowchart for Repair or Replacement of Cylinder Head

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1.3.2 Removal of Cylinder Head

Remove the cylinder head as follows:

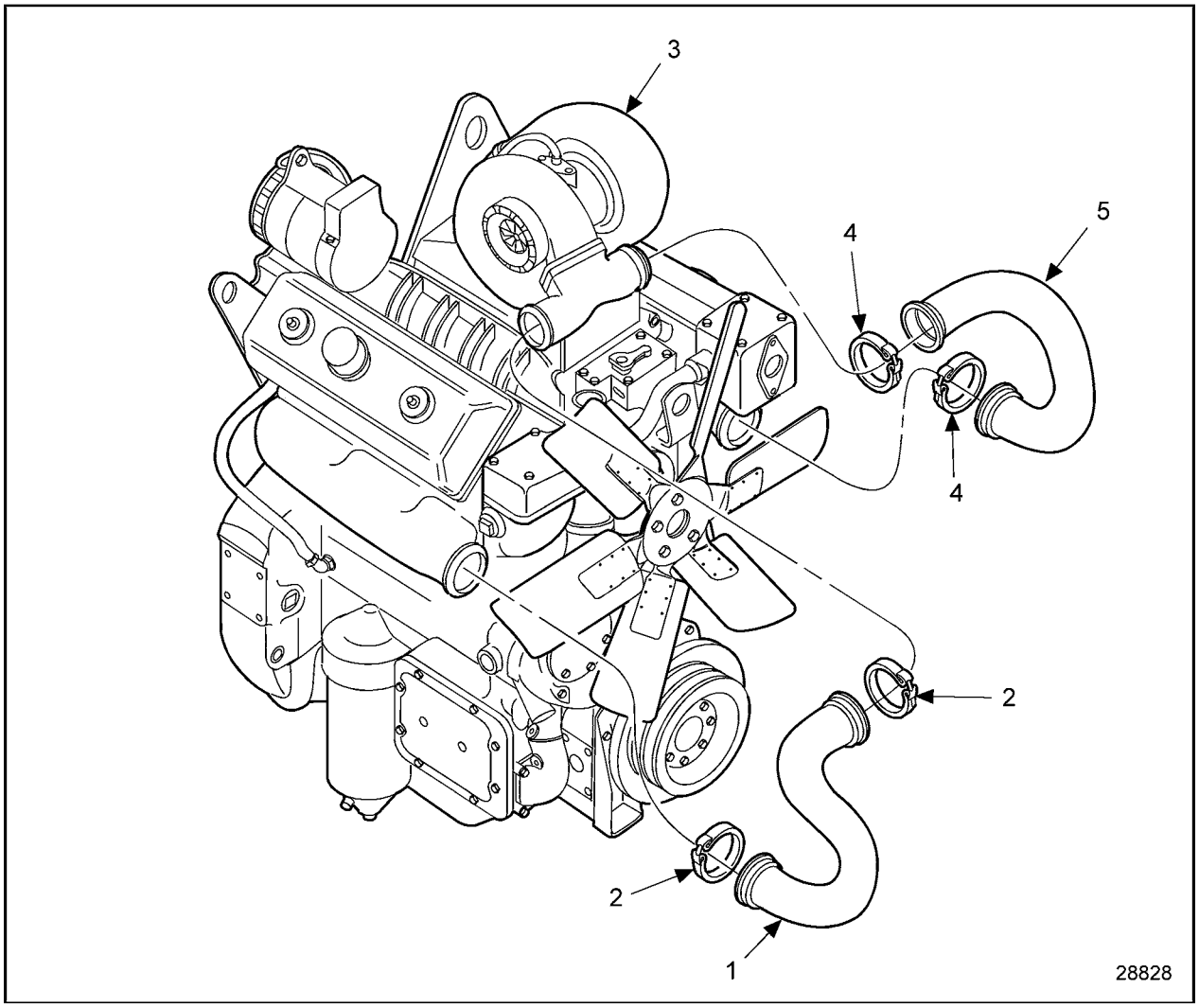
NOTE:
Only the general steps for cylinder head removal are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct installation.

NOTE:
To improve resistance to "wet stacking," Detroit Diesel recommends installing exhaust valve stem seals on industrial engines whenever a cylinder head is removed.

1. Drain the cooling system. Refer to section 13.12.3.
2. Disconnect the exhaust piping at the exhaust manifold. Refer to section 7.2.2.

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3. On turbocharged engines, remove the connections from the exhaust manifold to the turbocharger. See Figure 1-28.



1. Right-Bank Exhaust Manifold Tube
2. Right-Bank Exhaust Manifold Clamp (2)
3. Turbocharger
4. Left-Bank Exhaust Manifold Clamp (2)
5. Left-Bank Exhaust Manifold Tube

Figure 1-28 Turbocharger Exhaust Manifold Tubes

4. If necessary, remove the turbocharger. Refer to section 6.6.2.
5. Disconnect the fuel lines at the cylinder head. Refer to section 2.2.2.
6. Loosen the hose clamps, and remove the hose attached to the thermostat housing cover.
7. Loosen the hose clamps at each end of the water bypass tube, and remove the tube.
8. Remove the thermostat housing assembly. Refer to section 4.5.2.
9. Clean and remove the valve rocker cover. Refer to section 1.6.2. Discard the gaskets.

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10. Clean and remove the governor cover. Refer to section 2.24.2, step 4. Discard the gaskets.
11. On the mechanical unit injector, disconnect and remove the fuel rod from the injector control tube lever and the governor. Refer to section 2.24.2, step 6.
12. On engines equipped with a mechanical unit injector, loosen the fuel rod cover hose clamps. Slide the hose up the fuel rod cover toward the governor.
13. Remove injectors. Refer to section 2.2.2.
14. Remove the exhaust manifold. Refer to section 7.2.2.
15. Remove the water manifold, if used.
16. Remove the injector control tube and brackets as an assembly. Refer to section 2.33.3.
17. If disassembling the cylinder head to recondition the exhaust valves and valve seat inserts or to perform a complete overhaul, remove the fuel pipes and injectors. Refer to section 2.2.2 and refer to section ADDITIONAL INFORMATION.
18. Check the torque on the cylinder head bolts before removing the head.
19. Remove the bolts and washers. Lift the cylinder head from the cylinder block with tool J 22062-01.

NOTE:
If there is resistance between the rear end of the right-bank cylinder head and any of the flywheel attaching bolts, loosen the bolts. Check the torque before removing the head bolts, and examine the condition of the compression gaskets and seals after the head is removed. This may reveal the cause of any cylinder head problems.

20. Remove and discard the cylinder head compression gaskets, support shims, and the oil seals and water seals.
21. Drain the lubricating oil from the engine. Refer to section 13.5.2.
22. Refer to section 1.3.2.1 for cleaning of cylinder head, or refer to section 1.3.2.2 if cleaning a service replacement cylinder head.

1.3.2.1 Cleaning Cylinder Head

Clean the cylinder head as follows:

Prior to inspection, thoroughly steam clean the cylinder head.

If the water passages are heavily coated with scale, clean as follows:

1. Remove the injector tubes and water nozzles.

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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. Immerse the head in a bath of inhibited phosphoric acid.
3. Leave the head in the acid bath until the bubbling stops (approximately 30 minutes).

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

4. Lift the head, drain it, and re-immerse it in the same acid solution for 10 minutes.
5. Repeat procedure until all scale is removed.
6. Rinse the head in clear hot water to remove acid solution.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

7. Immerse the head in an alkaline bath to neutralize any remaining acid.

CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

8. Wash the head in clean water or steam clean it.

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⚠ 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.

9. Clean all of the cylinder head 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.

10. Dry them with compressed air.
11. Refer to section 1.3.3 for disassembly of the cylinder head.

1.3.2.2 Cleaning a Service Replacement Cylinder Head

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of rust preventive compound as follows:

NOTE:
A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes, pilot sleeves, bridge guides, valve spring seats and the necessary plugs. Shims, strip studs, cover plates, gaskets, lock washers, and nuts are provided to seal the unused water outlet openings. A length of flexible fuel hose and fittings are also included where required.

⚠ 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. Immerse the head in mineral spirits based solvent or fuel oil.
2. Scrub the head, and clean all of the openings with a soft bristle brush, particularly inside the integral fuel manifolds.

NOTE:
Attach a 1/8 in. diameter brass rod to brush J 8152 to make a suitable brush for cleaning the various passages in the 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.

3. Dry the cylinder head with compressed air.
4. Refer to section 1.3.3 for disassembly of the cylinder head.

1.3.3 Disassembly of Cylinder Head

If complete cylinder head disassembly is necessary, refer to section 1.4 and refer to section 1.5.

When overhauling a cylinder head, pressure test method is needed. Refer to section ADDITIONAL INFORMATION.

1.3.3.1 Inspect Firedeck

Inspect the firedeck as follows:

1. Use a heavy, accurate straight edge and feeler gage, tool J 3172, to check for transverse warpage at each cylinder head end and between all cylinders.
   [a] If warpage exceeds 0.011 mm (0.0040 in.), the cylinder head firedeck must be replaced. Refer to section 1.3.4.
   [b] If warpage is less than 0.011 mm (0.0040 in.), proceed with inspection.

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2. Check for longitudinal warpage in six places. See Figure 1-29.

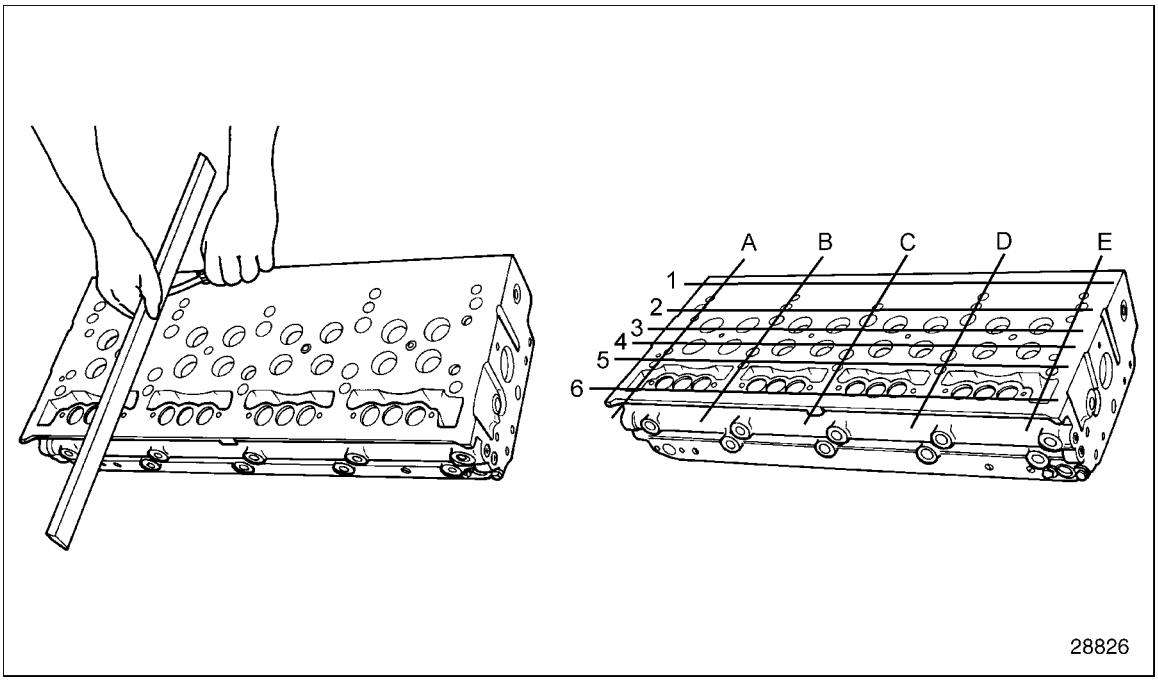


Figure 1-29 Checking Bottom Face of Cylinder Head

[a] If warpage exceeds 0.140 mm (0.0055 in.) on 6V engines or 0.203 mm (0.0080 in.) on 8V and 16V engines, the cylinder head firedeck must be replaced. Refer to section 1.3.4.

[b] If warpage is less than 0.140 mm (0.0055 in.) on 6V engines or less than 0.203 mm (0.0080 in.) on 8V and 16V engines, proceed with inspection.

3. Examine the firedeck for pitting.

   [a] If the firedeck is pitted, it must be replaced. Refer to section 1.3.4.

   [b] If the firedeck is not pitted, proceed with inspection.

4. Use the measurements obtained and the limits as a guide to determine the advisability of reinstalling the head on the engine or of re-facing it.

NOTE:
The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

NOTE:
If the cylinder head is to be refaced, remove the injector tubes prior to machining. Any machining of the fire deck can be done with the water nozzles in place. Do not remove

more metal from the fire deck of any cylinder head below the minimum distance of 89.81 mm (3.536 in.) See Figure 1-30.

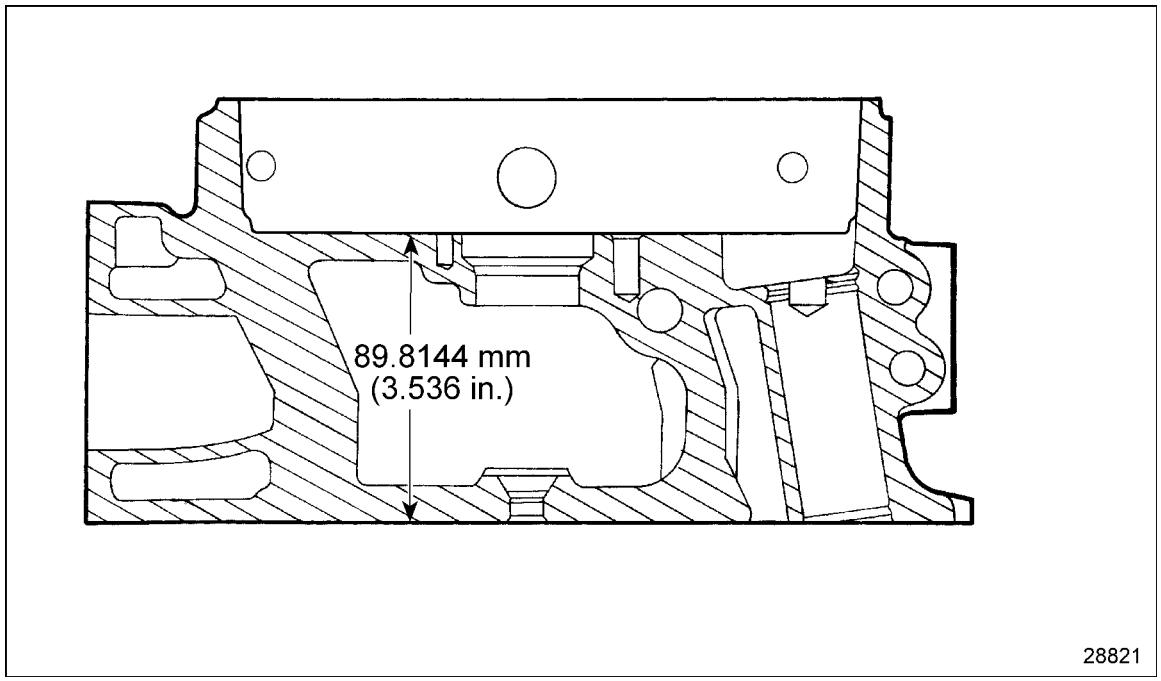


Figure 1-30 Minimum Distance Between Top and Bottom Faces of Cylinder Head

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

5. Install new injector tubes if the old tubes leaked or the cylinder head was refused. Refer to section 2.4.2.

NOTE:
If the engine overheated, injector tubes in both cylinder heads must be replaced

6. Inspect the exhaust valves seat inserts and valve guides. Refer to section 1.5.6.2.
7. Inspect the cam follower bores. Refer to section 1.3.3.2.

1.3.3.2 Inspection of Cam Follower Bore

Inspect the cam follower bores in the cylinder head as follows:

1. Inspect for scoring or wear.

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[a] If the bores are excessively scored or worn, replace the cylinder head. Refer to section 1.3.5.

⚠ 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.

[b] Light score marks may be cleaned up with crocus cloth wet with fuel oil.

2. Determine cam follower-to-cylinder head clearance.

   [a] Measure the bore diameters with a telescope gage and micrometer.

   [b] Measure the diameter of the cam followers with a micrometer.

   [c] Compare the readings of the cam followers and bores to determine the follower-to-bore clearances.

NOTE:
Refer to section ADDITIONAL INFORMATION for the specifications listed in Table 1-27, to determine the follower-to-bore clearances.

1.3.3.3 Inspection of Cylinder Head

Inspect the water hole nozzles as follows:

1. Check the water hole nozzles to ensure they are not loose.

   [a] If loose, replace the water hole nozzles. Refer to section ADDITIONAL INFORMATION.

   [b] If not loose, continue inspection.

2. Visually inspect manifold cover and exhaust manifold studs for damage.

   [a] If broken or damaged, replace the studs. Refer to section ADDITIONAL INFORMATION.

   [b] If not broken or damaged, proceed with inspection.

NOTE:
Apply sealant to the threads of new studs, and drive water manifold cover studs to 14-34 N·m (10-25 lb·ft) torque and exhaust manifold studs to 34-54 N·m (25-40 lb·ft) torque.

3. Inspect the pilot sleeves.

   [a] If pilot sleeves are damaged, they must be replaced.

   [b] If they are not flush or recessed, replace the pilot sleeves.

   [c] If the pilot sleeves are undamaged and properly positioned, proceed with inspection.

4. Inspect the fuel connectors for cracks, nicks, and damaged threads.
   [a] If cracked, nicked, or damaged, replace the fuel connectors. Refer to section 2.2.5, step 5.
   [b] If not cracked, nicked, or damaged, continue inspection.

1.3.3.4 Inspection of Cylinder Head (Pre-Installation)

Perform the following inspections prior to cylinder head installation:

1. Check the cylinder liner flange heights in relation to the cylinder block. Refer to section 1.23.3.
2. Ensure piston crowns are clean and free of foreign material.
   [a] If dirt and foreign material are evident, clean the piston crowns.
   [b] If no dirt and foreign material are evident, proceed with the inspection.
3. Ensure each push rod is threaded into its clevis until the end of the push rod projects through the clevis.

NOTICE:
Push rod inspection is important. If the push rods are threaded incorrectly, serious engine damage could occur when the crankshaft is rotated during engine tune-up.

   [a] If incorrectly threaded, remove and thread correctly.
   [b] If threaded correctly, continue with the inspection.
4. Check the cylinder block and cylinder head gasket surfaces, counterbores and seal grooves to ensure they are clean and free of foreign material, burrs and sharp edges.
   [a] If foreign material is evident, clean the block, gasket surfaces, counterbores, and seal grooves.
   [b] If burred and sharp edges are detected, use an emery cloth to remove burrs and sharp edges.
   [c] If clean and no burrs or sharp edges are detected, continue inspection.
5. Inspect the cylinder head bolt holes in the block for water, oil, or any foreign material.
   [a] If dirt, oil, water, or foreign materials are in the holes, clean the bolt holes thoroughly.
   [b] If holes are free of dirt, oil, water, or foreign materials, proceed with cylinder head installation.

1.3.4 Assembly of Cylinder Head

If complete cylinder head assembly is necessary, refer to section 1.4 and refer to section 1.5.

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1.3.5 Installation of Cylinder Head

Install the water and oil seal rings, support shims and compression gaskets as follows:

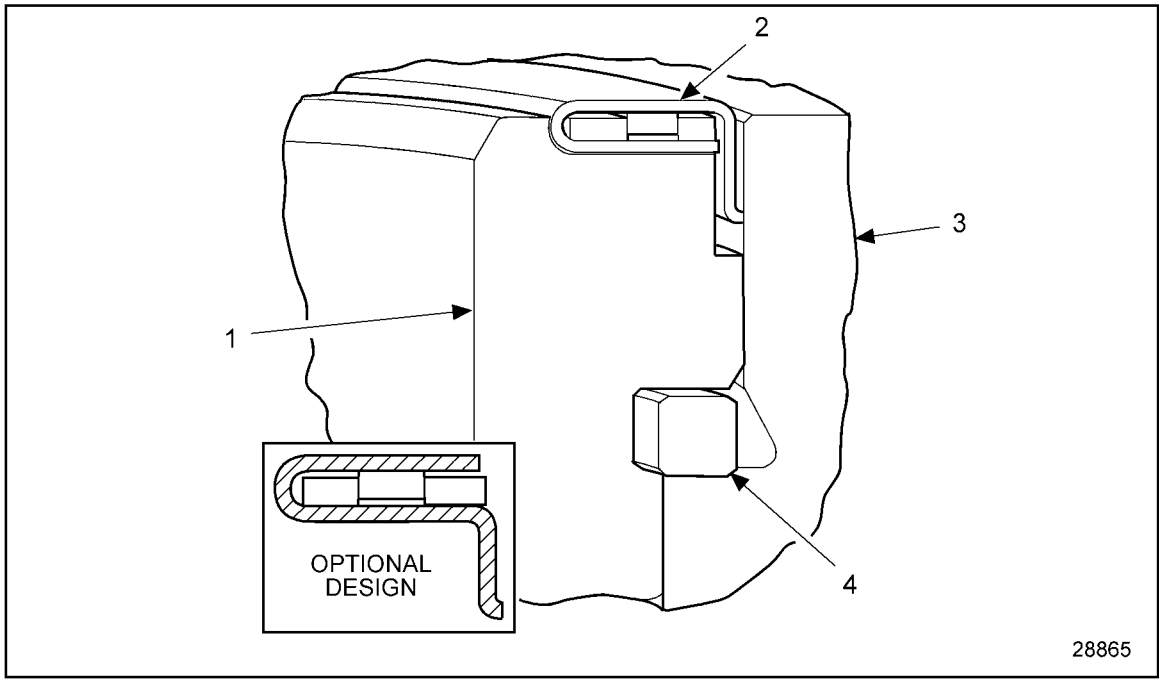
NOTICE:
Never install used compression gaskets or seals.

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

NOTE:
New compression gaskets are color coded (red, black or no-paint) on the outside diameter to identify gasket sizes. Only gaskets of one color code should be used under any one cylinder head.

2. Check the liner height. Refer to section 1.23.3.

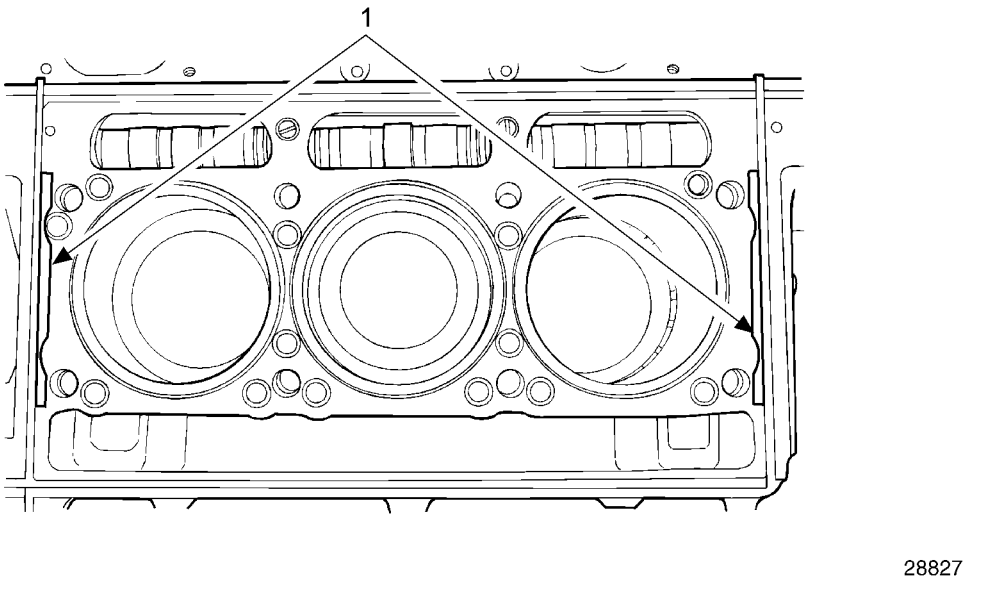
NOTE:
A new-source, optional design cylinder liner compression gasket has been released. See Figure 1-31. The new optional gasket will be of one thickness with the "no paint" identification. It can be intermixed on an engine under the same head only with the current "no paint" compression gasket.



1. Cylinder Liner
2. Gasket
3. Cylinder Block
4. Insert

Figure 1-31 Compression Gasket Mounting in Cylinder Block

NOTE:
To prevent end cylinder head bolt breakage, support shims are attached at each end of the cylinder block (two per cylinder bank). See Figure 1-32.



1. Support Shims

Figure 1-32 Cylinder Head Support Shims in Place

3. Remove the adhesive paper and place the support shims, adhesive side down, at each end of the cylinder block. The scallop in the shim placed at the rear of the block must be at the oil supply hole.
4. Place new seal rings in the water and oil hole counterbores.

NOTICE:
Silicone-composition water hole seals can be damaged if they move out of position in the cylinder block counterbore. Damaged seals can allow engine coolant to contaminate lube oil, causing serious engine damage. Spray adhesive may be used to hold seals in place.

If a spray adhesive is used, install the water and oil seal rings, support shims and compression gaskets as follows:

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

NOTE:
Use a high-tack, spray type adhesive suitable for synthetic rubber seals (3M Super Tack™ Gasket Adhesive No. 8082, or equivalent).

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NOTICE:
Do not apply adhesive directly to the seal. The adhesive will coat the seal inner diameter, causing the seal to temporarily swell.

2. Spray a light, uniform coating of adhesive into the seal counterbores. Keep the adhesive off adjacent block surfaces. Wipe any spray from the firedeck or liner bores.

NOTE:
Allow the adhesive to dry to a high-tack before installing the seal. This permits liquid propellant used with the adhesive to evaporate.

3. Install a new oil seal in the groove around the cylinder block perimeter.

NOTE:
The colored side of the seal should face away from the cylinders. This ensures an oil seal between the cylinder head and block.

NOTE:
The seal must lay flat in the groove and must not be twisted or stretched when installed.

NOTE:
3M Company Super Tack Gasket adhesive No. 8082 or equivalent may be used to hold the peripheral head-to-block oil seals in place during cylinder head installation.

4. To install the cylinder head on the engine without disturbing the gaskets and seals, install guide studs J 24748 in two outboard corner bolt holes in the cylinder block.

NOTE:
Do not install guide studs in the bolt holes that line-up with the pilot sleeves in the head.

5. Attach lifting tool J 22062-01 to the cylinder head. Lift the head above the cylinder block.

NOTICE:
Gaskets and seals that are not seated properly will cause leaks, "blow-by," and result in poor engine performance and damage. Out of place shim strips can damage cylinder head bolts.

6. Make a final visual check of the compression gaskets, seals and shims to ensure they are in place before the cylinder head is lowered.
7. Wipe debris from the bottom of the cylinder head.
8. Lower the head over the guide studs and onto the surface of the cylinder block.
9. Apply a small amount of International Compound No. 2, or equivalent, to the threads and underside of the head of all cylinder head attaching bolts.

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10. Install a 6 point bolt and an 11/16 in. washer or 12 point washer faced bolt through each piloting sleeve at the inboard corners of the head.

NOTE:
Cylinder head bolts must not be replaced by ordinary bolts.

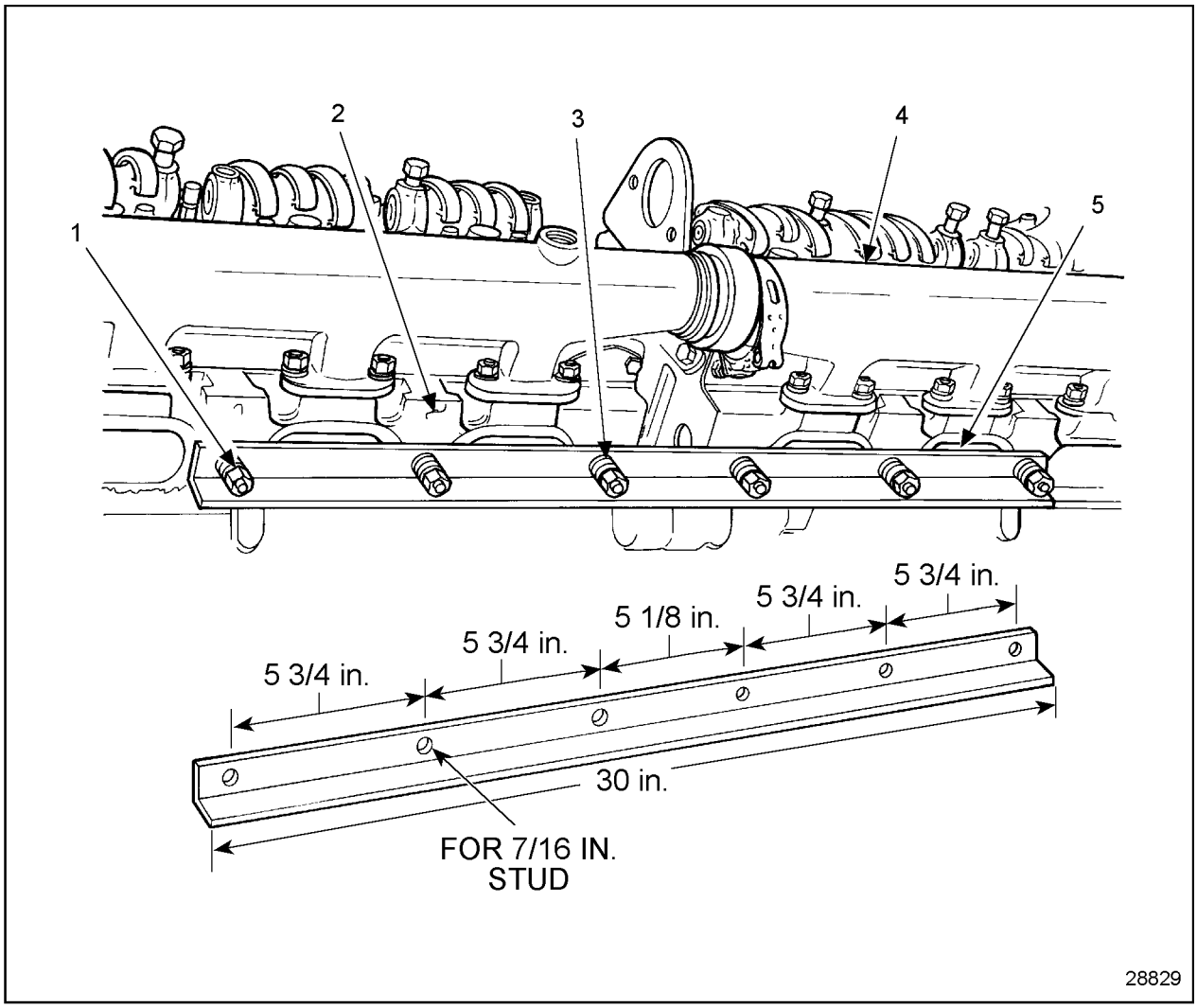
11. Finger-tighten the bolts into the cylinder block.

NOTE:
To ensure adequate head bolt clamp load, all 12 point head bolts with "LE" head identification should be replaced. Do not use the 11/16 in. washer with the washer faced bolt.

12. Install the bolts on the camshaft side of the head to take up tension on the push rod springs.
13. Remove the guide studs and lifting fixture.
14. Install the remaining bolts.
15. Tighten the bolts to 20-27 N·m (15-20 lb·ft) torque with a speed handle.

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16. To prevent cylinder head misalignment on 12V and 16V engines, use an alignment fixture. See Figure 1-33.



1. Nut
2. Cylinder Head
3. Spacer
4. Water Manifold
5. Fixture

Figure 1-33 Cylinder Head Alignment Fixture for 12V and 16V Engines

NOTICE:

When replacing the cylinder head(s) on a Series 92 engine, the required installation procedure and torque specifications *must* be used to ensure the integrity of the cylinder head-to-block seal. Failure to follow the required cylinder head installation procedure and observe required torque values may result in head-to-block seal leakage, causing loss or contamination of lubricating oil or coolant or both and subsequent severe engine damage.

17. Tighten the cylinder head attaching bolts using the following torque-turn method:

    [a] Using an accurately calibrated torque turn wrench and working in increments of 41 N·m (50 lb·ft), gradually tighten the cylinder head mounting bolts to 204 N·m (150 lb·ft) torque in the sequence shown. See Figure 1-34. Hold the wrench at this torque for 2-3 seconds to allow bolts to turn while the compression leaks yield to their crushed thickness.

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[b] Perform the following operations one bolt at a time in the sequence shown. See Figure 1-34.

NOTE:
The loosening, retightening, and torque turn procedures that follow *must* be completed on each bolt separately before moving on to the next bolt.

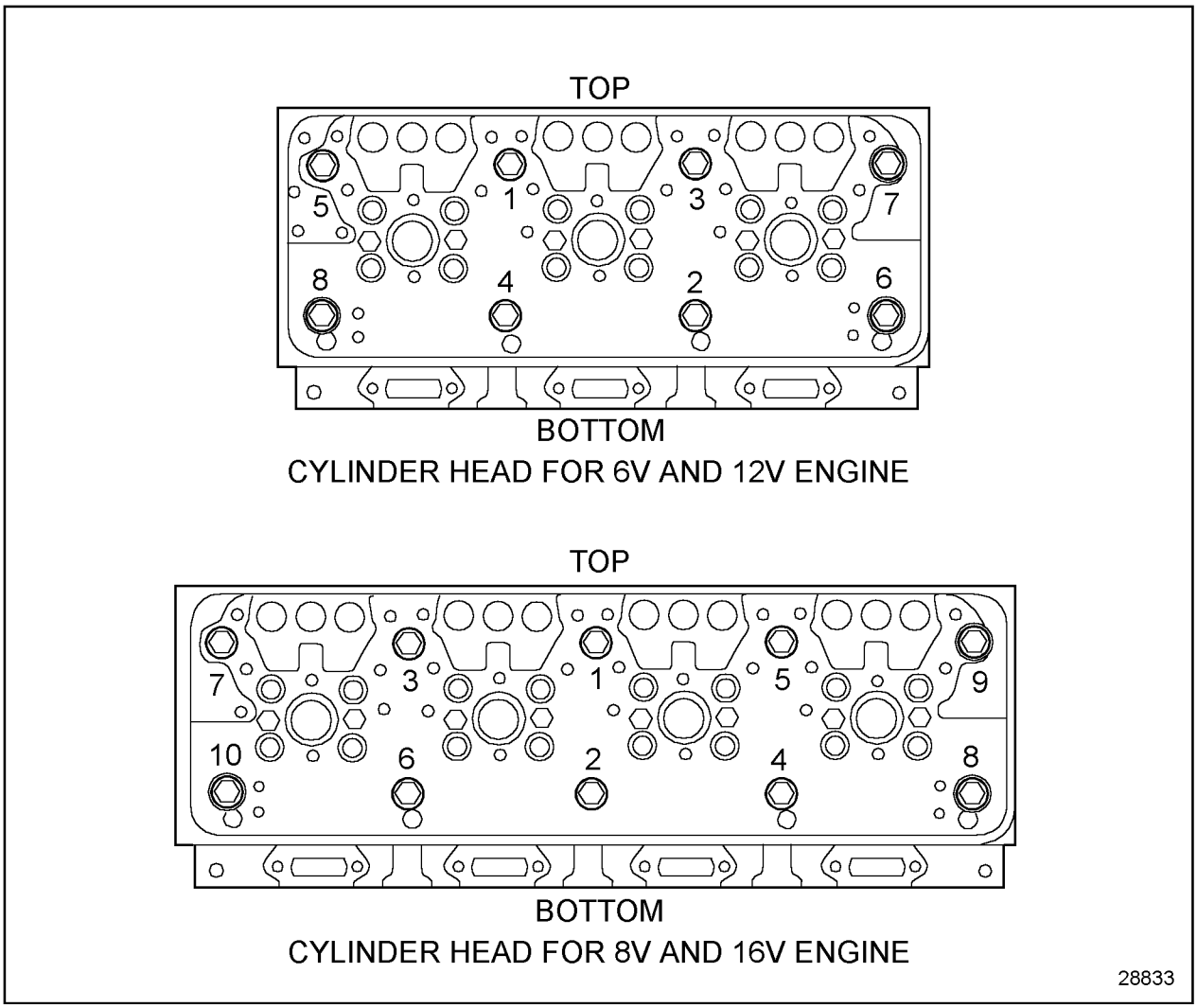


Figure 1-34 Cylinder Head Bolt Tightening Sequence

NOTE:
Detroit Diesel recommends using torque angle meter J 37990 for the following operations. If not available, use an accurately calibrated torque wrench and premark a socket with four marks 90 degrees apart. At the start of each turn, mark the head with a grease pencil at one mark in the socket and turn to the next mark.

18. Starting with the number 1 bolt in the sequence shown (see Figure 1-34), back off the bolt until loose, at least 1/2 turn. Then tighten the bolt to 136 N·m (100 lb·ft) torque.

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

19. Rotate the bolt clockwise 90 degrees. Try to turn the bolt in a single arc with one pull of the wrench. See Figure 1-35.

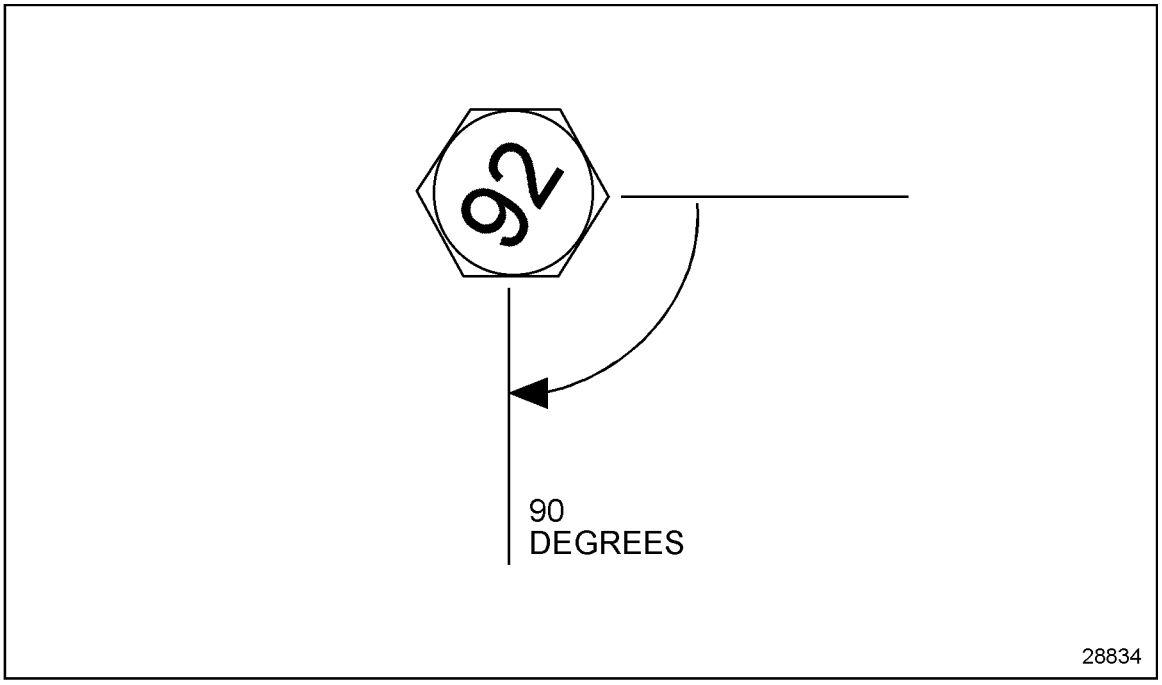


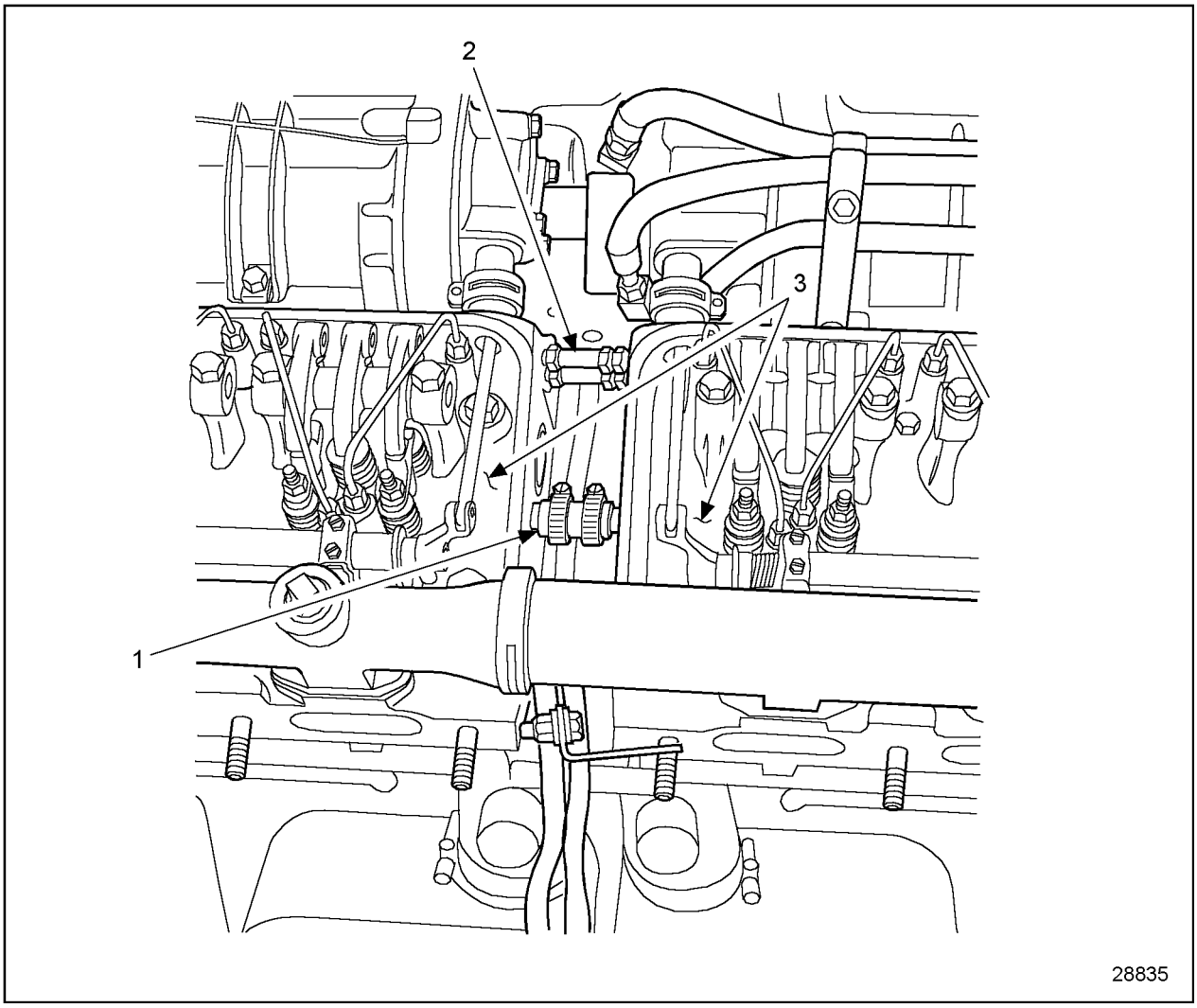
Figure 1-35 Bolt Torque-Turn Method

20. Repeat this procedure for each bolt in the required sequence. This will ensure an even clamp load on the cylinder head.

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

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21. On 12V and 16V engines, install the fuel and water connectors between the cylinder heads. Dry seal connectors are used at the fuel connection between the cylinder heads. See Figure 1-36.



1. Water Connections
2. Fuel Oil Connectors
3. Cylinder Heads

Figure 1-36 Fuel Connectors and Water Connections (12V and 16V Engines)

22. Ensure tapped holes in the water hole plugs are in alignment.
23. Adjust the exhaust valve bridges. Refer to section ADDITIONAL INFORMATION.
24. Tighten the rocker arm bracket bolts to the specified torque. Refer to section ADDITIONAL INFORMATION specifications.
25. Install the fuel injectors. Refer to section 2.2.5.
26. Install the fuel pipes. Refer to section 2.2.5.

27. Align the fuel pipes and connect them to the injectors and the fuel connectors. Refer to section 2.2.5, step 5.

NOTE:
Do not reuse the original fuel pipes. DDC recommends installing the new flared end fuel pipes.

NOTICE:
Follow the torque specifications closely and use the recommended tools to avoid damaging the fuel pipes. Fuel leaking from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

28. Use fuel line nut wrench J 8932-B and "clicker" type torque wrench J 24405 calibrated in inch-pounds to tighten fuel pipe nuts on fuel pipes. Specifications are listed in Table 1-1.

Fuel Pipe Usage	Torque
Endurion®-Coated	14.69 N·m (130 lb·in.)
Uncoated	18.3 N·m (160 lb·in.)
*Jake Brake®	13.6 N·m (120 lb·in.)
Load Limiting Devices	18.3 N·m (160 lb·in.)
DDEC Engines	16.16 N·m (143 lb·in.)

* Not serviced. Available from Jacobs Vehicle Equipment Company. JJake Brake® is a registered trademark of Diesel Engine Retarders, Inc.

Table 1-1 Jumper Line Nut Torque

29. Install the injector control tube assembly. Refer to section 2.33.6.
30. Finger-tighten the attaching bolts.

NOTE:
When positioning the control tube, ensure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. One end of the control tube return spring should attach around an injector rack control lever and the other end should attach around a control tube bracket

31. Tighten the bracket bolts to 14-16 N·m (10-12 lb·ft) torque.

NOTE:
Revolve the injector control tube to ensure the return spring pulls the injector racks out (no-fuel position) after they have been moved all the way in (full-fuel position). If the control tube binds, tap it lightly. The injector racks must return to the no-fuel position by aid of the return spring only. Do not bend the spring. Replace the spring, if necessary.

32. Install the fuel rods. Refer to section 2.24.21.

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33. Slide the fuel rod cover hoses in place, and tighten the clamps.
34. Connect the fuel lines. Refer to section 2.21.5.

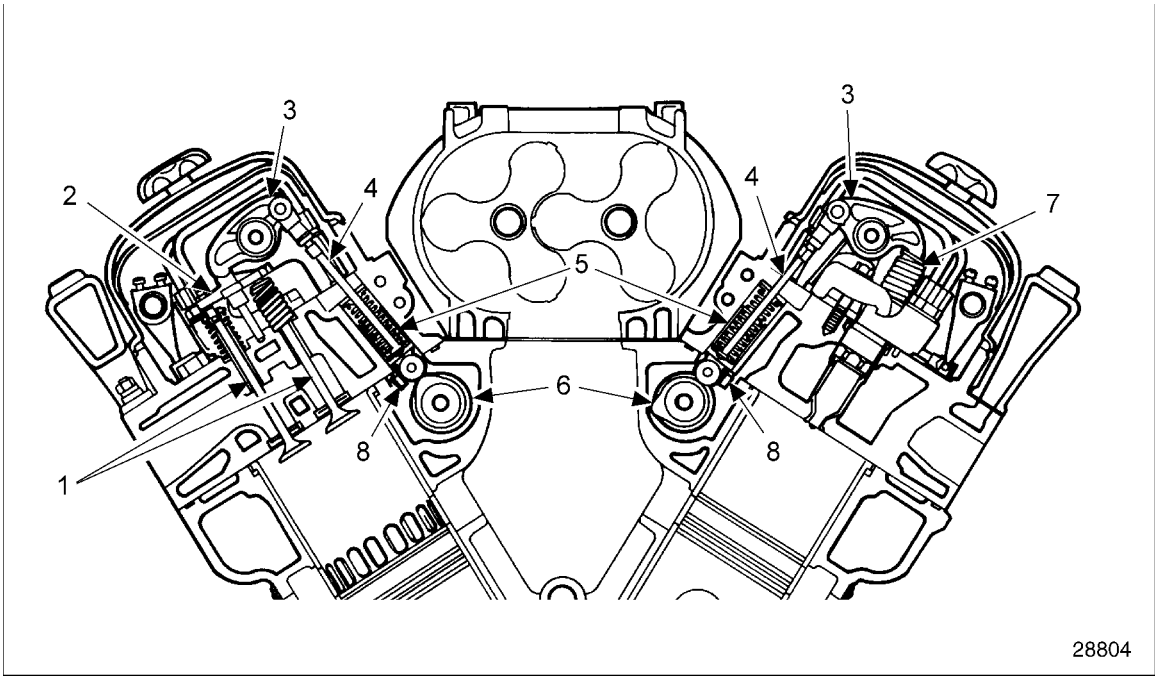
NOTE:
New Teflon stainless steel fuel crossover lines are being used on all upright and tilt coach engines, effective with engine serial numbers 6VF-106261 and 8VF-85643. The new hose assemblies replace the steel tube assemblies formerly used between the cylinder heads. When replacing a steel tube assembly,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

35. Install the thermostat housing and thermostat. Refer to section 4.5.3.
36. Install the water manifold, if used. Refer to section 4.4.3.
37. Install the water bypass tube, hoses and clamps.
38. Install the thermostat housing cover, hose and clamps. Refer to section 4.5.3.
39. Install the exhaust manifold and connect the exhaust piping. 7.2.3.
40. Fill the cooling system. Refer to section 13.12.2.
41. Fill the lubricating system. Refer to section 13.5.1.
42. Before starting the engine, perform an engine tune-up. 12.

1.4 VALVE AND INJECTOR OPERATING MECHANISM

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

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. See Figure 1-37. Removing the two bracket bolts allows the rocker arm assembly to be raised, providing easy access to the fuel injector and the exhaust valve springs.



1. Exhaust Valve
2. Valve Bridge
3. Rocker Arm
4. Push Rods
5. Cam Follower
6. Camshaft
7. Fuel injector
8. Bracket Retainer Cam Follower

Figure 1-37 Valve and Injector Operating Mechanism

The injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms. The boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm. The exhaust valve rocker arms also have a flat spot beneath the rocker shaft hole to ensure the valve bridge is cleared.

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

The camshaft, with cam followers and short push rods extending through the cylinder, operates the rocker arms.

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A shot peened injector rocker arm assembly is used on engines equipped with 115 mm (9215) or larger fuel injectors. A yellow stripe at the top of the arm and a shot peened stress relief cut identifies these arms.

A new injector rocker arm assembly is used on 6V coach engine models 8067-3421 and 8067-4423, effective with unit number 6VF015319. The new assembly has a larger outer diameter clevis pin bushing to improve lubrication and increase part life. The entire clevis end is prelubricated to minimize the chance of bushing damage at initial engine start up.

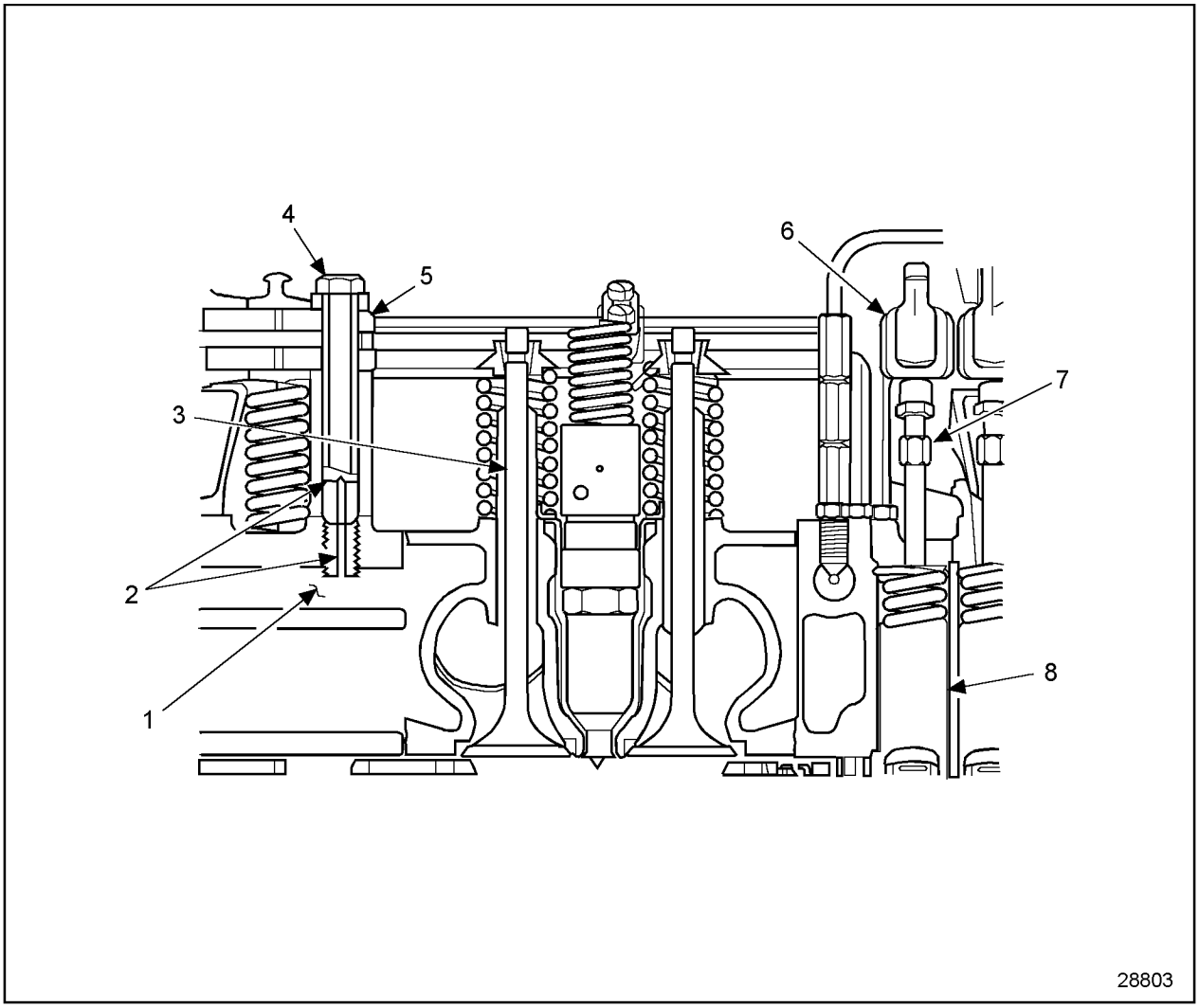
The new injector rocker arm assembly (identified by a blue or bright pink paint stripe on the back) and the former assembly (identified by an orange paint stripe) are completely interchangeable and may be mixed in an engine. Since bushing life is extended on the current assembly, DDC recommends replacing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

Each cam follower operates in a cylinder head bore. A cam follower retainer bracket for each set of three followers holds the cam followers in place and aligns the cam follower rollers with the camshaft lobes.

A coil spring, located inside each cam follower, maintains a predetermined load on the cam follower to ensure constant cam roller to camshaft lobe contact.

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Oil from a longitudinal oil passage on the camshaft side of the cylinder head lubricates the valve and injector operating mechanism. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft, lubricating the rocker arms. See Figure 1-38.



1. Cylinder Head Oil Passage
2. Oil Passages
3. Exhaust Valve
4. Bolt
5. Rocker Shaft
6. Rocker Arm
7. Push Rod
8. Cam Follower

Figure 1-38 Location of Valve Operating Mechanism

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

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1.4.1 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 1-39.

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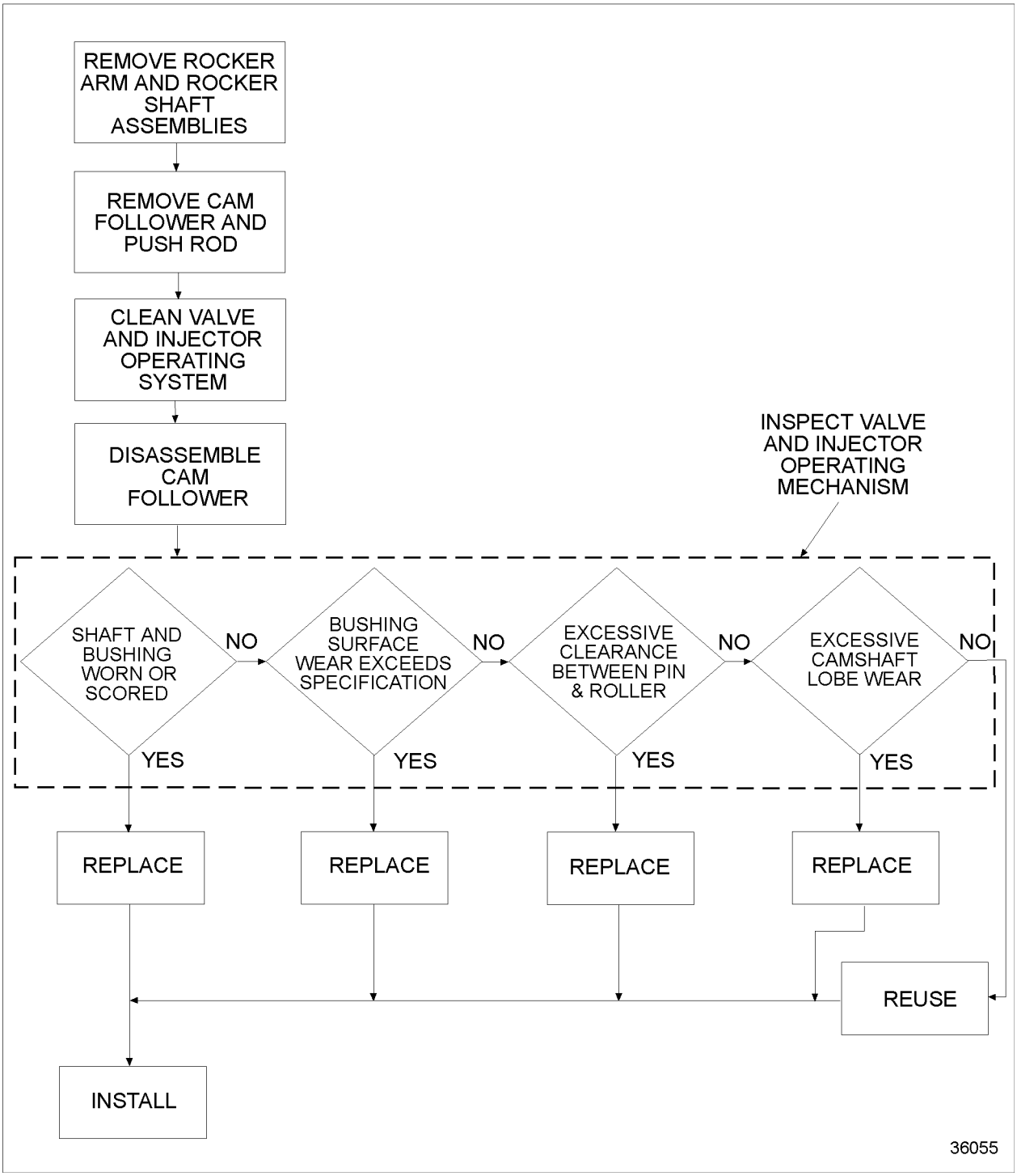


Figure 1-39 Flowchart for Repair or Replacement of Valve and Injector Operating Mechanism

1.4.2 Removal of Rocker Arm and Rocker Shaft

Remove the rocker arm and shaft as follows:

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1. Clean and remove the valve rocker cover. Refer to section 1.6.2. Discard the gasket.
2. Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

NOTE:
Do not bar the crankshaft in a left-hand direction with a wrench or barring tool on the crankshaft bolt. This could loosen the bolt.

NOTICE:
When removing the rocker arm shaft, fold the three rocker arms back. Do not force the rocker arms all the way back with the shaft in place. This may impose a load that could bend the push rods.

3. Remove the two bolts securing the rocker arm shaft brackets to the cylinder head. Remove the brackets and shaft.
4. Loosen the locknuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods. If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be installed in their original positions.

1.4.3 Removal of Cam Follower and Push Rod (Cylinder Head on Engine)

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

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

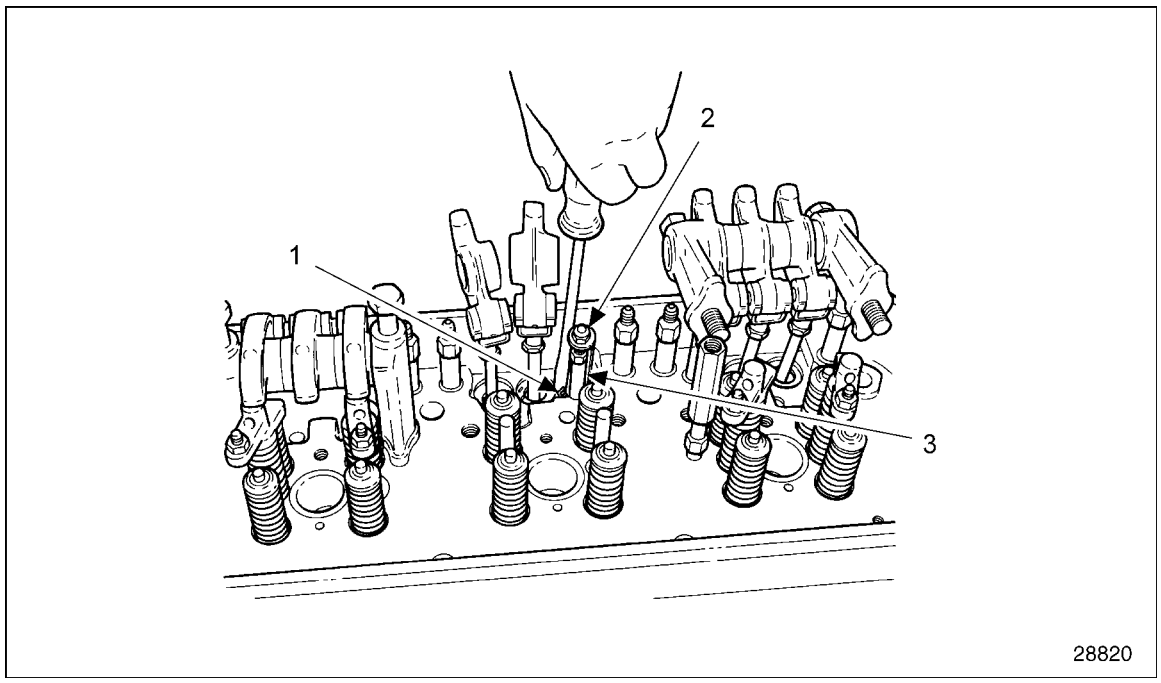
1. Remove the rocker arm shaft and brackets.
2. Loosen the locknut, and unscrew the rocker arm from the push rod.
3. Remove the locknut.
4. With the lower end of the tool resting on the upper spring seat, install remover (J 3092-01), a flat washer, and the locknut on the push rod.
5. Thread the nut down to compress the spring. Refer to section 1.4.4.1.

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⚠ 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 spring seat retainer from the groove in the cylinder head. See Figure 1-40.



1. Retainer
2. Washer
3. Remover

Figure 1-40 Removing Push Rod from Upper Side of Cylinder Head using Tool J 3092-01

7. Unscrew the locknut to release the spring. Remove the nut, flat washer, and tool from the push rod.
8. Pull the push rod, spring, spring seats, and cam followers out of the cylinder head.

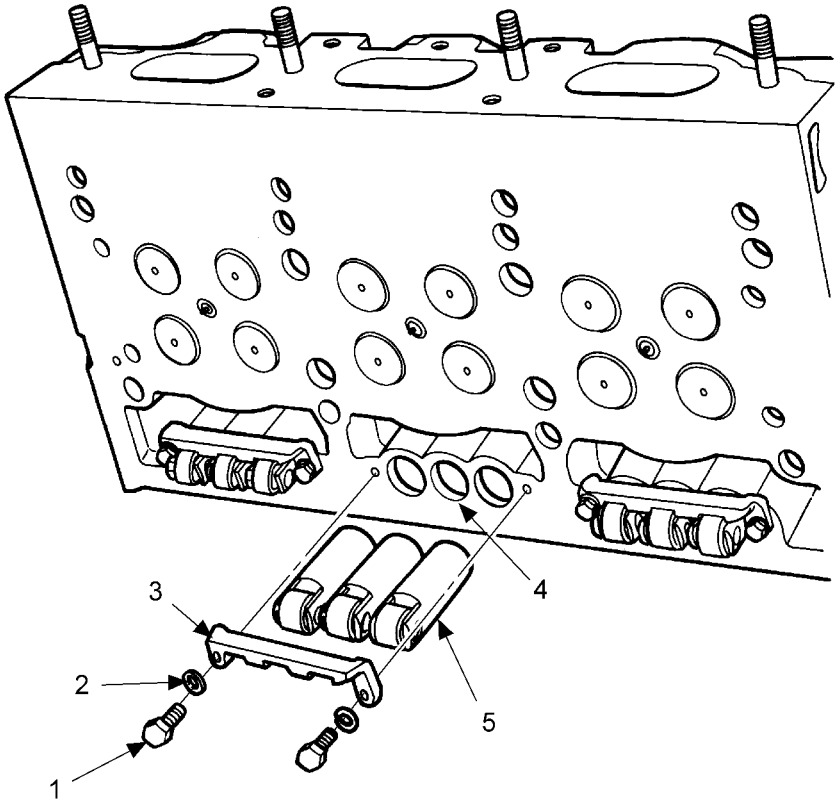
1.4.4 Removal of Cam Follower and Push Rod (Cylinder Head Removed)

Remove a cam follower and push rod with the cylinder head removed as follows:

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

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1. Rest the cylinder head on its side, and remove the cam follower guide. See Figure 1-41.



1. Bolt
2. Washer
3. Cam Follower Retainer Bracket
4. Cam Follower Bore
5. Cam Follower

Figure 1-41 Cam Followers and Guide

2. Pull the cam follower out of the cylinder head.
3. Remove the fuel pipes from the injector and the fuel connectors.

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

4. Loosen the push rod locknut, and unscrew the push rod from the rocker arm clevis.

5. Pull the push rod and spring assembly from the bottom of the cylinder head.
6. Remove the push rod locknut, spring, and spring seats from the push rod. Refer to section 1.4.4.1.

NOTE:
When replacing the cylinder head, remove the spring retainers, and install them in the new head

1.4.4.1 Cleaning of Valve and Injector Operating Mechanism

Prior to disassembly, clean the valve and injector operating mechanism as follows:

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.

1. Wash the rocker arms, shaft, brackets, and bolts with clean fuel oil.
2. Use a small wire to clean the drilled oil passages in the rocker arms and rocker shaft bolts.

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 parts with compressed air.

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NOTICE:

Do not use fuel oil to clean the cam followers. Fuel oil working its way between the cam roller bushing and pin may cause scoring on initial engine start-up.

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.

4. Wash the cam followers with lubricating oil or Cindol® 1705, and wipe them dry.

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.

5. Wash the push rods, springs, and spring seats with clean fuel oil.

CAUTION:

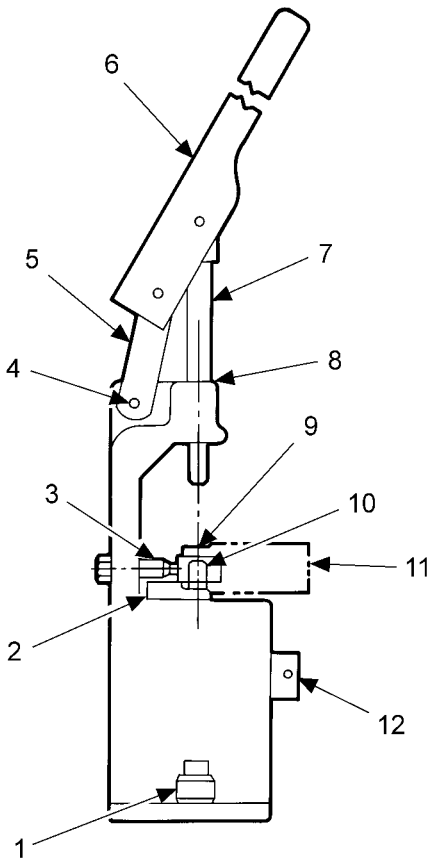
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

6. Dry with compressed air.

1.4.5 Disassembly of Cam Follower

Using tool set J 33421-A, disassemble the cam follower as follows:

1. Pull the adjustable sliding support out against its stop. See Figure 1-42.



1. Assembly Adaptor for Flat Legs
2. Support Plate
3. Roller Stop Screw
4. Clevis Pin
5. Connecting Link
6. Handle
7. Pressing Ram
8. Bronze Bushing
9. Upper Follower Leg
10. Spring Loaded Guided Pin
11. Cam Follower
12. Adjustable Sliding Support

Figure 1-42 Removing or Installing Cam Follower Roller using Tool Set J 33421-A

2. Place the cam follower, with follower pin resting on the spring-loaded guide pin, in the fixture.
3. Push the follower down until the lower leg engages the slot in the support plate. This supports the roller that supports the upper follower leg.

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4. Push the follower in until it contacts the roller stop screw. This should align the roller pin with the pressing ram.
5. Lower the handle to put pressure on the roller pin.
6. Push the adjustable sliding support in until there is resistance. This supports the lower follower leg.
7. Press the pin from the cam follower.

1.4.5.1 Inspection of Valve and Injector Mechanism

Inspect the valve and injector operating mechanism as follows:

1. Visually inspect the rocker arm shaft and rocker arm bushings for wear.
   [a] If worn, replace the rocker arm shaft and rocker arm bushings.
   [b] If no wear is evident, continue inspection.
2. Check shaft-to-bushing clearances.
   [a] If maximum shaft to bushing clearance exceeds 0.10 mm (0.004 in.), replace the shaft and bushings.
   [b] If no wear is indicated, continue with inspection.
3. Visually inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces).

NOTICE:
To avoid damage to the rocker arm, use care when surface grinding to avoid overheating the rocker arm.

   [a] If worn, the surface may be refaced up to a maximum of 0.25 mm (0.010 in.).

NOTE:
Maintain the radius and finish as close to the original surface as possible.

   [b] Replace if worn beyond the maximum allowance.
   [c] If no wear is evident, continue with inspection.
4. Visually inspect the valve bridges for wear.
   [a] If excessively worn, replace the valve bridges.
   [b] If no wear is evident, continue with inspection.
5. Inspect the rocker arm shaft brackets for cracks.
   [a] If cracked, replace the rocker arm shaft.
   [b] If no cracks are present, continue with inspection.

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1.4.5.2 Inspection of Cam Follower and Parts

Inspect the cam follower and its related parts as follows:

NOTE:
When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts, and inspect them for excessive wear. A change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

1. Examine the cam follower rollers for scoring, pitting, or flat spots. The rollers must turn freely on their pins.
   [a] If scored, pitted, or flat, or the rollers do not turn freely, replace the cam follower rollers. Refer to section 1.4.6.
   [b] If none of these conditions exist, continue with the inspection.
2. Measure the total diametric clearance and side clearance. See Figure 1-43.

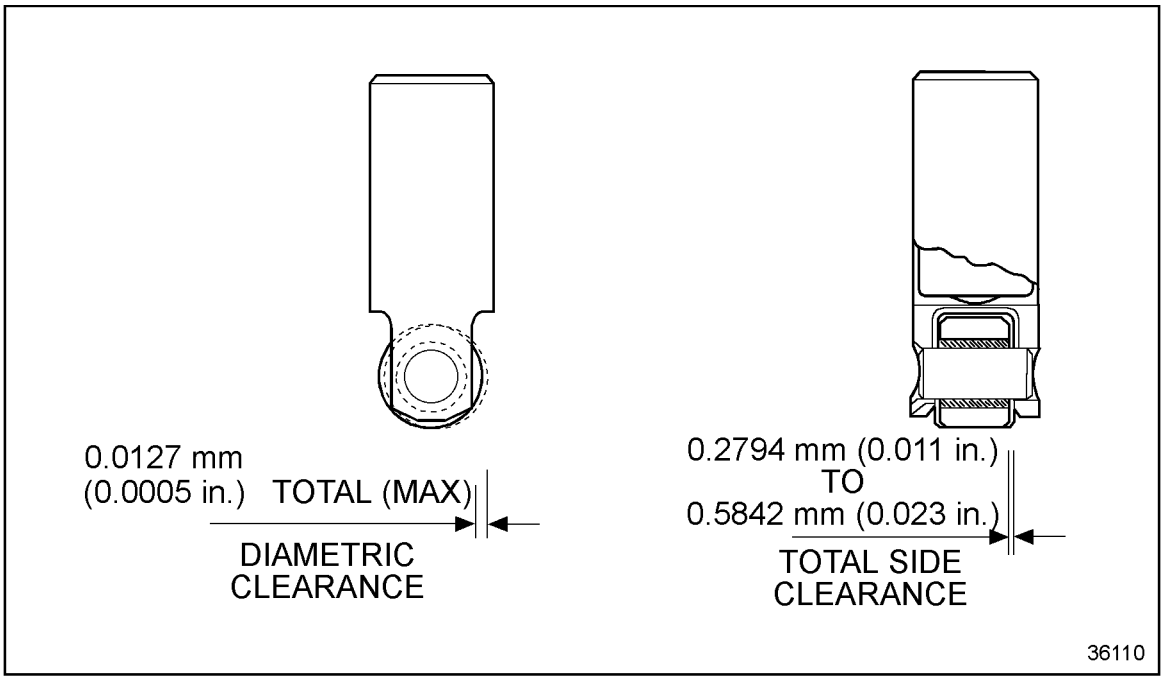


Figure 1-43 Cam Roller Clearance

   [a] If the clearances exceed those specified, install a new roller and pin. Refer to section 1.4.6.
   [b] If clearances are within the specified limits, continue with inspection.
3. Inspect the camshaft lobes for scoring, pitting, or flat spots.
   [a] If scored, pitted, or flat, replace the camshaft. Refer to section 1.26.6.
   [b] If no scoring, pitting, or flat spots are detected, continue with the inspection.

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4. Inspect the cam follower inner bore for spring contact.
   [a] If spring contact is present, replace the follower. Refer to section 1.4.6.
   [b] If the spring is not contacting the inner bore, continue inspection.
5. Visually inspect the push rods and spring seats for wear or damage.
   [a] If worn or damaged, replace the push rod or spring seats. Refer to section 1.4.8, step 5.

NOTE:
If the push rod requires replacement, inspect the rocker arm for wear or cracks. Refer to section 1.4.8.

   [b] If the push rod and spring seats are not worn or damaged, continue with inspection.
6. Visually inspect the push rod for breaks or bends.
   [a] If the push rod is broken or bent, replace the cam follower. Refer to section 1.4.6.
   [b] If the push rod is not broken or bent, continue with inspection.
7. Visually inspect the cam follower springs for wear or damage.
   [a] If worn or damaged, replace the cam follower springs. Refer to section 1.4.6.
   [b] If there is no damage or wear, continue with inspection.
8. Check the spring load with spring tester J 22738-02.

[a] When a load of less than 113.25 Kg (250 lbs.) will compress the spring to a length of 2.1406 in., it should be replaced. See Figure 1-44. Refer to section 1.4.6.

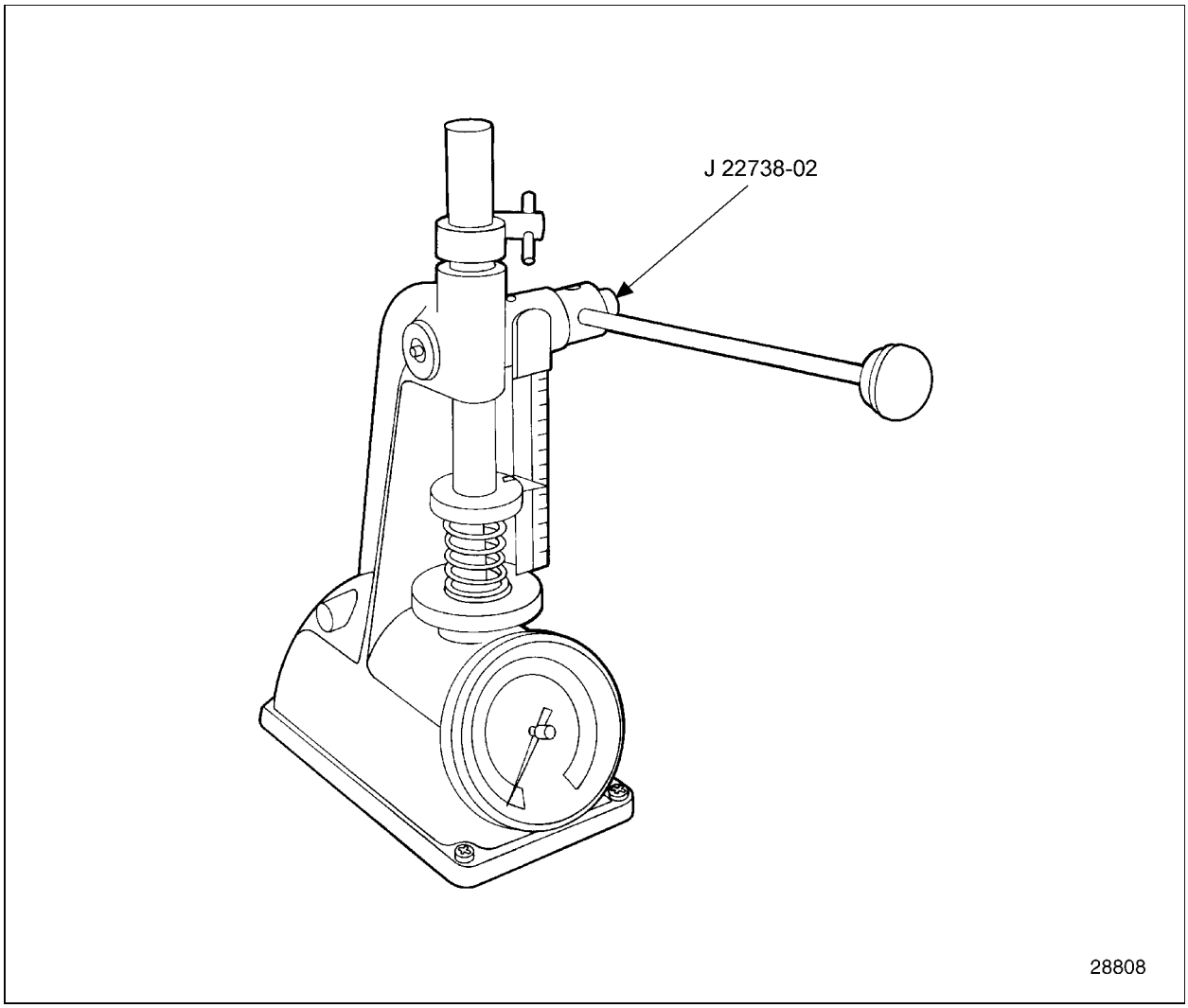


Figure 1-44 Testing Cam Follower Spring with Tool J 22738-02

[b] If the spring withstands loads over 113.25 Kg (250 lbs.), it may be reused.

1.4.5.3 Inspection of Cam Follower-to-Bore Clearance

Inspect the cam follower-to-bore clearance as follows:

1. Measure the cam follower bores in the cylinder head with a telescope gage and micrometer. Record the readings.
2. Measure the diameter of the cam followers with a micrometer. Record the readings.
3. Compare the follower and bore readings to determine the cam follower-to-bore clearances. Refer to section ADDITIONAL INFORMATION for specifications.

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[a] If worn beyond specifications, replace the cam follower. Refer to section 1.4.7.

[b] If clearances are within specifications, the cam follower may be reused.

1.4.5.4 Test Cam Roller and Pin Load

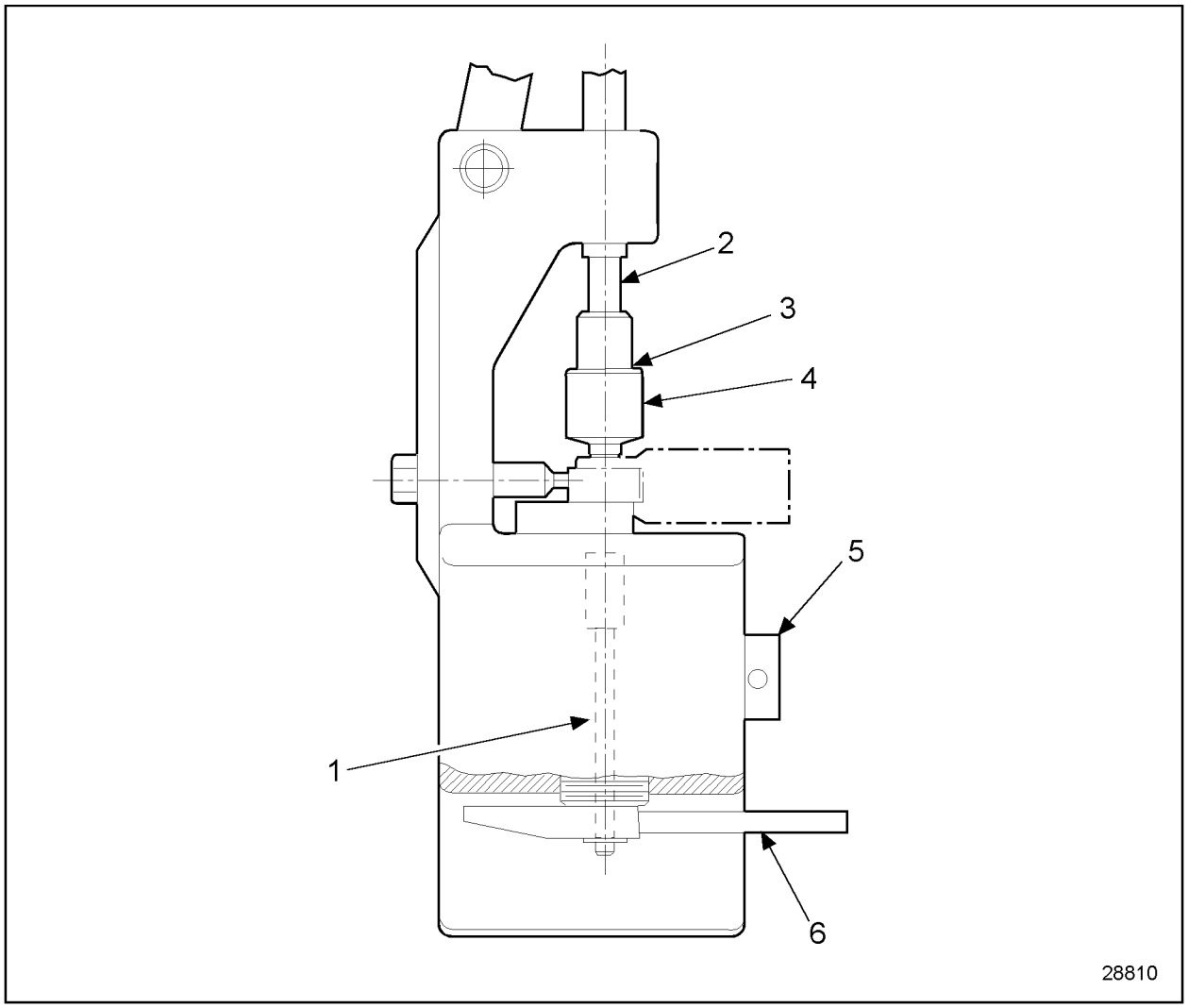
Whenever a cam follower is rebuilt, the cam roller and pin must be tested as follows:

NOTE:
Use load test cell J 33421-A to test the cam roller.

1. Install the load cell on the service fixture pressing ram.

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2. Push spring-loaded guide pin J 33421-12 (found in set J 33421-A) down and insert fork J 33421-A. See Figure 1-45.



1. Guide Pin
2. Ram
3. White Line
4. Load Cell
5. Adjustable Support
6. Guide Pin Retaining Fork

Figure 1-45 Testing Roller Pin on Load Test Cell J 33421-A

3. Pull support slide J 33421-A down.
4. Install cam follower, and lower the handle, putting slight pressure on the roller pin.

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5. Push support J 33421-A until there is resistance.

NOTE:
Do not continue downward force after the white line disappears. This will cause the load cell to bottom out and eventually push out the pin. Do not use the load cell for roller installation or removal.

6. Apply pressure on the handle until the white line on the load cell disappears from view. The pin must sustain an axial force of 135.9 Kg (300 lbs.) without pushing out.
7. If it fails the test, replace the pin. Refer to section 1.4.6.

1.4.6 Assembly of Cam Follower

Assemble the cam follower as follows:

1. Before installing the new roller and pin, remove the preservative. Refer to section 1.4.4.1 for cleaning instructions.
2. Pull the adjustable sliding support out.
3. Position the cam follower, with follower pin resting on the spring-loaded guide pin, in the fixture.
4. Align the pin over the follower leg.
5. Lower handle, and place pressure on the pin.

NOTE:
When assembling the cam follower with flats on the outside of the legs, push adaptor J 33421-3 (found in setJ 33421-A) onto the pressing ram to the press limit depth. When pressing the pin into the follower with rounded legs, use adaptor J 33421-22 (found in set J 33421-A). Both adaptors have a spring-loaded plunger in the set screw that does not normally require any adjustment.

6. To support the lower follower leg, lower handle, and push the adjustable sliding support in until there is resistance.
7. Press the pin into place.
8. Remove the cam follower from the fixture.
9. Check the side clearance. The clearance must be 0.28-0.58 mm (0.011-0.023 in.).
10. If cylinder head is installed, refer to section 1.4.6.1, and if cylinder head is removed, refer to section 1.4.6.2.

1.4.6.1 Cleaning Cam Follower and Push Rod (Cylinder Head Installed)

Perform the following procedure for cleaning the cam follower and push rod:

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

Before cam followers are installed, immerse them in clean Cindol® 1705 as follows:

1. Heat the Cindol 1705 in a small pail with a screen insert. Heat to 38-52°C (100-125°F).

NOTE:
The screen will prevent the cam followers from touching the bottom of the pan and avoid contamination.

2. Rotate the cam rollers during the soaking period to purge any air from the bushing-roller area.
3. Soak for at least one hour to ensure initial cam roller pin and bushing lubrication.

NOTE:
Since it is less viscous than engine oil, heated Cindol oil flows freely between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the trapped air cooling in the bushing and pin area will pull the lubricant into the cavity.

4. Refer to section 1.4.6.3 for inspection.

1.4.6.2 Cleaning Cam Follower and Push Rod (Cylinder Head Removed)

Perform the following procedure for cleaning the cam follower and push rod:

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

Immerse cam followers in clean Cindol 1705 as follows:

1. Heat the Cindol 1705 in a small pail with a screen insert. Heat to 38-52°C (100-125°F).

NOTE:
The screen will prevent the cam followers from touching the bottom of the pan and avoid contamination.

2. Rotate the cam rollers during the soaking period to purge any air from the bushing-roller area.

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3. Soak for at least one hour to ensure initial cam roller pin and bushing lubrication.

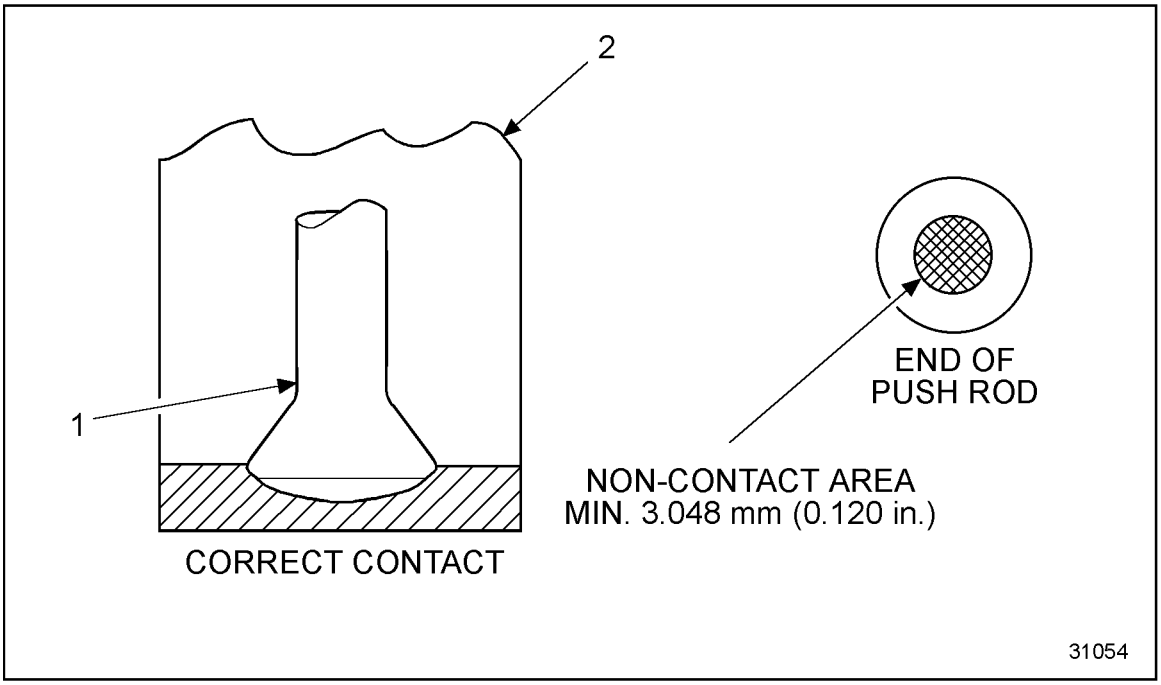
NOTE:
Since it is less viscous than engine oil, heated Cindol oil flows freely between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the trapped air cooling in the bushing and pin area will pull the lubricant into the cavity.

4. Refer to section 1.4.6.3 for inspection.

1.4.6.3 Inspection of Cam Followers and Push Rod

Prior to installing a cam follower and push rod, the push rod seating within the cam follower body must first be inspected to ensure the proper loading if the cam follower is being realized. Inspect the push rod seating using the following procedure:

1. Apply bluing to the cam follower end of push rod and seat it into the cam follower body.
2. Check the "non-contact" area of the push rod seat. The "non-contact" area in the center must be a minimum of 3.05 mm (0.120 in.) diameter, and the contact area must extend to the outer edge of the push rod sphere. See Figure 1-46.



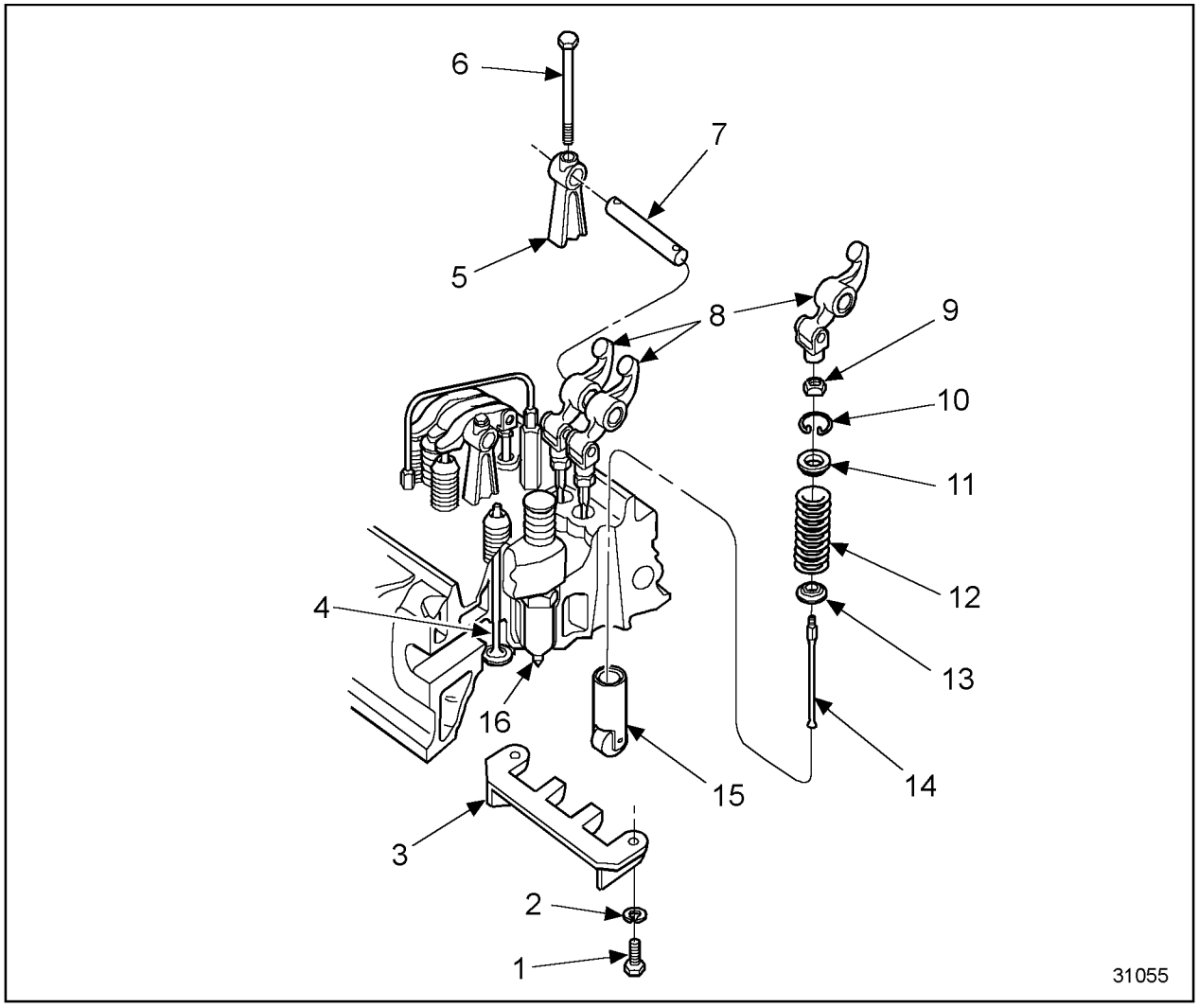
1. Push Rod
2. Cam Follower

Figure 1-46 Push Rod and Cam Follower Area

[a] If the push rod sphere meets both criteria, then it is a serviceable part. If cylinder head is installed, refer to section 1.4.7. If cylinder head is removed, refer to section 1.4.8.

[b] If push rod fails either criteria, a new push rod must be used. If cylinder head is installed, refer to section 1.4.7. If cylinder head is removed, refer to section 1.4.8.

NOTE:
Install reusable cam followers and push rods in their original locations. See Figure 1-47.



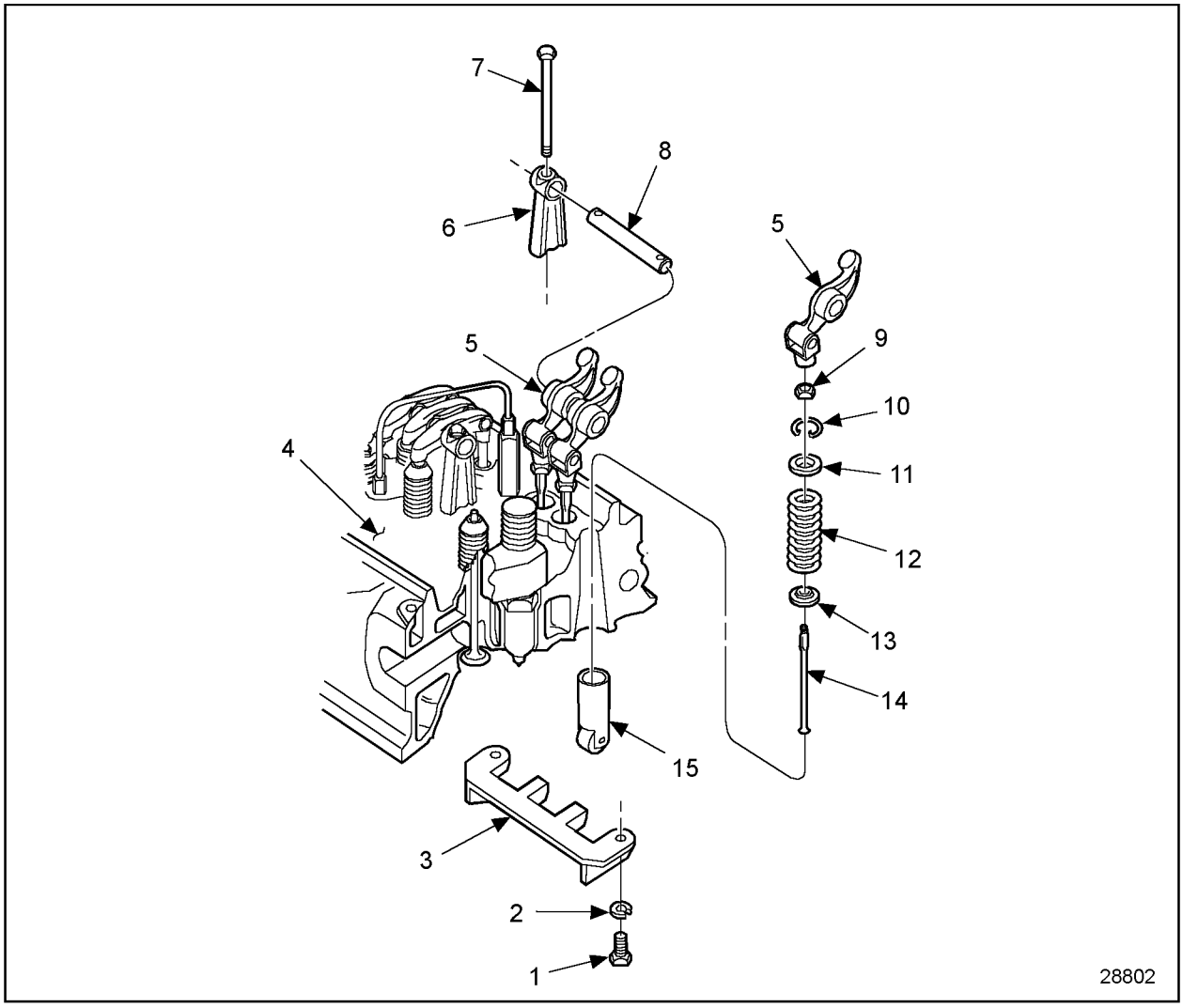
1. Bolt
2. Lock Washer
3. Cam Follower Guide
4. Valve
5. Bracket
6. Bracket Bolt
7. Rocker Arm Shaft
8. Rocker Arms
9. Locknut
10. Spring Retainer
11. Upper Spring Seat
12. Valve Spring
13. Lower Spring Seat
14. Push Rod
15. Cam Follower
16. Fuel Injector

Figure 1-47 Valve and Injector Operating Mechanism

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1.4.7 Installation of Cam Followers and Push Rods (Cylinder Head Installed)

Install the cam followers and push rods as follows. See Figure 1-48:



1. Cam Follower Bolt
2. Washer
3. Cam Follower Guide
4. Cylinder Head Assembly
5. Rocker Arms
6. Rocker Arm Shaft Bracket
7. Shaft Bolt
8. Rocker Arm Shaft
9. Locknut
10. Spring Retainer
11. Upper Spring Seat
12. Spring
13. Lower Spring Seat
14. Push Rod
15. Cam Follower

Figure 1-48 Cam Follower and Push Rod Installation

1. With the oil hole in the cam follower directed away from the exhaust valves, slide the cam follower into position in the cylinder head.
2. Assemble the serrated lower spring seat, spring, and upper spring seat on the push rod.
3. Place a flat washer over the upper spring seat, and start the locknut on the push rod.
4. Place tool J 3092-01 on the push rod between the washer and the upper spring seat, and place the push rod assembly in the cam follower.
5. Thread the locknut on the push rod until the spring is compressed sufficiently to permit spring retainer installation.
6. Install the retainer, with the tangs facing the notch, in the cylinder head.
7. Remove the nut, flat washer, and tool.
8. Install the locknut, and thread it is far as possible on the push rod. Refer to section 1.4.9.

1.4.8 Installation of Cam Followers and Push Rod — Cylinder Head Removed

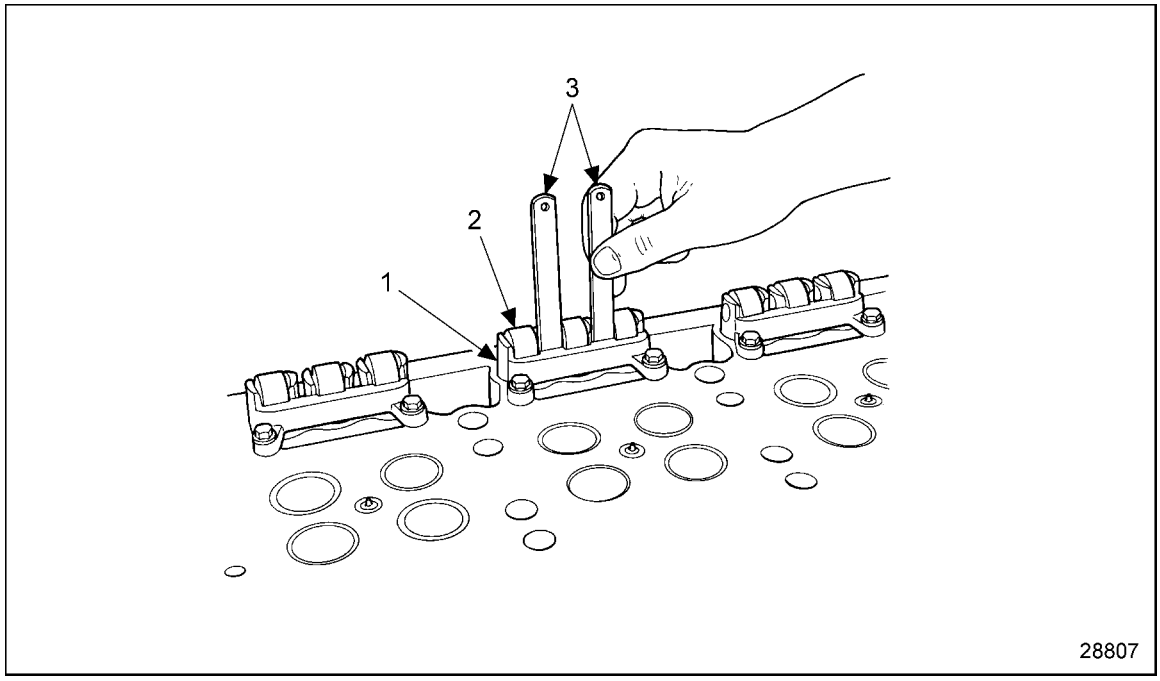
Install the cam followers and push rods as follows:

1. Assemble the serrated lower spring seat, spring, upper spring seat, and locknut on the push rod.
2. With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.
3. With the oil hole directed away from the exhaust valves, slide the cam follower in position from the bottom of the head.
4. Attach the follower guide to the cylinder head to hold the group of three cam followers in place.

NOTE:
The correct bolt must be used. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

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5. Tighten the guide bolts to 16-20 N·m (12-15 lb·ft) torque. There should be at least 0.13 mm (0.005 in.) clearance between the cam follower legs and the cam follower guide. See Figure 1-49.

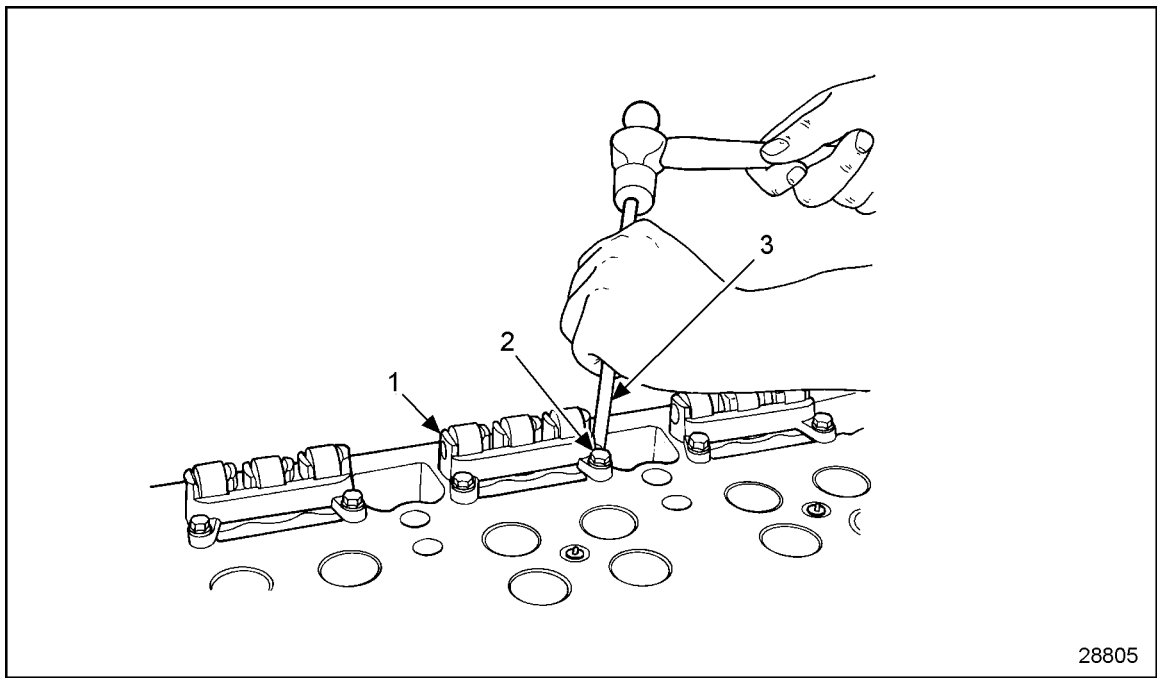


1. Cam Follower Guide
2. Cam Follower
3. Feeler Gages

Figure 1-49 Checking Cam Follower-to-Guide Clearance

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6. If there is insufficient clearance, loosen the guide bolts slightly, and tap each corner of the guide with a brass rod. See Figure 1-50.



1. Cam Follower Guide
2. Cam Follower Bolt
3. Brass Rod

Figure 1-50 Adjusting Cam Follower Guide

7. Tighten the bolts to the specified torque. Refer to section 1.4.9.

1.4.9 Installation of Rocker Arm and Rocker Shaft

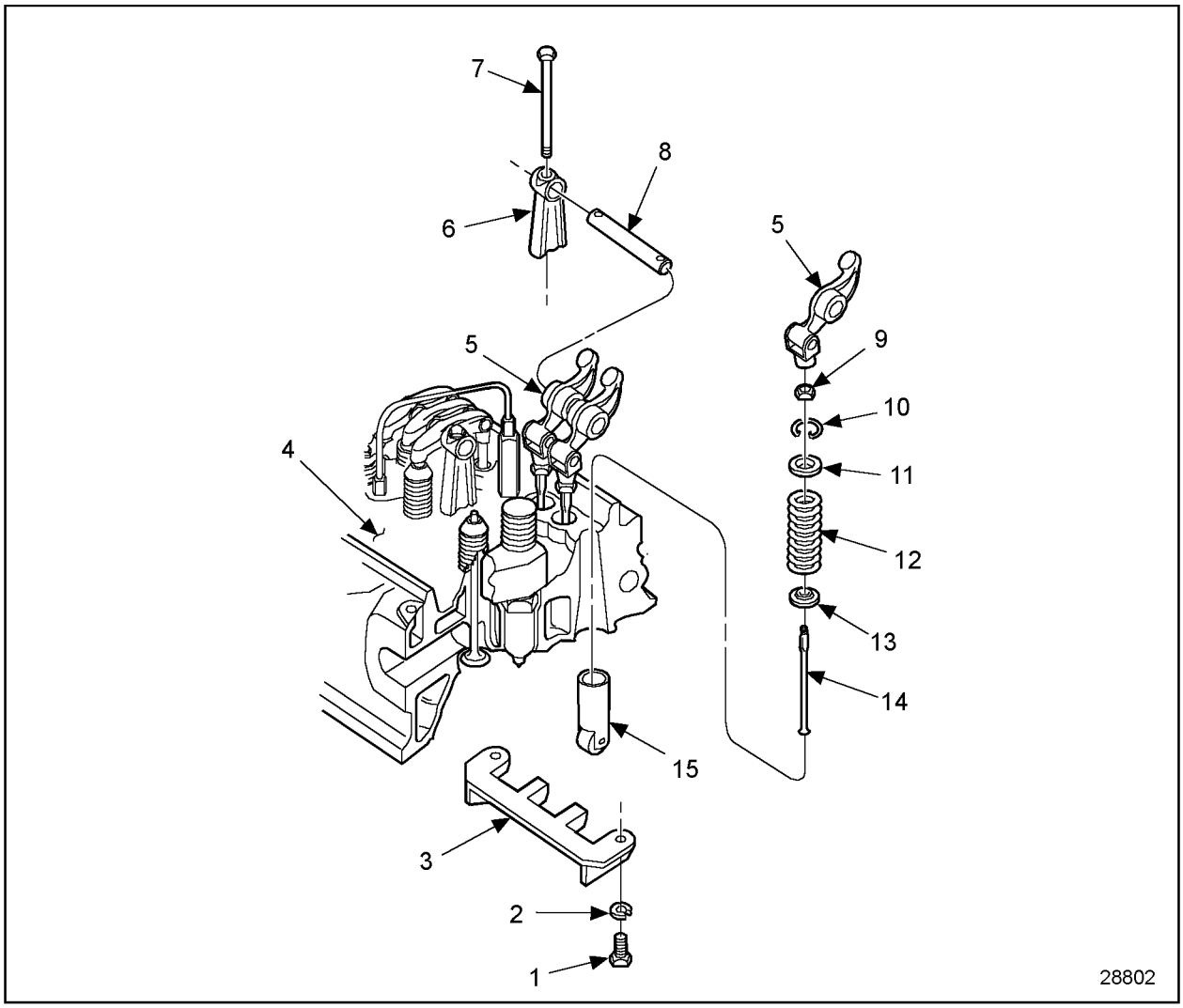
Install rocker arms and shaft as follows:

NOTE:
When replacing the injector rocker arm shaft assemblies on 6V and 8V-92TA coach engines, only the new cross-drilled rocker arm shaft assembly should be used. The injector rocker arm shaft assemblies can be mixed in the same coach engine.

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. See Figure 1-51. This will provide sufficient initial

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clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.



1. Cam Follower Bolt
2. Washer
3. Cam Follower Guide
4. Cylinder Head Assembly
5. Rocker Arms
6. Rocker Arm Shaft Bracket
7. Shaft Bolt
8. Rocker Arm Shaft
9. Locknut
10. Spring Retainer
11. Upper Spring Seat
12. Spring
13. Lower Spring Set
14. Push Rod
15. Cam Follower

Figure 1-51 Cam Follower and Push Rod Installation

2. Install the cylinder head (if removed) on the engine. Refer to section 1.3.5.

3. Lubricate the valve bridge guides with sulphurized oil, and position the valve bridges on the guides.
4. Adjust the valve bridges. Refer to section ADDITIONAL INFORMATION.
5. Install the fuel injectors, if removed.

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.

6. Apply clean engine oil to the rocker arms. Place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.
7. Insert the rocker arm bracket bolts through the brackets and the shaft.
8. Tighten the bolts to the specified torque. Refer to section ADDITIONAL INFORMATION specifications.

NOTICE:

Do not bend the fuel pipes, and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and results in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

9. Align the fuel pipes, and connect them to the injectors and the fuel connectors.

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NOTICE:

Detroit Diesel recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932-01 (from set J 8932-B and "clicker" type torque wrench J 24405 (calibrated in inch-pounds) to apply proper torque and avoid damaging the fuel pipes. Torque specifications are listed in Table 1-2. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, that may result in serious engine damage.

Fuel Pipe Usage	Torque
Endurion-Coated	14.69 N·m (130 lb·in.)
Uncoated	18.3 N·m (160 lb·in.)
*Jake Brake	13.6 N·m (120 lb·in.)
Loading Limiting Devices	18.3 N·m (160 lb·in.)
DDEC Engines	16.16 N·m (143 lb·in.)

* Not serviced. Available from Jacobs Vehicle Systems™

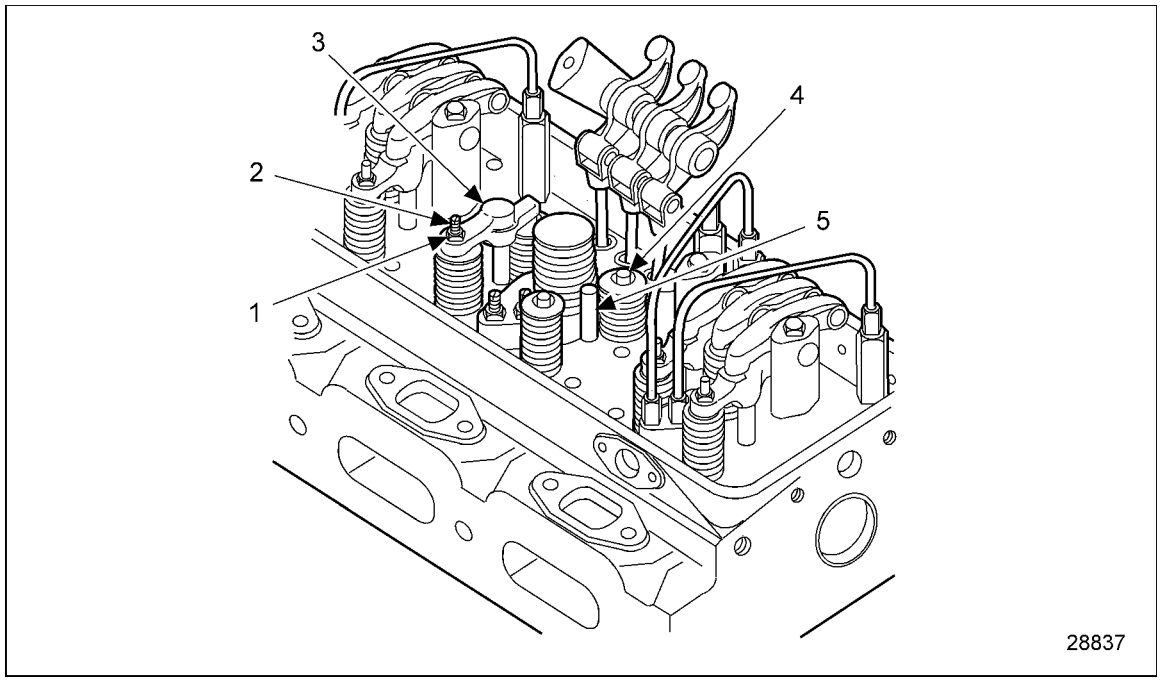
Table 1-2 Jumper Line Nut Torque

10. Fill the cooling system. Refer to section 13.12.2.
11. Adjust the exhaust valve clearance, and time the injectors. Refer to section 12.2 and refer to section 12.3.
12. If necessary, perform an engine tune-up. Refer to section 12.1.

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1.5 EXHAUST VALVES

Four exhaust valves are provided for each cylinder. See Figure 1-52. The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end that contacts the valve bridge.

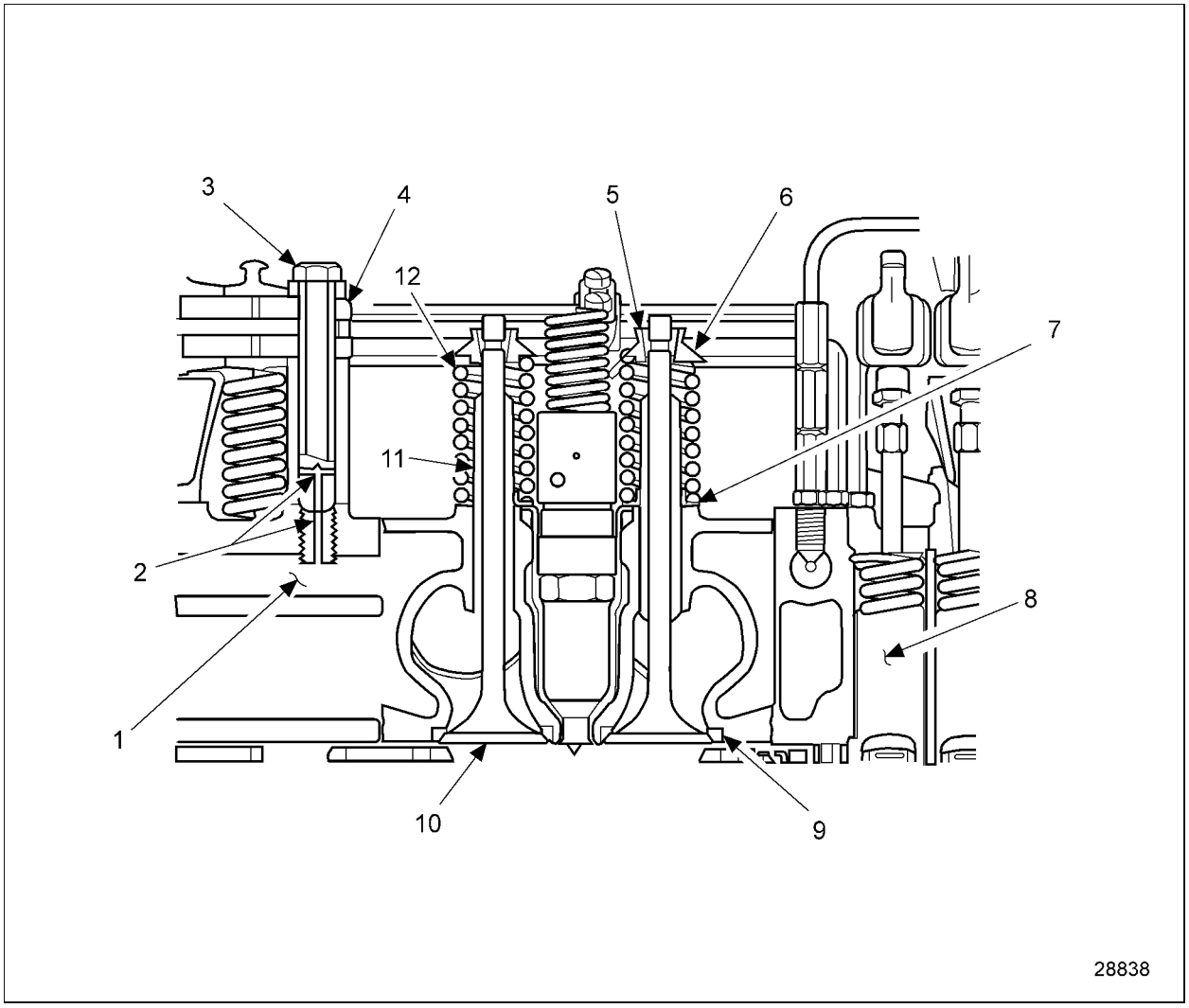


1. Locknut
2. Adjusting Screw
3. Valve Bridge
4. Exhaust Valve
5. Bridge Guide

Figure 1-52 Location of Exhaust Valves

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The exhaust valve stems are contained within exhaust valve guides, that are placed into the cylinder head. Exhaust valve seat inserts, pressed into the cylinder head, permit accurate exhaust valve seating under various temperatures and prolong cylinder head life. See Figure 1-53. Valve spring caps and tapered two-piece valve locks hold the exhaust valve springs in place.



1. Cylinder Head Oil Passage
2. Oil Passages
3. Bolt
4. Rocker Shaft
5. Valve Keepers
6. Spring Cap
7. Spring Seat
8. Cam Follower
9. Valve Seat Insert
10. Exhaust Valve
11. Valve Guide
12. Valve Spring

Figure 1-53 Assembly of Exhaust Valves and Guides

Excess oil from the rocker arms lubricates the exhaust valve stems. Airflow from the blower cools the valves each time the air inlet ports are uncovered.

Proper engine maintenance and operation is important to long valve life. Normal engine operating temperature should be maintained. Refer to section 11.5. Low operating temperatures (due to extended idling periods or light engine loads) result in incomplete combustion, lubricating oil sludge, excessive carbon deposits, and fuel lacquer formations on the valves and related parts.

Unsuitable fuels may cause deposits on the valves, especially when operating at low temperatures.

When carbon deposits build up around the valve stems, especially the portion of the stem that operates in the valve guide, the valves will stick and will not be able to seat properly, resulting in pitted, burned valves, burned valve seats and compression loss.

To avoid sludge accumulation, recommended lubricating oil and oil filters should be used and maintenance procedures should be followed. Refer to section 5.2 and refer to section 13.5.

As a result of valve stems that have been scored from foreign matter in the lubricating oil, antifreeze (glycol) leaking into the lubricating oil, and bent or worn valve guides; the piston may strike the sticking valves.

Injector timing and valve clearance must be accurately adjusted and periodically checked. Improperly timed injectors or tightly adjusted valves will adversely affect combustion.

1.5.1 Repair or Replacement of Exhaust Valves

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-54.

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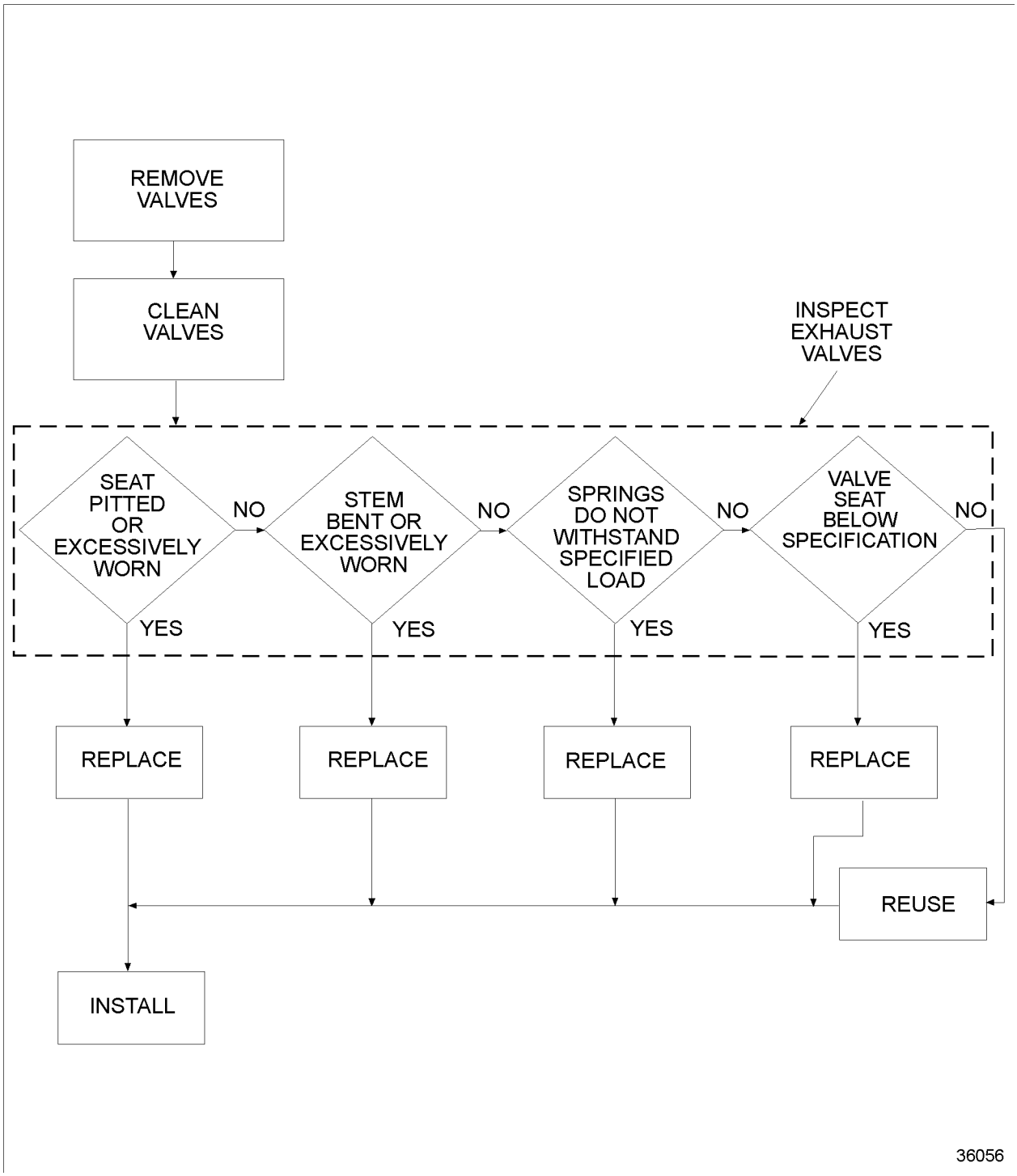


Figure 1-54 Flowchart for Repair or Replacement of Exhaust Valves

1.5.2 Removal of Exhaust Valve Spring (Cylinder Head Installed)

Exhaust valve springs may be removed without removing the cylinder head from the engine. Proceed as follows:

1. Remove and clean the valve rocker cover. Discard the gasket.

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:
When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft to the left. The bolt could be loosened.

2. Crank the engine over to bring the valve and injector rocker arms horizontally in line.

NOTE:
Once Tool J 22582 is bolted onto the flywheel housing, the engine can be hand rotated with a 3/4 in. drive and ratchet. Tool J 22582 bolts to the flywheel housing in the same position as the engine starter.

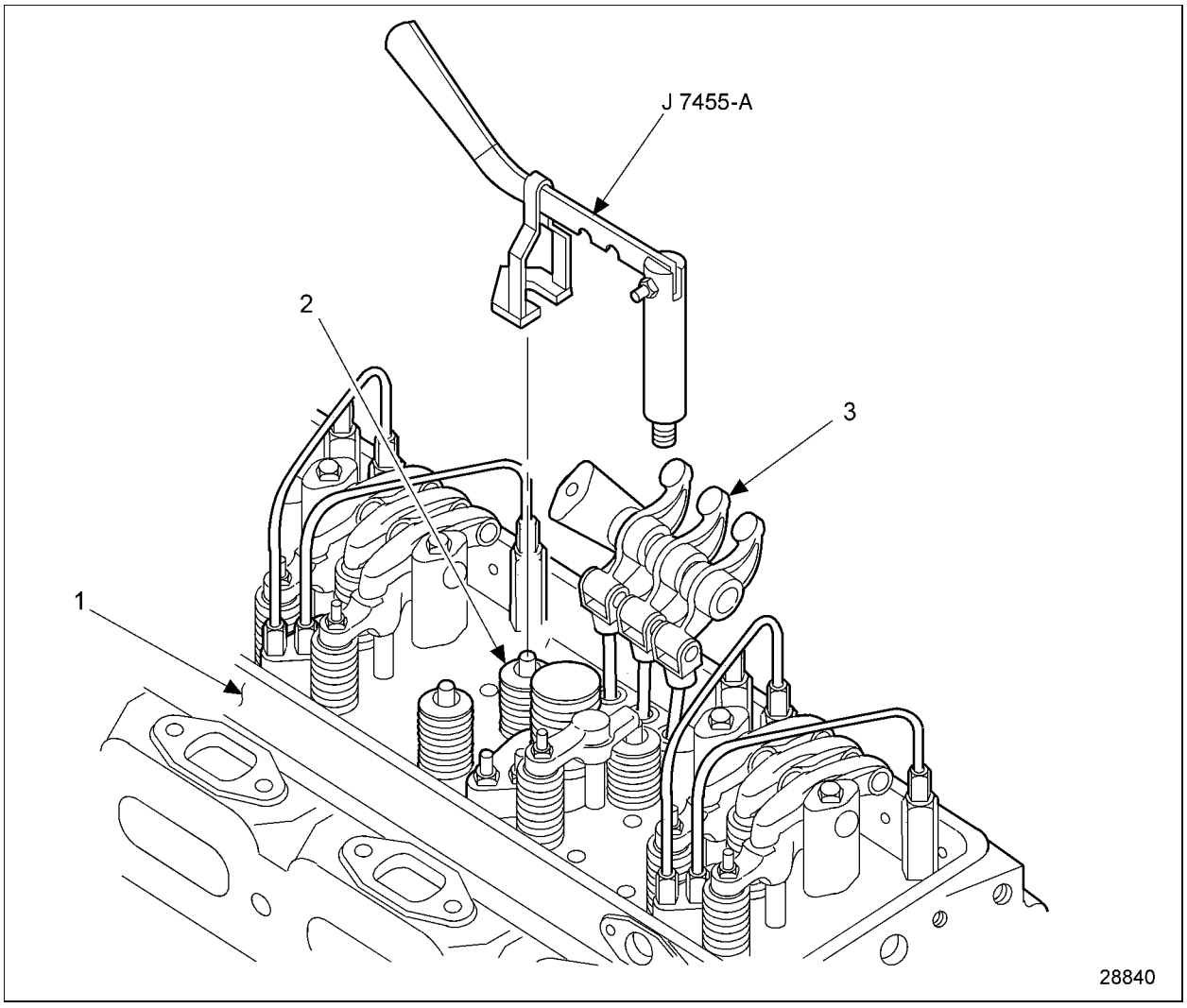
3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

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

4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head.
5. Remove the brackets and shaft.
6. Remove the exhaust valve bridge.
7. Remove the cylinder block air box cover to observe piston travel. Refer to section ADDITIONAL INFORMATION.
8. Turn the crankshaft until the piston is at the top of its stroke.

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9. Thread the valve spring compressor adaptor J 7455-7 from set J 7455-A into the rocker arm bracket bolt in the cylinder head. See Figure 1-55.



1. Cylinder Head Assembly
2. Exhaust Valve Spring
3. Rocker Arm Assemblies

Figure 1-55 Removing Exhaust Valve Spring with Tool J 7455-A

10. Compress the valve spring, and remove the two-piece tapered valve lock.
11. Release the tool, and remove the spring cap, valve spring, and spring seat.

1.5.3 Removal of Exhaust Valve and Valve Spring (Cylinder Head Removed)

To remove exhaust valves and valve springs, the cylinder head must be removed. Refer to section 1.3.2. Proceed as follows:

NOTE:
Do not damage or scratch the critical sealing area around the intermediate water nozzles.

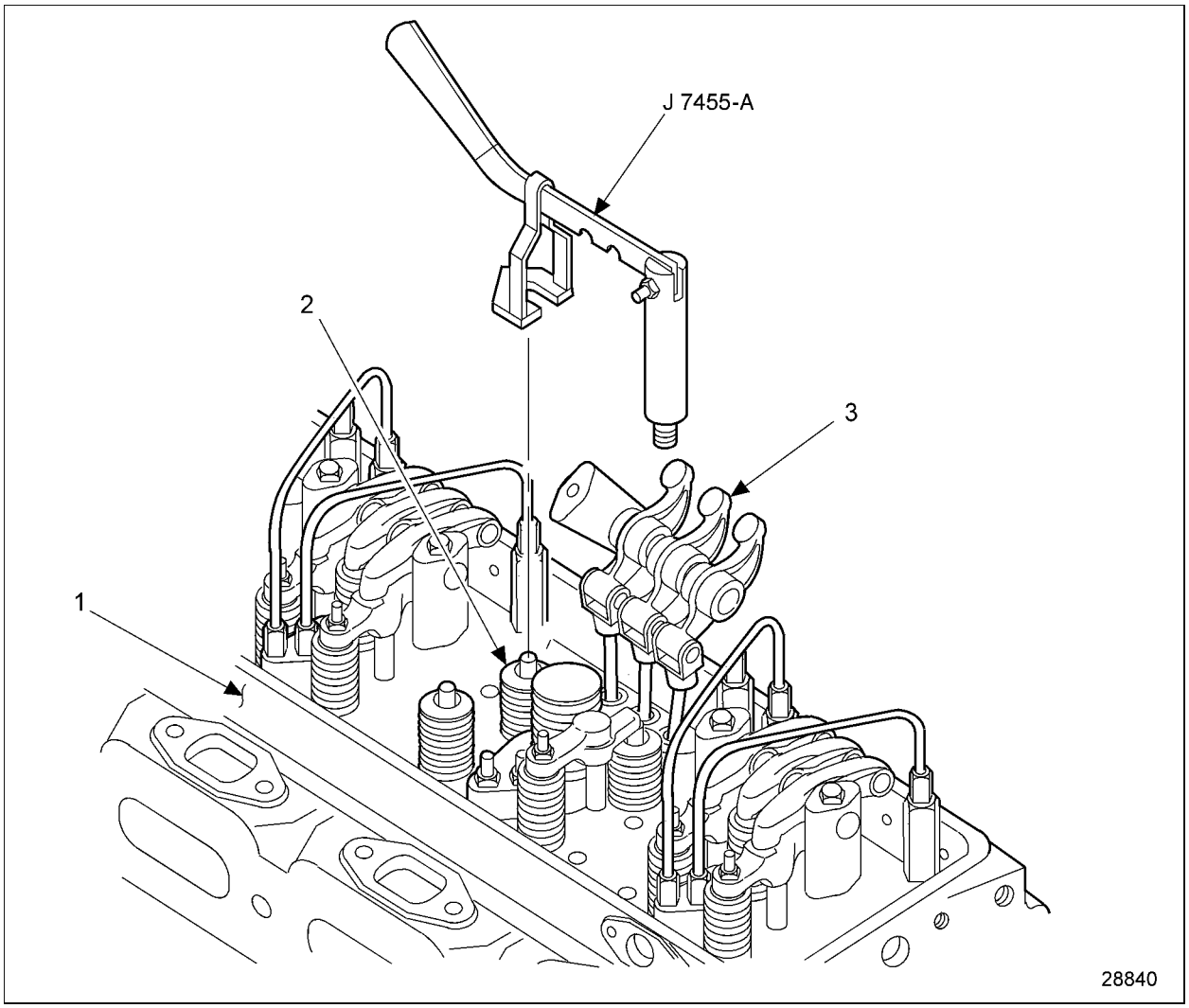
1. Support the cylinder head on 2 in. thick wood blocks to keep the cam followers clear of the bench.
2. Remove the fuel pipes from the injector and the fuel connectors.

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

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head.
4. Remove the brackets from the shaft.
5. Remove the fuel injectors. Refer to section 2.2.2.
6. Remove the exhaust valve bridge guides.
7. Place a block of wood under the cylinder head to support the exhaust valves.

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8. Thread the valve spring compressor adaptor J 7455-7 from set J 7455-A into the rocker arm bracket bolt in the cylinder head. See Figure 1-56.



1. Cylinder Head Assembly
2. Exhaust Valve Spring
3. Rocker Arm Assemblies

Figure 1-56 Removing Exhaust Valve Spring with Tool J 7455-A

9. Compress the valve spring, and remove the two-piece tapered valve lock.
10. Release the tool, and remove the spring cap, valve spring, and spring seat.
11. Turn the cylinder head over, without letting the valves fall out of the head.

12. If the valves will be reused, number each valve to facilitate installation in the same location.

NOTE:
To improve resistance to "wet stacking," Detroit Diesel recommends installing exhaust valve stem seals on industrial engines whenever a cylinder head is removed.

13. Remove the valves from the cylinder head.
14. Remove the cam followers and push rod assemblies. Refer to section 1.4.3.

1.5.4 Removal of Exhaust Valve Guide

Remove the exhaust valve guide as follows:

1. Remove and discard the valve guide oil seal, if used.
2. Support the cylinder head, bottom side up, on 2 in. thick wood blocks.

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3. Drive the valve guide out of the cylinder head with tool J 6569-A. See Figure 1-57.

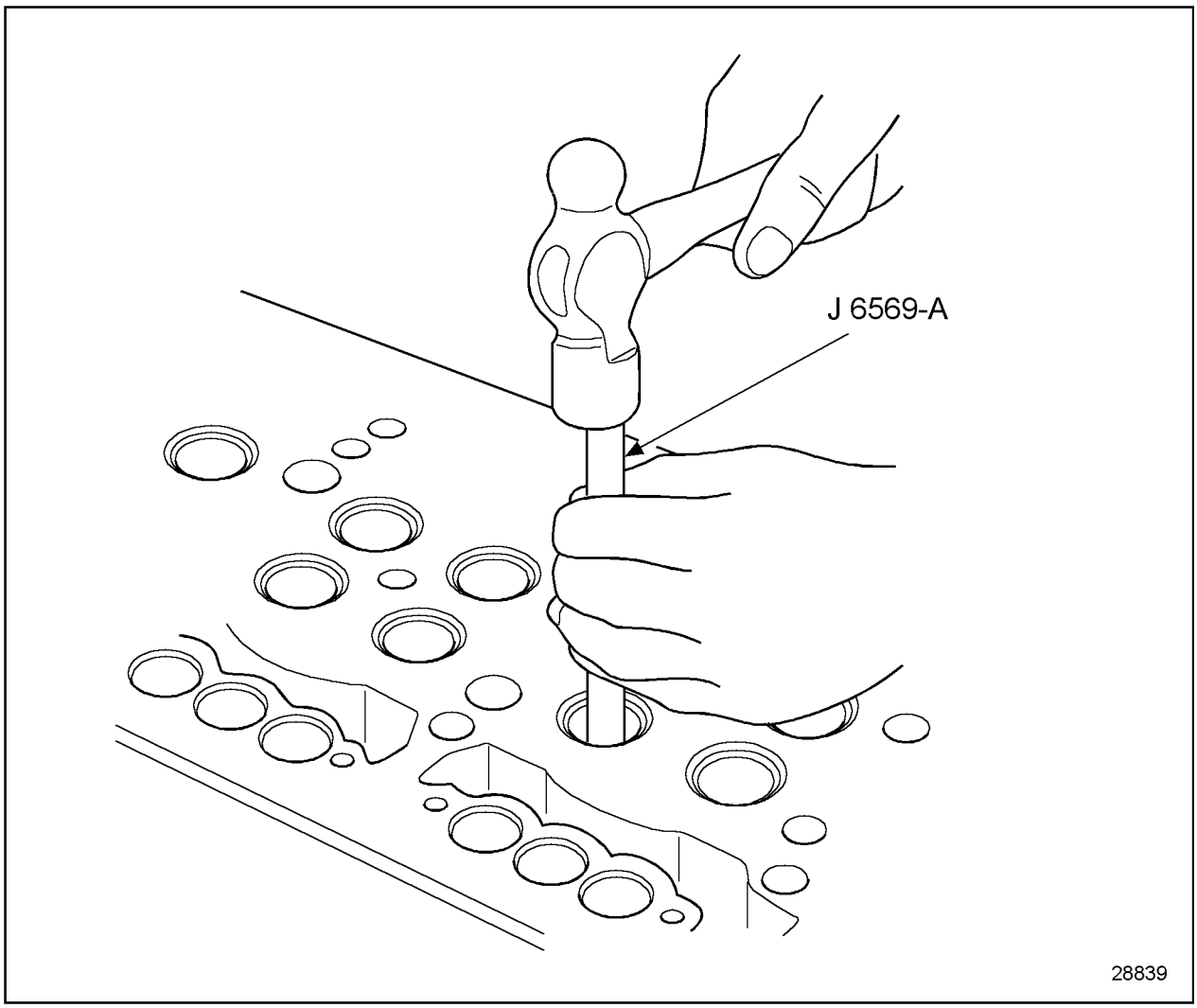


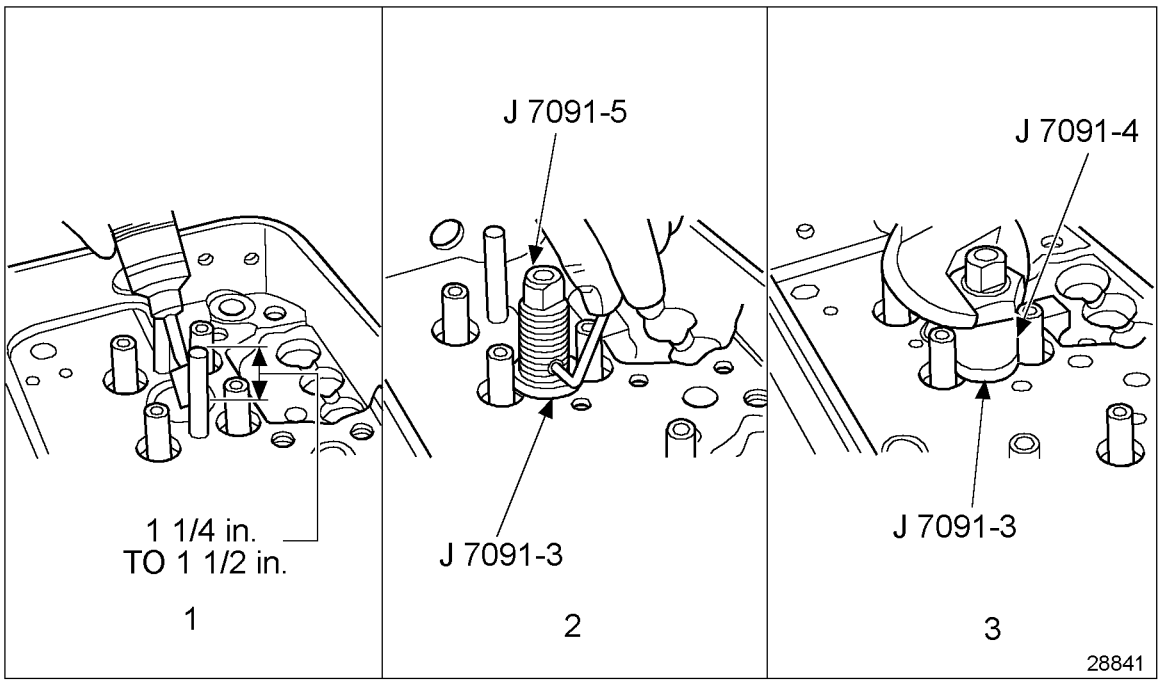
Figure 1-57 Removing Exhaust Valve Guide using Tool J 6569-A

1.5.5 Removal of Exhaust Valve Bridge Guide

Remove the press-fit valve bridge guide as follows:

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

2. Using tool set J 7091-01, place spacer J 7091-03 over the guide. See Figure 1-58.



1. Grind Notches
2. Install Removing Tools
3. Removing Guide

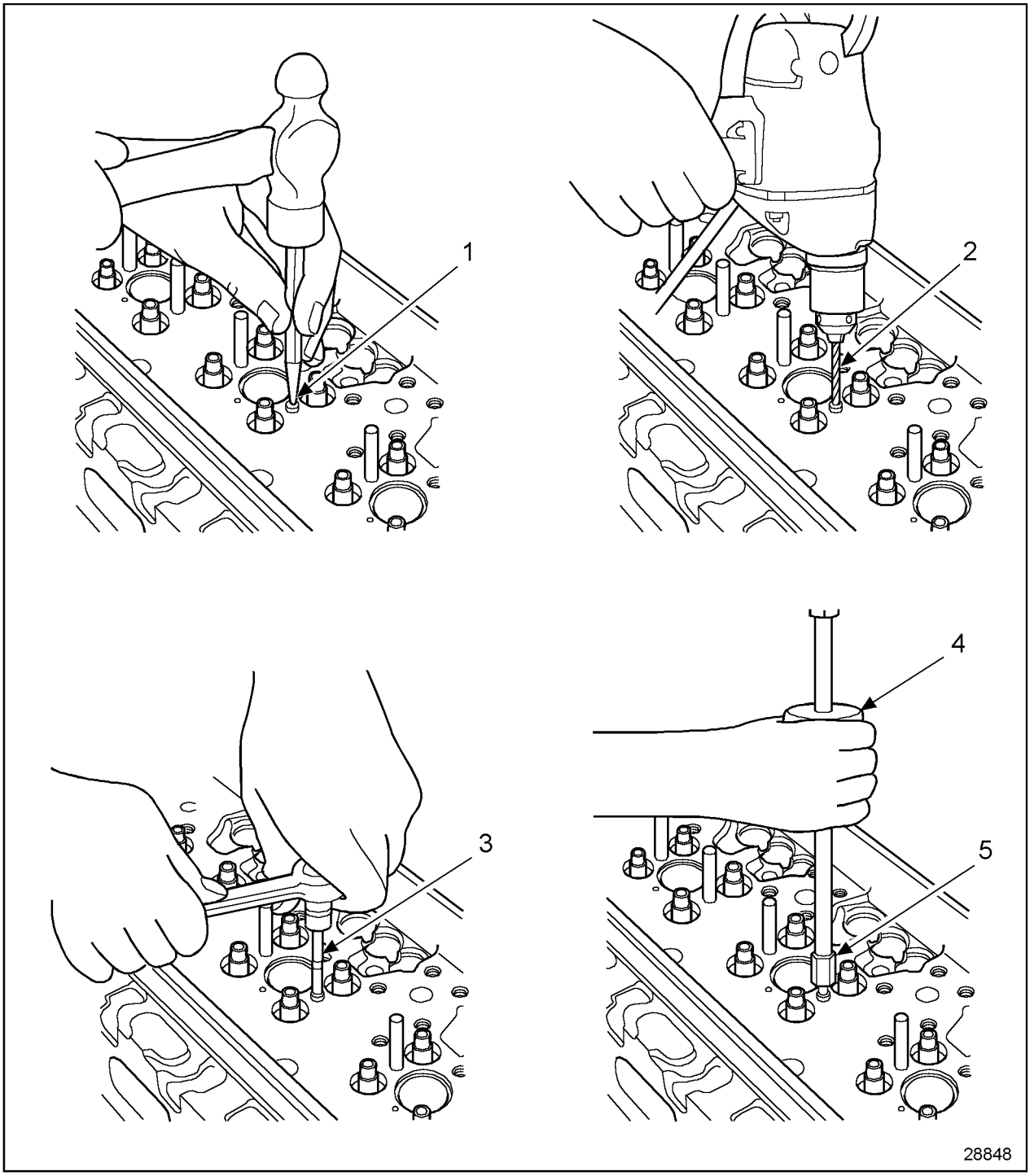
Figure 1-58 Removing Press-Fit Exhaust Valve Bridge Guide

3. Slide the guide remover J 7091-5 from set J 7091-01 over the guide, and align the set screws with the notches in the guide.
4. Tighten the set screws to secure the tool.
5. Place spacer J 7091-4 from set J 7091-01 over the guide remover.
6. Thread the nut on the guide remover, and turn it clockwise to withdraw the guide from the cylinder head.

To remove a broken valve bridge guide, proceed as follows:

1. Drill a hole approximately 1/2 in. deep in the end of the guide with a No. 3 (0.2130 in.) drill.
2. Tap the guide with a 1/4 in.-28 bottoming tap.
3. Thread remover J 7453 into the guide.
4. Attach slide hammer J 6471-02 to the remover tool. One or two sharp blows with the puller weight will remove the broken guide. See Figure 1-59.

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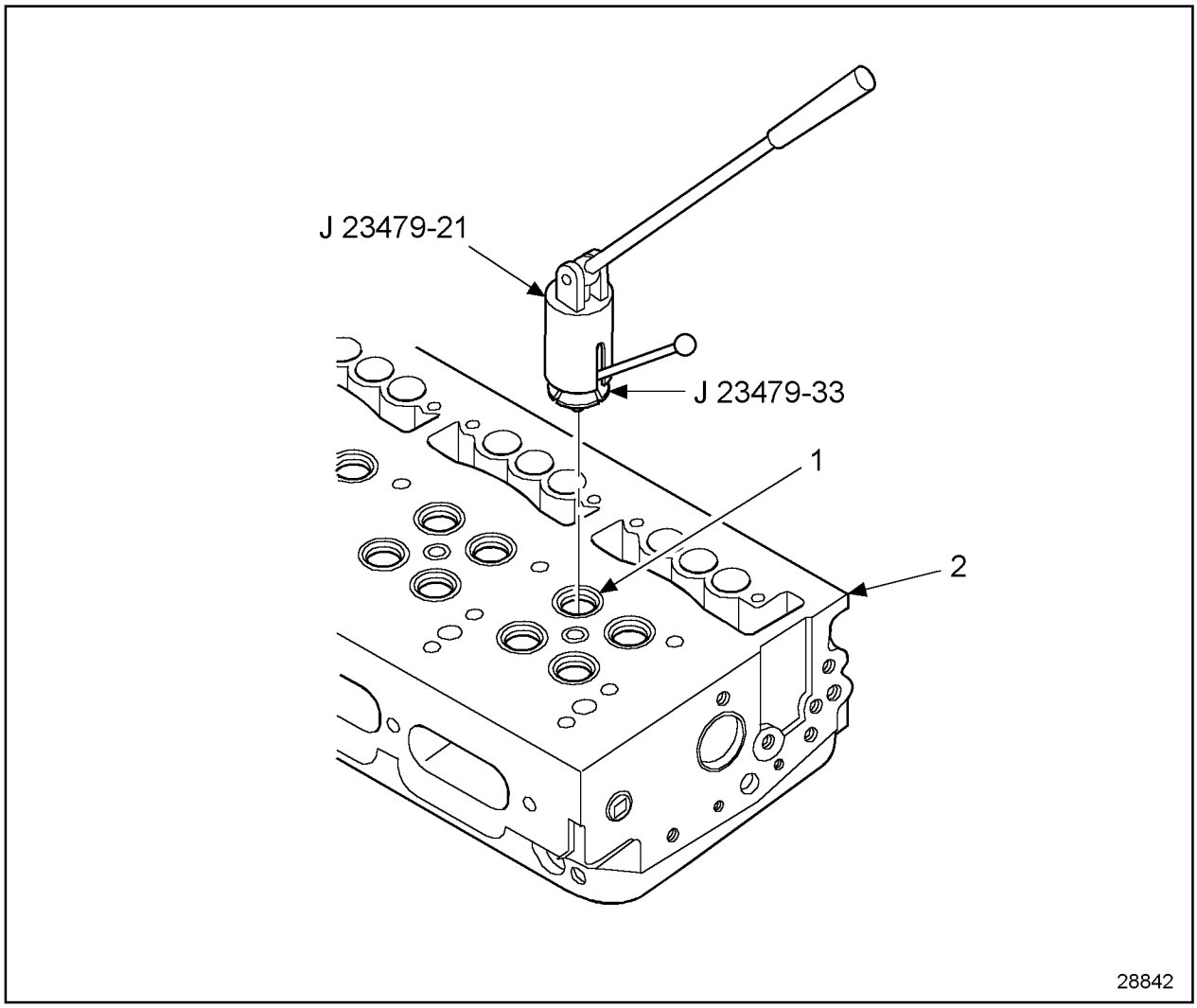
1. Center Punch
2. No. 3 Tap Drill
3. Bottoming Tap 1/4 in.-28
4. Slide Hammer
5. Remover Tool

Figure 1-59 Removing Broken Exhaust Valve Bridge Guide Tool J 7453 and Slide Hammer J 6471-02

1.5.6 Removal of Exhaust Valve Seat Insert

Remove the exhaust valve seat insert as follows:

1. Use the cam operated exhaust valve seat insert puller and collet from set J 23479-E and collet. See Figure 1-60.



1. Exhaust Valve Seat Insert
2. Cylinder Head Assembly

Figure 1-60 Exhaust Valve Seat Insert Removal

2. Hold handle in lax position, and install collet portion into valve seat insert.
3. While holding receiver body down and square with cylinder head, pull handle down until resistance is felt and hold.

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4. While holding puller handle down with one hand, grasp the collet handle with other hand and rotate back and forth several times.

NOTE:
Rotate cam only in direction of arrow.

5. Transfer grasp from collet to receiver body and continue pulling handle down until insert is removed. Refer to section 1.5.6.1.

1.5.6.1 Cleaning of Exhaust Valve

Prior to inspection, clean the exhaust valve as follows:

⚠ 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.

1. Clean the springs 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 springs with compressed air.

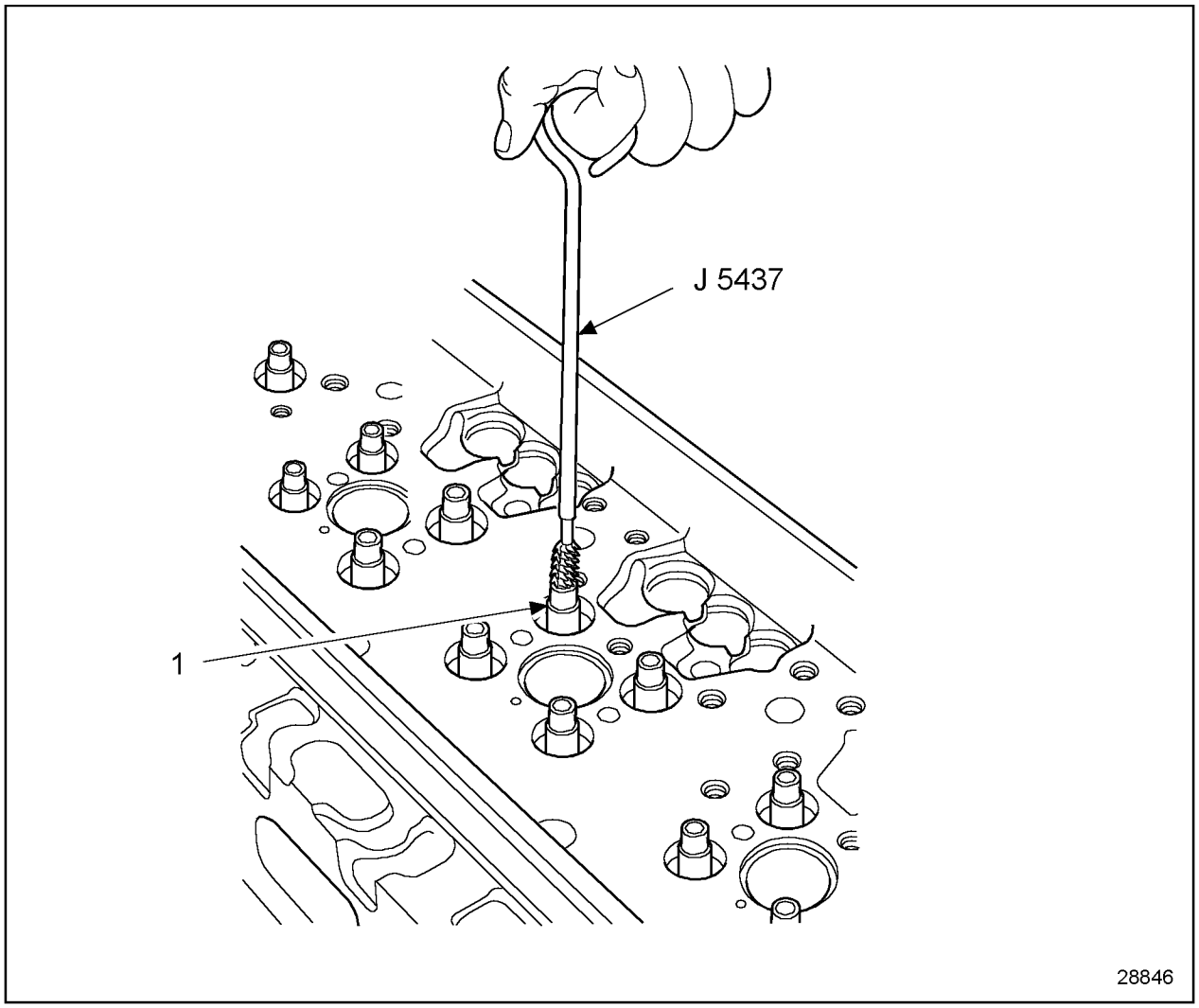
⚠ CAUTION:

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.

3. Remove carbon from the valve stems, and wash the valves with fuel oil.

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4. Clean the inside diameter of the valve guides with brush J 5437. See Figure 1-61. This brush will remove all gum or carbon deposits from the guides, including the spiral grooves.



1. Exhaust Valve Guide

Figure 1-61 Cleaning Exhaust Valve Guide with Tool J 5437

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⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

5. Clean the valve insert counterbore in the cylinder head with Tech Solv 340 or comparable solvent.
6. Wash the valve seat insert with the same solvent.

⚠ 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.

7. Dry both the counterbore and the insert with compressed air.

1.5.6.2 Inspection of Exhaust Valve

Inspect the exhaust valve as follows:

1. Visually inspect the valve seats for pitting.
   [a] If pitted, replace the valve seats.
   [b] If no pitting is evident, continue with inspection.
2. Ensure valve stems move freely within the valve guides.
   [a] If they do not move freely, replace the valve stems. Refer to section 1.5.10.
   [b] If valve stems move freely within the valve guides, continue with inspection.
3. Check valve clearance. Refer to section 12.2.
   [a] If clearance is not within specifications, replace the valve stems.
   [b] If the clearance is within specified limits, continue inspection.
4. Visually inspect the springs for pitting or fractures.
   [a] If the springs are pitted or fractured, replace them. Refer to section 1.5.10.
   [b] If the springs are not pitted or fractured, proceed with inspection.

5. Test the spring load with spring tester J 22738-02. See Figure 1-62.

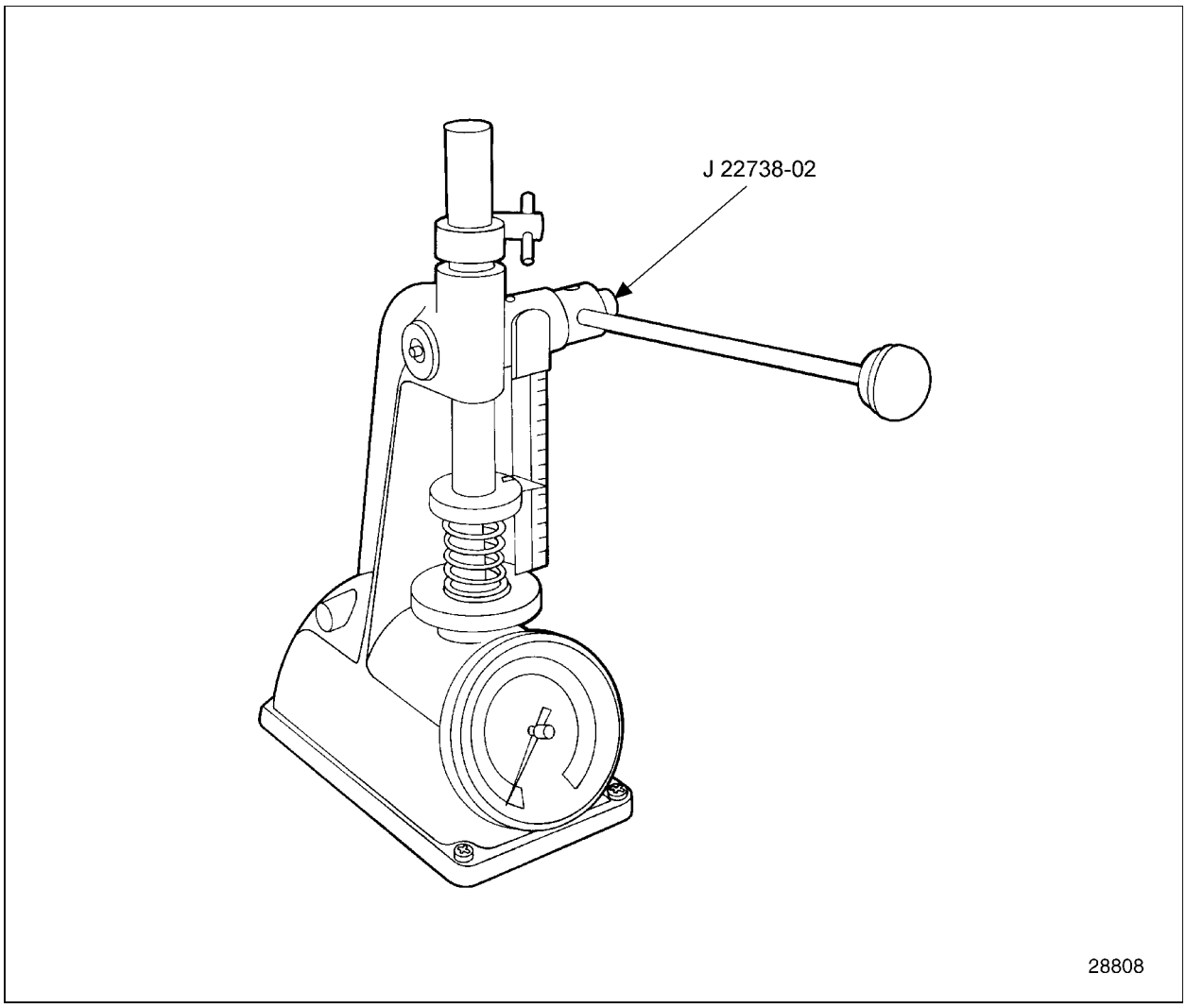


Figure 1-62 Testing Cam Follower Spring with Tool J 22738-02

[a] Replace the spring when a load of less than 11.325 Kg (25 pounds) will compress it to 45.7 mm (1.80 in.).

[b] If the spring withstands 11.325 Kg (25 pounds), continue the inspection.

6. Visually inspect the valve spring seats and caps for wear.

[a] If worn, replace with new parts.

[b] If no wear is present, continue inspection.

7. Inspect the valve seat insert for excessive wear, pitting, or cracking.

[a] If excessively worn, pitted, or cracked, the valve seat insert must be replaced. Refer to section 1.5.7.

[b] If not excessively worn, pitted, or cracked, proceed with inspection.

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8. Inspect the valve seat insert counterbore concentricity, flatness and cracks.

   [a] If counterbores have a diameter of 36.58-36.60 mm (1.440-1.441 in.), and a depth of 8.623-8.903 mm (0.3395-0.3505 in.), continue inspection.

NOTE:
The counterbores must be concentric with the valve guides within 0.002 in. total indicator reading.

   [b] If counterbores are not within specifications, use a valve seat insert which is 0.010 in. oversize on the outside diameter. Refer to section 1.5.7.

9. Inspect the valve seat insert for improper seat angle.

   [a] If the valve seating face is not angled at 30 degrees or the insert is not angled at 31 degrees, the valve seat insert may be refaced. Refer to section ADDITIONAL INFORMATION.

   [b] If the valve seat insert has already been ground to the extent that additional grinding would cause the grinding wheel to contact the cylinder head, install a new insert. Refer to section 1.5.7.

   [c] If the valve seating face angle is within specifications, proceed with inspection.

10. Examine the contact surfaces of the exhaust valve bridge guides, bridges, and adjusting screws for wear and galling.

   [a] If excessively worn or galled, replace parts.

   [b] If not excessively worn or galled, continue inspection.

11. Inspect the valve stems for scratches and scuff marks.

   [a] If scratched or scuffed, reface the valve stems.

   [b] If excessively scratched or scuffed, replace the valve stems.

   [c] If not scratched or scuffed, continue inspection.

12. Visually inspect the valve faces for ridges, cracks, or pitting.

   [a] If ridged or pitted, the valve face may be reground. Refer to section ADDITIONAL INFORMATION.

   [b] If excessively ridged, or pitted, or if the valve face is cracked, install a new valve. Refer to section 1.5.10.

   [c] If no ridges, cracks, or pits are evident, continue inspection.

13. Inspect for engine oil running down the exhaust valve stem into the exhaust chamber.

   [a] If engine oil is detected, replace the valve guide seals. If valve guide oil seals were not previously in use, install them. Refer to section 1.5.9.

   [b] If no engine oil is found, continue inspection.

14. Visually inspect the valve heads for warpage.

   [a] If the valve heads are warped, replace the valves. Refer to section 1.5.10.

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[b] If the valve heads are not warped, continue inspection.

15. Visually inspect the valve guides for fractures, chipping, scoring, or excessive wear.

    [a] If fractured, chipped, scored, or excessively worn, replace the valve guides. Refer to section 1.5.9.

    [b] If not fractured, chipped, scored, or excessively worn, proceed with inspection.

16. Measure valve guide clearances.

    [a] Measure the inside diameter of the valve guide with a pin gage or micrometer, and record the readings.

    [b] Measure the outside diameter of the valve stems with a micrometer, and record the readings. Proceed to step 17.

17. Compare the readings to obtain the valve-to-guide clearance.

    [a] If the clearance exceeds 0.13 mm (0.005 in.), replace the valve guides. Refer to section 1.5.9.

    [b] If the valve guide clearances do not exceed 0.13 mm (0.005 in.), proceed to installation. Refer to section 1.5.7.

1.5.7 Installation of Exhaust Valve Seat Insert

Install exhaust valve seat insert as follows:

1. Immerse the cylinder head for at least 30 minutes in 82-93°C (180-200°F) water.
2. Place the cylinder head, bottom side up, on a bench.

NOTICE:
To prevent part damage and ease installation, install the room temperature insert in the cylinder head while the head is still hot.

3. Place an insert in the counterbore, valve seat side up.
4. Drive the insert in place with installer J 24357 until it seats solidly in the cylinder head.
5. Grind the valve seat insert and check it for concentricity in relation to the valve guide. Refer to section ADDITIONAL INFORMATION.

1.5.8 Installation of Exhaust Valve Bridge Guide

Install the exhaust valve bridge guide as follows:

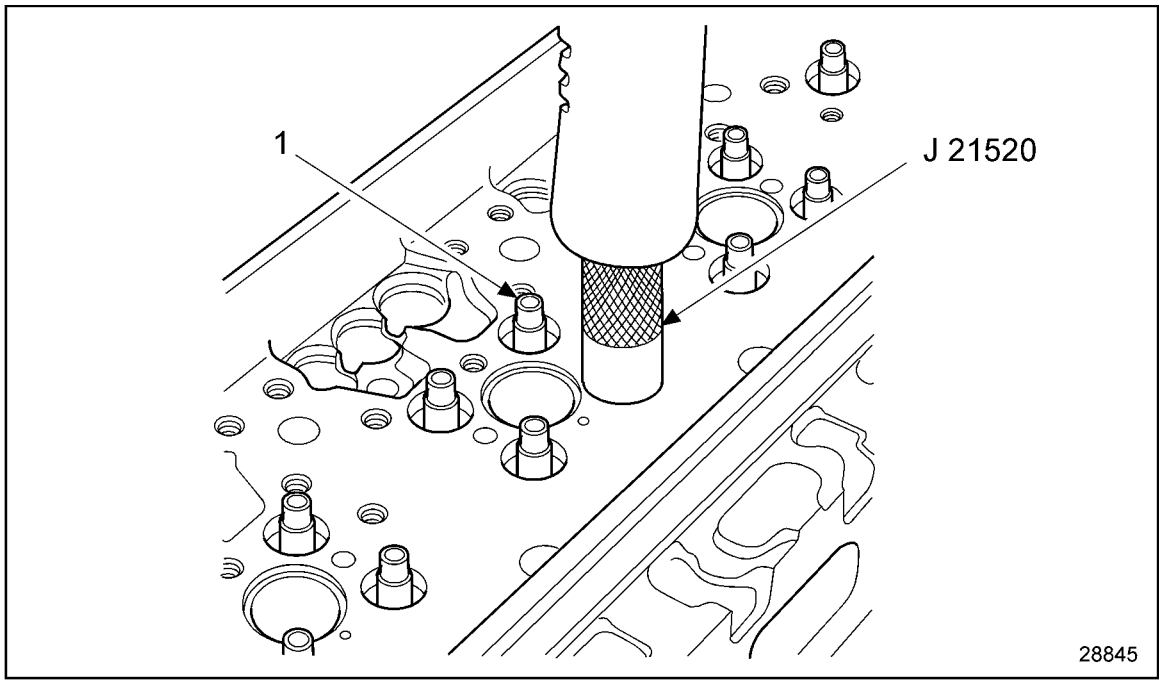
1. Apply Permatex® No. 1 sealant, or equivalent, to the valve bridge guide.
2. Start the guide into the cylinder head.
3. Place the installer J 7482 over the guide, and drive it into place. The installer will position the guide to the correct height.

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1.5.9 Installation of Exhaust Valve Guide

Install the exhaust valve guide as follows:

1. Place the cylinder head right side up on an arbor press.
2. Insert the internally threaded end of the valve guide in the valve guide installing tool J 21520. See Figure 1-63.



1. Valve Guide

Figure 1-63 Installing Valve Guide with Tool J 21520

3. Position the valve guide squarely in the cylinder head bore, and press the installing tool J 21520 gently to start the guide.

NOTICE:
Do not use the valve guides to turn the cylinder head over or to pick up the cylinder head. Failure to follow proper procedures may damage valve guides.

4. Press the guide in until the tool contacts the cylinder head. The tool installs the guide to 17.02-8.03 mm (0.670-0.710 in.) above the top of the cylinder head.

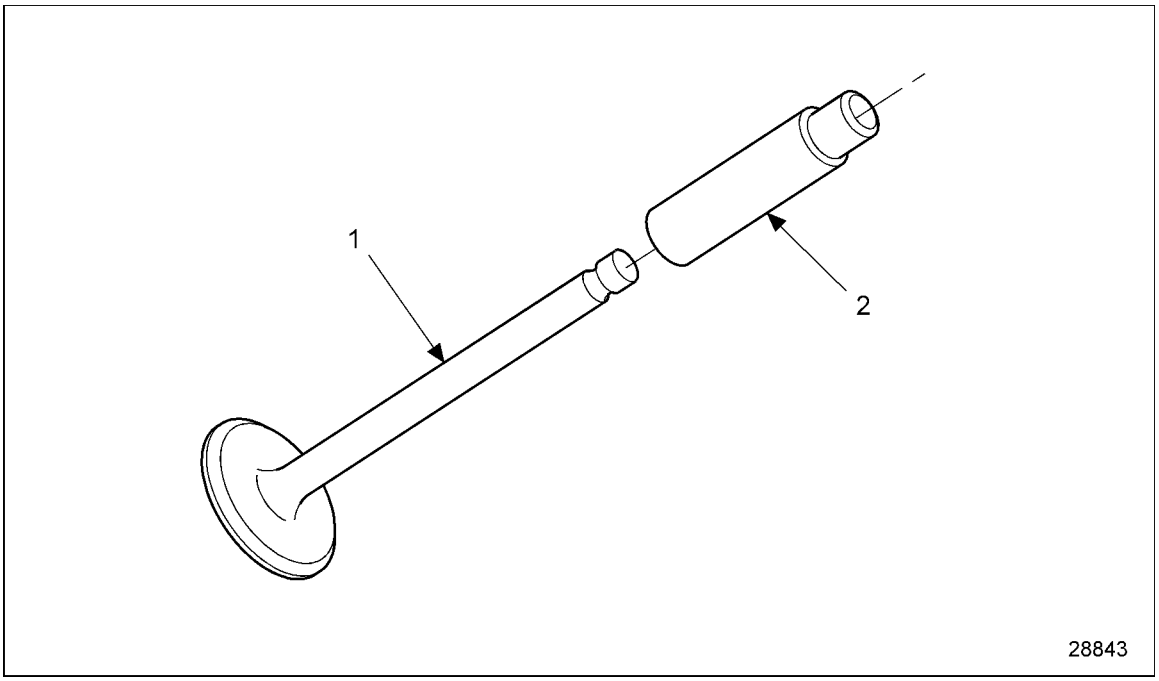
NOTE:
Service replacement valve guides are completely finish reamed. Do not ream after installation.

5. Install a new valve guide oil seal. Refer to section ADDITIONAL INFORMATION.

1.5.10 Installation of Exhaust Valve and Valve Spring (Cylinder Head Removed)

Install the exhaust valves and valve springs as follows:

1. Clean the valve guides. See Figure 1-64.



1. Exhaust Valve 2. Valve Guide

Figure 1-64 Cleaned Valve Guide and Lubricated Exhaust Valve

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the valve stems with sulphurized oil, and slide the valves into the guides.

NOTE:
If reconditioned valves are used, install them in their former location.

3. Hold the valves in place with a strip of masking tape, and turn the cylinder head right side up on the bench.
4. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.
5. Install the valve spring seats.

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6. If required, install the valve guide oil seal. Refer to section ADDITIONAL INFORMATION.
7. Install the valve springs and valve spring caps.
8. Thread the valve spring compressor J 7455-A into one of the rocker shaft bolt holes in the cylinder head.

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

NOTICE:
Use care to avoid scoring the valve stem with the valve cap when compressing the spring. Give the end of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will help properly seat the valve locks and reduce the chances of failure.

9. Apply pressure to free end of the tool, compressing the valve spring.
10. Install the two-piece tapered valve lock.
11. Release the tool, and install the valve locks on the remaining exhaust valves.
12. Check the position of the exhaust valve with spring checking gage J 25076-B.

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13. Observe the gage reading as the exhaust valve starts to open. See Figure 1-65.

NOTE:
The minimum allowable pressure required to open the exhaust valve, *must not* be less than 20 lbs.

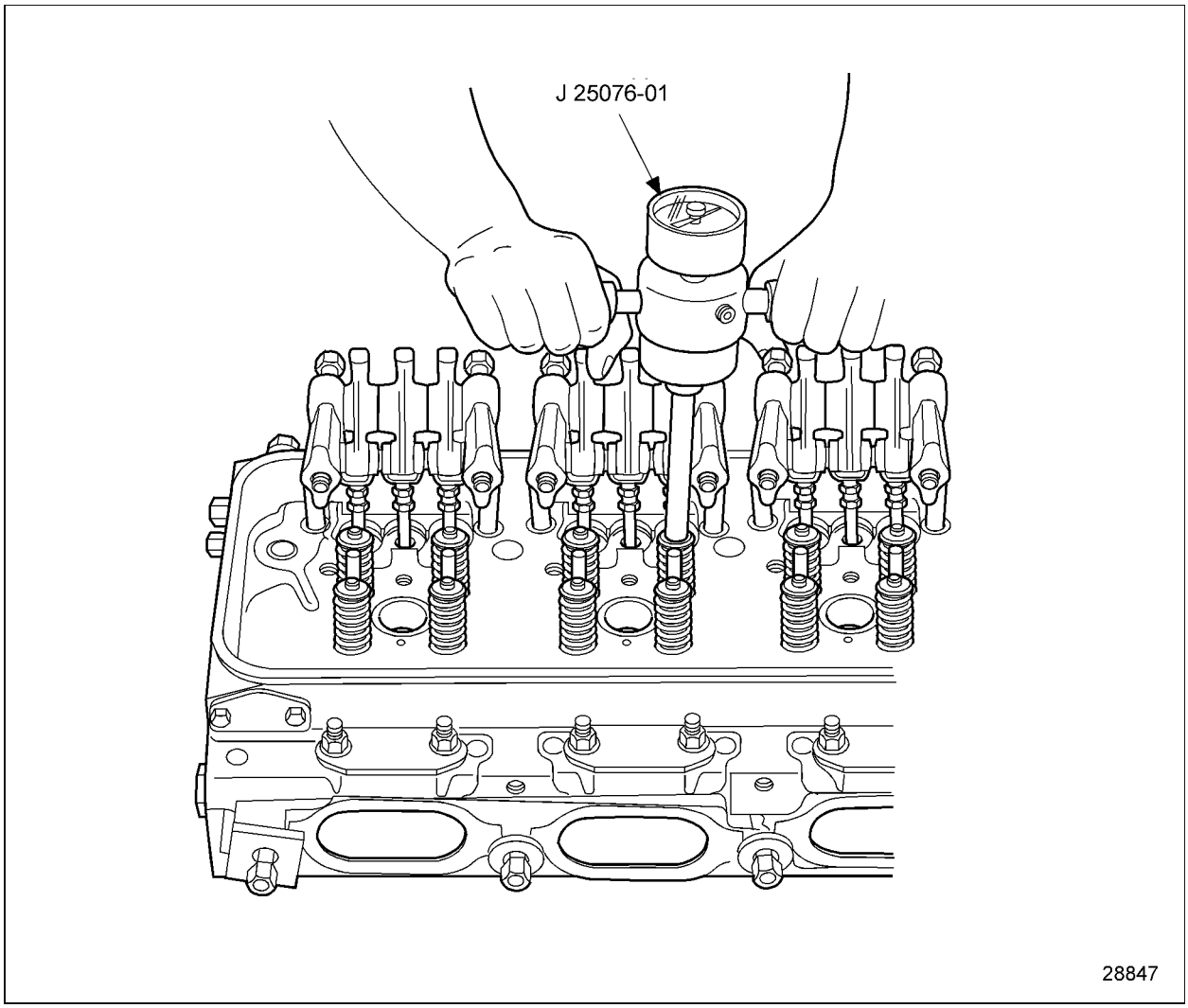


Figure 1-65 Checking Pressure Required to Open the Exhaust Valve in Cylinder Head with Tool J 25076-B

14. Install the injectors. Refer to section 2.2.5.
15. Install the rocker arms. Refer to section 1.4.9.
16. Install the shafts. Refer to section 1.4.9.
17. Install the brackets. Refer to section 1.4.9.
18. Install the cylinder head. Refer to section 1.3.5.
19. Adjust the exhaust valve bridges. Refer to section ADDITIONAL INFORMATION.

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20. Install the fuel pipes. Refer to section 2.2.5, step 5.
21. Fill the cooling system. Refer to section 13.12.2.
22. Adjust the exhaust valve clearance. Refer to section 12.2.
23. Time the injectors. Refer to section 12.3.
24. Start the engine, and check for leaks in the fuel, cooling and lubrication systems. Refer to section 13.11, refer to section 13.12, and refer to section 13.5.3.
25. Perform a complete engine tune-up. Refer to section 12.1.

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1.6 VALVE ROCKER COVERS

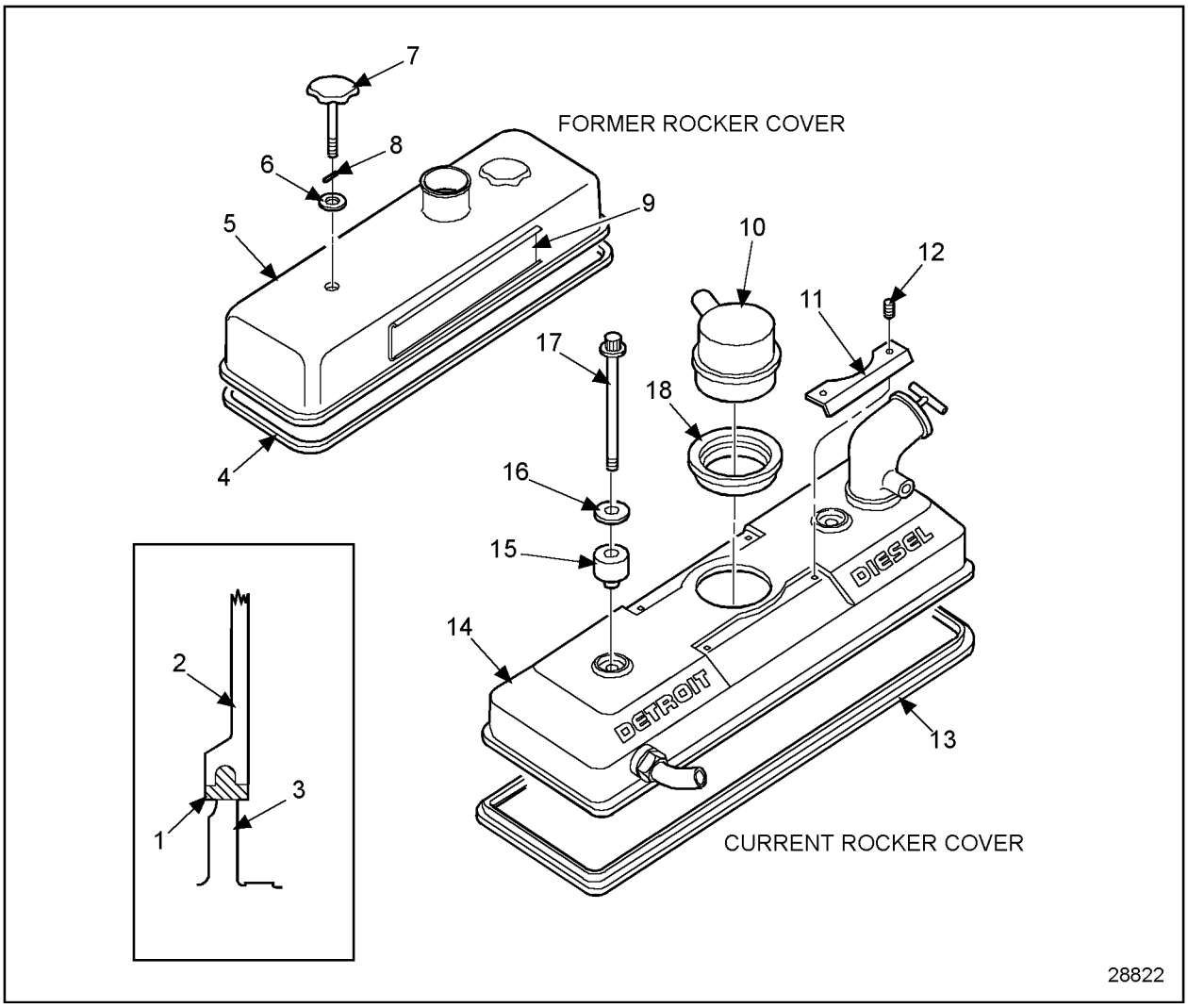
The valve rocker cover assembly completely encloses the valve and injector rocker arm compartment. Gaskets in the lower rail groove or in the flanged edge of the former stamped metal rocker cover, seal the cylinder head against oil leakage.

In former engines an option plate is inserted in the retainer and attached to one of the covers.

3/8 in.-16 twelve-point head shoulder bolts with a steel washer and silicone isolator hold the current die cast rocker cover in place. The bolts have a shoulder that bottoms against the cylinder head or throttle delay bracket. The isolators and gasket use low compression-set materials that provide sealing longevity and minimize engine noise levels.

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The former stamped metal rocker cover is held in place with hold-down knobs. See Figure 1-66.



1. Rocker Cover Gasket
2. Rocker Cover
3. Cylinder Head
4. Former Rocker Cover Gasket
5. Former Rocker Cover
6. Washer
7. Hold Down Knob
8. Locking Pin
9. Option Plate Retainer
10. Rocker Cover Breather
11. Hold Down Plate
12. Screw
13. Current Rocker Cover Gasket
14. Current Rocker Cover
15. Isolator
16. Washer
17. Hold Down Bolt
18. Breather Gasket

Figure 1-66 Valve Rocker Covers (Former and Current)

NOTICE:
Failure to use a rocker cover breather on the left-bank head can result in high engine crankcase pressure. Excessive pressure can cause crankshaft oil leakage and/or loss of oil through the dipstick tube.

Depending upon engine application, the valve rocker cover assembly may include a breather assembly or an oil filler.

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

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1.6.1 Repair or Replacement of Valve Rocker Cover

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-67.

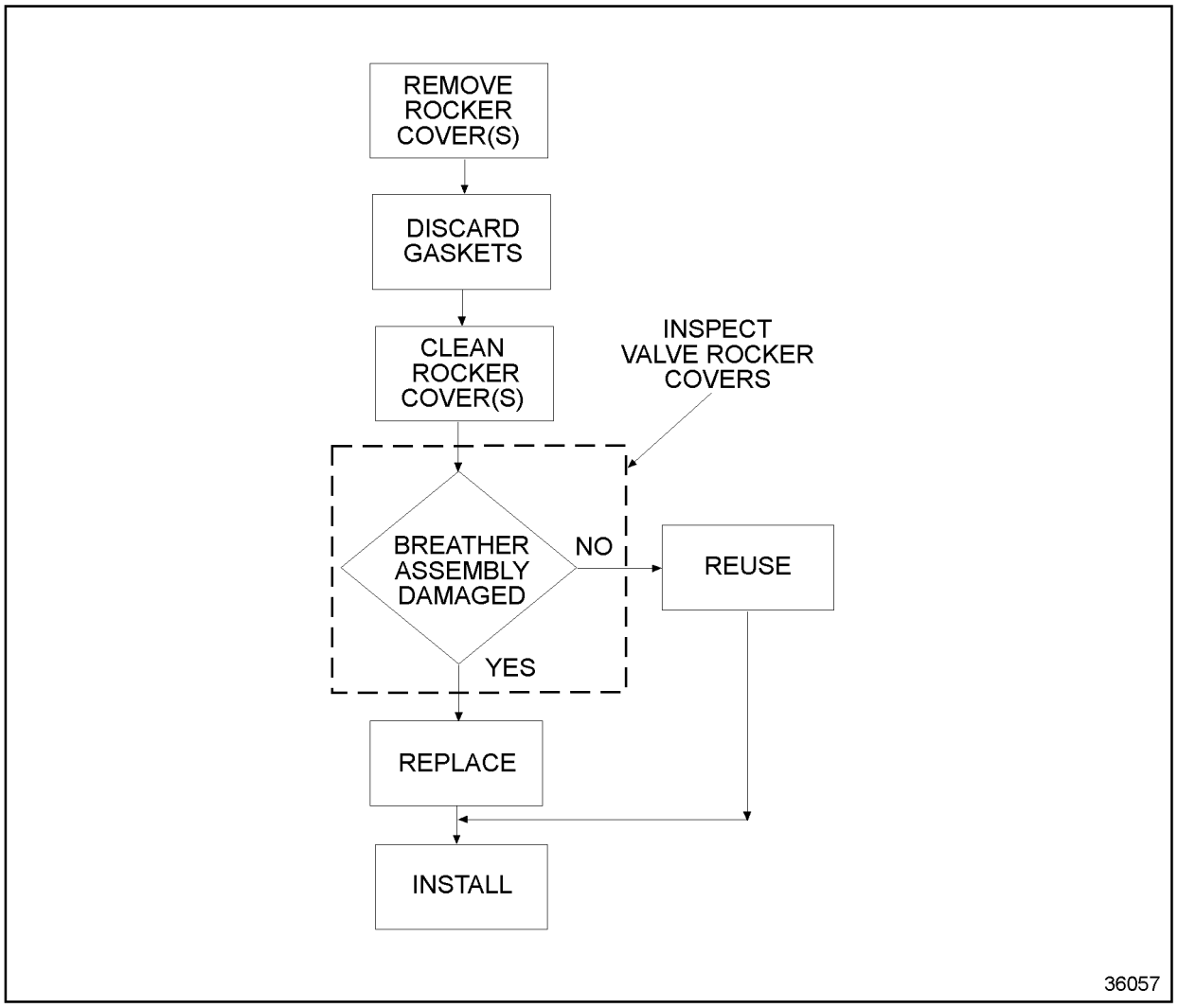


Figure 1-67 Flowchart for Repair or Replacement of Valve Rocker Cover

1.6.2 Removal of Valve Rocker Cover

Remove the valve rocker cover as follows:

1. Clean the valve rocker covers and around the covers before removing them from the engine to avoid dust or dirt from entering the valve mechanism.
2. Loosen the bolts or knobs.
3. Remove each cover from the engine.

1.6.2.1 Cleaning of Valve Rocker Cover

Prior to disassembly, clean the valve rocker cover 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. Blow out the groove in the rocker cover with compressed air to clean it.

NOTE:
Oil in the rocker cover or on the silicone gasket will make it difficult to install.

1.6.3 Disassembly of Valve Rocker Cover

Disassemble valve rocker cover as follows:

1. Press the stem side of the new "T" gasket out of the four corners of the groove.
2. Press the remainder of the gasket out of the groove.

1.6.3.1 Inspection of Valve Rocker Cover

Inspect the valve rocker cover as follows:

⚠ 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.

1. Wash 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 breather assembly with clean fuel oil and inspect for damage.
   [a] If breather assembly is damaged, it must be replaced.

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[b] If no damage is detected, the breather assembly may be reused.

1.6.4 Assembly of Valve Rocker Cover

Assemble the valve rocker cover as follows:

1. Press the stem side of the new "T" gasket into the four corners of the groove.
2. Press the remainder of the gasket in the groove.

NOTE:
Ensure the gasket stem bottoms in the groove. The gasket should not fall out when it is completely installed in the groove.

1.6.5 Installation of Valve Rocker Cover

Install the valve rocker cover as follows:

NOTE:
When replacing a former stamped rocker cover with the new die cast aluminum rocker cover, remove the adaptor studs from the cylinder head. The new bolts are installed directly into the tapped holes in the modulator mechanism.

NOTE:
Do not replace the valve rocker cover bolt with an ordinary bolt.

NOTE:
Do not use former gasket and hold-down knobs with the die cast cover.

CAUTION:
To avoid injury from fire, keep open flames, sparks, electrical resistance heating elements, or other potential ignition sources away when draining lubrication oil. Do not smoke when draining lubrication oil.

1. Lubricate the cylinder head rail and the flat surface of the gasket with a thin film of engine oil.
2. Place each cover on the engine.

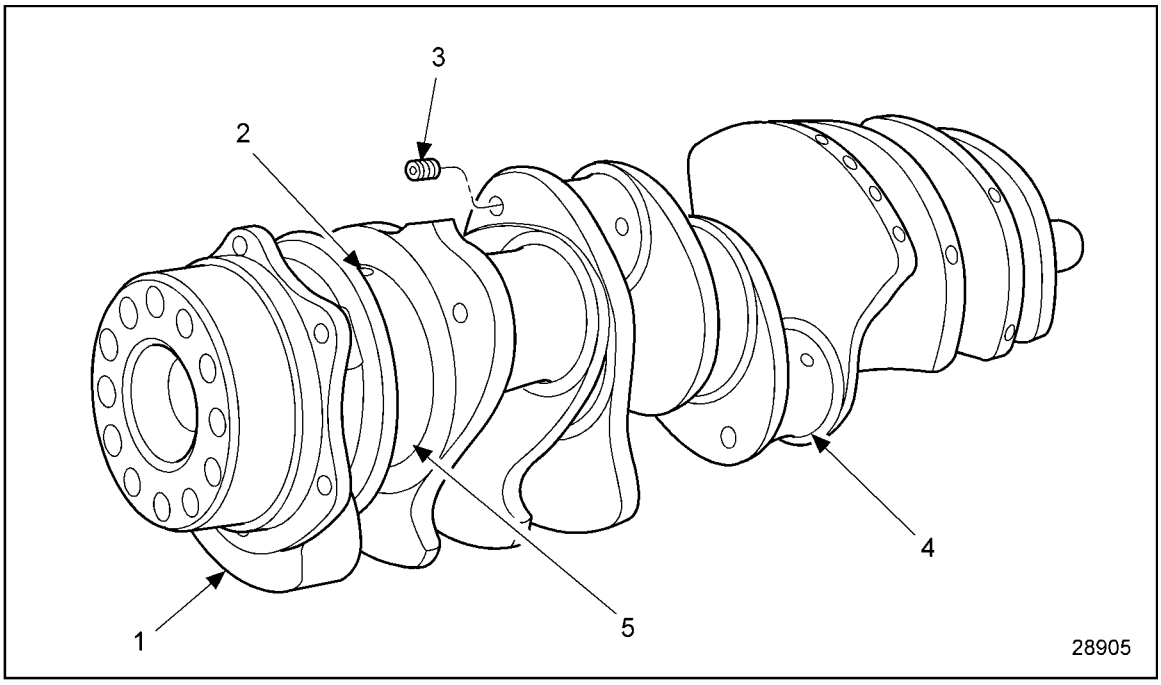
NOTICE:
Do not overtighten the shorter rocker cover bolt. If overtightened, the bracket will crack.

3. Tighten the bolts to 20-27 N·m (15-20 lb·ft) torque.

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1.7 CRANKSHAFT

The crankshaft is a one-piece steel forging, heat-treated to ensure strength and durability. See Figure 1-68. A two-piece crankshaft assembly is used on the 12V and 16V engines. The two halves are bolted together at the center flange. The main and connecting rod bearing journal surfaces and fillets on all crankshafts are induction hardened.



1. Counterweight
2. Lubricating Oil Hole
3. Plug
4. Connecting Rod Journal
5. Rear Main Bearing Journal

Figure 1-68 Typical 8V-92 Crankshaft

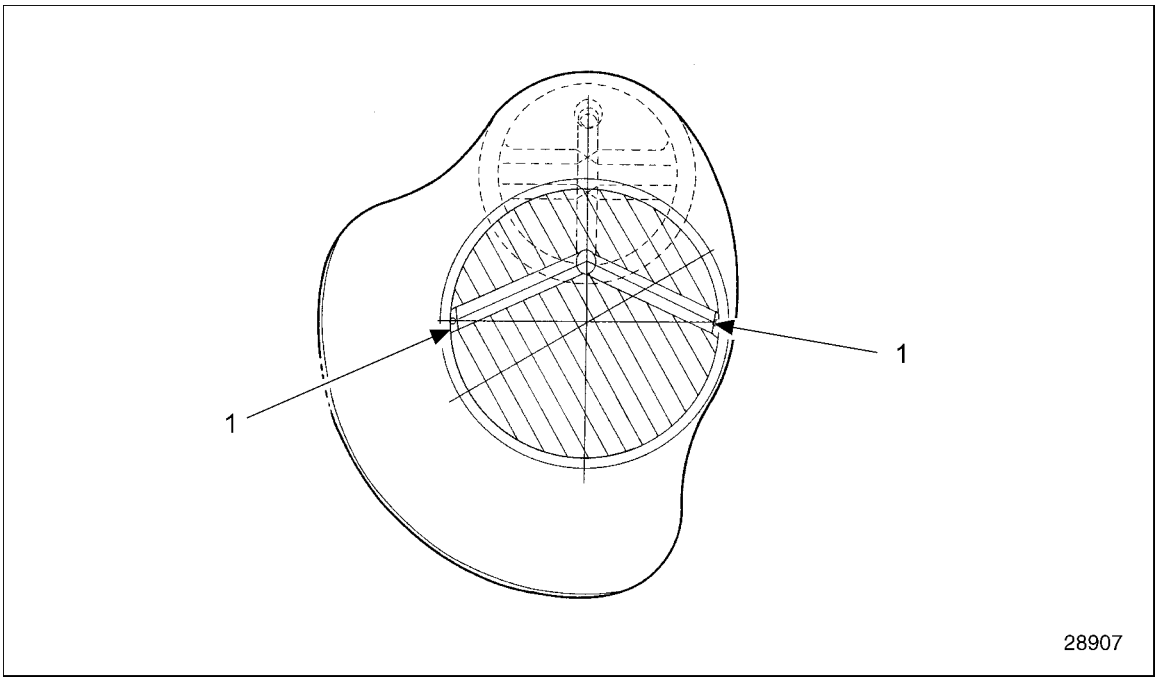
Counterweights incorporated in the crankshaft achieve complete static and dynamic crankshaft balance.

Thrust washers located at the rear main bearing cap control crankshaft end play. Drilled passages within the crankshaft and cylinder block provide full pressure lubrication to all connecting rod and main bearings. Twelve equally spaced tapped holes attach the flywheel on 8V engines.

Each main bearing journal has a 114.3 mm (4.5 in.) diameter and each connecting rod journal has a 76.2 mm (3 in.) diameter.

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The current crankshafts differ from the former in that the main bearing journal oil holes are offset approximately 90 degrees to the oil holes in the former crankshafts and are drilled at intersecting angles. See Figure 1-69. These changes provide up to a 50% thicker oil film on the main bearing journals during engine operation.



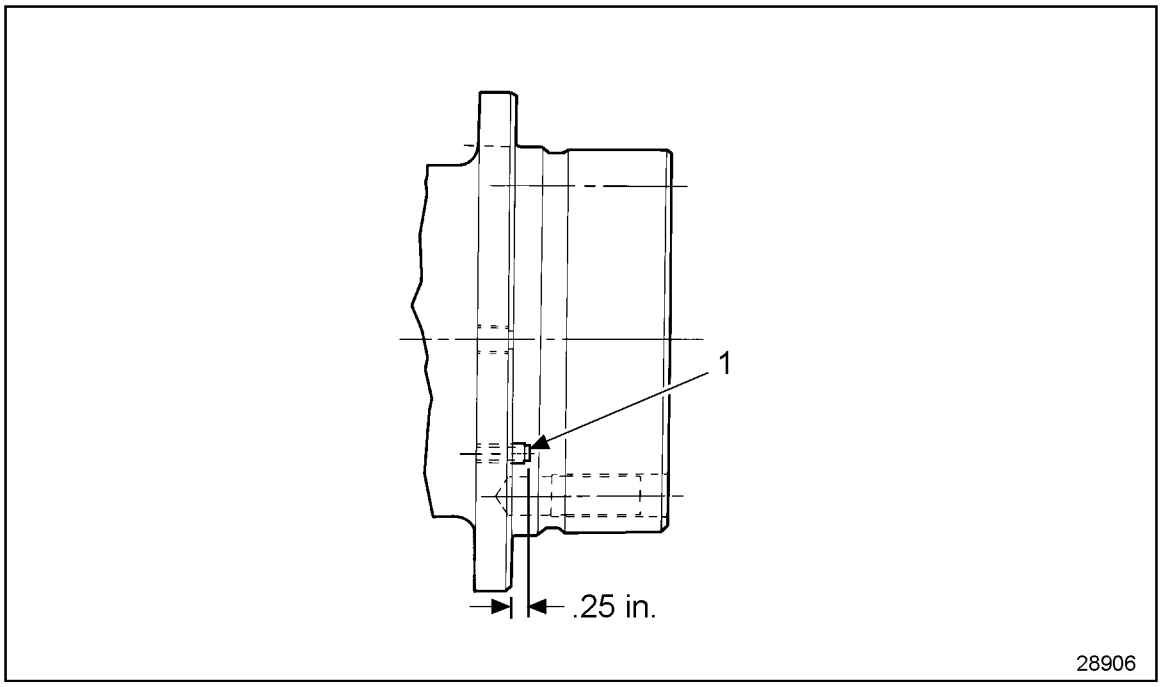
1. Oil Hole

Figure 1-69 Cross Sectional View of Crankshaft Showing Offset, Relocated Main Bearing Journal Oil Holes

The current crankshafts are unidirectional. Right-hand rotation crankshafts must be used with right-hand rotating engines. Left-hand rotation crankshafts must be used with left-hand rotating engines.

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Current timing gears have a hole drilled in their bolt flanges. This hole provides clearance for a new 1/4 in. x 3/4 in. roll pin installed in the timing gear end of the new crankshafts. See Figure 1-70. The pin permits the installation of right-hand crankshaft timing gears on right-hand crankshafts and left-hand timing gears on left hand crankshafts.



1. Roll Pin

Figure 1-70 Roll Pin Installed in End of Crankshaft

A similar clearance hole and roll pin is used in the mating flanges of the current 12V and 16V crankshaft halves to ensure that the right-hand front crankshaft half will only assemble to the right-hand rear crankshaft half, and the left-hand front crankshaft half will only assemble to the left-hand rear crankshaft half.

The new crankshafts have a seven-digit forging number on the front counterweights, followed by a letter "R" or "L." This distinguishes the former from the current and designates crankshaft rotation. The 12V and 16V crankshaft halves have new assembly marks that are used for alignment. These marks must be lined up when halves are assembled. The marks are abbreviated as follows:

- "FRH" Front Right-Hand
- "RRH" Rear Right-Hand
- "FLH" Front Left-Hand
- "RLH" Rear Left-Hand

New 8V crankshafts have an increased diameter at the in-pan oil pump drive gear area.

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The press fit oil pump drive gear eliminates the use of Loctite to secure the gear. Because of the large diameter in this area, a different oil pump drive hub is used on 8V engines with front cover oil pumps. The 6V crankshaft does not have the increased diameter at the oil pump drive gear area and may use the former oil pump drive hub with front cover oil pump. New production 6V engines are built with the new oil pump drive hub.

NOTE:
The new crankshafts and timing gears are completely interchangeable with the former crankshafts and timing gears for the same engine rotation. Only the new parts will be serviced.

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1.7.1 Repair or Replacement of Crankshaft

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-71.

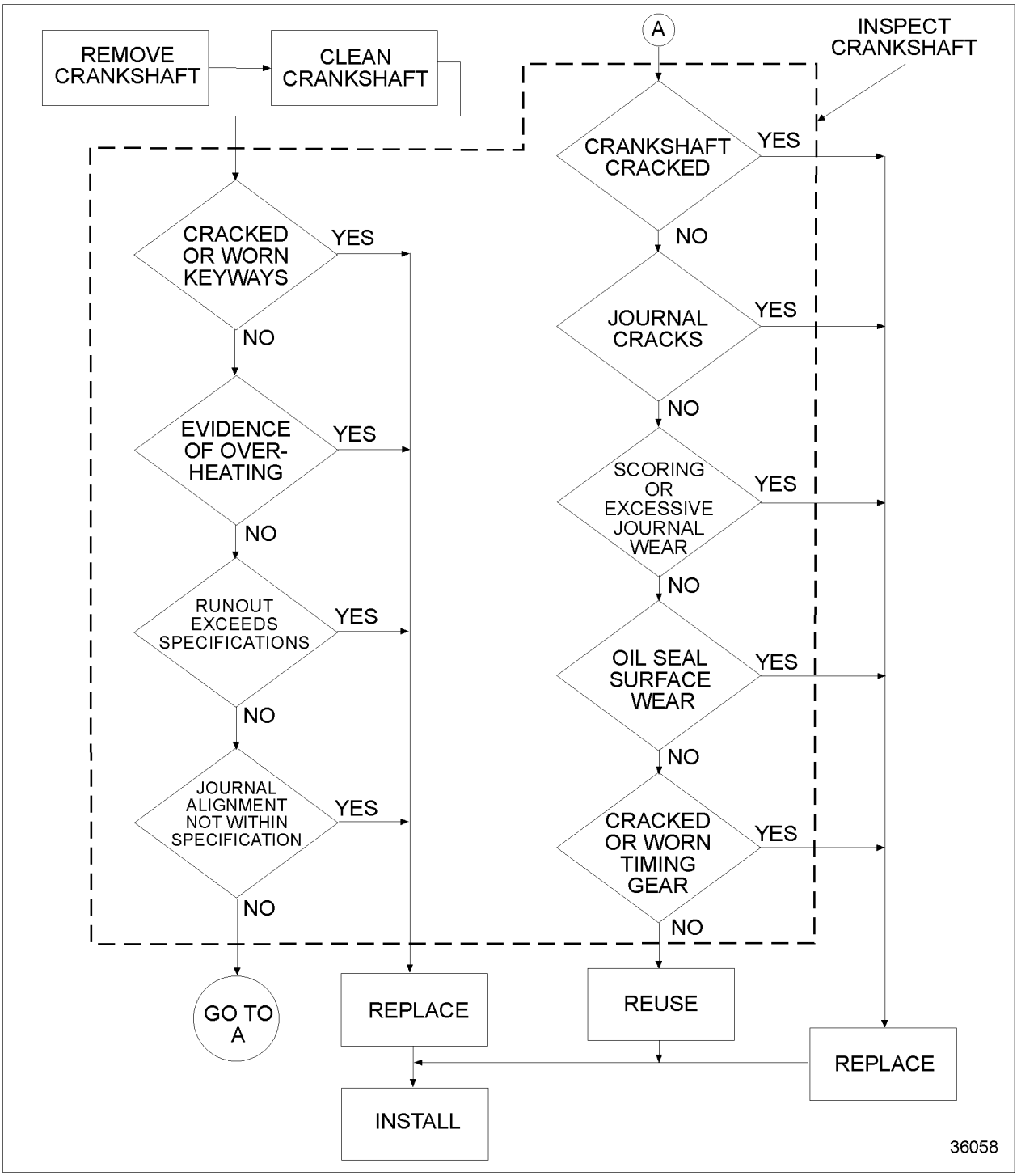


Figure 1-71 Flowchart for Repair or Replacement of Crankshaft

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1.7.2 Removal of Crankshaft

Prior to removing the crankshaft, remove the following components:

1. Remove the transmission. Refer to section 1.1.2.
2. Clean the engine exterior **.**
3. Drain the lubricating system. Refer to section 13.5.2.
4. Drain the cooling system crankcase. Refer to section 13.12.3.
5. Remove all engine to base attaching bolts.

⚠ CAUTION:

To avoid injury from a falling engine, do not use the engine lifter brackets alone when lifting the engine with a marine gear, main alternator, engine skid, engine module, radiator, or similar component attached. The engine lifter brackets are designed to lift the engine only.

6. Attach chain hoist and sling to the lifter brackets or eye bolts at each end of the engine.
7. Remove the engine.
8. Remove all of the accessories and assemblies necessary to mount the engine on the overhaul stand.

⚠ 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.

9. Mount the engine on an overhaul stand, and fasten it securely to the mounting plate.

NOTE:
For 6V and 8V engines, use overhaul stand J 29109 with adaptor J 33850. For 12V and 16V engines, use overhaul stand J 9389-04 and adaptor J 8650.

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⚠ CAUTION:

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

10. Release the lifting sling.
11. Remove the oil pan. Refer to section 3.11.2.
12. If it is mounted on the main bearing caps, remove the lubricating oil pump. Refer to section 3.2.2.
13. Remove the flywheel. Refer to section 1.16.2.
14. Remove the flywheel housing. Refer to section 1.16.2.

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

NOTICE:

Use care when removing the crankshaft cap or pulley retaining bolts so the vibration damper does not come off. If the damper is allowed to fall, damage to the internal components of the damper may result.

15. Remove the crankshaft cap or pulley retaining bolt and washer.
16. Remove the pulley if used.
17. Remove the vibration damper, except on 12V and 16V engines.
18. Remove the front engine support.
19. Remove the crankshaft front cover and oil pump assembly.
20. Remove the vibration damper inner cone or oil seal spacer.
21. Remove the cylinder heads. Refer to section 1.3.2.
22. Remove the connecting rod bearing caps.
23. Remove the main bearing caps and stabilizers.
24. Remove the thrust washers from each side of the rear main bearing cap.
25. Remove the pistons. Refer to section 1.21.2.
26. Remove the connecting rods. Refer to section 1.21.2.
27. Remove the liners. Refer to section 1.23.2.

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⚠ CAUTION:

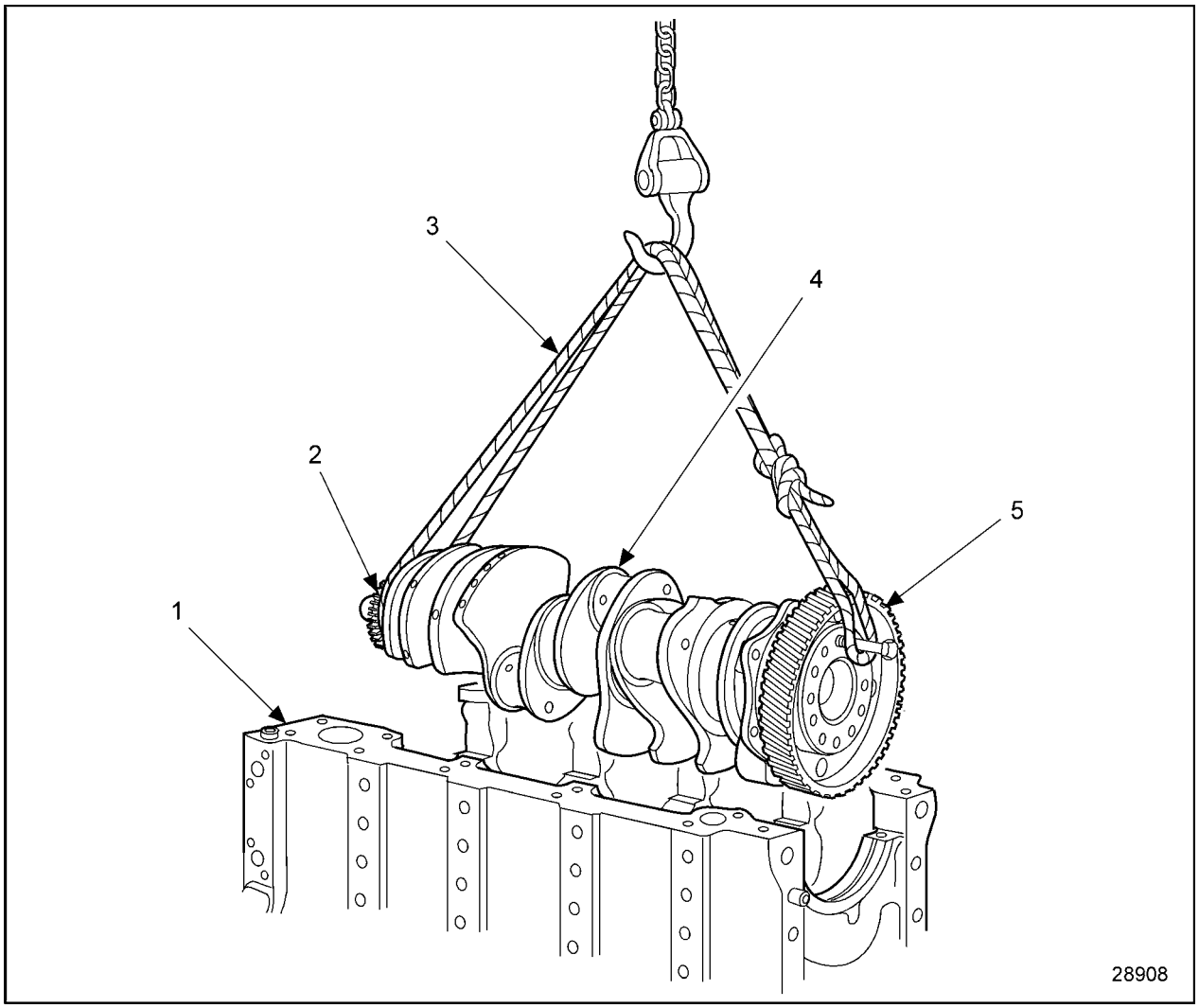
To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure crankshaft is securely attached to the lifting sling before removing from the engine. Part damage may result if the crankshaft breaks away from the lifting sling and falls.

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28. Remove the crankshaft, including the timing gear and oil pump drive gear. See Figure 1-72.



1. Cylinder Block
2. Oil Pump Drive Gear
3. Suitable Lifting Sling
4. Crankshaft
5. Crankshaft Timing Gear

Figure 1-72 Removing or Installing Crankshaft

29. On 6V and 8V engines, refer to step 31 to continue removal procedure.
30. On 12V and 16V engines, remove the following:
    - ☐ Remove the crankshaft, including the damper assembly. Refer to section 1.14.3.
    - ☐ Remove the timing gear, and hub at the front end. Refer to section 1.29.3.
    - ☐ Remove the oil pump driving gear and timing gear at the rear end. Refer to section 1.29.3.
    - ☐ Refer to section 1.7.2.1 for cleaning of crankshaft.
31. Remove the crankshaft timing gear from the crankshaft. Refer to section 1.29.2.

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32. Remove the oil pump drive gear and Woodruff keys from the crankshaft.

1.7.2.1 Cleaning of Crankshaft

Prior to inspection, clean the crankshaft as follows:

1. Remove the plugs and clean out the oil passages with a stiff wire brush.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

2. Clean the crankshaft 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.

3. Dry with compressed air.
4. Install the plugs. Torque to 14-16 N·m (10-12 lb·ft).
5. Use tool J 34650 to install the new seal-coated 1/8 in.-27 pipe plug.

1.7.2.2 Inspection of Crankshaft

Inspect crankshaft as follows:

1. Visually inspect the keyways for cracks or wear.
   [a] If cracked or worn, replace crankshaft.
   - For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.

- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no wear is evident, continue with the inspection.

2. Visually inspect the oil pump drive keyway for damage.

[a] If damaged, replace crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no damage is evident, proceed with inspection.

3. Visually inspect the crankshaft for evidence of overheating.

[a] If the heat treatment has been destroyed, replace crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If the heat treatment is not destroyed, continue inspection.

4. Inspect the crankshaft run-out by supporting the crankshaft on its front and rear journals on V-blocks, in a lathe or the inverted engine block, with only the front and rear upper bearing shells in place, check the bow.

[a] If the run-out limit is greater than that listed in Table 1-3, replace crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

Engine	Journals Supported On	Journals Measured	Max. Run-Out (Total Indicator Reading)
6V	No. 1 and No. 4	No. 2 and No. 3	0.05 mm (0.002 in.)
8V	No. 1 and No. 5	No. 2 and No. 4 No. 3	0.05 mm (0.002 in.) 0.10 mm (0.004 in.)
12V	No. 1 and No. 8	No. 2 and No. 7 No. 3 and No. 6 No. 4 and No. 5	0.05 mm (0.002 in.) 0.10 mm (0.004 in.) 0.15 mm (0.006 in.)
16V	No. 1 and No. 10	No. 2 and No. 9 No. 3 and No. 8 No. 4 and No. 7 No. 5 and No. 6	0.05 mm (0.002 in.) 0.10 mm (0.004 in.) 0.15 mm (0.006 in.) 0.20 mm (0.008 in.)

Table 1-3 Run-Out Limits

[b] If the run-out limit is within specification, continue inspection.

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Inspect the following run-out high spots on the adjacent journals:

5. If the run-out high spots on the adjacent journals are in *opposite directions,* the sum must not exceed 0.08 mm (0.003 in.) total indicator reading.

   [a] If the sum exceeds 0.082 mm (0.003 in.), replace crankshaft.

   - For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
   - For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

   [b] If the sum does not exceed 0.08 mm (0.003 in.), continue inspection.

6. If the run-out high spots on the adjacent journals are in the *same direction*, the difference must not exceed 0.08 mm (0.003 in.) total indicator reading.

   [a] If the sum exceeds 0.08 mm (0.003 in.), replace crankshaft.

   - For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
   - For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

   [b] If the sum does not exceed 0.08 mm (0.003 in.), continue inspection.

7. If the run-out high spots on the adjacent journals are at *right angles* to each other, the sum must not exceed 0.10 mm (0.004 in.) total indicator reading or 0.05 mm (0.002 in.) on each journal.

   [a] If the sum exceeds 0.10 mm (0.004 in.) total indicator reading or 0.05 mm (0.002 in.) on each journal, replace crankshaft.

   - For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
   - For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

   [b] If the sum does not exceed 0.10 mm (0.004 in.) total indicator reading or 0.05 mm (0.002 in.) on each journal, continue inspection.

8. Measure adjacent journal alignment.

[a] Measure all main and connecting rod bearing journals. See Figure 1-73.

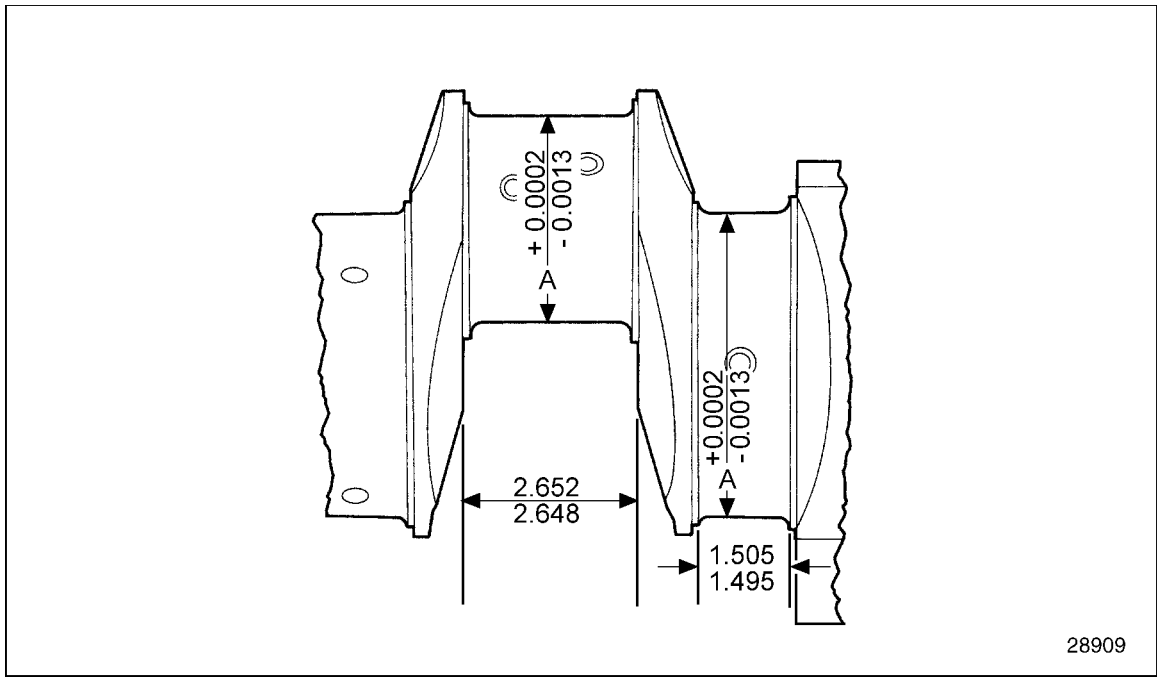


Figure 1-73 Dimensions of Crankshaft Journals

NOTE:
Measure the journals at several places on the circumference so that taper, out-of-round, and bearing clearances can be determined.

NOTE:
Crankshaft measurements must be accurate to the nearest 0.005 mm (0.0002 in.).

[b] If the maximum connecting rod or main bearing journal-to-bearing shell clearance, with new shells exceeds 0.114 mm (0.0045 in.) on connecting rod journals or 0.140 mm (0.0055 in.) on main bearing journals, regrind the crankshaft. Refer to section ADDITIONAL INFORMATION.

[c] If a used crankshaft main bearing journal taper exceeds 0.010 mm (0.0004 in.) or the out-of-round is greater than 0.013 mm (0.0005 in.), replace crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[d] If the measurements fall within these specifications, proceed with inspection.

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9. Measure the crankshaft thrust washer surfaces. See Figure 1-74.

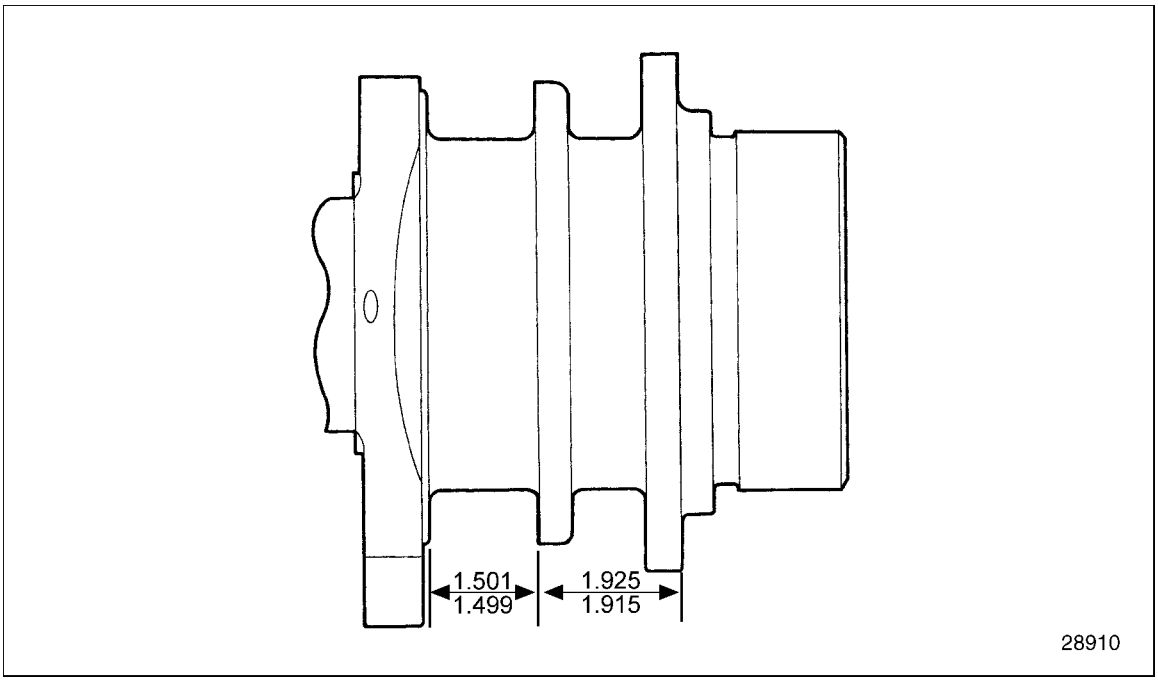


Figure 1-74 Standard Dimension at Rear Main Bearing Thrust Washer

[a] If the thrust washer surface measurements exceed the specified limits, replace crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If the thrust washer surface measurements fall within the specified limits, continue with inspection.

10. Visually inspect for bending fatigue failures starting at the pin fillet, progressing throughout the crank cheek, and possibly extending into the main journal fillet. The following will impose a bending stress on the crankshaft:
    - Main bearing bore misalignment
    - Improperly fitted bearings
    - Bearing failures
    - Loose or broken bearing cap
    - Unbalanced pulleys
    - Too tight drive belts

    [a] If fatigue failure is evident, correct the bending stress cause, and replace crankshaft.

    - For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.

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- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no fatigue failure is present, proceed with inspection.

11. Visually inspect for cracks on the crankshaft. Cracks will occur on either side of the damaged bearing. See Figure 1-75.

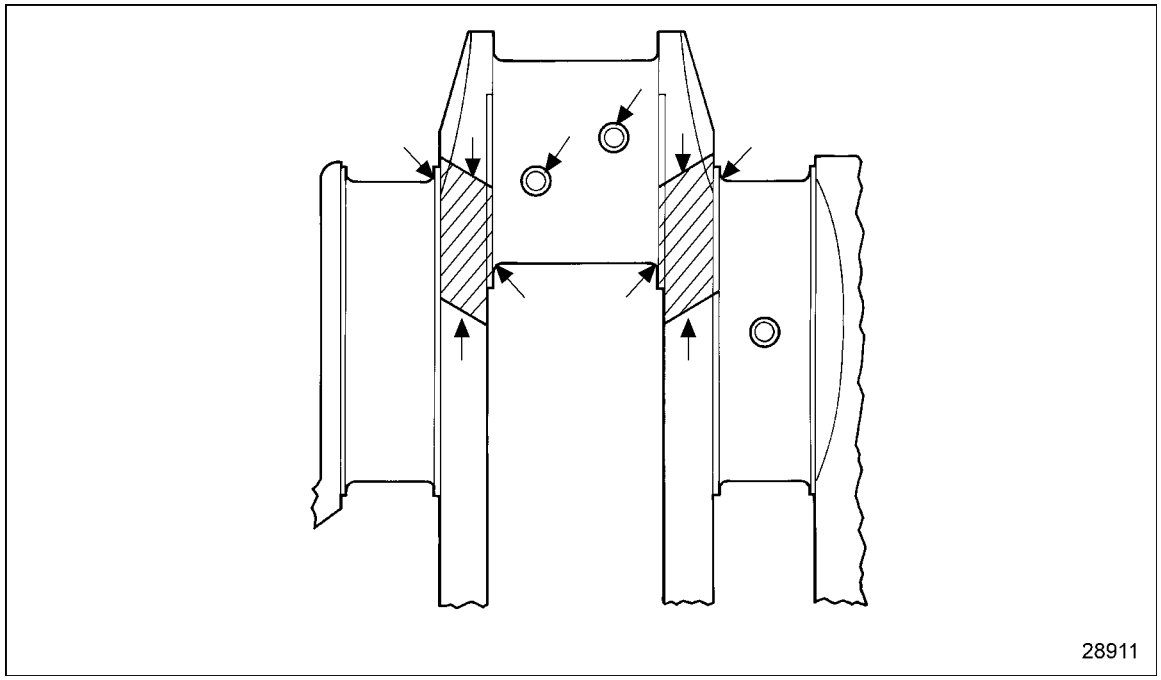


Figure 1-75 Critical Crankshaft Loading Zones

[a] If cracked, replace the crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If the crankshaft is not cracked, continue inspection.

12. Inspect for torsional fatigue in the following areas:
    - Connecting rod journal
    - Crank cheek in the rear
    - Front end of the crankshaft at the oil pump drive key slot
    - Connecting rod journal failures at the fillet or oil hole at 45 degrees to the shaft axis

NOTE:
A combination of abnormal speed and load conditions may cause torsional vibration, that imposes high stress at certain locations.

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NOTICE:
A loose, damaged, or defective vibration damper, a loose flywheel, or the introduction of improper or additional pulleys or couplings are usual causes of torsional failure. Overspeeding the engine or resetting the governor for speeds not intended for the engine application can contribute to torsional failure.

[a] If evidence of torsional fatigue is detected, replace the crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no evidence of torsional fatigue is detected, continue inspection.

13. Inspect the crankshaft journal surfaces for score marks.
    [a] If excessively scored, grind the journal surfaces. Refer to section ADDITIONAL INFORMATION.
    [b] If the journals are not scored, continue inspection.
14. Visually inspect the crankshaft oil seal contact surface for roughness or grooves.
    [a] If excessively rough or grooved, sleeve the surface. Install an oversized seal. Refer to section 1.8.5.
    [b] If the crankshaft oil seal contact surface is not rough or grooved, continue with inspection.
15. Visually inspect the crankshaft thrust surfaces for excessive wear or grooves.
    [a] If excessively worn or grooved, regrind the surfaces. Refer to section ADDITIONAL INFORMATION *"Crankshaft Grinding"*.
    [b] If not excessively worn or grooved, continue inspection.
16. Inspect the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth.
    [a] If worn or chipped, replace the gears. Refer to section 1.29.6.
    [b] If no wear or chipping is evident, proceed with inspection.
17. Inspect crankshaft for cracks. Refer to section 1.7.3 for *"Methods of Inspection"*.

1.7.3 Methods for Inspecting Crankshaft

Any one or a combination of the following methods can be used for checking a crankshaft for cracks. If any method reveals cracks, the crankshaft should be replaced.

1.7.3.1 Inspection of Crankshaft using the Magnetic Particle Method

Perform the magnetic particle method as follows:

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1. Magnetize the crankshaft.
2. Cover with a fine magnetic powder or solution.

NOTE:
The magnetic powder or solution will gather around any cracks. See Figure 1-76.

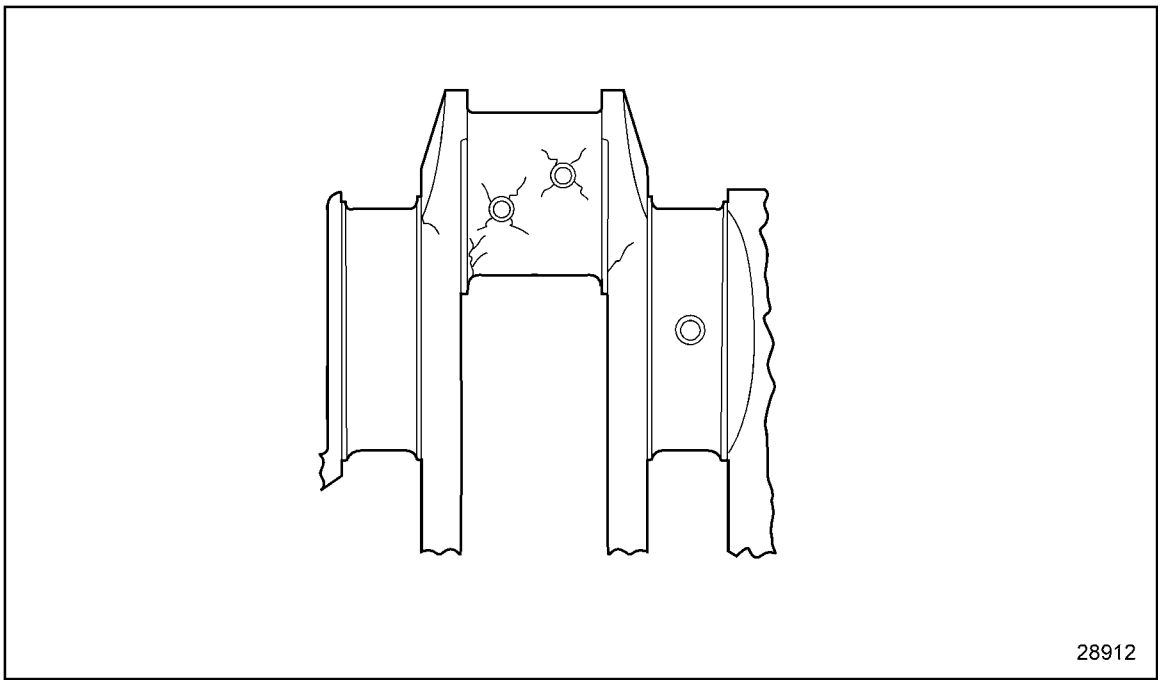


Figure 1-76 Crankshaft Fatigue Cracks

[a] If any cracks are revealed, replace the crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no cracks are evident, reuse the crankshaft.

3. Demagnetize the crankshaft.

1.7.3.2 Inspect Crankshaft using Fluorescent Magnetic Particle Method

Perform the fluorescent magnetic particle method as follows:

1. Magnetize the crankshaft.
2. Cover with magnetic, fluorescent powder or solution.
3. Hold the crankshaft under a "black light."

NOTE:
Very fine cracks will be disclosed, especially on discolored or dark surfaces.

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[a] If any cracks are revealed, replace the crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no cracks are evident, reuse the crankshaft.

4. Demagnetize the crankshaft.

1.7.3.3 Inspect Crankshaft using Fluorescent Penetrant Method

Perform the fluorescent penetrant method as follows:

1. Apply a highly fluorescent liquid penetrant to the crankshaft.
2. Wipe off excess penetrant.
3. Dry the crankshaft.
4. Apply a developing powder to draw the penetrant out of the flaws.
5. Hold the crankshaft under a "black light."

NOTE:
Cracks will be disclosed under the "black light."

[a] If any cracks are revealed, replace the crankshaft.

- For replacement of the *one piece* crankshaft, refer to section 1.7.4, refer to section 1.7.4.1, and refer to section 1.7.5.
- For replacement of the *two piece* crankshaft, refer to section 1.7.6, refer to section 1.7.6.1, and refer to section 1.7.7.

[b] If no cracks are evident, reuse the crankshaft.

1.7.4 Installation of the One Piece Crankshaft

Install the one piece crankshaft as follows:

1. If a new crankshaft is to be installed, steam clean it to remove the rust preventive.

⚠ 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 out the oil passages with compressed air.
3. Install the plugs.
4. Install the crankshaft timing gear on the crankshaft. Refer to section 1.29.7.
5. Install the oil pump drive gear on the crankshaft. Refer to section 3.2.7.
6. Install the upper main bearing shells in the block. Refer to section 1.10.3. If installing oil bearing shells, place them in the same locations from where 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 be installed.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

7. Apply clean engine oil 360 degrees around all crankshaft bearing journals.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure crankshaft is securely attached to the engine before releasing the lifting sling. Part damage may result if the crankshaft breaks away from the engine and falls.

8. Install the crankshaft in the engine. Align the timing gear and idler gear. Refer to section 1.25 for the correct gear train timing method.

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

NOTE:
If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. See Figure 1-77. Dimensions are listed in Table 1-4.

Nominal Size	Thrust Washer Thickness (Minimum)	Thrust Washer Thickness (Maximum)
Standard	3.023 mm (0.1190 in.)	3.099 mm (0.1220 in.)
0.005 in. Oversize	3.150 mm (0.1240 in.)	3.226 mm (0.1270 in.)
0.010 in. Oversize	3.277 mm (0.1290 in.)	3.353 mm 1.4 (0.1320 in.)

Table 1-4 Dimensions for Oversize Thrust Washers

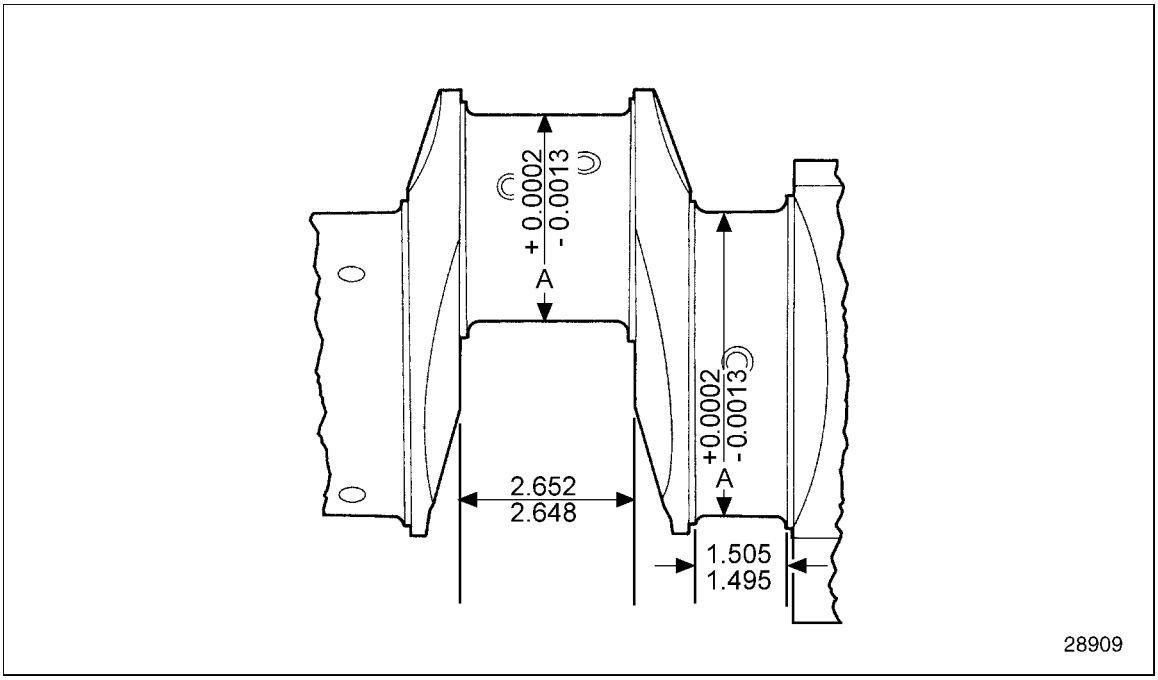


Figure 1-77 Dimensions of Crankshaft Journals

10. Install the lower bearing shells (no oil slot) in the bearing caps. If the old bearing shells are reused, install them in the same bearing from which they were removed. Refer to section 1.10.3.
11. Install the bearing caps and lower bearing shells. Refer to section 1.10.3.

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

12. Install the cylinder liner, piston, and connecting rod assemblies. Refer to section 1.23.3.
13. Install the cylinder heads. Refer to section 1.3.5.
14. Install the flywheel housing. Refer to section 1.19.3.
15. Install the flywheel. Refer to section 1.16.5.

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

16. Install the crankshaft front cover.
17. Install the oil pump assembly. Refer to section 3.2.9.
18. Install the engine front support.
19. Install the vibration damper inner cone or oil seal spacer.
20. Install the vibration damper assembly, if used.
21. Install the crankshaft cap or pulley. Refer to section 1.9.3.
22. Install the 12V and 16V engine lubricating oil pump assembly. Refer to section 3.2.10.

1.7.4.1 Inspection of the One Piece Crankshaft for Distortion

Inspect the crankshaft for distortion as follows:

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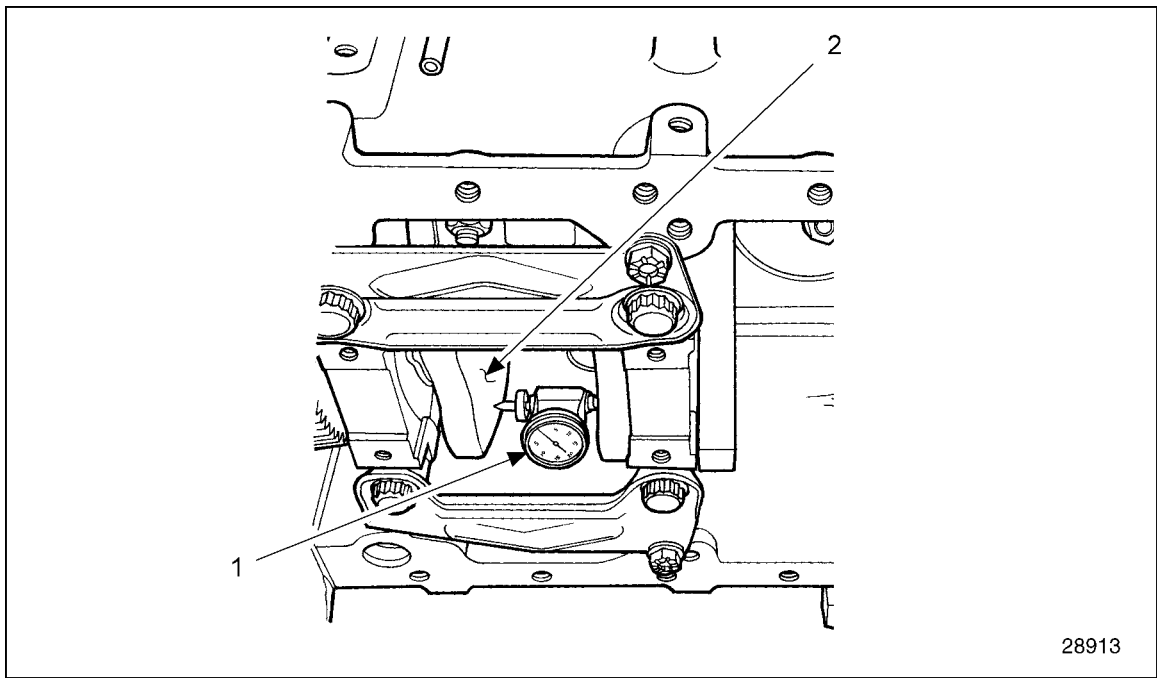
NOTICE:
Check the crankshaft for distortion at the rear connecting rod journal counterweights before and after installing the power take-off reduction gear assembly, transmission, or power generator. An improperly installed power take-off reduction gear assembly, transmission, or power generator can distort the crankshaft and cause a crankshaft failure.

NOTICE:
Overtightened drive belts can cause crankshaft distortion. Refer to section 13.18 for recommended tensions.

NOTICE:
Detroit Diesel is not responsible for system damage caused by engine-to-driven component interference and/or distortion. The engine crankshaft end play check and crankshaft distortion check must be performed.

1. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the six o'clock position.
2. Center punch a 6.4 mm (0.25 in.) hole in the inside face of each counterweight cheek.

3. Install a Starrett® No. 696 dial gage, or equivalent, in the center punch holes in the cheek of each counterweight. See Figure 1-78.



1. Dial Indicator Gage
2. Crankshaft Cheek

Figure 1-78 Crankshaft Distortion Measuring Gage (Mounted on Crankshaft)

4. Set the dial indicator at zero.
5. Rotate the crankshaft approximately 90 degrees in both directions. Do not allow the gage to contact the connecting rod caps or bolts.
6. Keep a record of the dial indicator readings at the 3, 6, and 9 o'clock positions. The maximum allowable variation is 0.114 mm (0.0045 in.) total indicator reading.
7. If the gage reading exceeds 0.114 mm (0.0045 in.), check the reduction gear, transmission, or power generator for improper installation.
8. Realign, if necessary.
9. Remove the dial gage.

1.7.5 Installation of the One Piece Crankshaft (Continued)

Continue installing the crankshaft as follows:

1. Affix a new gasket to the oil pan flange. Install the oil pan. Refer to section 1.7.5.

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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.

CAUTION:

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

2. Attach chain hoist and sling to the lifting bracket or eye bolts at each end of the engine.
3. Remove the engine from the overhaul stand.

NOTICE:

Failure to inspect parts thoroughly before installation, failure to install the proper parts, or failure to install parts properly can result in component or engine malfunction and/or damage.

4. Install all accessories that were removed.
5. Refill the crankcase to the proper level on the dipstick. Refer to section 13.5.1.
6. Refer to section 11.5 for engine run-in procedures.

1.7.6 Installation of the Two Piece Crankshaft

Install the two piece crankshaft as follows:

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. If a new crankshaft is to be installed, steam clean it to remove the rust preventive.

⚠ 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 out the oil passages with compressed air.
3. Install the plugs.

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 be installed.

4. Assemble the crankshaft timing gear and front timing gear damper. Refer to section 1.29.6.
5. Install the upper slotted main bearing shells in the cylinder block. Refer to section 1.10.3.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

6. Apply clean engine oil 360 degrees around all crankshaft bearing journals.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure crankshaft is securely attached to the engine before releasing the lifting sling. Part damage may result if the crankshaft breaks away from the engine and falls.

7. Position each crankshaft half in the cylinder block.

NOTE:
Install the crankshaft in place so the timing marks on the crankshaft timing gear and the idler gear match. Refer to section 1.29 for the correct method of timing the gear train.

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

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 be installed.

NOTE:
If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. See Figure 1-79. Dimensions are listed in Table 1-5.

Nominal Size	Thrust Washer Thickness (Minimum)	Thrust Washer Thickness (Maximum)
Standard	3.023 mm (0.1190 in.)	3.099 mm (0.1220 in.)
0.005 in. Oversize	3.150 mm (0.1240 in.)	3.226 mm (0.1270 in.)
0.010 in. Oversize	3.277 mm (0.1290 in.)	3.353 mm 1.4 (0.1320 in.)

Table 1-5 Dimensions for Oversize Thrust Washers

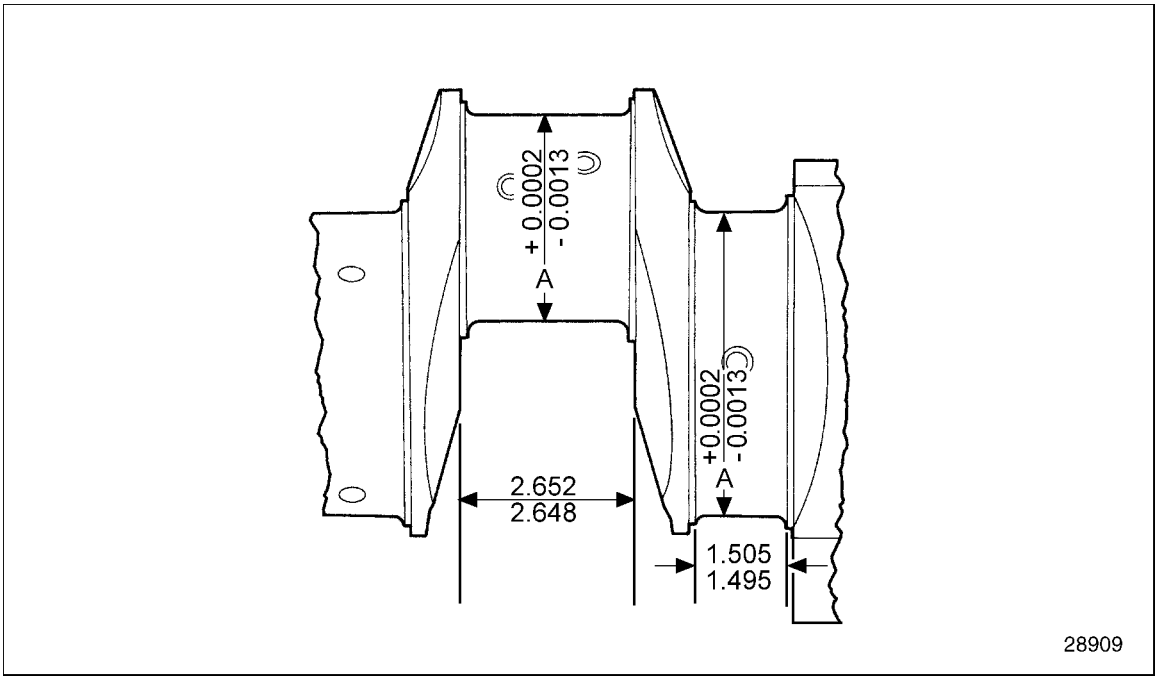


Figure 1-79 Dimensions of Crankshaft Journals

9. Sharply rap the caps with a soft hammer to seat them properly.

10. Uniformly tighten each set of the former main bearing cap bolts to 339-352 N·m (250-260 lb·ft) torque.

NOTE:
Do not mix the former and new main bearing cap bolts on an engine.

11. Tighten the new bolts that require a 15/16 in. socket to 312-325 N·m (230-240 lb·ft) torque.

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

12. Position a dial indicator on No. 5 and No. 6 journals.
13. Rotate the crankshaft halves until the crankshaft assembly marks "F" and "R" are in alignment on the two crankshaft end flanges.

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14. Install four bolts and nuts 90 degrees apart. See Figure 1-80.

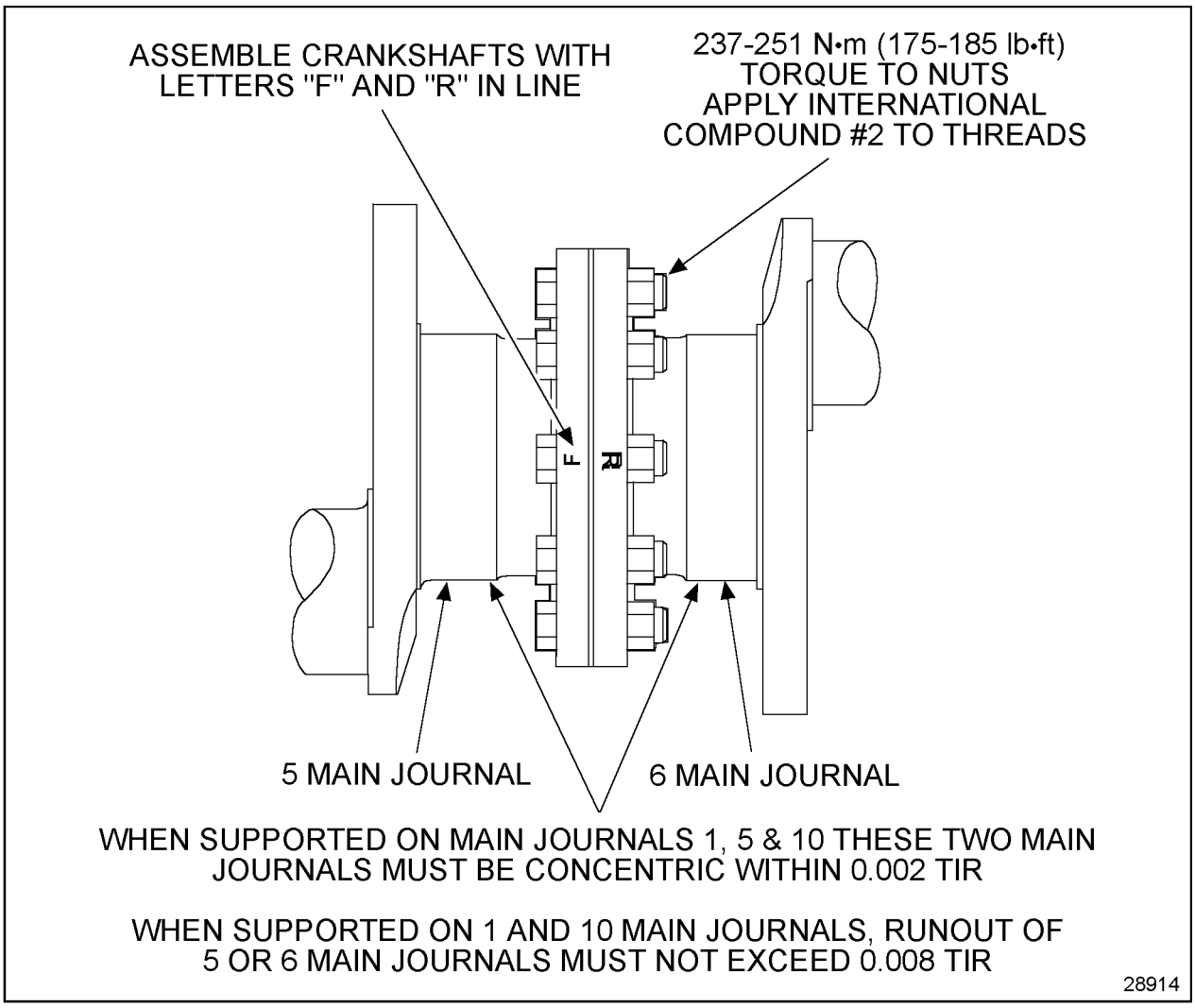


Figure 1-80 Two-Piece Crankshaft (12V and 16V)

15. Tighten the four bolts and nuts.
16. While slowly rotating the crankshaft, tap the flanges. The two center adjacent journals must be concentric within 0.05 mm (0.002 in.) total indicator reading and must not run-out more than 0.20 mm (0.008 in.) total indicator reading.
17. Install the remaining bolts and nuts.
18. Alternately torque each nut (180 degrees apart) until all nuts have been tightened to 238-251 N·m (175-185 lb·ft).

NOTE:
Because of the space limitations, a torque wrench adaptor J 22898-A must be used. The torque wrench reading must be adjusted according to the increase in the torque wrench

length. Use the following formula to determine the adjusted torque reading: Tw = Ta (L / (L + A))

If the effective length of the wrench (L) is 22 in., and the adaptor (A) is 3 in., a reading of 215 N·m (158 lb·ft) should be obtained. This will ensure that the bolt is torqued to 244 N·m (180 lb·ft). See Figure 1-81.

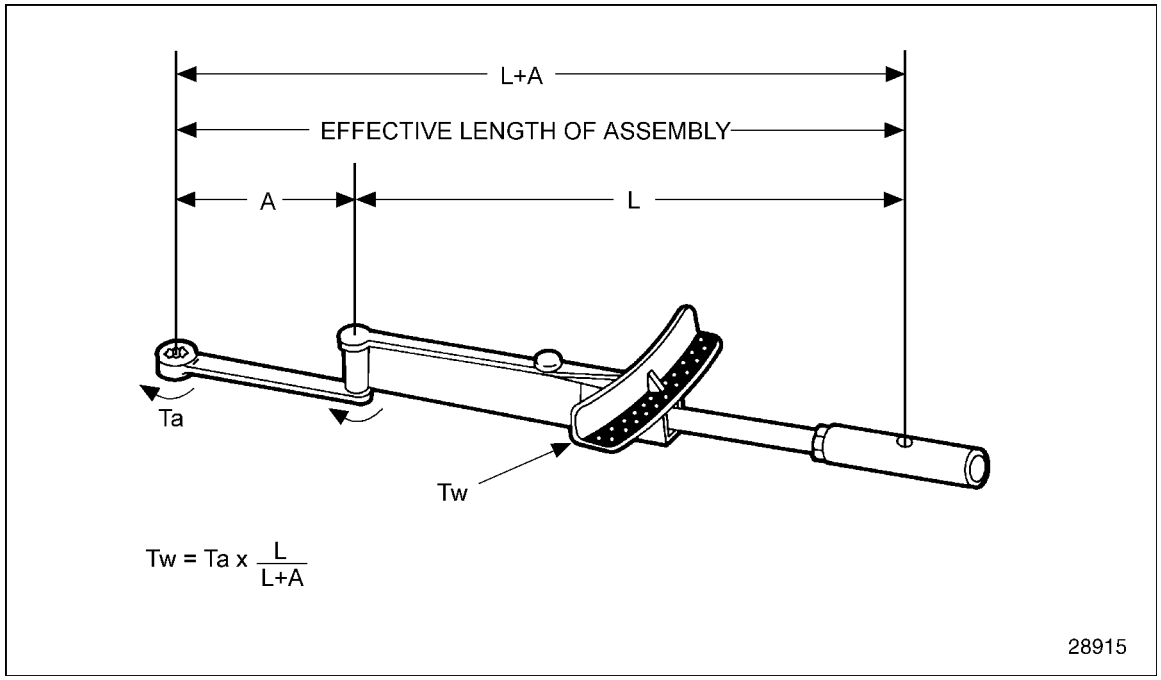


Figure 1-81 Calculating Torque When an Adaptor is Used

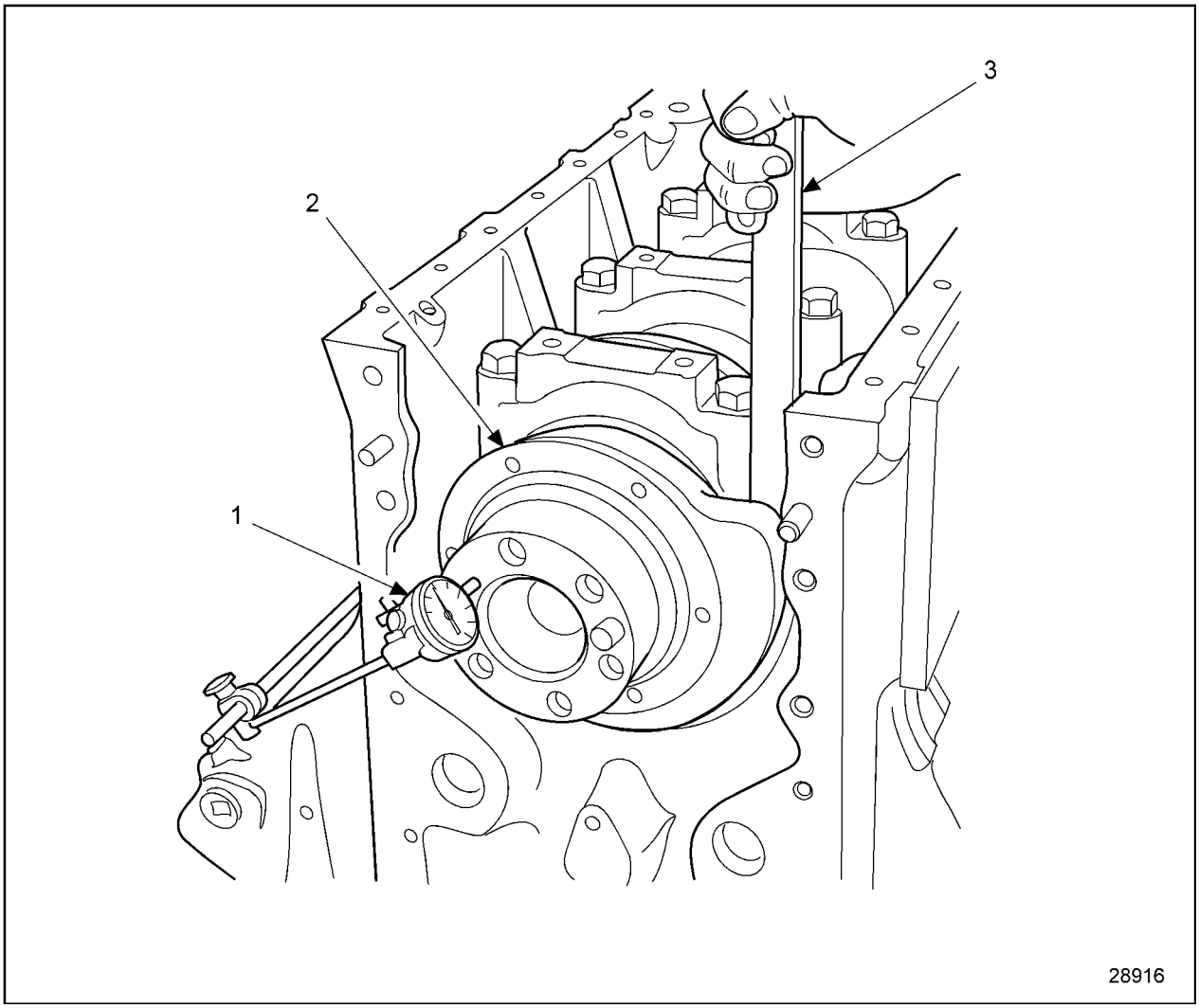
19. Install the two center main bearing caps.

1.7.6.1 Inspection of the Two Piece Crankshaft for End Play

Check the crankshaft end play as follows:

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1. Move the crankshaft toward the gage with a small (less than 12 in.) pry bar. See Figure 1-82.



1. Dial Indicator
2. Crankshaft
3. Pry Bar

Figure 1-82 Checking Crankshaft End Play

2. Keeping constant pressure on the pry bar, set the dial indicator to zero.
3. Remove and insert pry bar on the other side of the bearing cap.
4. Force crankshaft in the opposite direction, and observe the amount of end play on the dial. The end play should be 0.10-0.28 mm (0.004-0.011 in.) with new parts or a maximum of 0.46 mm (0.018 in.) with used parts.

NOTE:
Insufficient end play can result from a misaligned rear main bearing or a burr or dirt on the inner face of one or more thrust washers.

1.7.7 Installation of the Two Piece Crankshaft (Continued)

Continue crankshaft installation as follows:

1. Install the cylinder liner, piston, and connecting rod assemblies. Refer to section 1.23.3.
2. Install the cylinder heads. Refer to section 1.3.5.
3. Install the flywheel housing. Refer to section 1.19.3.
4. Install the flywheel. Refer to section 1.16.5.

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

5. Install the crankshaft front cover.
6. Install the oil pump assembly. Refer to section 3.2.9.
7. Install the engine front support.
8. Install the vibration damper inner cone or oil seal spacer.
9. Install the vibration damper assembly, if used.
10. Install the crankshaft cap or pulley. Refer to section 1.15.

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NOTICE:
Check the crankshaft for distortion at the rear connecting rod journal counterweights before and after installing the power take-off reduction gear assembly, transmission, or power generator. An improperly installed power take-off reduction gear assembly, transmission, or power generator can distort the crankshaft and cause a crankshaft failure.

NOTICE:
Overtightened drive belts can cause crankshaft distortion. Refer to section 13.18 for recommended tensions.

NOTICE:
Detroit Diesel is not responsible for system damage caused by engine-to-driven component interference and/or distortion. The engine crankshaft end play check and crankshaft distortion check must be performed.

11. Install the 12V and 16V engine lubricating oil pump assembly. Refer to section 3.2.10.

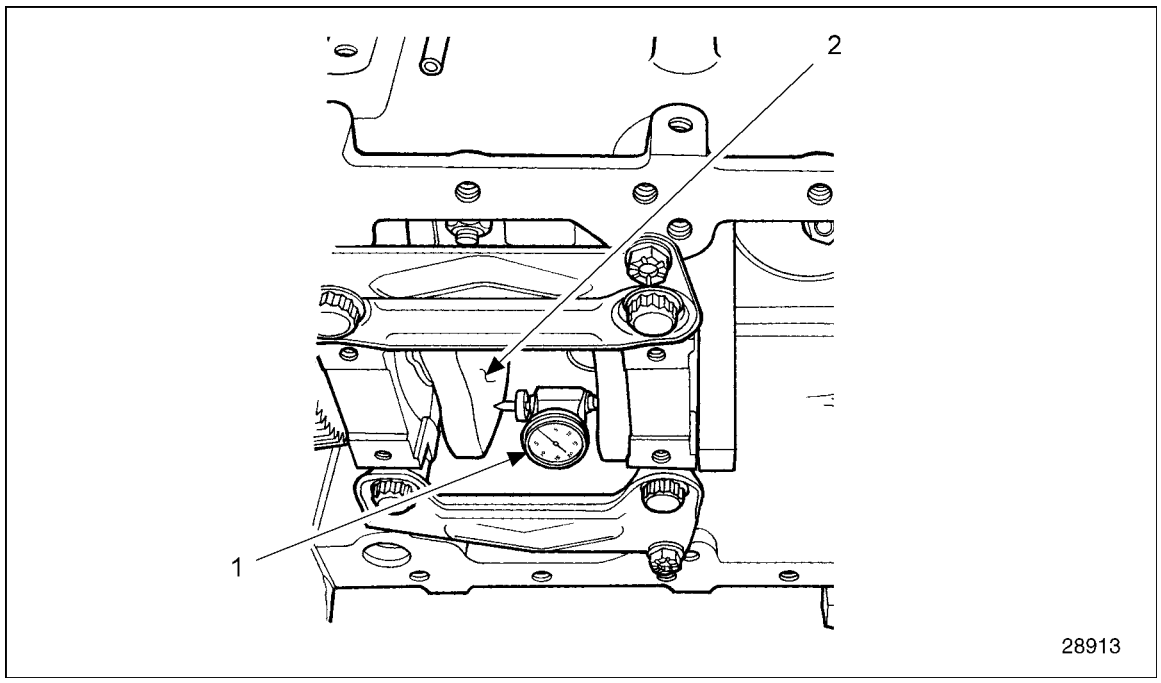
1.7.7.1 Inspection of the Two Piece Crankshaft for Distortion

Check the crankshaft for distortion as follows:

1. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the six o'clock position.
2. Center punch a 6.4 mm (0.25 in.) hole in the inside face of each counterweight cheek.

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3. Install a Starrett Co. No. 696 dial gage, or equivalent, in the center punch holes in the cheek of each counterweight. See Figure 1-83.



1. Dial Indicator Gage
2. Crankshaft Cheek

Figure 1-83 Crankshaft Distortion Measuring Gage (Mounted in Crankshaft)

4. Set the dial indicator at zero.
5. Rotate the crankshaft approximately 90 degrees in both directions. Do not allow the gage to contact the connecting rod caps or bolts.
6. Keep a record of the dial indicator readings at the 3, 6, and 9 o'clock positions. The maximum allowable variation is 0.114 mm (0.0045 in.) total indicator reading.
7. If the gage reading exceeds 0.114 mm (0.0045 in.), check the reduction gear, transmission, or power generator for improper installation.
8. Realign, if necessary.
9. Remove the gage.

1.7.8 Installation of the Two Piece Crankshaft (Completion)

Complete crankshaft installation as follows:

1. Affix a new gasket to the oil pan flange. Install the oil pan. Refer to section 3.11.3.

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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.

CAUTION:

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

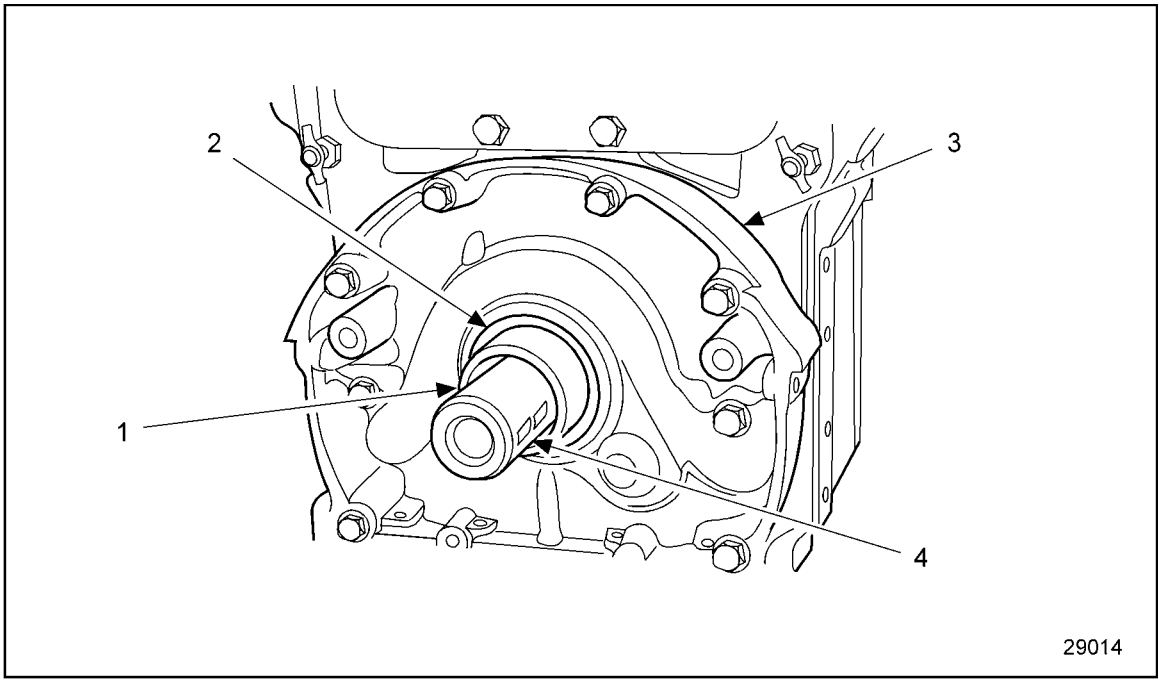
2. Attach chain hoist and sling to the lifting bracket or eye bolts at each end of the engine.
3. Remove the engine from the overhaul stand.
4. Install all accessories that were removed.
5. Fill the crankcase to the proper level on the dipstick. Refer to section 13.5.1.
6. Refer to section 11.5 for engine run-in procedures.

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1.8 CRANKSHAFT OIL SEALS (FRONT AND REAR)

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. A coil spring holds the sealing lips of the crankshaft oil seals firmly, but not tightly, against the crankshaft sealing surfaces, preventing oil from escaping from the engine crankcase.

The front oil seal in 6V and 8V engines is pressed into the crankshaft front cover. See Figure 1-84. In the 12V and 16V engines, the seal is pressed into the engine front cover or trunnion assembly. The seal lip bears against a removable spacer or vibration damper inner cone on the end of the crankshaft.



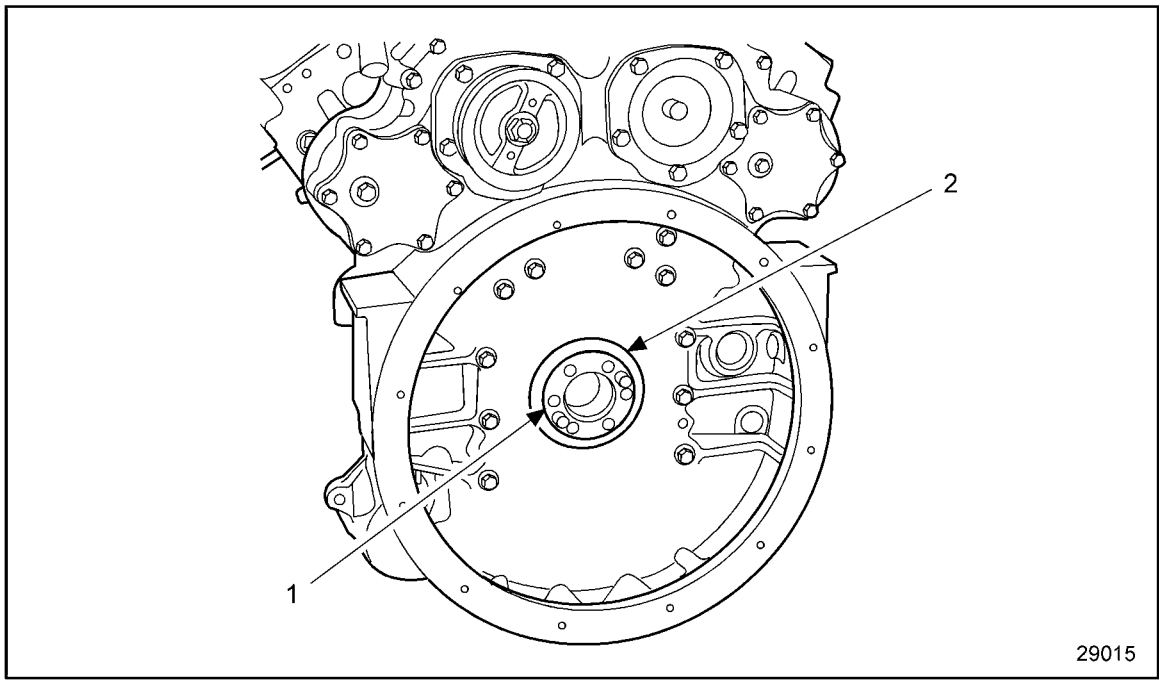
1. Sleeve
2. Oil Seal
3. Crankshaft Front Cover
4. Crankshaft

Figure 1-84 Typical Crankshaft Front Oil Seal Mounting

New lip-type crankshaft front oil seals have been released to service engines operated in sustained low ambient temperatures. The new service-only seals are made of a special low-temperature polyacrylic material and are unidirectional. Because these seals are intended for operation in temperatures as low as -32°C (-25°F), they may not provide satisfactory service life on engines operated at normal ambient temperatures.

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The crankshaft rear oil seal is pressed into the flywheel housing. Standard production seals seat directly on the crankshafts. See Figure 1-85.



1. Crankshaft
2. Oil Seal

Figure 1-85 Crankshaft Rear Oil Seal Mounting

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

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

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

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

1.8.1 Repair or Replacement of Crankshaft Oil Seals

To determine if replacement is necessary, perform the following procedure. See Figure 1-86.

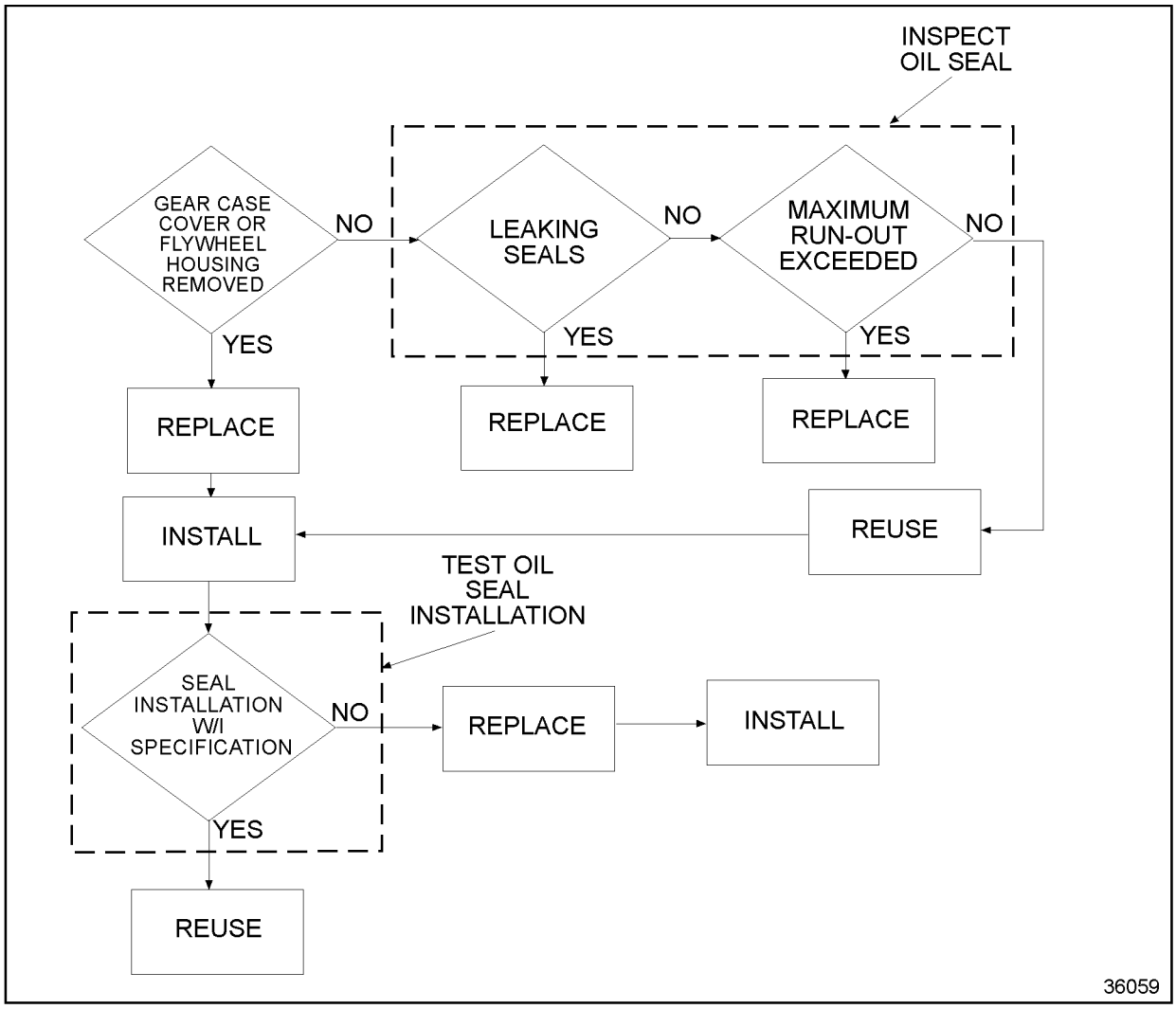


Figure 1-86 Flowchart for Repair or Replacement of Crankshaft Oil Seals

1.8.2 Removal of Crankshaft Oil Seal (with Front Cover, Trunnion, or Flywheel Housing Removed)

Remove the crankshaft oil seals as follows:

1. Remove the engine front cover. Refer to section 1.11.2.
2. Remove the flywheel housing. Refer to section 1.19.2.
3. Support the outer face of the cover, trunnion, or housing on wood blocks.
4. Drive the oil seal out, and clean the seal bore in the cover or housing.

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1.8.3 Removal of Front/Rear Crankshaft Oil Seal (with Front Cover, Trunnion, or Flywheel Housing Installed)

When necessary, oil seals may be removed without removing the front cover, trunnion, or flywheel housing as follows:

1. Drill holes directly opposite each other in the seal casing.
2. Install metal screws with flat washers.
3. Pry against the flat washers with suitable pry bars to remove the seals.

1.8.4 Removal of Oil Seal Sleeve

If necessary, remove the oil seal sleeve as follows:

1. Peen the outside diameter until the sleeve stretches sufficiently so that it becomes loose.
2. Slip the sleeve off the crankshaft

NOTE:
On 12V and 16V trunnion mounted engines, a replaceable sleeve is part of the vibration damper hub. For proper replacement procedures, refer to section 1.14.4.

1.8.4.1 Inspection of Crankshaft Oil Seals

Oil seals may become worn or damaged due to the following conditions:

- ☐ Improper Installation
- ☐ Excessive Main Bearing Clearances
- ☐ Excessive Flywheel Housing Bore Run-Out
- ☐ Damaged Seal, or Wear Sleeve

Inspect the crankshaft oil seals as follows:

1. Inspect the rear end of the crankshaft for oil leaks.

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

   [a] If dirt buildup is found, replace seal. Refer to section 1.8.4.2.

   [b] If no dirt buildup is found, continue inspection. Refer to step 1[c].

   [c] If oil seal wear or damage is found, replace seal. Refer to section 1.8.4.2.

   [d] If there is no visible seal wear or seal damage, refer to section 1.8.4.2.

1.8.4.2 Inspection of Oil Seal Bore Run-Out

Inspect the oil seal bore run-out as follows:

1. Keep the flywheel housing or 12V and 16V front cover or trunnion on the engine, and remove the oil seal to perform the check.
2. With the dial indicator mounted on the end of the crankshaft, check the bore as you would flywheel concentricity. Refer to section ADDITIONAL INFORMATION.

NOTE:
The maximum run-out of the oil seal bore in the front cover or trunnion on all 12V and 16V engines to the flywheel housing on all V engines is 0.20 mm (0.008 in.).

[a] If the maximum run-out exceeds 0.05 mm (0.002 in.). Replace flywheel housing. Refer to section 1.19.2.

[b] If the maximum run-out is within the specified limits and the crankshaft has passed all crankshaft inspection procedures, install oil seal and wear sleeve. Refer to section 1.8.5.

1.8.5 Installation of Crankshaft Oil Sleeve

Install an oil sleeve as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.
2. Coat the area of the shaft where the sleeve will be positioned with Permatex No. 3, or equivalent.
3. Press the sleeve on the shaft. Use oil seal sleeve installer J 21983 or J 4194-01, as required. Refer to section ADDITIONAL INFORMATION.
4. Wipe off the excess sealant.

1.8.6 Installation of Front Oil Seal

Install the front oil seal as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Liberally lubricate the seal inner diameter and the crankshaft with clean SAE 30 or 40 weight engine oil.

NOTE:
The vibration damper inner cone or the oil seal spacer must be removed from 6V or 8V engines before installing the oil seal. Once installed, lubricate the spacer.

2. Position the seal in the front cover or trunnion with the seal lip facing the inner face of the cover.

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3. Drive a new oil seal into the crankshaft front cover on 6V or 8V engines with tool J 9783. This tool seats the oil seal in the bore.

NOTE:
The tool is designed to drive only on the outer edge of the seal casing to prevent damage to the seal. No handle is required.

4. On 12V or 16V front cover and trunnion mount, install the crankshaft front cover and trunnion bearing support. Refer to section 1.14.5.
5. On non-trunnion mount 12V and 16V engines, place the oil seal expander J 22425-B (standard sized seal) or J 4195-01 (oversized seal) on the front end of the crankshaft to avoid damage to the oil seal lip. No handles or guide studs are required with Tool J 4195-01.
6. Drive or press the oil seal in a 12V or 16V engine front cover and trunnion with tool J 9727-A, handle J 3154-1A, and guide studs J 9727-5 (from set J 9727-A). This tool seats the oil seal in the bore.
7. Install the required vibration damper inner core, oil seal spacer, or vibration damper hub. Refer to section 1.14.4.

NOTE:
A revised crankshaft oil seal expander, J 22425-B, has been released to facilitate the installation of standard sized front crankshaft oil seals on 12V and 16V engines. It can be used to install standard sized rear crankshaft oil seals on 6V, 8V, and 12V engines. Guide stud set J 25002 is used to hold the expander in place during seal installation, instead of O-rings. Flywheel dowel pins are no longer installed in the crankshafts. Refer to section ADDITIONAL INFORMATION to update tool J 25002 to J 22425-B.

1.8.7 Installation of Rear Oil Seal Method A

Install crankshaft rear oil seal using method A as follows:

1. Install the flywheel housing. Refer to section 1.19.3.
2. Place oil seal expander J 4239 (standard seal) against the end of the crankshaft. Use handle J 8092 and guide studs J 25002 with the expander. Use expander J 8682 for an oversized seal. Do not use a handle or guide studs with expander J 8682.

NOTICE:

Failure to adequately lubricate the inner diameter seal, the crankshaft or crankshaft oil seal sleeve, if used, and the crankshaft oil expander during installation can result in seal lip damage at engine start up.

NOTICE:

Series 92 crankshaft oil seals are made of an oil-resistant synthetic silicone rubber that is precoated with a special lubricant. Keep this seal lip clean and free from scratches. Do not remove the plastic sealant coating. Doing so will cause seal lip damage.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. On non-Teflon oil seals, liberally lubricate the inner diameter seal, the crankshaft or the crankshaft oil seal sleeve, if used, and the crankshaft oil seal expander with clean SAE 30 or 40 weight engine oil.
4. Install Teflon lip seals dry. This allows Teflon to transfer to the crankshaft or wear sleeve for proper sealing.
5. With the seal lip toward the engine, slide the seal over the expander and onto the crankshaft.
6. Remove the seal expander and guide studs.

NOTICE:

Unidirectional crankshaft rear oil seals are designated for use on either right-hand or left-hand rotating engines. An arrow imprinted on the seal case indicates the direction of crankshaft rotation. Failure to observe crankshaft rotation and install the correct unidirectional seal on an engine will result in seal damage and/or serious oil leakage.

7. Using handle J 3154-1A, install crankshaft rear oil seal installer J 21112-B and guide studs J 9727-5 (from set J 9727-A).

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8. Drive the seal in place until the installer seats squarely on the butt of the crankshaft. See Figure 1-87.

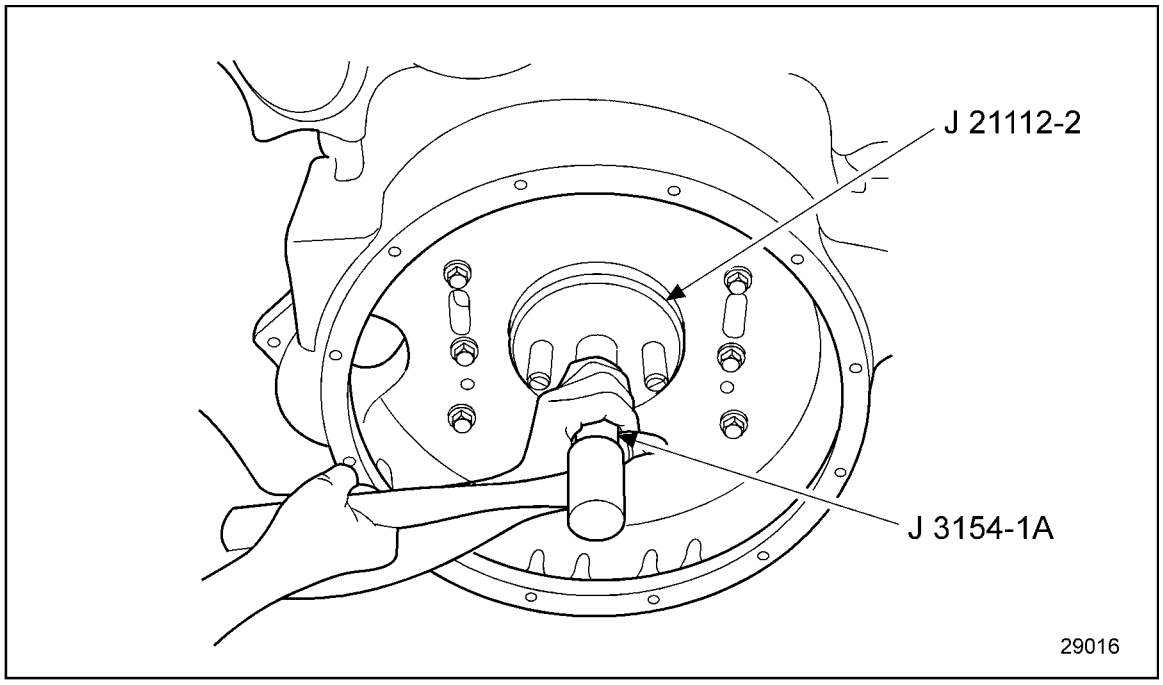


Figure 1-87 Installing Crankshaft Rear Seal with Installer Set J 21112-B and Handle J 3154-1A

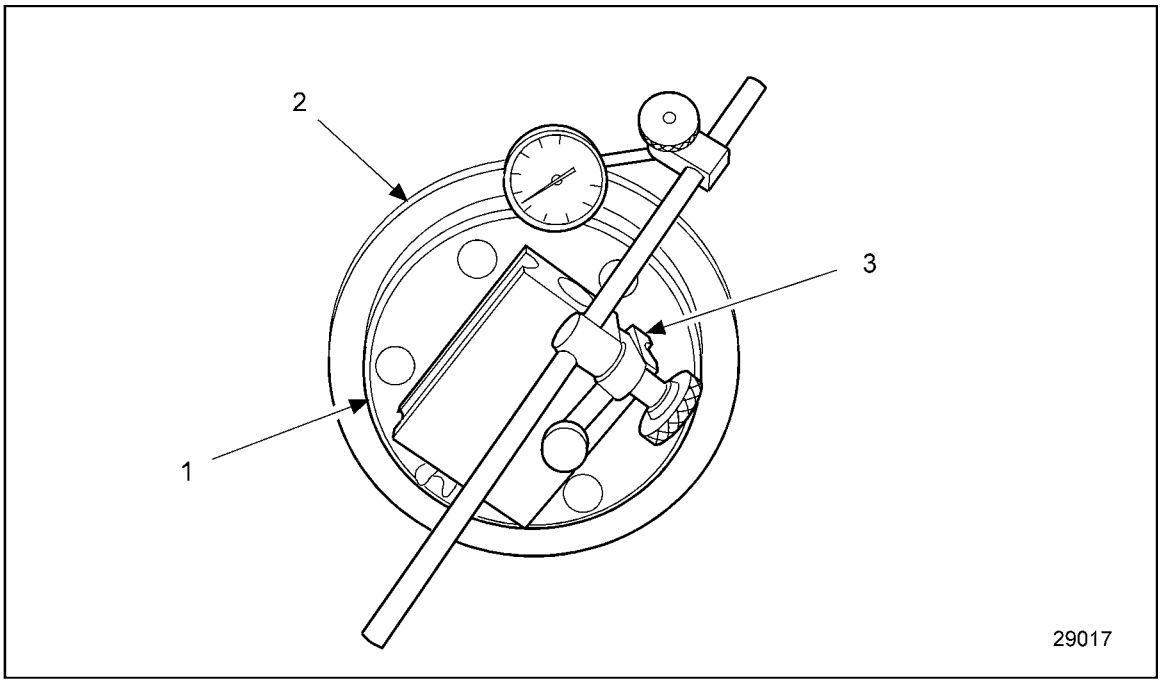
9. Remove the seal installer and guide studs.
10. Remove any excess sealant from the flywheel housing and the seal.

1.8.7.1 Test Seal Installation

Ensure seal fits squarely in relation to the crankshaft face as follows:

NOTE:
Before performing the following steps, pry the crankshaft toward one end of the block to ensure end play is in one direction only.

1. Attach magnetic base dial indicator J 7872 to the rear butt of the crankshaft. See Figure 1-88.



1. Crankshaft
2. Crankshaft Rear Oil Seal
3. Magnetic Base Dial Indicator

Figure 1-88 Checking Crankshaft for Seal Squareness

2. Position the point of the dial indicator on the seal face.

NOTICE:
To avoid serious engine damage, always bar the engine clockwise. Ensure the bolt does not loosen.

3. Rotate the crankshaft and note the seal face readings at the 12, 9, 6 and 3 o'clock positions. The total run-out at each position should not exceed 0.38 mm (0.015 in.).

NOTE:
If any reading is over 0.38 mm (0.015 in.), place the seal installer J 21112-B over the seal, and lightly tap with a soft-faced hammer at the high points.

1.8.8 Installation of Rear Oil Seal Method B

Install the crankshaft rear oil seal sleeve with method B as follows:

1. Install guide stud set J 25002 into the crankshaft butt end.

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2. Apply a thin, even coat of Permatex No. 3, or equivalent, to the inside diameter of the oversized wear sleeve.
3. Using crankshaft oil seal sleeve installer J 21983 and handle J 8092, drive the sleeve onto the crankshaft butt.

NOTE:
Install Teflon lip seals dry. This allows Teflon to transfer to the crankshaft or wear sleeve for proper sealing.

4. Wipe off excess sealant.
5. Using oil seal installer J 21112-B and handle J 3154-1A, drive the seal into place.
6. Remove the guide studs from the end of the crankshaft.
7. Remove any excess sealant from the flywheel housing and the seal.

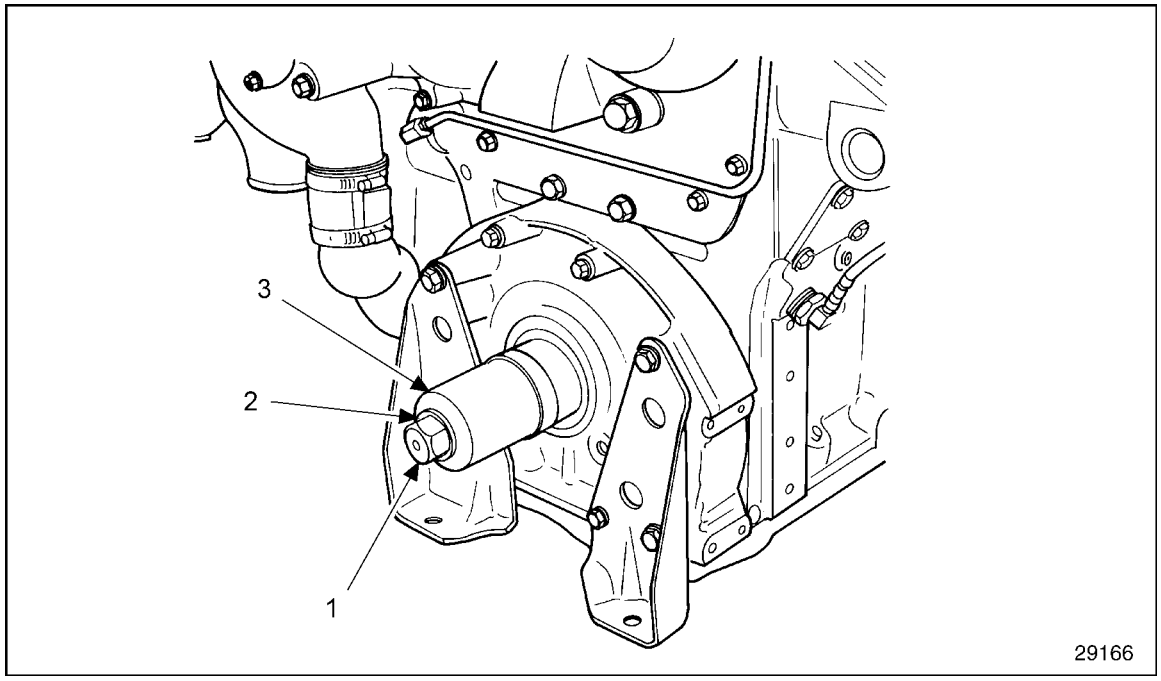
1.8.8.1 Testing of Seal Installation

To minimize the chance of crankshaft rear oil seal leakage, the seal must be square in relation to the flywheel housing face. Verify as follows:

1. Attach magnetic base dial indicator J 7872 to the crankshaft rear butt.
2. Position the dial indicator point at the outer perimeter of the seal face.
3. Rotate the crankshaft and not the seal face readings at the 12, 9, 6, and 3 o'clock positions. The total run-out across the entire seal should not exceed 0.38 mm (0.015 in.).
4. If any reading is over 0.38 mm (0.015 in.), place seal installer J 9727-A over the seal.
5. Lightly tap the edge of the installer with a soft-faced hammer at the high points.
6. Take the dial readings.
7. If the seal cannot be brought within specifications using this method, replace it with a new seal. Ensure the new seal is square in relation to the flywheel housing face.

1.9 CRANKSHAFT CAP

On engines without a crankshaft pulley, a crankshaft cap is installed on the front end of the crankshaft. See Figure 1-89. The crankshaft cap securely fastens the vibration damper assembly to the crankshaft, or when no vibration damper is used, the cap secures the oil seal spacer. A special bolt and washer attaches the cap to the crankshaft.



1. Bolt
2. Washer
3. Crankshaft Cap

Figure 1-89 Crankshaft Cap Mounting

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

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⚠ CAUTION:

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

NOTICE:

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. The barring operation should ALWAYS be performed clockwise. Make certain that the bolt has not been loosened during the barring operation. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

Crankshaft bolts are Lubrite®-coated to prevent possible bolt thread galling and to increase the clamp load on the front end stack up (crankshaft pulley, vibration damper, etc.). The washer (retainer) is case hardened.

1.9.1 Repair or Replacement of Crankshaft Cap

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-90.

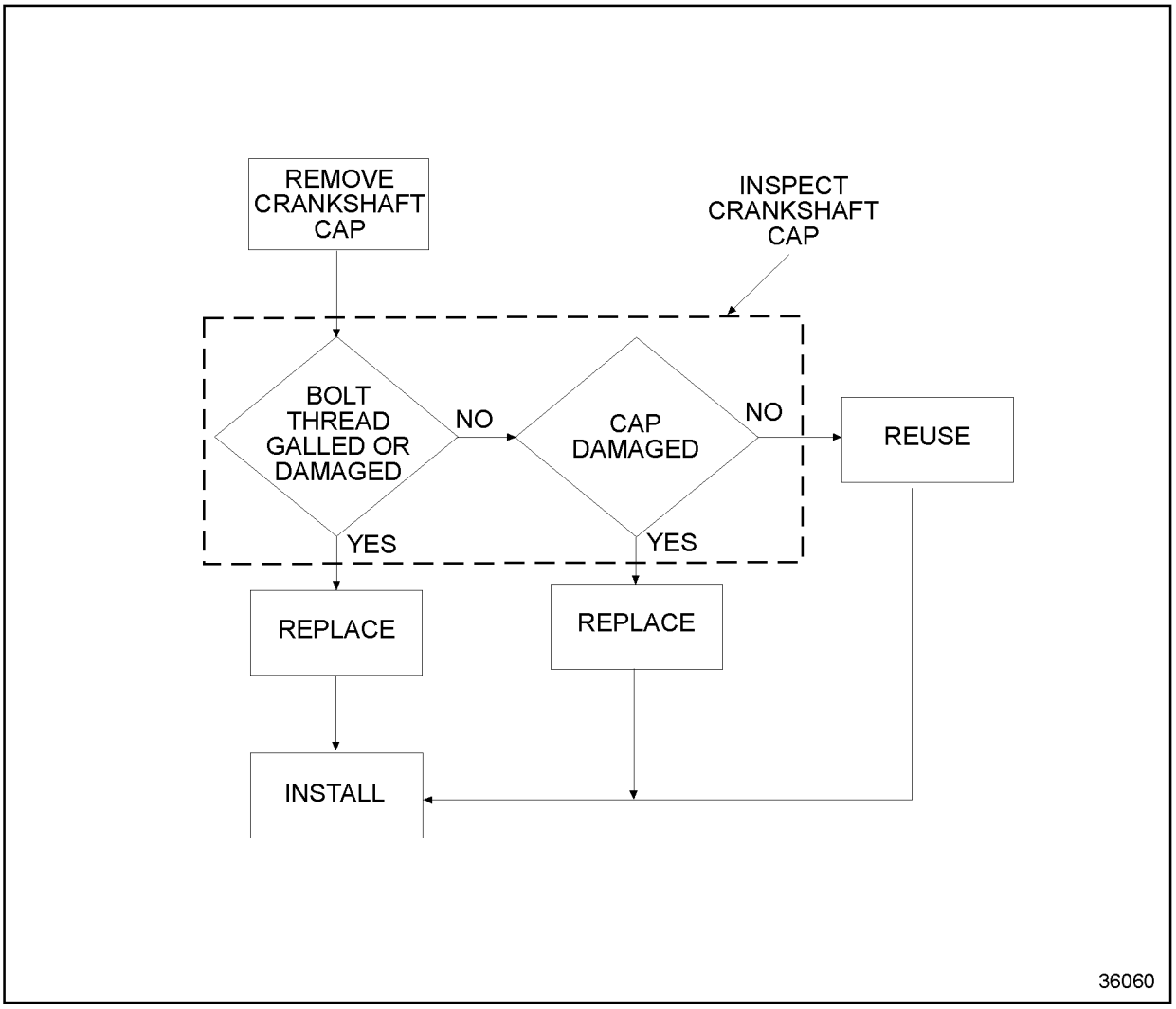


Figure 1-90 Flowchart for Repair or Replacement of Crankshaft Cap

1.9.2 Removal of Crankshaft Cap

Remove the crankshaft cap as follows:

1. Remove the bolt and washer.
2. Remove the crankshaft cap.

1.9.2.1 Inspection of Crankshaft Cap

Inspect the crankshaft cap for cracks or other physical damage.

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1. Visually inspect the crankshaft cap bolt for thread galling and bolt damage.
   [a] If galled or damaged, replace the bolt.
   [b] If no galling or damage is evident, reuse the bolt.
2. Visually inspect for cap damage.
   [a] If damaged, replace the cap.
   [b] If not damaged, reuse the cap.

1.9.3 Installation of Crankshaft Cap

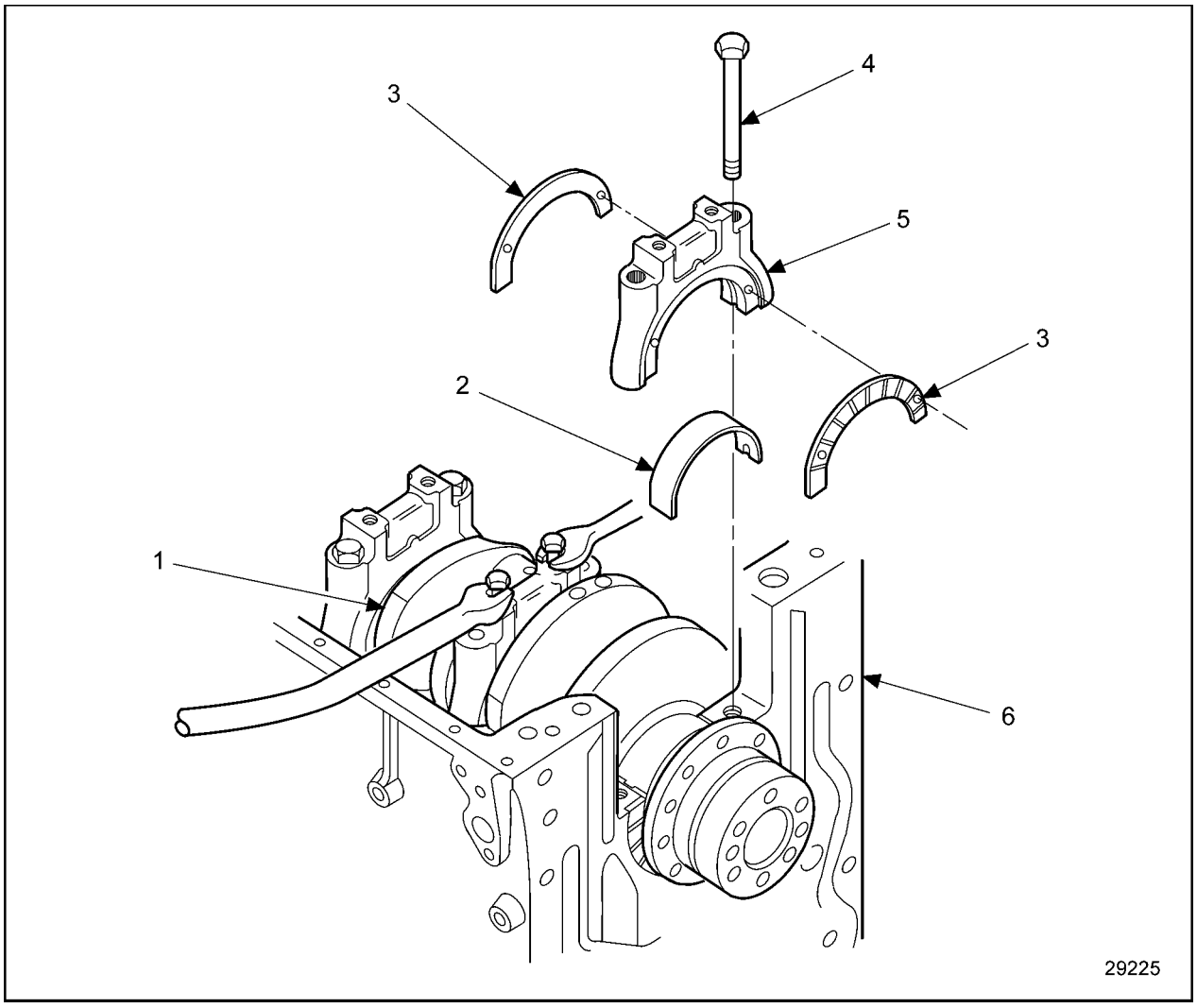
Install the crankshaft cap as follows:

1. Install the cap.
2. Install the washer and bolt.
3. Tighten the crankshaft cap retaining bolt as follows:
   [a] Tighten the bolt to 244 N·m (180 lb·ft) torque.
   [b] Strike the end of the bolt once with a 2 to 3 lb. lead hammer.
   [c] Tighten the bolt to 407 N·m (300 lb·ft) torque, and strike the bolt again.
   [d] Tighten the bolt to 393-421 N·m (290-310 lb·ft) torque.

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

1.10 CRANKSHAFT MAIN BEARING SHELLS

The crankshaft main bearing shells are precision made and are replaceable without machining. See Figure 1-91. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The upper and lower bearing shells are located in the block and bearing cap respectively. A tang at the parting line of each bearing shell holds them in place. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.



1. Crankshaft
2. Lower Main Bearing Shell
3. Thrust Washers
4. Main Bearing Bolt
5. Main Bearing Cap
6. Cylinder Block

Figure 1-91 Main Bearing Caps, Bearing Shells and Thrust Washers

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A through slot in each upper bearing shell registers with a vertical oil passage in the cylinder block. Pressurized lubricating oil passes from the cylinder block oil gallery, by way of the bearing shells, to the drilled passage in the crankshaft. It flows from the drilled passages to the connecting rod bearings.

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

Thrust washers, positioned on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap. The upper halves are not doweled.

Since all of the main bearing load is carried on the lower bearings, wear will occur on the lower bearing shells first. Remove the main bearing caps to observe the condition of the lower bearing shells.

Bearing cap stabilizers are used at all main bearing cap positions on the 6V, 8V, 12V, and 16V engine cylinder blocks. See Figure 1-92.

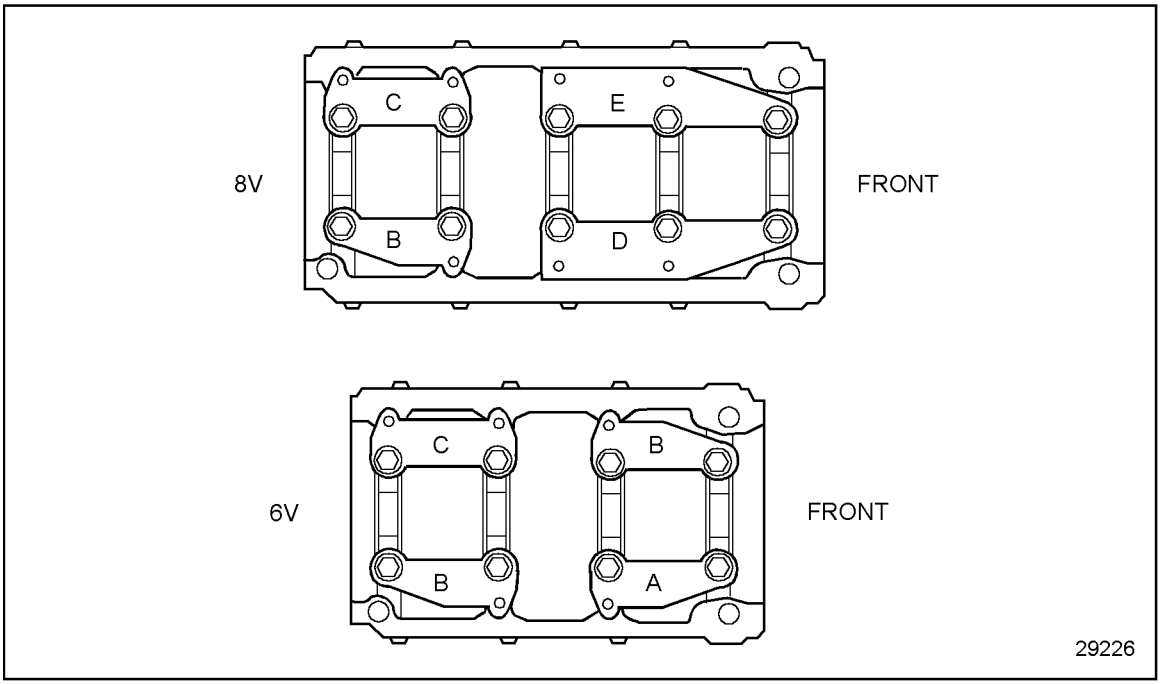


Figure 1-92 Stabilizers Mounted on Back and Main Bearing Caps (6V and 8V Engines)

The main bearing cap has a press fit of 0.005-0.107 mm (0.0002-0.0042 in.) in the main bearing saddle area of the cylinder block. The saddle area is 213.792-213.843 mm (8.4170-8.4190 in.) and the width of the bearing cap is 214.102-213.898 mm (8.4292-8.4212 in.). The press fit allows main bearing cap installation on the block and maintenance of specified bore alignment.

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1.10.1 Repair or Replacement of Crankshaft Main Bearing Shells

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-93.

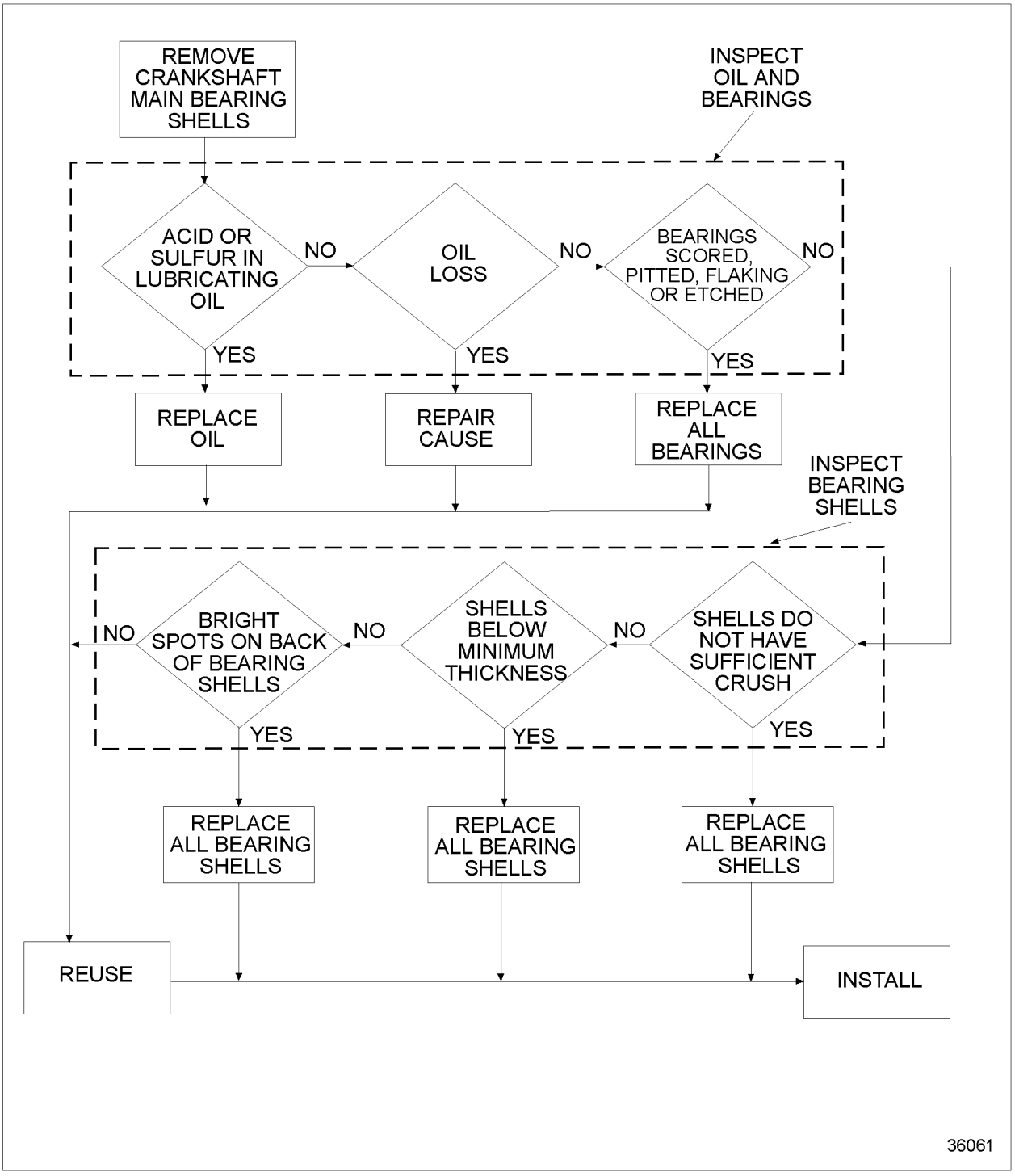


Figure 1-93 Flowchart for Repair or Replacement of Crankshaft Main Bearing Shells

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1.10.2 Removal of Crankshaft Main Bearing Shells

Remove the crankshaft main bearing shells as follows:

NOTE:
All crankshaft main bearing journals, except the rear journal, have a drilled oil passage. The procedure for removing the upper bearing shells with the crankshaft in place is somewhat different for drilled journals than for the rear journal.

NOTE:
The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions. When removed, they must be installed in their original position.

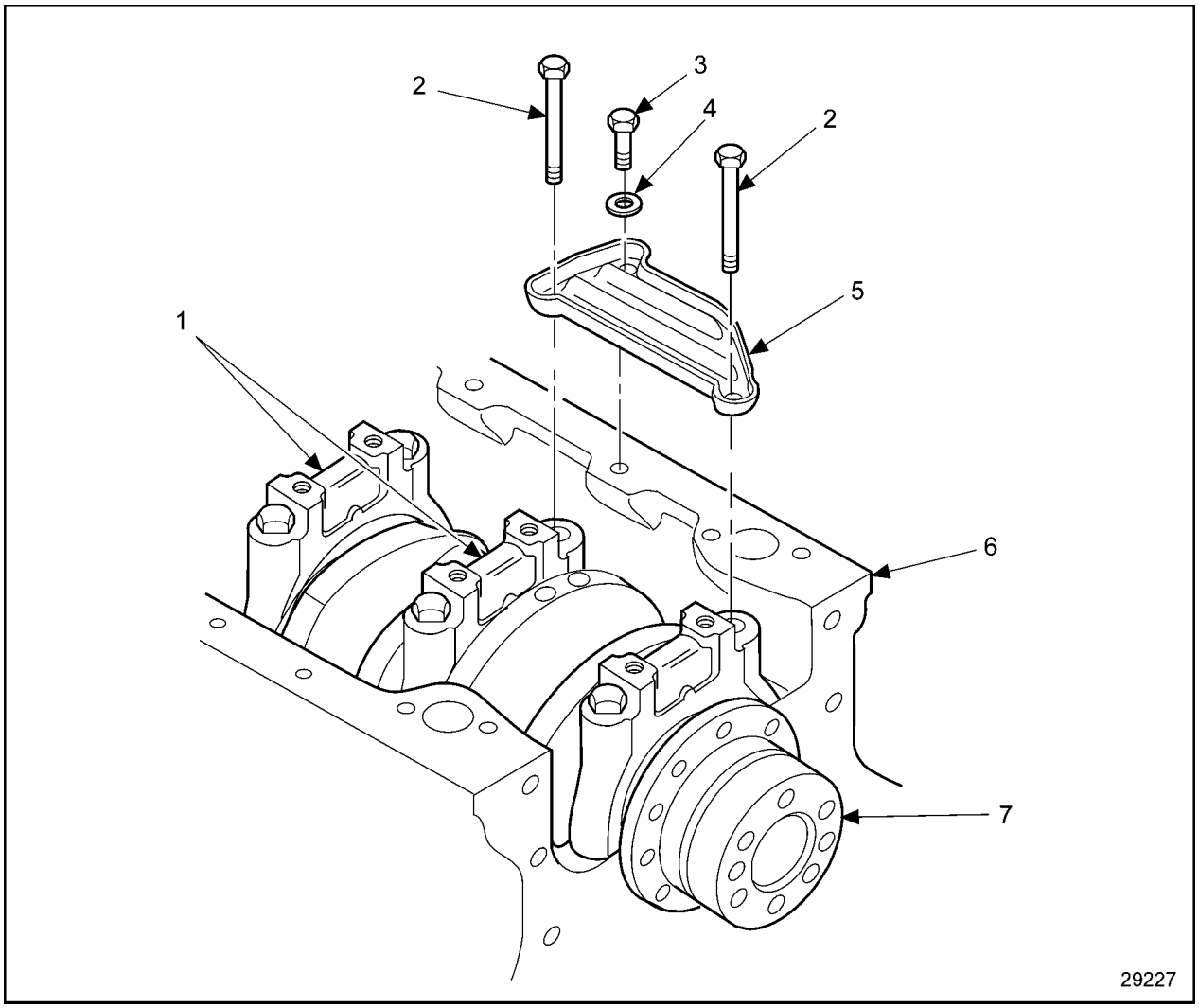
1. Drain the oil pan. Refer to section 13.5.2.
2. Remove the oil pan to expose the main bearing caps. Refer to section 3.11.3.
3. Remove the oil pump and the oil inlet and outlet pipe assemblies. Refer to section 3.2.2.

NOTE:
If shims are used between the oil pump and the main bearing caps, save the shims. Install them in exactly the same location.

4. Remove one main bearing cap stabilizer at a time. Place washers (equal to the thickness of the stabilizer) on the bearing cap bolts, and install the bolts.

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Remove one main bearing cap at a time, and remove the bearing shells. See Figure 1-94.



1. Main Bearing Caps
2. Main Bearing Cap Bolts
3. Stabilizer Block Mounting Bolt
4. Special Washer
5. Stabilizer
6. Cylinder Block
7. Crankshaft

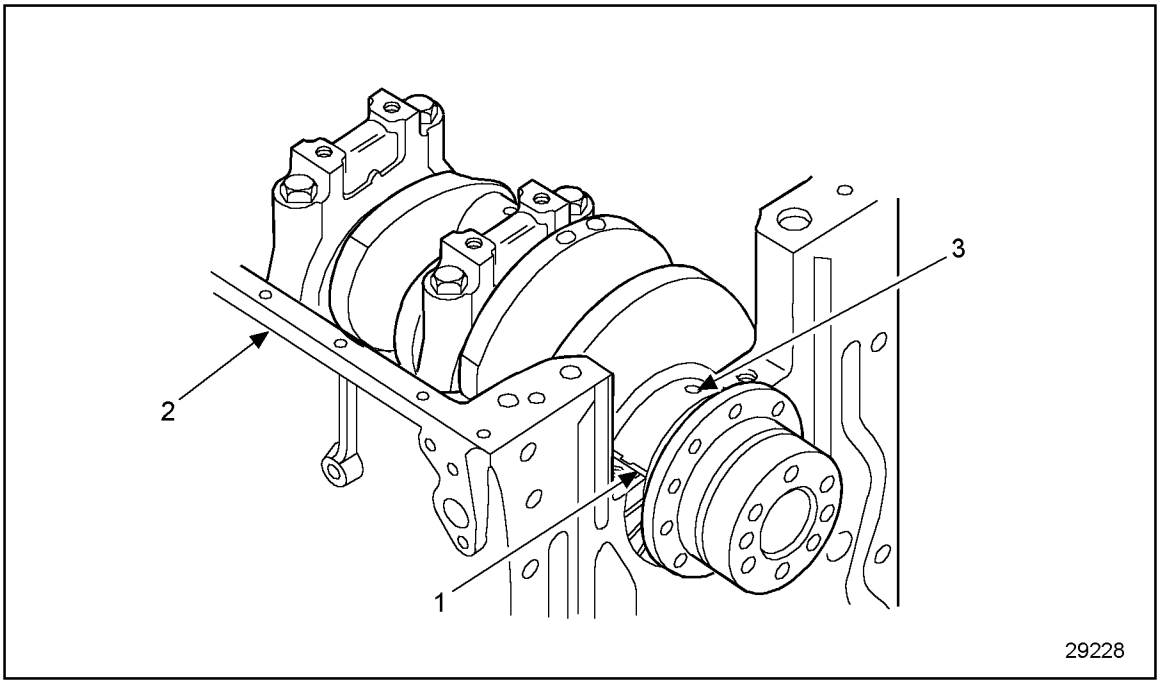
Figure 1-94 Removal/Installation of Main Bearing Stabilizers

1. To remove all upper main bearing shells except the rear main upper bearing shell, insert a 5/16 in. x 1 in. bolt with a 1/2 in. diameter and a 1/16 in. thick head (made from a standard bolt) into the crankshaft journal oil hole.

NOTE:
Install each bearing shell and bearing cap before removing another bearing cap.

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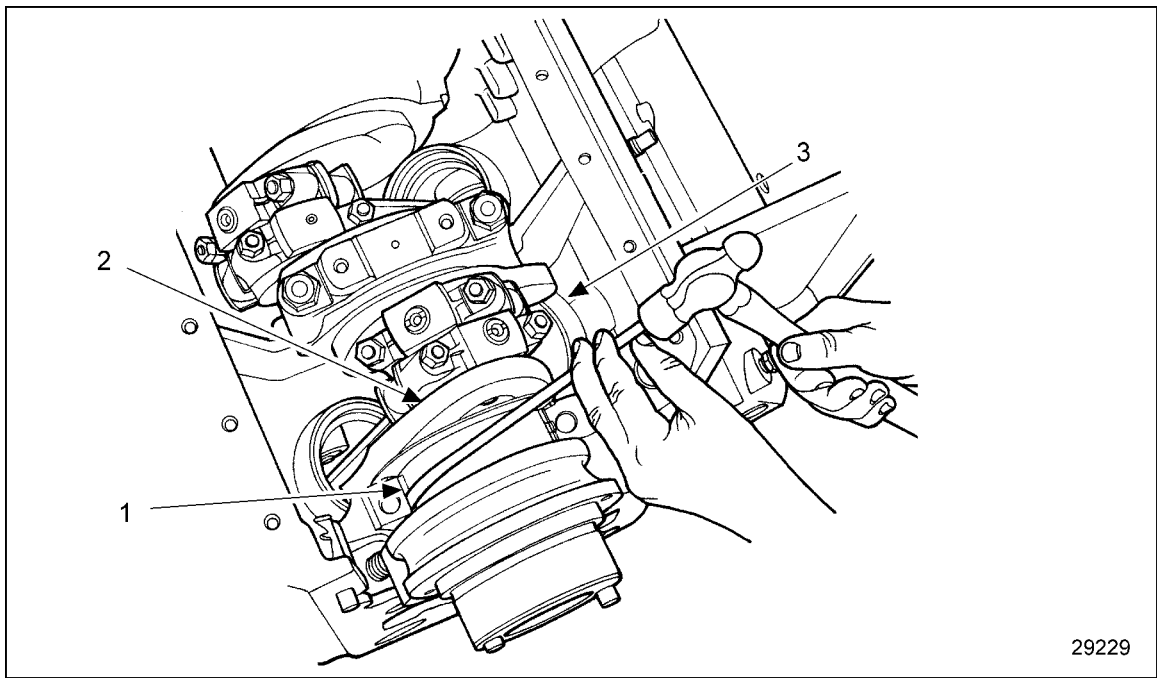
2. Revolve the shaft to the right (clockwise), and roll the bearing shell out of position. See Figure 1-95. The head of the bolt must not extend beyond the outside diameter of the bearing shell.



1. Upper Main Bearing Shell
2. Cylinder Block
3. Oil Journal Hole

Figure 1-95 Set-Up for Removing Upper Main Bearing Shell

3. Tap on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out. See Figure 1-96.



1. Upper Main Bearing Shell
2. Crankshaft
3. Cylinder Liner

Figure 1-96 Removal of Upper Main Bearing Shells

4. The lower halves of the crankshaft thrust washers will be removed with the rear main bearing cap. Push on the ends of the washers upper halves with a small rod, forcing them around and out of the main bearing support.

1.10.2.1 Inspection of Crankshaft Main Bearings

Perform inspection of crankshaft main bearing as follows:

1. Analyze the lubricating oil for corrosive acid and sulfur. Refer to section 5.2.1.9 and refer to section 13.5.4.
   [a] If contaminated with acid, replace the oil. Refer to section 13.5.4.
   [b] If not contaminated with acid, proceed with the inspection.
2. Inspect oil for contamination or oil loss.
   [a] If contaminated, replace the oil. Refer to section 13.5.1.
   [b] If oil loss is indicated, determine and correct its cause.

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[c] If not contaminated and no oil has been lost, proceed with the inspection.

NOTE:
Bearing failures may result from deterioration (acid formation), contamination, or oil loss. These cause acid etching, flaking and pitting. Bearing seizure may be due to low or no oil.

3. Check the oil filter elements for damage or wear.
   [a] If damaged or worn, replace the oil filter elements. Refer to section 3.6.5.
   [b] If not damaged or worn, continue with inspection.
4. Check the oil bypass valve to ensure it operates freely and is not plugged.
   [a] If plugged, clean or replace as necessary. Refer to section 3.9.2.1.
   [b] If oil bypass valve is not plugged and operates freely, proceed with inspection.
5. Inspect the bearings for scoring, pitting, flaking, etching, babbitt loss, or signs of overheating. See Figure 1-97.

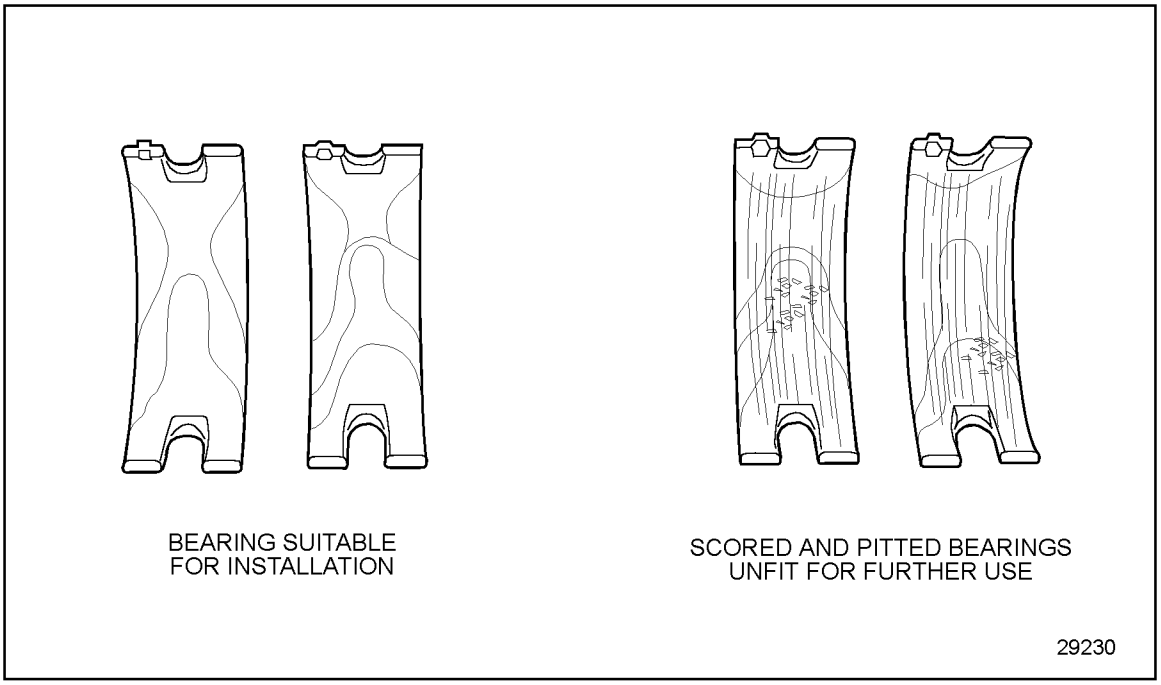


Figure 1-97 Comparison of Lower Main Bearing Shells

NOTE:
The lower bearing shells, that carry the load, will normally show signs of distress before the upper bearing shells. Babbitt plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. The bearing function is in no way impaired. Do not replace them for these minor surface imperfections.

[a] If excessively scored, pitted, flaking, etched, and overheated, replace the bearings. Refer to section 1.10.3.

[b] If the bearings are not scored, pitted, flaking, etched, or overheated, continue inspection.

6. Inspect the bearing shells for sufficient "crush."

NOTE:
The bearing shells do not form a true circle. When installed, they have a squeeze fit in the main bearing bore and must be tight when the bearing cap is down. This "crush" assures a tight, uniform contact between the bearing shell and bearing seat. If bearing shells do not have sufficient "crush," they will not have uniform contact, as shown by shiny spots on the back.

[a] If the bearing shells do not have sufficient "crush," they must be replaced. Refer to section 1.10.3.

[b] If the bearing shells have sufficient "crush," continue inspection.

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

7. Inspect the crankshaft journals for bending fatigue and cracks from damaged bearings. Refer to section 1.7.2.2.

NOTE:
If a new or reground crankshaft is to be used, install all new bearing shells.

[a] If the journals are bent or cracked, replace the crankshaft. Refer to section 1.7.4.

[b] If the journals are not bent or cracked, proceed with inspection.

8. Inspect the crankshaft thrust washers for scoring and wear.

[a] If the washers are scored or excessively worn, they must be replaced. Refer to section 1.10.3.

[b] If the washers are not scored or excessively worn, continue inspection.

9. Check the crankshaft end play.

[a] If the crankshaft end play is excessive, replace the thrust washers. Refer to section 1.10.3.

[b] If the crankshaft end play is not excessive, continue inspection.

10. Inspect the crankshaft thrust surfaces. Refer to section 1.7.2.2.

[a] If surfaces are slightly damaged, grind the thrust surfaces. Refer to section 1.10.3.

[b] If excessively damaged, replace the crankshaft. Refer to section 1.10.3.

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[c] If the crankshaft thrust surfaces are not damaged, proceed with inspection.

NOTE:
Improper clutch adjustment can contribute to excessive thrust washer wear. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is 2.227-3.099 mm (0.1190-0.1220 in.) thick. Thrust washers are available in 0.005 in. and 0.010 in. oversize.

11. Inspect the main bearing bores alignment.

    [a] If the main bearing bores are not aligned when a replacement bearing cap is used, the block must be line-bored. Refer to section ADDITIONAL INFORMATION.

    [b] If the main bearing bores are aligned, proceed with inspection.

1.10.2.2 Inspection of Main Bearing Shells

Inspect the bearing shells as follows:

NOTE:
Do not replace one main bearing shell by itself. If one bearing shell requires replacement, install all new upper and lower shells.

1. Inspect the backs of the bearing shells for shiny spots.

NOTE:
Bright spots indicate that they have been moving in the bearing caps or bearing supports.

    [a] If spots are evident, replace the bearing shells. Refer to section 1.10.3.

    [b] If not spotted, continue inspection.

2. Measure the thickness of the bearing shells at point "C," 90 degrees from the parting line. See Figure 1-98 and see Figure 1-99.

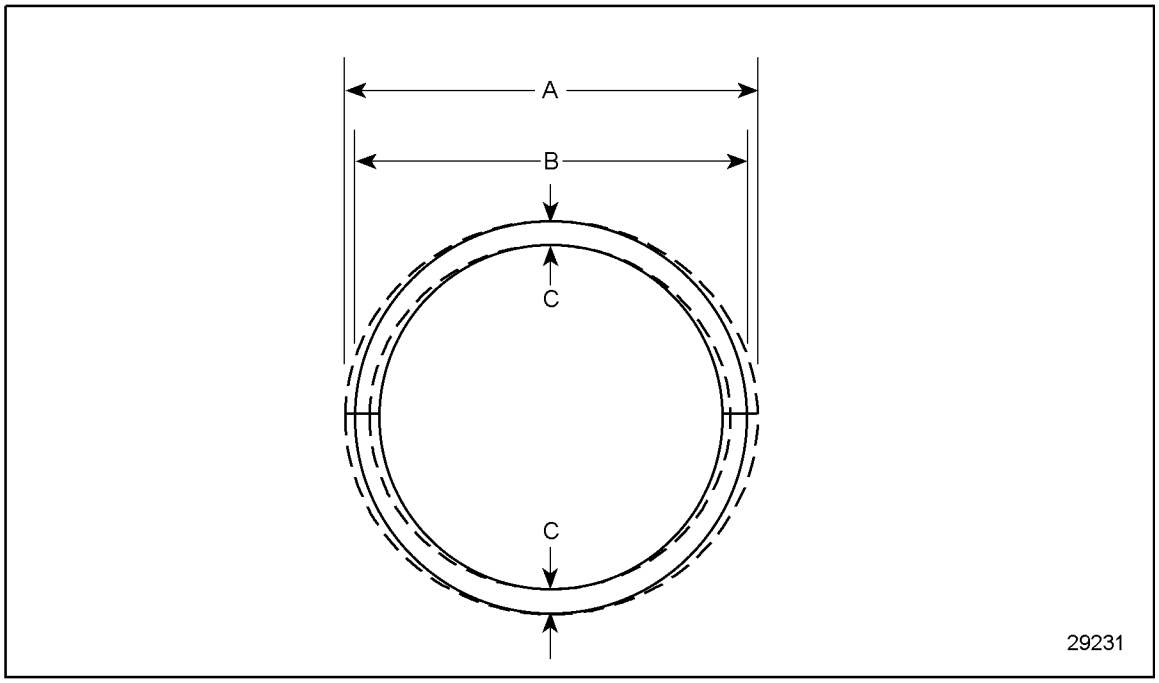
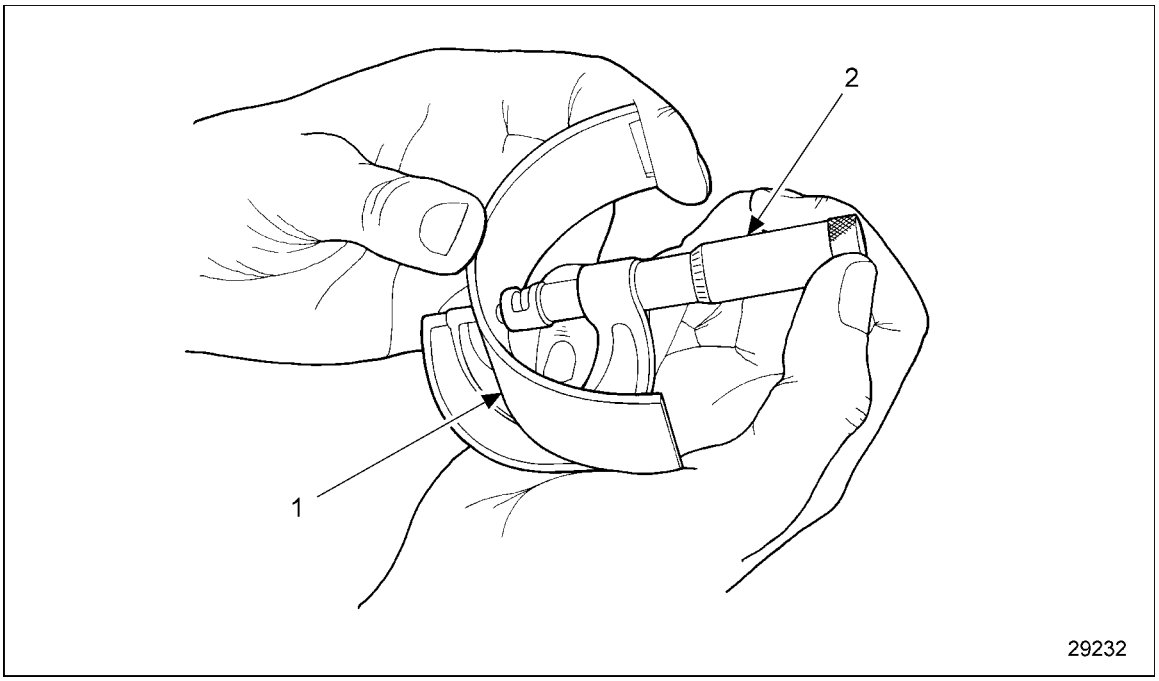


Figure 1-98 Main Bearing Shell Measurements



1. Bearing Shell
2. Micrometer

Figure 1-99 Measuring Thickness of Bearing Shell with Micrometer

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3. Place tool J 4757 between the bearing shell and a micrometer to get an accurate measurement.

NOTE:
The bearing shell thickness is the total thickness of the steel ball in the tool and the bearing shell, less the ball diameter. The minimum thickness of a worn standard main bearing shell is 3.912 mm (0.1540 in.). A new standard bearing shell has a thickness of 3.924-3.9421 mm (0.1545-0.1552 in.). See bearing dimensions listed in Table 1-6.

Bearing Size	Bearing Thickness	Minimum Thickness
Standard	3.92 mm / 3.94 mm (0.1545 in. / 0.1552 in.)	3.91 mm (0.154 in.)
0.010 in. Undersize	4.05 mm / 4.07 mm (0.1595 in. / 0.1602 in.)	4.04 mm (0.159 in.)
0.020 in. Undersize	4.18 mm / 4.20 mm (0.1645 in. / 0.1652 in.)	4.17 mm (0.164 in.)
0.030 in. Undersize	4.31 mm / 4.32 mm (0.1695 in. / 0.1702 in.)	4.83 mm (0.169 in.)

Table 1-6 Bearing Dimensions

[a] If any bearing shell is thinner than this dimension, replace all bearing shells. Refer to section 1.10.3.

[b] If the bearing shells measurements are within the specified dimensions, continue inspection.

1.10.2.3 Inspection of Main Bearing Shells and Crankshaft Journal

Check the clearance between the main bearings and the crankshaft journals as follows:

1. Place a soft plastic measuring strip between the journal and the bearing when the crankshaft is in place. Refer to section ADDITIONAL INFORMATION.
2. When the crankshaft is removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells, in place and with the proper torque on the bearing cap bolts.

NOTE:
When installed, the bearing shells are 0.03 mm (0.001 in.) larger in diameter at the parting line than at 90 degrees from the parting line.

[a] If the clearance between any crankshaft journal and its bearing shells exceeds 0.152 mm (0.0060 in.), all bearing shells must be discarded and replaced. Refer to section 1.10.3.

NOTE:
New part clearance is 0.041-0.127 mm (0.0016-0.0050 in.).

[b] If the clearance indicates slight journal wear, slightly grind the journal and replace bearing shell with an undersize bearing shell.

NOTE:
Undersized bearing shells are available in 0.010 in., 0.020 in. and 0.030 in. sizes for service with reground crankshafts. To determine the bearing size required, refer to section ADDITIONAL INFORMATION *Crankshaft Grinding*. Ensure the correct bearing-to-journal clearances are maintained when using these parts.

[c] If the clearance is within specification, reuse the crankshaft main bearings.

1.10.3 Installation of Crankshaft Main Bearing Shells

Install the crankshaft main bearing as follows:

1. Ensure all of the parts are clean.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Apply clean engine oil around each crankshaft bearing journal.

NOTE:
Upper and lower bearing shells are serviced only in sets. Do not replace one main bearing shell by itself. If one bearing shell requires replacement, install all new upper and lower bearing shells. If a new or reground crankshaft is to be used, install all new bearing shells.

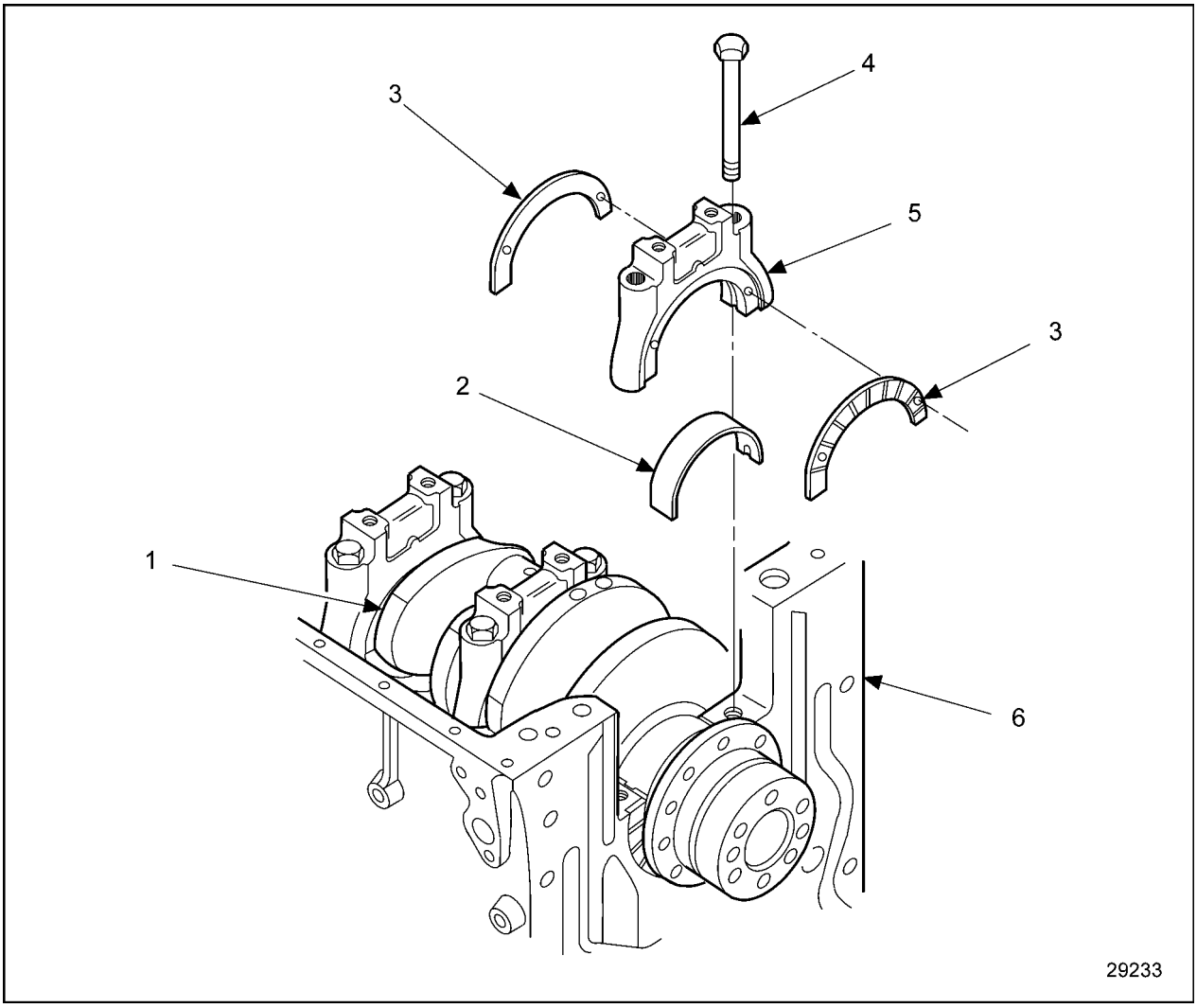
NOTE:
The upper and lower main bearing shells are not alike. The upper shell has a through slot for lubrication, the lower shell does not. Ensure the installation of the grooved slot shells are in the cylinder block and the plain bearing shells are in the bearing caps. The oil flow to the bearings and to the upper end of the connecting rods will be blocked off.

NOTE:
Used bearing shells must be installed on the same journal from which they were removed.

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

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4. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap. See Figure 1-100.



1. Crankshaft
2. Lower Main Bearing Shell
3. Thrust Washers
4. Main Bearing Bolt
5. Main Bearing Cap
6. Cylinder Block

Figure 1-100 Installation of Main Bearing Caps, Bearing Shells and Thrust Washers

NOTE:
Clean both halves of the thrust washer carefully and remove any burrs from the washer seats. The slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place.

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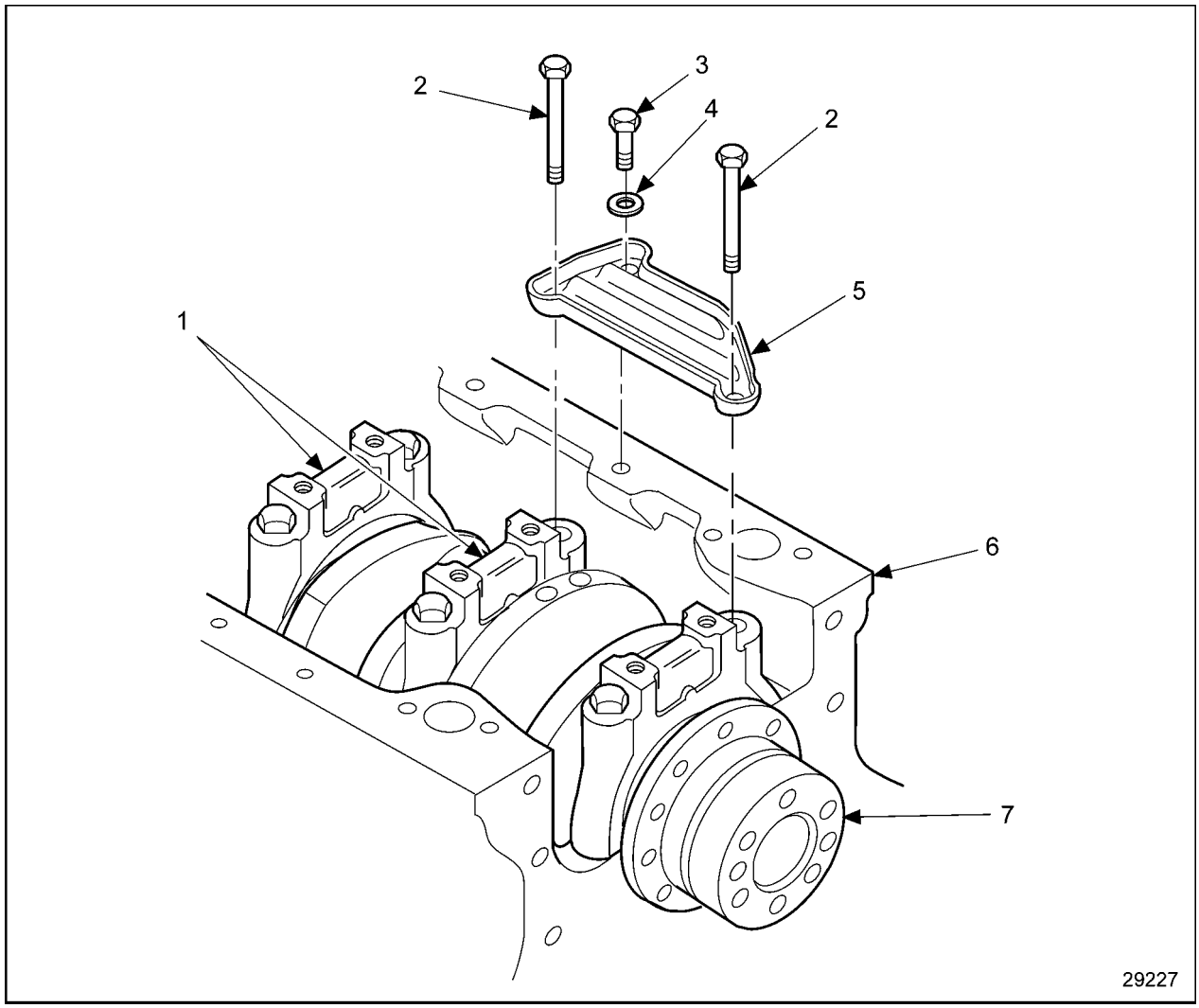
5. Assemble the crankshaft thrust washers before installing the rear main bearing cap. Assemble the lower halves over the dowel pins in the bearing cap.

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

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

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7. Install the bearing caps and bearing cap stabilizers, and tighten the bolts. See Figure 1-101.



1. Main Bearing Caps
2. Main Bearing Cap Bolts
3. Stabilizer Block Mounting Bolt
4. Special Washer
5. Stabilizer
6. Cylinder Block
7. Crankshaft

Figure 1-101 Installation of Main Bearing Stabilizers

8. Strike the caps sharply with a soft hammer to seat them properly.

NOTE:
The former and new main bearing cap bolts should not be intermixed.

9. Tighten all of the former main bearing cap bolts ***(except the rear main bearing cap bolts)*** to 339-352 N·m (250-260 lb·ft) torque starting with the center bearing cap bolts and

working alternately towards both ends of the block. Tighten the new bolts (these require a 15/16 in. socket) to 312-325 N·m (230-240 lb·ft) torque.

10. Tighten the *rear main bearing cap bolts* to 54-68 N·m (40-50 lb·ft) torque.
11. Strike both ends of the crankshaft two or three times with a soft hammer to ensure proper rear main bearing cap seating in the block saddle.
12. Refer to step 9 and retorque all bearing cap bolts to the torque specified in that step ***(including the rear main bearing cap bolts)***.
13. Tighten the 7/16 in. -14 stabilizer bolts to 95-102 N·m (70-75 lb·ft) torque.

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

14. Check the crankshaft end play. Refer to section 1.7.2.2.
15. Install the lubricating oil pump and the oil inlet and outlet pipe assemblies. Refer to section 3.2.9.

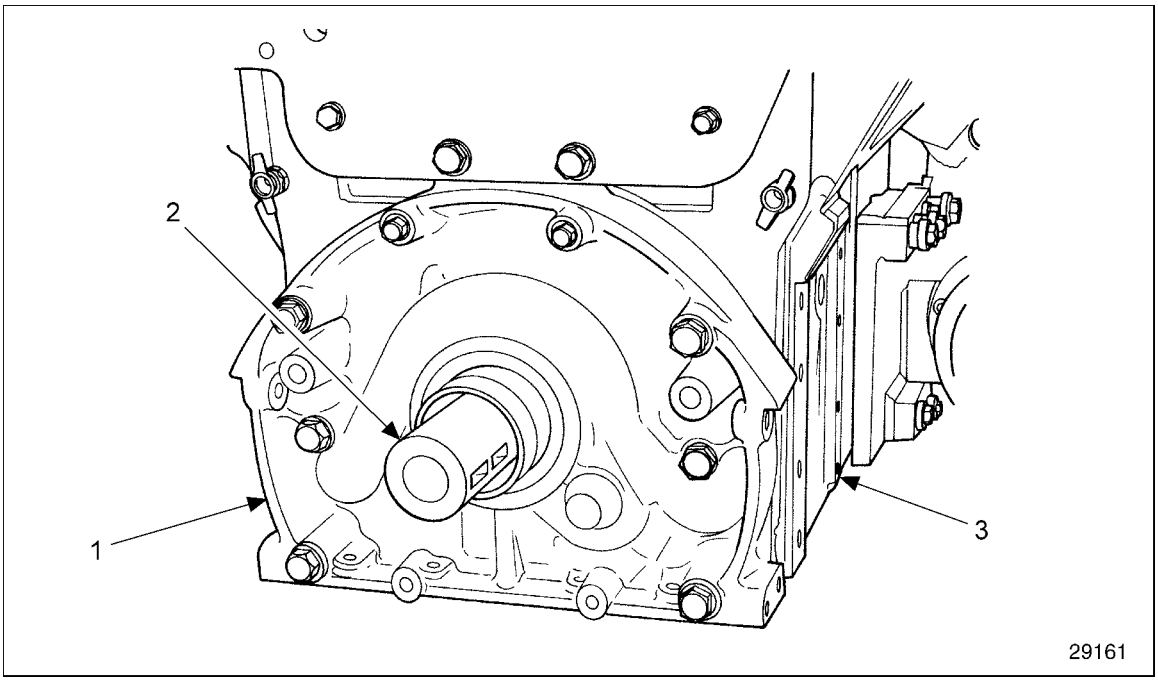
NOTE:
If shims were used between the pump and the bearing caps, install them in their original positions. Check the oil pump gear clearance. Refer to section 3.2.10.

16. Install a new gasket on the oil pan.
17. Install the oil pan. Refer to section 3.11.3.
18. Fill the crankcase to the proper level on the dipstick with the recommended grade and viscosity lubricating oil. Refer to section 13.5.1.
19. Operate the engine on a run-in schedule. Refer to section 11.6.

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1.11 ENGINE FRONT COVER

The engine front cover is mounted against the cylinder block at the lower front end of the engine. See Figure 1-102. It serves as a retainer for the crankshaft front oil seal. On 6V and 8V engines, the cover houses the lubricating oil pump. Supports attached to the front cover support the engine.



1. Lower Front Cover
2. Crankshaft
3. Cylinder Block Assembly

Figure 1-102 Engine Front Cover Mounting (6V and 8V Engines)

When the engine is overhauled or the crankshaft is removed or installed, the engine front cover must be removed. The front cover must be removed to service the lubricating oil pump on 6V and 8V engines. If the front cover is used with trunnion mounts, it must be removed to replace the crankshaft front oil seal.

1.11.1 Repair or Replacement of Engine Front Cover

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-103.

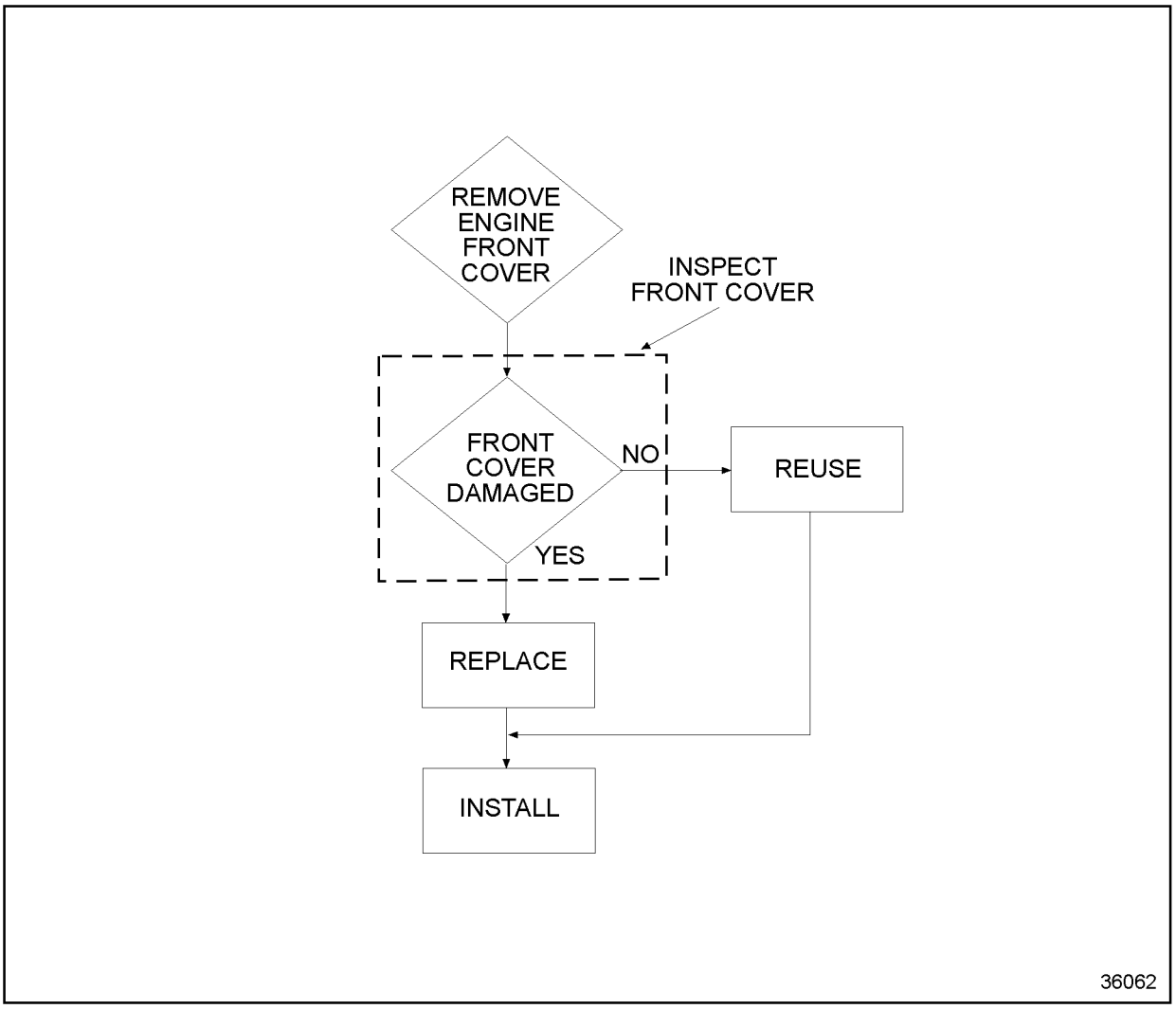


Figure 1-103 Flowchart for Repair or Replacement of Engine Front Cover

1.11.2 Removal of Engine Front Cover

Remove the front cover as follows:

1. Drain the oil. Refer to section 13.5.2.
2. Remove the four oil pan-to-front cover attaching bolts and lock washers. Loosen all remaining oil pan bolts.

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NOTICE:
Do not damage the gasket. If damaged, the oil pan will have to be removed and the gasket will have to be replaced.

3. Lower the oil pan and gasket approximately 6.4 mm (0.25 in.) at the front end of the engine.
4. Remove the crankshaft pulley. Refer to section 1.15.2.
5. Remove the vibration damper, if used. Refer to section 1.14.2.
6. Remove the vibration damper inner cone or oil seal spacer.
7. Disconnect the lubricating oil pump inlet tube at the bottom of the front cover on 6V or 8V engines. Refer to section 3.2.6.
8. Remove the cover-to-cylinder block attaching bolts. Refer to section 1.1.2.
9. Strike the edges of the cover alternately on each side with a soft hammer to free it from the dowels.
10. Pull the cover straight off the crankshaft.
11. Remove the gasket from the cover or the cylinder block.
12. Replace the oil seal. Refer to section 1.8.6.

1.11.2.1 Inspection of Engine Front Cover

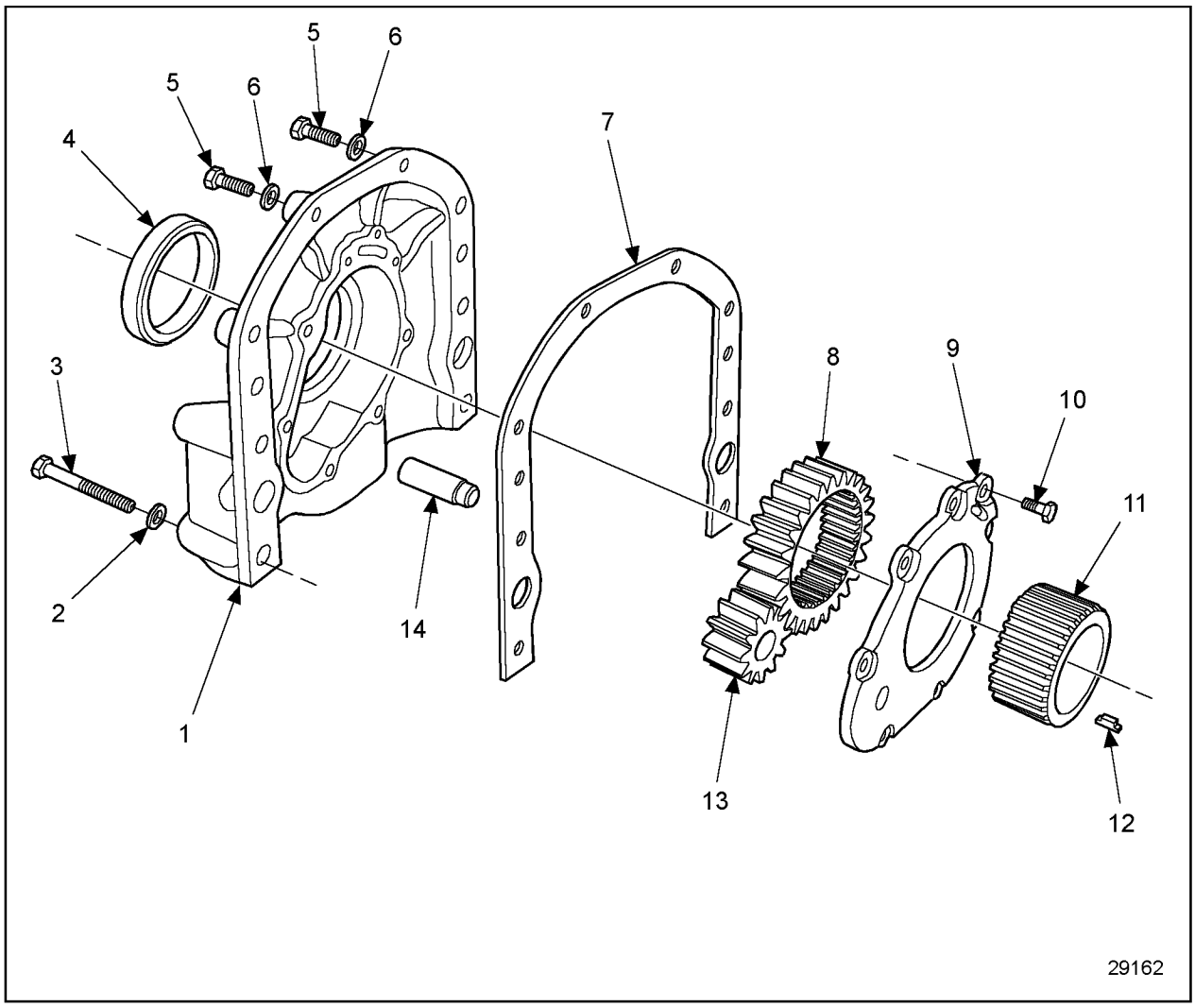
Inspect the front cover as follows:

1. Inspect the front cover for damage.
   [a] If damaged, replace the cover.
   [b] If not damaged, reuse the cover.

1.11.3 Installation of Engine Front Cover

Prior to installing the engine front cover, install the oil pump and the oil seal (6V and 8V engines). Refer to section 3.2.11.

See Figure 1-104, and install the front cover as follows:



1. Front Cover
2. Lock Washer
3. Lower Front Cover Bolts
4. Oil Seal
5. Bolt
6. Lock Washers
7. Gasket
8. Drive Gear
9. Retaining Plate
10. Rear Plate Bolt
11. Drive Hub
12. Keyway
13. Driven Gear
14. Shaft

Figure 1-104 Lower Front Cover (6V and 8V Engines)

1. Affix a new gasket to the inner face of the cover.

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

NOTICE:

Failure to adequately lubricate the seal inner diameter, the crankshaft, and the crankshaft oil seal during seal installation can result in seal lip damage at engine start-up.

2. Liberally lubricate the seal inner diameter, the crankshaft, and the crankshaft oil seal expander with clean SAE 40 or 30 weight engine oil.
3. Install the front cover using oil seal expander J 22425-B with guide studs J 25002 (standard size seal) or J 4195-01 (oversize seal) to pilot oil seal over the crankshaft.

NOTE:
The cover should be over the crankshaft and up against the cylinder block.

4. Remove the oil seal expander.
5. Install the cover attaching bolts and lock washers. Tighten the 3/8 in.-16 bolts to 34-41 N·m (25-30 lb·ft) torque and the 1/2 in.-13 bolts to 108-122 N·m (80-90 lb·ft) torque.

NOTE:
Studs are provided on certain engines to allow installation of front support and idler pulley mounting brackets.

⚠ CAUTION:

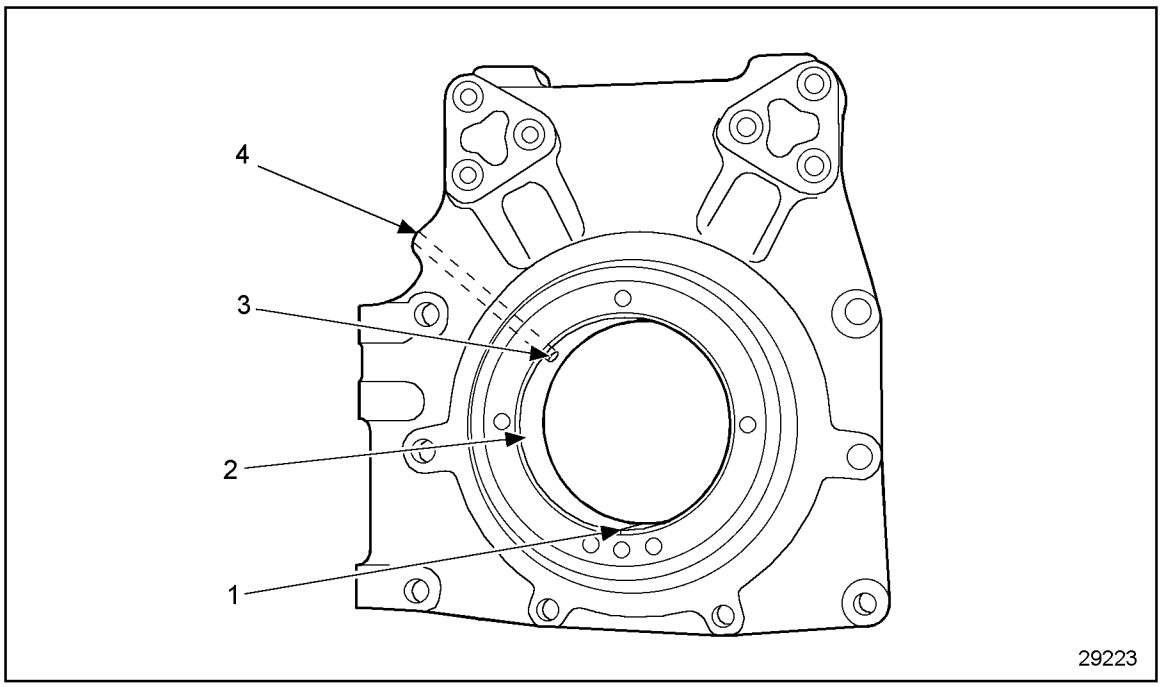
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

6. Apply engine oil to the vibration damper inner cone or oil seal spacer. Slide it onto the crankshaft.
7. Affix a new gasket to the flange on the oil pump inlet tube (6V or 8V engines). Attach the tube to the bottom of the engine cover.
8. Install the four oil pan-to-front cover attaching bolts and lock washers. Tighten all oil pan attaching bolts to 20-27 N·m (15-20 lb·ft) torque.
9. Install the vibration damper. Refer to section 1.14.4.
10. Install the crankshaft pulley. Refer to section 1.15.3.
11. Fill the crankcase with oil to the proper level on the dipstick. Refer to section 13.5.1.

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1.12 CRANKSHAFT OUTBOARD BEARING SUPPORT (TRUNNION)

A crankshaft outboard bearing support (trunnion) is provided on 12V and 16V industrial engines to give additional frontal support to the crankshaft. See Figure 1-105. The bearing support (trunnion), which is attached to the engine front cover, incorporates a clevite bearing (bushing). The trunnion serves as a retainer for the crankshaft front oil seal. Oil seal rings (O-rings) are used between the engine front cover and the bearing support.



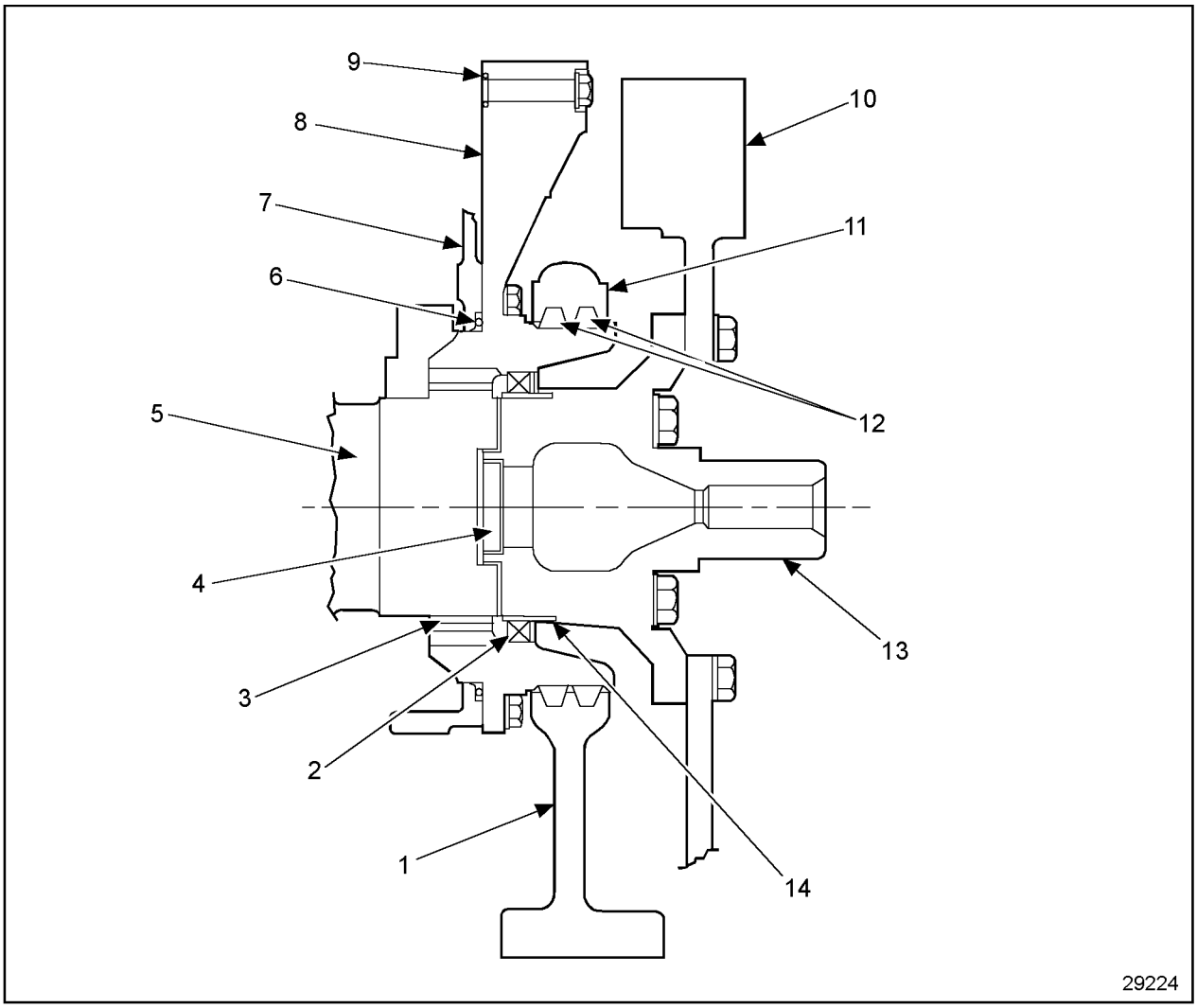
1. Split Line
2. Bearing
3. Oil Hole
4. Oil Passage

Figure 1-105 Outboard Bearing Support (Trunnion)

If a rear outboard bearing support is installed on the engine, a special rear crankshaft half is used to supply oil from the rear main bearing to the rear outboard support bearing.

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Bearing and crankshaft lubrication are provided from the engine front oil gallery, through an external oil tube, to a drilled and tapped oil passage in the bearing support. See Figure 1-106.



1. Trunnion Support
2. Oil Seal
3. Outboard Bearing
4. Cup Plug
5. Crankshaft
6. Seal Ring
7. Front Cover
8. Bearing Support (Trunnion)
9. Seal Ring
10. Vibration Damper
11. Bearing Support Cap
12. Bearing Support Cushions
13. Vibration Damper Hub
14. Oil Seal Sleeve

Figure 1-106 Outboard Bearing Support (Trunnion)

The bearing support should not require any servicing, except for bearing or oil seal replacement, when necessary. When bearing replacement is required, remove the bearing support.

1.12.1 Repair or Replacement of the Outboard Bearing Support (Trunnion)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-107.

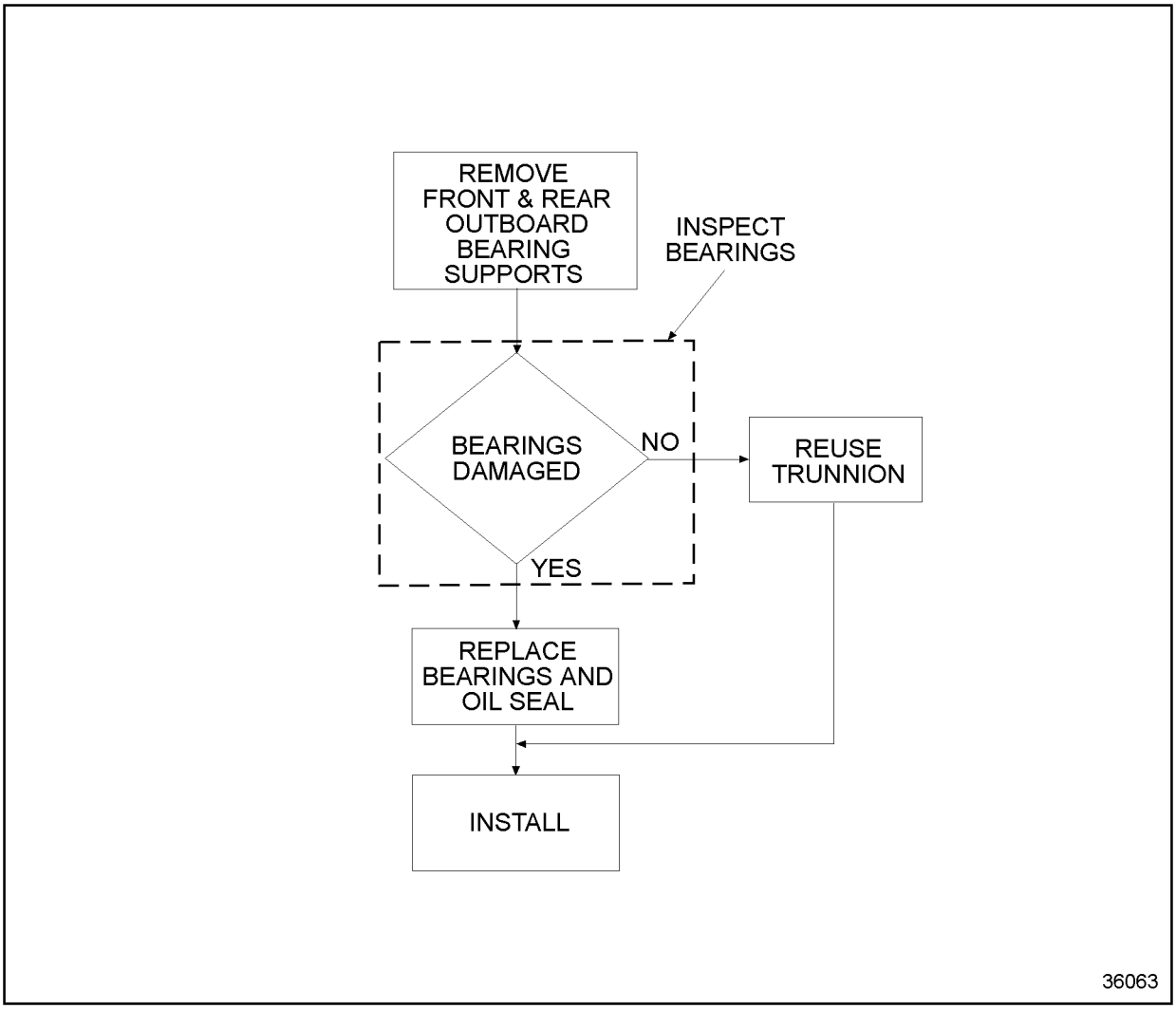


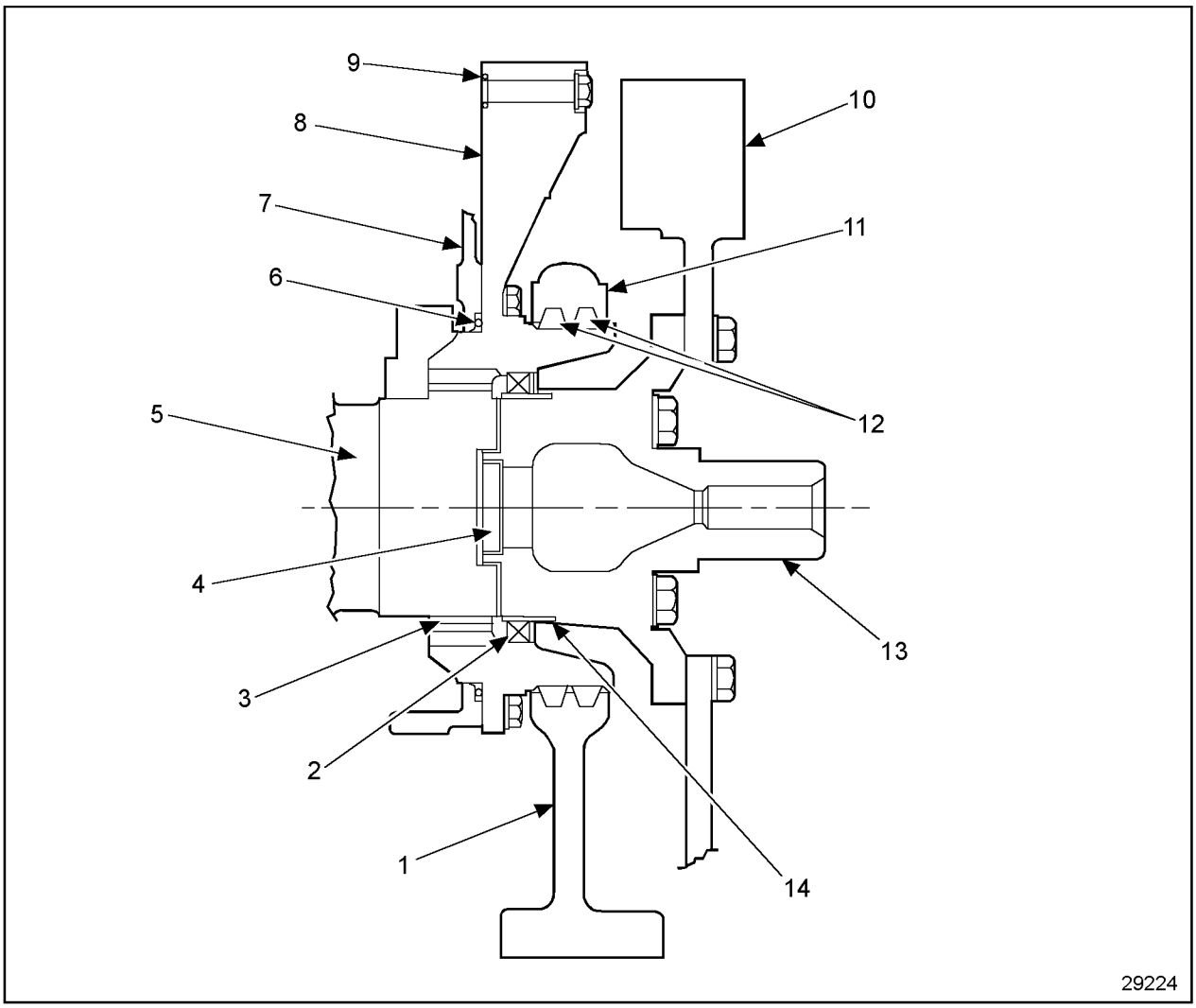
Figure 1-107 Flowchart for Repair or Replacement of the Outboard Bearing Support (Trunnion)

1.12.2 Removal of the Front Outboard Bearing Support (Trunnion)

Remove the front trunnion as follows:

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1. Remove the trunnion (engine) support. See Figure 1-108.



1. Trunnion Support
2. Oil Seal
3. Outboard Bearing
4. Cup Plug
5. Crankshaft
6. Seal Ring
7. Front Cover
8. Bearing Support (Trunnion)
9. Seal Ring
10. Vibration Damper
11. Bearing Support Cap
12. Bearing Support Cushions
13. Vibration Damper Hub
14. Oil Seal Sleeve

Figure 1-108 Outboard Bearing Support (Trunnion)

2. Remove the outboard bearing to cylinder block oil tube.
3. Remove the outboard bearing support (trunnion).

1.12.3 Removal of Rear Outboard Support Bearing (Trunnion)

Remove a rear outboard support bearing as follows:

1. Remove flywheel. Refer to section 1.16.2.
2. Remove the rear outboard bearing bolts.
3. Remove the outboard bearing.
4. Remove the flywheel housing. Refer to section 1.19.2.

1.12.3.1 Inspection of Outboard Bearing Support (Trunnion)

Inspect the outboard bearing support as follows:

1. Inspect the bearing in the support for damage.
   [a] If damaged, replace the bearing and the oil seal. Refer to section 1.8.6.
   [b] If the bearing is not damaged, reuse the trunnion.

1.12.4 Installation of Front Outboard Bearing Support (Trunnion)

Install the front trunnion as follows:

NOTICE:
When installing a new bearing, press the bearing in flush with the outer surface of the support. Ensure the lubricating hole in the bearing lines up with the drilled oil passage, and the split line in the bearing is at the bottom of the support. If installed incorrectly, oil fed to the bearing and crankshaft will be blocked off, consequently causing engine damage.

1. Install a new large seal (O-ring) and six new small seal rings on the back side of the bearing support (trunnion).

CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the bearing and oil seal lip with clean engine oil. Guide the bearing support over the crankshaft.
3. Tighten the top two middle inboard and bottom two middle bolts.

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4. Using a soft faced mallet, strike the trunnion firmly on the top center of the housing to drive it downward.

NOTE:
All vertical crankshaft-to-bearing clearances should be at the bottom of the crankshaft. Clearance from side to side should be visually centered. Adjust, if necessary.

5. Tighten all bolts with a hand wrench. Torque them to 95-102 N·m (70-75 lb·ft).
6. Install the bearing support-to-cylinder block oil line.

NOTE:
Ensure the line is clean and free of obstructions.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

7. Fill the drilled feed hole in the support with clean engine oil before connecting the line.
8. Install the trunnion support with two 5/8 in.-11 bolts and lock washers. Tighten the bolts to 186-200 N·m (137-147 lb·ft) torque.
9. Install hub and vibration damper. Refer to section 1.14.4.
10. Prelubricate the oil seal sleeve before installing the hub.
11. Install the hub.

1.12.5 Installation of Rear Outboard Bearing Support (Trunnion)

Install the rear outboard bearing support as follows:

1. Install the flywheel housing. Refer to section 1.19.3.
2. Rotate the crankshaft so that the maximum run-out of the bearing surface is down.

NOTE:
The rear outboard shaft bearing will be installed in a line-to-line condition with the crankshaft in this position.

3. Mount a magnetic base dial indicator on the flywheel housing with the indicator tip on the bottom of the crankshaft rear outboard bearing surface.
4. Rotate the crankshaft, and determine the maximum run-out location.

NOTE:
The actual amount of measured run-out is not important at this point.

5. Rotate the crankshaft until the maximum run-out point is on the bottom, or at the 6:00 o'clock position.

NOTE:
Do not rotate the crankshaft from this position until rear outboard shaft bearing installation is complete.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

6. Apply a film of clean engine oil to the outside diameter of the seal, and press it flush to the support.

NOTE:
The lip or open side of the seal should face the bushing in the bearing support assembly.

7. Apply a thin film of Lubriplate, or equivalent, to the rear outboard shaft bearing-to-flywheel housing seal ring. Place the ring on the back of the bearing support assembly in the counterbore of the flywheel housing.

NOTE:
The outboard bearing support assembly is adjustable in the flywheel housing. It should be positioned upward to the crankshaft when the engine is in the upright position without lifting the crankshaft.

NOTE:
To ensure the crankshaft is not lifted off the rear main bearing, place a magnetic base dial indicator on the flywheel housing directly above the vertical axis of the crankshaft. Position the indicator probe on the top portion of the crankshaft that protrudes from the rear outboard shaft bearing. The indicator reading must remain unchanged while adjusting the outboard bearing. Under no circumstances should the indicator show that the crankshaft has moved.

8. Install the bolts and washers to hold the bearing support assembly in place, but do not tighten.
9. Lift upward on the bearing support assembly by hand until the bearing just contacts the crankshaft. Tighten the twelve bolts to 47-61 N·m (35-45 lb·ft) torque.
10. Check the dial indicator to ensure the crankshaft has not been lifted.
11. Using a 1/4 in. feeler gage, check the clearance between the bearing and the crankshaft.

NOTE:
The largest clearance must occur at the top on the vertical axis and must not be less than 0.08 mm (0.003 in.) or more than 0.25 mm (0.010 in.). There should be no clearance at

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the bottom (a line-to-line condition) or not more than 0.038 mm (0.0015 in.). Clearances at the sides should be approximately equal.

NOTE:
If top and bottom clearance requirements are not met, loosen the bolts slightly and pry up on the bearing support assembly until clearance requirements are obtained. Ensure the crankshaft is not lifted during this adjustment.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

12. Lightly coat the sleeve on the flywheel assembly with clean engine oil.
13. Install two guide studs in the rear of the crankshaft.
14. Attach a flywheel lifting tool, and using a chain hoist, position the flywheel into the flywheel housing.
15. Align flywheel bolt holes with crankshaft bolt holes and push the flywheel in evenly to prevent damage to the oil seal.
16. Install flywheel. Refer to section 1.16.5.

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1.13 CRANKSHAFT REAR OUTBOARD BEARING SUPPORT

A rear outboard bearing support is provided on certain current 16V engines for generator set applications. See Figure 1-109. The support assembly is mounted in the flywheel housing to improve the ability of the engine rear crankshaft main bearing to sustain loads and bending forces externally induced by drive components.

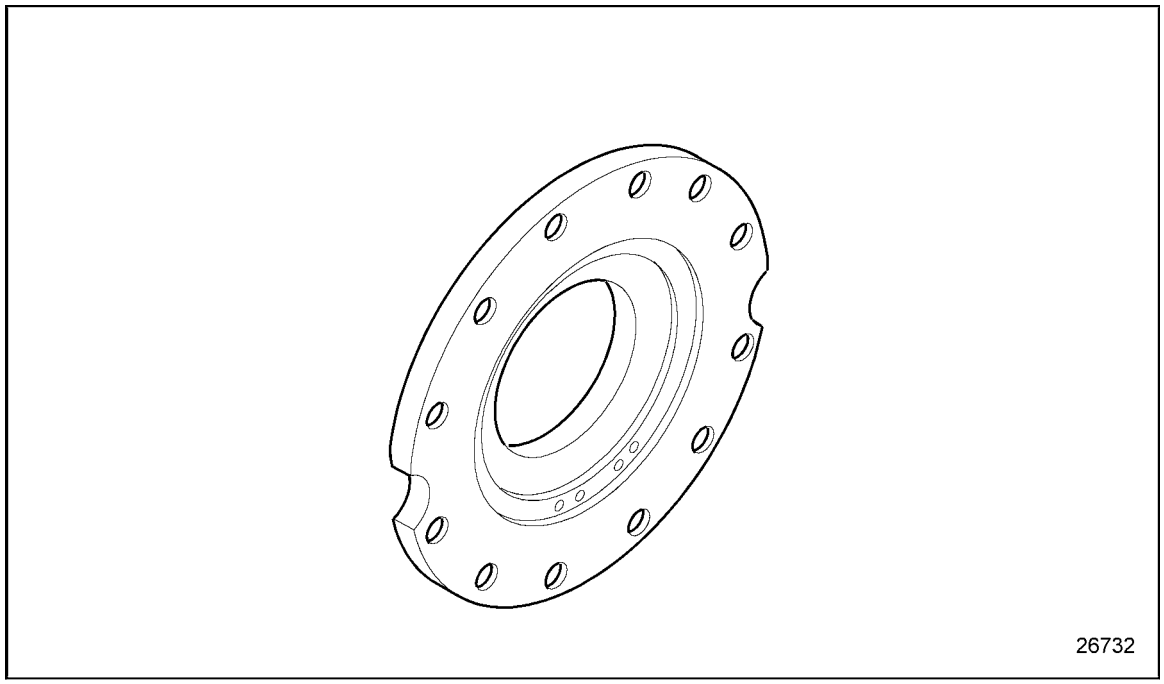


Figure 1-109 Rear Outboard Bearing Support Assembly

The outboard bearing support assembly incorporates the bearing support and a crankshaft outboard bushing.

The support assembly also serves as a retainer for the crankshaft rear oil seal. This seal is not supplied with the support assembly but is serviced as a separate item. A seal ring is used on the back of the support assembly that fits between the support assembly and the flywheel housing.

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The flywheel housing is counterbored to accommodate the outboard bearing support assembly. See Figure 1-110.

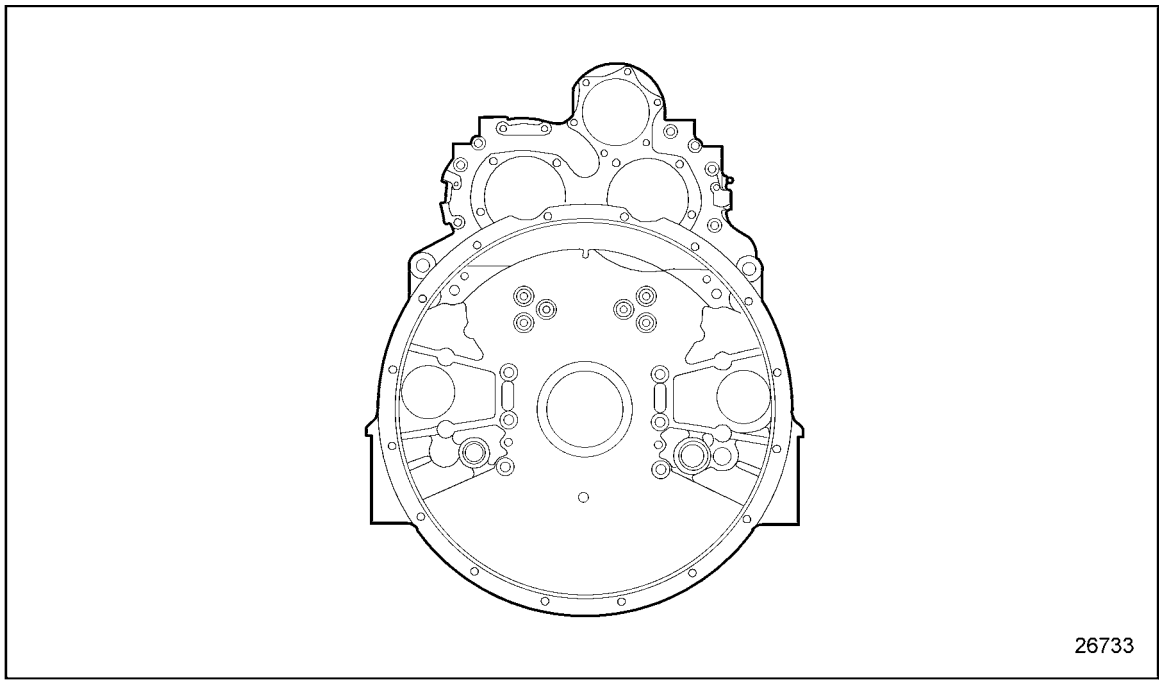
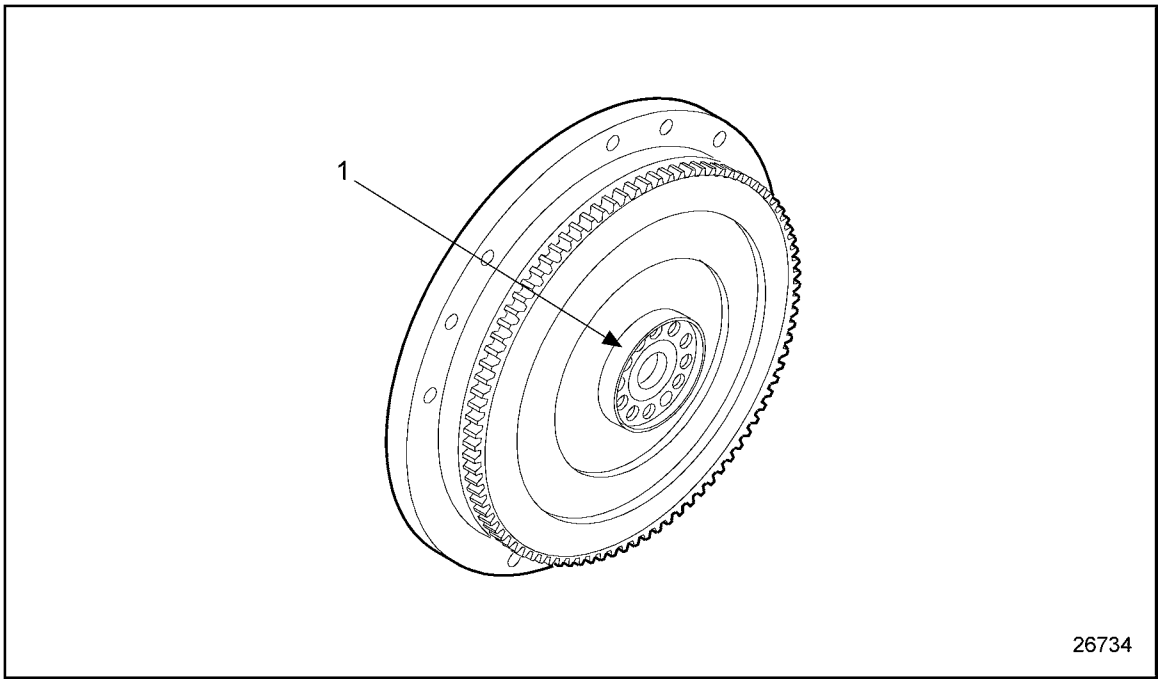


Figure 1-110 Flywheel Housing with Counterbore

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The flywheel incorporates an oil seal sleeve for the crankshaft oil seal. See Figure 1-111. The rear crankshaft oil seal, mounted in the outboard support, seals on the oil seal sleeve instead of the crankshaft.

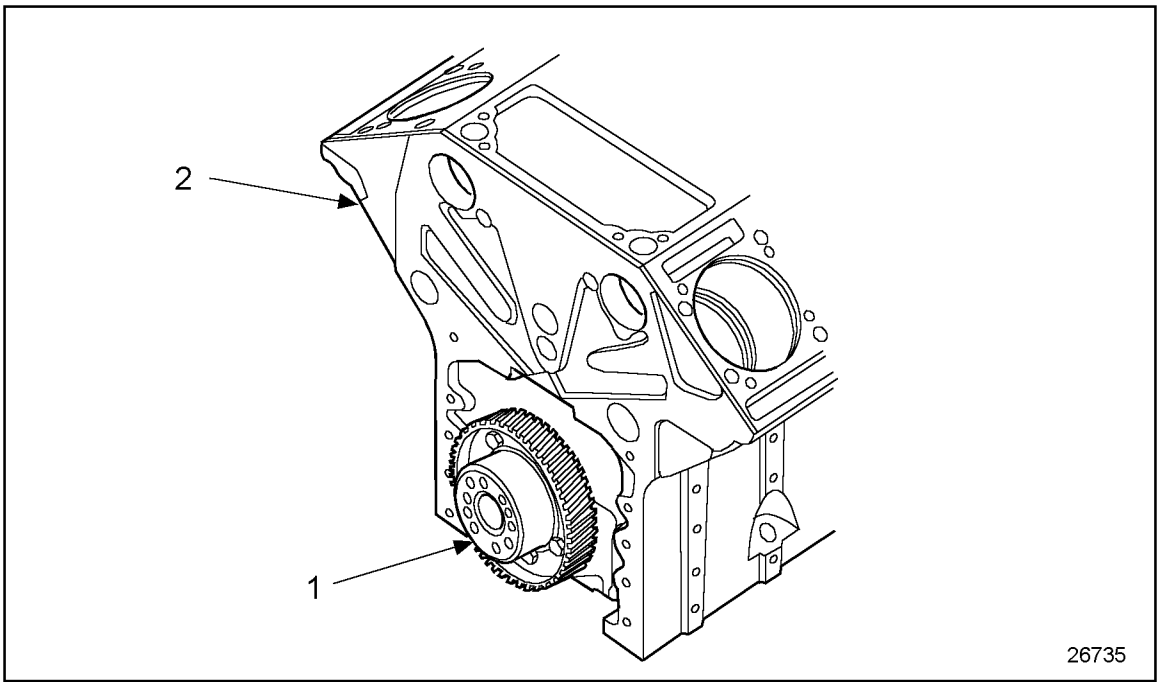


1. Sleeve

Figure 1-111 Flywheel Assembly

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A different crankshaft timing gear is used in this application. See Figure 1-112. The timing gear used on engines with a rear outboard bearing support has a narrower flange and uses 7/8 in. long bolts instead of the 1 in. long bolts used on non-outboard support applications. The new timing gear is attached to the flywheel using six 3/8-24 x 7/8 bolts and torqued to 47-53 N·m (35-39 lb·ft).

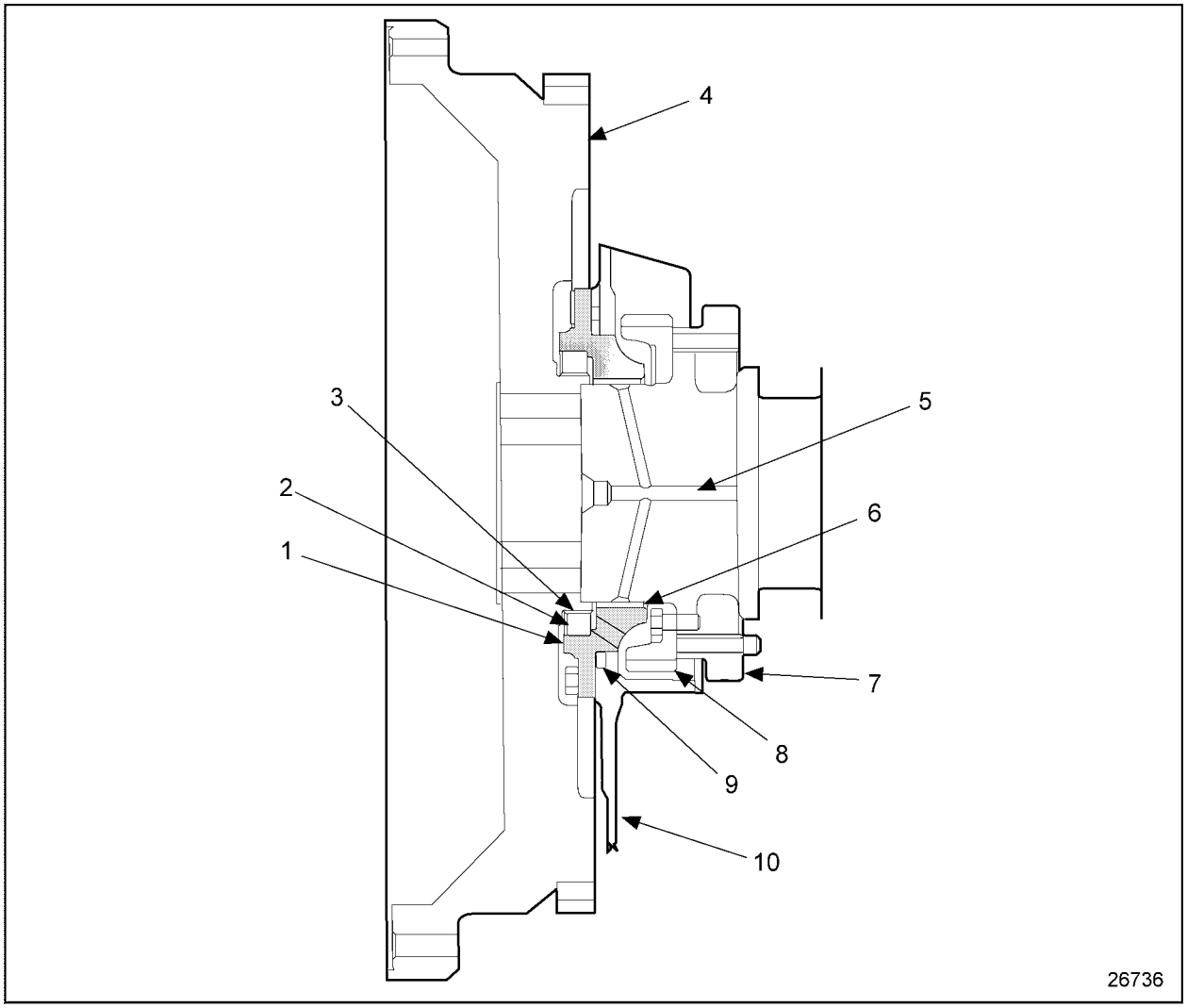


1. Rear Crankshaft Timing Gear
2. Cylinder Block

Figure 1-112 Rear Crankshaft Timing Gear

NOTICE:
For the rear outboard support to function properly, the engine is equipped with a special rear crankshaft half to supply pressure lubrication to the bearing support. The rear crankshaft half of engines without a rear outboard support is not to be used on engines with a rear outboard bearing support, since the resulting lack of lubrication will cause severe bearing damage. See Figure 1-113 for an illustration of the rear outboard bearing support.

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1. Outboard Bearing Support
2. Crankshaft Oil Seal
3. Sleeve
4. Flywheel
5. Drilled Oil Passage in Crankshaft End
6. Bushing
7. Timing Gear
8. Crankshaft Gear
9. Outboard Bearing Support Seal
10. Flywheel Housing

Figure 1-113 Lubrication of the Rear Outboard Bearing Support (Current Engines)

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1.13.1 Repair or Replacement of Rear Outboard Bearing Support

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-114.

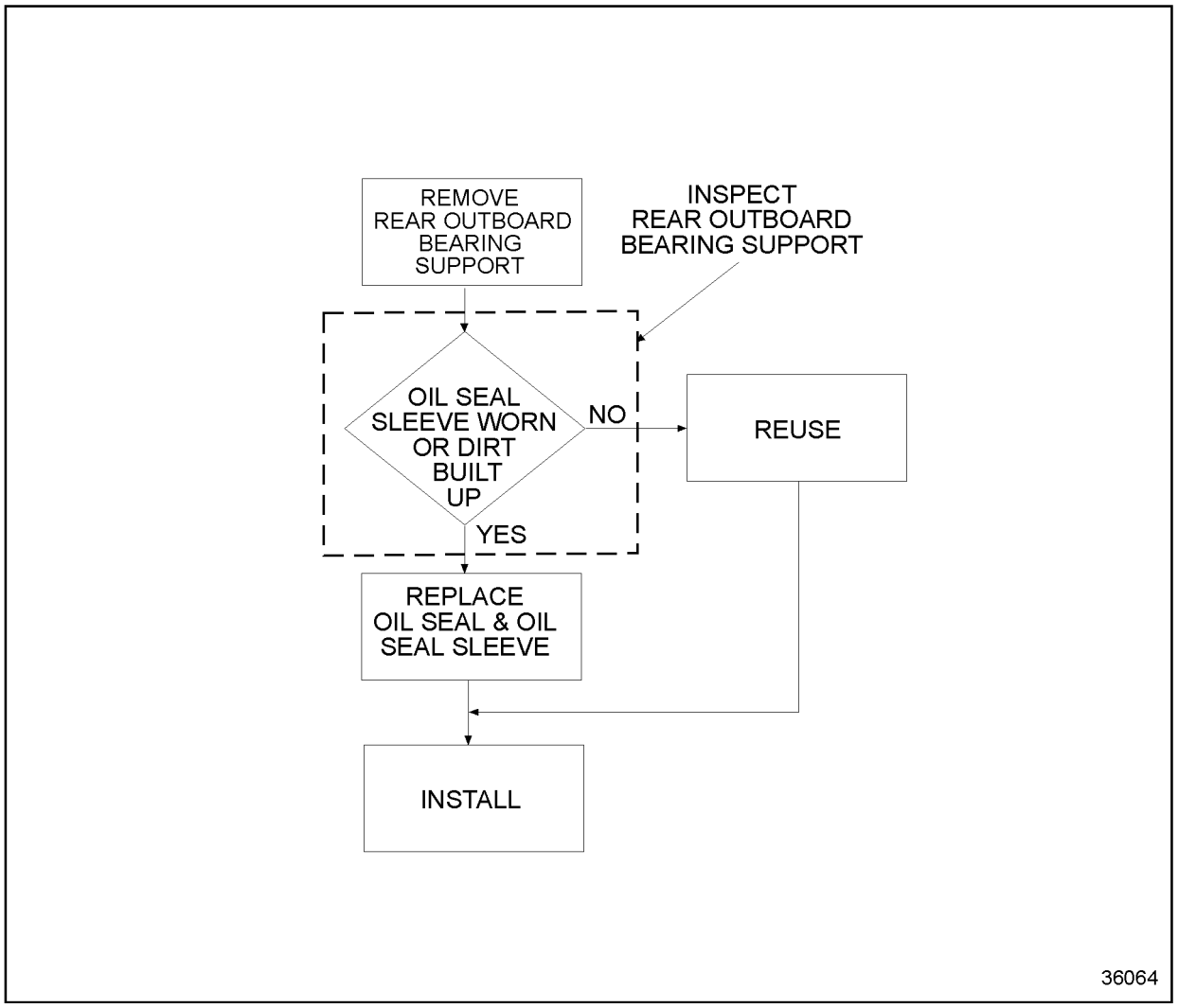


Figure 1-114 Flowchart for Repair or Replacement of Rear Outboard Bearing Support

1.13.2 Removal of Rear Outboard Bearing Support

Remove the rear outboard bearing support as follows:

1. Remove the flywheel or flywheel coupling assembly. Refer to section 1.16.2.
2. Remove the bolts and flat washers securing the outboard bearing support to the engine flywheel housing and remove the support and seal ring.

1.13.2.1 Inspection of Rear Outboard Bearing Support

Oil leaks indicate worn or damaged oil seals. Perform the following inspection of the flywheel or flywheel coupling assembly oil seal sleeve:

1. Inspect the flywheel or flywheel coupling assembly oil seal sleeve for wear or dirt build up.
   [a] If the seal is worn or damaged, install a new oil seal and oil seal sleeve, refer to section 1.13.3.
   [b] If seal has dirt build up install a new oil seal and oil seal sleeve, refer to section 1.13.3.

NOTE:
Oil leaks in the outboard bearing support area may come from the cup plug or pipe plug in the end of the crankshaft or some of the other bolts behind the flywheel.

NOTE:
To ensure proper sealing, replace the oil sleeve whenever a new oil seal is installed. The standard rear crankshaft seal is not used. Ensure the correct seal is installed on the support assembly.

   [c] If no damage is detected, the oil seal and oil seal sleeve may be reused.

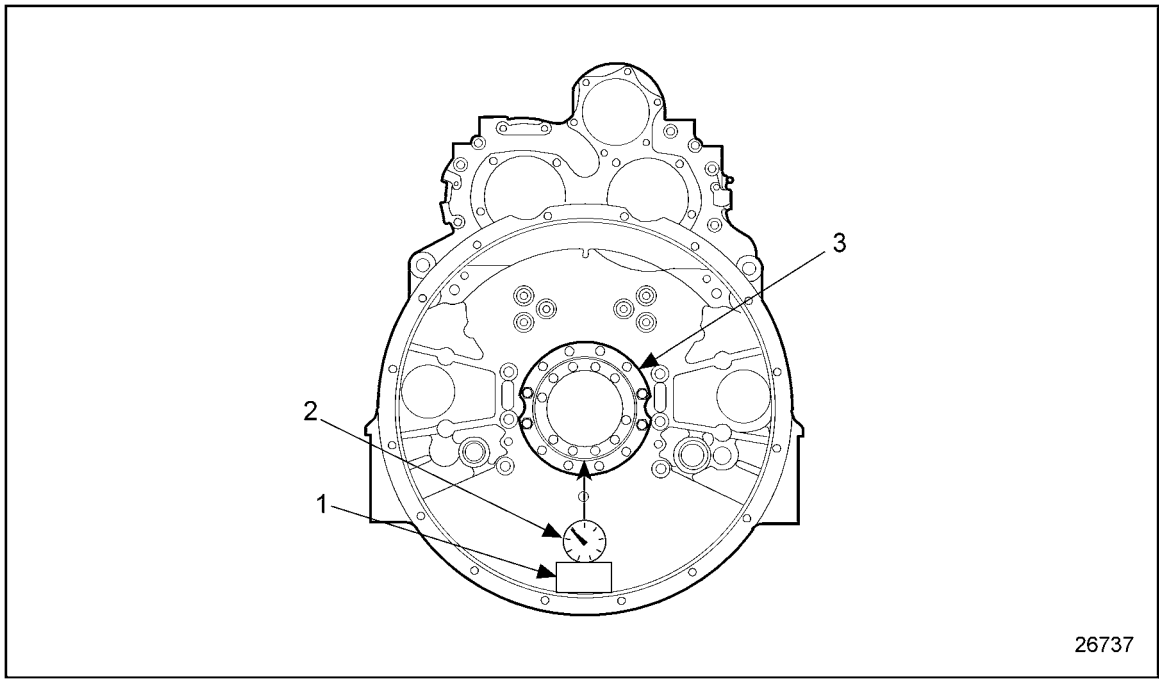
1.13.3 Installation of Rear Outboard Bearing Support

The rear outboard bearing support assembly is adjustable in the flywheel housing to provide maximum support. The assembly should be installed with minimum clearance to the crankshaft and yet not have the possibility of interference. To do this, the crankshaft is rotated so that maximum run-out of the bearing surface is at the bottom of the crankshaft circle.

The support assembly is installed with the crankshaft in this position.

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1. To locate maximum run-out, mount a magnetic base dial indicator on the flywheel housing below the vertical axis of the crankshaft with the indicator probe on the bottom of the crankshaft bearing surface. See Figure 1-115.



1. Magnetic Base
2. Dial Indicator
3. Outboard Bearing Support

Figure 1-115 Placement of Magnetic Base Dial Indicator to Locate Crankshaft Run-Out

2. Rotate the crankshaft and determine location of maximum run-out. The magnitude of run-out is not a concern at this point.
3. Rotate the crankshaft until the observed run-out is at the 6:00 o'clock position. Do not rotate the crankshaft until installation is complete.
4. Apply a thin coat of Lubriplate, or equivalent, over a new seal ring and place the seal ring on the back of the support assembly.

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NOTICE:
Teflon-lip seals *must* be installed dry. This allows transfer of the Teflon to the sleeve surface for proper sealing. Lubricating the seal may result in seal leakage.

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

5. If a new lip seal has been installed in the support assembly, apply a thin film of clean engine oil to the outside diameter of the seal and press the seal flush to the support housing.

NOTE:
The lip side is positioned toward the bushing in the support assembly. **If a new "lay-down" Teflon seal has been installed** (service only availability), **DO NOT apply an oil film to the outside diameter of the seal.**

6. Install the assembly upward to the crankshaft when the engine is in the upright position, taking care not to lift the crankshaft off the rear main bearing.

NOTE:
The support assembly is attached to the flywheel housing with twelve bolts.

7. Install the support assembly in flywheel housing counterbore with two recesses on the outer flange oriented so they are approximately at 3:00 and 9:00 o'clock position and in line with two flywheel housing attaching bolts.

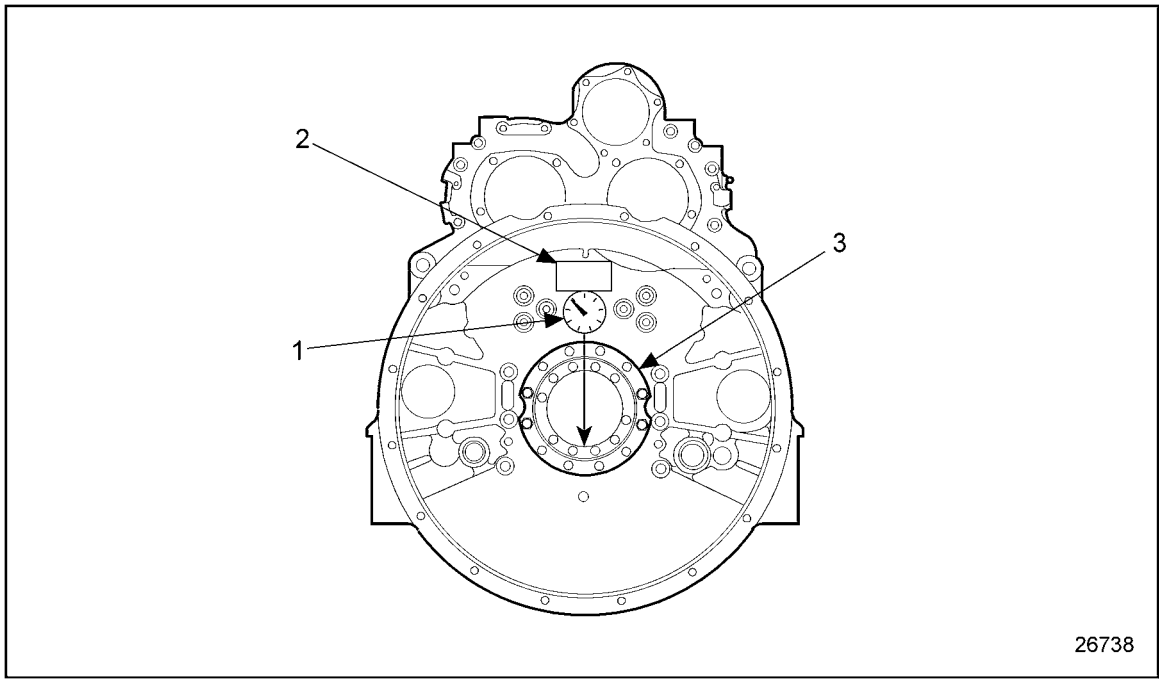
NOTE:
The four oil drain holes must be at the 6:00 o'clock position.

8. Install four washers and bolts in a criss-cross pattern snug enough to hold the support assembly in place, but do not tighten completely.
9. Move the support assembly by hand up and down and side to side to get the "feel" for the approximate bearing-to-crankshaft clearance.
10. When the support assembly feels approximately centered on the crankshaft side to side, lift upward on the support assembly until it contacts the crankshaft.
11. Adjust the clearances before installing the remaining washers and bolts. Refer to step 13.

NOTE:
The threads of attaching bolts are coated with sealant to provide oil sealing to the crankcase.

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12. To ensure the crankshaft is not lifted off the rear main bearing, place a magnetic base dial indicator on the flywheel housing above the vertical axis of the crankshaft with the indicator probe positioned on top of the crankshaft bearing surface. See Figure 1-116.



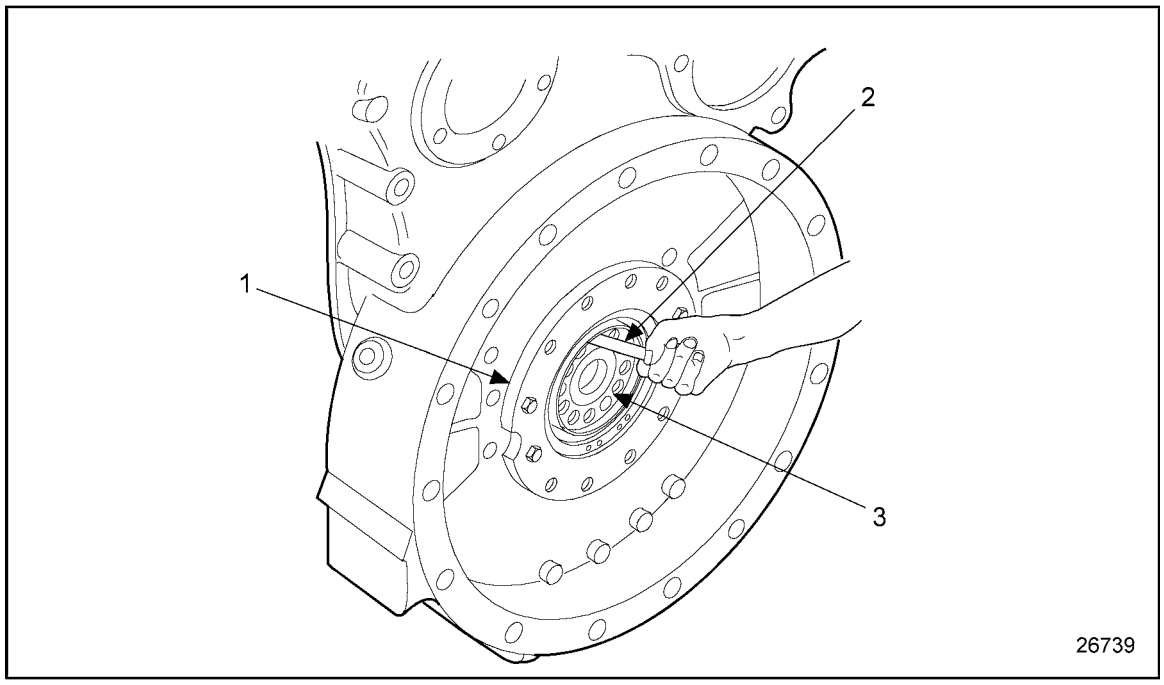
1. Dial Indicator
2. Magnetic Base
3. Outboard Bearing Support

Figure 1-116 Placement of Magnetic Base Dial Indicator to Adjust Outboard Bearing Support

13. Check the clearance between the bearing and crankshaft with a narrow thickness gage.

NOTE:
The greatest clearance must be allowed at the top on the vertical axis of the crankshaft. The top clearance must not be less than 0.08 mm (0.003 in.) or more than 0.25 mm (0.010 in.). See Figure 1-117. There should be no clearance at the bottom. The

clearance at the bottom should never be more than 0.038 mm (0.0015 in.). The side-to-side clearance should be approximately equal.



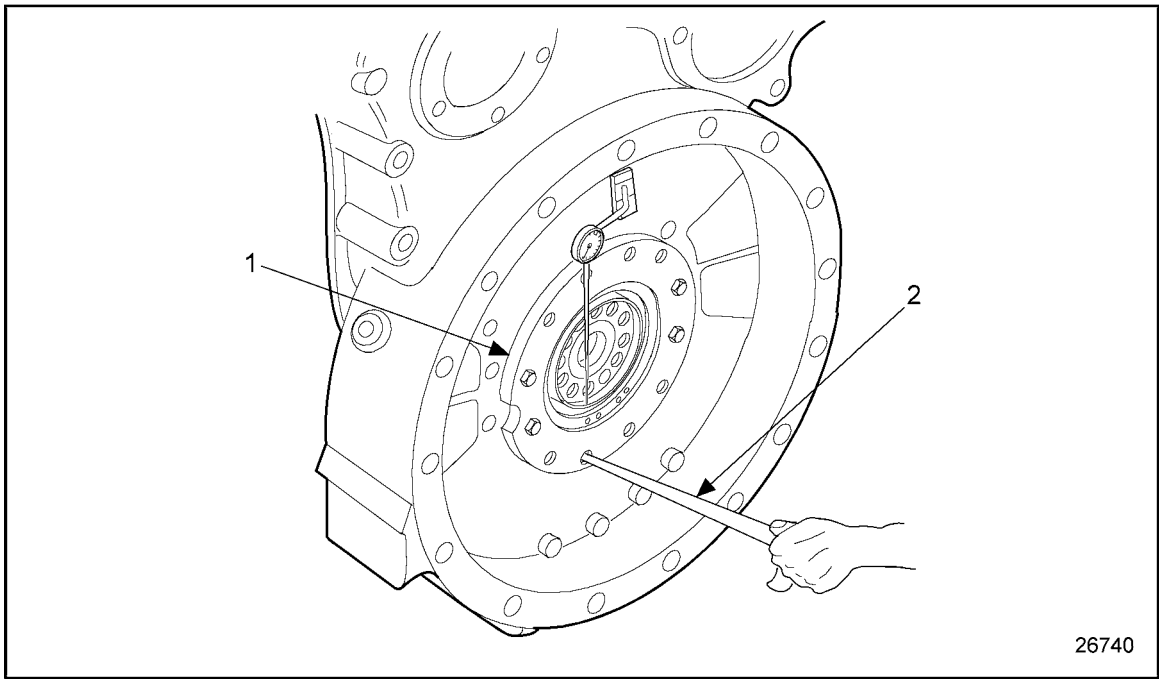
1. Outboard Bearing Support
2. Feeler Gage
3. Crankshaft

Figure 1-117 Checking the Clearance Between the Crankshaft and Outboard Bearing

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NOTICE:
When positioning the flywheel, always use the guide studs to prevent seal damage. Push the flywheel in evenly.

14. To adjust clearances, insert the narrow end of a rolling head pry bar into a bolt hole at the bottom of the support assembly and pry in the direction required to set the required clearance. See Figure 1-118.



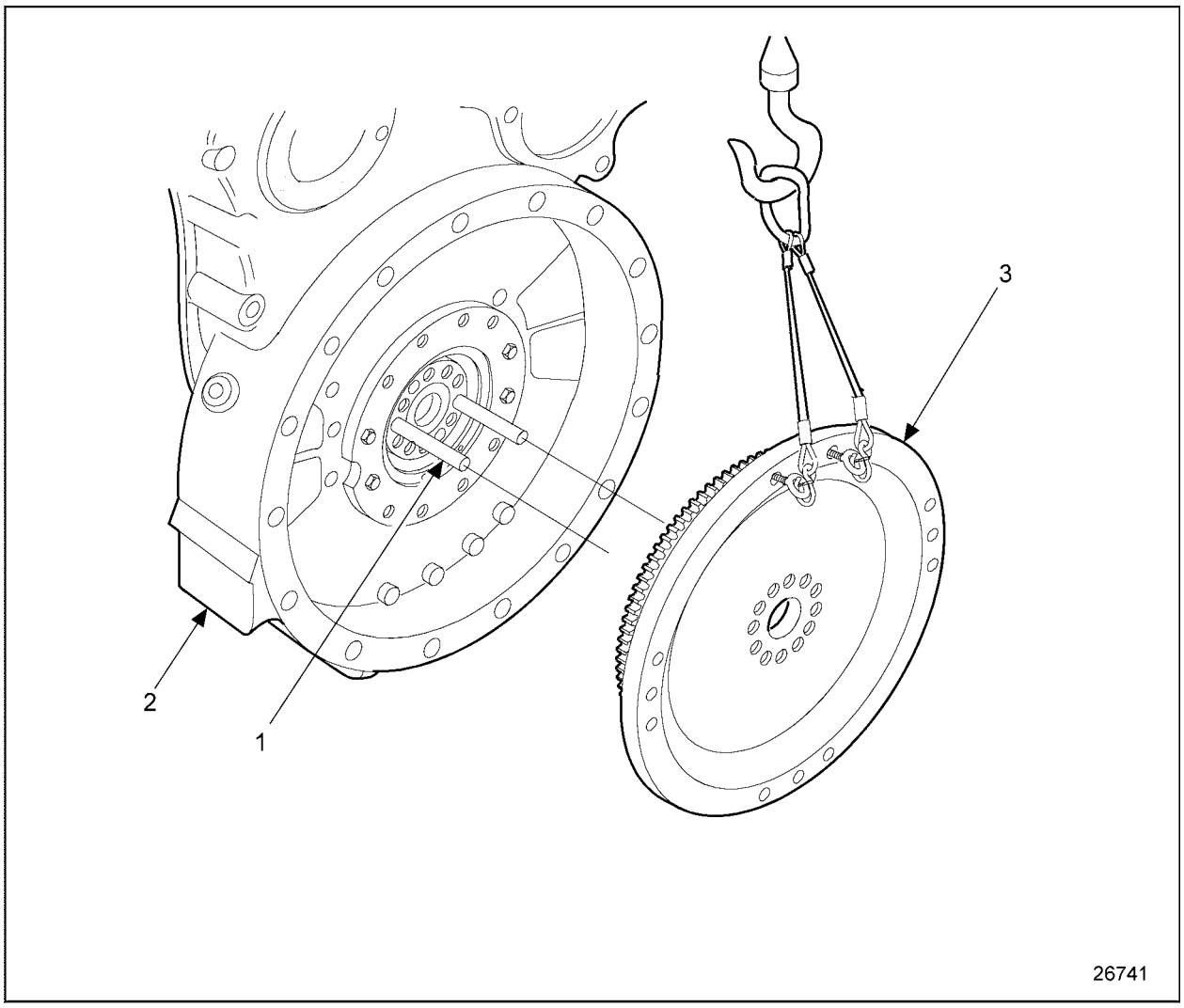
1. Outboard Bearing Support
2. Pry Bar

Figure 1-118 Tightening the Outboard Bearing Support Attaching Bolts

15. With the support assembly in this position, install the remaining washers and bolts. Tighten and torque sequentially in criss-cross pattern to 47-54 N·m (35-40 lb·ft).
16. While tightening the bolts, observe the dial indicator to verify that the support assembly has not moved, or that the crankshaft has not been lifted off the rear main bearing.
17. Attach flywheel lifting tool J 25026-A with two eye bolts onto the flywheel.

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18. Using a chain hoist, position the flywheel into the flywheel housing. See Figure 1-119.



1. Guide Studs
2. Flywheel Housing
3. Flywheel

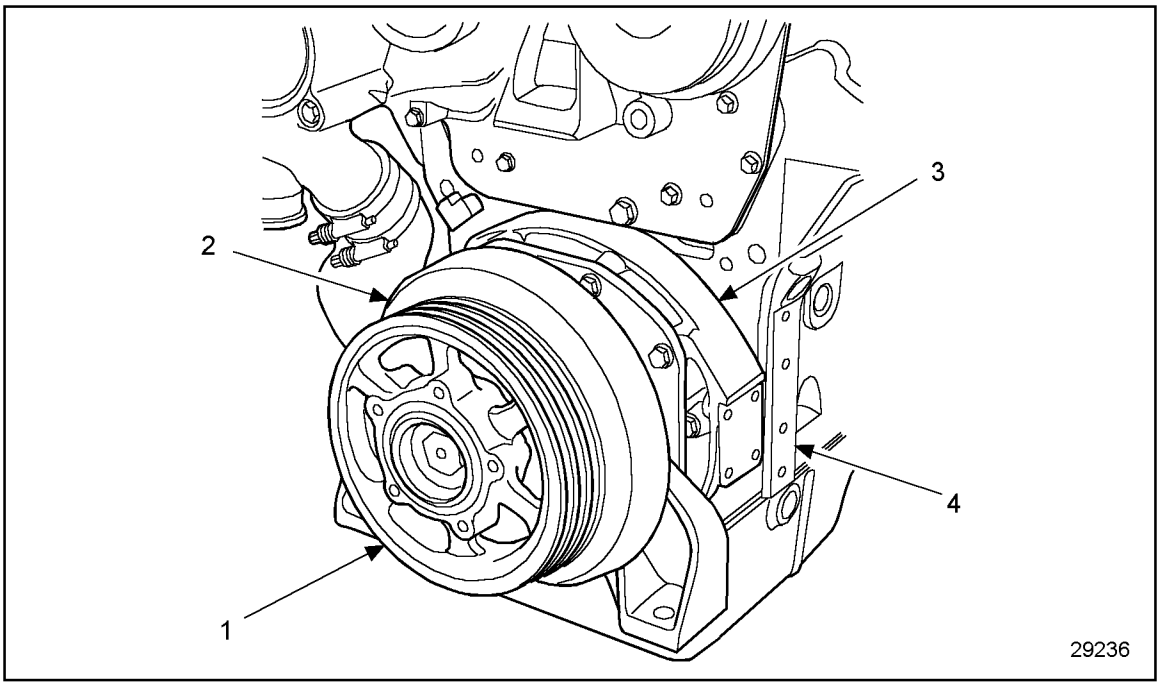
Figure 1-119 Position Flywheel using Guide Studs

19. Align the flywheel bolt holes with the crankshaft bolt holes. Continue flywheel installation. 1.16.5.

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1.14 CRANKSHAFT VIBRATION DAMPER

A 12 in. (8V engine), a 13.5 in. (12V engine) or an 18 in., formerly 15 in., (16V engine) viscous type vibration damper is mounted on the front end of the crankshaft to reduce crankshaft stress. See Figure 1-120. The vibration damper is bolted to a hub retained on the front end of the crankshaft.



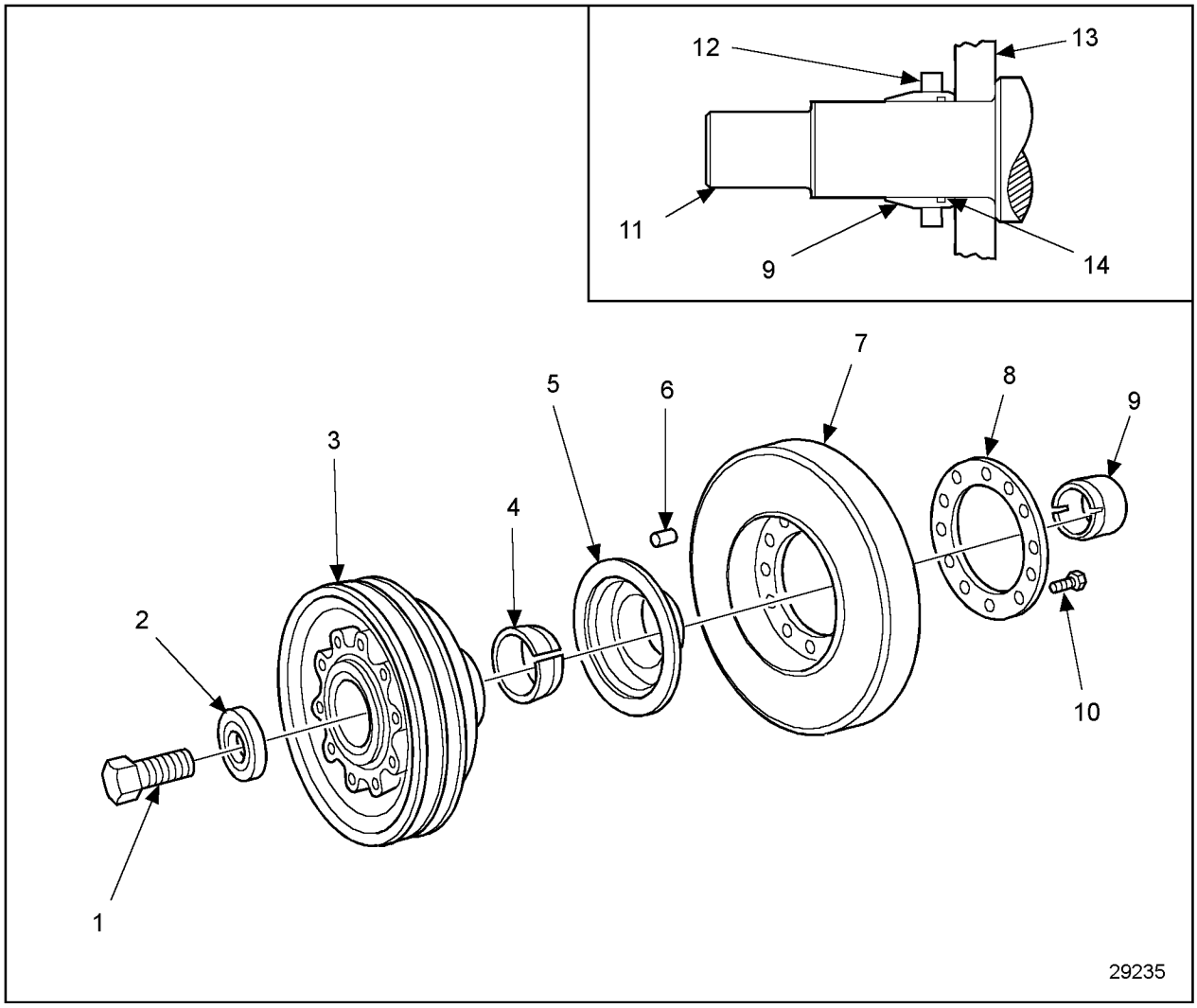
1. Crankshaft Pulley
2. Vibration Damper
3. Lower Front Cover
4. Cylinder Block

Figure 1-120 Vibration Damper Mounting (8V Engines)

A viscous type vibration damper consists of a flywheel enclosed in a fluid-tight outer case, but separated by a thin layer of viscous liquid. The fluid friction restricts flywheel movement and dampens excessive torsional crankshaft vibrations.

Effective with engine serial number 8VF-2373, the 12 in. (8V engine) vibration damper has a 6.35 mm (0.250 in.) thick flange and utilizes a hub and dowel assembly with ten tapped holes, a scuff plate, and a new outer cone with a 3.05 mm (0.120 in.) slot (saw cut)

The current inner cone is grooved on the inner diameter and includes a Nitrile seal ring. The former vibration damper has a 3.81 mm (0.150 in.) thick flange and utilizes a hub and dowel assembly with six tapped holes. See Figure 1-121.



1. Bolt
2. Washer
3. Front Pulley
4. Outer Cone
5. Hub
6. Dowel
7. Vibration Damper
8. Scuff Plate
9. Inner Cone
10. Bolt
11. Crankshaft
12. Front Cover Oil Seal
13. Oil Pump Drive Gear
14. Seal Ring

Figure 1-121 Vibration Damper (8V Engine)

A nylon-coated internal flywheel vibration damper is now being used on current engines, effective with engine serial numbers 8VF-8259 and 16VF-2333.

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

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

The new bolts and washer are black. The former bolts and washer are a steel (gray) color.

A vibration damper safety shield is mandatory in certain industrial and marine applications in which the engine operates without a hood or in an open or unprotected area. A properly designed and installed safety shield prevents direct physical contact with the damper during engine operation. It also keeps the damper from "walking off" the crankshaft and causing property damage or personal injury.

Detroit Diesel Corporation does not manufacture, sell, or install vibration damper safety shields. The OEM or distributor designs and/or manufactures vibration damper safety shields. However, DDC believes that the following guidelines should be followed when fabricating or installing shields:

- Shields should be made from 3.175-4.763 mm (0.1250-0.1875 in.) perforated steel or heavy steel screen.
- The perforated or open screen area of the shield should be equal to, or greater than, the total area of both sides of the damper and its circumference.
- Shields should be no closer than 12.7 mm (0.5 in.) from the damper when installed.
- In all cases, safety shields must permit the vibration damper to be well ventilated during engine operation to prevent overheating.

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1.14.1 Repair or Replacement of Crankshaft Vibration Damper

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

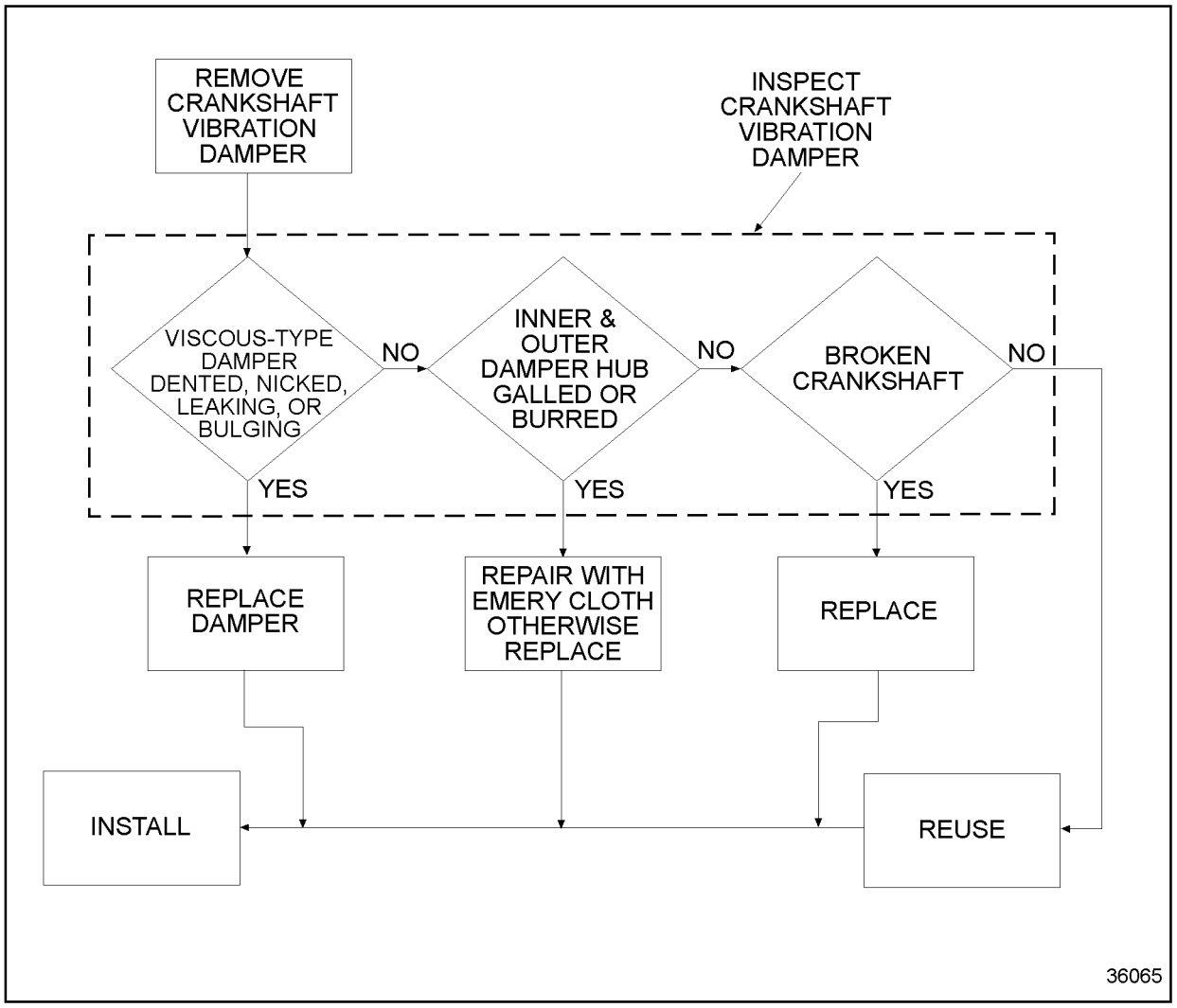


Figure 1-122 Flowchart for Repair or Replacement of Crankshaft Vibration Damper

1.14.2 Removal of Crankshaft Vibration Damper (8V Engines)

On 8V engines, remove the vibration damper as follows:

NOTE:
Regardless of the condition, the damper must be replaced at time of normal major engine overhaul.

1. Remove the crankshaft pulley retaining bolt and washer.

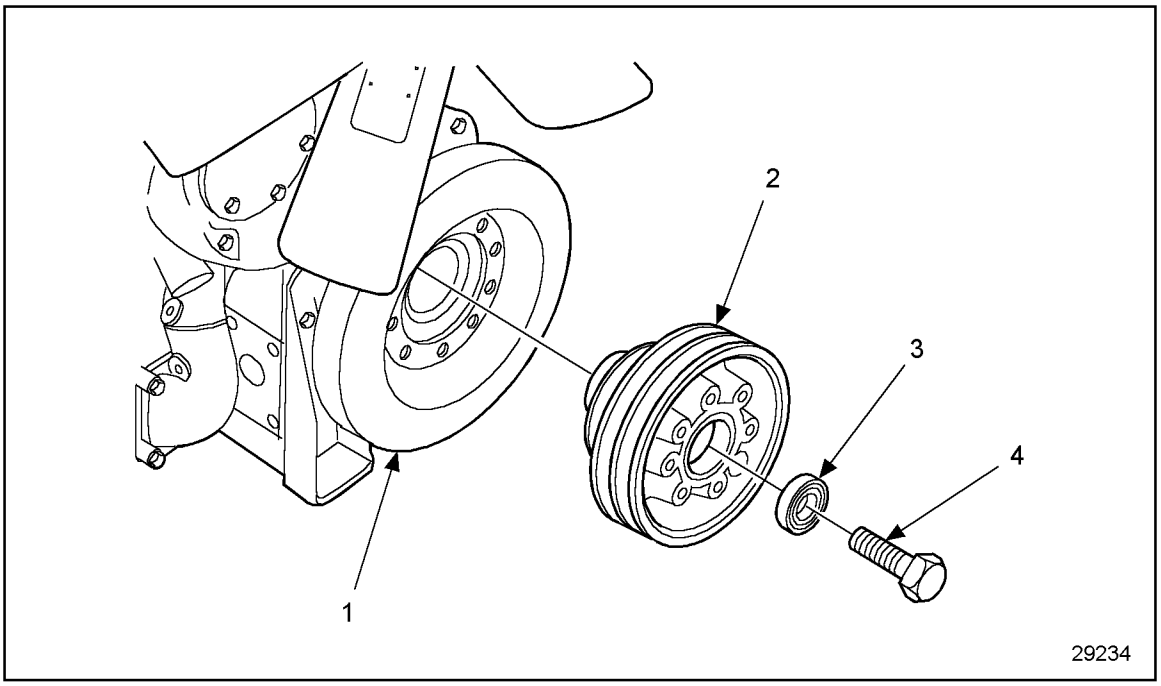
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NOTICE:
Use care when removing the crankshaft pulley as the vibration damper may come off. If the damper is allowed to fall, damage to the internal components of the damper may result.

2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley. Refer to section 1.15.2.
3. Install the pulley retaining bolt in the end of the crankshaft.

NOTE:
The number of bolts attaching the vibration damper to the crankshaft was reduced from 10 to 8. This provides two threaded open bolt holes, located 90 degrees from the dowel pin locations, for puller tool J 24420-C. Service removal of these two bolts is permitted on engines built after 8VF-2373.

4. Attach puller J 24420-C to the vibration damper hub with two long bolts threaded into the two 3/8 in.-24 tapped holes provided in the hub. See Figure 1-123.



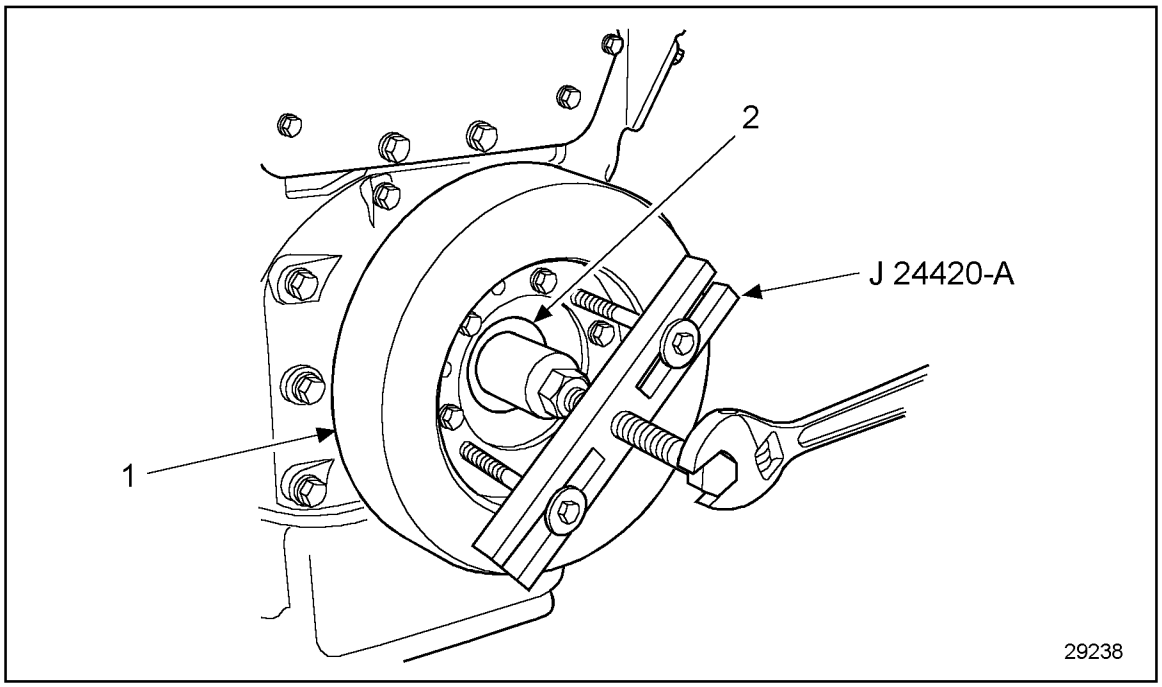
1. Vibration Damper
2. Front Pulley
3. Washer
4. Bolt

Figure 1-123 Removal of Vibration Damper Front Pulley

5. Pull the damper, hub assembly, and the outer cone until the outer cone is loose on the crankshaft.

NOTE:
If the puller method does not free the damper, use a punch in the split of the cone to remove it.

6. Remove the puller from the damper hub, and pull the outer cone off of the crankshaft. See Figure 1-124.



1. Vibration Damper
2. Outer Cone

Figure 1-124 Removing Vibration Damper and Outer Cone

NOTICE:
When removing a viscous type damper from the crankshaft, do not pound on the damper with a hammer or pry with other tools. Dents in the damper outer case may render the damper ineffective. The damper cannot be repaired.

7. Slide the vibration damper, damper hub, and retainer (current engines), as an assembly, off the end of the crankshaft by hand.

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8. If necessary, remove the vibration damper inner cone from the crankshaft. On the current inner cone, remove and discard the seal ring.

NOTE:
The current inner cone is grooved on the inner diameter and includes a Nitrile seal ring. Remove and discard the seal ring.

1.14.3 Removal of Crankshaft Vibration Damper (12V and 16V Engines)

On 12V and 16V engines, remove vibration damper from crankshaft as follows:

1. Remove the crankshaft pulley retaining bolt and washer.

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.

2. Remove the crankshaft pulley. If required, use a suitable puller to remove the pulley.
3. Remove the bolts securing the vibration damper to the hub.

NOTICE:
When removing a viscous type damper from the crankshaft, do not pound on the damper with a hammer or pry with other tools. Dents in the damper outer case may render the damper ineffective. The damper cannot be repaired.

4. Lift the damper off the hub.

1.14.3.1 Inspection of Crankshaft Vibration Damper

Inspect the viscous type damper as follows:

NOTICE:
Shielded vibration dampers are difficult to inspect because of the design of the shield and/or end items in which the engine is installed. OEMs and distributors must supply written instructions to their product users, cautioning them to periodically inspect the viscous vibration damper for a split seam, bulged cover, leaks, dents, etc. If these conditions exist, replace the vibration damper shield. These conditions can prevent vibration dampers from functioning properly and cause serious engine damage.

1. Inspect the viscous type damper for dents, nicks, fluid leaks, or bulges in the outer casing of the damper.
   [a] If dented, nicked, leaking, or bulged, replace the damper. Refer to section 1.14.4.
   [b] If damage to the vibration damper is extensive, inspect the crankshaft. Refer to section 1.7.2.2.
   [c] If not dented, nicked, leaking, or bulged, continue inspection.

NOTE:
Due to close clearances between the damper internal flywheel and outer casing, dents may render the damper ineffective. Bulges or splits indicate fluid in the damper has deteriorated and has bulged or forced the casing open at its crimped edges.

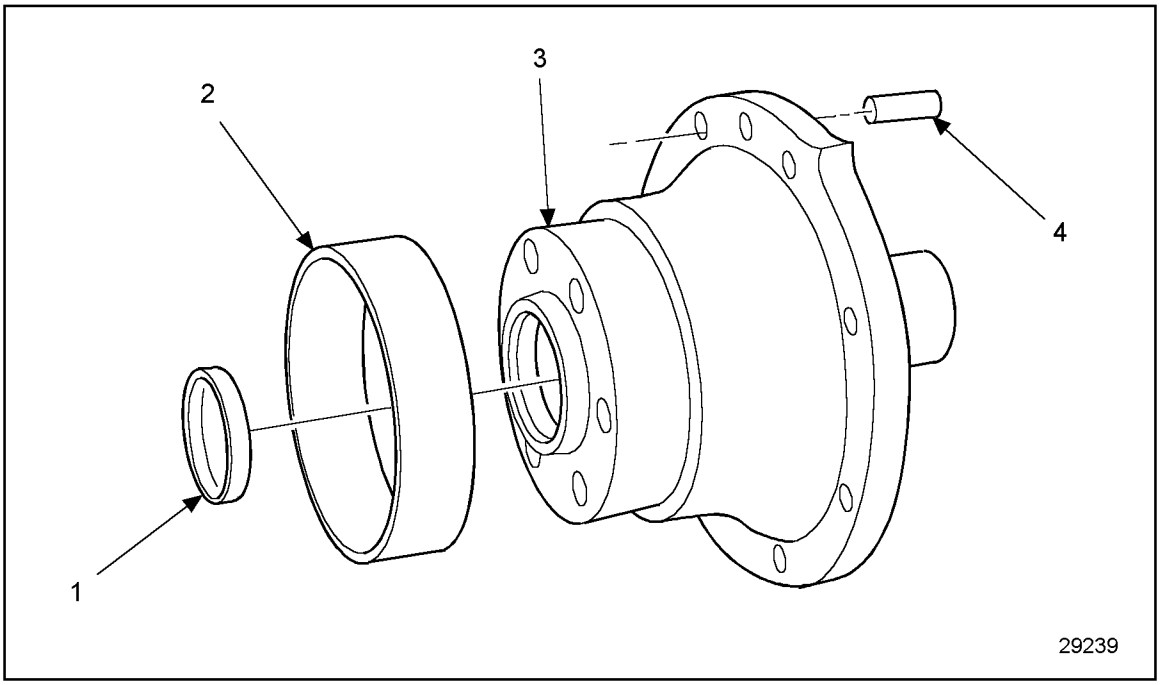
NOTE:
A loose or defective vibration damper, after a short period of operation, may cause a cracked crankshaft.

2. Inspect the damper inner and outer cones, damper hub and the end of the crankshaft for galling or burrs.
   [a] Remove slight scratches or burrs with emery cloth.
   [b] If seriously scratched or burred, replace the parts and refinish the end of the crankshaft. Refer to section 1.14.4.
   [c] If not scratched or burred, continue with the inspection.
3. Check the outside diameter of the inner cone for wear at the crankshaft front oil seal contact surface.
   [a] If worn, replace the oil seal and cone. Refer to section 1.8.6.
   [b] If not worn, continue inspection.
4. On the current inner cone, check the grooves on the inner diameter for wear.
   [a] If worn, replace the oil seal and cone. Refer to section 1.8.6.
   [b] If not worn, continue inspection.

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NOTICE:
A loose engine mount enables the engine to move during operation. This could damage the vibration damper.

5. Inspect the engine mounts to ensure they are not loose, cracked, or deteriorated.
   [a] If loose, cracked, or deteriorated, replace the engine mounts.
   [b] If not loose, cracked, or deteriorated, continue inspection.
6. Inspect the vibration damper hub sleeve (12V and 16V trunnion mounted engines) for wear at the trunnion oil seal contact surfaces. See Figure 1-125.



1. Cup Plug
2. Sleeve
3. Vibration Hub
4. Dowel Pin

Figure 1-125 Trunnion Mounted Vibration Damper Hub (12V and 16V)

   [a] If worn, replace the sleeve. Refer to section 1.8.5.
   [b] If not worn, reuse the sleeve.

1.14.4 Installation of Crankshaft Vibration Damper (8V Engines)

Install vibration damper on 8V engines as follows:

NOTE:
When replacing the former 12 in. (8V engine), 0.150 in. flange vibration damper or the six bolt hole hub assembly, the current 0.250 in. thick flange vibration damper, ten bolt

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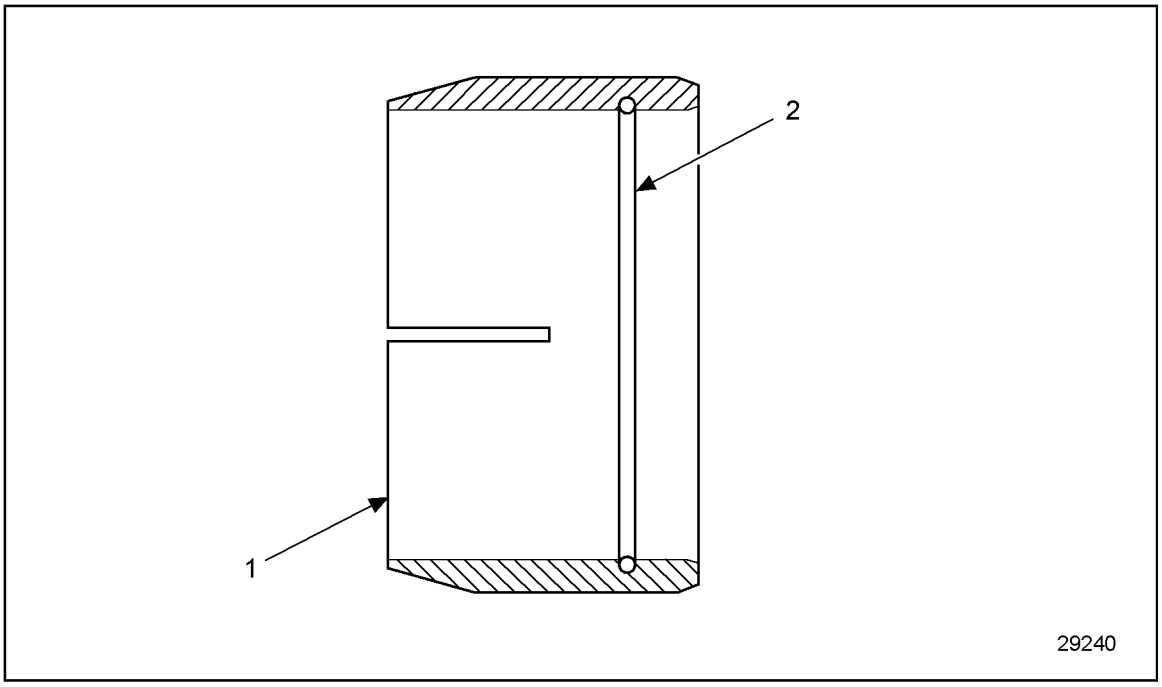
hole hub assembly, scuff plate, ten 7/16 in.-20 x 1 in. lock bolts, and the new 0.120 in. slot outer cone must be used.

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

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. If removed, lubricate the new seal ring with engine oil.
2. Install the seal ring in the groove on the inner diameter of the current damper inner cone. See Figure 1-126.



1. Inner Cone
2. Seal Ring

Figure 1-126 Inner Cone with Seal Ring (8V Engines)

3. If the engine was built prior to November 1976, install a new inner cone and Nitrile seal ring.

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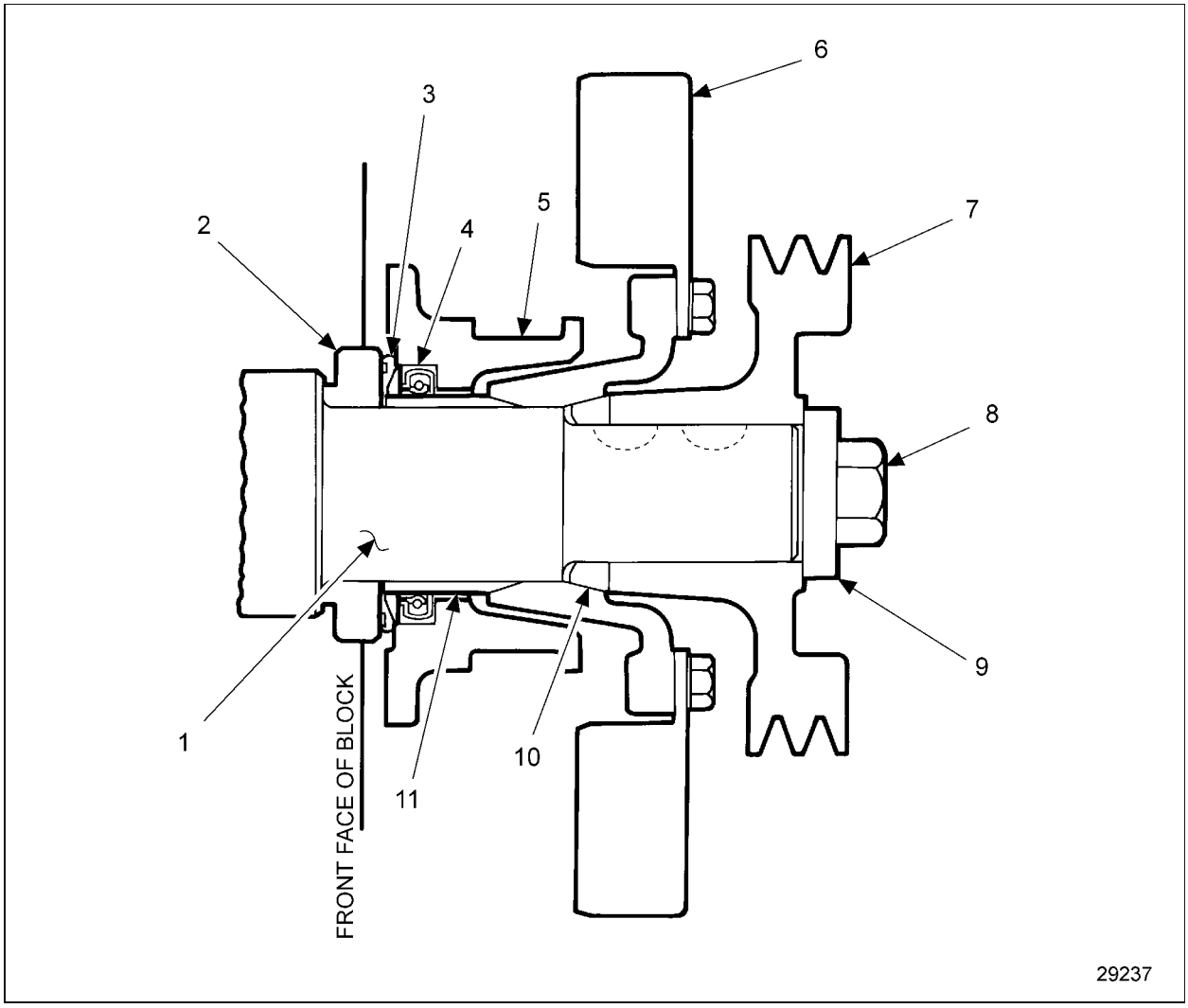
4. Guide the damper inner cone over the end of the crankshaft, through the oil seal, and up against the oil pump drive hub or oil slinger (bearing cap mounted oil pump).

NOTE:
The tapered end of the cone should point toward the front end of the crankshaft.

5. Assemble the current vibration damper and hub as follows:
   [a] Place the vibration damper on the hub and over the dowel.
   [b] Place the scuff plate over the dowels and against the damper. Install the eight or ten 7/16 in.-20 x 1 in. lock bolts.

[c] Tighten the bolts to 102-115 N·m (75-85 lb·ft) torque.

NOTE:
When overhauling engines with the former six bolt design vibration damper and hub assembly, the bolts should be tightened to the same torque as the current ten bolt design vibration damper and hub assembly. See Figure 1-127.



1. Crankshaft
2. Oil Pump Drive Gear
3. Oil Slinger
4. Oil Seal
5. Front Cover
6. Vibration Damper
7. Pulley
8. Bolt
9. Washer
10. Outer Cone
11. Inner Cone

Figure 1-127 Vibration Damper and Crankshaft Pulley Assembly Mounting

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NOTICE:
Do not hit the damper with a hammer to position it on the crankshaft. The damper may dent or bend rendering it ineffective. The damper cannot be repaired.

6. Slide the vibration damper and hub, as an assembly, over the end of the crankshaft (long end of hub facing inner cone) and up against the damper inner cone.
7. Slide the damper outer cone, pointed end toward the hub, over the end of the crankshaft and up against the damper hub.
8. Install the pulley on the crankshaft.
9. Place the washer on the crankshaft end bolt, and thread the bolt into the end of the crankshaft. If the engine was built prior to March 1977, install a new lubrite-coated bolt and washer.
10. Tighten the crankshaft end bolt as follows:
    [a] Tighten the bolt to 244 N·m (180 lb·ft) torque.
    [b] Strike the end of the bolt with a 2 to 3 pound lead hammer.
    [c] Tighten the bolt to 407 N·m (300 lb·ft) torque, and strike the bolt.
    [d] Tighten the bolt to 393-421 N·m (290-310 lb·ft) torque.

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

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

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⚠ CAUTION:

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

NOTICE:

The bolt must not loosen during the barring operation. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. The barring operation should always be performed clockwise.

1.14.5 Installation of Crankshaft Vibration Damper (12V and 16V Engines)

Install the vibration damper on 12V and 16V engines as follows:

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

1. Install the hub on the front end of the crankshaft, if removed.
2. Align the scuff plate and hub assembly with the crankshaft so that all six hub-to-crankshaft bolts can be installed.
3. Apply International Compound No. 2, or equivalent, to the bolt threads and the underside of the bolt heads.
4. Tighten the 9/16 in.-18 hub attaching bolts to 211-224 N·m (155-165 lb·ft) torque.

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

NOTICE:

Do not hit the damper with a hammer to position it on the crankshaft. The damper might be dented or bent.

5. Secure the vibration damper to the hub on the front end of the crankshaft with bolts and lock washers.
6. Tighten the bolts to 96-102 N·m (71-75 lb·ft) torque.

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7. Drive the crankshaft pulley, if used, straight on the hub with a wood block and a hammer.
8. Place the washer on the crankshaft end bolt, and thread the bolt into the end of the crankshaft.
9. Tighten the crankshaft end bolt as follows:
   [a] Tighten the bolt to 244 N·m (180 lb·ft) torque.
   [b] Strike the end of the bolt with a 2 to 3 pound lead hammer.
   [c] Tighten the bolt to 407 N·m (300 lb·ft) torque, and strike the bolt.
   [d] Tighten the bolt to 393-421 N·m (290-310 lb·ft) torque.

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

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

⚠ CAUTION:

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

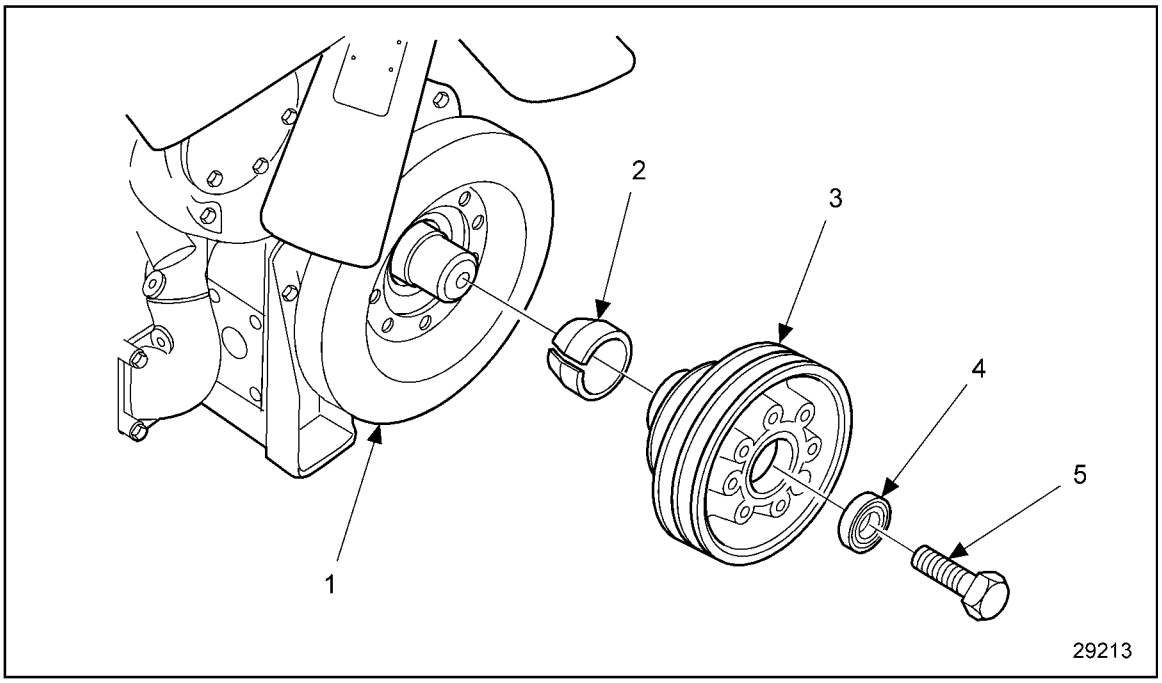
NOTICE:

The bolt must not loosen during the barring operation. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. The barring operation should always be performed clockwise.

1.15 CRANKSHAFT PULLEY

The crankshaft pulley is retained on the crankshaft with keys, cones, or a combination of both. It is secured with a special washer and bolt. See Figure 1-128.



1. Vibration Damper
2. Outer Cone
3. Pulley
4. Washer
5. Bolt

Figure 1-128 Front Pulley

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

The current bolts and washer are black. The former bolts and washer are a steel (gray) color.

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

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

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⚠ CAUTION:

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

NOTICE:

The bolt must not loosen during the barring operation. If the vibration damper or pulley is not securely fastened to the crankshaft, serious engine damage may result.

NOTICE:

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

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. The barring operation should always be performed clockwise.

1.15.1 Repair or Replacement of Crankshaft Pulley

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-129.

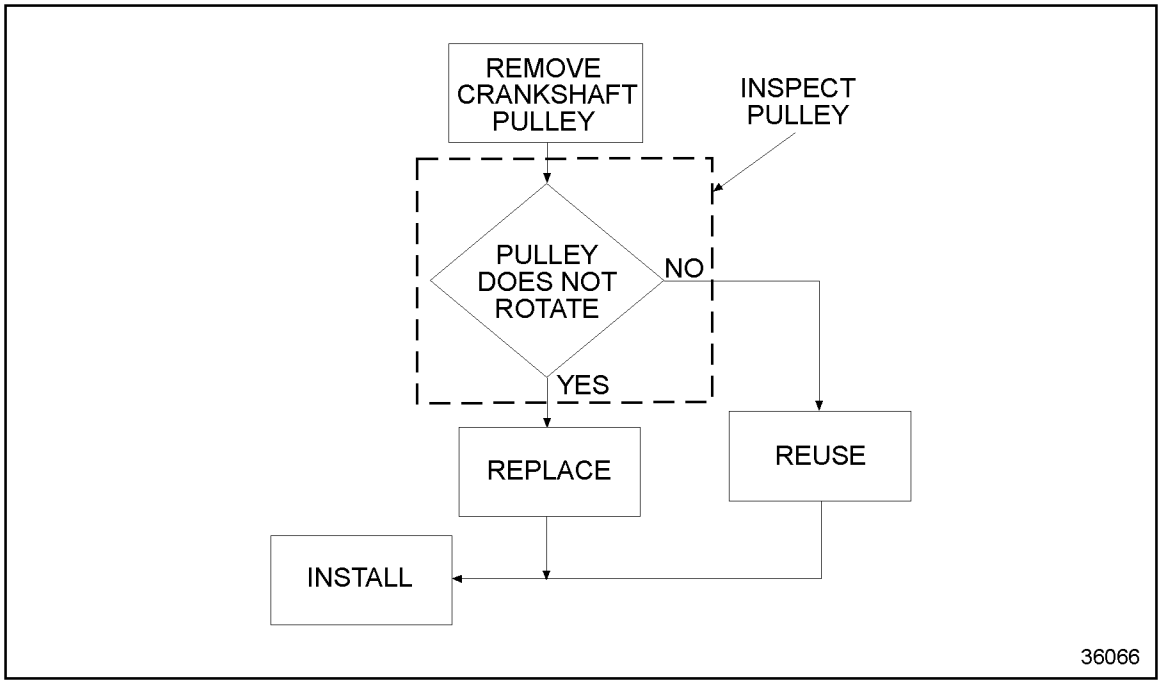


Figure 1-129 Flowchart for Repair or Replacement of Crankshaft Pulley

1.15.2 Removal of Crankshaft Pulley

Remove the crankshaft pulley as follows:

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.

1. Remove the pulley retaining bolt, washer, and static clip, if used.
2. Using a suitable puller, remove the pulley, or thread the pulley retaining bolt halfway into the crankshaft.
3. Strike the bolt with a 2 to 3 pound lead hammer while prying behind the pulley with two pry bars. Keep the ends of the pry bars as close to the crankshaft as possible.
4. If tapped holes are provided, install the pulley bolt in the end of the crankshaft.
5. Using puller J 24420-C, remove the pulley from the crankshaft.

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1.15.2.1 Inspection of Crankshaft Pulley

Inspect the crankshaft pulley as follows:

1. Inspect the pulley bushing for rotation.
2. Hold the crankshaft stationary, and apply pressure to the pulley.
   [a] If the pulley can be rotated, replace the bushing. Refer to section 1.15.3.
   [b] If the pulley cannot be rotated, reuse the bushing.

NOTE:
The reliability of the rubber bushed crankshaft cannot be determined by examining the rubber.

1.15.3 Installation of Crankshaft Pulley

Install the crankshaft pulley as follows:

1. Install the keys and/or cones in the front end of the crankshaft.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the end of the crankshaft with engine oil to facilitate pulley installation.
3. Slide the pulley on the end of the crankshaft.

NOTE:
In December 1990, the bolt torque requirements were increased to improve crankshaft pulley retention. The higher torque required that the current crankshaft pulley bolt with

the larger head replace the former bolt with the smaller head. Ensure the current bolt is installed on the engine. See Figure 1-130.

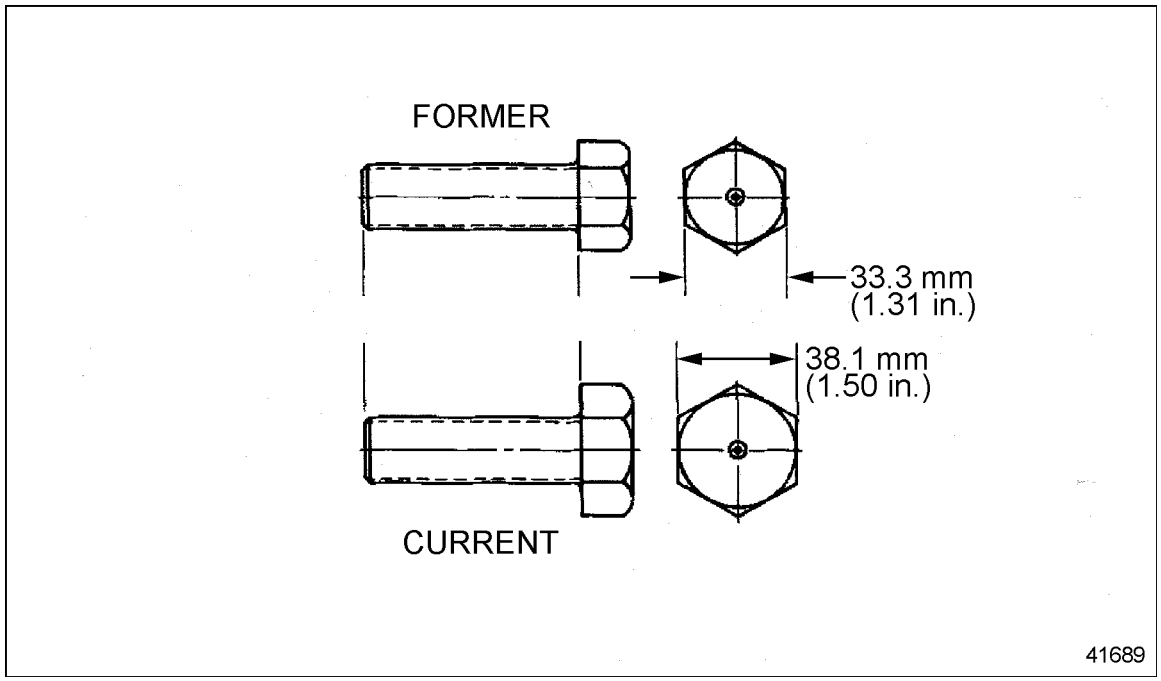


Figure 1-130 Former and Current Crankshaft Pulley Bolts

4. Place the washer and static clip, if used, on the bolt.
5. Thread the bolt into the end of the crankshaft.

NOTE:
If the engine is equipped with a vibration damper, the pulley must be tight against the outer cone. Refer to section 1.14.4.

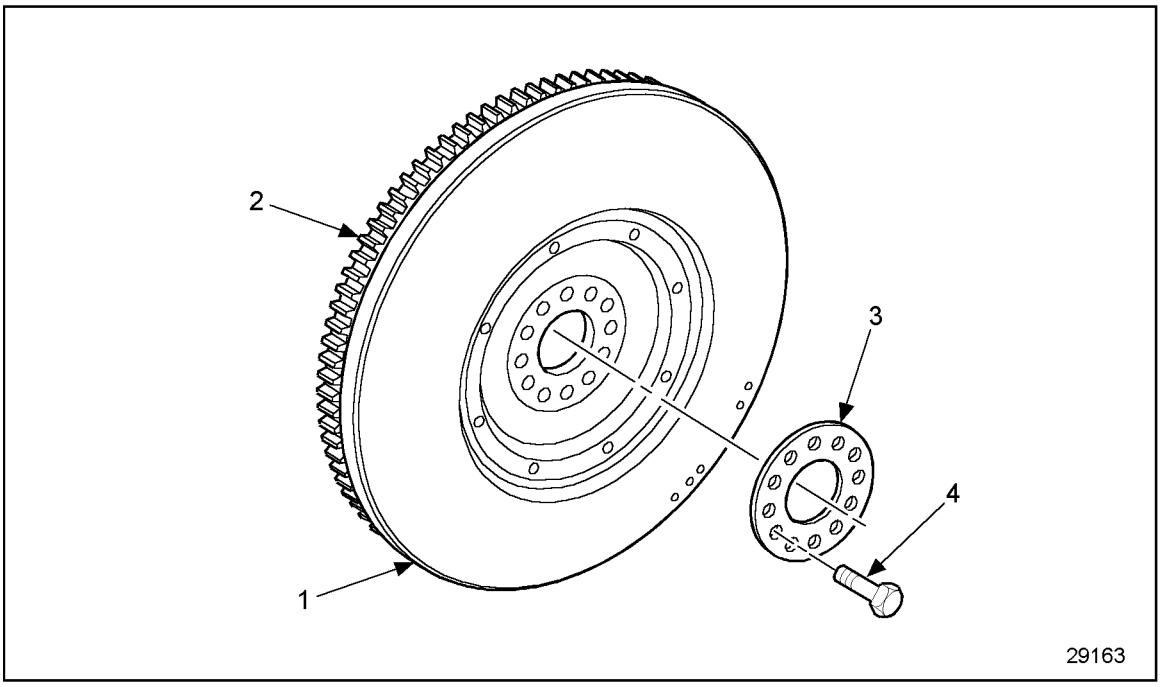
6. Tighten the crankshaft end bolt as follows:
   [a] Tighten the bolt to 244 N·m (180 lb·ft) torque.
   [b] Strike the end of the bolt with a 2 to 3 pound lead hammer.
   [c] Tighten to 610 N·m (450 lb·ft) torque, and strike the bolt.
   [d] Tighten the bolt to 596–624 N·m (440–460 lb·ft) torque.

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

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1.16 FLYWHEEL

On 8V engines the flywheel is attached to the rear end of the crankshaft with twelve self-locking bolts. See Figure 1-131. Six bolts are used on the 6V and 16V engines. A scuff plate is used between the flywheel and the bolt heads to prevent them from scoring the flywheel surface.

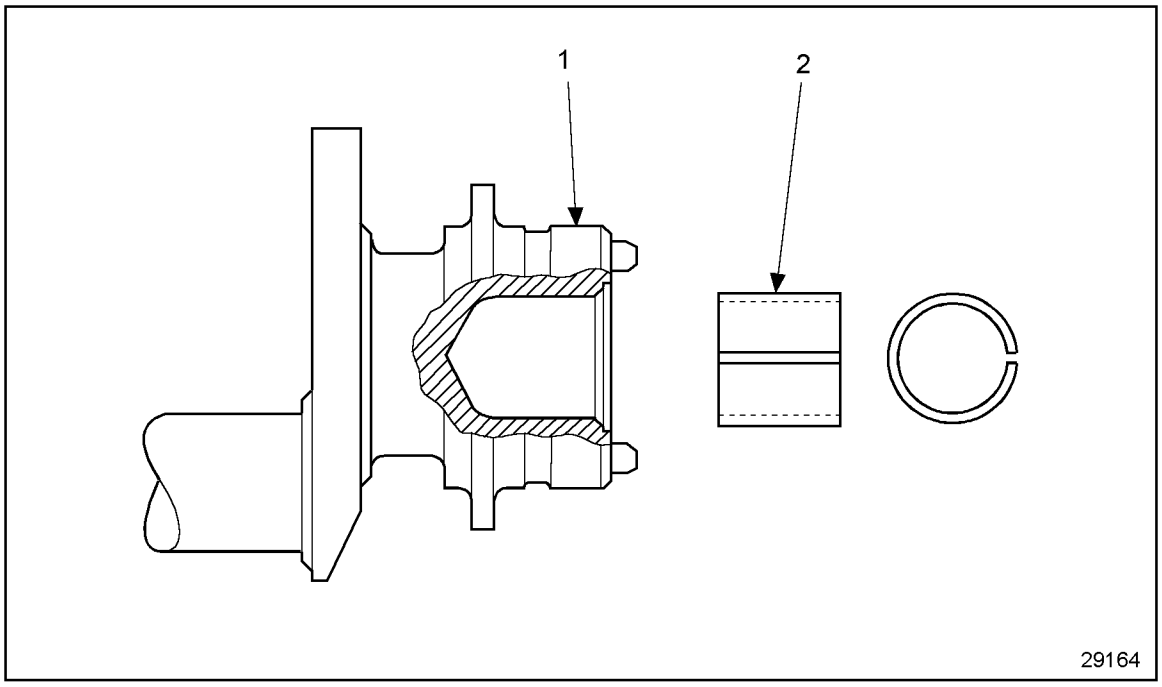


1. Flywheel
2. Ring Gear
3. Scuff Plate
4. Bolt

Figure 1-131 Typical Flywheel Assembly

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

On some engines, a split tube type retainer is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity. See Figure 1-132.



1. Crankshaft
2. Bearing Retainer (Split Tube Type)

Figure 1-132 Pilot Bearing Retainer

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

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

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1.16.1 Repair or Replacement of Flywheel

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-133.

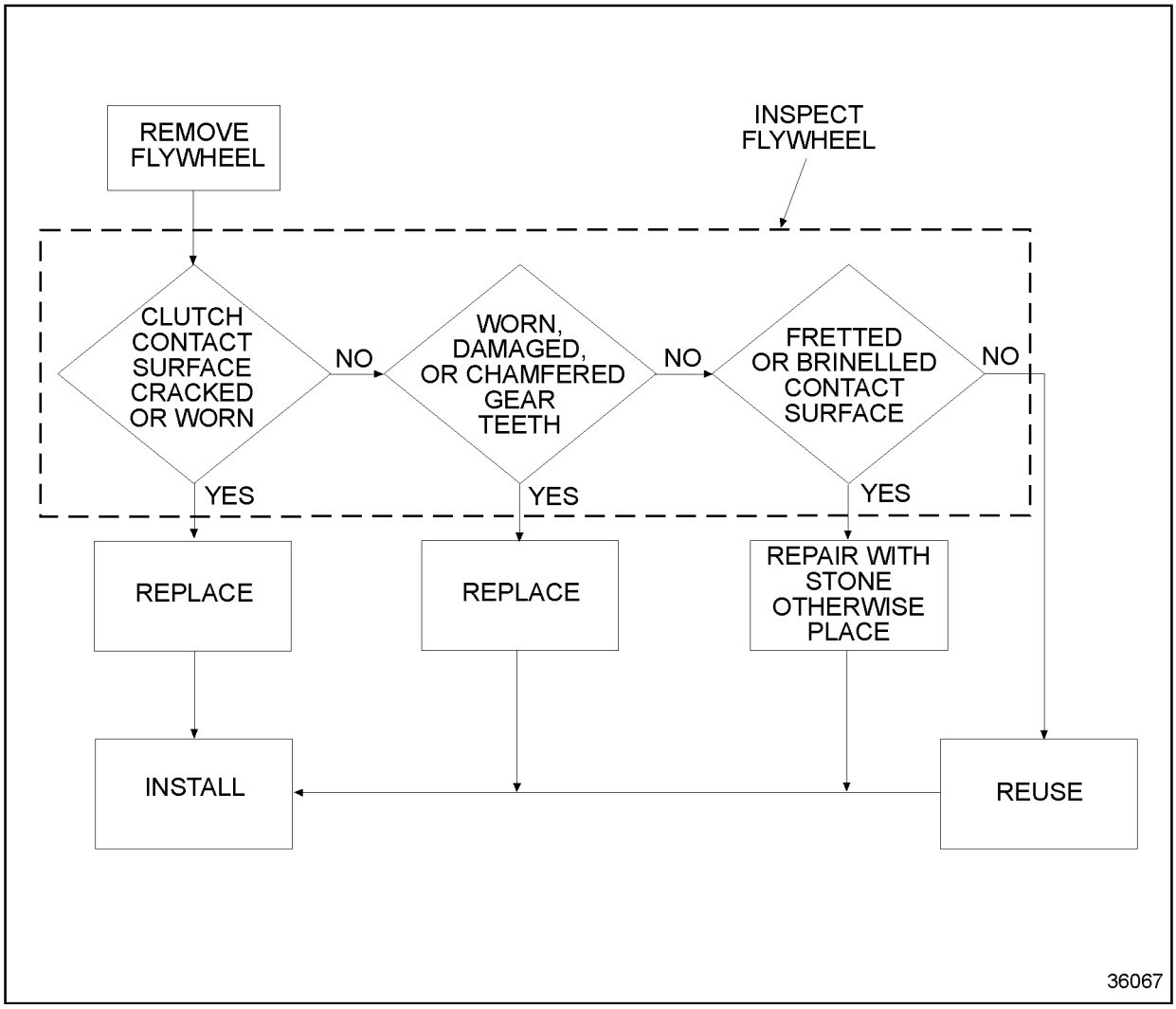


Figure 1-133 Flowchart for Repair or Replacement of Flywheel

1.16.2 Removal of Flywheel

With the transmission removed, remove the flywheel as follows:

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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.

1. Remove two flywheel bolts.
2. Install two suitable guide pins in the bolt holes to support the flywheel.
3. Remove the remaining flywheel attaching bolts and scuff plate.
4. Attach flywheel lifting tool J 25026-A, or some other suitable safe lifting device, to the flywheel.
5. Attach a chain hoist to the lifting tool to support the flywheel.
6. Remove the flywheel from the crankshaft and the flywheel housing.
7. Remove the clutch pilot bearing, if used. Refer to section 1.17.2.

NOTE:
It is not necessary to remove the split tube type bearing retainer (if applicable) from the crankshaft.

1.16.3 Removal of Ring Gear

Remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or hardwood block that is slightly smaller than the inside diameter of the ring gear.
2. Drive the ring gear off the flywheel with a suitable drift and hammer.

NOTE:
Work around the circumference of the gear to avoid binding the gear on the flywheel.

1.16.3.1 Inspection of Flywheel

Inspect the flywheel as follows:

1. Visually inspect the clutch contact surface of the flywheel or wear plate for cracks or wear.

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NOTICE:
Do not remove more than 0.020 in. (0.508 mm) of metal from the flywheel. Maintain all of the radii when refacing the flywheel. If cavities of any size appear, fill them so no damage can result to the clutch.

[a] If the flywheel is cracked or worn, it may be refaced.

[b] If excessively cracked or worn, replace the flywheel. Refer to section 1.16.5.

[c] If not cracked or worn, reuse the flywheel.

2. Visually inspect the gear teeth for wear, damage, or chamfering.

   [a] If excessively worn, damaged, or chamfered, replace the ring gear. Refer to section 1.16.4.

   [b] If not worn, damaged, or chamfered, continue inspection.

NOTE:
The replacement gear must be installed so that the chamfer on the teeth faces the same direction as on the gear that has been removed.

3. Visually inspect the crankshaft butt end and flywheel contact surface for fretting or brinelling.

   [a] If fretted or brindled, lightly stone the crankshaft end and the flywheel contact surface.

NOTE:
If material is removed from the flywheel face, mark or stamp the quantity removed on a non-critical flywheel area, e.g., 0.25 mm (0.010 in.).

   [b] If excessively fretted or brindled, replace the flywheel. Refer to section 1.16.5.

   [c] If not fretted or brindled, continue inspection.

4. Inspect the dowel extension.

   [a] If dowels extend more than 12.7 mm (0.5 in.) from the crankshaft, ensure the proper size dowels are being used. Refer to section 1.16.4.

   [b] If dowels extend less than 12.7 mm (0.5 in.) from the crankshaft, ensure the proper size dowels are being used. Refer to section 1.16.4.

1.16.4 Installation of Ring Gear

Install the ring gear as follows:

1. Support the flywheel, ring gear side up, on a solid flat surface.

NOTICE:
Do not heat the gear over 400°F (204°C). Excessive heat may destroy the original heat treatment.

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.

NOTE:
Heat indicating "crayons," that melt at a predetermined temperature, may be obtained from most tool vendors. Placing a "crayon" on the ring gear will help prevent overheating.

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 against the shoulder on the flywheel.

NOTICE:
Do not heat the gear over 400°F (204°C). Excessive heat may destroy the original heat treatment.

5. If the gear cannot be readily seated all the way around, remove it and apply additional heat.

1.16.5 Installation of Flywheel

Install the flywheel as follows:

NOTE:
Before attaching the flywheel, ensure the crankshaft, flywheel contact surfaces, and the bolt threads in the crankshaft end are clean and dry. This will ensure proper metal-to-metal contact and maximum friction.

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

NOTE:
The flywheel bolt tap depth in the 8V engine crankshaft has been reduced from 66.548 to 41.148 mm (2.620 to 1.620 in.) beginning with approximate engine serial number 8VF-3120. With this change, shorter flywheel attaching bolts are used. The current shorter bolts can be used with the former crankshaft.

1. Using a chain hoist, attach the flywheel lifting tool.

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2. Position the flywheel in the flywheel housing (use guide studs).
3. Align the flywheel bolt holes with the crankshaft bolt holes.
4. Install the clutch pilot bearing, if used.
5. Install two bolts through the scuff plate 180 degrees from each other. Tighten the bolts to hold the flywheel and scuff plate to the crankshaft.
6. Remove the guide studs.
7. Remove the flywheel lifting tool.
8. Apply International Compound No. 2, or equivalent, to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2.
9. Wipe off excess compound.

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

10. Install and tighten the remaining bolts.
11. Remove the two bolts used temporarily to retain the flywheel.
12. Apply International Compound No. 2.
13. Install the bolts.
14. Using an accurately calibrated torque wrench, tighten the bolts to 68 N·m (50 lb·ft) torque.
15. Mark the heads of the bolts and rotate each as follows to obtain required clamping. See Figure 1-134.

    [a] Bolts 2 3/4 in. long and under-turn 90-100 degrees.

[b] Bolts over 2 3/4 in. long-turn 150-180 degrees.

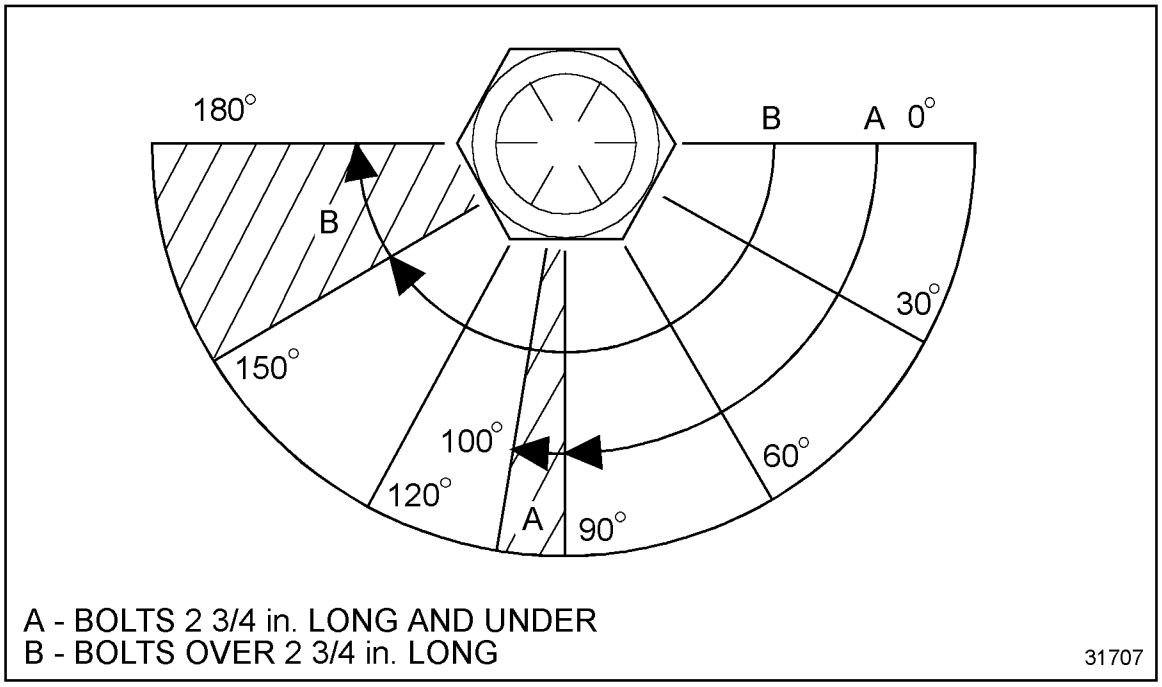


Figure 1-134 Torque-Turn Limits

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

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

16. Mount a dial indicator on the flywheel housing, and check the flywheel run-out at the clutch contact face.

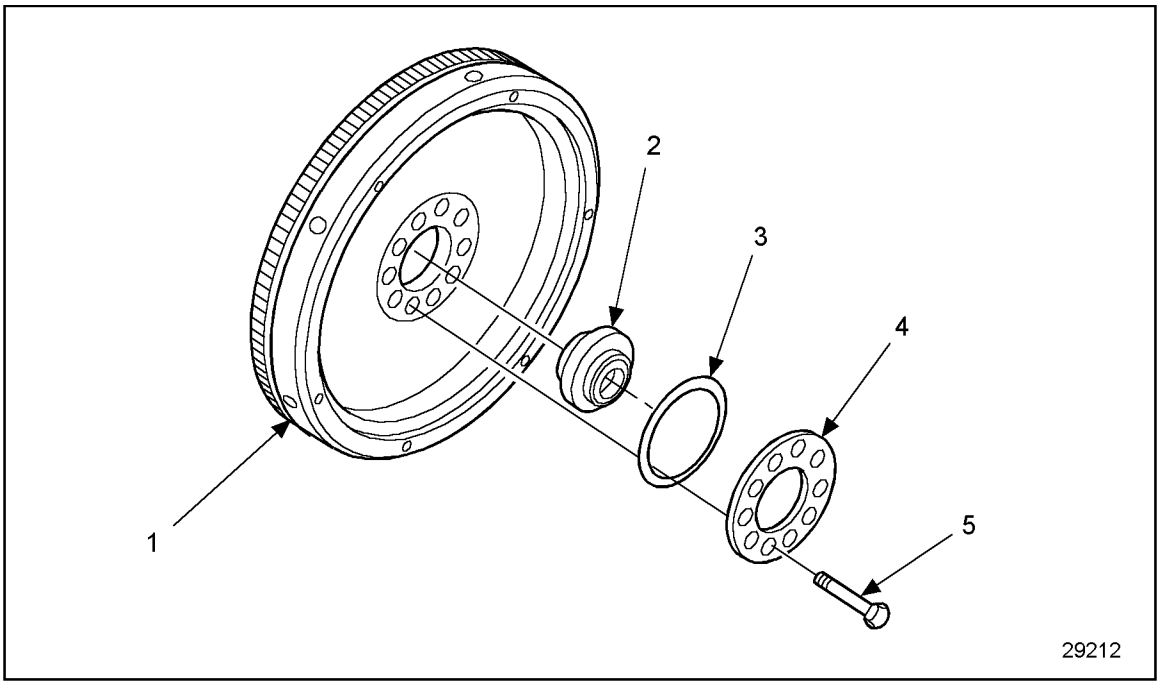
NOTE:
The maximum allowable run-out is 0.025 mm (0.001 in.) total indicator reading per inch of radius. The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

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1.17 CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft. A split tube type retainer is driven in the end of the crankshaft to prevent the pilot bearing from entering the crankshaft cavity. Refer to section 1.16.

A scuff plate, or bearing retainer, holds the clutch pilot bearing in place, and the flywheel attaching bolts secure it. See Figure 1-135.



1. Flywheel Assembly
2. Clutch Pilot Bearing
3. Seal
4. Scuff Plate
5. Flywheel Mounting Bolt

Figure 1-135 Clutch Pilot Bearing Removal/Installation

On some engines, a gasket provides an oil-tight seal between the bearing retainer and the flywheel.

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

1.17.1 Repair or Replacement of Clutch Pilot Bearing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-136.

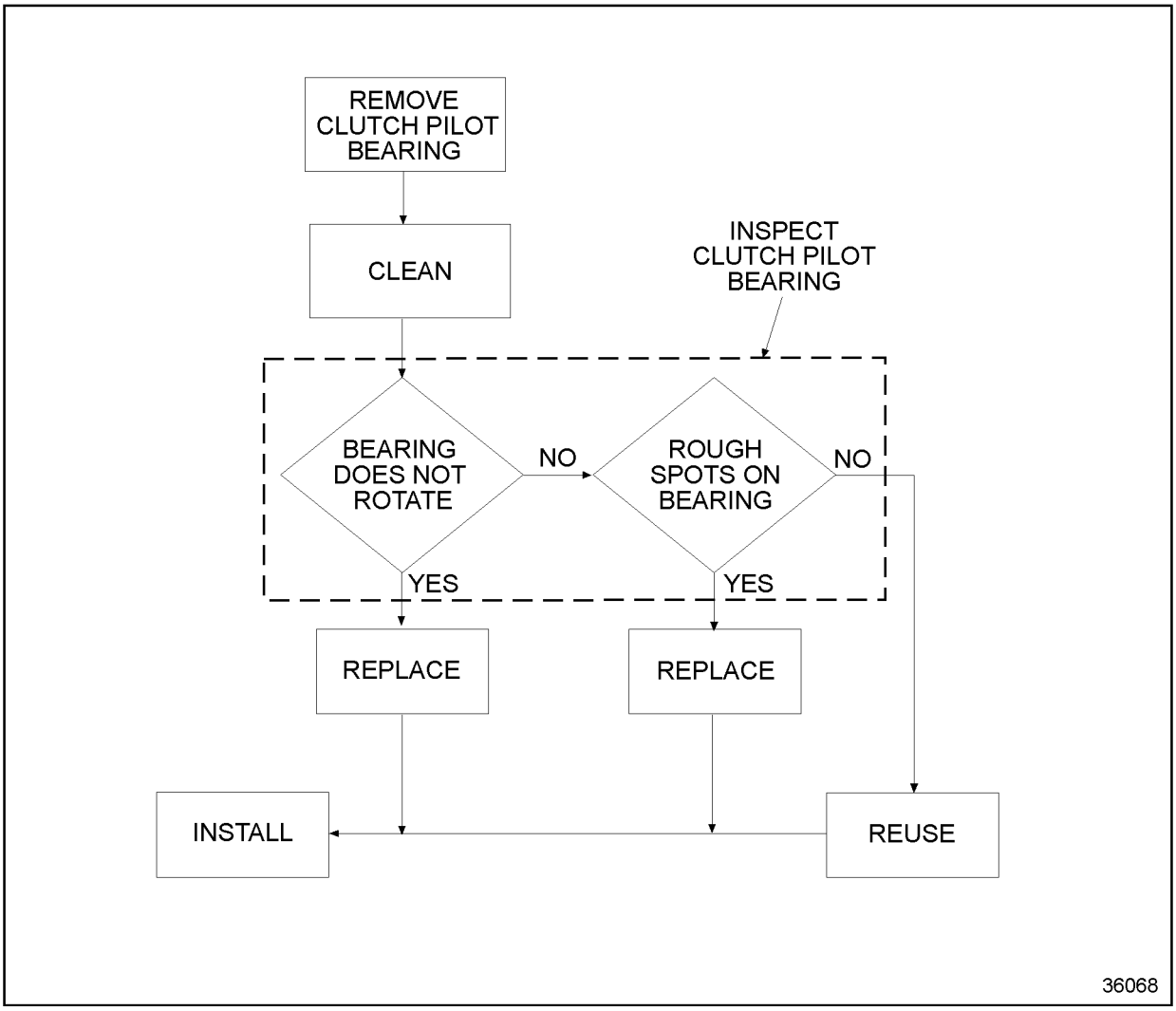


Figure 1-136 Flowchart for Repair or Replacement of Clutch Pilot Bearing

1.17.2 Removal of Clutch Pilot Bearing

With the transmission removed and the flywheel attached to the engine, remove the clutch pilot bearing as follows:

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⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

1. Remove the bolts attaching the flywheel to the crankshaft.
2. Remove the bearing retainer, and install two 9/16 in.-18 studs to prevent the flywheel from falling off the end of the crankshaft.
3. With the clutch pilot bearing remover adaptor J 23907-2 attached to slide hammer J 23907-1, insert the adaptor fingers through the pilot bearing.
4. Tighten the thumbscrew to expand the fingers against the inner race of the bearing.
5. Tap the slide hammer against the shaft shoulder, and pull the bearing out of the flywheel.
6. Remove the oil seal, if used.

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

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

1.17.3 Cleaning Clutch Pilot Bearing

Prior to inspection, clean the clutch pilot bearing as follows:

1. Wipe the prepacked double-sealed bearing clean on the outside.

NOTE:
Do not wash shielded bearings. Dirt may be washed in and the cleaning fluid cannot be entirely removed from the bearing.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

⚠ 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. Clean the other bearing types thoroughly with clean fuel oil, and dry them with compressed air.

1.17.3.1 Inspection of Clutch Pilot Bearing

Inspect the clutch pilot bearing as follows:

1. Hold the inner race and revolve the outer race slowly by hand. The bearing should roll freely.
   [a] If the bearing does not roll freely, replace the bearing.
   [b] If the bearing rolls freely, proceed with inspection.
2. Visually inspect for rough spots in the bearing.
   [a] Replace the bearing if it has rough spots.
   [b] If no rough spots are detected, reuse the bearing.

1.17.4 Installation of Clutch Pilot Bearing

Install the clutch pilot bearing as follows:

1. Install the oil seal, if used, in the flywheel.
2. Lubricate the outside diameter of the bearing with clean engine oil.

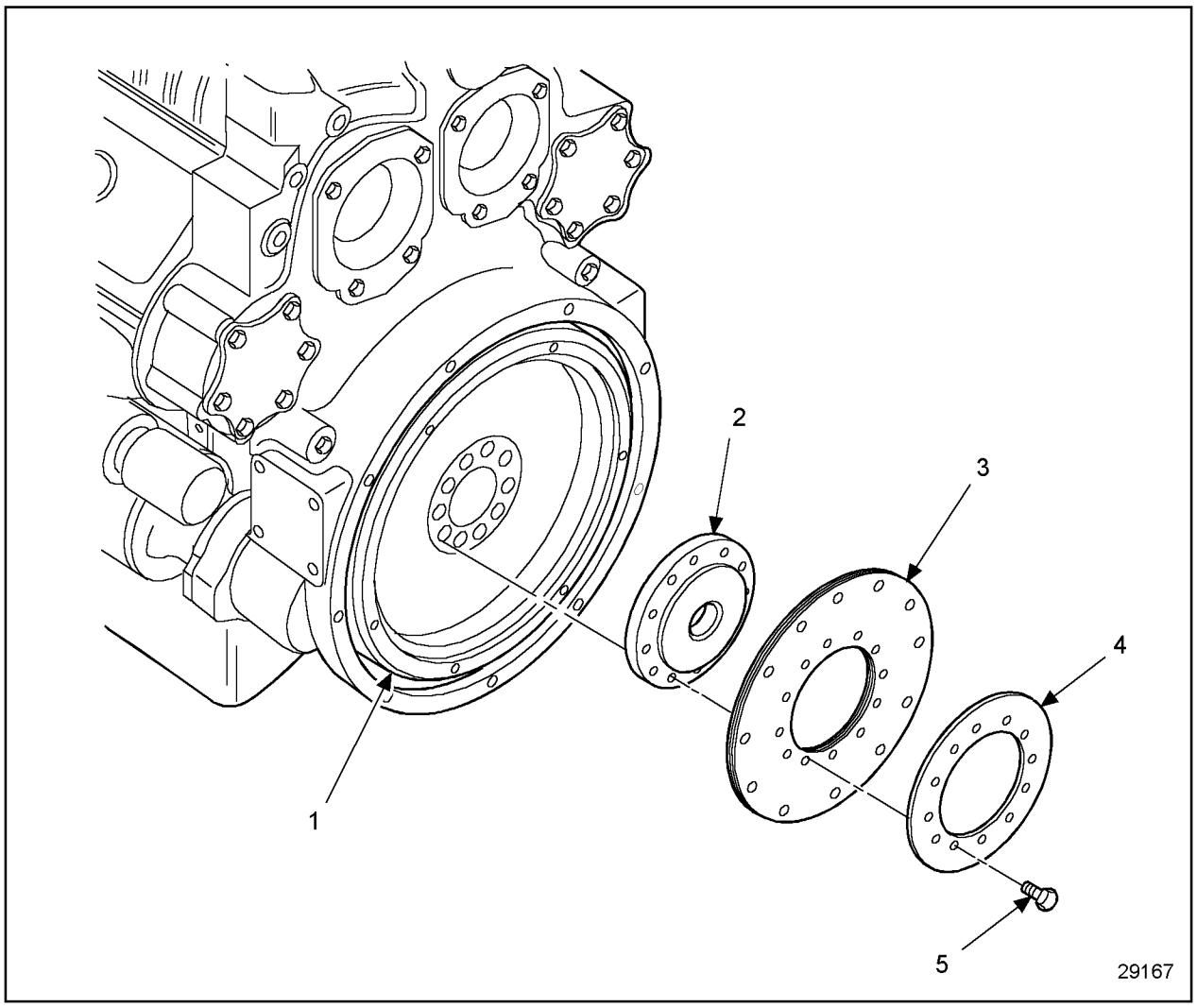
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3. Start the bearing in the bore of the flywheel, with the numbered side of the bearing facing away from the engine.
4. Drive the bearing in place with bearing installer J 3154-1A and suitable adaptor plates.
5. Install the flywheel on the crankshaft. Refer to section 1.16.5.

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1.18 ENGINE DRIVE SHAFT FLEXIBLE COUPLING

The engine drive shaft flexible coupling, used on some vehicle applications, is bolted to the engine flywheel and serves as a drive. See Figure 1-137. It dampens torque fluctuations between the engine and the Allison® HT-700 and CLBT-700 transmissions.

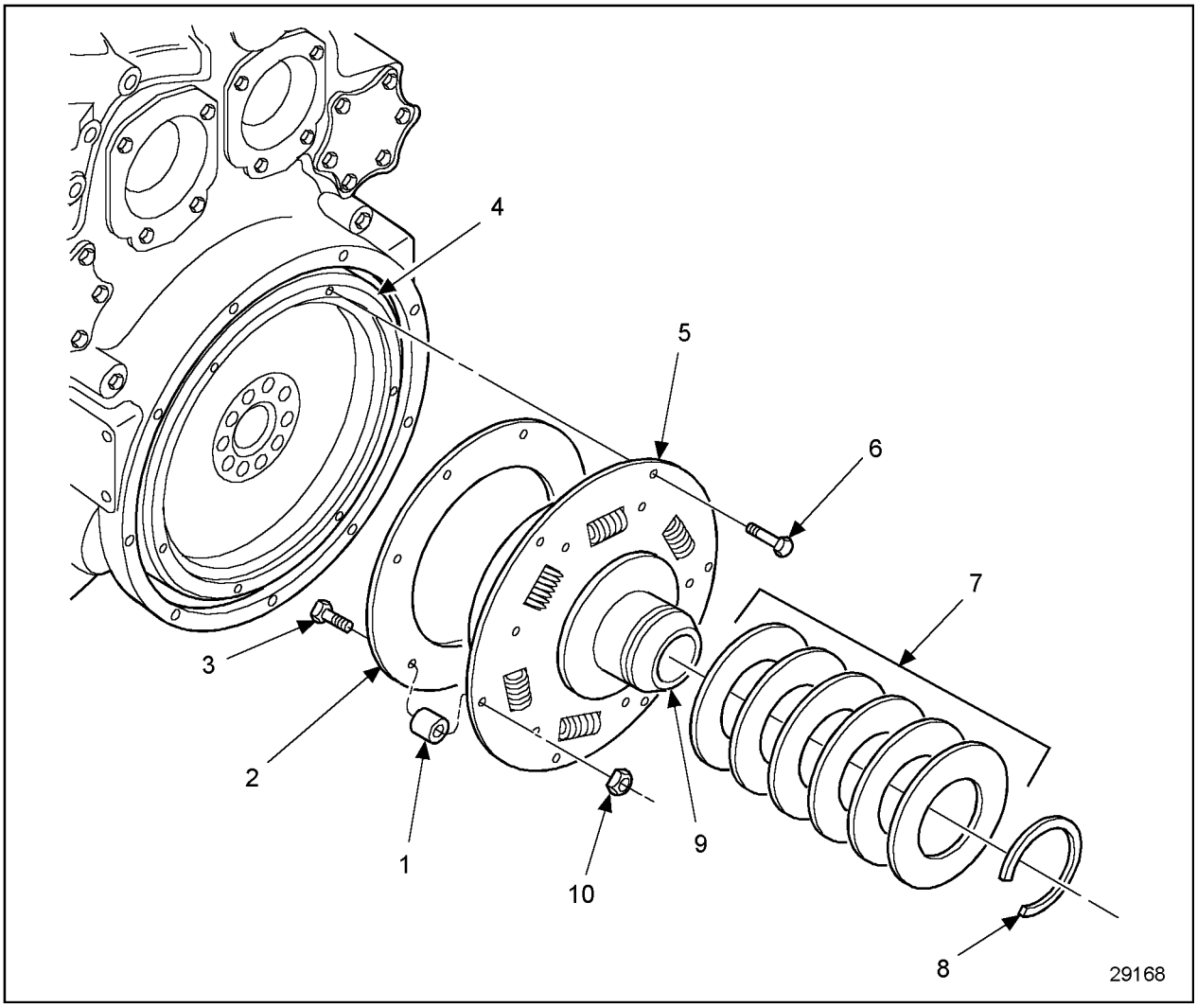


1. Flywheel Assembly
2. Hub
3. Disc and Disc Assembly
4. Plate
5. Bolt

Figure 1-137 Engine Drive Shaft Flexible Coupling

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A high capacity spring loaded engine drive shaft flexible coupling is used between the engine and Allison remote mounted CLBT-750 transmission. The coupling is bolted to the engine flywheel. See Figure 1-138.



1. Spacer
2. Rear Support Plate
3. Rear Plate Mounting Bolt
4. Flywheel
5. Mounting Plate
6. Bolt
7. Spring Washers
8. Snap Ring
9. Hub
10. Nut

Figure 1-138 Engine Drive Shaft Flexible Coupling (Remote Mounted Transmission)

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1.18.1 Repair or Replacement of Engine Drive Shaft Flexible Coupling

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

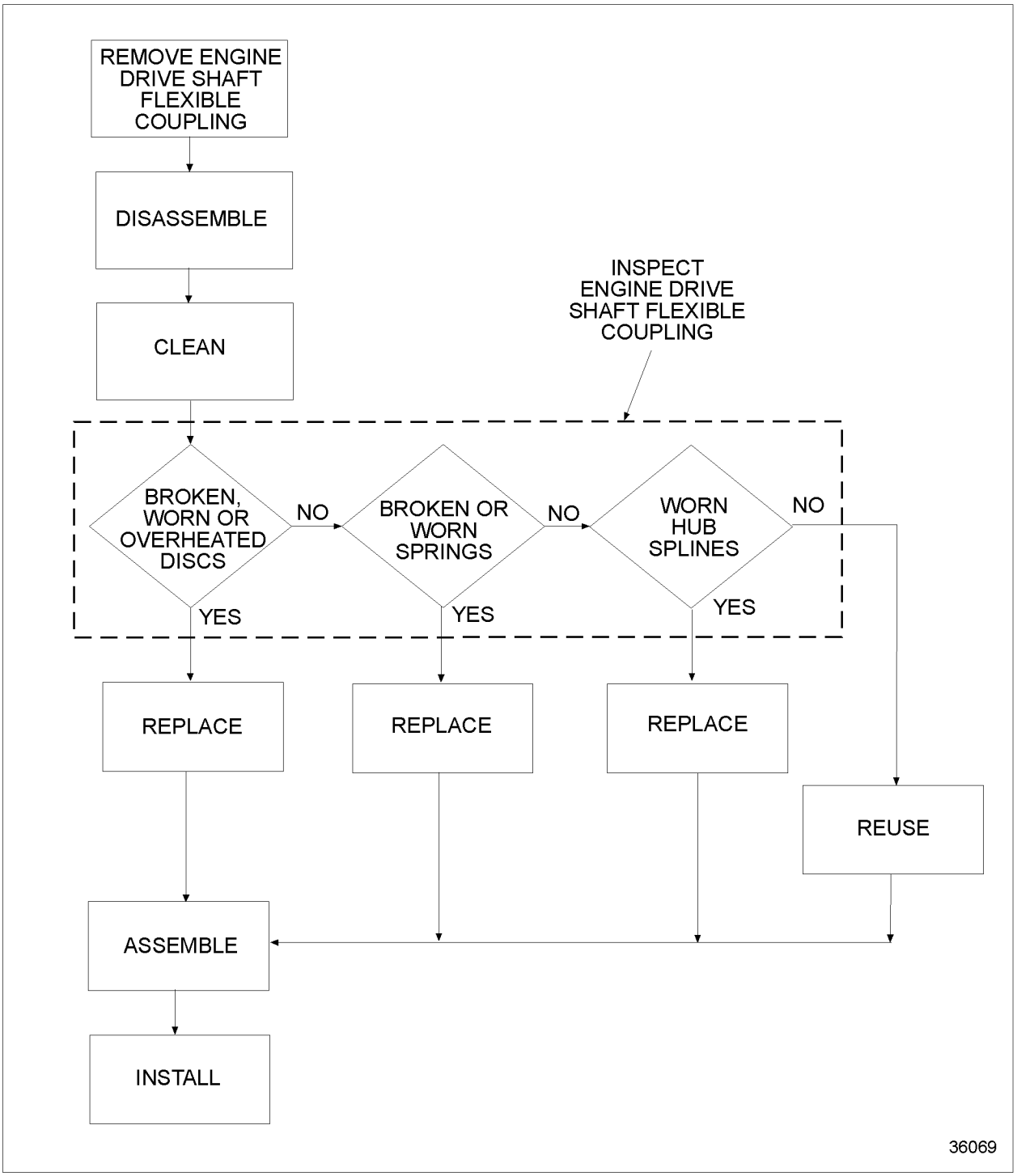


Figure 1-139 Flowchart for Repair or Replacement of Engine Drive Shaft Flexible Coupling

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1.18.2 Removal of Engine Drive Shaft Flexible Coupling (Transmission Removed)

With the transmission removed, remove the engine drive shaft flexible coupling as follows:

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

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

1.18.3 Removal of Coupling (Remote-Mounted Transmission)

With a remote-mounted transmission, remove the coupling as follows:

1. Remove the eight 3/8 in.-16 x 0.875 in. bolts which attach the coupling to the flywheel.
2. Remove the coupling.

1.18.4 Disassembly of Engine Drive Shaft Flexible Coupling

Disassemble the engine drive shaft flexible coupling as follows:

1. Remove the twelve 1/2 in.-20 x 0.75 in. lock bolts holding the coupling assembly together.

1.18.5 Disassembly of Drive Shaft Coupling (Remote-Mounted Transmission)

Disassemble the remote-mounted transmission drive shaft coupling as follows:

1. Remove the six bolts, lock washers, nuts, and spacers holding the two plates together.
2. Remove the smaller plate.

1.18.5.1 Cleaning of Engine Drive Shaft Flexible Coupling

Prior to inspection, clean the engine drive shaft flexible coupling as follows:

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash the coupling 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.

1.18.5.2 Inspection of Engine Drive Shaft Flexible Coupling

Inspect the engine drive shaft flexible coupling as follows:

1. Visually inspect the engine drive shaft flexible coupling for broken, worn, or over-heated discs.
   [a] If broken, worn, damaged, or over-heated replace the discs. Refer to section 1.18.8.
   [b] If not broken, worn, damaged, or over-heated continue inspection.
2. Inspect the remote mounted transmission coupling for broken or worn springs.
   [a] If broken or worn, replace the springs. Refer to section 1.18.8.
   [b] If not broken or worn, continue inspection.
3. Visually inspect the hub splines for wear.

NOTE:
Since the plates, spacers and hubs are manufactured in matched sets, worn hubs or plates cannot be replaced individually but must be replaced by a complete flexible coupling assembly.

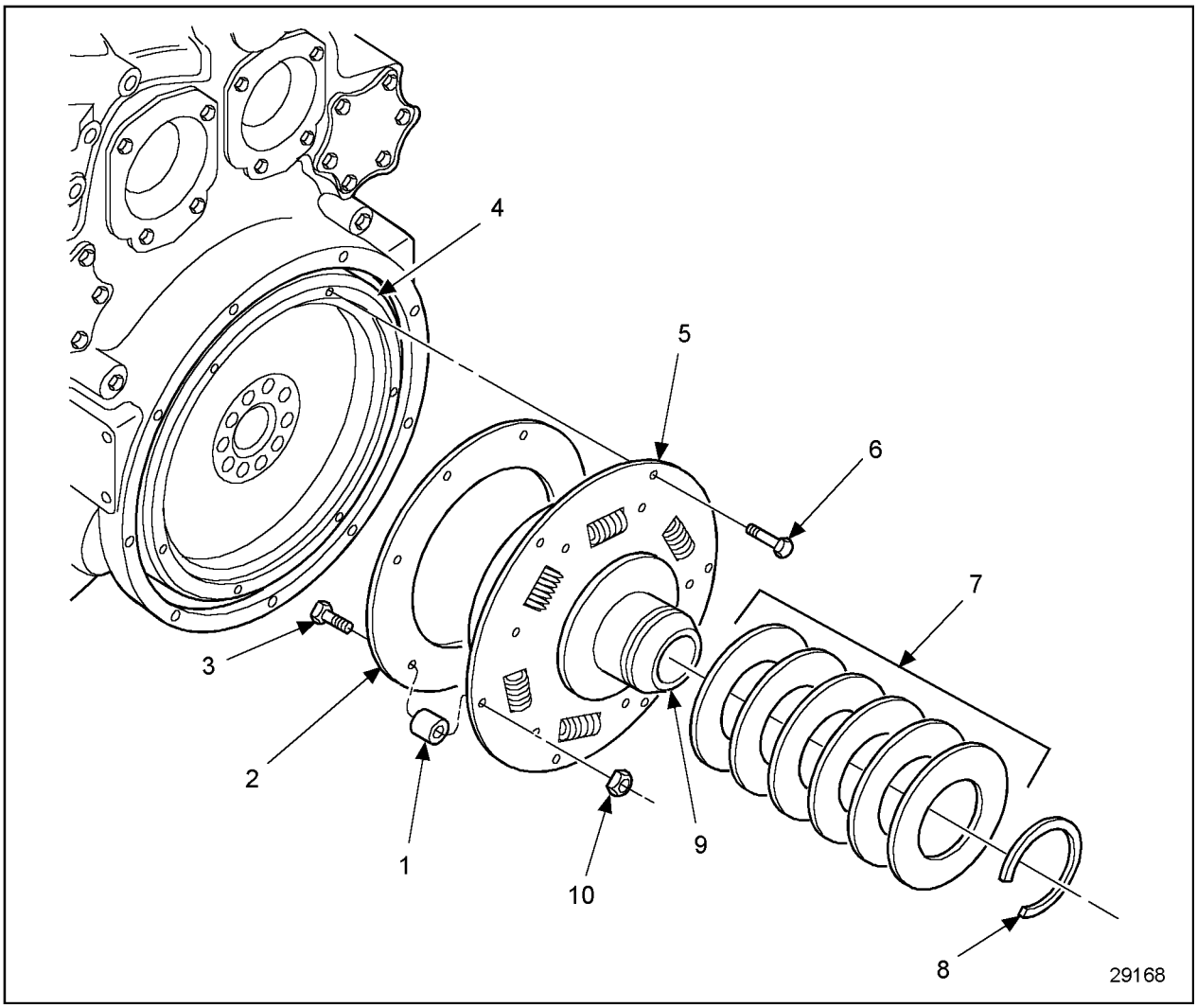
   [a] If excessively worn, replace the drive shaft coupling assembly. Refer to section 1.18.8.
   [b] If not worn, continue inspection.
4. Visually inspect the mounting plate for warping.
   [a] If warped, replace the drive shaft coupling assembly. Refer to section 1.18.8.
   [b] If the mounting plate is not warped, reuse the assembly.

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1.18.6 Assembly of Engine Drive Shaft Flexible Coupling

Assemble the engine drive shaft flexible coupling as follows:

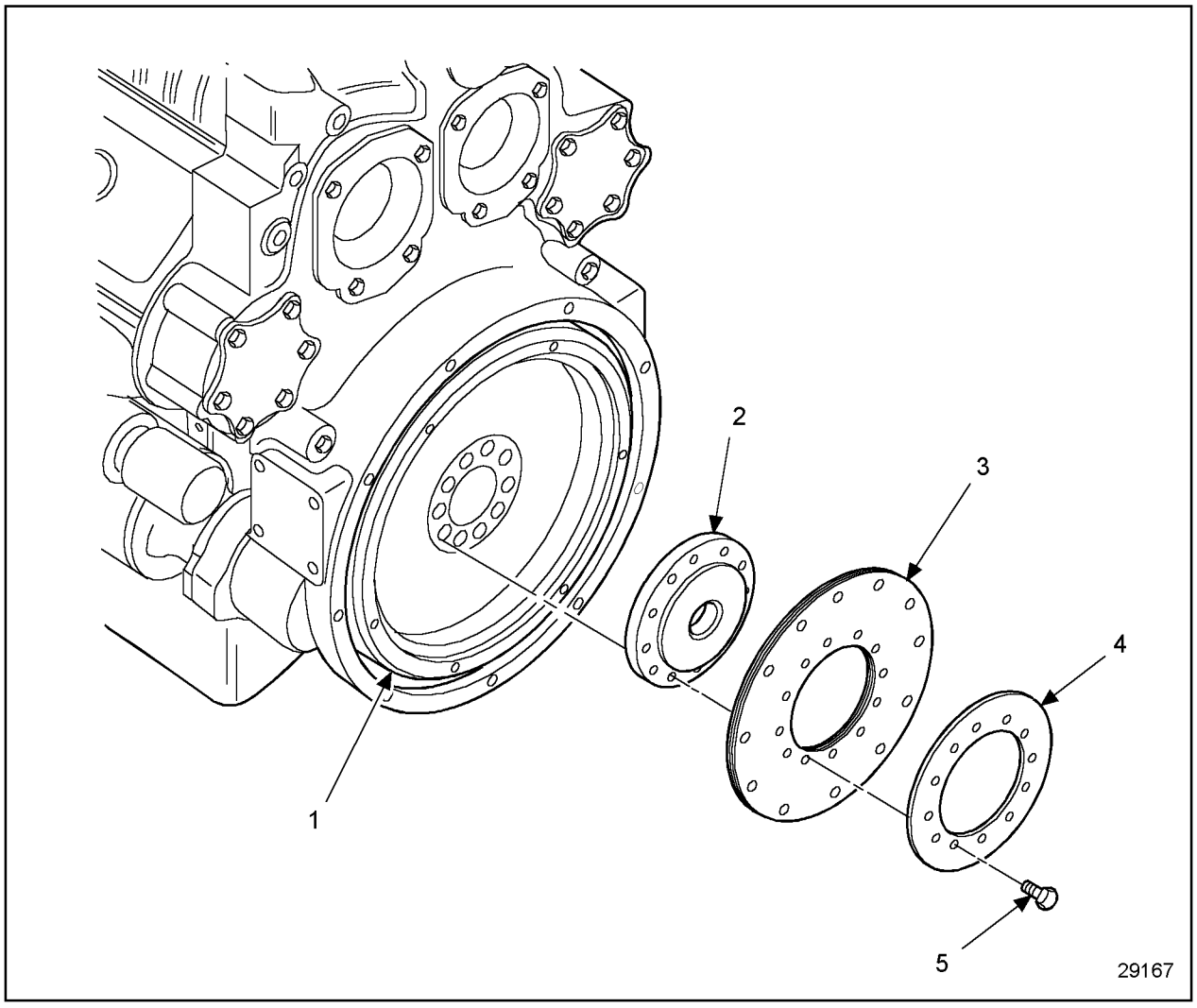
1. Install the twelve 1/2 in.-20 x 0.75 in. lock bolts. See Figure 1-140 and see Figure 1-141.



1. Spacer
2. Rear Support Plate
3. Rear Plate Mounting Bolt
4. Flywheel
5. Mounting Plate
6. Bolt
7. Spring Washers
8. Snap Ring
9. Hub
10. Nut

Figure 1-140 Engine Drive Shaft Flexible Coupling (Remote Mounted Transmission)

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1. Flywheel Assembly
2. Hub
3. Disc and Disc Assembly
4. Plate
5. Bolt

Figure 1-141 Engine Drive Shaft Flexible Coupling

2. Tighten the bolts to 130-156 N·m (96-115 lb·ft) torque.

1.18.7 Assembly of Drive Shaft Coupling (Remote Mounted Transmission)

Assemble the remote mounted transmission drive shaft coupling as follows:

1. Replace smaller plate.
2. Install the six bolts, lock washers, nuts, and spacers.
3. Tighten the nuts to 34-41 N·m (25-30 lb·ft).

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1.18.8 Installation of Engine Drive Shaft Flexible Coupling

Install the engine drive shaft flexible coupling as follows:

1. Align the bolt holes in the coupling with the tapped holes in the flywheel.
2. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and contact area of the flywheel attaching bolts.
3. Remove the guide pins, and install the scuff plate and the 9/16 in.-18 x 1.75 in. lock bolts.
4. Tighten the bolts.
5. On remote mounted transmission engine drive shaft flexible couplings, install the eight 3/8 in.-16 x 0.875 in. bolts, and tighten them to 61-75 N·m (45-55 lb·ft) torque.

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1.19 FLYWHEEL HOUSING

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

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing. Refer to section 1.4.5.

1.19.1 Repair or Replacement of Flywheel Housing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-142.

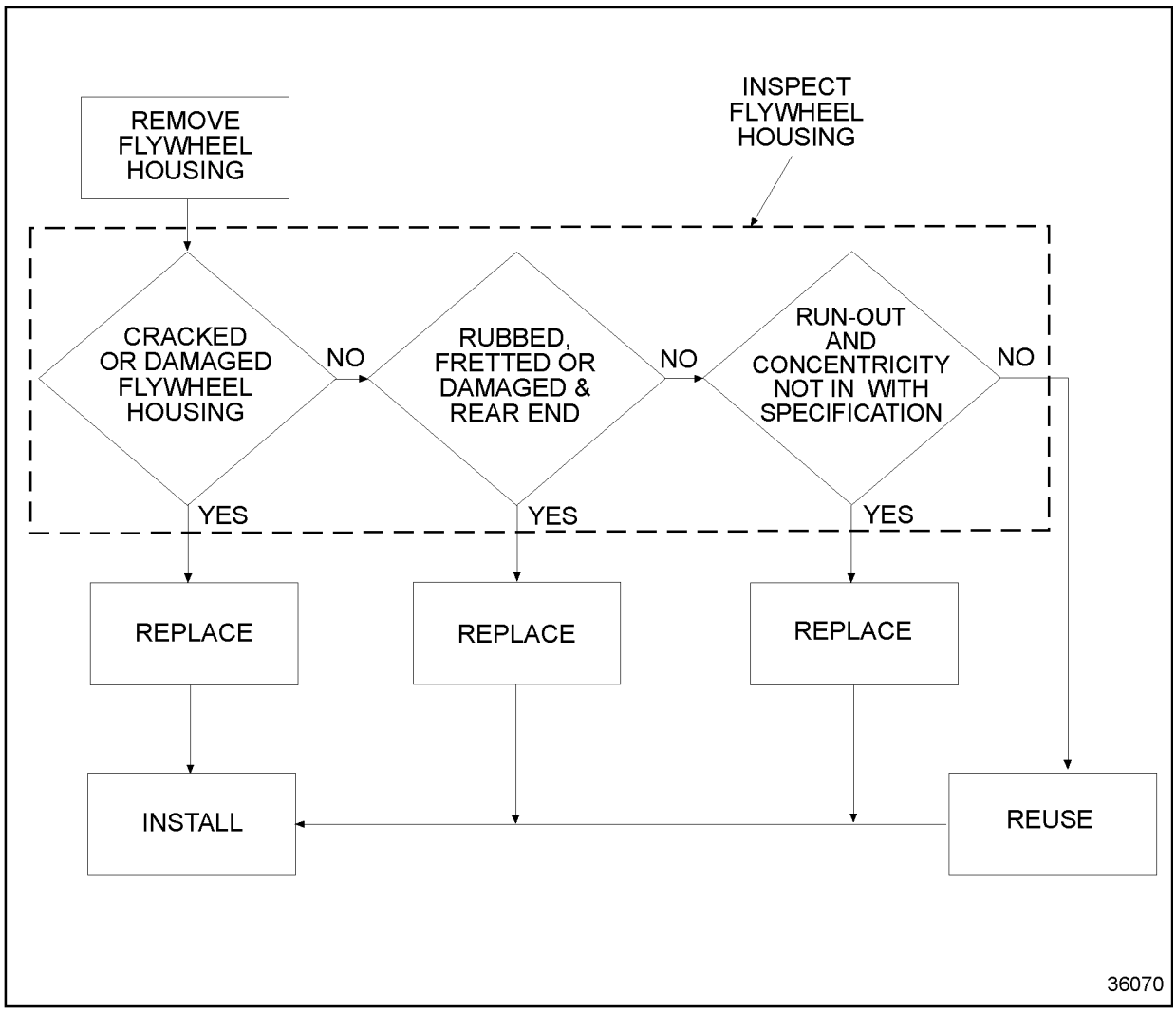


Figure 1-142 Flowchart for Repair or Replacement of Flywheel Housing

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1.19.2 Removal of Flywheel Housing

Remove the flywheel housing as follows:

⚠ CAUTION:

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

1. Mount the engine on an overhaul stand. Refer to section 1.1.2 for mounting procedures and precautions.
2. Remove the flywheel housing support brackets attached to the housing and the cylinder heads.
3. Remove the accessories attached to the flywheel housing.
4. Remove the starting motor. Refer to section 8.2.2.
5. Remove the flywheel. Refer to section 1.16.2.
6. Remove the oil pan. Refer to section 3.11.3.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

7. Remove the twelve attaching bolts located in the housing bell.
8. Remove one attaching bolt located behind the small hole cover on the right-hand side of the flywheel housing.
9. Remove the remaining bolts around the upper portion of the housing and the two bolts that go through the rear end plate from the front and thread into the housing.

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

⚠ CAUTION:

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

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

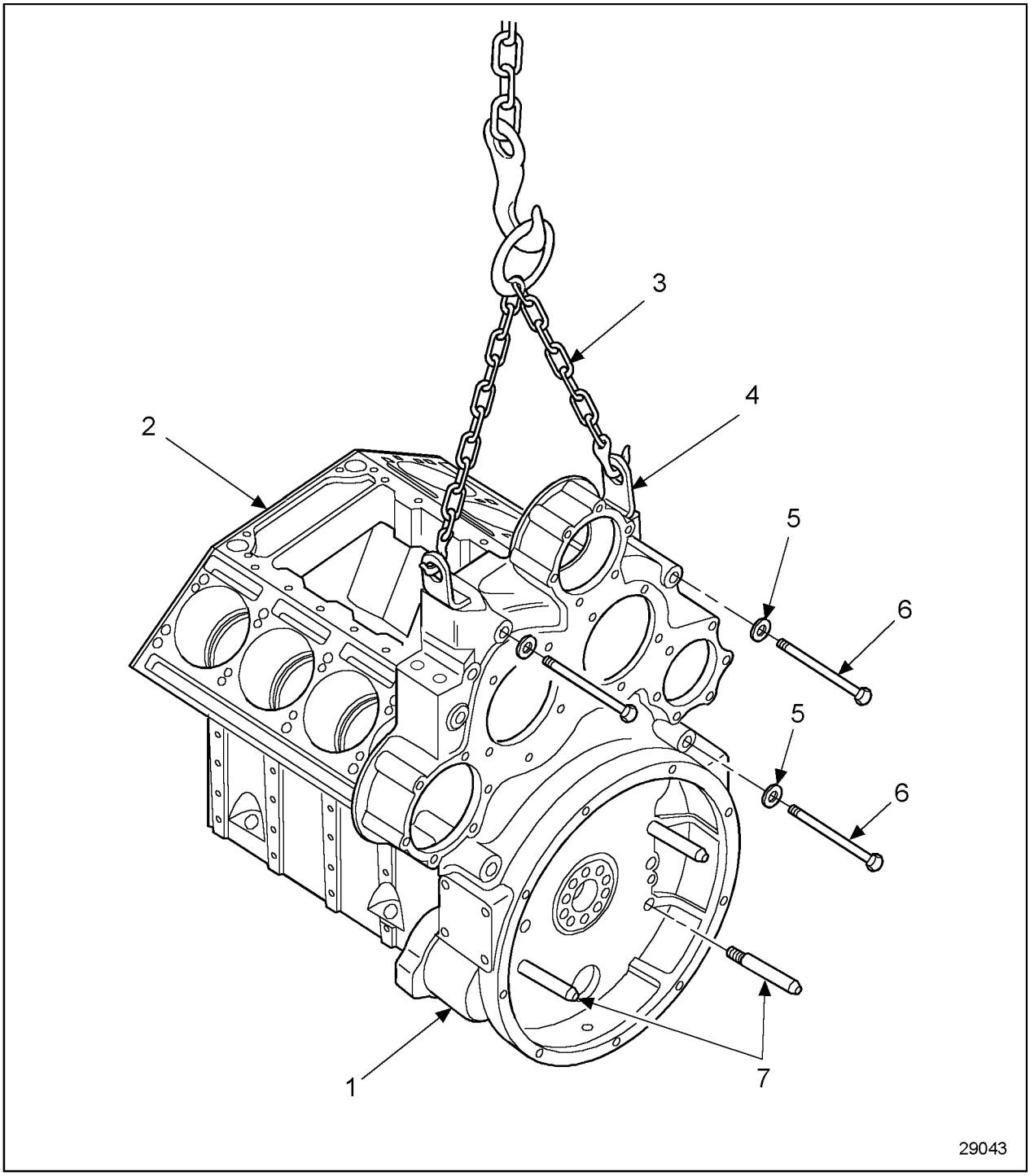
A bracket that is bent or otherwise damaged may fail, causing the flywheel housing to fall when lifted. This may result in component damage when the flywheel housing is being removed/installed from the equipment. To help avoid these situations, replace any damaged or bent brackets before attempting removal/installation.

NOTICE:

The flywheel housing must be securely attached to the lifting sling before removing from the engine. Damage to Flywheel housing may result if it breaks away from the lifting device and falls.

10. Install aligning studs J 1927-01 to guide the housing until it clears the crankshaft during removal. See Figure 1-143.

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1. Flywheel Housing
2. Cylinder Block
3. Chain Hoist
4. Rear Lifter Brackets
5. Washer
6. Bolt
7. Guide Studs

Figure 1-143 Removal and Installation of Flywheel Housing

11. With the flywheel housing supported by a chain hoist attached to the lifter brackets, strike the front face of the housing alternately on each side of the engine with a soft hammer to work it off the dowels and away from the cylinder block rear end plate.
12. Remove all traces of the old gasket from the cylinder block rear end plate and the flywheel housing.
13. Remove the rear oil seal.

1.19.2.1 Inspection of Flywheel Housing

Inspect the flywheel housing as follows:

1. Visually inspect the flywheel housing for cracks or other damage.
   [a] If damaged, replace the flywheel housing. Refer to section 1.19.3.
   [b] If not damaged, proceed with inspection.
2. Inspect the rear end of the crankshaft for wear from the oil seal rubbing, dirt buildup, or fretting caused by the flywheel.

NOTE:
The crankshaft must be clean and smooth, otherwise the oil seal lip will be damaged when the flywheel housing is installed.

   [a] If rubbed, fretted, or damaged, replace the crankshaft. Refer to section 1.7.5.
   [b] If dirt has built up, clean the crankshaft. Refer to section 1.7.2.1.
   [c] If not rubbed, fretted, damaged, or dirty, continue inspection.
3. Inspect the flywheel housing concentricity and bolting flange face run-out. Refer to section ADDITIONAL INFORMATION.
   [a] If the concentricity and run-out are not within specified limits, replace the flywheel housing. Refer to section 1.19.3.
   [b] If the concentricity and run-out are within specified limits, reuse the flywheel housing. Refer to section 1.19.3.

1.19.3 Installation of Flywheel Housing

Install flywheel housing, except the 16V reinforced flywheel housing, as follows:

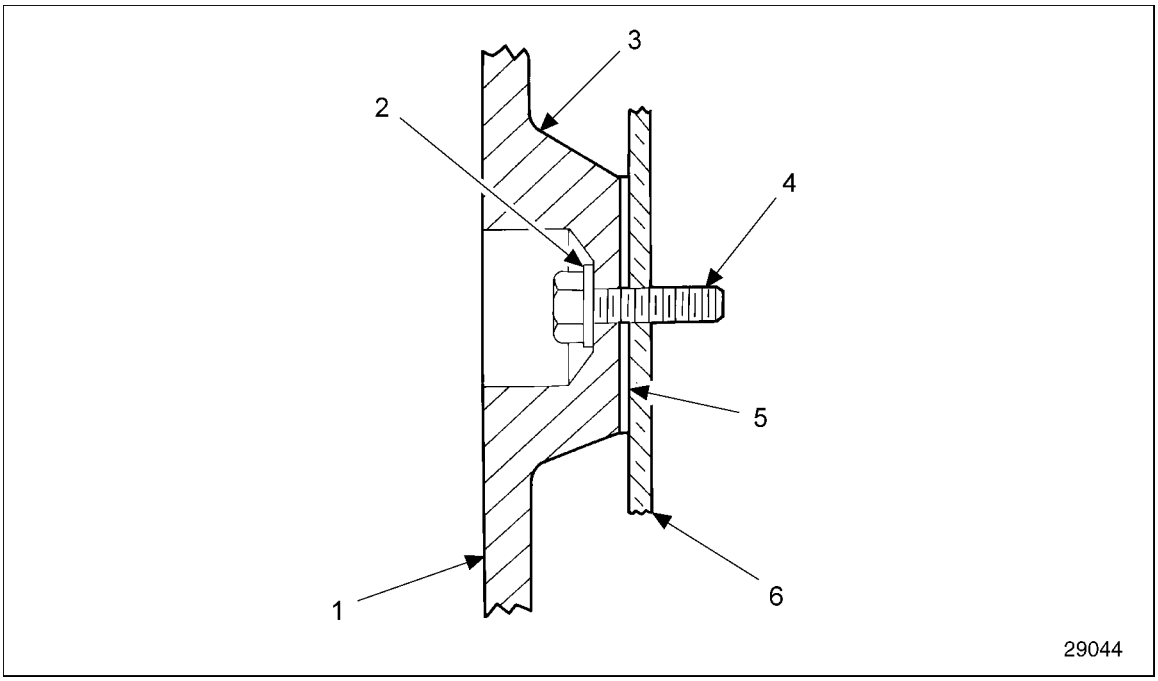
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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the gear train teeth with clean engine oil.
2. Affix a new gasket to the flywheel housing.

NOTE:
On certain flywheel housings, the idler gear hole spacer is cast in the housing, opposite the idler gear. See Figure 1-144. A shim must be installed between the flywheel housing and the cylinder block end plate. Use grease to hold the shim on the spacer during installation.



1. Flywheel Housing
2. Washer
3. Integrally Cast Spacer Hub
4. Housing to Block Bolt
5. Shim
6. Block End Plate

Figure 1-144 Idler Gear Hole Spacer Shim

3. Thread two aligning studs J 1927-01 into the cylinder block to guide the housing into place.

NOTE:
Before installing the flywheel housing, ensure the 5/8 in.-11 x 1 in. rear end plate to cylinder block bolt is installed and tightened. Refer to section 1.2.4.

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CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

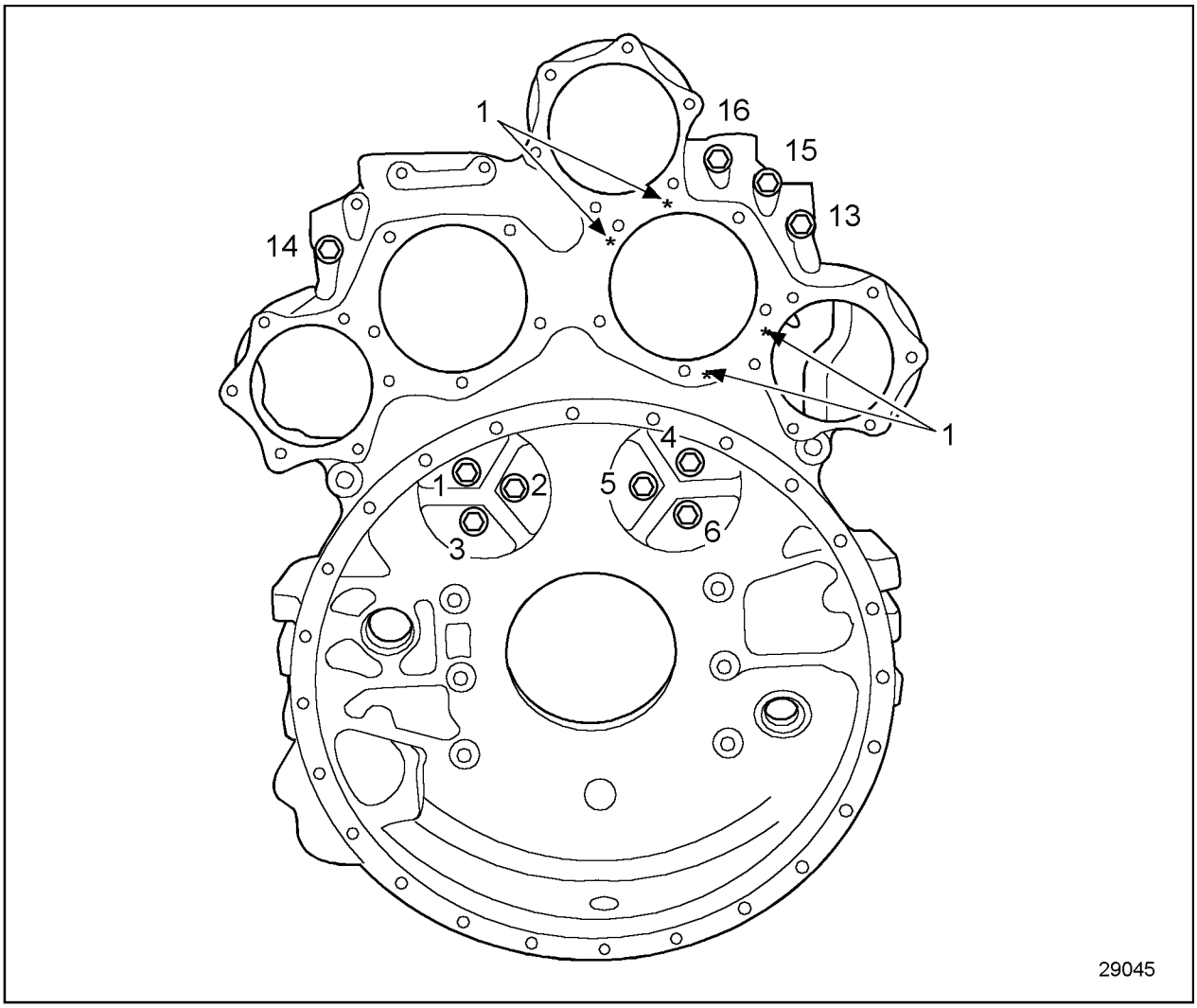
NOTICE:

The flywheel housing must be securely fastened to the engine before releasing the lifting sling. Part damage may result if the flywheel housing breaks away from the engine and falls.

4. With the housing suitably supported, position the housing over the crankshaft and up against the cylinder block rear end plate and gasket.

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5. Remove the pilot studs, and install the flywheel housing bolts, with washers and lock washers. Finger-tighten. See Figure 1-145.



1. Stud Locations

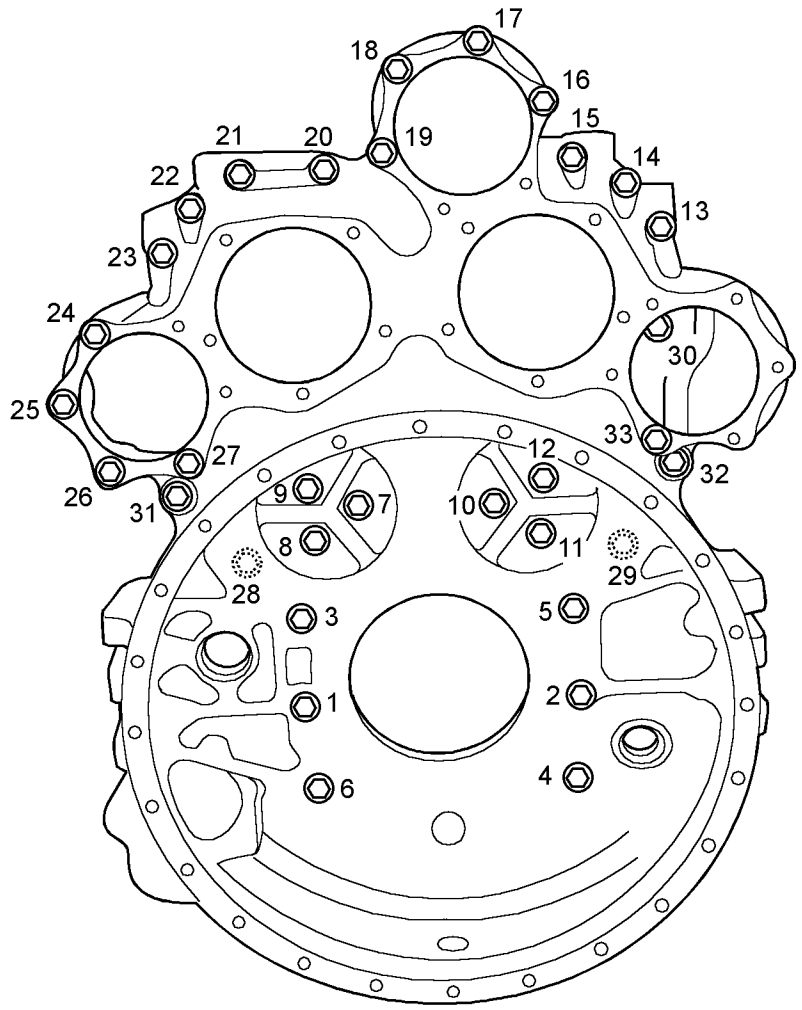
Figure 1-145 Flywheel Housing Bolt Guide Stud Location

6. Install the 3/8 in.-16 x 1.255 in. sealant-coated flange hex head bolts in dummy hub and idler hub positions 1 through 6.

NOTE:
The flange hex head bolts replace the former standard hex head bolt and washer. Flange hex head bolts should not be used with a washer.

NOTE:
To prevent installation of bolts that are too long and bottom out on the blower drive step-up gear (on naturally aspirated engines), studs are used. The Teflon-coated stud ends are threaded into the housing.

7. Install three new flywheel housing nylon patch bolts at the right-bank camshaft gear area. For positions 13, 14, and 15, see Figure 1-146.



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

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Figure 1-146 Flywheel Housing Bolt Torque Sequence

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NOTE:
Whenever the sealant patch bolts are removed, they should be replaced with new sealant patch bolts at both the idler gear spacer and idler gear positions.

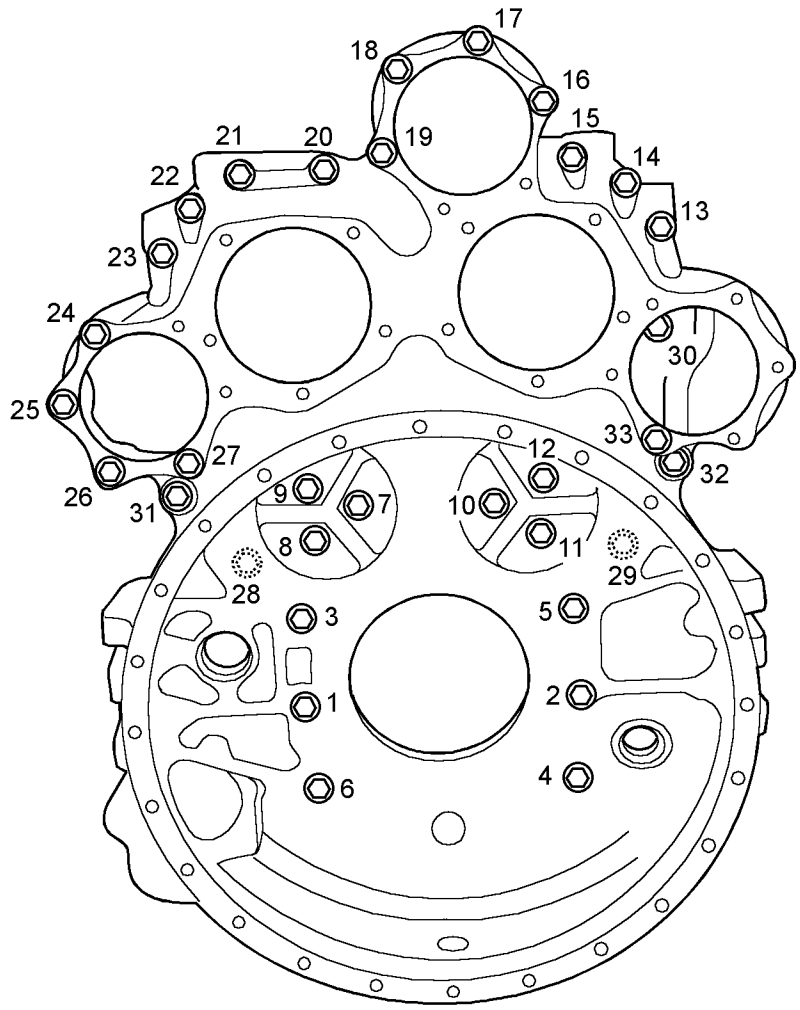
8. Tighten the bolts in sequence.
9. Starting at number 4 on a right-hand rotation engine or at number 1 on a left-hand rotation engine, tighten the flywheel housing bolts.

NOTE:
If the idler gear hole spacer is integrally cast into the housing, ensure the shim is in place. When tightening the flywheel housing bolts, the idler gear hub bolts should always be tightened first. Turn the crankshaft by hand while tightening the idler gear hub bolts to prevent any binding or brinelling of the tapered roller bearing rollers and cups.

NOTICE:
To eliminate oil leaks on marine engines, ensure the plugs in the top two holes of the wet flywheel housing mounting pads are properly sealed and tightened 7 N·m (5 lb·ft) torque.

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10. See Figure 1-147 for the final bolt tightening sequence. Starting at number 1, tighten the flywheel housing bolts to the specified torque.



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

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Figure 1-147 Flywheel Housing Bolt Torque Sequence

11. Torque bolts as follows:

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[a] 3/8 in.-24 bolts to 34-41 N·m (25-30 lb·ft).

[b] 3/8 in.-16 flange hex head idler gear hub and idler gear hole spacer bolts to 41-47 N·m (30-35 lb·ft).

[c] Remaining 3/8 in.-16 bolts (number 30 with nylon patch) to 41-47 N·m (30-35 lb·ft).

[d] 1/2 in.-13 bolts to 122-136 N·m (90-100 lb·ft).

[e] The two 5/8 in.-11 outboard flywheel housing bolts on left and right side to 186-200 N·m (137-147 lb·ft).

NOTE:
Rotate the crankshaft when tightening the idler gear hub bolts.

NOTE:
Aluminum flywheel housings are being used on 6V-92TA 43 degree tilt coach engines, effective with engine serial number 6VF-102676. Effective with engine serial number 6VF-102867, 6V-92TA 15 degree tilt coach engines are provided with aluminum flywheel housings. The new coach flywheel housings have an additional cast-in drilled boss that provides for a left-side waist bolt.

12. Check flywheel concentricity. Refer to section ADDITIONAL INFORMATION.
13. Install the crankshaft rear oil seal. Refer to section 1.8.7.
14. Install the flywheel. Refer to section 1.16.4.
15. Install the oil pan. Refer to section 3.11.3.
16. Install the starting motor. Refer to section 8.2.3.
17. Install accessories attached to the flywheel housing.
18. Install the large hole covers on the flywheel housing.
19. Tighten the 3/8 in.-24 stud nuts to 27-34 N·m (20-25 lb·ft) torque, the 3/8 in.-24 bolts, 7/16 in.-14 bolts, and the 1/2 in.-13 bolts to 41-47 N·m (30-35 lb·ft) torque.

NOTE:
Current engines include thread inserts at the small and large hole cover stud hole positions.

⚠ 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.

⚠ CAUTION:

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

⚠ CAUTION:

To avoid injury from a falling engine, do not use the engine lifter brackets alone when lifting the engine with a marine gear, main alternator, engine skid, engine module, radiator, or similar component attached. The engine lifter brackets are designed to lift the engine only.

20. Remove the engine from the overhaul stand.
21. An RTV (Room Temperature Vulcanizing) sealant is now being used in place of the gasket to seal flywheel housing small hole cover ("star cover"). Replace the covers as follows:
    [a] Clean the old gasket material and/or loose sealant from the housing and cover. It is not necessary to remove all old sealant.
    [b] Apply a 0.125 in. diameter continuous, unbroken bead of sealant to the perimeter of the cover just inside the bolt holes.

NOTE:
To provide an effective seal, this should be done not more than ten minutes before the cover is to be secured to the flywheel housing.

    [c] To ensure the sealant is properly applied, use a sample gasket as a template prior to installing the bead.

22. Attach the cover to the flywheel housing with the proper bolts. Torque to 41-47 N·m (30-35 lb·ft).

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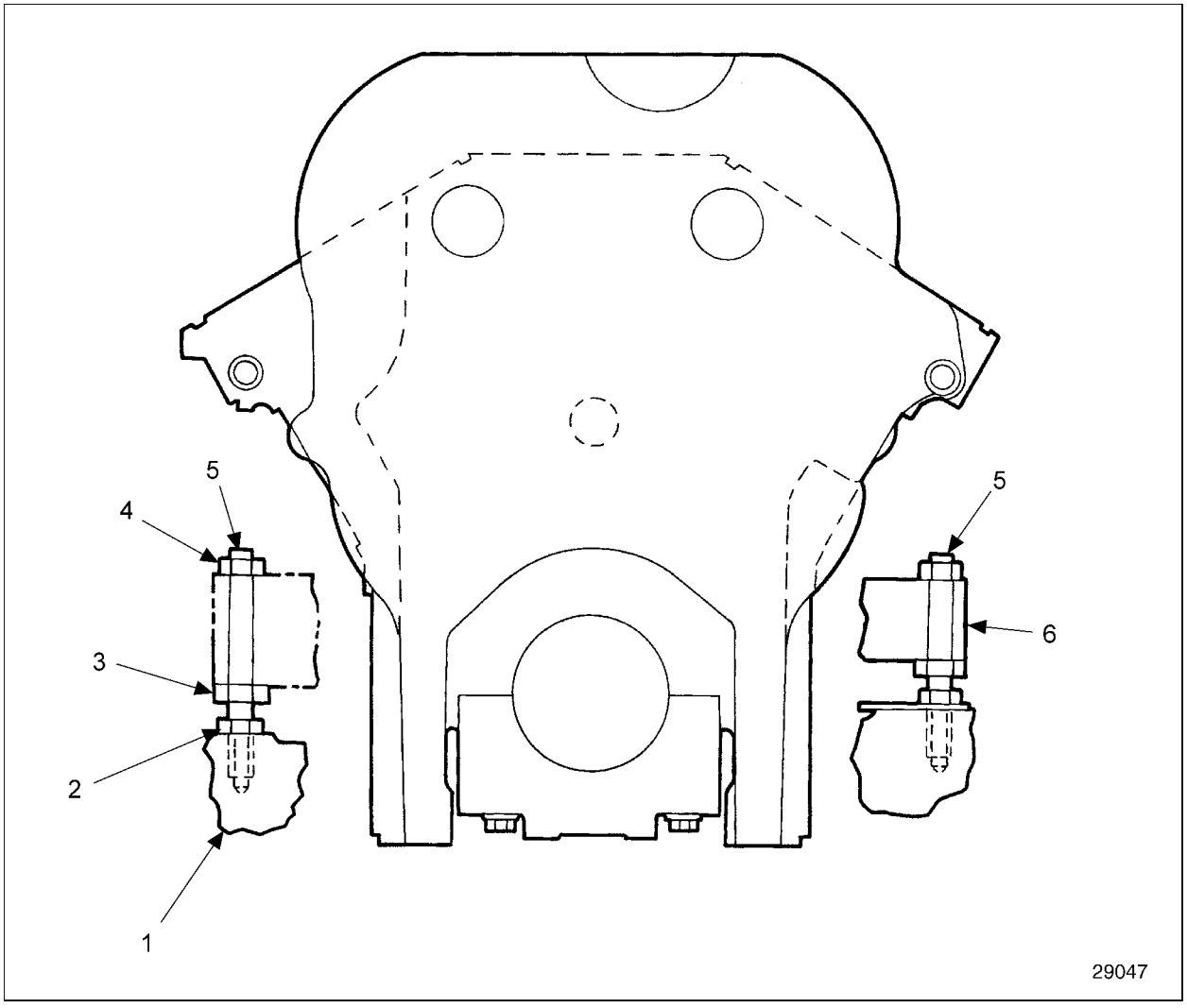
1.19.4 Installation of Reinforced Flywheel Housing (16V)

Install the reinforced flywheel housing (16V) as follows:

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

1. Thread jam nuts "A" and "C" on the studs. See Figure 1-148.

NOTE:
Thread the longer stud into the left-bank side of the cylinder block and the shorter stud into the right-bank through the hole in the rear end plate. Tighten the studs.



1. Cylinder Block
2. Nut "C"
3. Nut "A"
4. Nut "B"
5. Stud
6. Flywheel Housing

Figure 1-148 Location of Reinforced Flywheel Housing Support Studs

2. Turn nuts "C" on the studs until they contact the cylinder block. Tighten nuts "C."
3. Affix a new gasket to the flywheel housing.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the gear train teeth with clean engine oil.

CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

The flywheel housing must be securely fastened to the engine before releasing the lifting sling. Part damage may result if the flywheel housing breaks away from the engine and falls.

5. Thread two aligning studs J 1927-01 into the cylinder block to guide the housing in place.
6. Install six 3/8 in.-16 x 1.125 in. self-locking bolts with flat washers in the tapped holes of the idler gear hub and idler gear hole spacer. Finger-tighten.
7. Remove the aligning studs, and install six 1/2 in.-13 x 3.25 in. housing-to-cylinder block bolts with lock washers. Finger-tighten.
8. Install the remaining flywheel housing attaching bolts with lock washers. Finger-tighten.

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9. Tighten the bolts and nuts in sequence. See Figure 1-149(Operation 1).

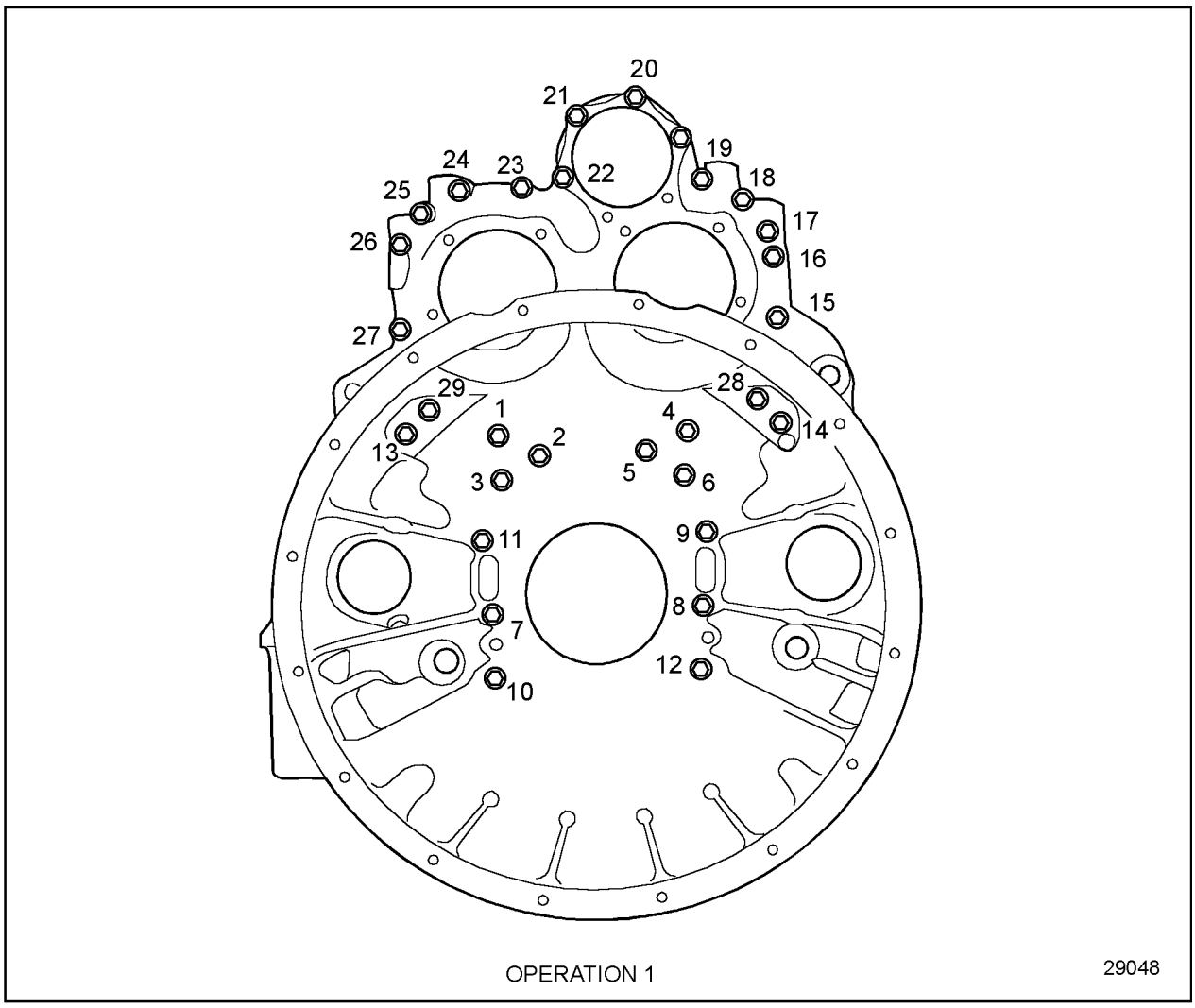
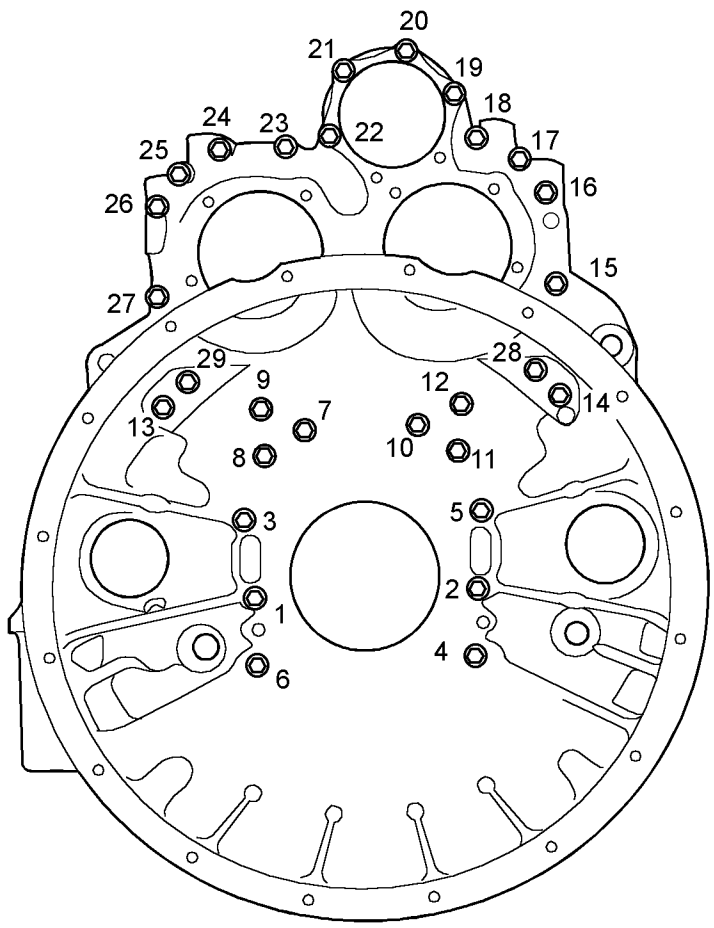


Figure 1-149 Reinforced Flywheel Housing (16V) Bolt and Nut Tightening Sequence

10. Starting at number 4 on a right-hand rotation engine or at number 1 on a left-hand rotation engine, tighten the flywheel housing bolts and nuts. Refer to section 1.28.

NOTE:
When tightening the idler gear hub bolts, turn the engine crankshaft to keep the idler gear bearing assembly from binding.

11. Tighten the bolts and nuts in sequence. See Figure 1-150(Operation 2).



OPERATION 2

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

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Figure 1-150 Reinforced Flywheel Housing (16V) Final Bolt and Nut Tightening Sequence

12. Starting at number 1, tighten the flywheel housing bolts and nuts to the specified torque as follows:

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[a] The 3/8 in.-24 bolts and nuts to 34-41 N·m (25-30 lb·ft).

[b] The 3/8 in.-16 self-locking idler gear hub and idler gear spacer hub bolts to 54-61 N·m (40-45 lb·ft).

[c] The remaining 3/8 in.-16 bolts to 41-47 N·m (30-35 lb·ft).

[d] The 1/2 in.-13 bolts to 122-136 N·m (90-100 lb·ft).

[e] The two 5/8 in.-11 outboard flywheel housing bolts on the left and right side to 186-200 N·m (137-147 lb·ft).

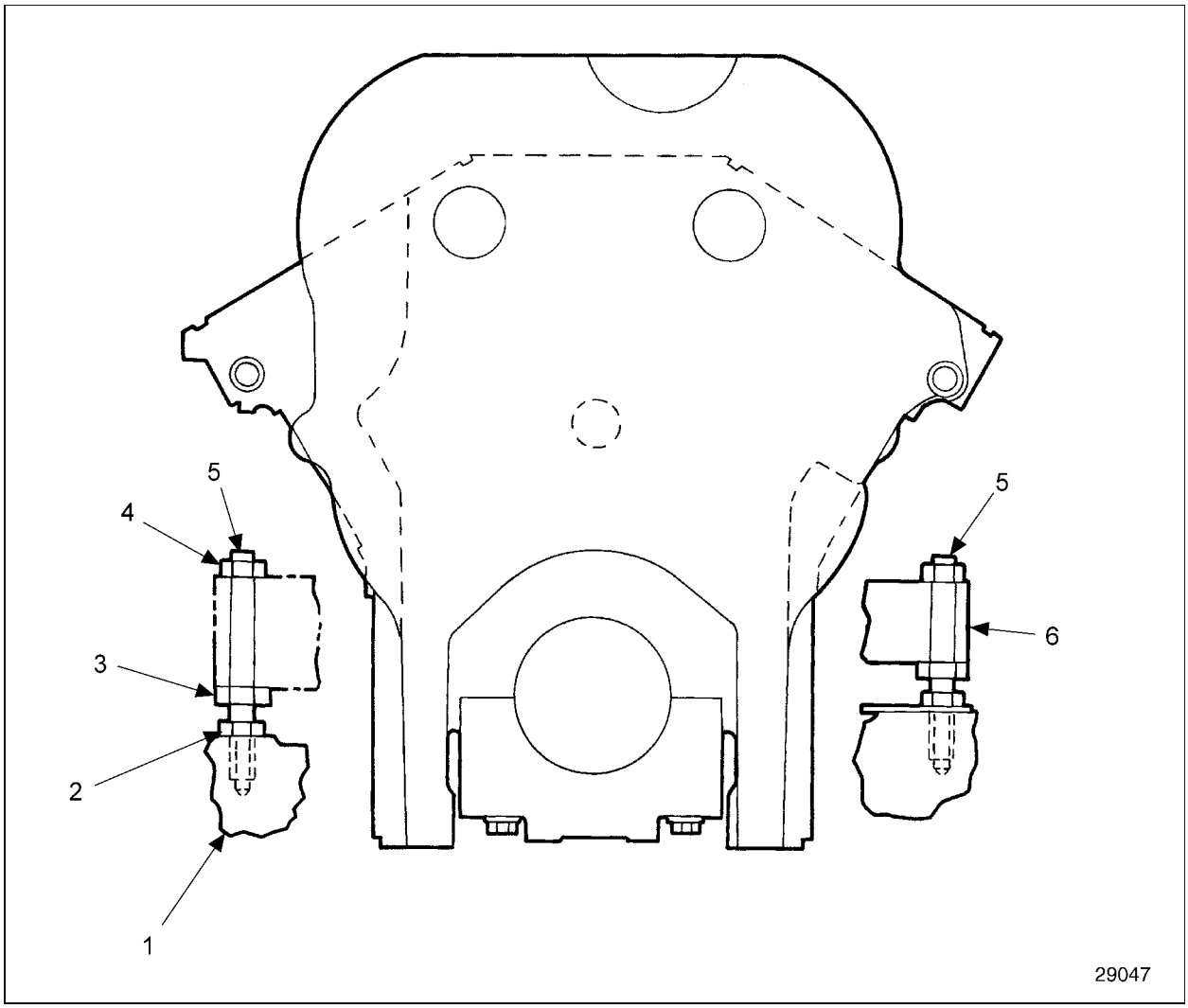
NOTE:
Rotate the crankshaft when tightening the idler gear hub bolts.

13. Replace the crankshaft rear oil seal. Refer to section 1.8.7.
14. Install the flywheel. Refer to section 1.16.5.
15. If removed, place the upper oil pan in position against the cylinder block and flywheel housing.
16. Install all 3/8 in.-16 oil pan attaching bolts and lock washers. Finger-tighten.
17. Install the two 3/4 in.-10 oil pan to flywheel housing bolts and lock washers.
18. Tighten the 3/8 in.-16 oil pan bolts to draw the oil pan tight against the cylinder block.
19. Tighten the 3/4 in.-10 bolts to 325-339 N·m (240-250 lb·ft) torque and the 3/8 in.-16 oil pan bolts to 14-27 N·m (10-20 lb·ft) torque.

NOTE:
When tightening the oil pan bolts, tighten the center bolts first.

20. Thread jam nut "A" against the flywheel housing, and tighten stud nuts "B" to 217-231 N·m (160-170 lb·ft) torque while holding nut "A" from rotating.
21. Check the flywheel housing concentricity and run-out. Refer to section ADDITIONAL INFORMATION. If the dial indicator readings are not within the limits specified, loosen

stud nut "B" slightly and tighten jam nut "A" on either side of the flywheel housing to bring the dial indicator reading within the specified limits. See Figure 1-151.



1. Cylinder Block
2. Nut "C"
3. Nut "A"
4. Nut "B"
5. Stud
6. Flywheel Housing

Figure 1-151 Location of Reinforced Flywheel Support Studs

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⚠ 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.

⚠ CAUTION:

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

⚠ CAUTION:

To avoid injury from a falling engine, do not use the engine lifter brackets alone when lifting the engine with a marine gear, main alternator, engine skid, engine module, radiator, or similar component attached. The engine lifter brackets are designed to lift the engine only.

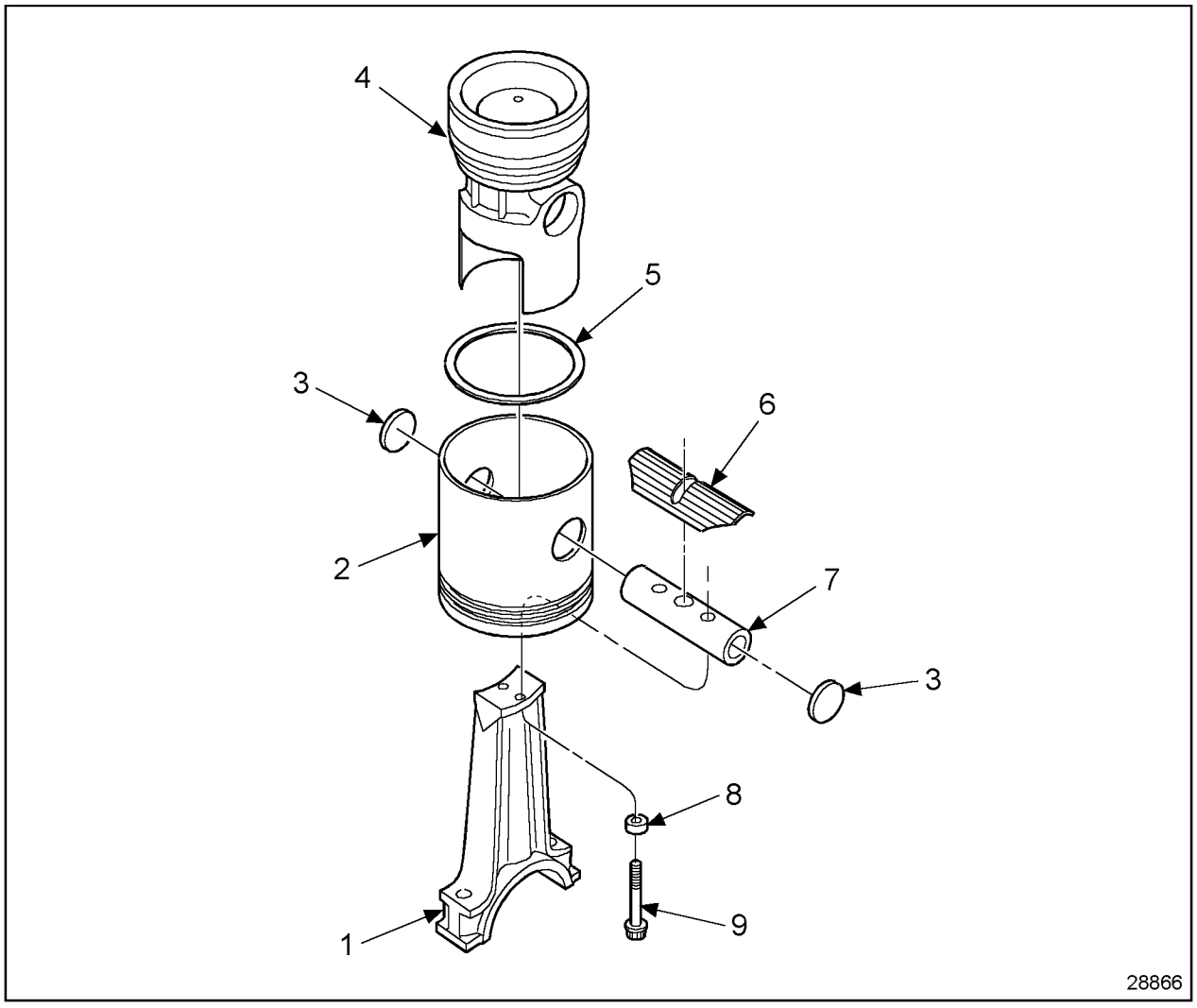
22. Remove the engine from the overhaul stand.
23. Complete engine assembly.
24. An RTV (Room Temperature Vulcanizing) sealant is now being used in place of the gasket to seal flywheel housing small hole cover ("star cover"). Replace the covers as follows:
    [a] Clean the old gasket material and/or loose sealant from the housing and cover. It is not necessary to remove all the old sealant.
    [b] Apply a 0.125 in. diameter continuous, unbroken bead of sealant to the perimeter of the cover just inside the bolt holes.

NOTE:
To provide an effective seal, this should be done not more than ten minutes before the cover will be secured to the flywheel housing. To ensure the sealant is properly applied, use a sample gasket as a template prior to installing the bead.

    [c] Attach the cover to the flywheel housing with the proper bolts, and torque to 41-47 N·m (30-35 lb·ft).

1.20 PISTON AND PISTON RINGS

The cross-head piston is a two-piece piston consisting of a crown and a skirt. A Viton rubber oil seal ring is used between the crown and skirt, which are held together by the piston pin. Ring grooves are machined in the piston crown for a fire ring and two compression rings. The crown is also machined to accept a 150 degree slipper type bushing (bearing). The piston skirt incorporates two oil control ring grooves, piston pin holes, and piston pin retainer counterbores. Equally spaced drain holes are located in the oil ring groove area to permit excess oil, scraped from the cylinder walls, to return to the crankcase. See Figure 1-152.



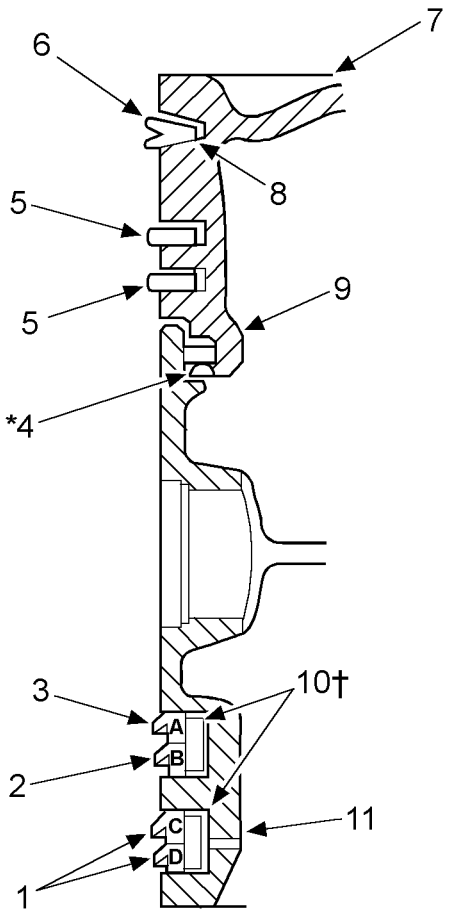
1. Connecting Rod
2. Piston Skirt
3. Pin Retainer
4. Piston Dome
5. Viton Rubber Seal
6. Bearing (Bushing)
7. Piston Pin
8. Spacer
9. Connecting Rod and Bolt

Figure 1-152 Crosshead Piston and Connecting Rod Components

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

The improved piston ring sets include fire rings, which replace former grooveless, barrel-faced rings 23502891 and 23504772. See Figure 1-153.



1. Oil Control Ring 5144622 Slotted No Chrome
2. Oil Control Ring 5102737 Non-Slotted (Orange Stripe No Chrome)
3. Oil Control Ring 5102736 (Orange Stripe Chrome O.D)
4. Dome-to-Skirt Seal Ring*
5. Compression Ring (Either Side to Face Top of Dome
6. Fire Ring (Identification Mark to Face Top of Dome)
7. Top (Piston Crown)
8. Keystone Fire Ring (Grooved) Chrome Flash Lower Side)
9. Dome
10. Oil Ring Expander Usage†
11. Skirt

* Prelube with engine oil at assembly

† Use oil ring expanders 5101568 yellow paint (high tension) for non-turbo and transit bus applications. Use oil ring expanders green paint 23503268 (low tension) for other applications.

Locate A and C ring gaps 180° from expander gaps, and B and D ring gaps from A and C gaps.

Install oil control rings with scraper edges pointed away from top of dome.

Align gaps of first and third rings 180° from gap of second ring.

Use 23524192 wide gap fire ring for 75 horsepower per-cylinder engines and above. All others use standard gap fire ring 23524191.

Figure 1-153 Crosshead Piston Ring Orientation

NOTE:
The improved piston rings are not interchangeable with the former rings. Rings should not be mixed within the engine.

- New grooved, wide-gap fire ring 23524192 will replace former grooveless, barrel-faces ring 23504772. This ring is identified by a blue stripe and three circles on the top of the ring near the gap.
- New grooved, standard gap fire ring 23524191 will replace former grooveless, barrel-faced ring 23502891. This ring is identified by two circles on the top of the ring near the gap.

NOTE:
Fire rings **must** be installed with identification marks facing up.

- The improved oil control ring sets use non-slotted, chrome scraper edge ring 5102736 and black, non-slotted ring 5102737 in the top “A” and “B” positions, respectively. Slotted oil control rings 5144622 are used in the bottom “C” and “D” groove positions.

Two different sets of oil control ring expanders are also included in the sets:

- Low tension expander 23503268 (green stripe) is used in all turbocharged engine applications, except transit buses.
- High tension expander 5101568 (yellow stripe) is used in all non-turbocharged engine and transit bus engine applications.

The top (fire) ring and the upper compression ring (second groove) are prestressed. Both are identified by a small indentation on the top side. The fire ring is chrome-plated on the lower side. Wide-gap keystone fire rings were recently released on Series 92 high output engines. A standard-gap ring was also released for Series 92 Engines.

To improve durability, a barrel face top compression fire ring replaces the grooved ring formerly used on all Series 92 Federal and California-certified engines. The new ring is used in conjunction with the current low oil consumption oil ring package.

To optimize combustion system performance and meet 1988 California vehicle emission standards, the 18:1 piston dome replaces the 17:1 dome on all 8V-92 California-certified engines. Short port (21.59 x 508 mm or 0.85 x 20 in.) liners replace the large port (24.13 x 635 mm or 0.95 x 25 in.) liners formerly used on these engines.

All 8V Federal and 6V Federal and California-certified engines use the 17:1 piston dome and the 24.13 mm (0.95 in.) port height liner.

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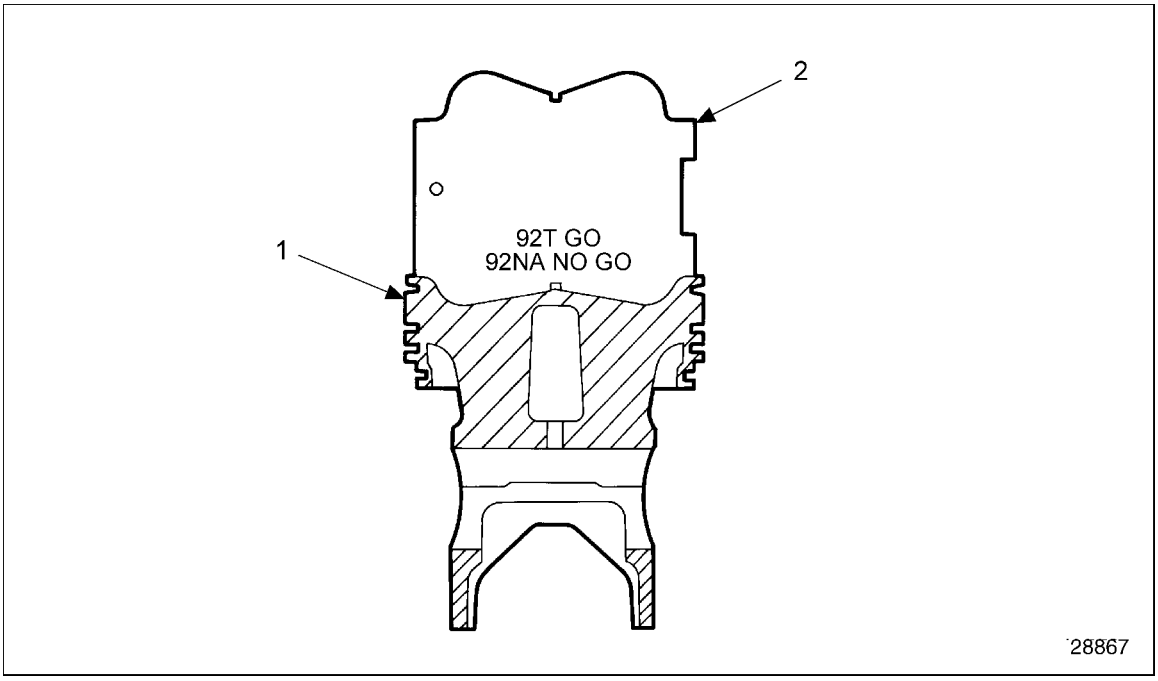
All 6V air-to-air charge-cooled Federal-certified engines use the 18:1 piston dome and the 19.1 mm (0.75 in.) port height liner.

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

Engine lubricating oil cools and lubricates internal parts of the piston. Oil is pressure-fed through the drilled passage in the connecting rod, through the oil tube in the piston pin, and through the center hole in the bushing to the underside of the piston crown. A portion of the oil flows along the grooves in the bushing to lubricate the piston pin.

During engine operation, the piston pin and bushing accept the gas loads pushing down on the piston crown. The piston skirt is free from vertical load distortion. Thermal distortion is also reduced as the piston crown expands. As the connecting rod swings to one side during downward piston travel, the piston skirt accepts a major portion of the side load.

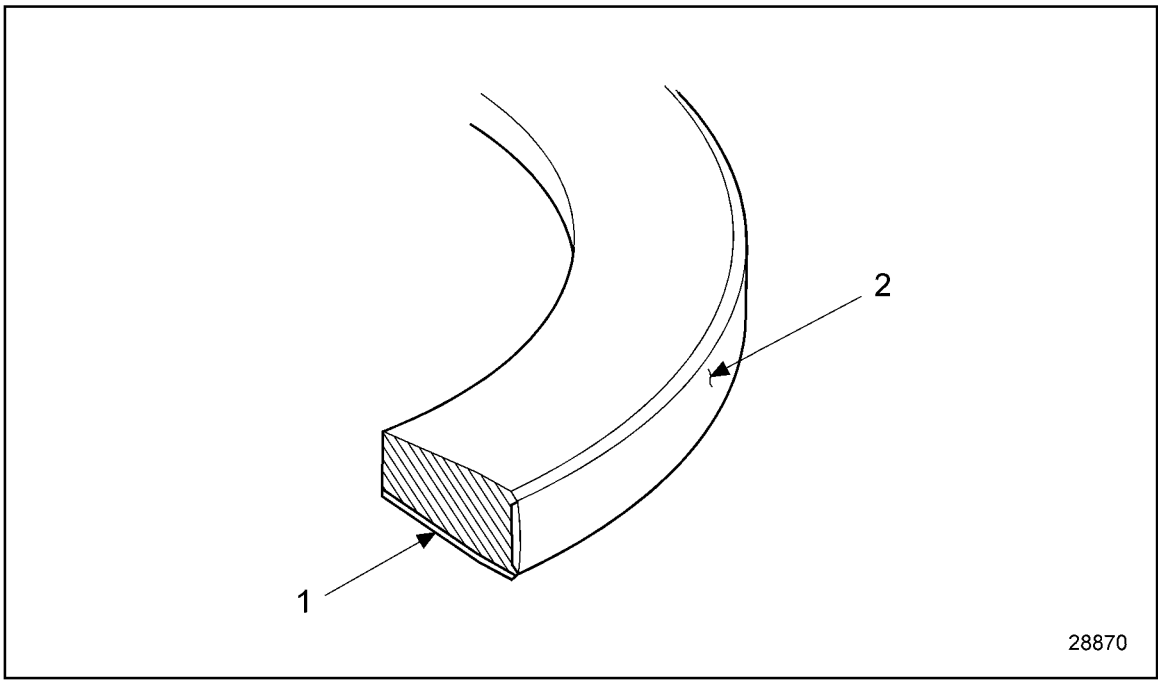
The non-turbocharged (naturally aspirated) engines use a 19:1 compression ratio piston and the turbocharged engines use a 17:1 compression ratio piston. Fit the proper side of the gage in the piston crown bowl. When the gage rests on the rim of the crown, it is a "GO" check for a piston used in a turbocharged engine. When there is a space of approximately 1.02 mm (0.040 in.), it identifies a piston used in a naturally aspirated engine. See Figure 1-154.



1. Piston Dome
2. Gage J 25397-B

Figure 1-154 Identification of Piston using Gage J 25397-B

Detroit Diesel engines are designed to operate on diesel fuels containing less than 0.5% sulfur. Plasma-faced fire rings may be used in areas where approved fuel is not commercially available or economically feasible to obtain. See Figure 1-155. Even with the use of the high-sulfur fuel modification and maintenance procedures, engine life may still not equal that obtained with recommended fuels. Refer to section 5.2 and refer to section 13.5.



1. Chromate Plated Bottom
2. Plasma Facing

Figure 1-155 Plasma Faced Fire Ring Cutaway

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

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1.20.1 Repair or Replacement of Piston and Piston Ring

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-156.

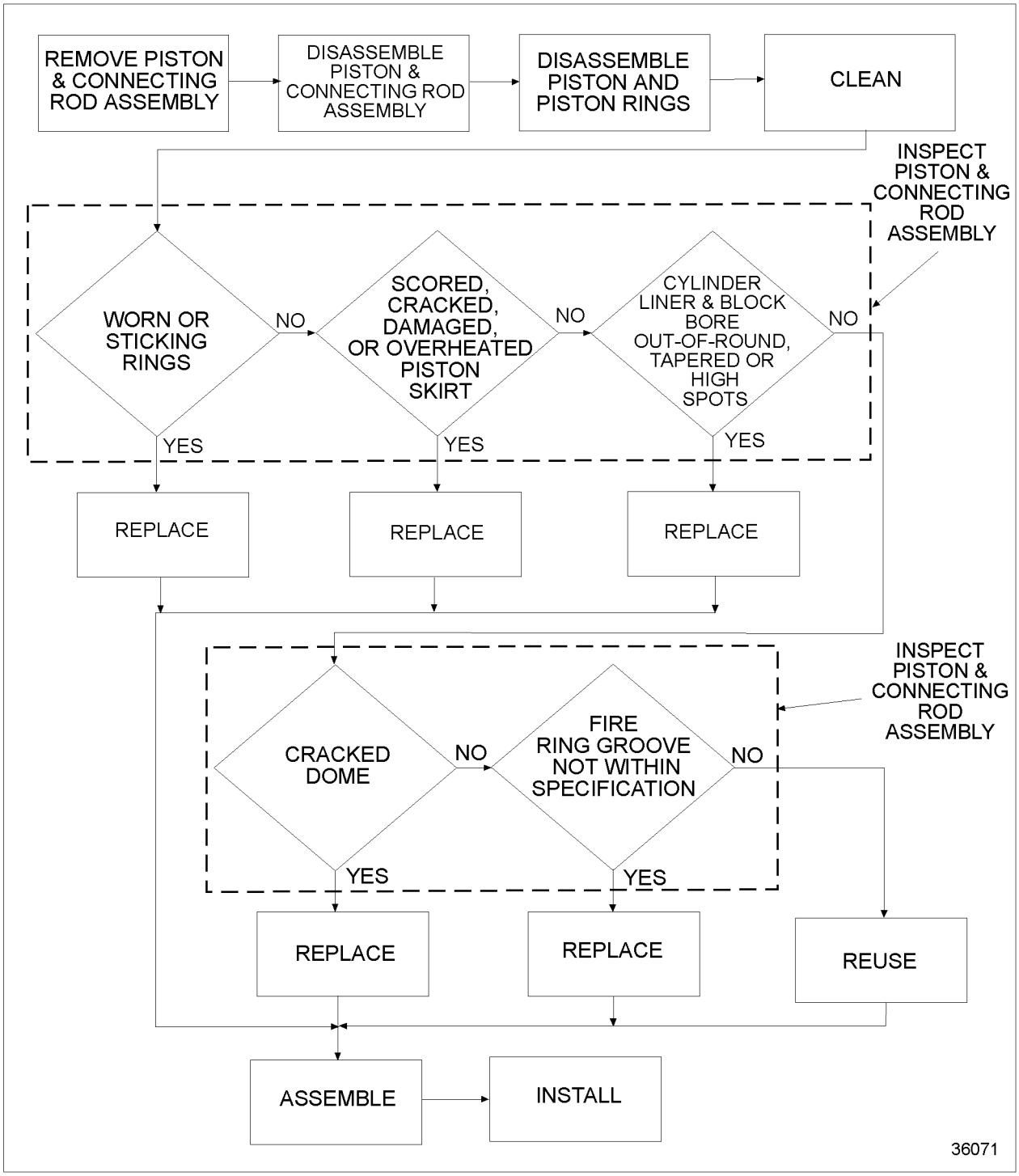


Figure 1-156 Flowchart for Repair or Replacement of Piston and Piston Ring

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1.20.2 Removal of Piston and Piston Ring

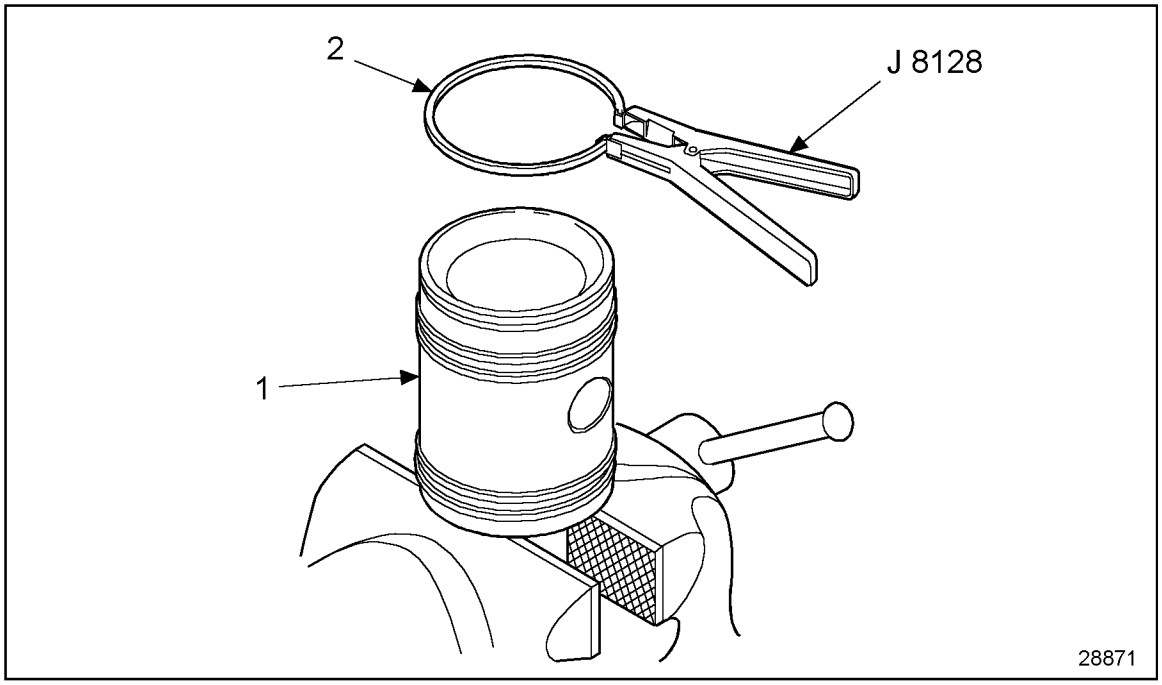
Refer to section 1.21.2 for piston and connecting rod assembly removal procedures.

1.20.3 Disassembly of Piston and Piston Ring

Remove the rings and disassemble the piston, as follows:

NOTE:
Piston assembly components should be matchmarked during disassembly to ensure that they are assembled in the same position.

1. Secure the connecting rod in a soft-jawed vise.
2. Remove the piston rings with tool J 8128. See Figure 1-157.



1. Piston Assembly
2. Fire Ring

Figure 1-157 Removing Piston Rings

3. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch.
4. Pry both retainers from the piston. Do not damage the piston or bushing.
5. Loosen the two bolts securing the connecting rod to the piston pin.
6. Remove the rod and piston assembly from the vise, and place the assembly on the bench. Remove the two bolts and spacers and the connecting rod.
7. Withdraw the piston pin.

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8. Use a mallet to disassemble the dome from the piston assemblies skirt with fluoroelastomer seal rings.
9. Grasp the piston assembly by the skirt, and bring the dome pin area down onto the tool's neoprene head with sufficient force to separate the dome from the skirt.

NOTE:
The neoprene-padded base of the tool will absorb the impact of any dropped piston skirt.

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.

10. Remove the seal ring from the piston crown.
11. Remove the piston pin bushing (bearing).

1.20.3.1 Cleaning of Piston and Piston Ring

Prior to inspection, clean the pistons and piston rings as follows:

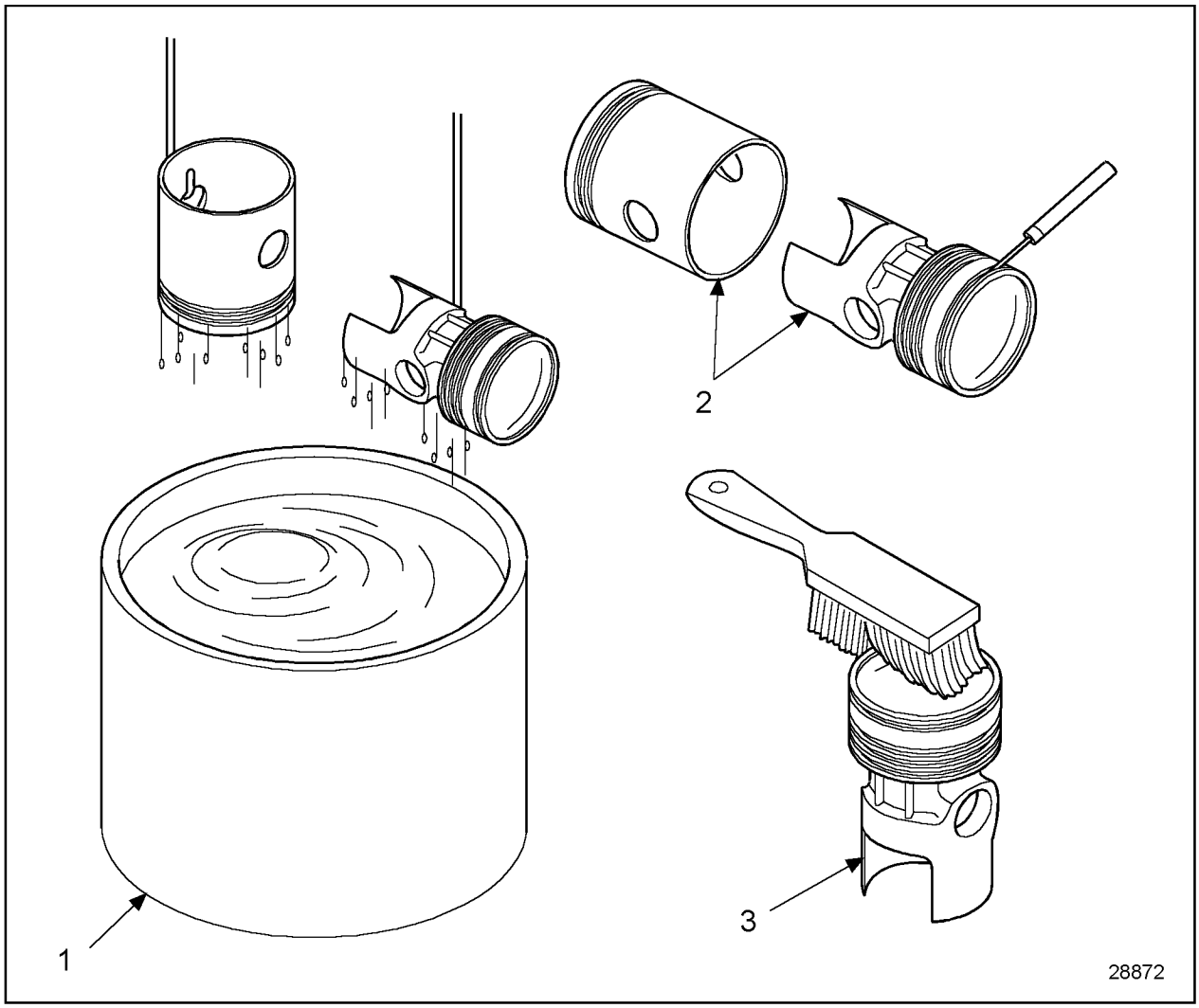
CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

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 piston components with fuel oil and dry them with compressed air. See Figure 1-158.



1. Carbon Deposit Removal
2. Cleaning Compression Ring Grooves
3. Cleaning Piston Crown

Figure 1-158 Piston Cleaning Procedure

NOTE:
If fuel oil does not remove the carbon deposits, use an approved chemical solvent that will not harm the tin-plate on the piston skirt. Do not use chemical solvent on the bushing.

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

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4. Clean the inside surfaces of the piston crown and skirt and the oil drain holes in the lower half of the piston skirt.

NOTE:
Avoid enlarging the holes while cleaning them.

⚠ 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:

Do not attempt to clean the piston skirt by glass beading. This will remove the tin-plating.

5. Use glass beading to clean a piston crown.

NOTE:
Mico Bead Glass Shot MS-M (0.074-0.147 mm or 0.0029-0.0058 in.) is recommended. Allowable air pressure is 552-689 kPa (80-100 lb/in.^{2}).

NOTE:
After cleaning, do not leave glass beads in the piston crown.

NOTICE:

Do not use crocus cloth on the bushing side of the pin. Do not polish or refinish the piston pin on the bushing side. This could damage the bushing side of the pin.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

6. Use crocus cloth wet with fuel oil to remove any trace of fretting and/or corrosion on the connecting rod saddle-to-piston pin contact surface.

1.20.3.2 Inspection of Piston and Piston Ring

Inspect the piston and piston rings as follows:

NOTE:
The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed.

1. Inspect for worn or sticking compression rings.
   [a] If worn or damaged, replace the rings. Refer to section 1.20.5.
   [b] If not worn or damaged, continue inspection.
2. Visually inspect the plating or grooves for wear.
   [a] If excessively worn, replace the piston and piston rings. Refer to section 1.20.5 and refer to section 1.20.7.
   [b] If not worn, continue inspection.
3. Check compression ring pressure.

NOTE:
If the rings are free and the plating or grooves are not worn away, compression should be within operating specifications.

[a] If compression is not within specification. Replace.

[b] If compression is within specification, proceed with inspection.

NOTE:
If the tin-plate on the piston skirt and the original grooves in the piston rings are intact (no wear step on the lower groove land), little wear has occurred.

NOTE:
Excessively worn or scored piston skirts, rings, or cylinder liners may be an indication of abnormal maintenance or operating conditions which should be corrected to avoid a failure recurrence. Using the recommended lubricating oil filters and air cleaners and proper maintenance will minimize the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the wear rate.

NOTICE:
Avoid long periods of operation at idle speed and the use of improper lubricating oil or fuel. A heavy formation of carbon may result and cause the rings to stick, causing engine damage.

4. Visually inspect the piston skirt and crown for score marks, cracks, damaged ring groove lands, or indications of overheating.
   [a] If scored, cracked, damaged, or overheated, replace the piston. Refer to section 1.20.7.

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[b] If not scored, cracked, damaged, or overheated, continue inspection.

NOTE:
Overheating or burned spots may be the result of an obstruction in the connecting rod oil passage.

5. Check the cylinder liner and block bore for excessive out-of-round, taper or high spots. Refer to section ADDITIONAL INFORMATION.
   [a] If the cylinder liner is not within specifications, it must be replaced. Refer to section 1.23.3.
   [b] If the cylinder liner and block bore are within specifications, continue inspection.
6. Inspect the connecting rod, piston pin, and piston pin bushing. Refer to section 1.21.3.2.

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

7. Inspect the crosshead piston dome using one of the following methods.

1.20.3.3 Inspection of Piston Dome using Magnetic Particle

Perform the magnetic particle method as follows:

1. Magnetize the dome.
2. Cover it with a fine magnetic powder or solution.

NOTE:
The particles or solution will effectively mark the crack.

3. Demagnetize the dome, and clean thoroughly.
   [a] If magnetic particle inspection reveals a crack in any strut of a crosshead piston dome, the dome must be discarded and replaced. Refer to section 1.20.4.
   [b] If no cracks are revealed, continue inspection.

1.20.3.4 Inspection of Piston Dome using Fluorescent Magnetic Particle

Perform the fluorescent magnetic particle method as follows:

1. Magnetize the dome.
2. Cover with fluorescent magnetic particles.

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3. Place under a "Black Light."

NOTE:
Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the "Black Light."

[a] If cracked, replace the dome. Refer to section 1.20.4.

[b] If no cracks are revealed, continue inspection.

4. Demagnetize the dome.

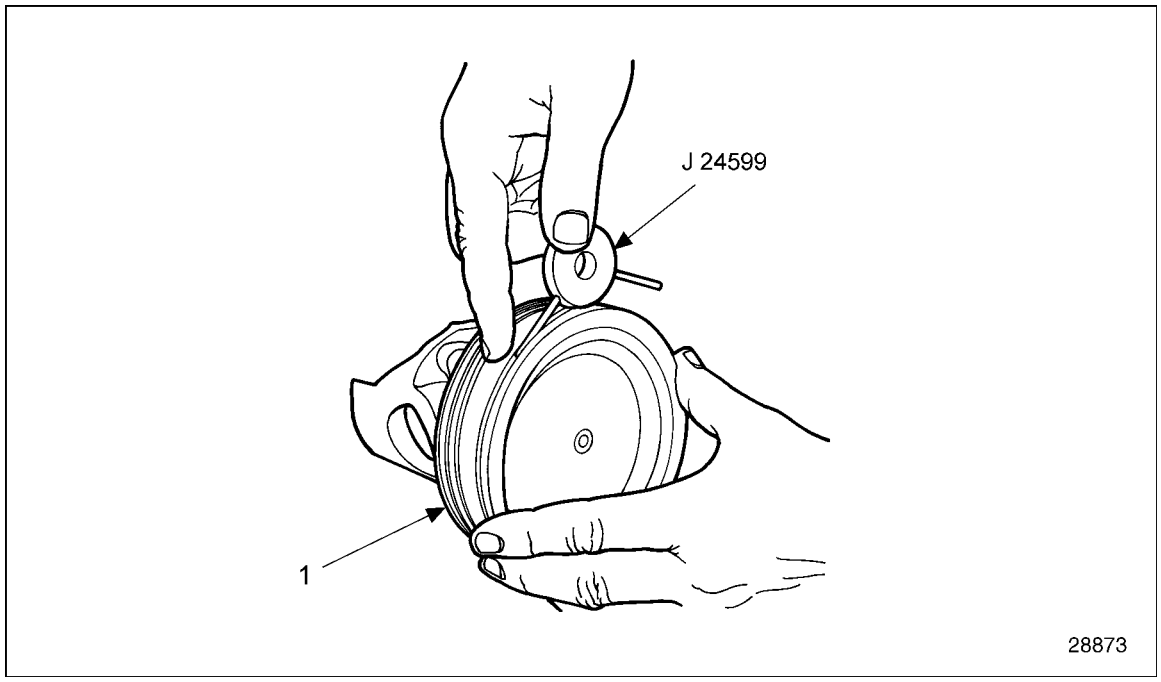
NOTICE:
Reusing a crosshead piston dome with a cracked strut can result in dome separation and serious engine damage.

NOTE:
When conducting a magnetic particle inspection, ensure that a casting joint is not mistaken for a crack.

1.20.3.5 Inspection of Tapered Fire Ring Groove

Inspect the tapered fire ring groove width as follows:

1. Check the tapered fire ring groove width in the current piston crown with tool J 24599. See Figure 1-159.



1. Piston Dome

Figure 1-159 Checking Fire Ring Groove in Piston Dome with Tool J 24599

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2. Slide the "NO-GO" wire 2.69 mm (0.106 in.) diameter completely around the fire ring groove.

   [a] If the wire is below flush at any one area, the piston crown must be replaced. Refer to section 1.20.4.

NOTE:
The "GO" wire 2.54 mm (0.100 in.) diameter should be flush or protrude slightly from the fire ring groove.

   [b] If the wire is flush or protrudes to the proper dimension, reuse the piston and piston rings.

1.20.4 Assembly of Piston and Piston Ring

Assemble the piston and piston ring assembly as follows:

1. Refer to section ADDITIONAL INFORMATION for specifications on reusing piston assembly components.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Use a mixture of clean engine oil and STP® (or equivalent) on all moving cylinder kit parts assembly.

NOTE:
This mixture adheres to the parts for a longer period of time than plain engine oil, preventing part scuffing at engine start-up. The suggested mix ratio is 8:1 (8 parts engine oil to 1 part STP, or equivalent).

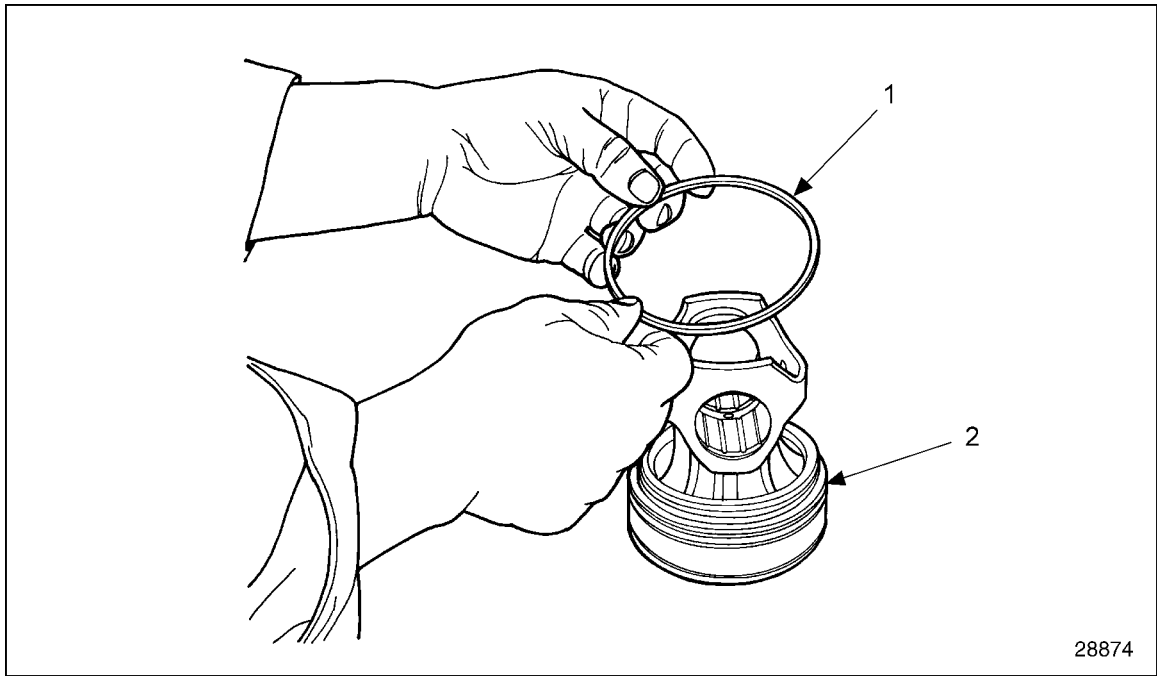
3. Install the bearing (bushing) in the piston crown.

NOTE:
The bearing should slide into the piston crown without force. With new parts, there is 0.013-2.667 mm (0.0005-0.0105 in.) clearance between the edge of the bushing and the groove in the piston crown.

⚠ 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.

4. Lubricate the fluoroelastomer seal ring liberally with the STP/oil mix, and install it on the piston. See Figure 1-160.



1. Seal Ring
2. Piston Dome

Figure 1-160 Installing Seal Ring

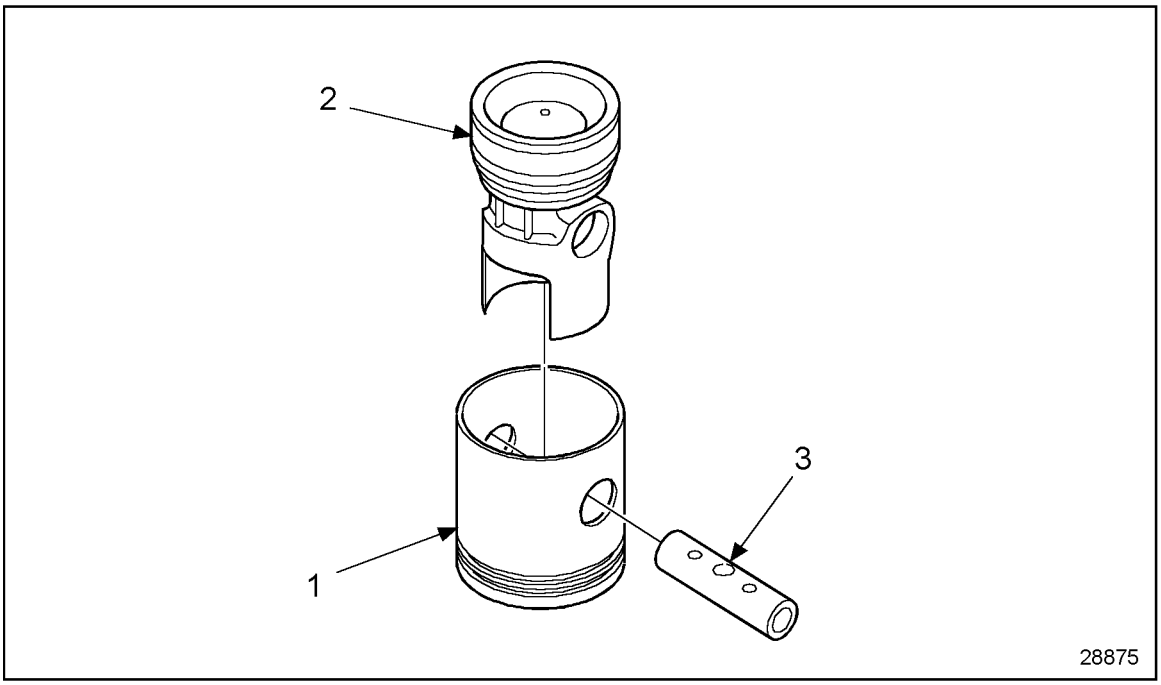
NOTE:
Unlike the former cast iron ring, the new fluoroelastomer ring is compressed when the skirt is pushed into position on the piston crown. No ring compressor tool is required.

5. Before completely assembling the piston, ensure the seal ring is installed correctly.

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

6. Lubricate the piston pin with the STP/oil mix, and install it. See Figure 1-161.

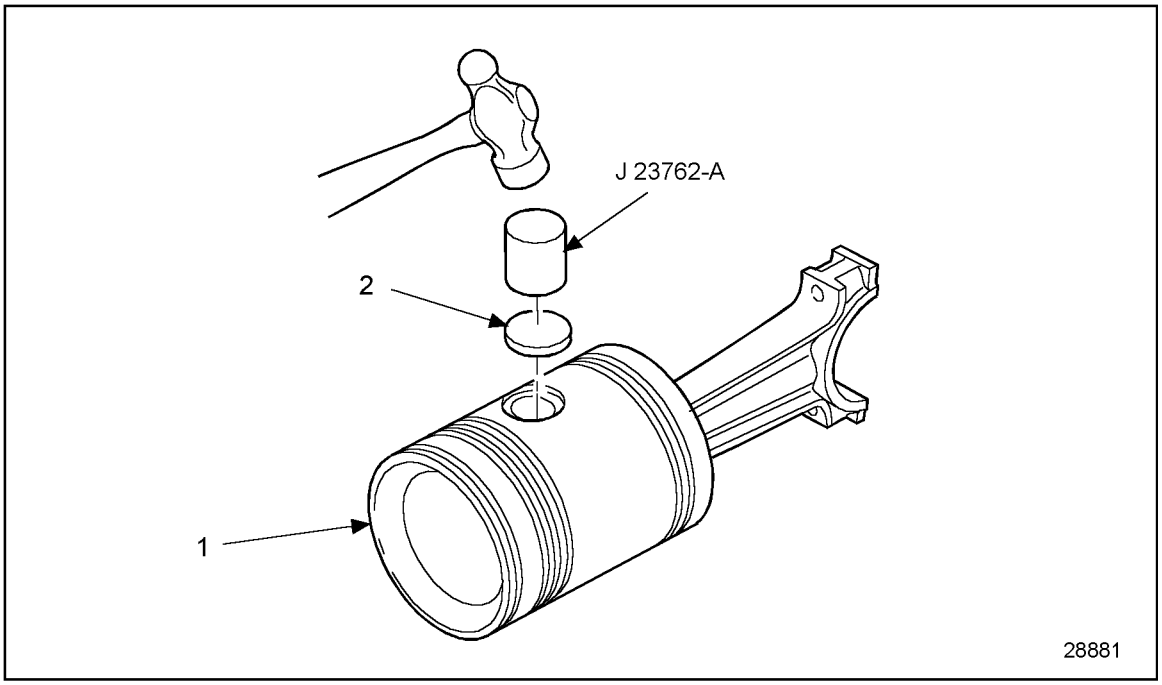


1. Piston Skirt
2. Piston Dome
3. Piston Pin

Figure 1-161 Installing Piston Dome, Piston Skirt and Piston Pin

7. Install the spacers on the two 7/16 in.-20 x 2 in. connecting rod-to-piston pin attaching bolts.
8. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact surfaces.
9. Install and tighten the bolts finger tight.
10. Clamp the connecting rod using tool J 36211, and tighten the bolts. Do not exceed 75-81 N·m (55-60 lb·ft) torque.
11. Position a new piston pin retainer.
12. Place the crowned end of installer J 23762-A against the retainer, and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston.
13. Position the second piston pin retainer.

14. Place the crowned end of installer J 23762-A against the retainer, and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston. See Figure 1-162.



1. Piston and Connecting Rod
2. Piston Pin Retainer

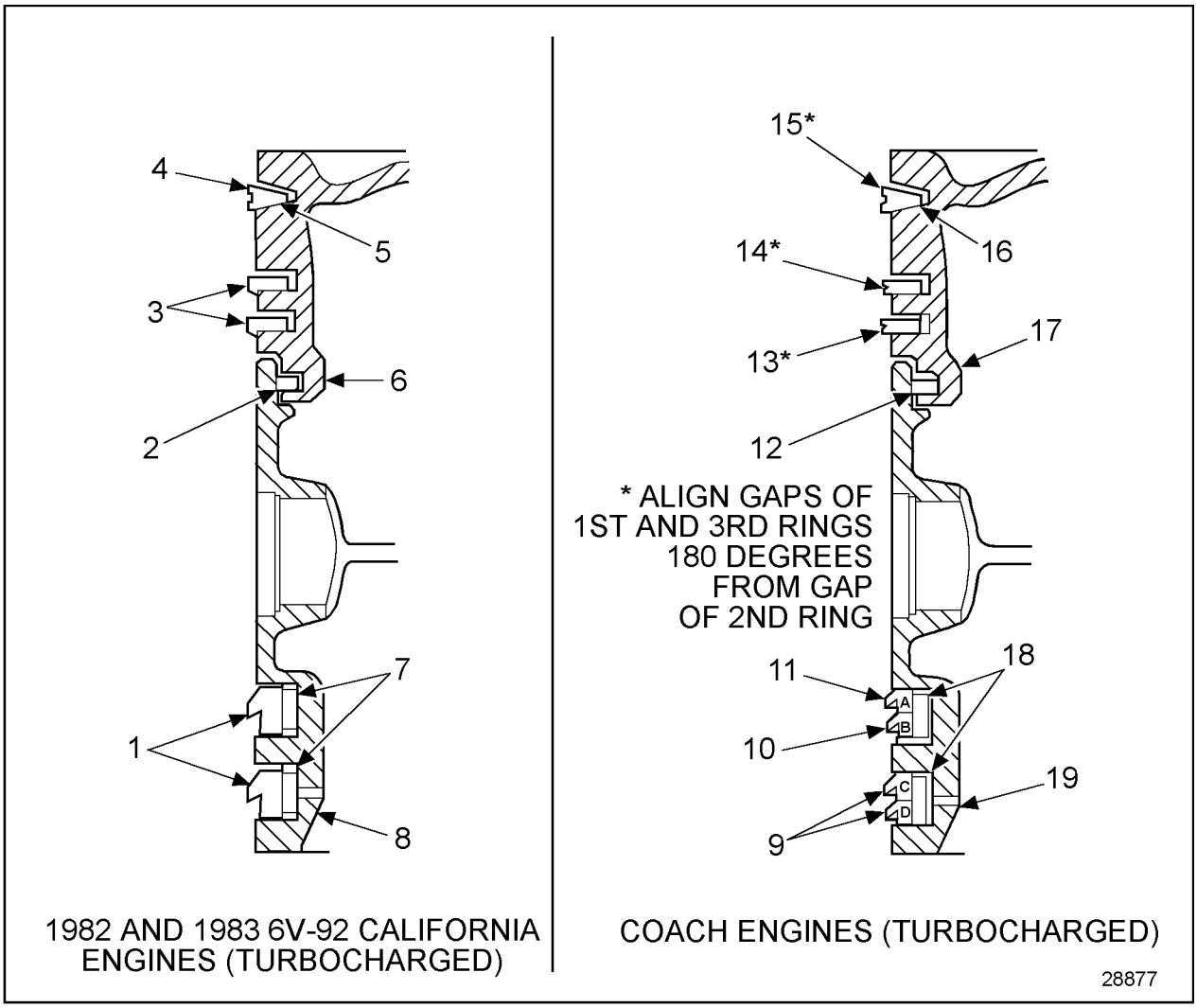
Figure 1-162 Installing Piston Pin Retainer with Tool J 23762-A

NOTE:
Due to the size of the counterbore in the piston skirt, be careful when installing the piston pin retainers. Inspect them to ensure they are not buckled and that they are fully seated in the counterbores. The width of the land should be even around the retainer.

NOTE:
Current specifications may not be available at the time of publication. Refer to your local distributor, or Detroit Diesel Parts Technical for additional information.

NOTE:
A new piston ring set has been released for all 1983 6V and 8V Federal-certified and 8V California-certified turbocharged automotive engines. California-certified 6V engines continue to use the 1982 ring package. See Figure 1-163.

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1. Oil Rings (Oil Ring Scraper Edges to Point Away from Dome)
2. Dome to Seal Ring (Install with Chamfer Away from Dome)
3. Compression Rings (Align Gaps of First and Third Rings, 180 Degrees from Gap of Second Ring)
4. Fire Ring (Identification Mark to Face Top of Dome)
5. Keystone Fire Ring, Chrome Flash Lower Side
6. Piston Dome
7. Oil Ring Expanders (Green Paint) 9-14 lbs. Tension
8. Piston Skirt
11. Upper Oil Control Ring Orange Stripe (Chrome OD)
12. Dome to Skirt Seal Ring, Install with Chamfer Away from Top of Dome as Shown
13. Third Compression Ring
14. Second Compression Ring
15. First Ring-Fire Ring, Identification Mark to Face Top of Dome
16. Keystone Fire Ring, Chrome Flash Lower Side
17. Piston Dome
18. Oil Ring Expanders (White Paint) 12-17 lbs. Tension

9. Bottom Side of Ring Slotted (Black Rings) Locate A and C Ring Gaps 180 Degrees from Expander Gaps, B and D Ring Gaps 90 Degrees from A and C Gaps
10. Lower Oil Control Ring Orange Stripe (No Chrome)
19. Piston Skirt

Figure 1-163 Piston Ring Installation

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

NOTE:
The new piston ring configuration may also be used to service all prior 6V and 8V Federal and California automotive engines, except the 1982 6V California, the 1983 6V California and all inter-city transit and parlor coach engines.

1.20.5 Installation of Compression Rings

Install the compression rings as follows:

1. Starting with the bottom ring, install the compression rings with tool J 8128.

NOTE:
To avoid breaking or over-stressing the rings, do not spread them any more than necessary to slip them over the piston.

2. Stagger the ring gaps around the piston.

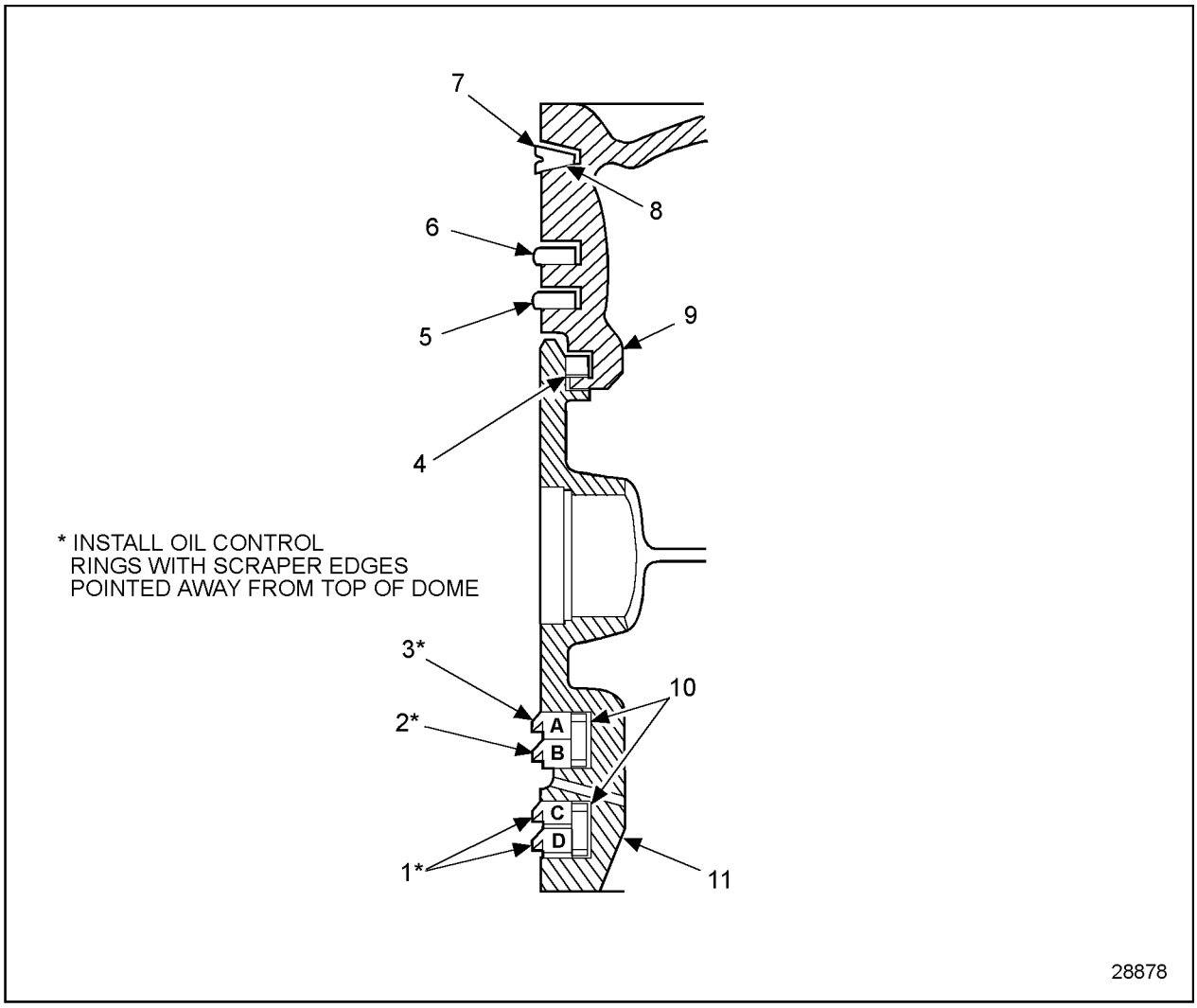
1.20.6 Installation of Oil Control Rings

Install the oil control rings as follows:

NOTICE:
Lubricate the piston rings and piston with STP, or equivalent, before installing to prevent serious engine damage.

1. See Figure 1-164 for the type and location.

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1. Lower Oil Control Ring, Bottom Side of Ring Slotted (Black Rings) Locate A & C Ring Gaps 180 Degrees from Expander Gaps, and B & D Ring Gaps 90 Degrees from A & C Gaps
2. Oil Control Ring, Orange Stripe (No Chrome)
3. Oil Control Ring, Orange Stripe (No Chrome OD)
4. Dome to Skirt Seal Ring Install with Chamfer Away from Top of Dome as Shown
5. Third Compression Ring, Align Gaps of First and Third Rings 180 Degrees from Gap of Second Ring
6. Second Compression Ring, Either Side to Face Top of Dome
7. First Ring, Fire Ring, Identification Mark to Face Top of Dome
8. Keystone Fire Ring Chrome Flash Lower Side
9. Piston Dome
10. Oil Ring Expanders (White Paint) 9-14 lbs. Tension
11. Piston Skirt

Figure 1-164 Piston Ring Installation, 1983 Federal, 1983 8V-92 California and Prior Engines (Turbocharged)

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NOTICE:
When installing the oil control rings, use care to prevent overlapping the ends of the ring expanders. An overlapped expander will cause the oil ring to protrude beyond allowable limits and will result in breakage when the piston is inserted in the ring compressor during installation in the cylinder liner.

NOTICE:
To prevent overlapping, do not cut or grind the ends of the expanders. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high lubricating oil consumption.

NOTICE:
Do not let the expander ends overlap while installing the piston. The rings will break.

2. Install the ring expanders in the oil control ring grooves in the piston skirt. Install the peripheral abutment type ring expanders with the legs of the free ends toward the top of the piston. See Figure 1-165.

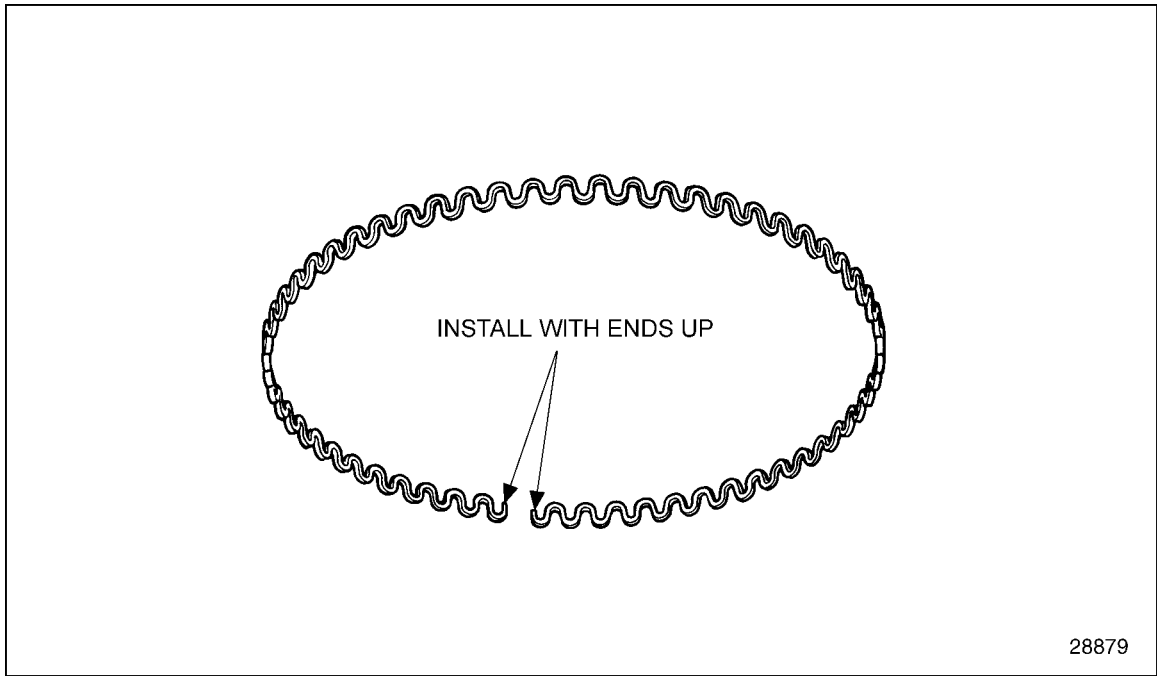


Figure 1-165 Peripheral Abutment Type Oil Ring Expander

3. Lubricate the oil control rings with STP, or equivalent.

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

4. Install the rings by hand. Starting with the upper half of the top oil ring, align the gaps.

1.20.7 Installation of Piston and Connecting Rod Assembly

Install the piston and connecting rod assembly as follows:

1. Install the piston and connecting rod assembly in the engine. Refer to section 1.23.2.2.

1.20.8 Installation of Cylinder Liner Seal Ring

Install the cylinder liner seal ring as follows:

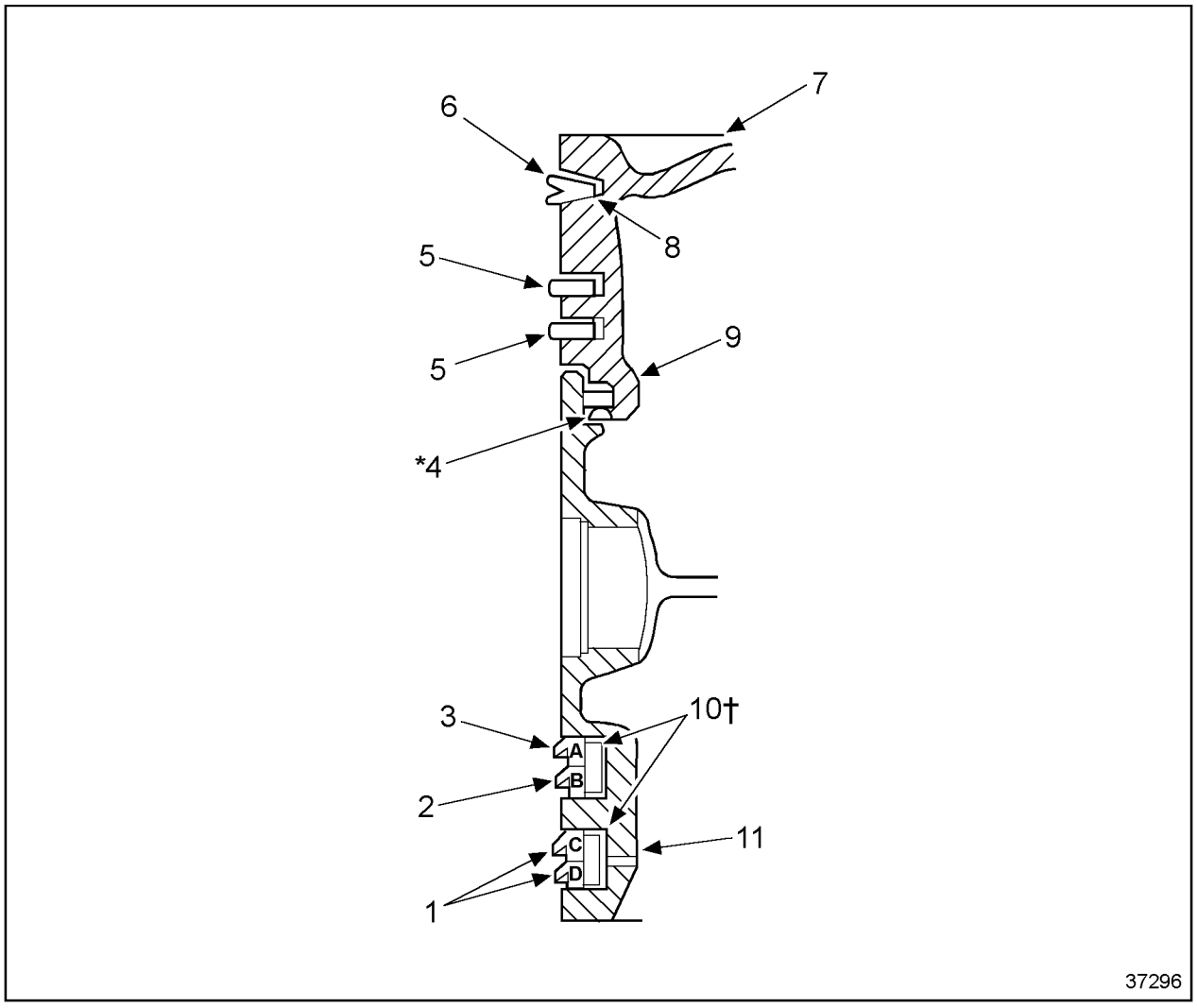
NOTE:
The following instructions apply when cylinder liners or complete cylinder kit components are being replaced on the engine. They do not apply when replacement involves piston ring sets only.

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

NOTE:
The cylinder liner seal rings presently being used are improved composition seal rings with an orange Teflon coating. They provide highly effective resistance to heat, chemical and mechanical distortion. Clean engine oil may be used as an assembly lubricant on the seal rings when installing the liner.

NOTE:
Discontinue the use of hydrogenated vegetable type shortening as a lubricant when installing Teflon-coated seals. See Figure 1-166.

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1. Oil Control Ring 5144622 (Slotted No Chrome)
2. Oil Control Ring 5102737 (Orange Stripe-No Chrome)
3. Oil Control Ring 5102736 (Orange Stripe-Chrome OD)
4. Dome-to-Skirt Seal Ring*
5. Compression Ring (Either Side to Face Top of Dome)
6. Fire Ring (Identification Mark to Face Top of Dome)
7. Top (Piston Crown)
8. Keystone Fire Ring (Grooved) Chrome Flash Lower Side
9. Dome
10. Oil Ring Expander Usage†
11. Skirt

* Prelube with engine oil at assembly

† Use oil ring expanders yellow paint (high tension) for non-turbo and transit bus applications. Use oil ring expanders green paint (low tension) for other applications.

Locate A and C ring gaps 180° from expander gaps, and B and D ring gaps from A and C gaps.

Install oil control rings with scraper edges pointed away from top of dome.

Align gaps of first and third rings 180° from gap of second ring.

Use wide gap fire ring for 75 horsepower per-cylinder engines and above. All others use standard gap fire ring.

Figure 1-166 Piston Ring Installation

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1. Check piston to liner clearances. Refer to section ADDITIONAL INFORMATION.

1.20.8.1 Test Retainer for Leak

Test for leaks as follows:

1. Check each retainer for proper sealing with leak detector J 23987-B. See Figure 1-167.

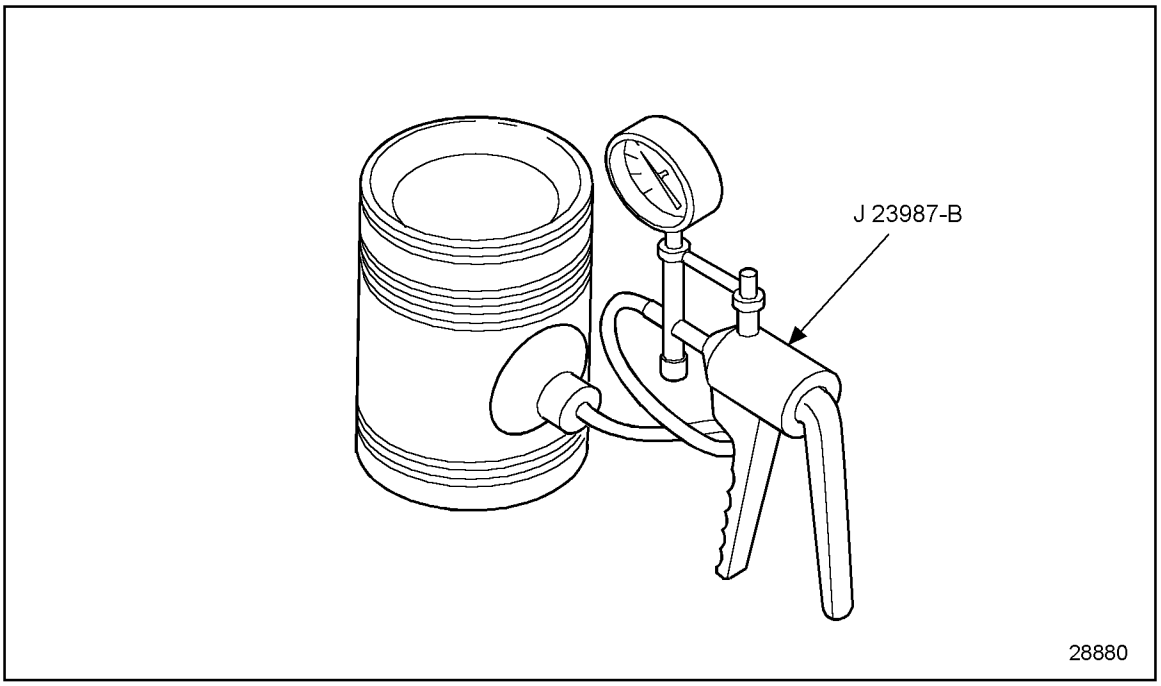


Figure 1-167 Checking Piston Pin Retainer for Proper Sealing with Tool J 23987-B

2. Place the suction cup over the retainer.
3. Hand operate the lever to pull a vacuum of ten inches on the gage. A drop in the gage reading indicates air leakage at the retainer.
   [a] If air is leaking, remove the retainer and inspect for burrs. Install a new retainer and repeat test.
   [b] If no air is leaking, refer to section 1.20.9 for installation.

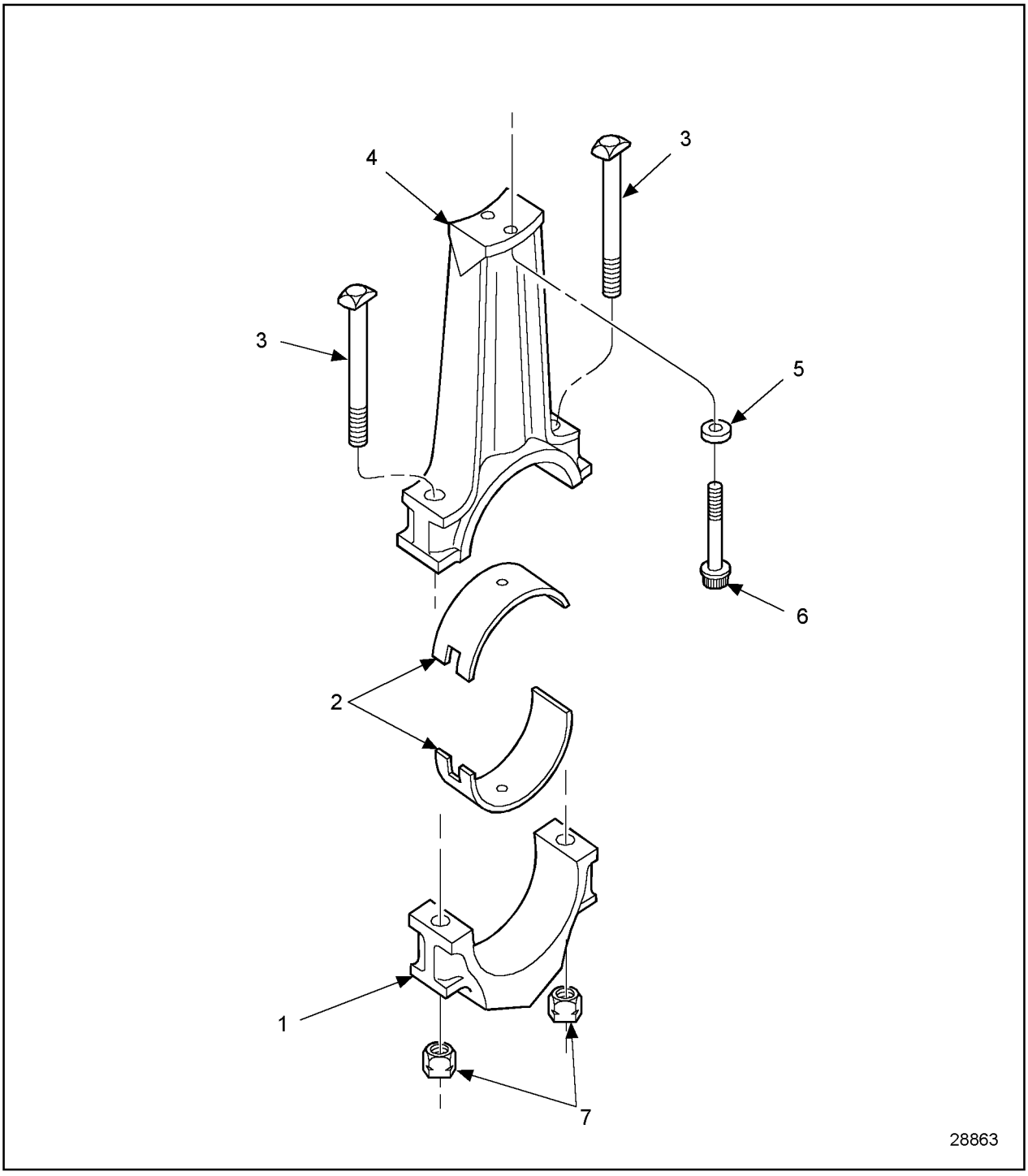
1.20.9 Installation of Piston and Piston Rings

Install the piston and piston rings as follows:

1. Refer to section 1.21.5 to install the piston and connecting rod assembly.

1.21 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. See Figure 1-168. The bearing cap and connecting rod are forged in one piece and bored prior to separation.



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1. Bearing Cap
2. Bearing Shells
3. Connecting Rod Bolts
4. Connecting Rod
5. Spacers (2)
6. Piston Pin Bolts (2)
7. Connecting Rod Nuts

Figure 1-168 Connecting Rod Assembly

The upper end of the connecting rod is machined to match the piston pin contour. The piston pin is secured to the connecting rod with two self-locking bolts and spacers. Two specially machined bolts and nuts secure the lower bearing cap to the connecting rod.

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

A service connecting rod includes the bearing cap, attaching bolts, and nuts. Refer to section 1.22 for the replaceable connecting rod bearing shells.

Effective with approximate engine serial numbers 6VF-634, 8VF-1243 and 16VF-1004, a solid core piston pin is used in turbocharged engines. See Figure 1-169. The piston pin has a drilled oil hole in the center. A tapped hole on each side of the oil hole is provided to receive the connecting rod attaching bolts. The solid core piston pin is still used, but the identification was removed.

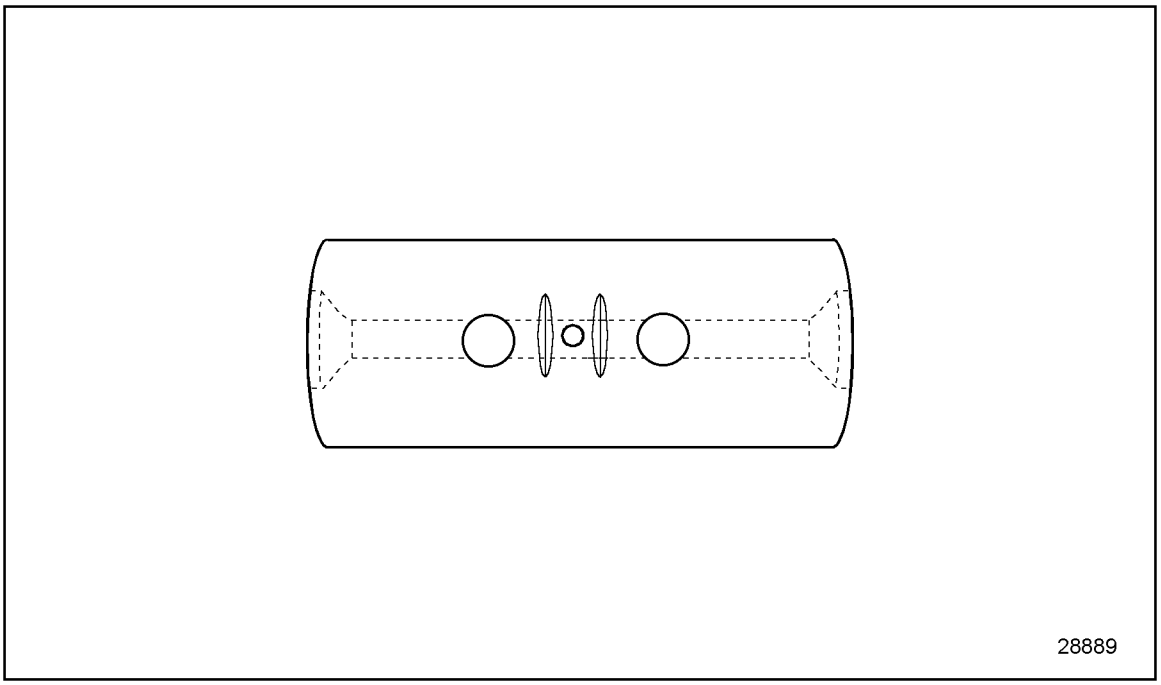


Figure 1-169 Solid Core Piston Pin

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1.21.1 Repair or Replacement of Connecting Rod

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-170.

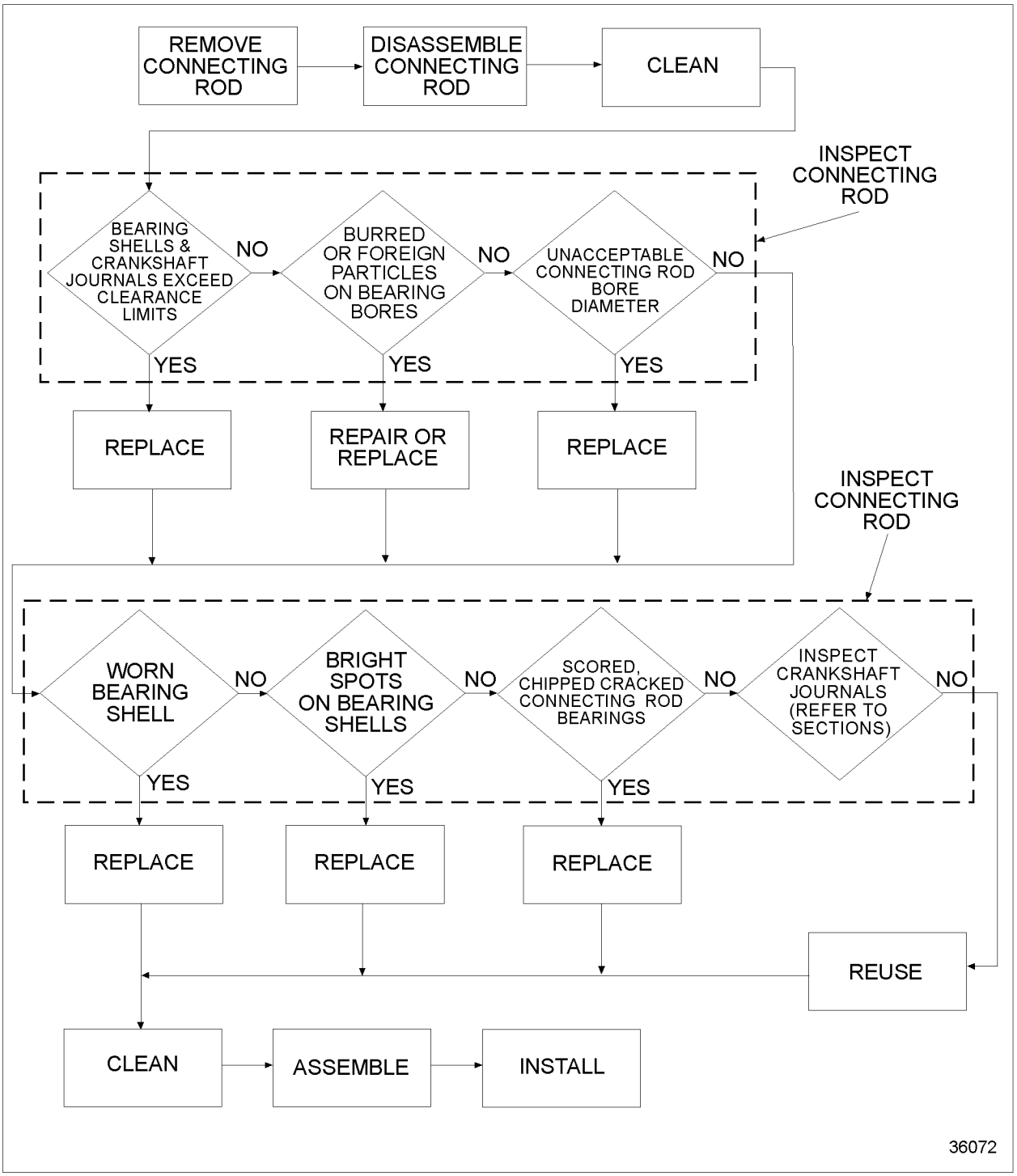


Figure 1-170 Flowchart for Repair or Replacement of Connecting Rod

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1.21.2 Removal of Connecting Rod

Remove the connecting rod as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Drain the oil. Refer to section 13.5.2.
3. Remove the oil pan. Refer to section 3.11.3.
4. Remove the oil pump and inlet and outlet pipes, if necessary. Refer to section 3.2.2.
5. Remove the cylinder head. Refer to section 1.3.2.
6. Remove the carbon deposits from the upper inner surface of the cylinder liner.
7. Remove the bearing cap and the lower bearing shell from the connecting rod.
8. Push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.
9. Reassemble the bearing cap, and lower bearing shell to the connecting rod.

1.21.3 Disassembly of Connecting Rod

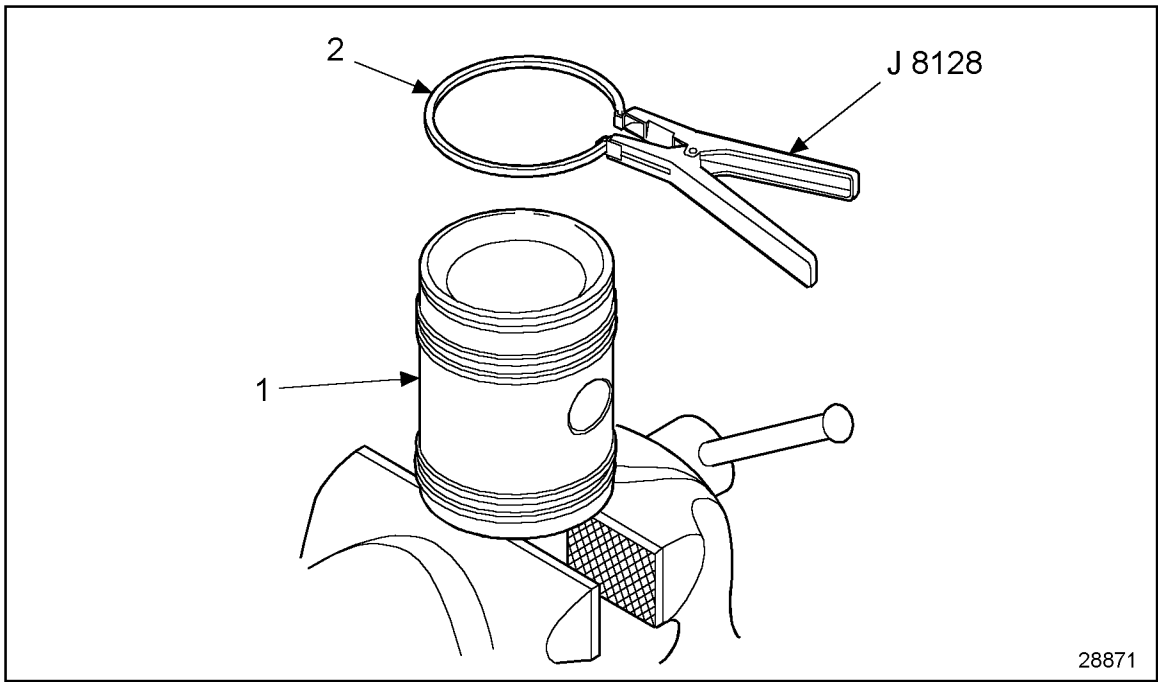
Disassemble the piston and connecting rod as follows:

NOTE:
Piston assembly components should be matchmarked during disassembly to ensure that they are reassembled in the same position.

1. Secure the connecting rod in a soft-jawed vise.

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2. Remove the piston rings with tool J 8128. See Figure 1-171.



1. Piston Assembly
2. Fire Ring

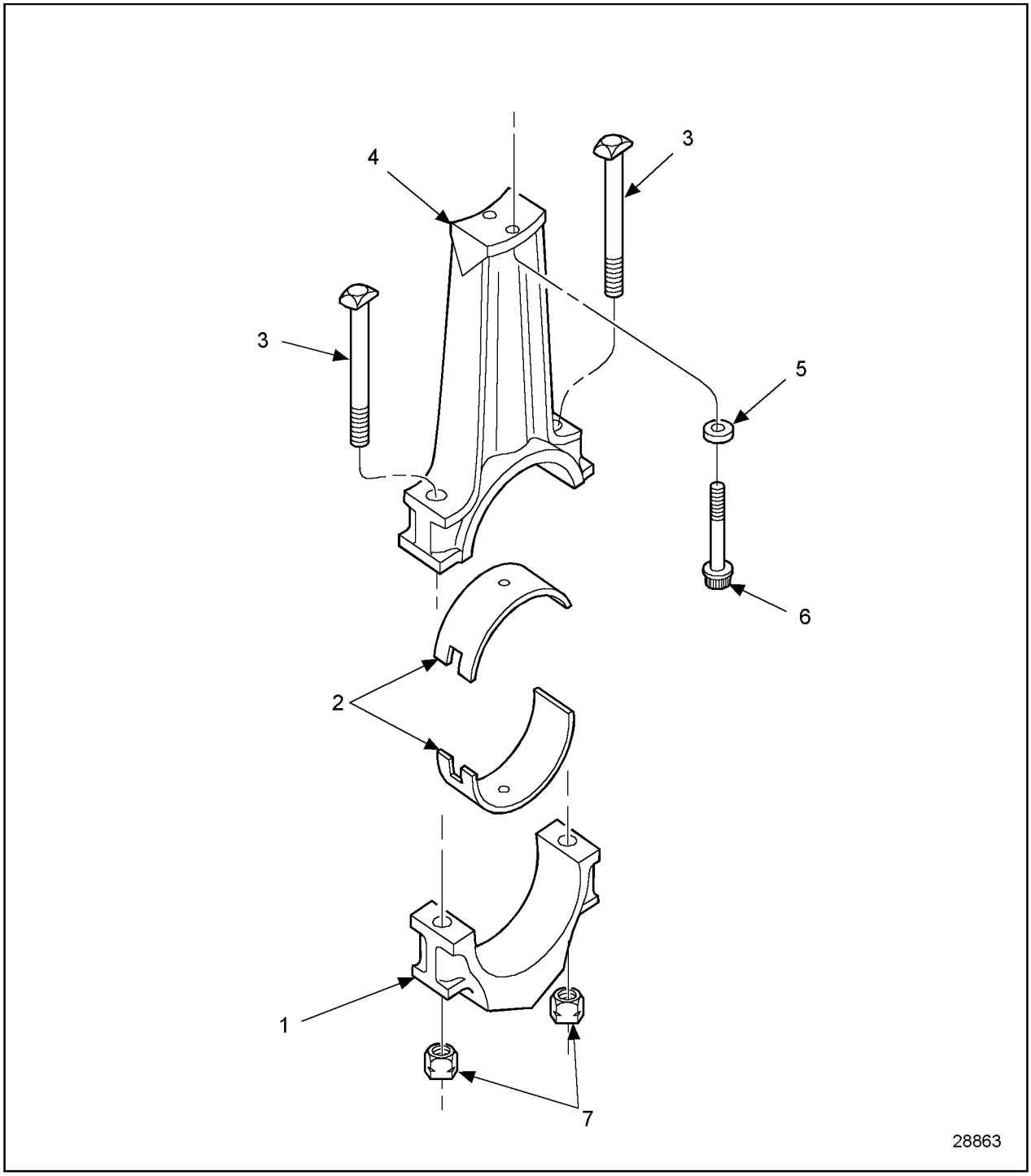
Figure 1-171 Removing Piston Rings

3. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch.

NOTICE:
When prying retainers from the piston, do not damage the piston or bushing.

4. Pry both retainers from the piston.
5. Loosen the two bolts securing the connecting rod to the piston pin. See Figure 1-172.

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1. Bearing Cap
2. Bearing Shells
3. Connecting Rod Bolts
4. Connecting Rod
5. Spacers (2)
6. Piston Pin Bolts (2)
7. Connecting Rod Nuts

Figure 1-172 Connecting Rod Assembly

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6. Remove the rod and piston assembly from the vise, and place the assembly on the bench. Remove the two bolts and spacers and the connecting rod.
7. Withdraw the piston pin.

1.21.3.1 Cleaning of Connecting Rod

Prior to inspection, clean the connecting rod as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

⚠ 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 connecting rod and piston pin with fuel oil, and dry them with 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.

2. Blow compressed air through the oil passage in the connecting rod to clear obstructions.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Use crocus cloth, wet with fuel oil, to remove any trace of fretting and/or corrosion on the connecting rod saddle and piston pin contact surface before reassembly.

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

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

1.21.3.2 Inspection of Connecting Rod

Inspect the connecting rod as follows:

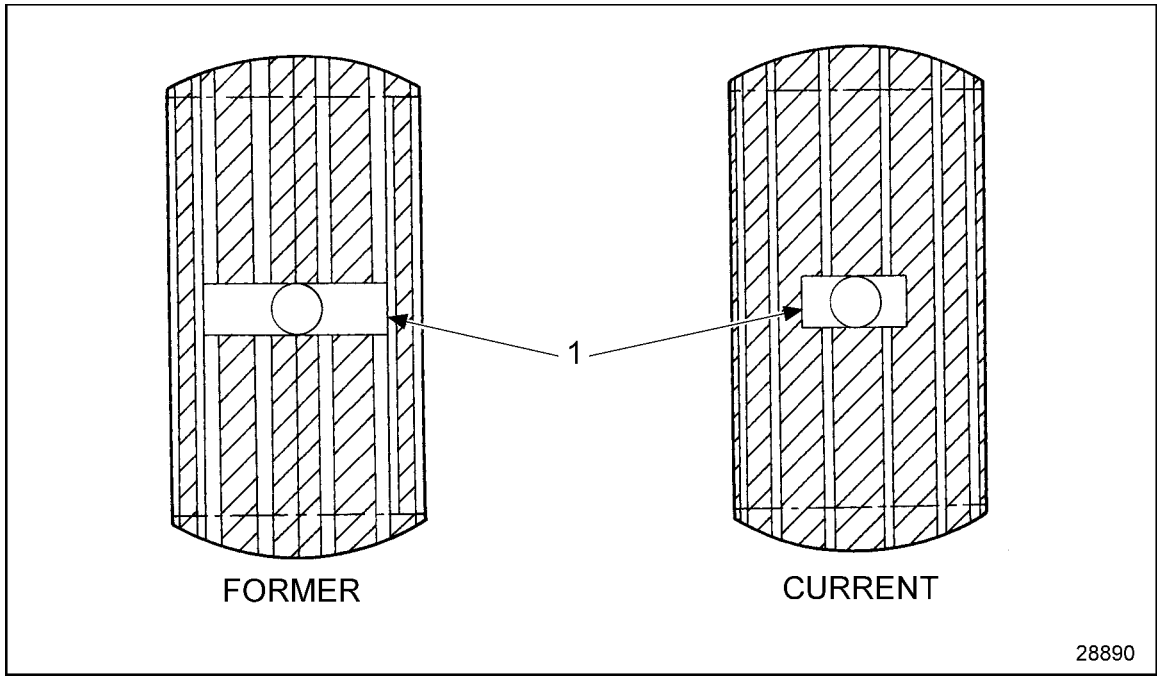
1. Visually inspect for damage, bending, fretting at split line between connecting rod and cap, previous bearing or related failure, or blue at either end.
   [a] If any of these conditions exist, replace the connecting rod. Refer to section 1.21.5.
   [b] If none of these conditions exist, continue inspection.
2. Inspect the bearing (bushing) for scoring, overheating, or other damage.
   [a] If scored, overheated, or damaged, replace the bushing.
   [b] If not scored, overheated, or damaged, continue inspection.
3. Measure the thickness of the bushing along the center.

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[a] Replace the bushing if it is worn to a thickness of 2.18 mm (0.086 in.) or less.

NOTE:
A new bushing should be 2.21-2.24 mm (0.087-0.088 in.) thick.

NOTE:
A new piston pin bushing with a shorter oil distribution slot replaced the long slot bushing in 1986. See Figure 1-173. The short slot bushing provides optimum piston pin and bushing lubrication, even at maximum loads. Only this bushing should be used.



1. Oil Slot

Figure 1-173 Bearing Faces (ID) of Former and New Piston Pin Bushings

[b] If not worn, continue inspection.

4. Inspect the piston pin for fretting and wear.

NOTICE:
Do not polish or refinish the piston pin. Rapid bushing wear could result.

[a] Replace the piston pin if it is worn to a diameter of 38.049 mm (1.4980 in.) or less. Refer to section 1.22.3.

NOTE:
A new piston pin has a diameter of 38.090-38.100 mm (1.4996-1.5000 in.).

[b] If not worn, continue inspection.

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5. Visually inspect for nicks and burrs in the connecting rod bolt holes.

   [a] Remove any nicks or burrs from the connecting rod bolt holes.

   [b] If excessively nicked or burred, replace the connecting rod.

NOTE:
If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap. Refer to section 1.23.2.2.

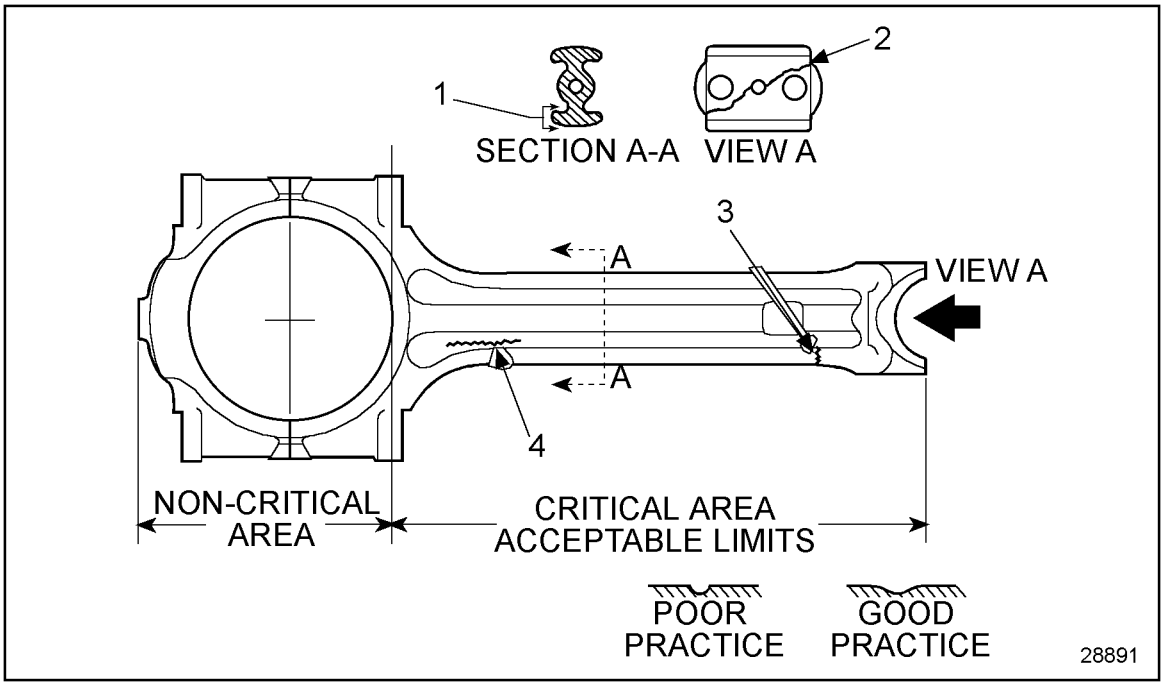
   [c] If not nicked or burred, proceed with inspection.

NOTE:
When qualifying a used connecting rod from a source other than an original build engine, the following additional checks should be made. Refer to section 1.21.3.3 and refer to section 1.21.3.4.

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1.21.3.3 Inspect using Magnetic Particle Method

See Figure 1-174. Perform the magnetic particle method as follows:



1. Do not use or attempt to salvage rods with an indication over 0.13 mm (0.005 in.) deep, and extending over edges of "H" section on both sides of flange. Cross-Sectioned area is the most highly stressed.
2. Start of fatigue crack resulting from overloading (due to hydrostatic lock). Do not attempt to salvage.
3. Examples of a transverse indication that does not follow longitudinal forging flow lines. The indications can be either a forging lap heat-treat crack or start of a fatigue crack.
4. Example of an indication following longitudinal forging flow lines.

NOTE: Indications in non-critical areas are acceptable unless they can be observed as obvious cracks without magnetic inspection.

NOTE: Transverse indications (across flow lines), having a maximum length of 12.7 mm (0.50 in.), which can be removed by grinding no deeper than 0.4 mm (1/64 in.), are acceptable after their complete removal. An exception to this is a rod having an indication that extends over the edge of the "H" section and is present on both sides of the flange. In this case, maximum allowable depth is 0.13 mm (0.005 in.).

NOTE: Longitudinal indications following forged lines are usually seams, and are not considered harmful if less than 0.793 mm (0.0313 in.) deep.

Figure 1-174 Magnetic Particle Inspection Limits for Connecting Rod

1. Magnetize the connecting rod.
2. Apply magnetic particles or solution.

NOTE:
The particles will gather around and cracks in the connecting rod.

[a] If cracks are evident, replace the connecting rod. Refer to section 1.22.3.

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[b] If no cracks were detected, continue inspection.

3. Demagnetize the connecting rod.

1.21.3.4 Inspect using Bore Diameter Method

See Figure 1-175. Determine the average bore diameter of the rod, using a dial bore gage and master ring as follows:

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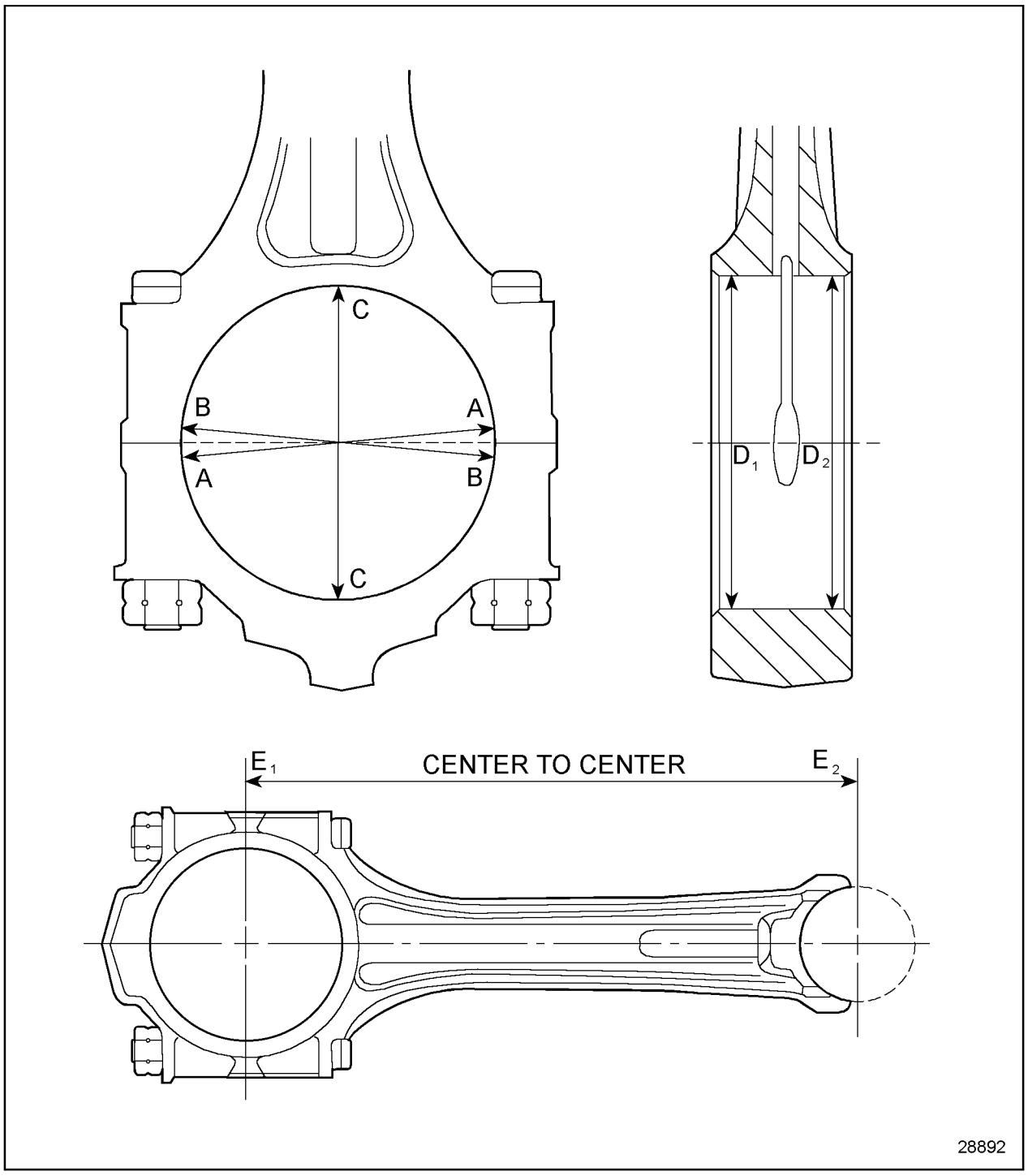


Figure 1-175 Dimensional Inspection of Cross-Head Piston Connecting Rod

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

1. Install the connecting rod cap on the connecting rod, and tighten the bolt nuts to 81-95 N·m (60-70 lb·ft) torque.

NOTICE:
If the crosshead connecting rod bore does not meet specifications, the rod cannot be machined. It must be replaced.

2. Measure diameter A and B.
3. Obtain average of A and B to obtain size at split line. X = Average of A + B X = [A + B] / 2
4. Measure C. The difference in the results of the measurements X and C gives the average bore out-of-round and can be 0.013 mm (0.0005 in.) maximum.
5. Add C to X and average to obtain average bore size. Average diameter of bore that must be within: 82.55-82.58 mm (3.250-3.251 in.) = [C + X] / 2

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See Figure 1-176. Determine taper as follows:

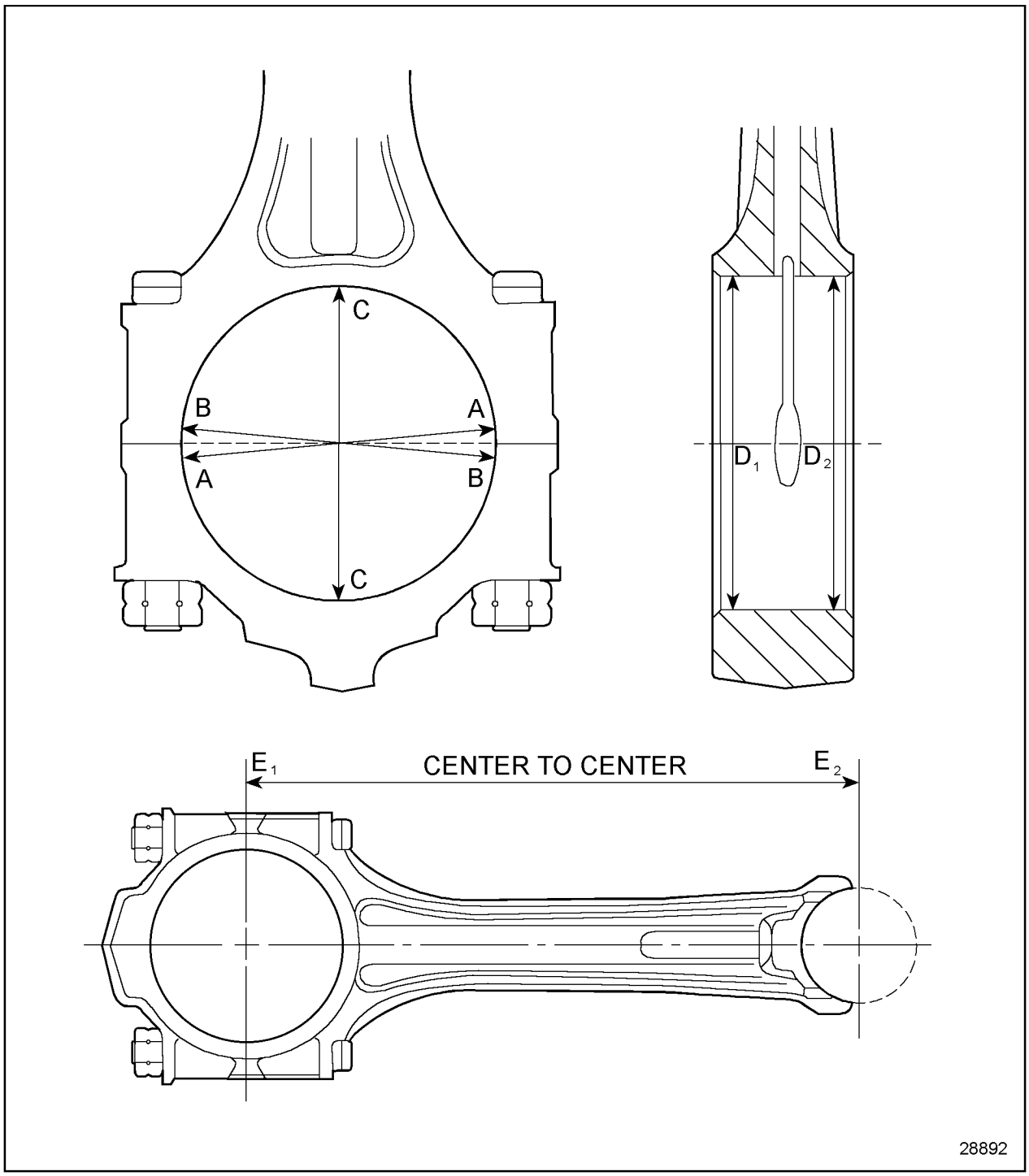


Figure 1-176 Dimensional Inspection of Cross-Head Piston Connecting Rod

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6. Subtract D1 from D2 to find the difference.

NOTE:
The difference can be 0.013 mm (0.0005 in.) maximum.

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

7. Determine length by finding the distance between E1 and E2.

NOTE:
The specifications are 257.07-257.20 mm (10.121-10.126 in.).

[a] If the bore is not within specification, replace the connecting rod. Refer to section 1.22.3.

[b] If the bore is within specifications, reuse the connecting rod.

1.21.4 Assembly of Connecting Rod

Assemble the connecting rod as follows:

NOTE:
The current connecting rod has a 37.34 mm (1.470 in.) wide column and provides greater strength under severe operating conditions. It can be identified by white paint on the bottom of the bearing cap. The former connecting rods (33.27 mm and 40.64 mm or 1.310 in. and 1.600 in. wide column) have been superseded and will not be serviced. See Figure 1-177. The former and current rod assemblies can be mixed in an engine.

For maximum benefit, however, a complete set of the current connecting rods should be installed.

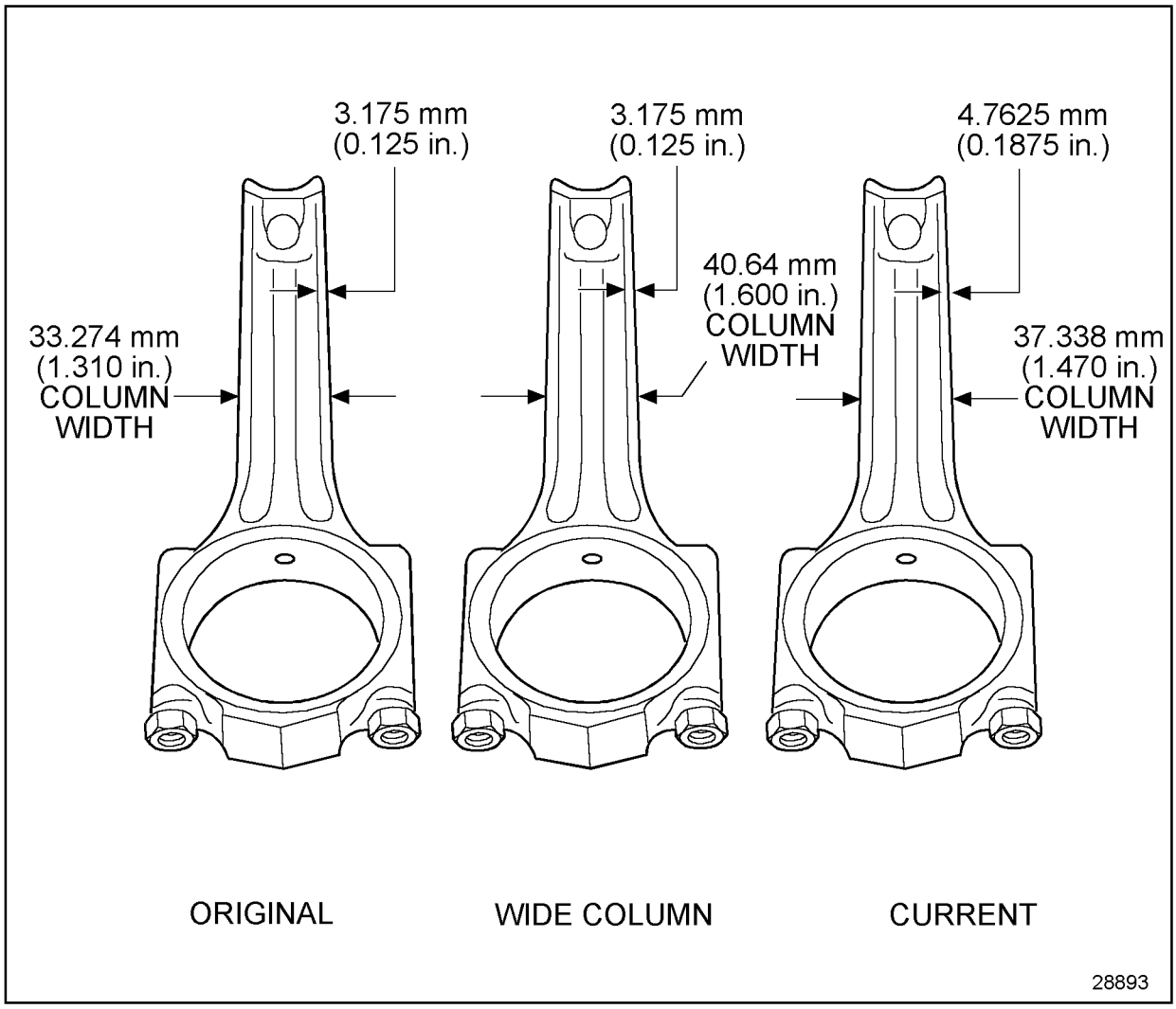


Figure 1-177 Comparison of Connecting Rods

1. Attach the piston pin.
2. Install the two bolts and spacers in the connecting rod and piston.
3. Tighten the bolts.
4. Attach the retainers.
5. Install the piston rings.

1.21.5 Installation of Connecting Rod

Install the connecting rod as follows:

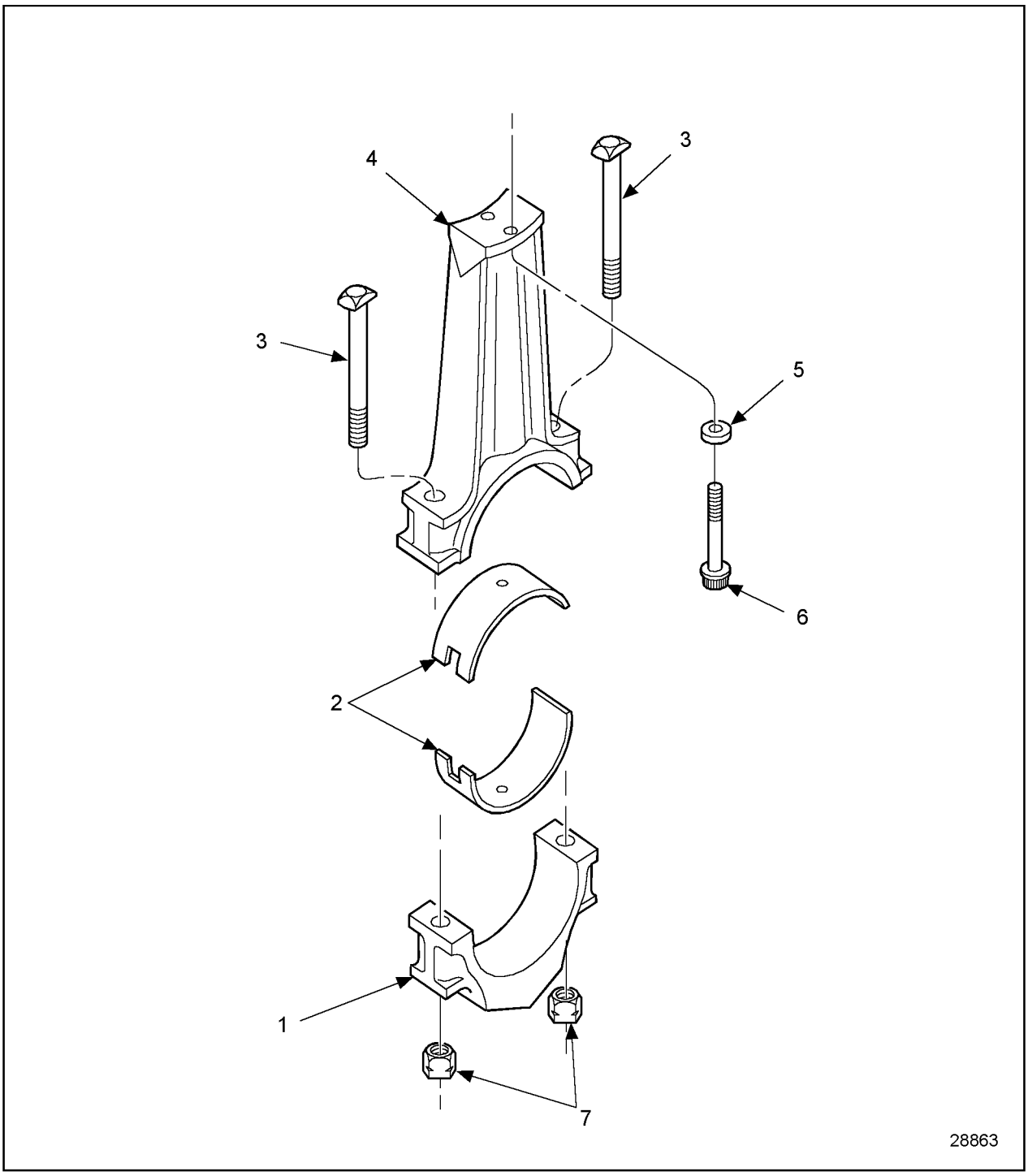
1. Place the piston and rod assembly into the cylinder block.

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2. Install the bearing cap and lower bearing shell on the connecting rod.
3. Install the cylinder head. Refer to section 1.3.5.
4. Install the oil pump and inlet and outlet pipes, if necessary. Refer to section 3.2.9.
5. Install the oil pan. Refer to section 3.11.3.
6. Refill the lubricating system. Refer to section 13.5.1.
7. Refill the cooling system. Refer to section 13.12.

1.22 CONNECTING ROD BEARINGS

The connecting rod bearing shells consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. A tang at the parting line on one end of each bearing shell supports the upper and lower bearing shells in the connecting rod. See Figure 1-178.



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1. Bearing Cap
2. Bearing Shells
3. Connecting Rod Bolts
4. Connecting Rod
5. Spacers (2)
6. Piston Pin Bolts (2)
7. Connecting Rod Nuts

Figure 1-178 Description of Connecting Rod Assembly

The multiple layer copper-lead co-plated bearings have an inner surface called the matrix, of copper-lead. A thin deposit of lead-tin is then plated onto the matrix. This improves load carrying characteristics. These bearings have a satin silver sheen overlay when new and a dull gray sheen after being in service.

The upper and lower connecting rod bearing shells are not interchangeable. Both shells are notched midway, 19.1 mm (0.75 in.) from each parting line between the bearing edges, for bolt clearance and oil flow. The lower bearing shell has a circumferential oil groove that terminates at the notched ends. These notches maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, providing a constant supply of lubricating oil to the connecting rod bearings and piston pin bushing.

1.22.1 Repair or Replacement of Connecting Rod Bearing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-179.

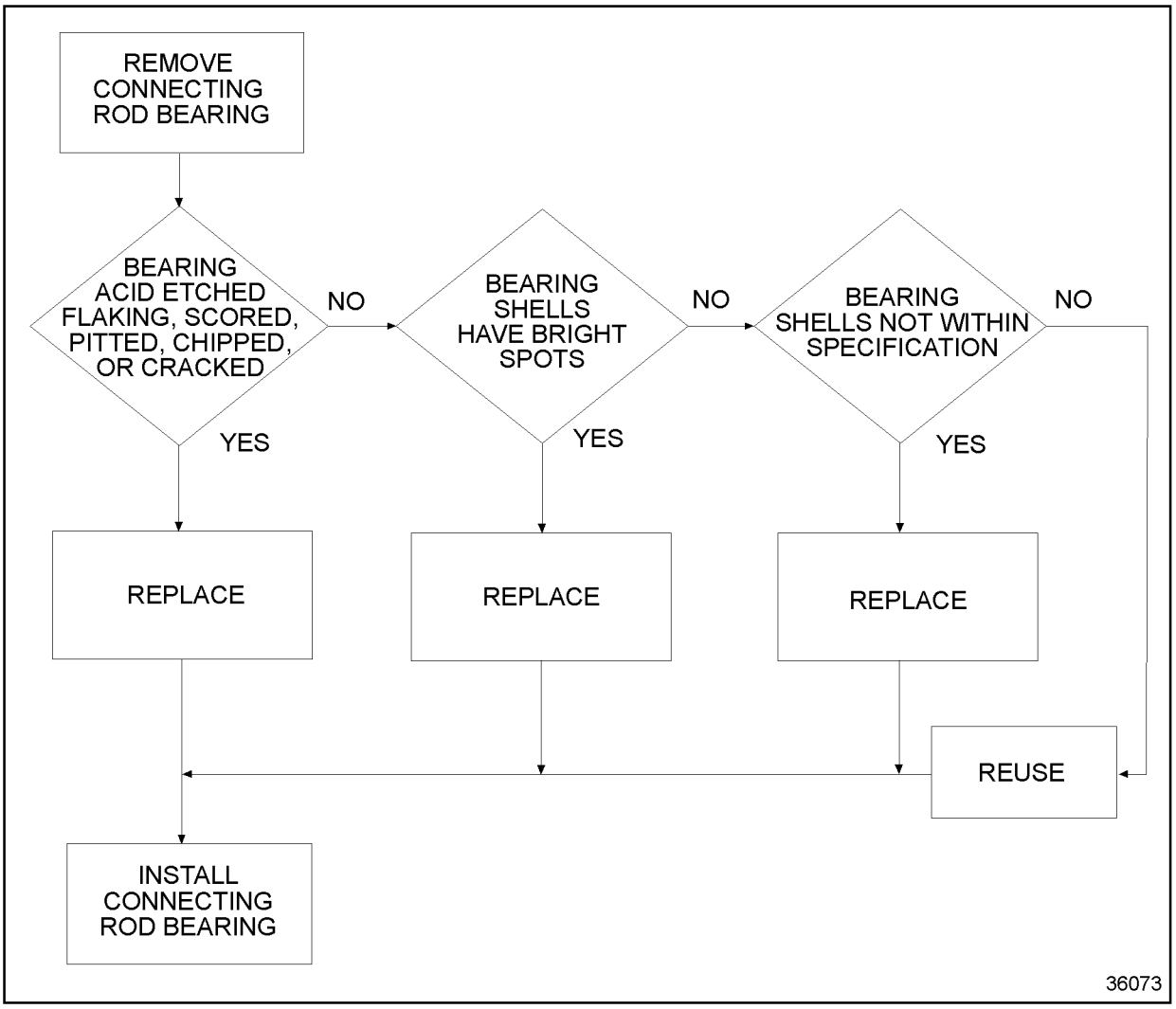


Figure 1-179 Flowchart for Repair or Replacement of Connecting Rod Bearing

1.22.2 Removal of Connecting Rod Bearing

Remove the connecting rod bearings as follows:

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

1. Drain the oil. Refer to section 13.5.2.

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2. Remove the oil pan. Refer to section 3.11.2.
3. Disconnect and remove the lubricating oil pump inlet pipe and screen assembly. Refer to section 3.2.2.
4. If the oil pump is mounted on the main bearing caps, remove the oil pump. Refer to section 3.2.3.
5. Remove one connecting rod bearing cap.
6. Push the connecting rod and piston assembly up into the cylinder liner.

NOTICE:
To avoid shell damage, do not pound on the edge of the bearing shell with a sharp tool.

7. Remove the upper bearing shell.
8. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

1.22.2.1 Inspection of Connecting Rod Bearing

Inspect the bearings as follows:

1. Visually inspect the bearings for acid etching, flaking, pitting, scoring, chipping, cracking, overlap loss, and overheating.
   [a] If any of these defects are present, replace the bearings. Refer to section 1.22.3.
   [b] If none of these defects are evident, proceed with inspection.

NOTE:
Bearing seizure results from low oil or no lubricating oil.

NOTE:
Overlay plated bearings may develop minute cracks or small isolated cavities on the bearing surface during engine operation. These are characteristics of and are NOT detrimental to this type of bearing. The bearings should not be replaced for minor surface imperfections.

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

2. Inspect the backs of the bearing shells for bright spots that indicate they have been shifting in their supports.
   [a] If bright spots are present, replace the bearing shells. Refer to section 1.10.3.
   [b] If no bright spots are detected, continue inspection.
3. Examine the backs of the bearing shells for areas of no contact and wear.

[a] If excessively worn and not contacting, replace the bearings and/or the connecting rod. Refer to section 1.21.5.

[b] If not worn and contacting, continue inspection.

4. Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757. Refer to section 1.10.2.2.

NOTE:
The minimum thickness of a worn standard connecting rod bearing shell should not be less than 3.124 mm (0.1230 in.). A new standard bearing shell has a thickness of 3.147-3.162 mm (0.1240-0.1245 in.), as listed in Table 1-7.

Bearing Size	New Bearing Thickness	Minimum Worn Thickness
Standard	3.15 mm / 3.16 mm (0.1240 in. / 0.1245 in.)	3.12 mm (0.1230 in.)
0.010 in. Undersize	3.28 mm / 3.29 mm (0.1290 in. / 0.1295 in.)	3.25 mm (0.1280 in.)
0.020 in. Undersize	3.40 mm / 3.42 mm (0.1340 in. / 0.1345 in.)	3.38 mm (0.1330 in.)
0.030 in. Undersize	3.53 mm / 3.54 mm (0.1390 in. / 0.1395 in.)	3.51 mm (0.1380 in.)

* Thickness 90° from parting line of bearing.

Table 1-7 Rod Bearing Shell Thickness

[a] If either bearing shell is thinner than this dimension, replace both bearing shells. Refer to section 1.10.3.

[b] If bearing shells are within the specified dimensions, continue inspection.

NOTE:
Do not replace one connecting rod bearing shell by itself. If one bearing shell requires replacement, install new upper and lower bearing shells.

5. Check the clearance between the connecting rod bearing shells and the crankshaft journal. Squeeze a soft plastic measuring strip between the journal and the bearing. Refer to section ADDITIONAL INFORMATION.

NOTE:
The maximum connecting rod bearing-to-journal clearance with used parts is 0.142 mm (0.0056 in.)

[a] If the clearance exceeds specifications, replace the connecting rod bearing shells. Refer to section 1.10.3.

[b] If the clearances are within specifications, proceed with inspection.

6. Inspect the connecting rod bearing bore for burrs and foreign particles.

[a] If burrs and foreign particles are present, resurface the bores.

[b] If excessively burred, replace the connecting rod. Refer to section 1.21.5.

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[c] If not burred, continue inspection.

7. Inspect the crankshaft journals. Refer to section 1.7.2.2.

NOTE:
Bearing shells are NOT reworkable from one undersize to another under any circumstances. The set must be the same.

[a] If a new or reground crankshaft will be used, install all new bearing shells. Refer to section 1.10.3.

[b] If reusing the crankshaft and the bearings have passed inspection procedures, reuse the bearings.

NOTE:
Undersize bearing shells are available in 0.010 in., 0.020 in. and 0.030 in. for service with reground crankshafts. To determine the required bearing size, refer to section ADDITIONAL INFORMATIONCrankshaft Grinding. Ensure the correct bearing to journal clearances are maintained when using these parts.

1.22.3 Installation of Connecting Rod Bearing

Install the connecting rod bearing as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wipe the journal, and lubricate it with clean engine oil.
2. Install the upper bearing shell (the one without the continuous oil groove).

NOTE:
Ensure the tang on the shell fits in the groove in the rod.

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

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

NOTE:
Upper and lower bearing shells are serviced only in sets. Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. If a new or reground crankshaft is to be used, install all new bearing shells.

3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.
4. Note the number and letter stamped on the bearing cap, and install the lower bearing shell (the one with the continuous oil groove) into the bearing cap.
5. Install the cap and shell.
6. Lock the bearing caps securely in place with bolts and nuts.

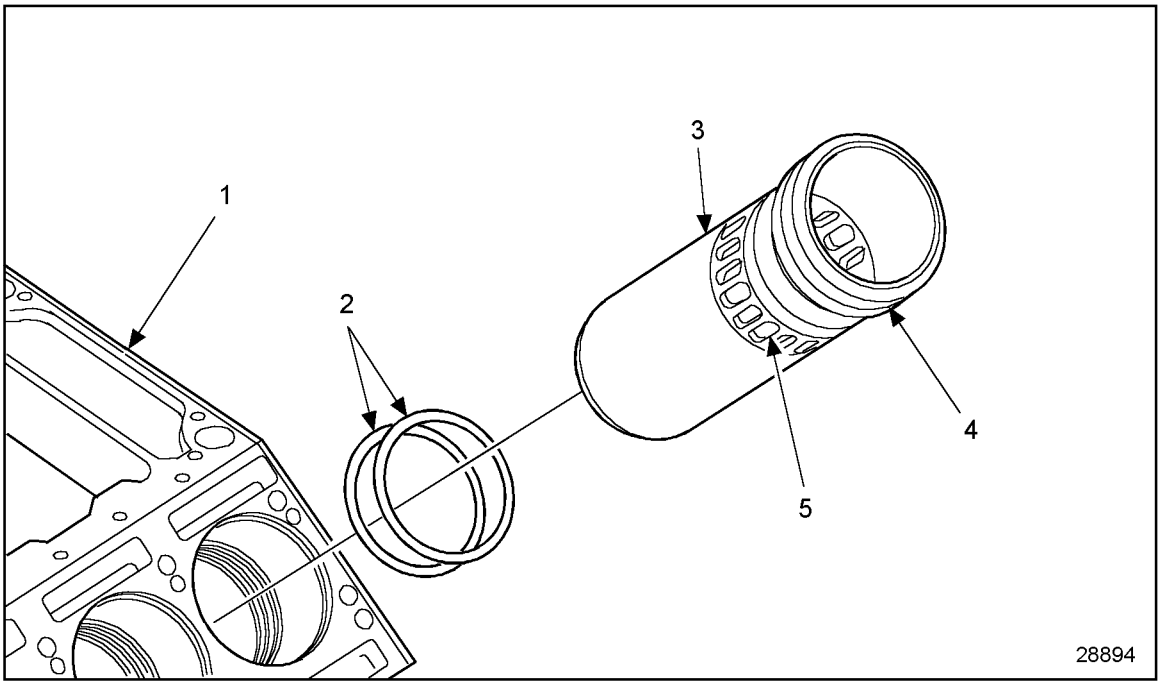
NOTE:
Ensure the connecting rod bolt has not turned in the connecting rod before applying torque to the nut.

7. Tighten the connecting rod bolt nuts (lubrite nut) to 81-95 N·m (60-70 lb·ft) torque.
8. Install the lubricating oil pump inlet pipe and screen assembly.
9. Install the oil pump. Refer to section 3.2.9.
10. Install the oil pan. Refer to section 3.2.9.
11. Refill the crankcase to the proper level on the dipstick. Refer to section 13.5.1.
12. If new bearings were installed, operate the engine on the run-in schedule. Refer to section 11.6.6.

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1.23 CYLINDER LINER

The cylinder liner is a replaceable wet type (water above ports), made of hardened alloy cast iron. See Figure 1-180. 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 the cylinder block counterbore and rests on a replaceable cast iron insert that permits accurate alignment of the cylinder liner.



1. Cylinder Block
2. Seal Rings
3. Cylinder Liner
4. Flange
5. Air Inlet Ports

Figure 1-180 Typical Cylinder Liner Description

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

Surrounding water cools the upper half of the liner. Air introduced into the cylinder through equally spaced inlet ports cools the entire liner. And water inside the surrounding cylinder block water jacket cools the lower half of the liner.

The air inlet ports in the liner are angled to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. To avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly.

1.23.1 Repair or Replacement of Cylinder Liner

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-181.

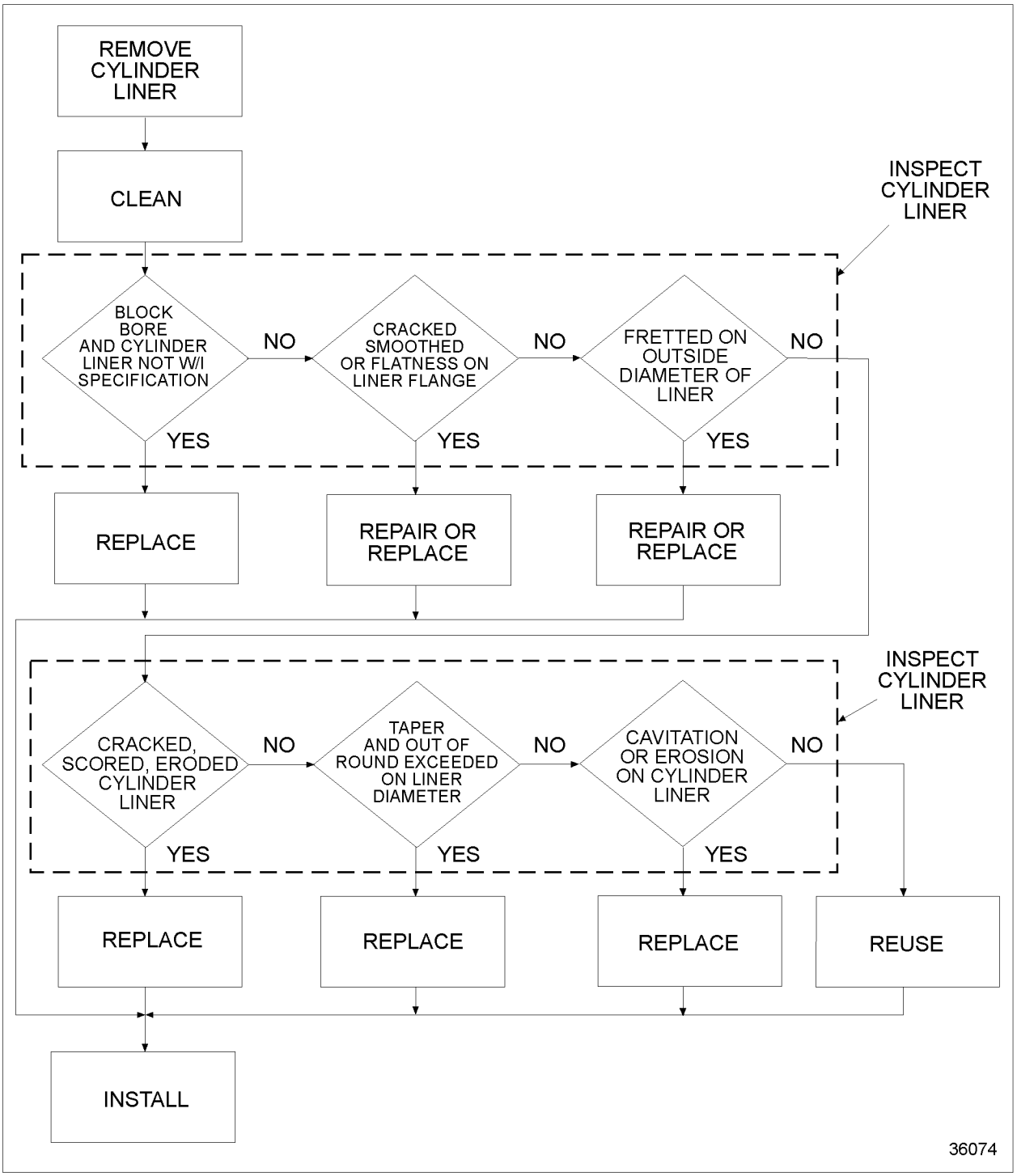
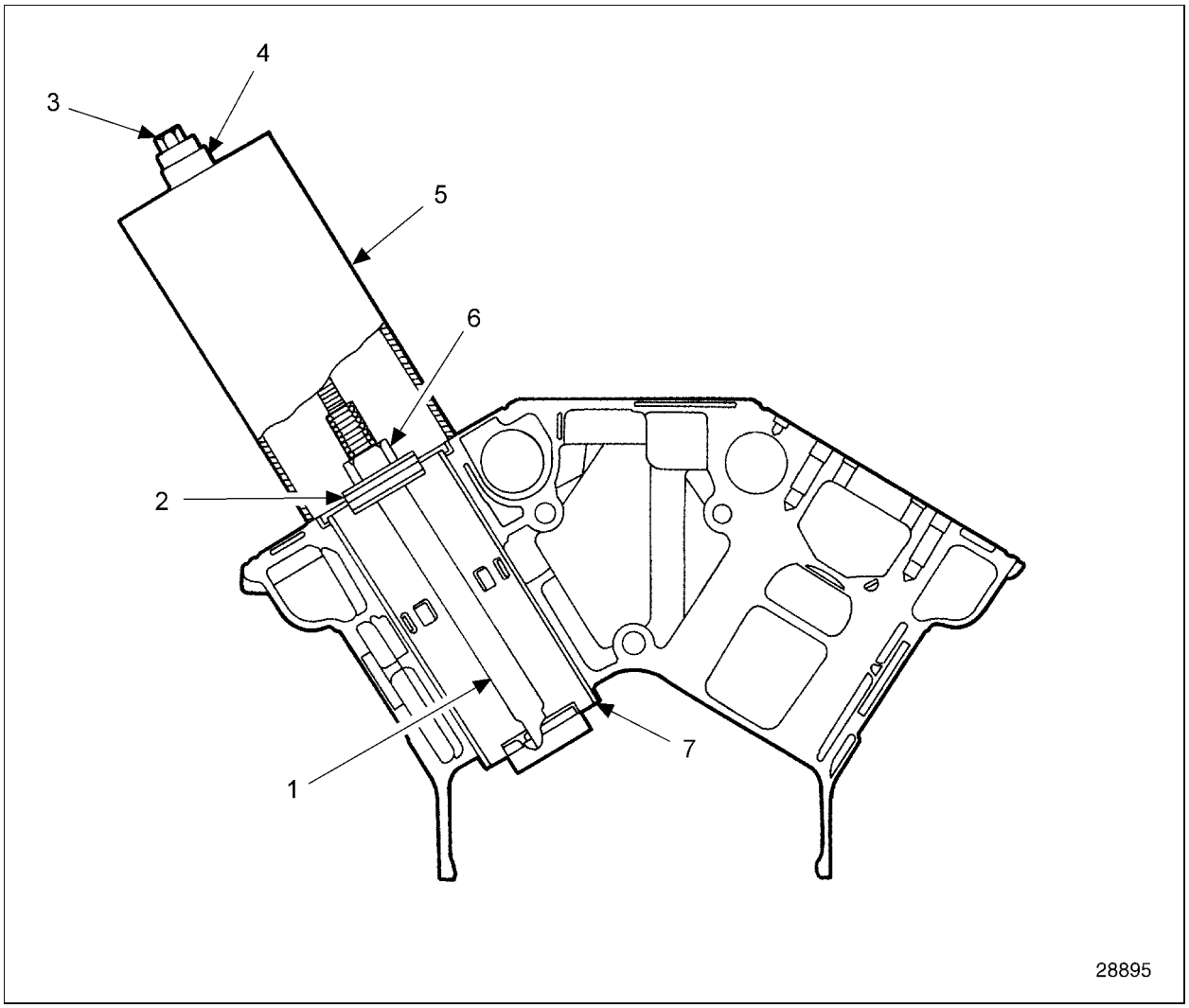


Figure 1-181 Flowchart for Repair or Replacement of Cylinder Liner

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1.23.2 Removal of Cylinder Liner

See Figure 1-182, and remove the cylinder liner as follows:



1. Lower Shoe and Bolt Assembly
2. Upper Shoe
3. Bolt
4. Thrust Bearing
5. Bridge Assembly
6. Nut
7. Cylinder Liner

Figure 1-182 Removing Cylinder Liner with J 24563-A

NOTICE:

Do not attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft. The piston may be damaged or the upper ring groove may collapse.

1. Remove the piston and connecting rod assembly. Refer to section 1.20.2 and refer to section 1.21.2.
2. Ease the lower shoe and bolt assembly into the liner. Place the shoe on the bottom edge of the liner with the shoe flat parallel to the crankshaft bore.
3. Using tool set J 24563-A, hold the lower shoe and bolt assembly in the pulling position.
4. Place the upper shoe, the flat parallel to the crankshaft bore, over the threaded end of the bolt.
5. Thread the nut on the bolt assembly.

NOTE:

Ensure pilots on both of the shoes are seated properly.

6. Place the bridge assembly, open end down, over the upper shoe and against the block.
7. With the thrust bearing on the bolt, install the bolt through the bridge assembly strap hole.
8. Thread the bolt into the bolt assembly female threads.

NOTICE:

Always store liners in an upright position. Liners left on their side for any length of time can become egg-shaped and distorted, making installation in cylinder bores difficult or impossible.

9. Turn the bolt clockwise, and withdraw the liner from the block.
10. Remove the tool from the liner.
11. Remove and tag the liner insert from the block counterbore.

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

⚠ 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:

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

12. Remove and discard both cylinder liner seal rings from the cylinder block bore grooves.

1.23.2.1 Inspection of Cylinder Liner

Inspect the cylinder liner as follows:

1. Inspect cylinder liner for cracks, scoring, poor contact on outer surface, flange irregularities, inside diameter, outside diameter, out-of-round, and taper.
   [a] If cracked or excessively scored, replace the liner. Refer to section 1.23.3.
   [b] If slightly scored, clean and reuse.
   [c] If not cracked or scored, continue inspection.
2. Examine the outside diameter of the liner for fretting below the ports.

NOTE:
Fretting is the result of a slight liner movement in the block bore during engine operation, which causes material from the block to adhere to the liner.

   [a] If fretted, replace. Refer to section 1.23.3.
   [b] If not fretted, continue inspection.
3. Visually inspect for metal particle on the liner surface.
   [a] Remove the metal particles from the liner surface with a coarse, flat stone.
   [b] If no metal particles are evident, proceed with inspection.

4. Examine the liner for cavitation erosion above the ports.
   [a] If eroded, replace the liner. Refer to section 1.23.3.
   [b] If not eroded, continue inspection.
5. Inspect the liner flange for smoothness and flatness on both the top and bottom surfaces.
   [a] If not smooth or flat, replace as necessary. Refer to section 1.23.3.
   [b] If smooth and flat, continue inspection.
6. Visually inspect for cracks at the flange.
   [a] If cracked, replace the liner. Refer to section 1.23.3.
   [b] If not cracked, proceed with inspection.
7. Visually inspect the liner insert for smoothness and flatness on the top and bottom surfaces.
   [a] If not flat or smooth, replace the liner insert. Refer to section 1.23.3.
   [b] If flat and smooth, proceed with inspection.
8. Inspect the liner insert for brinelling.
   [a] If brinelling is evident, replace the insert. Refer to section 1.23.3.
   [b] If no brinelling is detected, continue inspection.
9. Measure the block bore and the outside diameter of the liner. Refer to section ADDITIONAL INFORMATION for the liner-to-block specifications.
   [a] If not within specified limits, replace. Refer to section 1.23.3.
   [b] If within specified limits, hone the liner and reuse. Refer to section ADDITIONAL INFORMATION and refer to section 1.23.3.

1.23.2.2 Inspection of Taper and Out-of-Round

Inspect taper and out-of-round as follows:

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1. Install the liner (new or used) in the proper cylinder block bore, and measure the inside diameter at various points. See Figure 1-183.

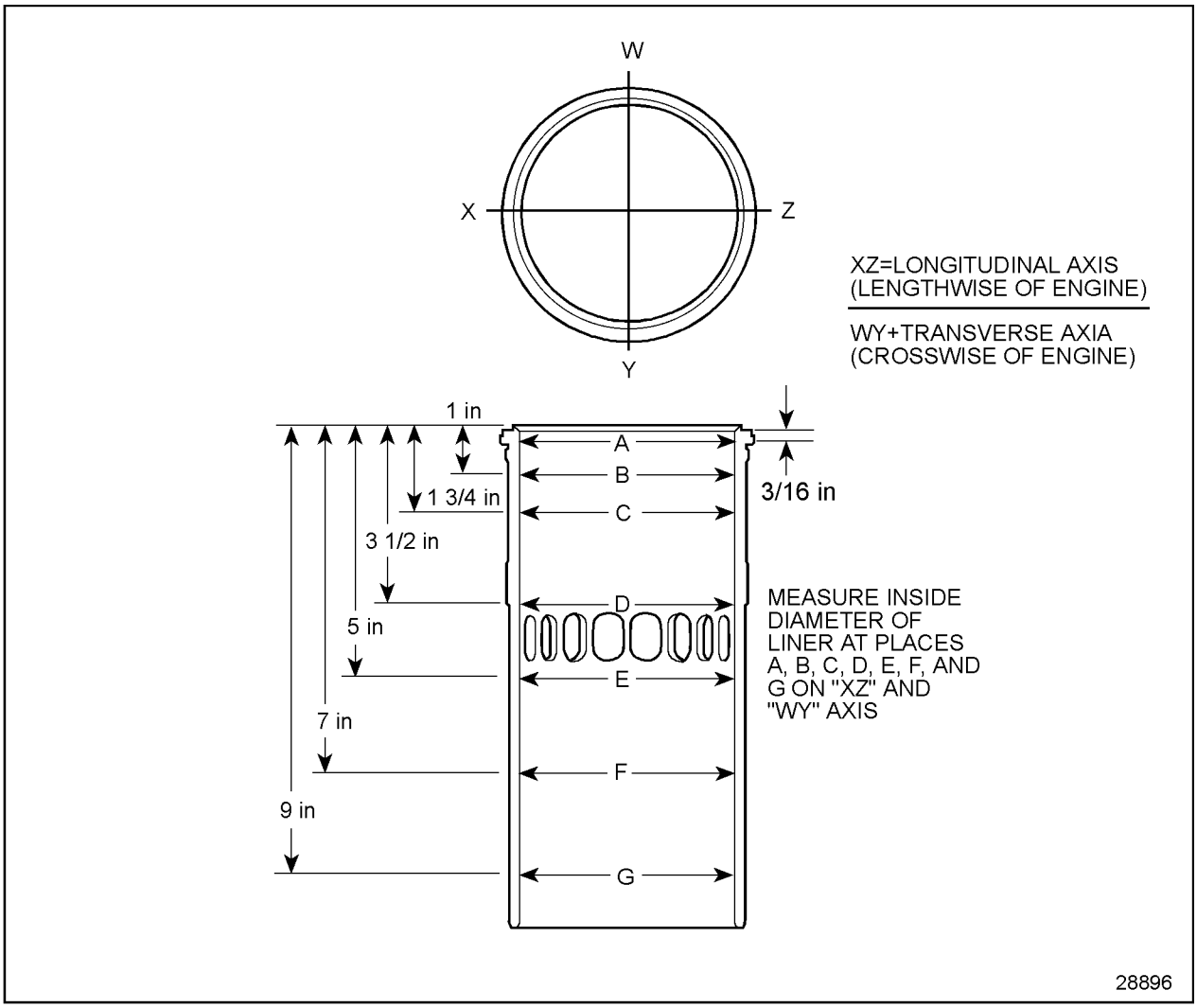


Figure 1-183 Cylinder Liner Measurement Diagram

NOTE:
New service liners have an inside diameter of 122.911-122.974 mm (4.8390-4.8415 in.).

2. Use cylinder bore gage J 5347-B, that has a dial indicator calibrated in 0.0001 in. increments.

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

3. Set the cylinder bore gage on zero in master ring gage J 24564.

4. Check the liner for taper and out-of-round.

NOTE:
The piston-liner clearance must be within the specified limits. Refer to section ADDITIONAL INFORMATION. The taper and the out-of-round must not exceed 0.064 mm (0.0025 in.) on a used liner. The taper must not exceed 0.038 mm (0.0015 in.) and the out-of-round must not exceed 0.05 mm (0.002 in.) on a new liner.

[a] If the taper and out-of-round exceed specified limits, replace the liner. Refer to section 1.23.3.

[b] If the taper and out-of-round are within specified limits, reuse the liner.

1.23.3 Installation of Cylinder Liner

Fit the cylinder liner in the block bore as follows:

NOTE:
Smoke and fuel economy improvements were introduced by changing the cylinder liner port configurations. The port height was *reduced from* 26.67 to 24.13 mm (1.05 to 0.95 in.) resulting in an increased expansion stroke. The port angle was changed from 30 degrees to 25 degrees to optimize cylinder swirl conditions. These changes reduce engine smoke levels while meeting required emission levels. Engines must be fitted with the appropriate cylinder liners.

1. Wipe the inside and outside of the liner clean.

NOTICE:
No two adjacent block counterbores may range in depth more than 0.025 mm (0.001 in.) when gaged along the longitudinal cylinder block centerline.

2. Ensure the block bore and counterbore are clean.
3. The cylinder liner is classified according to the flange thickness to help control the distance from the top of the liner to the top of the cylinder block.

NOTE:
This will allow the liner insert to seat properly. The block counterbore depth must be from 12.077-12.116 mm (0.4755-0.4770 in.) and must not vary more than 0.038 mm (0.0015 in.) in depth around the circumference.

- A cylinder liner with a flange thickness of 7.897-7.874 mm (0.3109-0.3100 in.) (C1) has the part number etched on the lower bottom half of the liner.
- A liner with a flange thickness of 7.925-7.899 mm (0.3120-0.3110 in.) (C2) has the part number etched on the upper bottom half of the liner (below the air inlet ports).
- Effective December of 1987, liners also have an "L" or "H" etched next to the part number in these locations. The "L" denotes the thinner range (7.897-7.874 mm

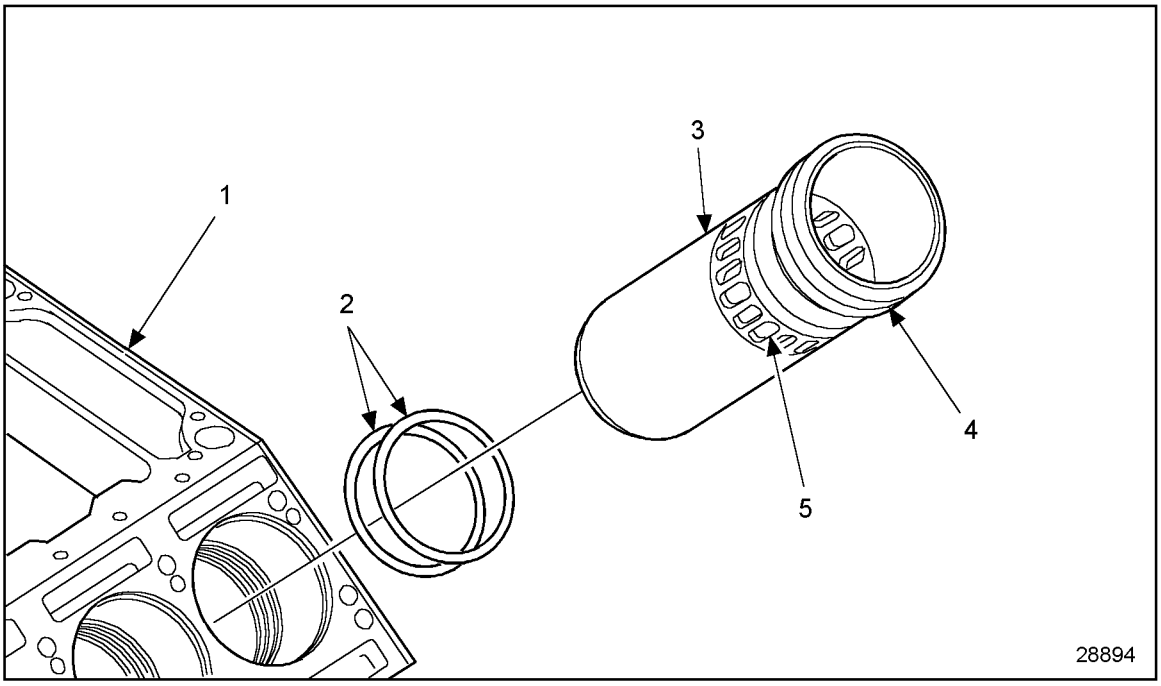
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or 0.3109-0.3100 in.), while the "H" denotes the thicker range (7.925-7.899 mm or 0.3120-0.3110 in.).

4. Place the liner insert (previously tagged) in the block counterbore. See Figure 1-184. Dimensions and identification of the liner inserts available are listed in Table 1-8.

Size	Thickness	Identification (New Inserts)
std.	3.02-3.03 mm (0.1188-0.1193 in.)	Black Oxide or 2 Purple Stripes
std.	3.05-3.06 mm (0.1200-0.1205 in.)	No Color
std.	3.078-3.1 mm (0.1212-0.1217 in.)	Copper or 2 Orange Stripes
+ 0.015 in.	3.399-3.4 mm (0.1338-0.1343 in.)	White and Purple Strip
+ 0.015 in.	3.43-3.44 mm (0.1350-0.1355 in.)	White Strip
+ 0.015 in.	3.46-3.47 mm (0.1362-0.1367 in.)	White and Orange Strip

Table 1-8 Dimensions and Identification of Liner Inserts



1. Cylinder Block
2. Seal Rings
3. Cylinder Liner
4. Flange
5. Air Inlet Ports

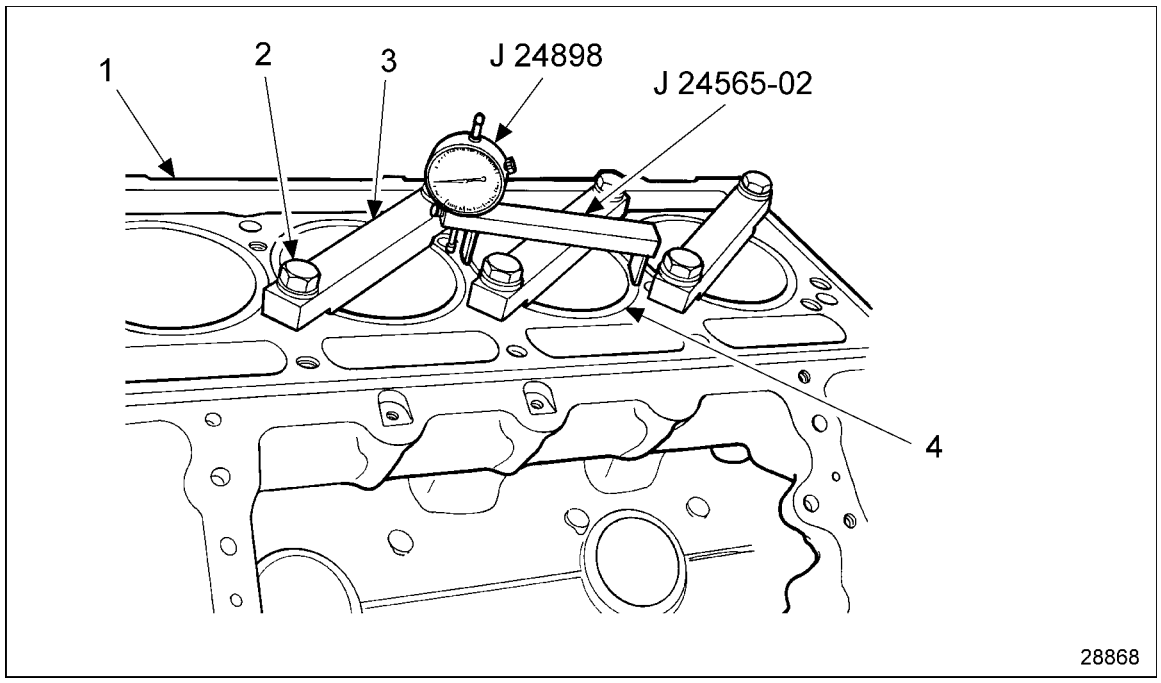
Figure 1-184 Typical Cylinder Liner Description

5. Push the cylinder liner into the cylinder block until the liner flange rests on the insert. The liner should slide smoothly in place with hand pressure.
6. Clamp the liner in place with hold-down clamp J 24565-02.

7. Tighten the two bolts to 68 N·m (50 lb·ft) torque.

NOTE:
The cylinder head bolt hole counterbore has been increased in depth to 20.32 mm (0.800 in.) on current cylinder blocks. The depth was formerly 12.7 mm (0.500 in.). This necessitates the use of longer bolts (11/16-11 x 3 in.) for use with the hold-down clamps.

8. Measure the distance from the top of the liner to the top of the block with a dial indicator. See Figure 1-185.



1. Cylinder Block
2. Hold Down Bolt
3. Hold Down Clamp
4. Cylinder Liner

Figure 1-185 Checking Distance of Liner Flange Below Top Face of Block using Clamp J 24565-02 and Gage J 24898

NOTE:
The liner flange must be 1.062-1.224 mm (0.0418-0.0482 in.) below the surface of the block. However, even though all of the liners are within these specifications, there must not be over 0.038 mm (0.0015 in.) difference between any two adjacent liners when measured along the cylinder longitudinal centerline. If the above limits are not met, install

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a different thickness insert. Install the liner in another cylinder bore and recheck, or use a new cylinder liner, listed in Table 1-9.

Size	Thickness	Identification (New Inserts)
std.	3.02-3.03 mm (0.1188-0.1193 in.)	Black Oxide or 2 Purple Stripes
std.	3.05-3.06 mm (0.1200-0.1205 in.)	No Color
std.	3.078-3.1 mm (0.1212-0.1217 in.)	Copper or 2 Orange Stripes
+ 0.015 in.	3.399-3.4 mm (0.1338-0.1343 in.)	White and Purple Strip
+ 0.015 in.	3.43-3.44 mm (0.1350-0.1355 in.)	White Strip
+ 0.015 in.	3.46-3.47 mm (0.1362-0.1367 in.)	White and Orange Strip

Table 1-9 Dimensions and Identification of Liner Inserts

9. Matchmark the liner and the cylinder block with a felt pen so the liner may be installed in the same position in the same block bore. Place the matchmarks on the side opposite the camshaft.
10. Remove the hold-down clamp and the cylinder liner.

NOTE:
Do not remove the liner insert.

Install the cylinder liner as follows:

1. Assemble the piston. Refer to section 1.20.4.
2. Assemble the connecting rod. Refer to section 1.21.4.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

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

NOTICE:

Inspect the ring compressor for nicks or burrs, especially at the non-tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will damage the piston rings.

4. Place the piston ring compressor on a wood block, with the tapered end of the ring compressor facing up.
5. Stagger the piston ring gaps on the piston. Ensure ends of the oil control ring expanders are not overlapped.

6. Start the top of the piston straight into the ring compressor. Push the piston down until it contacts the wood block. See Figure 1-186 for *"Operation 1"*.

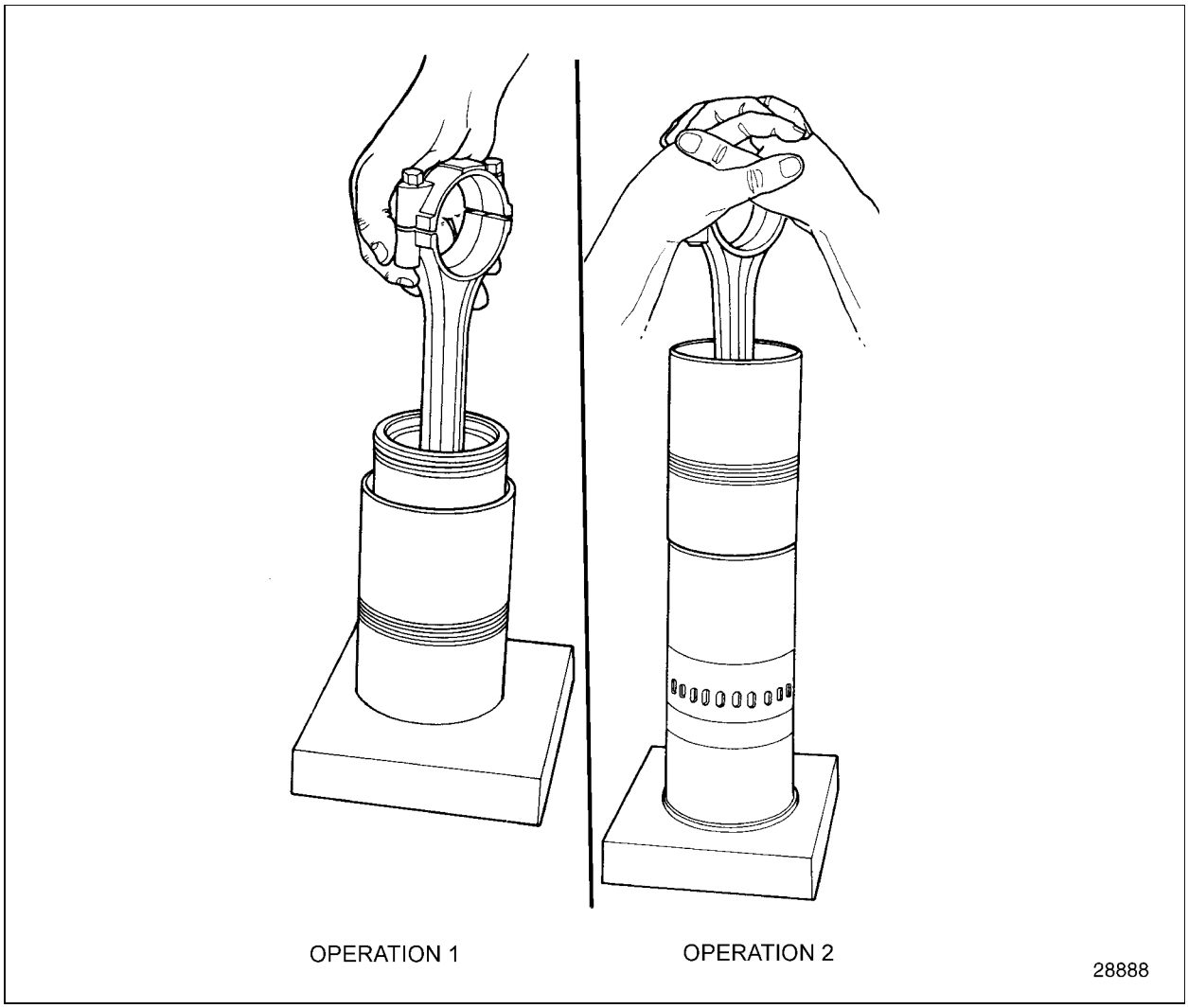


Figure 1-186 Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

7. Note the position of the matchmark, and place the liner, with the flange end down, on the wood block.
8. Place the ring compressor and the piston and connecting rod assembly on the liner so the rod and cap numbers are aligned with the matchmark on the liner. See Figure 1-187 for *"Operation 2"*.

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

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NOTICE:
Do not force the piston into the liner. The peripheral abutment type expanders apply considerable force on the oil ring. Extra care must be taken while loading to prevent ring breakage.

9. Push the piston and connecting rod assembly into the liner until the piston is free of the ring compressor. See Figure 1-187 for *"Operation 2"*.

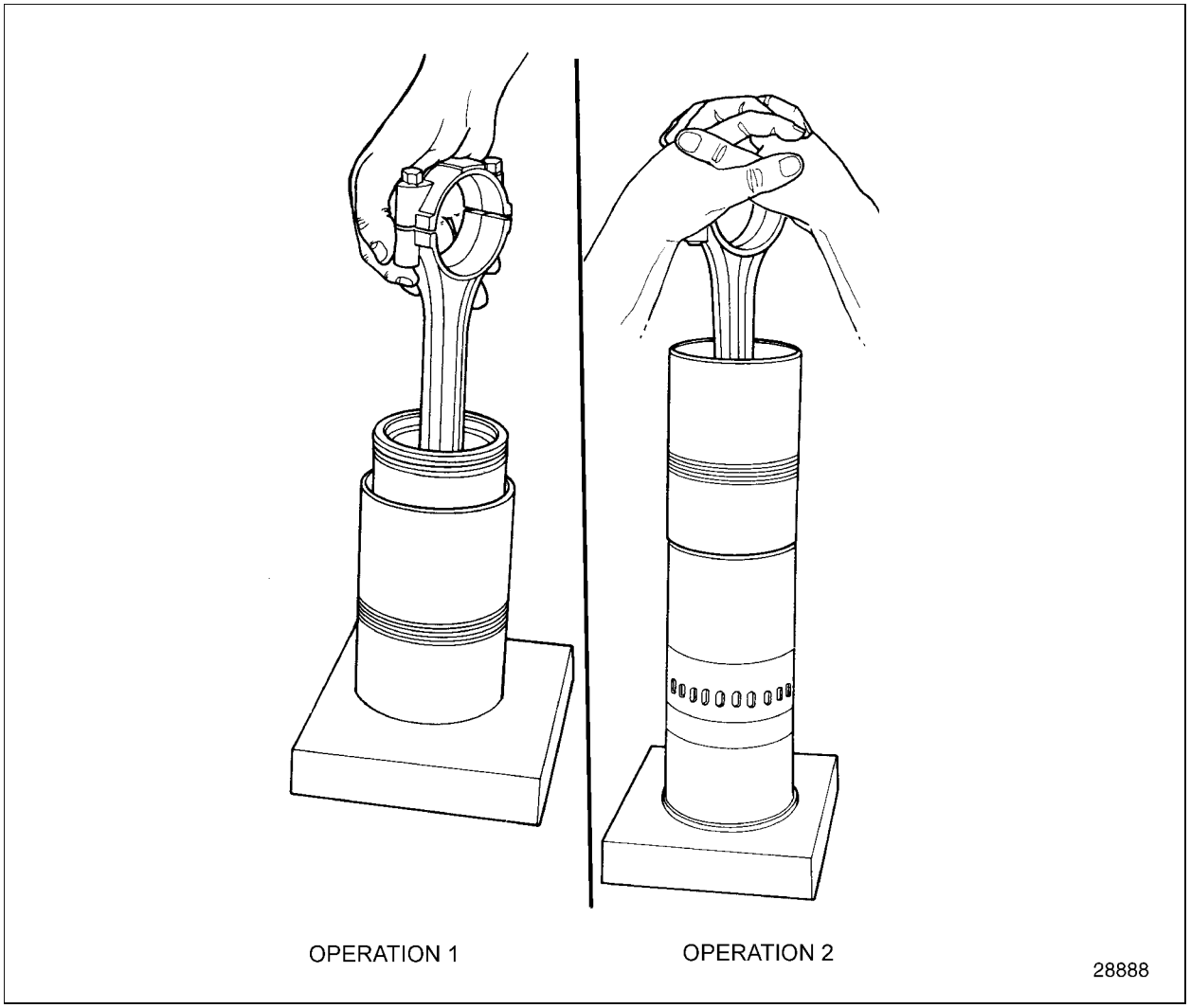


Figure 1-187 Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

10. Remove the connecting rod cap and the ring compressor.
11. Push the piston down until the compression rings pass the cylinder liner ports.
12. Ensure the seal ring grooves in the cylinder block bore are clean. Install a new seal ring in each groove.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

NOTE:
Clean engine oil may be used to supplement lubrication when installing liner-to-block seal rings. Do not use hydrogenated vegetable type shortening.

NOTICE:

During liner installation, always check to ensure that the seal rings remain in the seal ring grooves of the block.

13. If any of the pistons and liners are already in the engine, use hold-down clamps to retain the liners in place when the crankshaft is rotated.
14. Rotate the crankshaft until the connecting rod journal of the cylinder is at the bottom of its travel.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

15. Wipe the journal, and lubricate it with clean engine oil.
16. Install the piston and connecting rod assembly. Refer to section 1.20.7 and refer to section 1.21.5.
17. If new parts were installed, operate the engine on the run-in schedule. Refer to section 11.6.6.

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1.24 ENGINE BALANCE AND BALANCE WEIGHTS

In the balance of the two cycle engine, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds; unbalanced forces and unbalanced couples. These forces and couples are considered either primary or secondary, depending on whether their frequency is equal to or twice the engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are inconsequential compared to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple because of the crankshaft arrangement. This unbalanced couple tends to move the ends of the engine in an elliptical path. This couple is canceled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the camshafts. These camshaft balance weights are integral to the camshaft gears and the camshaft front pulley. An additional balance weight is bolted to the water pump drive gear used on the 6V and 8V engines. This balance arrangement produces a couple that is equal in magnitude and opposite in direction to the primary couple.

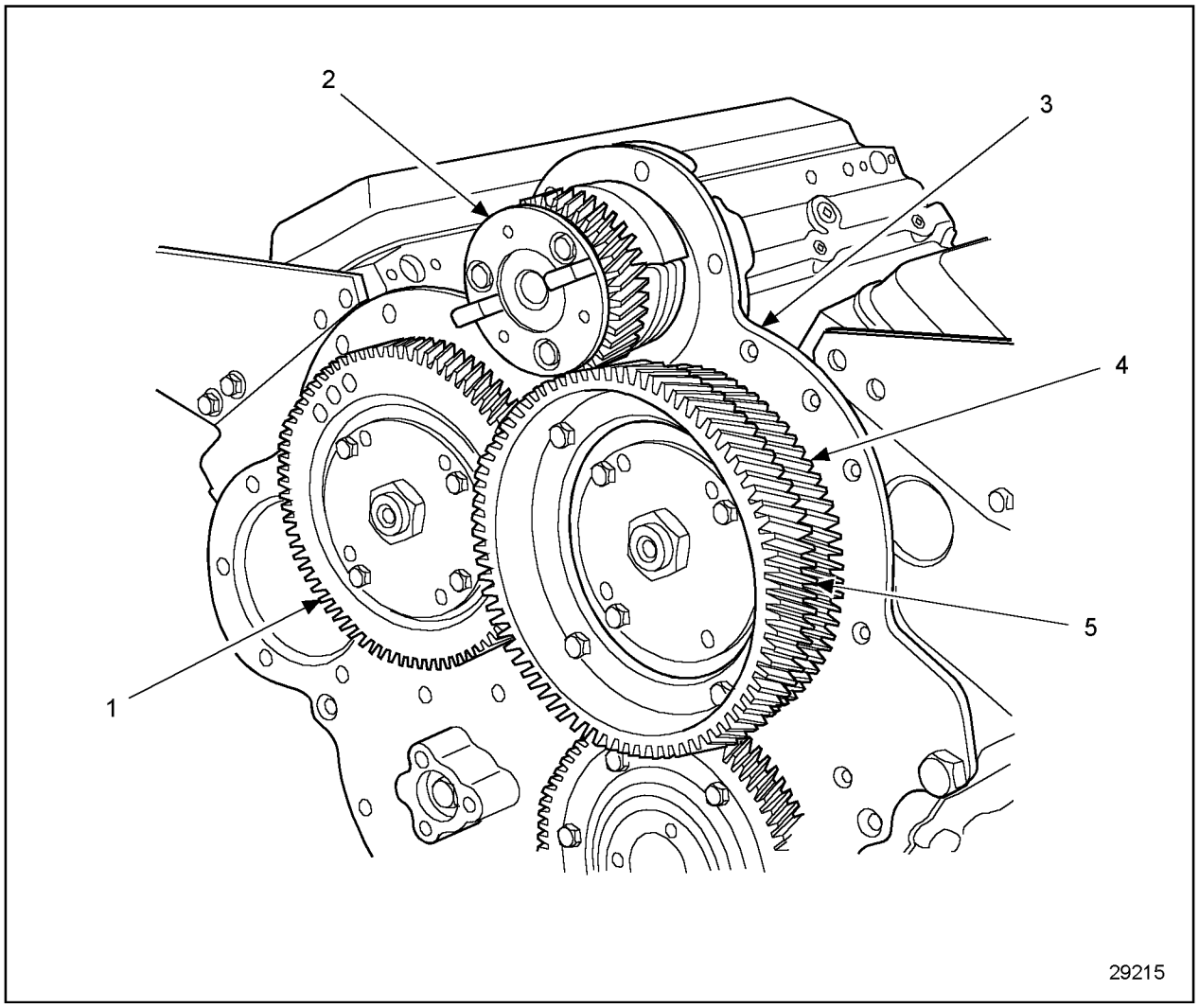
On the camshafts, each set of weights (weights on the outer ends of one cylinder comprise a set) rotate in opposite directions. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces oppose each other are canceled. The front balance weights act in a direction opposite to the rear balance weights. Therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple that completely balances the primary couple.

Both the rotating and primary reciprocating forces and couples are completely balanced in the engine. There are no secondary forces present. Consequently, the engine will operate smoothly and in balance throughout its entire speed range.

A camshaft torsion vibration damper is mounted to an adaptor hub attached to the water pump driver gear used on the 8V engines.

1.25 GEAR TRAIN AND ENGINE TIMING

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the engine. The gear train includes a crankshaft gear, an idler gear, two camshaft gears and a blower drive gear. For non-turbocharged engines, a step-up gear is attached to the right-bank camshaft gear that meshes with and drives the blower drive gear. See Figure 1-188.

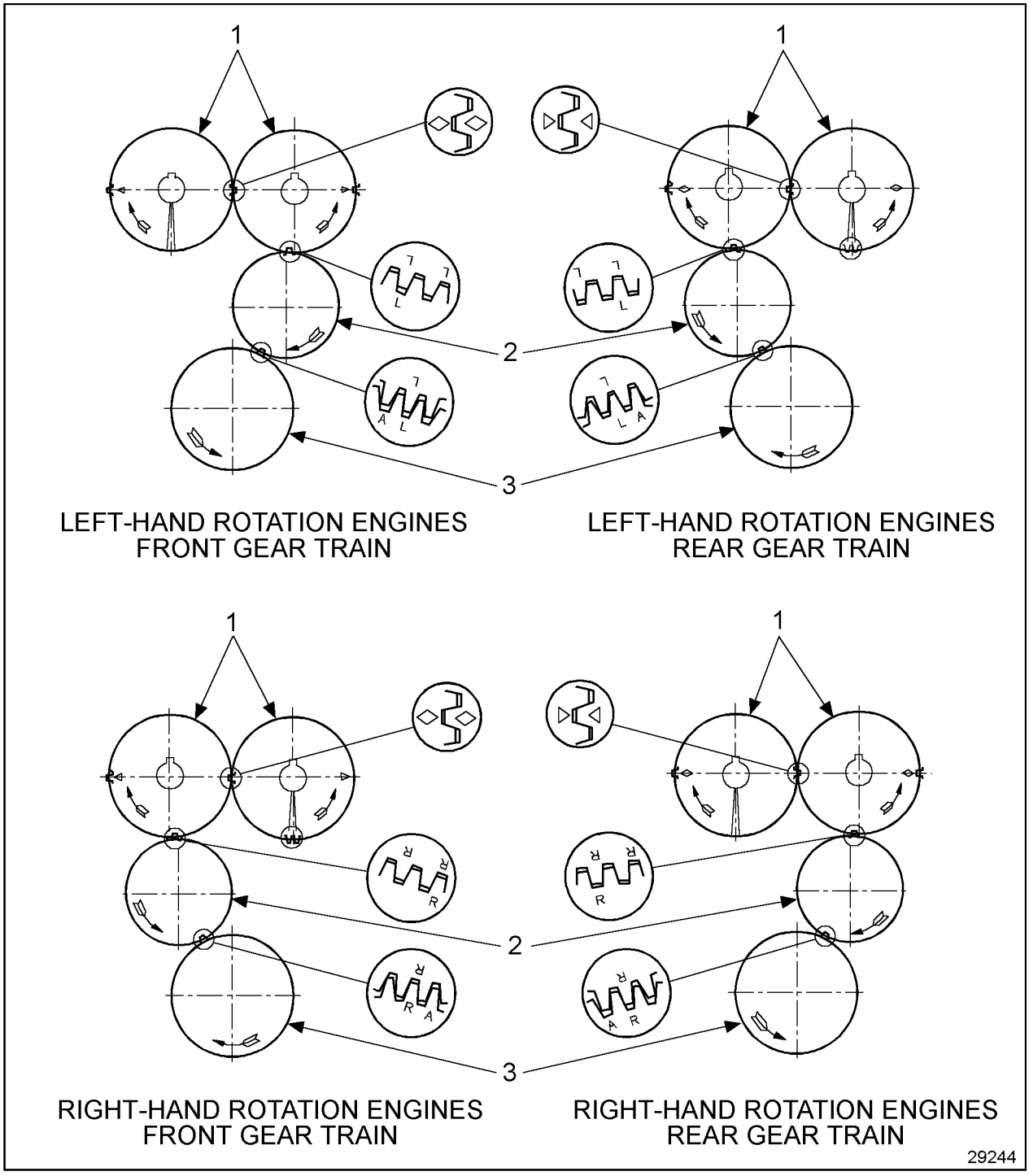


1. LH Camshaft Drive Gear
2. Blower Drive Assembly
3. Rear End Plate
4. RH Camshaft Gear
5. Step-Up Gear

Figure 1-188 Blower Drive Gear Mounting (Non-Turbocharged Engines)

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A helical gear train is located at each end of a 12V or 16V engine. Each gear train includes two camshaft gears, an idler gear and a crankshaft timing gear. See Figure 1-189.



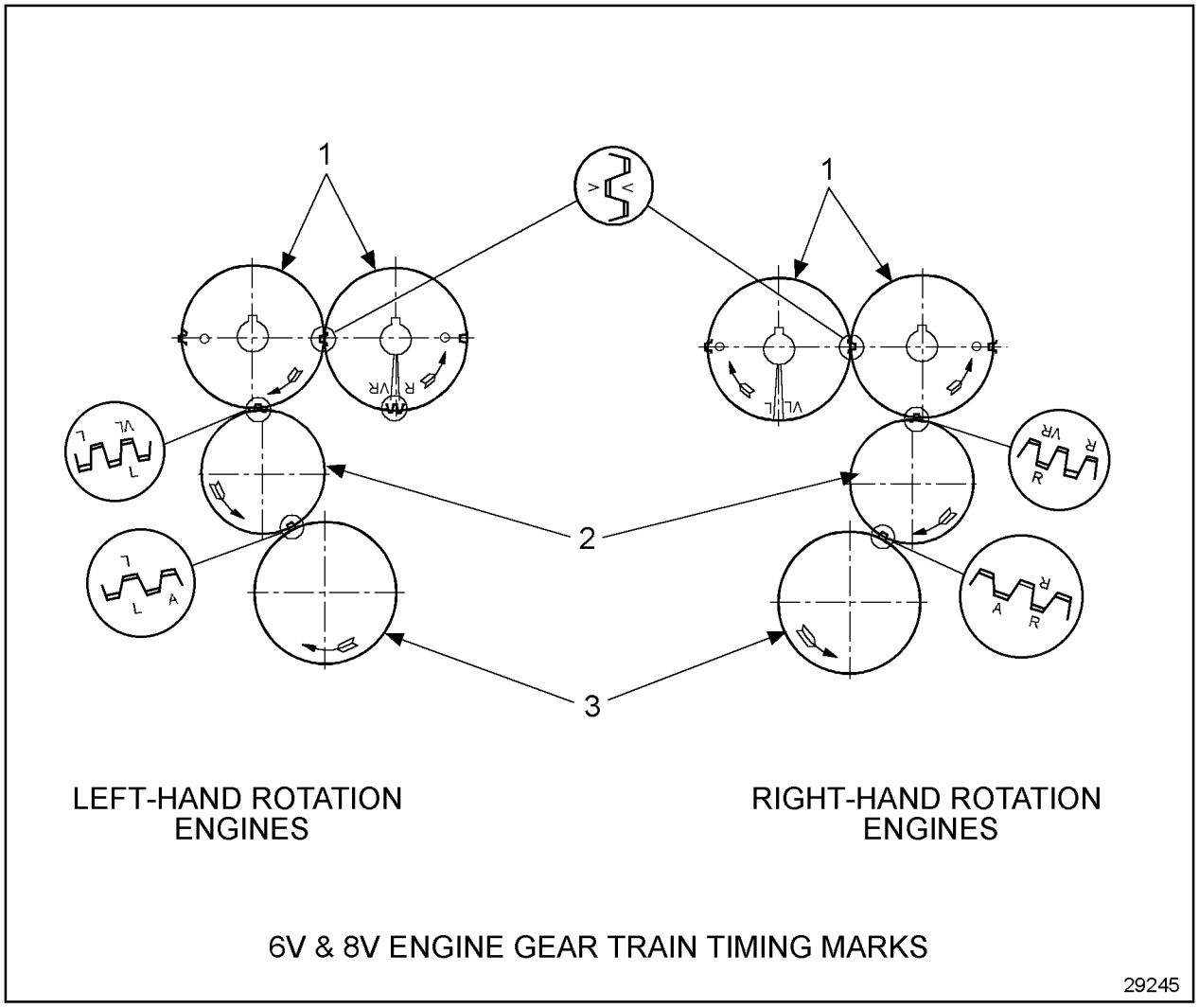
1. Camshaft Gears
2. Idler Gear
3. Crankshaft Gear

Figure 1-189 Gear Train and Timing Marks for 12V and 16V Engines

The crankshaft gear, bolted to the flange at the rear of the crankshaft, drives the camshaft gears and the blower drive gear through an idler gear mounted on a stationary hub on either the right or left-hand side of the engine, depending upon the engine rotation.

The camshaft gears are pressed on and keyed to their respective shafts. Each is secured with a nut and gear nut retainer.

The two camshaft gears mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft gears must be in time with each other, and the two, as a unit, must be in time with the crankshaft gear, timing marks have been stamped on the gear faces to facilitate correct gear train timing. See Figure 1-190. The symbol system of gear marking makes gear train timing a comparatively easy operation. When assembling the engine, remember the engine rotation. Working from the crankshaft gear, to the idler gear, and to the camshaft gear, line up the appropriate symbols on the gears as each gear assembly is installed on the engine.



1. Camshaft Gears
2. Idler Gear
3. Crankshaft Gear

Figure 1-190 Gear Train and Timing Marks for 6V and 8V Engines

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Since there are no timing marks on the accessory drive gear or the blower drive gear, it is not necessary to align these gears in any particular position during installation.

The correct relationship between the crankshaft and the two camshafts must be maintained to properly control fuel injection, the opening and closing of the exhaust valves, and engine balance. An "out-of-time" engine may result in pre-ignition, uneven running, and power loss.

Since one attaching bolt hole is offset, the crankshaft timing gear can be mounted in only one position. The keyway location in each camshaft dictates the only position the two camshaft gears can be mounted. When the engine is properly timed, the timing marks on the various gears will match.

Since the blower drive gear and the accessory drive gear have about half as many teeth as the camshaft gears, they turn at approximately twice the crankshaft speed.

The backlash between the various mating gears in the gear train should be 0.01-0.03 mm (0.002-0.008 in.), and should not exceed 0.04 mm (0.010 in.) backlash between worn gears.

Overflow oil from the camshaft pockets spilling into the gear train compartment and splash from the oil pan lubricates the gear train. Some oil spills into the gear train compartment from the camshaft rear end bearings, the blower drive gear bearing, and the idler gear bearing. Oil, directly from the cylinder block oil gallery to the idler gear bearing hub, lubricates the idler gear bearing. The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

When an engine is out of time, the camshaft timing can be checked by following the camshaft timing check procedure. If the engine is out of time, visually inspect the gear train.

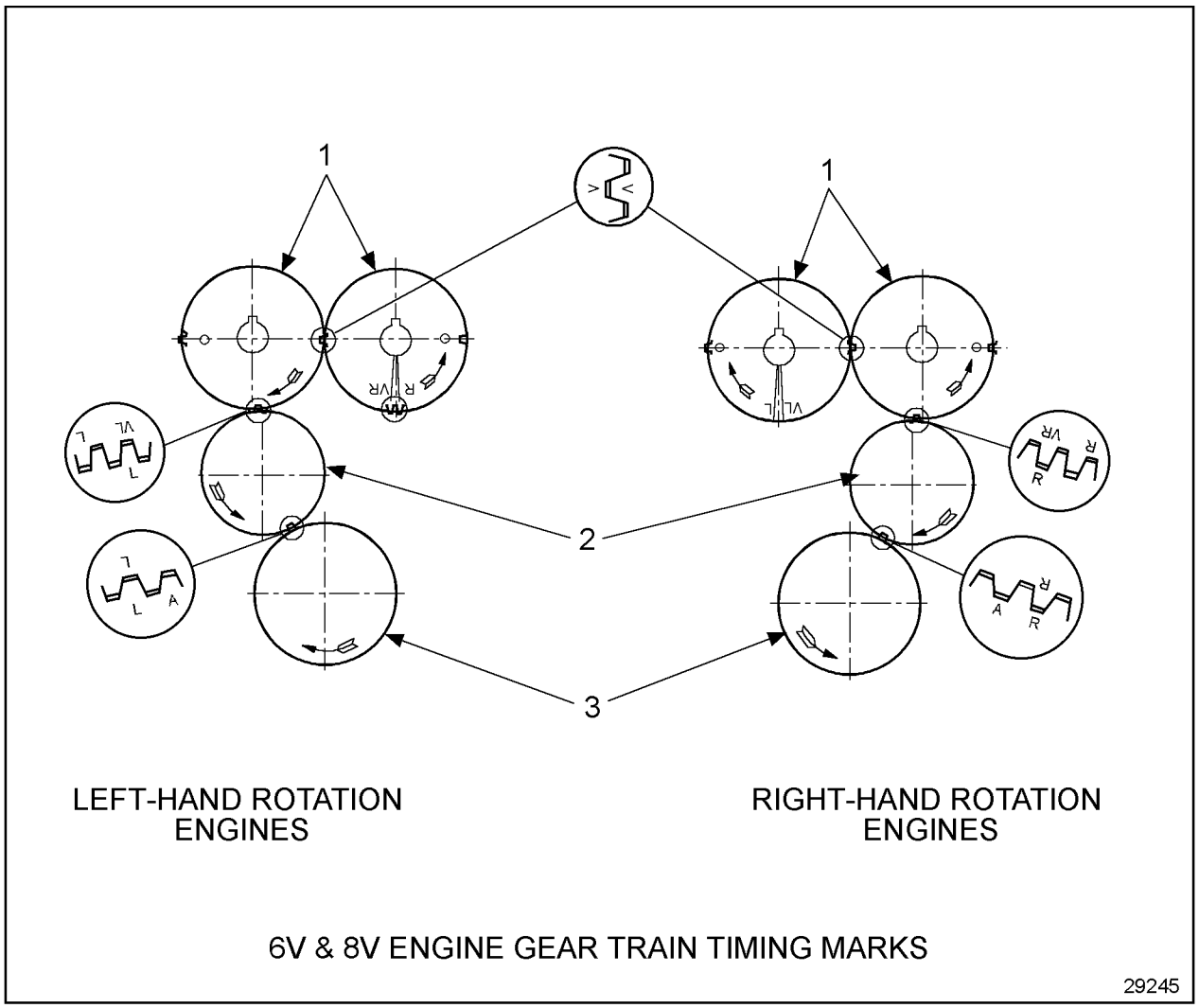
Refer to section 1.25.1 and perform all steps.

NOTE:
Line up the timing marks and make a sketch indicating their position before removing or replacing any gears in the gear train.

NOTE:
Before removing or replacing any of the gears, rotate the crankshaft in the direction of engine rotation until the diamond timing marks are aligned on the front camshaft gears or the triangle timing marks are aligned on the rear camshaft gears. See Figure 1-191.

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Check whether the "L" or "R" timing mark on the crankshaft gear is aligned with the "L" or "R" on the idler gear. Record this information for reassembly purposes.



1. Camshaft Gears
2. Idler Gear
3. Crankshaft Gear

Figure 1-191 Gear Train and Timing Marks for 6V and 8V Engines

NOTE:
When the gear train is installed (and the timing marks properly aligned) at one end of the engine, the crankshaft must be rotated 180 degrees in the direction of engine rotation to align the timing marks on the gear train at the other end of the engine.

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth, or excessive bearing wear. When noise develops in a gear train, the flywheel housing should be removed to inspect the gear train and its bearings. A rattling noise usually indicates excessive gear lash. A whining noise indicates too little gear lash.

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1.25.1 Inspect Engine Timing

Check the engine timing without removing the flywheel and flywheel housing as follows:

NOTE:
Access to the vibration damper or crankshaft pulley is necessary when performing the timing check.

1. Clean and remove one valve rocker cover. Refer to section 1.6.2.
2. Select any cylinder adjacent to any valve rocker cover bolt or stud holes for the timing check.
3. Remove the injector. Refer to section 2.2.2.
4. Carefully slide a rod, approximately 12 in. long, through the injector tube until the rod end rests on top of the piston.
5. Place the throttle in the no-fuel position.
6. Turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel.
7. Remove the rod, and turn the crankshaft, opposite the direction of engine rotation, between 1/16 and 1/8 of a turn.
8. Select a dial indicator with 0.001 in. graduations and a spindle movement of at least one inch.
9. Provide an extension for the indicator spindle.

NOTE:
The extension must be long enough to contact the piston just before it reaches the end of its upward stroke.

10. Select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.
11. Mount the indicator over the injector tube.

NOTE:
The indicator mounting may be threaded into the rocker cover stud or the tapped hole in the cylinder head. The indicator spindle must move freely in the injector tube hole.

12. Attach a suitable pointer to the crankshaft front cover.

NOTE:
The outer end of the pointer should extend over the top of the crankshaft pulley or vibration damper.

13. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand stops moving.

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14. Continue turning the crankshaft until the indicator hand starts to move again.
15. Reset the dial to zero.
16. Turn the crankshaft until the indicator reading is 0.010 in.
17. Scribe a line, aligned with the pointer end, on the crankshaft pulley or vibration damper.
18. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand stops moving.
19. Continue turning the crankshaft until the indicator hand starts to move again.
20. Reset the dial to zero.
21. Turn the crankshaft until the indicator reading is 0.010 in.
22. Scribe a second line, aligned with the pointer end, on the crankshaft pulley or vibration damper.
23. Scribe a third line half way between the first two lines. This is top dead center.
24. Remove the indicator and rod from the engine.
25. If the crankshaft pulley retaining bolt has loosened, tighten it to the specified torque. Refer to section 1.15.3.
26. Install the injector. Refer to section 2.2.5.
27. Adjust the valve clearance, and time the injector. Refer to section 12.2.
28. Turn the crankshaft in the direction of engine rotation until the selected cylinder's exhaust valves are completely open.
29. Install the dial indicator so the indicator spindle rests on top of the injector follower.
30. Set the indicator dial to zero.
31. Turn the crankshaft slowly in the direction of engine rotation until the center mark on the pulley is aligned with the pointer.

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32. Note the indicator reading, and compare it with the dimensions listed in Table 1-10.

Engine	Year of Certification	Federal Certification Label	California Certification Label	Cam ID*	Indicator Reading Correct at 1 Tooth †	Indicator Reading Retarded at 1 Tooth †	Indicator Reading Advanced at 1 Tooth †	Correct (at Cam)
All 6V and 8V	1974-1976	X	X	3J28	0.230	0.197	0.262	0.187
	1977-1978	X	—	3J28	0.230	0.197	0.262	0.187
	1977-1978	—	X	3J33	0.197	0.165	0.230	0.160
	1979	X	X	3J32	0.204	0.171	0.237	0.166
	1980-1981	X	—	3J32	0.204	0.171	0.237	0.166
	1980-1981	—	X	3J41	0.139	0.106	0.172	0.113
	1982-1983	X	X	3J32	0.204	0.171	0.237	0.166
	1984	X	—	3J28	0.230	0.197	0.262	0.187
	1984	—	X	3J32	0.204	0.171	0.237	0.166
	1987	X	X	3J30	0.230	0.187	0.251	0.178
	1985-1989	X	—	3J32	0.204	0.171	0.237	0.166
	1985-1989	—	X	3J41	0.139	0.106	0.172	0.113
	1988-1990 ‡	X	X	21J36	0.192	0.159	0.224	0.156
	1991 ‡	X	X	21J42	0.145	0.112	0.178	0.118
All 12V								
Rear Cam	1980-1989	-	-	3J32	0.204	0.171	0.237	0.166
Front Cam	1980-1989	-	-	3J32	0.215	0.182	0.248	0.175
All 16V								
Rear Cam	1974-1989	-	-	3J28	0.230	0.197	0.262	0.187
Front Cam	1974-1989	-	-	3J28	0.241	0.208	0.271	0.196

* Camshaft identification stamped in rear end of camshaft

† Indicator readings shown are nominal values. The allowable tolerance is ± 0.005 in.

‡ DDEC Engines

Table 1-10 Engine Timing

33. Remove the dial indicator.
34. Remove the pointer from the crankshaft front cover.
35. Install the valve rocker cover.

1.26 CAMSHAFTS AND BEARINGS

The contra-rotating camshafts are located just below the top of the cylinder block. A left cylinder bank and a right cylinder bank camshaft are provided to actuate the exhaust valve and injector operating mechanism.

A bearing assembly, consisting of a flanged housing and two bushings, support both ends of each camshaft. Intermediate two-piece bearings support the camshafts at uniform intervals throughout their length. Lock rings secure the intermediate bearings to the camshaft, permitting them to be inserted in the cylinder block with the shafts. After the camshafts are installed, each intermediate bearing is secured with a lock screw threaded into a cylinder block top counterbored hole.

Two thrust washers, one on each end of the rear camshaft end bearing, absorbs the camshaft gear thrust load on each shaft.

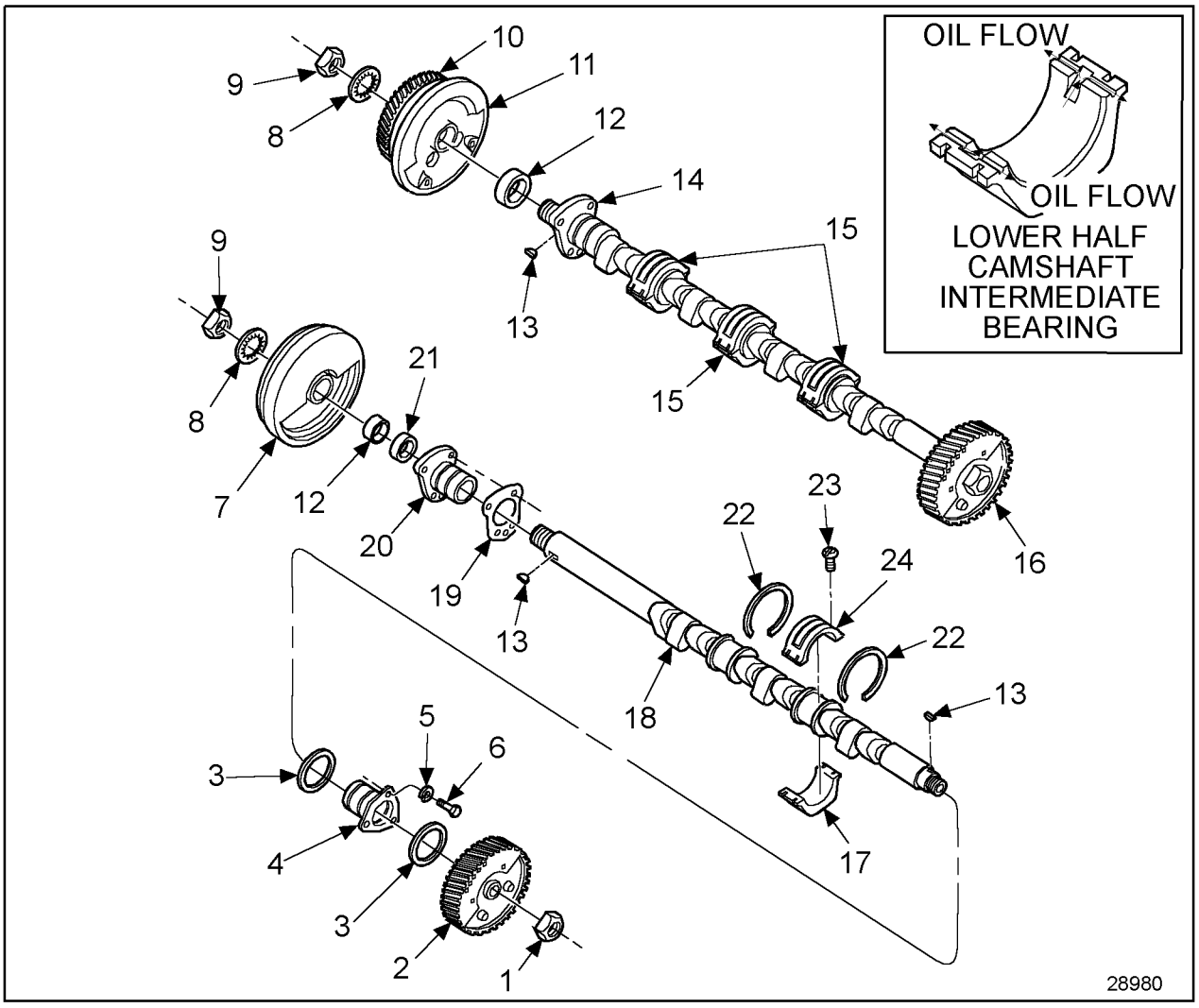
A camshaft front pulley (integral weight) is attached to the front end of the left-bank camshaft. A water pump drive gear (bolt-on weight) is attached to the front end of the right-bank camshaft. A camshaft gear is attached to the rear end of each camshaft. The pulley and the gears are retained on the camshafts with a retaining nut or a lock bolt and washer.

8V engines are equipped with a rubber bushed camshaft torsional vibration damper that is keyed and bolted to a hub attached to the water pump drive gear with three bolts, plain washers, and lock washers.

Lubricating oil is supplied under pressure to the bearings via drilled passages in the rear of the cylinder block, which lead from the main oil gallery to each rear end bearing. From the rear end bearings, the oil passes through the drilled oil passages in the camshafts to the intermediate bearings and to the front end bearings.

The lower halves of the camshaft intermediate bearings are grooved along the horizontal surface that mates with the upper halves of the bearings. Oil from the camshaft passage is forced through the milled slots in the bearing and out the grooves to furnish additional oil to the cam follower rollers. The cam pocket fills rapidly to the operating oil level immediately after starting the engine. See Figure 1-192.

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1. Nut
2. LH Camshaft Gear
3. Thrust Washers
4. LH Rear End Bearing
5. Lock Washer
6. Bolt
7. LH Front Pulley
8. Front Pulley Lock Washer
9. Front Pulley Nut
10. Water Pump Drive Gear
11. RH Balance Weight Assembly
12. Spacer
13. Woodruff Key
14. RH Front End Bearing
15. Intermediate Bearing Assemblies
16. RH Camshaft Gear
17. Lower Intermediate Bearing
18. Camshaft
19. LH Front End Bearing Gasket
20. LH Front End Bearing
21. Oil Seal
22. Locking Rings
23. Hold-Down Screw
24. Upper Intermediate Bearing

Figure 1-192 Description of Camshaft and Bearing Assembly

On 12V and 16V engines, the counter-rotating camshafts are located near the top of the cylinder block. There are two camshafts in each cylinder bank. Each camshaft actuates the valve and injector operating mechanism in one of the cylinder heads.

A three-piece bearing supports the end of each camshaft. Intermediate two-piece bearings support the camshafts at uniform intervals throughout their length. Lock rings hold these intermediate bearings around the camshaft bearing surfaces, permitting them to be inserted into the block with the shaft. A lock screw, sunk into a counterbore at the top of the block, secures each intermediate bearing and inner end bearing. A 3/8 in. x 0.5 in. split copper washer is used under the lock screws at the inner end bearings on current engines.

Lubrication is supplied under pressure, via angular drilled passages in the ends of the cylinder block, which lead from the main oil gallery to each camshaft rear end bearing. From the rear end bearings, oil flows through the drilled camshafts to the intermediate bearings and the inner end bearings.

The current inner camshaft end bearings have one 12.7 mm (0.5 in.) chamfered hole and two 6.4 mm (0.25 in.) chamfered holes to ensure alignment with the oil supply hole to the overhead mechanism. At engine overhaul, be sure to install the current bearings on early engines (prior to approximate engine serial No. 16VF-1260).

1.26.1 Repair or Replacement of Camshafts and Bearings

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-193.

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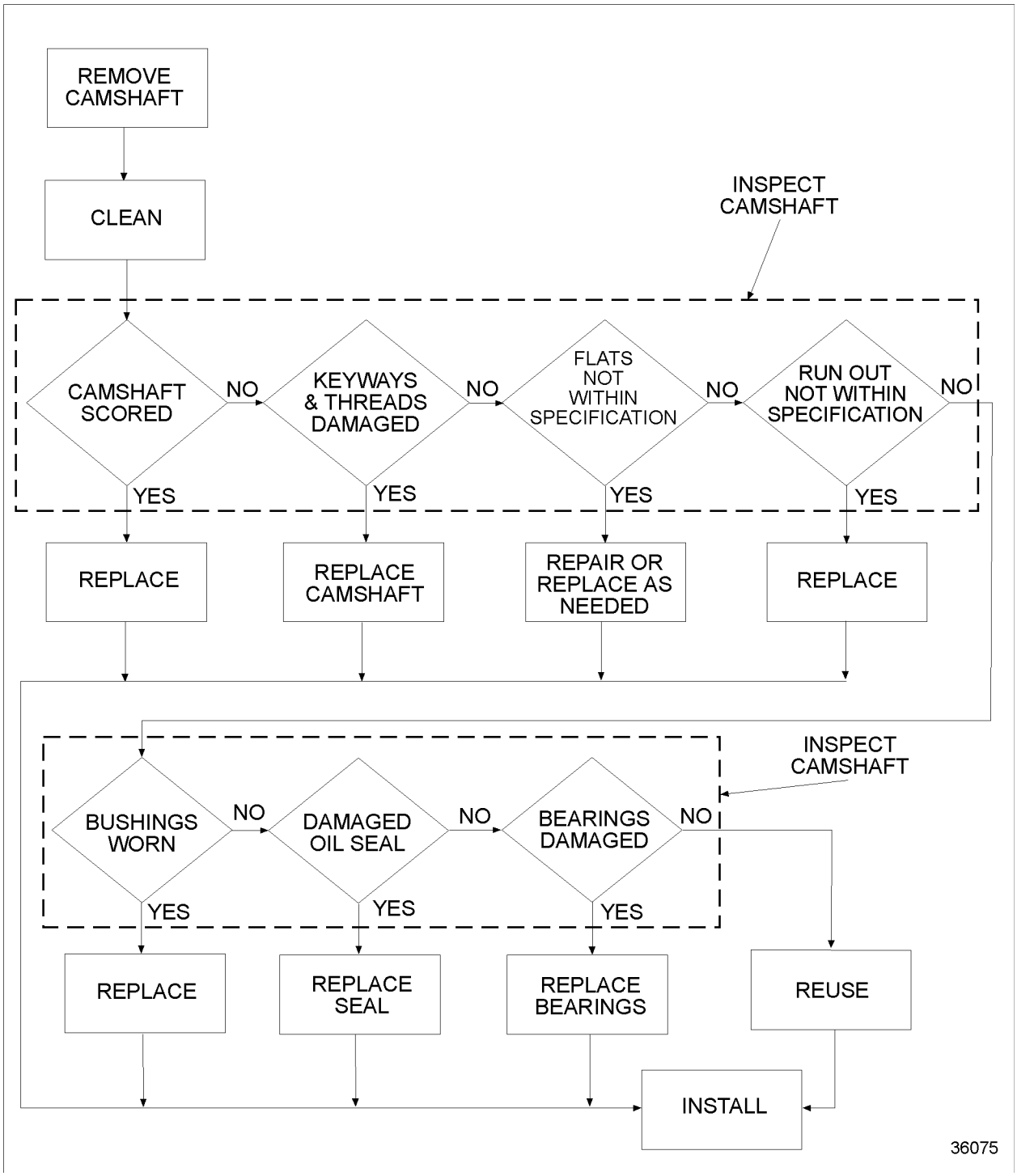


Figure 1-193 Flowchart for Repair or Replacement of Camshafts and Bearings

1.26.2 Removal of Camshafts and Bearings (Flywheel Housing and Transmission Removed)

Whenever an engine is to be completely reconditioned, or the bearings, thrust washers, or gears need replacing, remove the camshafts as follows:

1. Drain the engine cooling system. Refer to section 13.12.3.
2. Remove all of the accessories and assemblies necessary to mount the engine on an overhaul stand. Refer to section 1.1.2.
3. Mount the engine on the overhaul stand.

NOTICE:
Prior to releasing the lifting sling, ensure the engine is securely mounted on the overhaul stand. Serious personal injury and engine damage could result.

4. Remove the lifting sling.
5. Remove the cylinder heads. Refer to section 1.3.2.
6. Remove the flywheel. Refer to section 1.16.2.

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CAUTION:

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

CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

CAUTION:

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

NOTICE:

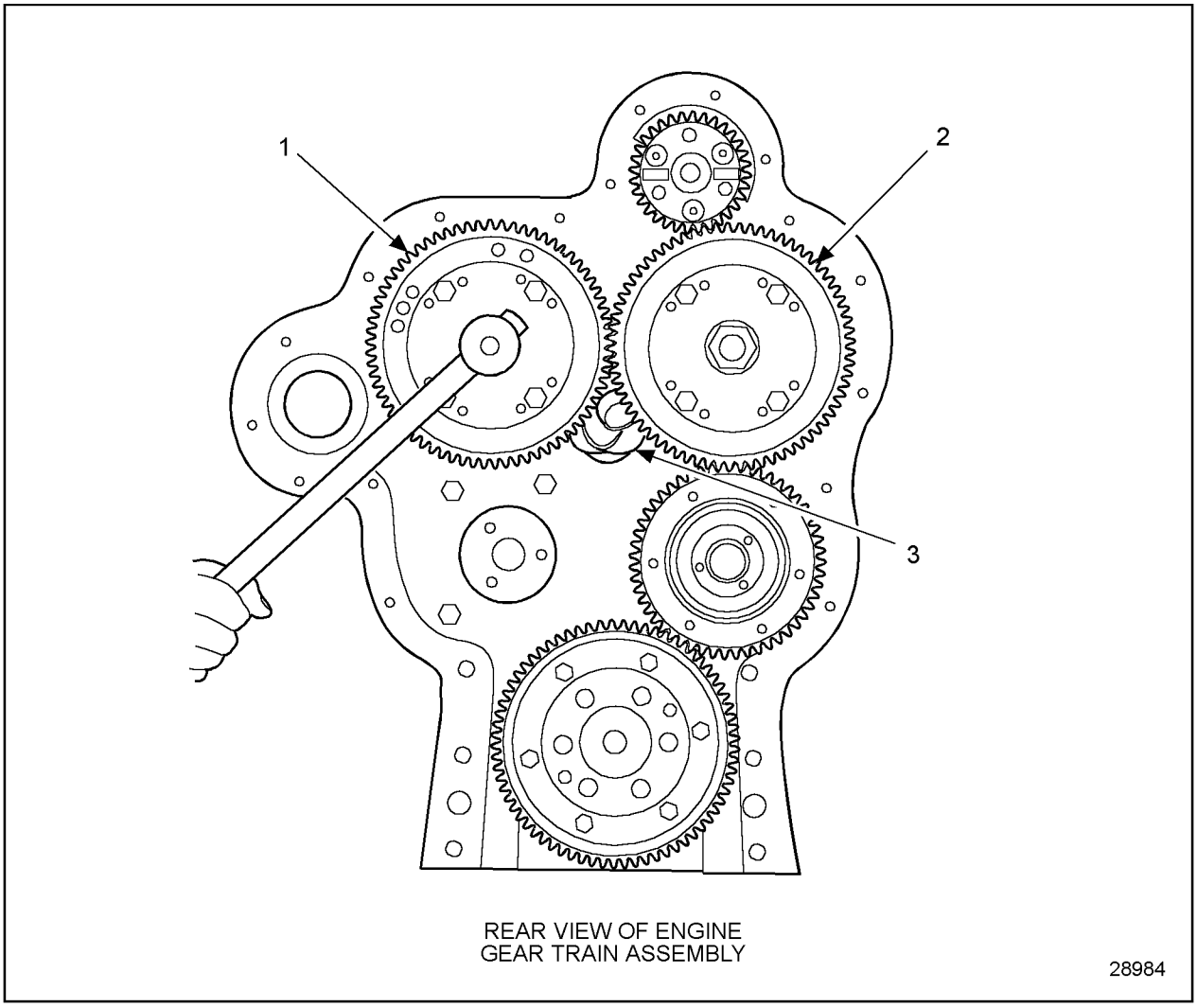
The flywheel housing must be securely attached to the lifting sling before removing from the engine. Damage to Flywheel housing may result if it breaks away from the lifting device and falls.

7. Remove the flywheel housing. Refer to section 1.19.2.
8. Remove the water pump. Refer to section 4.2.2.
9. Remove the front balance weight cover. Refer to section 1.26.2.
10. Remove the bolts and step-up gear, if used, from the rear right-bank camshaft gear. Refer to section 1.26.2.
11. Remove the bolts securing the nut retaining plates to the camshaft gears. Remove the nut retaining plates.

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12. Wedge a clean rag between the gears, and remove the gear retaining nut from both ends of each camshaft. See Figure 1-194.

NOTE:
On left– hand rotation engines, remove the lock bolt and washer from the right-bank camshaft.

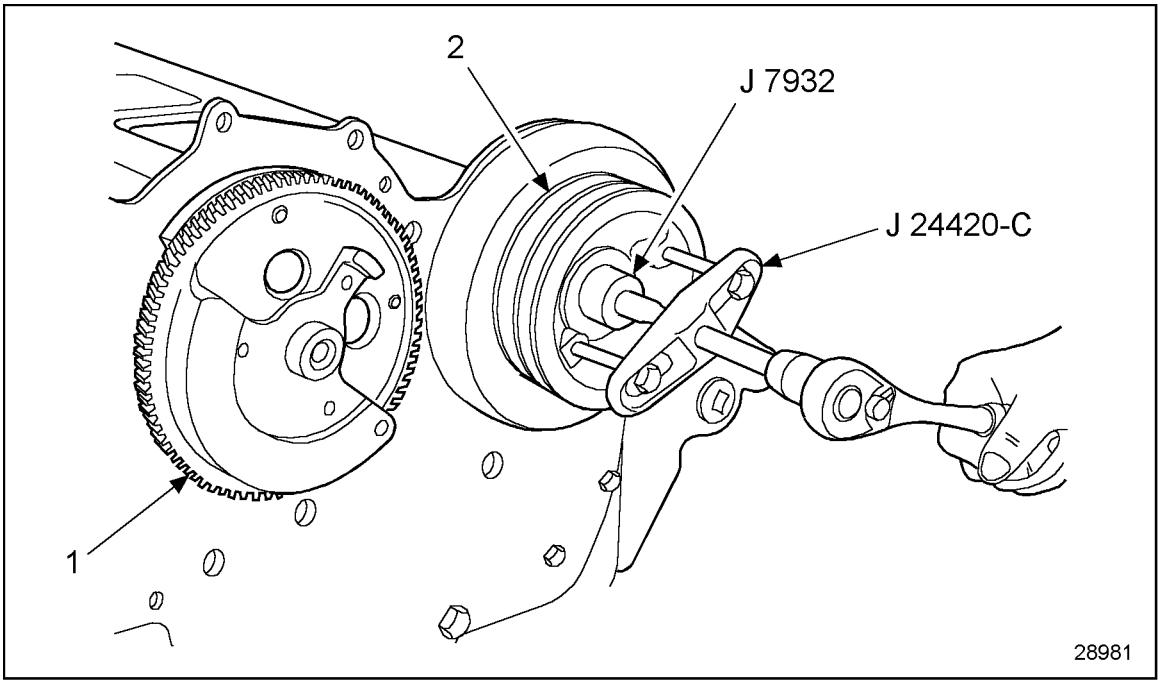


1. LH Camshaft Gear
2. RH Camshaft Gear
3. Rag

Figure 1-194 Loosening Camshaft Gear Retaining Nut

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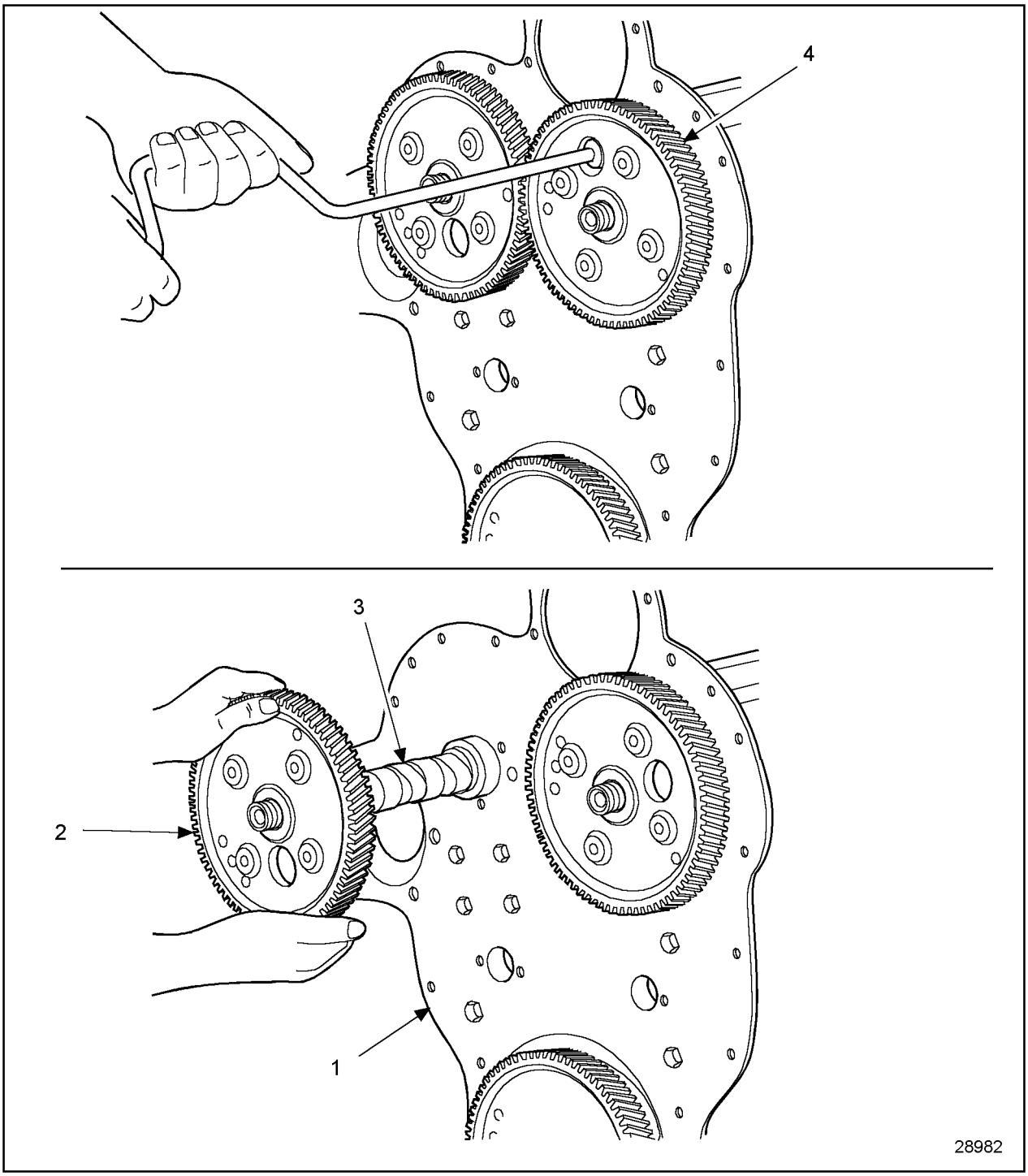
13. Attach puller J 24420-C to the camshaft pulley. Use cam pulley remover adaptor J 7932 between the end of the camshaft and the pulley screw to protect the end of the camshaft. See Figure 1-195.



1. RH Balance Weight and Camshaft Assembly
2. LH Camshaft Pulley

Figure 1-195 Removing Camshaft Pulley

14. Remove the camshaft vibration damper and hub from the water pump drive gear, if used.
15. Remove the water pump drive gear from the front end of the right-bank camshaft, using J 24420-C and water pump gear puller adaptor J 7932.
16. Remove the Woodruff key and the spacer from the front end of each camshaft.
17. Remove all camshaft intermediate bearing lock screws from the top of the cylinder block. On 12V and 16V engines, insert a socket wrench through the camshaft web hole to remove end bearing to cylinder block bolts.
18. Rotate the camshaft gears as required to reveal the camshaft end bearing retaining bolts. Remove the bolts. See Figure 1-196.



1. Rear End Plate
2. LH Camshaft Gear
3. Camshaft Assembly
4. RH Camshaft Gear

Figure 1-196 Removing Camshaft End Bearing Bolt and Camshaft Assemblies

19. Withdraw each camshaft, bearing, and gear assembly from the cylinder block.

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20. Remove the camshaft front end bearing retaining bolts. Withdraw the bearings from the cylinder block. If necessary, use a pry bar under the bearing flange.
21. On 12V and 16V engines, remove the lock screw and copper washer, if used, from the top of the cylinder block. Slide the bearings out of the block.

1.26.3 Removal of Camshaft (Flywheel Housing and Transmission Installed)

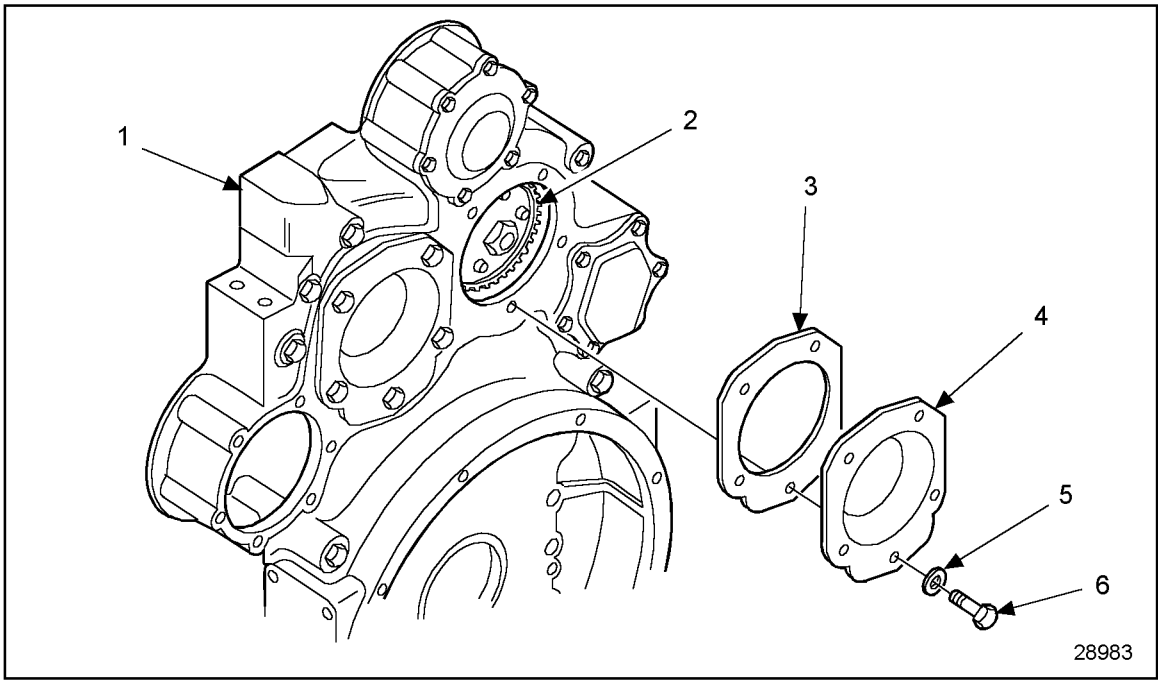
To remove camshafts when the flywheel housing and transmission are in place, proceed as follows:

NOTE:
The camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission if there is space enough to slide the shaft out through the front of the engine and attach the camshaft gear puller tool J 1902-B to the flywheel housing.

1. Drain the engine cooling system. Refer to section 13.12.3.
2. Remove the radiator. Refer to section 4.6.2.
3. Remove the heat exchanger and all attaching parts. Refer to section 4.9.2.

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4. Remove all parts, accessories and assemblies necessary to facilitate removal of the flywheel housing hole cover over the camshaft and the front balance weight cover. See Figure 1-197.



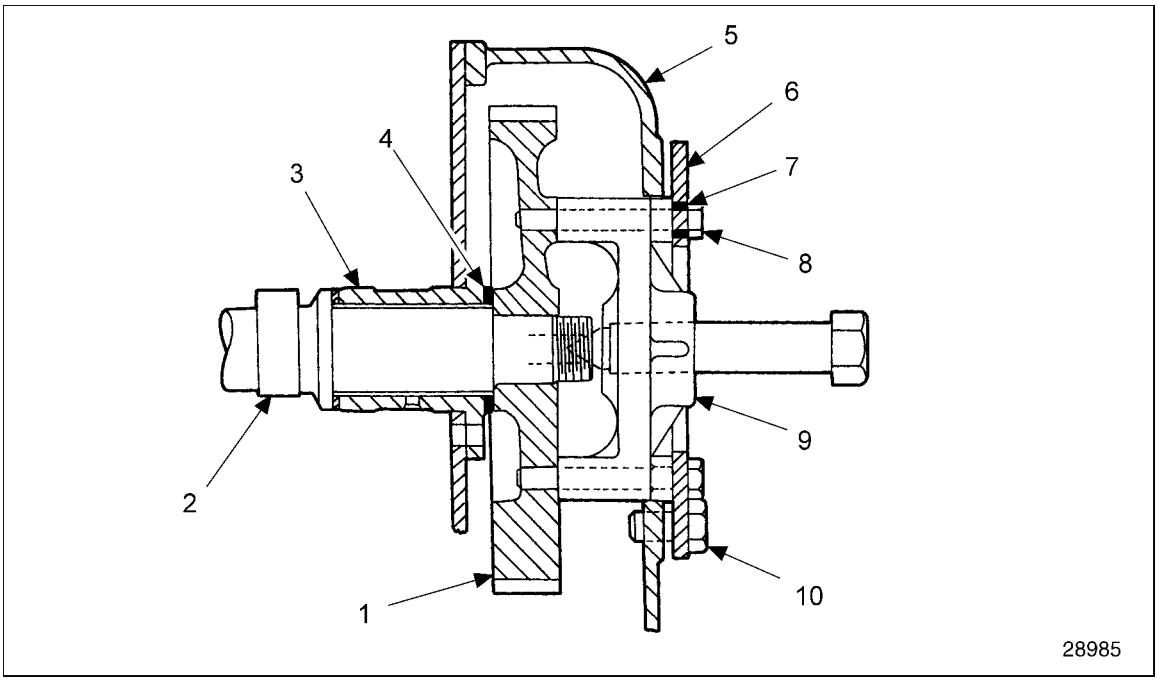
1. Flywheel Housing Assembly
2. Camshaft Gear
3. Gasket
4. Flywheel Housing Cover
5. Lock Washer
6. Bolt

Figure 1-197 Removing Flywheel Housing Covers

5. Remove the cylinder head. Refer to section 1.3.2.
6. Remove the front balance weight cover. Refer to section 1.26.2.
7. Remove the camshaft gear nut retaining plate.
8. Block the crankshaft, between the crankshaft throw and the cylinder block.
9. Remove the gear retaining nut or lock bolt and washer from both ends of the camshaft.
10. If removing a left-bank camshaft, attach puller J 24420-C to the camshaft pulley.
11. Use adaptor J 7932 between the end of the camshaft and the pulley screw to protect the end of the camshaft.
12. If removing a right-bank camshaft, remove the camshaft vibration damper and hub from the water pump drive gear, if used.
13. Remove the water pump gear and spacer from the front end of the camshaft, using puller J 24420-C and adaptor J 7932.
14. Remove the Woodruff key and the spacer from the front end of the camshaft.

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15. Remove all camshaft intermediate bearing lock screws from the top of the cylinder block.
16. Remove the three bolts that secure the camshaft bearing to the front end plate.
17. Install the camshaft gear puller J 1902-B, four spacers and camshaft gear puller adaptor plate from set J 6202-01 on the camshaft gear. See Figure 1-198.



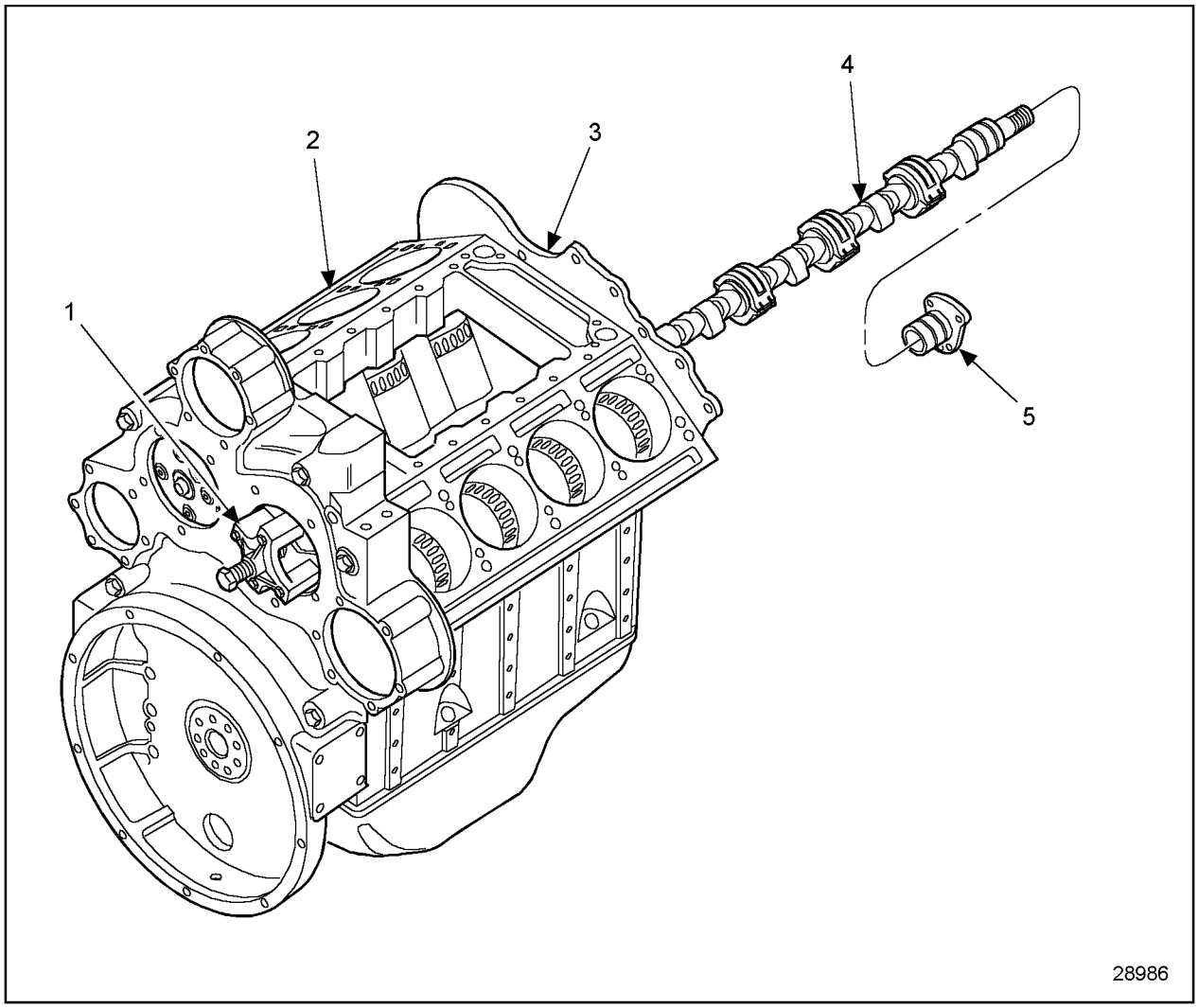
1. Camshaft Gear
2. Camshaft
3. Camshaft End Bearing
4. Thrust Washer
5. Flywheel Housing
6. Camshaft Puller Adaptor Plate
7. Spacer
8. Bolt (Adaptor) Plate-to-Gear
9. Camshaft Gear Puller Tool
10. Bolt (Adaptor Plate-to-Flywheel Housing)

Figure 1-198 Removing Camshaft Gear with Camshaft Gear Puller

18. Turn the puller center screw clockwise to disengage the camshaft gear.

NOTE:
Do not remove the puller or the adaptor plate until the camshaft is installed. The adaptor plate secured to both the flywheel housing and the camshaft gear, will hold the gear and the thrust washers securely in place. This will aid camshaft installation.

19. Remove the front bearing from the camshaft. Pull the camshaft and intermediate bearings from the cylinder block. See Figure 1-199.



1. Puller and Adaptor Plate Tool
2. Cylinder Block Assembly
3. Front End Plate
4. Camshaft Assembly
5. Front End Bearing

Figure 1-199 Removing Camshaft Assembly From Engine

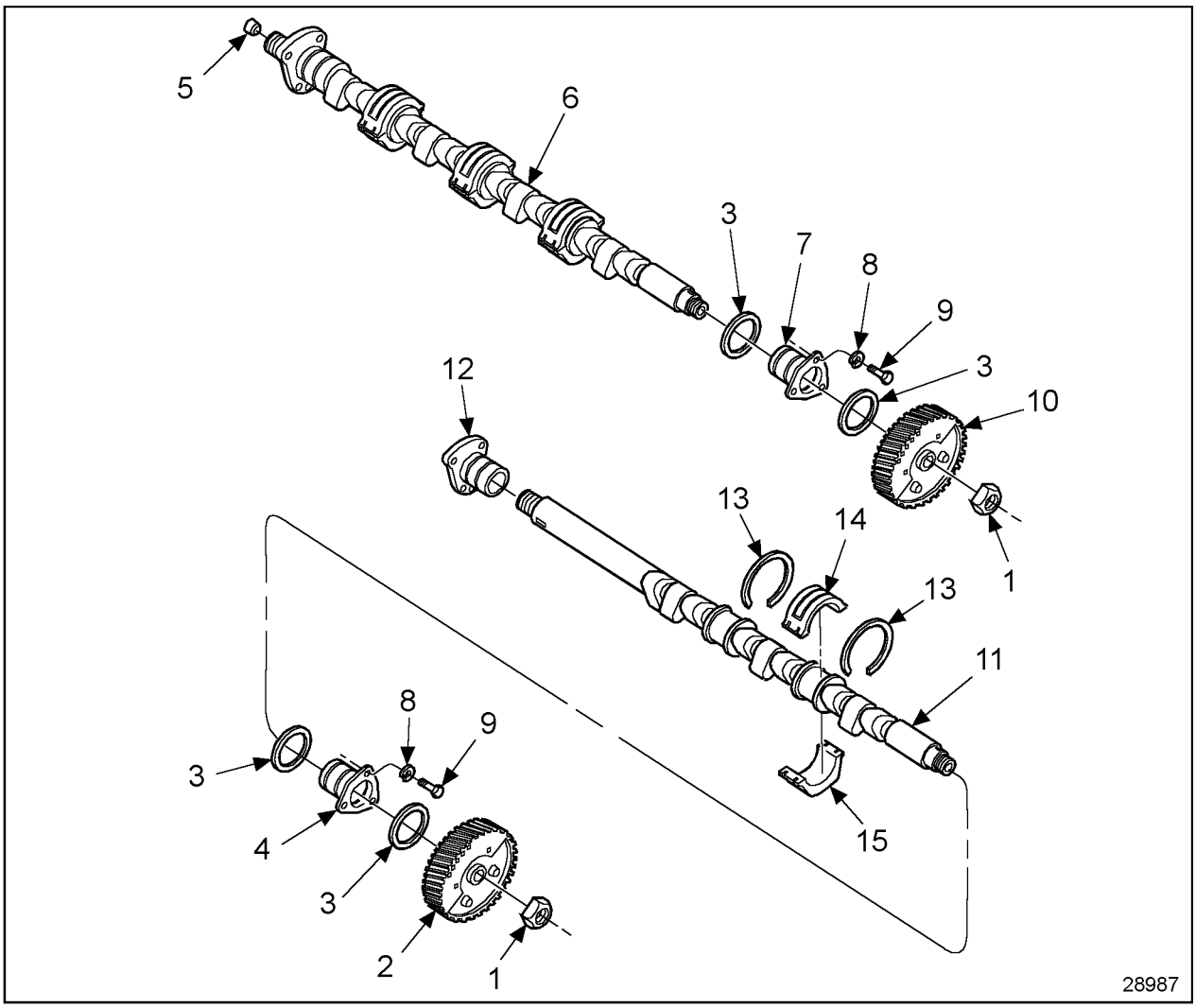
1.26.4 Disassembly of Camshaft

Disassemble the camshaft as follows:

1. Remove the gear from each camshaft. Refer to section 1.27.2.

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2. Slide the camshaft rear end bearing and thrust washers off each camshaft.



1. Camshaft Gear Nut
2. LH Camshaft Gear
3. Thrust Washer
4. LH Rear End Bearing
5. Camshaft Plug
6. RH Camshaft Assembly
7. RH Camshaft Rear End Bearing
8. Lock Washer
9. Bolt
10. RH Camshaft Gear
11. LH Camshaft Assembly
12. LH Front End Bearing
13. Lock Rings
14. Upper Intermediate Bearing
15. Lower Intermediate Bearing

Figure 1-200 Camshaft Disassembly

3. Remove the lock rings from the camshaft intermediate bearings, freeing the halves of each bearing.

To facilitate the removal of any foreign material lodged behind the plugs, remove the end plugs from each camshaft, as follows:

1. Clamp the camshaft in a soft-jawed vise, being careful not to damage the cam lobes or machined surfaces of the shaft.
2. Make an indentation in the center of the camshaft end plug with a 31/64 in. drill (carboloy tip).
3. Punch a deep hole with a center punch, to aid in breaking through the hardened surface of the plug.
4. Drill a hole straight through the center of the plug with a 1/4 in. drill (carboloy tip).
5. Use the 0.25 in. drilled hole as a guide, and drill the plug with a 0.3125 in. drill (carboloy tip).
6. Tap the drilled hole with a 3/8 in.-16 tap.
7. Thread a 3/8 in.-16 adaptor J 6471-2 (from set J 6471-02) into the plug.
8. Attach a slide hammer J 2619-5 to the adaptor, and strike a weight against the handle to remove the plug.
9. Insert a length of 3/8 in. steel rod in the camshaft oil gallery, and drive the remaining plug out.

If a steel rod is not available, remove the remaining plug as follows:

NOTICE:
Be careful not to damage the cam lobes or machined surfaces of the shaft.

1. Clamp the camshaft in a soft-jawed vise.
2. Make an indentation in the center of the camshaft end plug with a 31/64 in. drill (carboloy tip).
3. Punch a deep hole with a center punch, to aid in breaking through the hardened surface of the plug.
4. Drill a hole straight through the center of the plug with a 1/4 in. drill (carboloy tip).
5. Use the 1/4 in. drilled hole as a guide, and drill the plug with a 5/16 in. drill (carboloy tip).
   [a] Tap the drilled hole with a 3/8 in.-16 tap.
   [b] Thread a 3/8 in.-16 adaptor J 6471-2 (from set J 6471-02) into the plug. Remove the plug by striking the handle.

1.26.4.1 Cleaning of Camshaft and Bearings

Prior to inspection, clean the camshafts and bearings as follows:

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Soak the camshaft in clean fuel oil.
2. Run a wire brush through the oil gallery to remove any foreign material or sludge.

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 the camshaft exterior, and blow out the oil gallery and the oil holes with compressed air.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

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. Clean the camshaft bearings and related parts with fuel oil, and dry them with 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.

5. If a new camshaft is to be installed, steam clean it to remove the rust preventive, and blow out the oil passages with compressed air.

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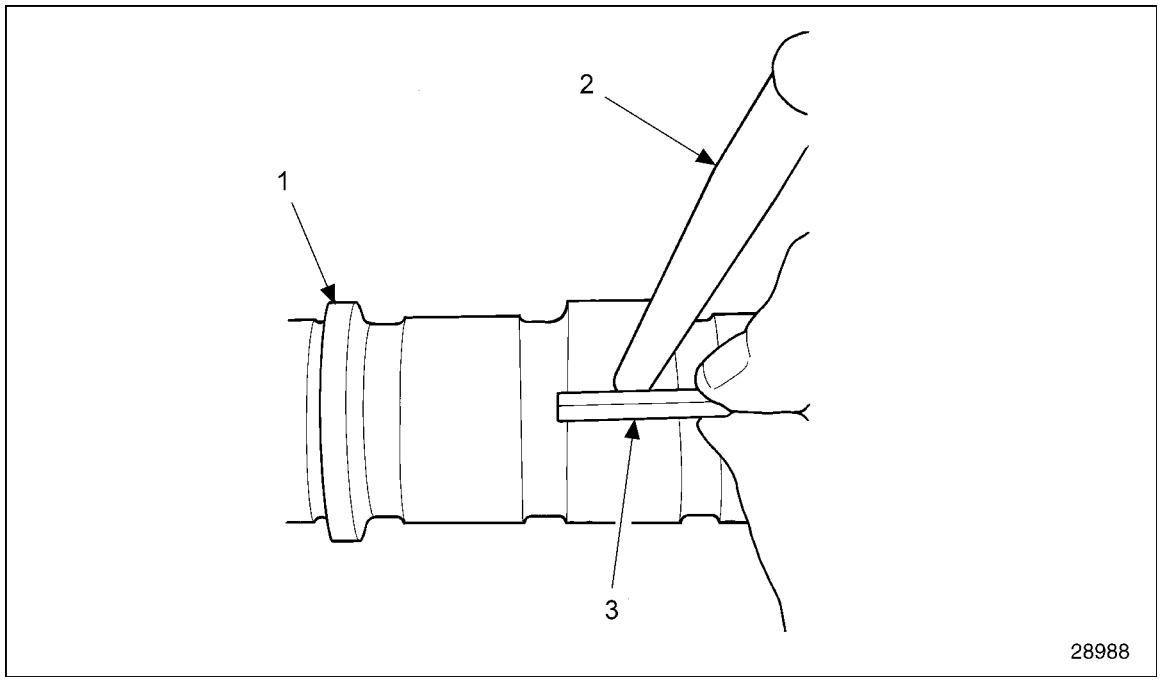
1.26.4.2 Inspection of Camshafts and Bearings

Inspect the camshafts and bearings as follows:

1. Visually inspect the cams and journals for wear or scoring.
   [a] If the cams are scored, inspect the cam followers. Refer to section 1.5.6.2.
   [b] If the cams and journals are excessively scored or worn, replace them.
   [c] If not worn or scored, continue inspection.
2. Inspect the camshaft keyways and threads for damage.
   [a] If damaged, replace the camshaft. Refer to section 1.26.6.
   [b] If not damaged, continue inspection.

NOTE:
The camshaft can be in or out of the engine during this inspection.

3. With a tapered leaf set of feeler gages, 0.038-0.25 mm (0.0015-0 .010 in.), and a square piece of hard material (1/8 in. x 3/8 in. x 1 in.), measure the flat on the injector rise side of the cam lobes. See Figure 1-201.



1. Camshaft
2. Feeler Gage
3. Harden Material

Figure 1-201 Checking Cam Lobe Wear

   [a] If the flats measure more than 0.08 mm (0.003 in.) in depth, replace the camshaft. Refer to section 1.26.6.

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[b] If the flats measure less than 0.08 mm (0.003 in.) in depth, and there are no other defects, the camshaft is serviceable. Continue inspection.

[c] A slightly worn cam lobe, still within acceptable limits, may be stoned and smoothed with a fine crocus cloth.

4. With the camshaft mounted on the end bearing surfaces, check the run-out at the center bearing.

   [a] If the run-out exceeds 0.05 mm (0.002 in.), replace the camshaft. Refer to section 1.26.6.

   [b] If the run-out does not exceed 0.05 mm (0.002 in.), continue inspection.

5. Visually inspect both faces of each camshaft rear end bearing and thrust washer for scoring or wear.

   [a] If excessively scored or worn, replace the bearings or thrust washer. Refer to section 1.26.6.

   [b] If minimally scored or worn, smooth with an oil stone.

   [c] If not scored or worn, continue inspection.

6. Visually inspect the surfaces of every camshaft and camshaft gear that contacts the thrust washers for wear or scoring.

   [a] Replace excessively worn or scored parts. Refer to section 1.26.6.

   [b] If minimally worn or scored, smooth with an oil stone.

   [c] If not worn or scored, continue inspection.

NOTE:
New standard size thrust washers are 3.02-3.10 mm (0.119-0.122 in.) thick. The clearance between the thrust washer and the thrust shoulder of the camshaft is .08-0.38 mm (0.003-0.0015 in.) with new parts, or a maximum of 0.46 mm (0.018 in.) with used parts. Excessive clearance may be reduced by using thrust washers that are 0.13-0.25 mm (0.005-0.010 in.) oversize.

NOTE:
When the thrust surfaces of a camshaft are ground undersize, a radius of 3.10-9.40 mm (0.122-0.370 in.) must be maintained between the bearing surface of the thrust collar

shoulder and the camshaft bearing surface. See Figure 1-202. A fillet radius gage may be used to measure the specified radii.

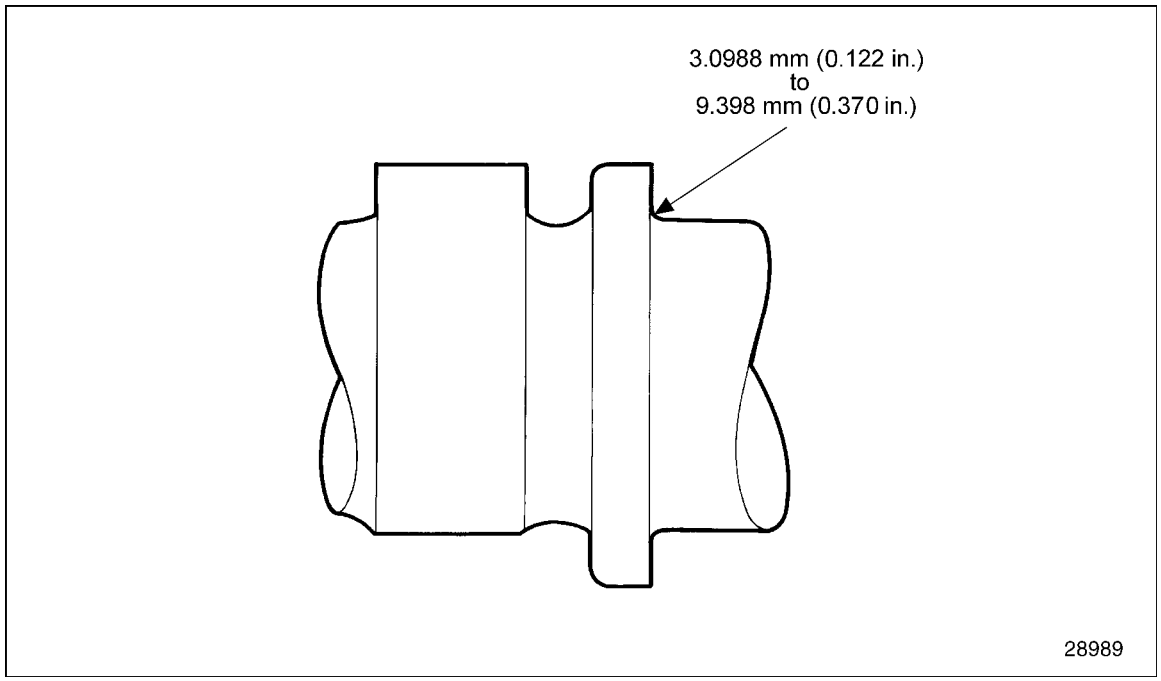


Figure 1-202 Camshaft Journal Fillet

7. Inspect the bushings in the front and rear camshaft end bearings for wear or turning in the bearing.

   [a] Replace the bushings if they are worn excessively (maximum of 0.152 mm or 0.006 in. bushing to shaft clearance) or if the bushings have turned in the bearing. Refer to section 1.26.5.

   [b] If the bushings are not worn or turned, continue inspection.

NOTE:
Rear camshaft end bearings are available in 0.010-0.020 in. undersize for use with worn or reground shafts with clearances that exceed the specified limits.

NOTE:
New bushings must be finish bored to a 20 rms finish after installation and checked for the proper press fit, which is indicated if the bushings will not move when a 2000 pound end load is applied. Also, the inside diameter of the bushings must be square with the rear face of the bearing within 0.038 mm (0.0015 in.) total indicator reading, and concentric with the outside diameter of the bearing housing within 0.05 mm (0.002 in.) total indicator reading. The bushings must project 1.14-1.40 mm (0.045-0.055 in.) from

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each end of the rear camshaft end bearings. The bushings in the front camshaft end bearings must be flush with the ends of the bushing bore.

NOTE:
The clearance between the camshaft end journals and the camshaft end bearing bushings for 6V engines is 0.064-0.102 mm (0.0025-0.004 in.). For 8V engines it is 0.089-0.13 mm (0.0035-0.005 in.) with new parts, or a maximum of 0.15 mm (0.006 in.) with used parts. Undersize and oversize camshaft end bearings are available for service.

8. Visually inspect the oil seal in the left-bank camshaft front end bearing for wear or damage.
   [a] If worn or damaged, replace the seal. Refer to section 1.26.6.
   [b] If not worn or damaged, proceed with inspection.
9. Visually inspect the spacer used at the front end of each camshaft for wear.

NOTE:
The outside diameter of the spacer used in the left-hand front end bearing must provide a smooth oil seal contact surface. The outside diameter is not ground and polished on the original spacer used on the right-bank camshaft. Only the polished spacer is available for service and may be used in either position.

   [a] If worn, replace the spacer. Refer to section 1.26.7.
   [b] If not worn, continue inspection.
10. Visually inspect the camshaft intermediate bearings for scoring or wear.
   [a] If excessively scored or worn, replace the camshaft intermediate bearings. Refer to section 1.26.6.
   [b] If not scored or worn, continue inspection.

NOTE:
The clearance between the camshaft journals and the intermediate bearings is 0.064-0.013 mm (0.0025-0.0005 in.) with new parts, or a maximum of 0.23 mm (0.009 in.) with worn parts. Undersize and oversize camshaft intermediate bearings are available for service.

11. Visually inspect the intermediate bearing lock screws and the tapped holes in the cylinder block for damaged threads.
   [a] If damaged, replace. Refer to section 1.26.5.
   [b] If not damaged, continue inspection.
12. Visually inspect the teeth of the water pump drive gear and the camshaft gears for scoring, pitting, or wear.
   [a] If the teeth are scored, pitted, or worn, replace the gears. Refer to section 1.27.3.
   [b] If the teeth are not scored, pitted, or worn, proceed with inspection.

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13. Visually inspect the keyways and tapped holes in the gears and the camshaft pulley for damage.

    [a] If damaged, replace gears and pulley. Refer to section 1.27.4 and refer to section 1.15.3.

    [b] If not damaged, continue inspection.

14. Inspect the rubber bushed torsion vibration damper for rubber deterioration, slippage of the outer ring, and alignment of the hub face to the rubber and outer ring.

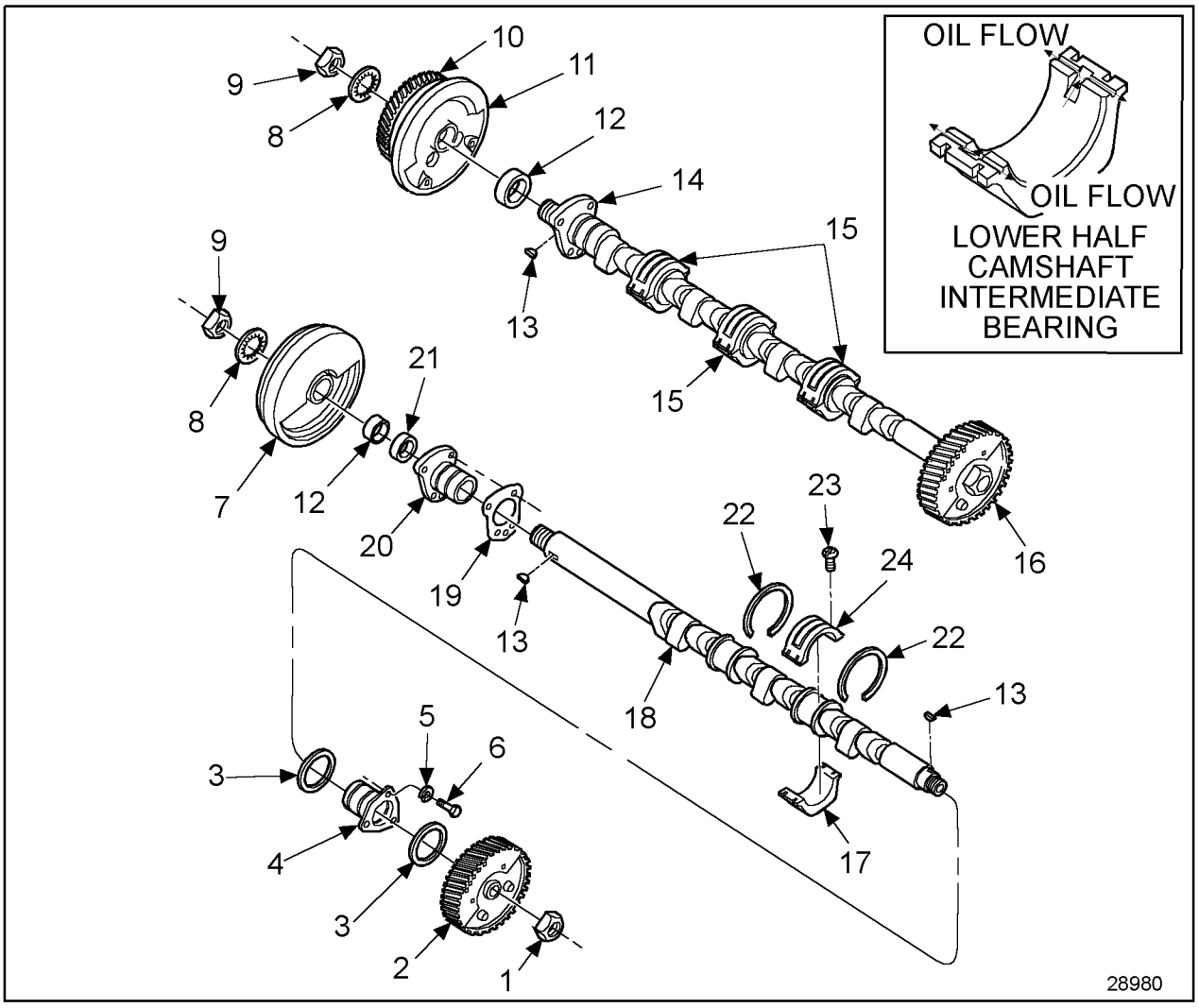
    [a] If rubber has deteriorated, outer ring slippage has occurred, or the hub face does not align with the rubber and outer ring, replace the vibration damper. Refer to section 1.14.4.

    [b] If the rubber has not deteriorated, the outer ring has not slipped, and the hub face aligns with the rubber and outer ring, reuse the camshaft.

1.26.5 Assembly of Camshaft

See Figure 1-203, and assemble the camshafts as follows:

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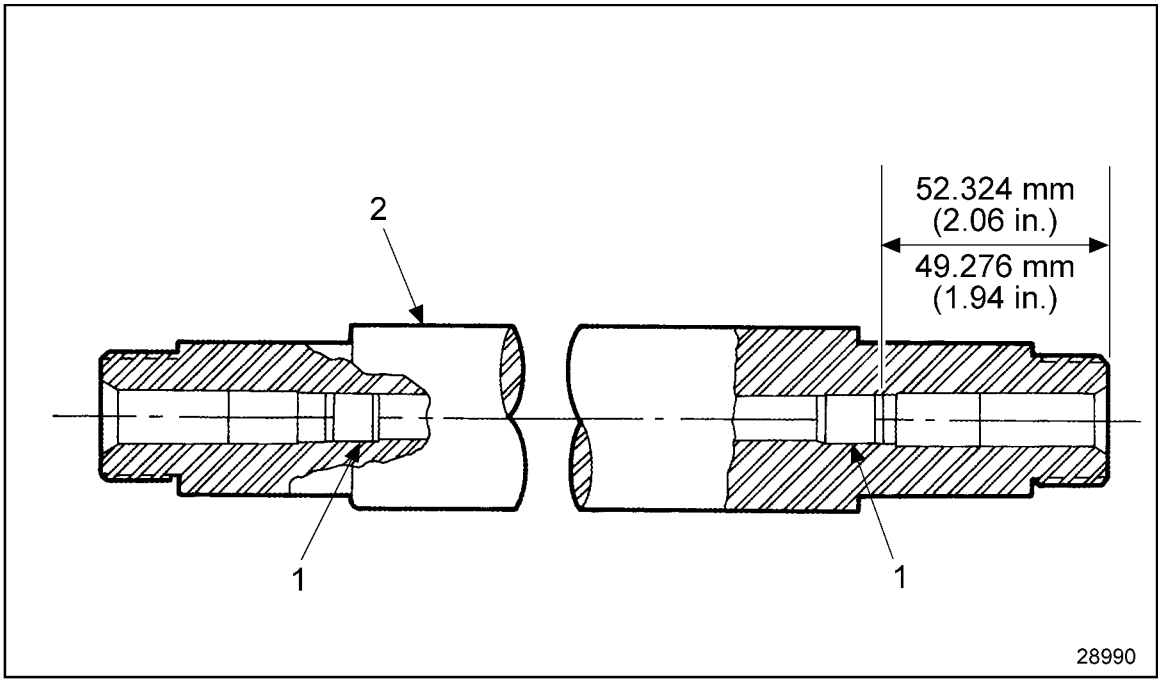
1. Nut
2. LH Camshaft Gear
3. Thrust Washers
4. LH Rear End Bearing
5. Lock Washer
6. Bolt
7. LH Front Pulley
8. Front Pulley Lock Washer
9. Front Pulley Nut
10. Water Pump Drive Gear
11. RH Balance Weight Assembly
12. Spacer
13. Woodruff Key
14. RH Front End Bearing
15. Intermediate Bearing Assemblies
16. RH Camshaft Gear
17. Lower Intermediate Bearing
18. Camshaft
19. LH Front End Bearing Gasket
20. LH Front End Bearing
21. Oil Seal
22. Locking Rings
23. Hold-Down Screw
24. Upper Intermediate Bearing

Figure 1-203 Description of Camshaft and Bearing Assembly

1. Coat the sides of the camshaft plugs with a light coating of Permatex Hi-Tack, or equivalent.

NOTICE:
Failure to install plugs correctly may cause engine damage.

2. Install new end plugs in each camshaft. Press the plugs in to a depth of 49.28-52.32 mm (1.940-2.060 in.). See Figure 1-204.



1. Camshaft Plug
2. Camshaft

Figure 1-204 Camshaft Plug Installation

3. Apply grease to the steel face of each thrust washer.
4. Place a thrust washer against each end of the two camshaft rear end bearings. Ensure the steel face of each thrust washer is next to the bearing.
5. Lubricate the rear camshaft bearing journal, and slide a rear end bearing on each camshaft, with the bearing bolting flange toward the outer (camshaft gear) end of the shaft.
6. Install the camshaft gear on each shaft. Refer to section 1.27.4.
7. Lubricate the camshaft intermediate bearing journals.
8. Place the two halves of each intermediate bearing on a camshaft journal, and lock the halves together with two lock rings.
9. Assemble each lock ring with the gap over the upper bearing and the ends an equal distance above the bearing split line.

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1.26.6 Installation of Camshaft and Bearing (Flywheel Housing and Transmission Removed)

Install the camshaft as follows:

NOTICE:
Use care not to damage the cam lobes when installing the camshaft.

1. Insert the camshaft front end, with the right-hand helix gear through the opening on the rear end plate right-bank side, until the first intermediate bearing enters the bore.
2. Continue to work the camshaft and bearings into the cylinder block until the camshaft gear teeth are about to engage the teeth of the mating gear.
3. Align the timing marks on the mating gears. Refer to section 1.25.
4. Slide the camshaft gear into place.
5. Secure the camshaft rear end bearing to the cylinder block with three lock washers and bolts.
6. Rotate the camshaft gear to install the bolts through the hole in the gear web.
7. Tighten the bolts to 47-54 N·m (35-40 lb·ft) torque.
8. Turn the camshaft intermediate bearings until the holes in the bearings are aligned with the tapped holes in the top of the cylinder block.
9. Install the lock screws, and tighten them to 20-27 N·m (15-20 lb·ft) torque.

Install the second camshaft as follows:

NOTICE:
Use care not to damage the cam lobes when installing the camshaft.

1. Insert the camshaft front end, with the right-hand helix gear through the opening on the rear end plate right-bank side, until the first intermediate bearing enters the bore.
2. Continue to work the camshaft and bearings into the cylinder block until the camshaft gear teeth are about to engage the teeth of the mating gear.
3. Align the timing marks on the mating gears. Refer to section 1.25.
4. Slide the camshaft gear into place.
5. Secure the camshaft rear end bearing to the cylinder block with three lock washers and bolts.
6. Rotate the camshaft gear to install the bolts through the hole in the gear web.
7. Tighten the bolts to 47-54 N·m (35-40 lb·ft) torque.

8. Turn the camshaft intermediate bearings until the holes in the bearings are aligned with the tapped holes in the top of the cylinder block.
9. Install the lock screws, and tighten them to 20-27 N·m (15-20 lb·ft) torque.

Complete installation as follows:

1. Attach a new gasket to the camshaft front end bearing that includes the oil seal.
2. Lubricate the bearing journal, and slide the bearing on the left-bank camshaft, with the bearing bolting flange toward the outer shaft end.
3. Secure the bearing to the cylinder block with three bolts and lock washers. Tighten the bolts to 47-54 N·m (35-40 lb·ft) torque.
4. Install the right-bank camshaft front end bearing (the one without the oil seal).
5. Secure the bearing to the cylinder block with three bolts and lock washers. Tighten the bolts to 47-54 N·m (35-40 lb·ft) torque.
6. Lubricate the spacer with the polished outside diameter, and slide it in place on the left-bank camshaft.
7. Install the other spacer on the right-bank camshaft.
8. Install a Woodruff key in each camshaft.
9. Install the pulley on the front end of the left-bank camshaft and the water pump drive gear and external weight on the right-bank camshaft.
10. Slip an internal tooth lock washer over the front end of each camshaft.
11. Start the gear and pulley retaining nuts on the camshafts.
12. Wedge a clean rag between the camshaft gears to prevent their turning. Tighten the nut on each end of both camshafts to 407-441 N·m (300-325 lb·ft) torque.
13. Attach the hub to water pump drive gear with three bolts, plain washers, and lock washer, if used. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.
14. Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 47-53 N·m (35-39 lb·ft) torque.
15. Check the clearance between the thrust washer and the thrust shoulder of each camshaft.

NOTE:
The specified clearance is 0.08-0.38 mm (0.003-0.015 in.) with new parts, or a maximum of 0.46 mm (0.018 in.) with used parts.

16. Install the step-up gear, if used over the pilot on the right-bank camshaft gear with five 3/8 in.-24 lock bolts. Refer to section 1.26.5.

NOTE:
Ensure the lip on the step-up gear is seated squarely in the pilot diameter ring groove in the camshaft gear before tightening the bolts.

17. Tighten the bolts to 68-81 N·m (50-60 lb·ft) torque.

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18. Check the backlash between the mating gears. The specified backlash between new gears is 0.05-0.20 mm (0.002-0.008 in.), or a maximum of 0.25 mm (0.010 in.) between worn gears.
19. Install the parts, accessories or assemblies (such as balance weight cover and camshaft vibration damper) that were removed from the engine.
20. Install the front balance weight cover. Refer to section 1.32.3.
21. Install the water pump. Refer to section 4.2.5.
22. Install the flywheel housing. Refer to section 1.19.3.
23. Install the flywheel. Refer to section 1.16.5.
24. Install the cylinder heads. Refer to section 1.3.5.
25. Refill the cooling system. Refer to section 13.12.2.

1.26.7 Installation of Camshaft and Bearing (Flywheel Housing and Transmission Installed)

Install the camshaft with the flywheel housing and transmission in place as follows:

NOTE:
On 12V and 16V engines, note the part number, listed in Table 1-11, listed in Table 1-12, and listed in Table 1-13, stamped on the camshaft before installing.

Part Number on Camshaft	Location of Camshaft in Cylinder Block (RH Engine)	Location of Camshaft in Cylinder Block (LH Engine)
5148795	Left-Bank Rear	Right-Bank Front
5148746	Right-Bank Rear	Left-Bank Front
5148747	Left-Bank Front	Right-Bank Rear
5148748	Right-Bank Front	Left-Bank Rear

Table 1-11 Camshaft Identification Chart 16V (Tumbled)

Part Number on Camshaft	Location of Camshaft in Cylinder Block (RH Engine)	Location of Camshaft in Cylinder Block (LH Engine)
5107758	Left-Bank Rear	Right-Bank Front
5107759	Right-Bank Rear	Left-Bank Front
5107760	Left-Bank Front	Right-Bank Rear
5107761	Right-Bank Front	Left-Bank Rear

Table 1-12 Camshaft Identification Chart 12V (Honed)

Part Number on Camshaft	Location of Camshaft in Cylinder Block (RH Engine)	Location of Camshaft in Cylinder Block (LH Engine)
5107306	Left-Bank Rear	Right-Bank Front
5107307	Right-Bank Rear	Left-Bank Front
5107308	Left-Bank Front	Right-Bank Rear
5107309	Right-Bank Front	Left-Bank Rear

Table 1-13 Camshaft Identification Chart 16V (Honed)

1. Install a Woodruff Key in the drive gear end of the camshaft. Insert the end into position from the engine front end.

NOTICE:
Use care not to damage the cam lobes when installing the camshaft.

2. Push the camshaft in until it slides into the rear end bearing.
3. Align the key in the shaft with the keyway in the drive gear, and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

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4. Remove the camshaft gear puller, spacers, and adaptor plate. Finger-tighten the gear retaining nut on the shaft.
5. Attach a new gasket to the front end bearing that includes an oil seal, and install the front end bearing (and spacer or spacer and oil seal) with the bolts and lock washers.
6. Lubricate the spacer with the polished outside diameter, and slide it in place on the left-bank camshaft. Tighten the bolts to 47-54 N·m (35-40 lb·ft) torque.
7. Install a Woodruff key in the front end of the camshaft.
8. Install either the pulley on the left-bank camshaft or the water pump drive gear and external weight on the right-bank camshaft.
9. Slip an internal tooth lock washer over the front end of the camshaft, and start the gear retaining nut on the camshaft. Tighten to 244-258 N·m (180-190 lb·ft).

NOTE:
On certain 6V and 8V left hand rotation engines, install a 9/16 in.-18 lock bolt and washer in the right-bank camshaft.

10. Block the crankshaft, between the crankshaft throw and the cylinder block to prevent rotation of the engine.
11. Tighten the restraining nuts at both ends of the camshaft to 407-441 N·m (300-325 lb·ft) torque.
12. Attach the hub, if used, to the water pump drive gear with three bolts, washers, and lock washers. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.
13. Revolve the camshaft intermediate bearings to align the bearing locking holes with the tapped cylinder block holes. Install the lock screws and tighten them to 20-27 N·m (15-20 lb·ft) torque.
14. Install the camshaft gear nut retainers with bolts and lock washers. Tighten the bolts to 47-53 N·m (35-39 lb·ft) torque (retainers not used with lock bolts).
15. Check the clearance between the thrust washer and the thrust shoulder of each camshaft.

NOTE:
The specified clearance is 0.08-0.38 mm (0.003-0.015 in.) with new parts, or a maximum of 0.46 mm (0.018 in.) with used parts.

16. Check the back lash between the mating gears.

NOTE:
The specified backlash between new gears is 0.05-0.20 mm (0.002-0.008 in.), or a maximum of 0.25 mm (0.010 in.) between worn gears.

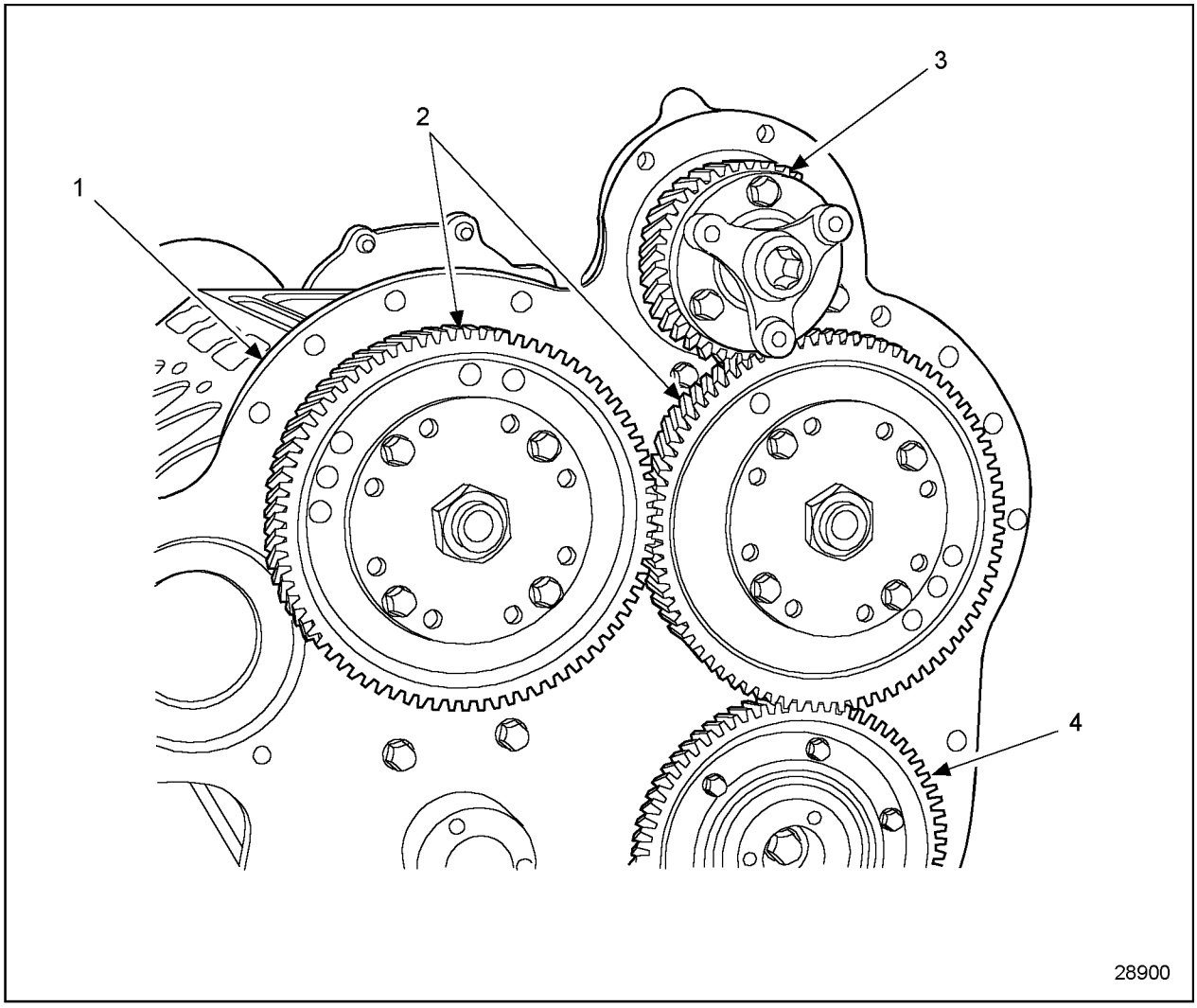
17. Install the parts, accessories, and assemblies that were removed.
18. Install the gear retaining nut or lock bolt and washer on both ends of the camshaft.
19. Install the camshaft gear nut retaining plate.

20. Install the front balance weight cover. Refer to section 1.32.3.
21. Install the cylinder head. Refer to section 1.3.5
22. Install the heat exchanger and all attaching parts. Refer to section 4.9.4
23. Install the radiator. Refer to section 4.6.3.
24. Refill the cooling system. Refer to section 13.12.

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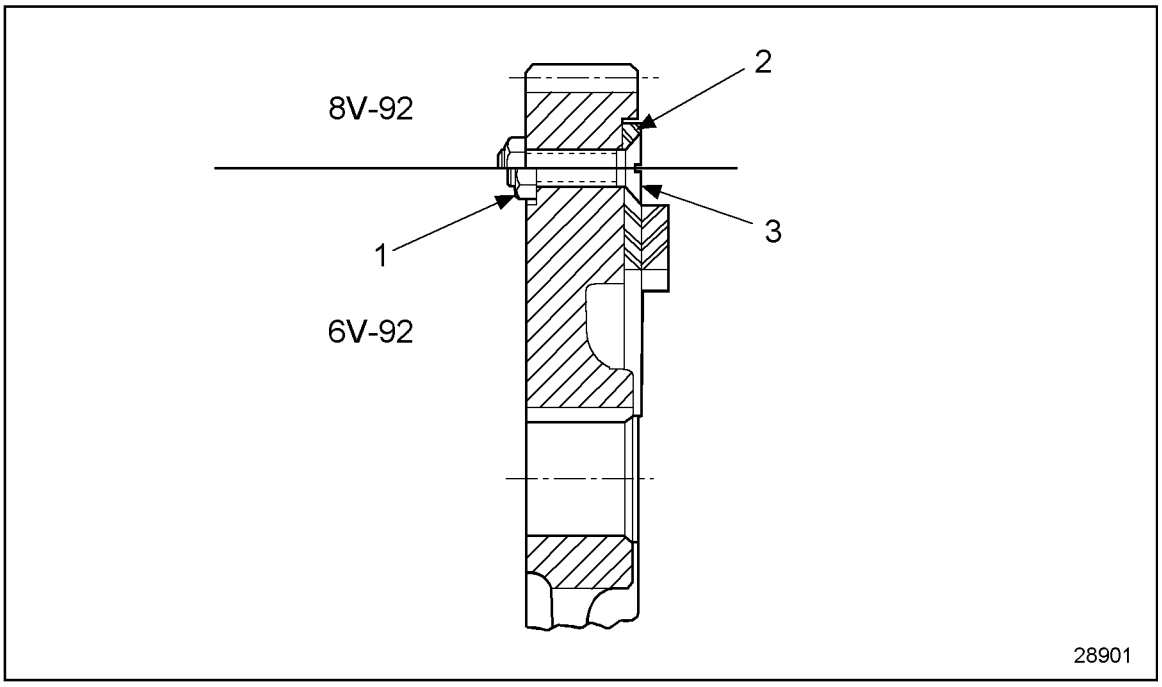
1.27 CAMSHAFT GEARS

The camshaft gears at the flywheel end of the engine mesh with each other and run at the same speed as the crankshaft timing gear through an idler gear, depending upon engine rotation. See Figure 1-205. When viewing the engine from the gear train end, the right-hand camshaft gear has right-hand helical teeth, and the left-hand camshaft gear has left-hand helical teeth. The idler gear mates with the right-hand camshaft gear on right-hand rotation engines, and the left-hand camshaft gear on left-hand rotation engines. Refer to section 1.28. See Figure 1-206.



1. Rear End Plate
2. Camshaft Gears
3. Blower Drive Gear
4. Idler Gear

Figure 1-205 Location of Camshaft Gears Mounted on Engine



1. Nut
2. Balance Weight
3. Screw

Figure 1-206 Difference in Camshaft Gear Weights 6V Vs. 8V

Since these gears must be in time with each other, timing marks are stamped on the rim of both camshaft gears, the idler gear, and the crankshaft gear.

The rear camshaft gears for the 6V and 8V engines are not interchangeable. The 8V gears are heavier than the 6V gears and, if installed on a 6V engine, will cause vibration in excess of the specified limits. Because of the difference in the integral balance weights size, the camshaft gears used on 16V engines are not interchangeable with those used on 6V or 8V engines.

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The 6V camshaft gears can be identified by cast markings "6V" and "92" opposite the center hole and two large round cast web holes through the gears. See Figure 1-207.

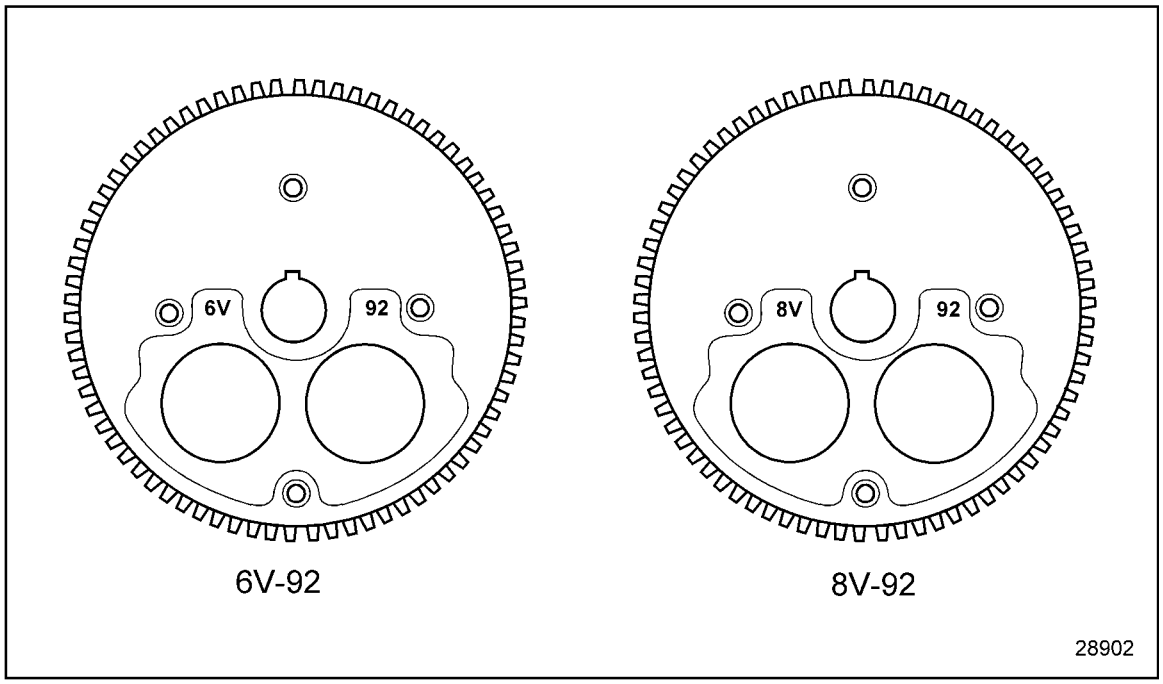


Figure 1-207 Identification of Camshaft Gears

The 8V camshaft gears can be identified by cast markings "8V" and "92" opposite web holes through the gear.

1.27.1 Repair or Replacement of Camshaft Gears

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-208.

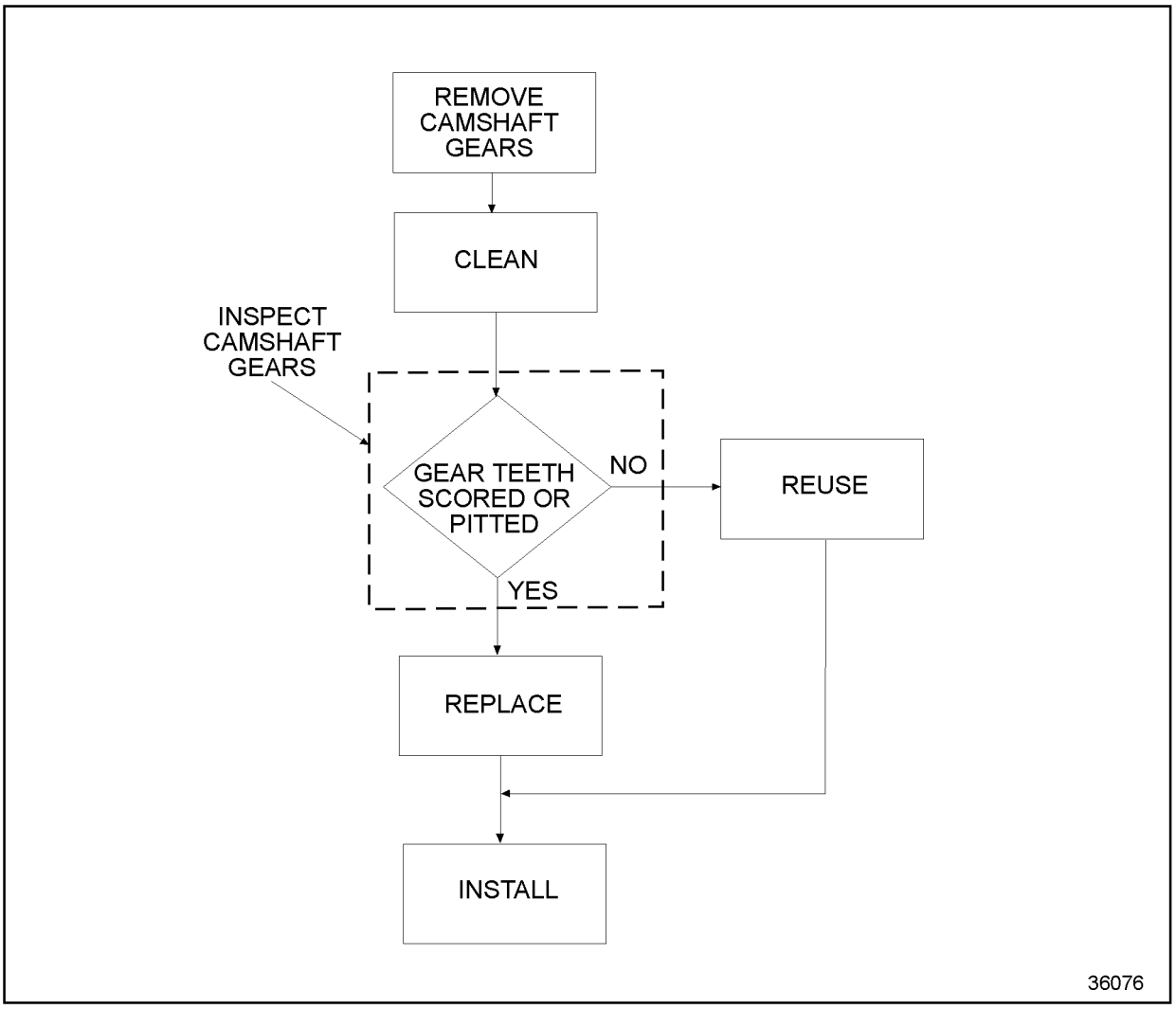


Figure 1-208 Flowchart for Repair or Replacement of Camshaft Gears

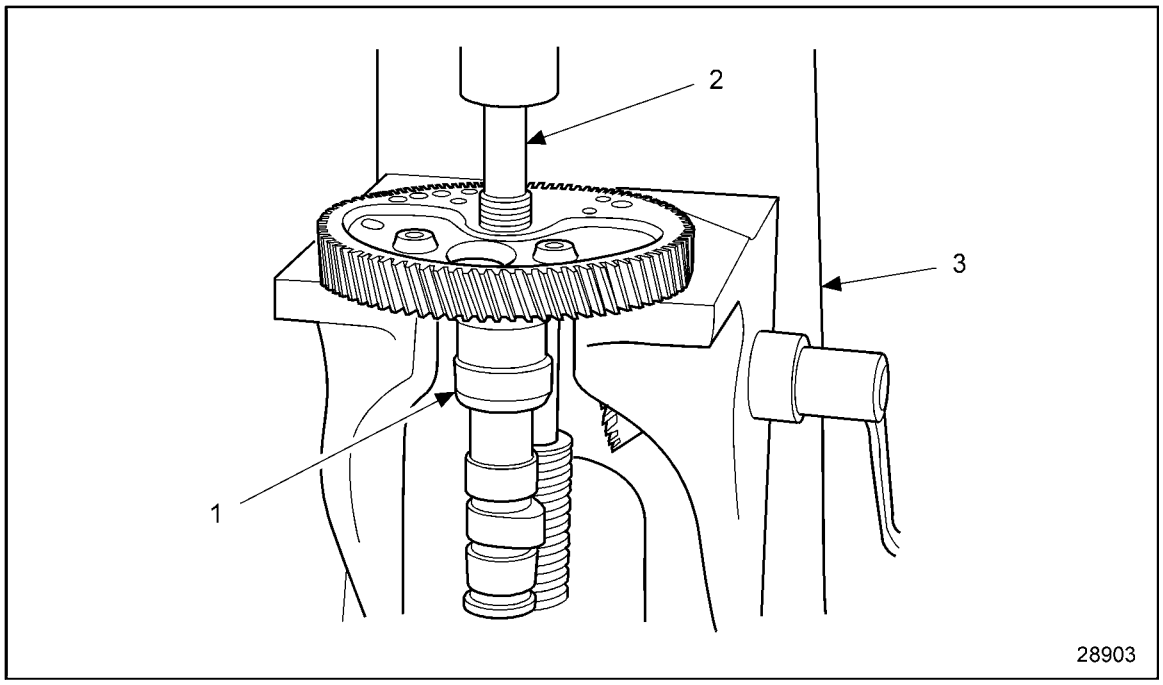
1.27.2 Removal of Camshaft Gear

Remove the camshaft gears as follows:

1. Remove the camshafts from the engine. Refer to section 1.26.2.

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2. Place one of the camshaft and gear assemblies in an arbor press. See Figure 1-209.



1. Camshaft Gear Assembly
2. Brass Rod
3. Arbor Press

Figure 1-209 Removing Camshaft Gear

3. Place a wooden block under the lower end of the camshaft to protect the threads.
4. Place a short, one-inch diameter brass rod on the end of the camshaft, and press the shaft out of the gear.

NOTE:
If an arbor press is not available, tool J 1902-B may be used to remove the gear from the camshaft.

5. Remove the Woodruff key from the camshaft, if necessary.
6. Place the second camshaft and gear assembly in the arbor press.

1.27.2.1 Cleaning of Camshaft Gear

Prior to inspection, clean the gears as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Clean the gears 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 gears with compressed air.

1.27.2.2 Inspection of Camshaft Gear

Inspect the camshaft gear as follows:

1. Visually inspect the gear teeth for scoring, pitting, or wear.
   [a] If excessively scored, pitted, or worn, replace the gears.
   [b] If not scored, pitted, or worn, reuse the camshaft gear.

NOTE:
The other gears in the gear train should also be inspected at this time.

1.27.3 Assembly of Camshaft Gears

If previously removed, install the camshaft rear end bearing and thrust washers on the camshaft as follows:

1. Apply grease to the steel face of each thrust washer, and place one washer at each end of the bearing. Ensure the steel face of each washer is next to the bearing.
2. Lubricate the bearing journal, and slide the bearing and thrust washers on the camshaft, with the bolting flange of the bearing toward the outer (gear) end of the shaft.

1.27.4 Installation of Camshaft Gears

Install the camshaft gear as follows:

1. Install a Woodruff key in the camshaft.

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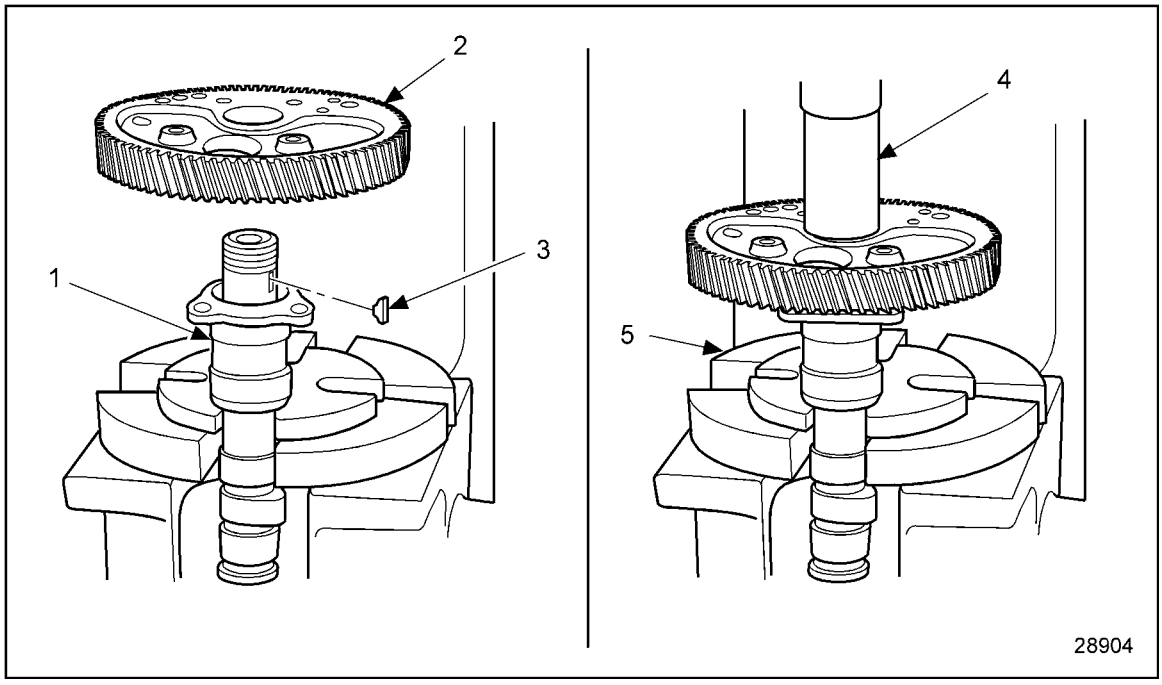
NOTICE:
Before installing a rear camshaft gear, observe the cast web holes identification. In addition, look for the "6V" or "8V" cast identification marks for proper gear installation.

2. Start the gear over the end of the camshaft, with the key in the shaft aligned with the keyway in the gear.

NOTE:
DDEC with advanced timing, install keys so the arrows point to each other.

3. With the camshaft supported in an arbor press, place a sleeve on top of the gear.
4. Press the gear tightly against the shaft shoulder. See Figure 1-210.

NOTE:
If an arbor press is not available, use tool J 1903 to install the gear on the camshaft.



1. Camshaft
2. Camshaft Gear
3. Woodruff Key
4. Sleeve
5. Arbor Press

Figure 1-210 Installing Camshaft Gear on Camshaft

5. Thread the camshaft gear retaining nut on the camshaft.
6. Tighten the nut after the camshaft is installed on the engine.
7. Repeat step 1 through step 6 to install the second camshaft.

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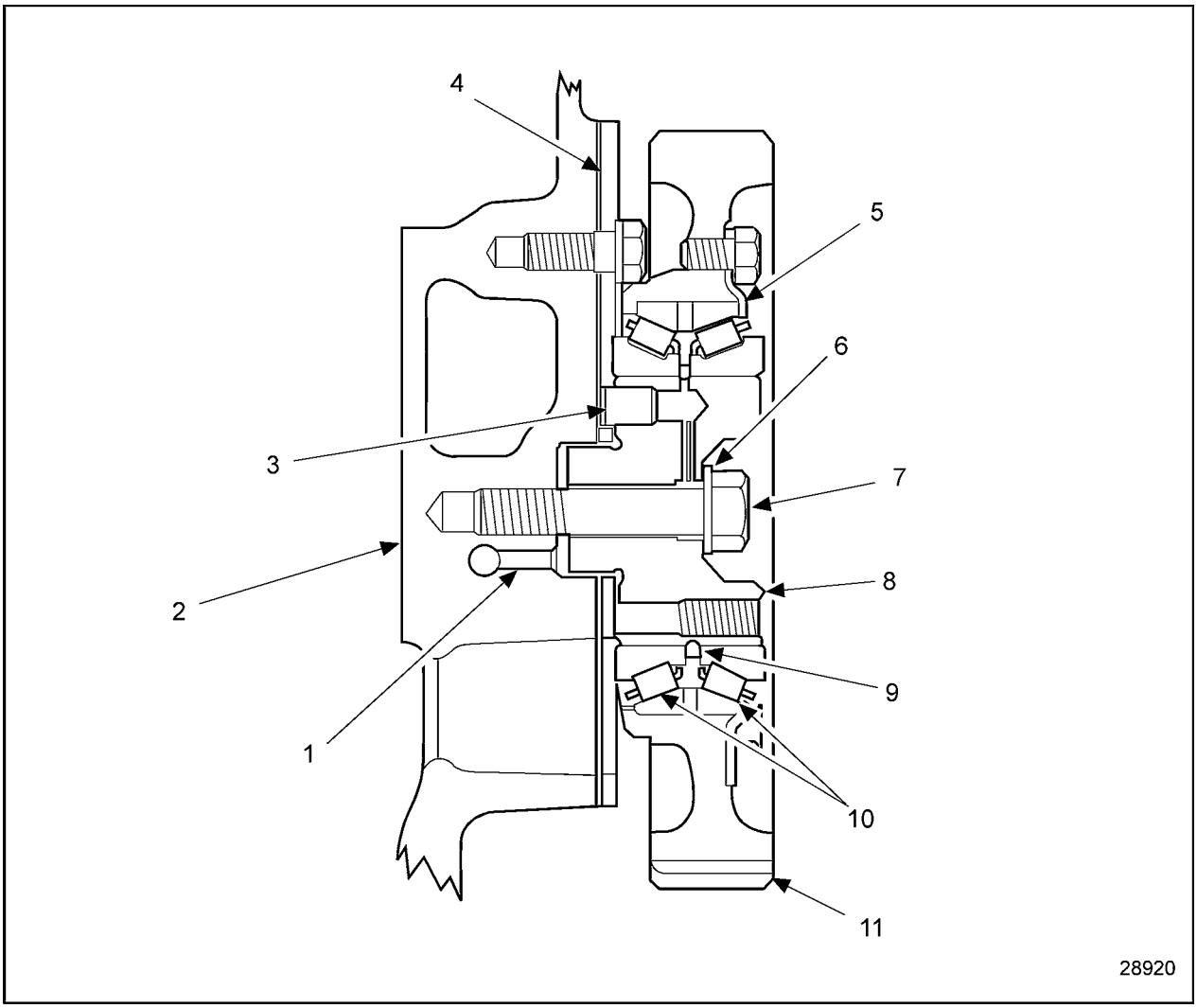
8. Install the camshaft and gear assemblies in the engine. Refer to section 1.26.6.
9. Tighten the camshaft gear retaining nuts after installed on engine.

NOTE:
The camshaft gears used on 12V and 16V engines are not interchangeable with those used on 6V or 8V engines due to the difference in the size of the integral balance weights.

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1.28 IDLER GEAR AND BEARING ASSEMBLY

The idler gear is mounted on a double-row, tapered roller bearing, that is supported on a stationary hub. See Figure 1-211. A bolt, that passes through the hub and rear end plate, secures the hub directly to the cylinder block. A dowel in the hub positions the hub and prevents it from rotating.



1. Oil Passage
2. Cylinder Block
3. Dowel (Hollow)
4. End Plate
5. Retainer Bearing
6. Special Washer
7. Bolt Hub-to-Block
8. Hub
9. Ring Spacer
10. Bearings
11. Idler Gear

Figure 1-211 Idler Gear Mounting

The idler gear is pressure lubricated by oil from the cylinder block rear cross oil gallery. Oil enters an opening between the cylinder block and the idler gear hub and circulates around the idler gear hub bolt, which has a smaller outside diameter than the inside diameter of the gear hub bolt hole. The oil is forced through a drilled passage in the gear hub to the roller bearing.

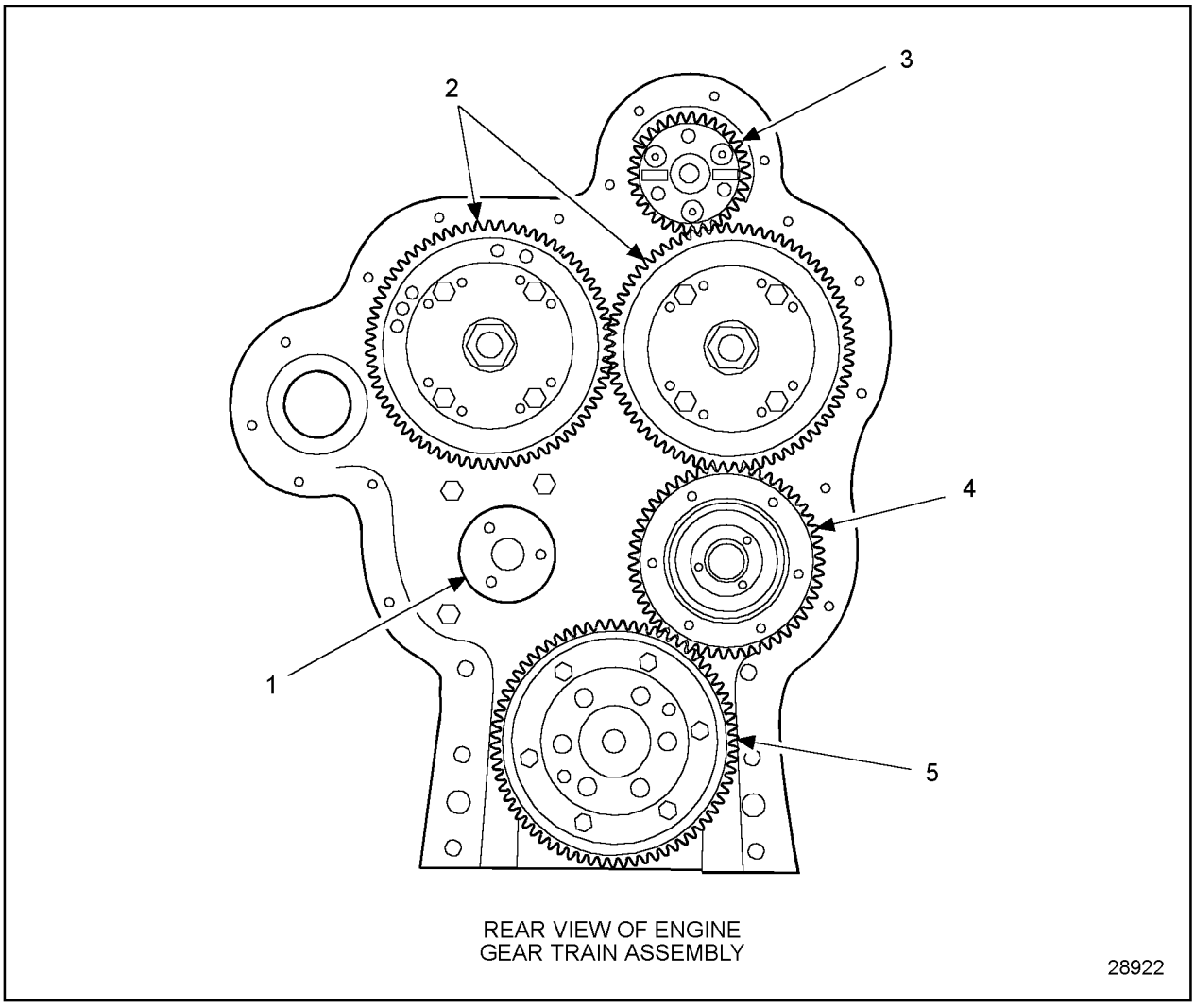
The idler gear bearing includes two cups, two cones and an outer and inner spacer ring.

The idler gear bearing cones are pressed onto the gear hub and do not rotate. Spacer rings separate the bearing cups and cones. The bearing cups are lightly press fit in the idler gear and are held against a flanged lip inside with idler gear on one side. A bearing retainer, secured with six lock bolts, holds the bearing cups on the other side.

A left-hand helix gear is provided for right-hand rotation engines, and a right-hand helix gear is provided for left-hand rotation engines. Refer to section 1.28.

An idler gear hole spacer (dummy hub) is used on the side opposite the idler gear.
See Figure 1-212.

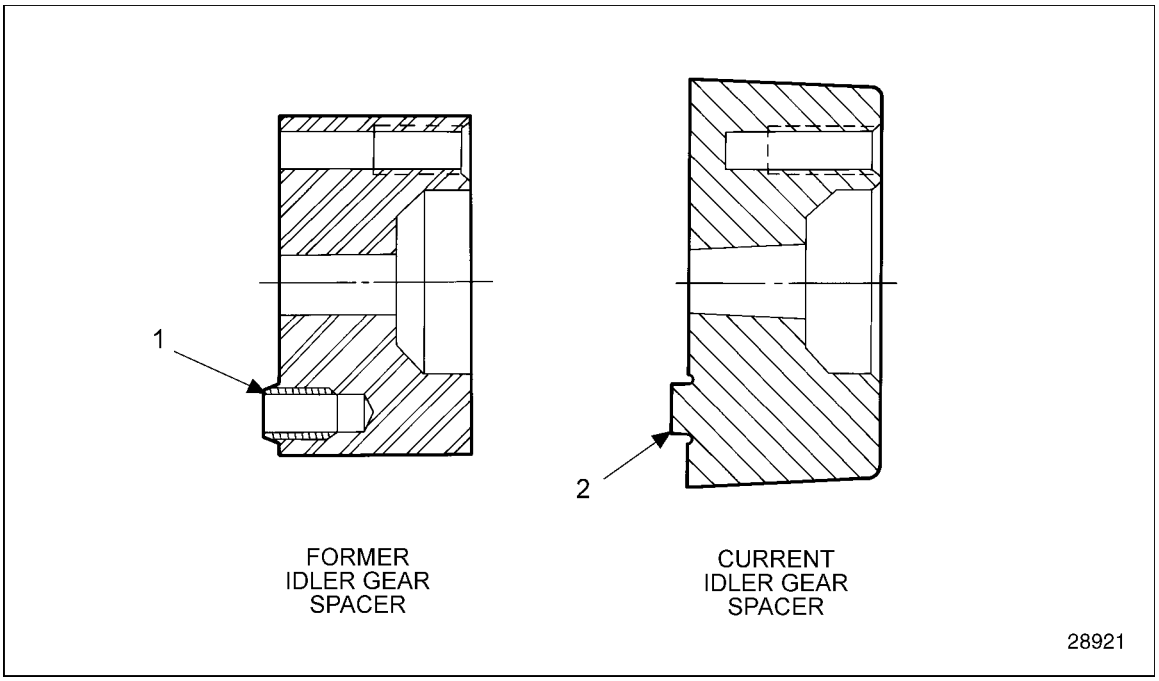
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1. Dummy Hub
2. Camshaft Gears
3. Blower Drive Gear
4. Idler Gear Assembly
5. Crankshaft Drive Gear

Figure 1-212 Location of Idler Gear and Dummy Hub

NOTE:
On some engines, the idler gear hole spacer is integrally cast in the flywheel housing, on the side opposite the idler gear. See Figure 1-213.

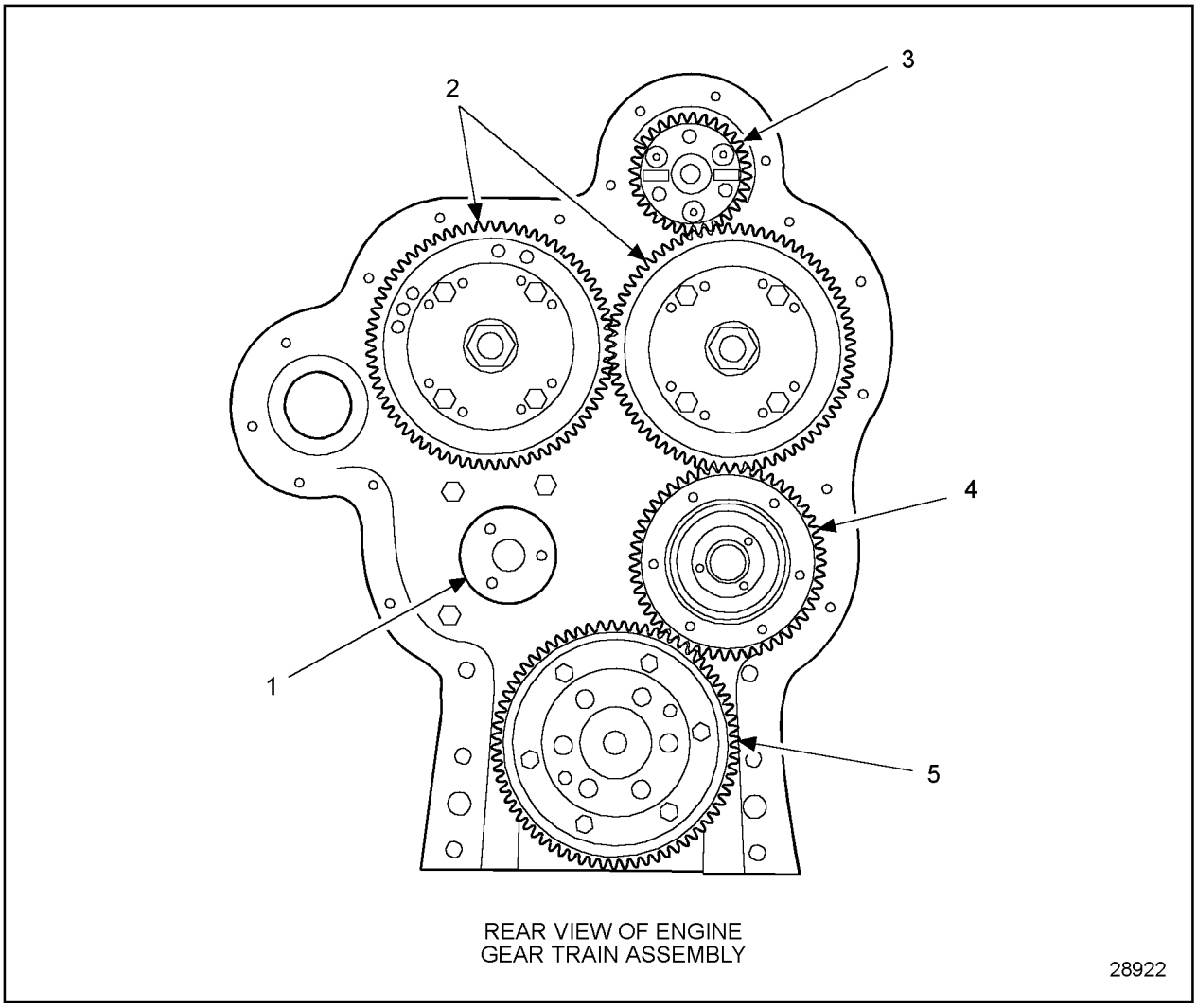


1. Dowel
2. Integral Dowel

Figure 1-213 Idler Gear Spacer

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To minimize oil leakage into the flywheel housing, the current idler gear spacer (dummy hub) is used in engines not equipped with an integral idler gear spacer type flywheel housing. See Figure 1-214.



1. Dummy Hub
2. Camshaft
3. Blower Drive
4. Idler Gear Assembly
5. Crankshaft Drive Gear

Figure 1-214 Location of Idler Gear and Dummy Hub

The former and current spacers are interchangeable. Only the new spacer will be serviced. The new flanged hex head bolts with a self locking sealing patch should be used with the new spacer. They can be used with the former spacer or at the idler gear position. Do not use a flat washer under the new flanged head bolts.

NOTE:
The service idler gear assemblies do not include the current "seal patch" bolts. The flat washer has been deleted. At the time of rebuild the new bolts should be used to minimize oil leakage into the flywheel housing.

Whenever the sealant patch bolts are removed, they should be replaced with new sealant patch bolts at the idler gear spacer and idler gear positions.

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1.28.1 Repair or Replacement of Idler Gear and Bearing Assembly

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-215.

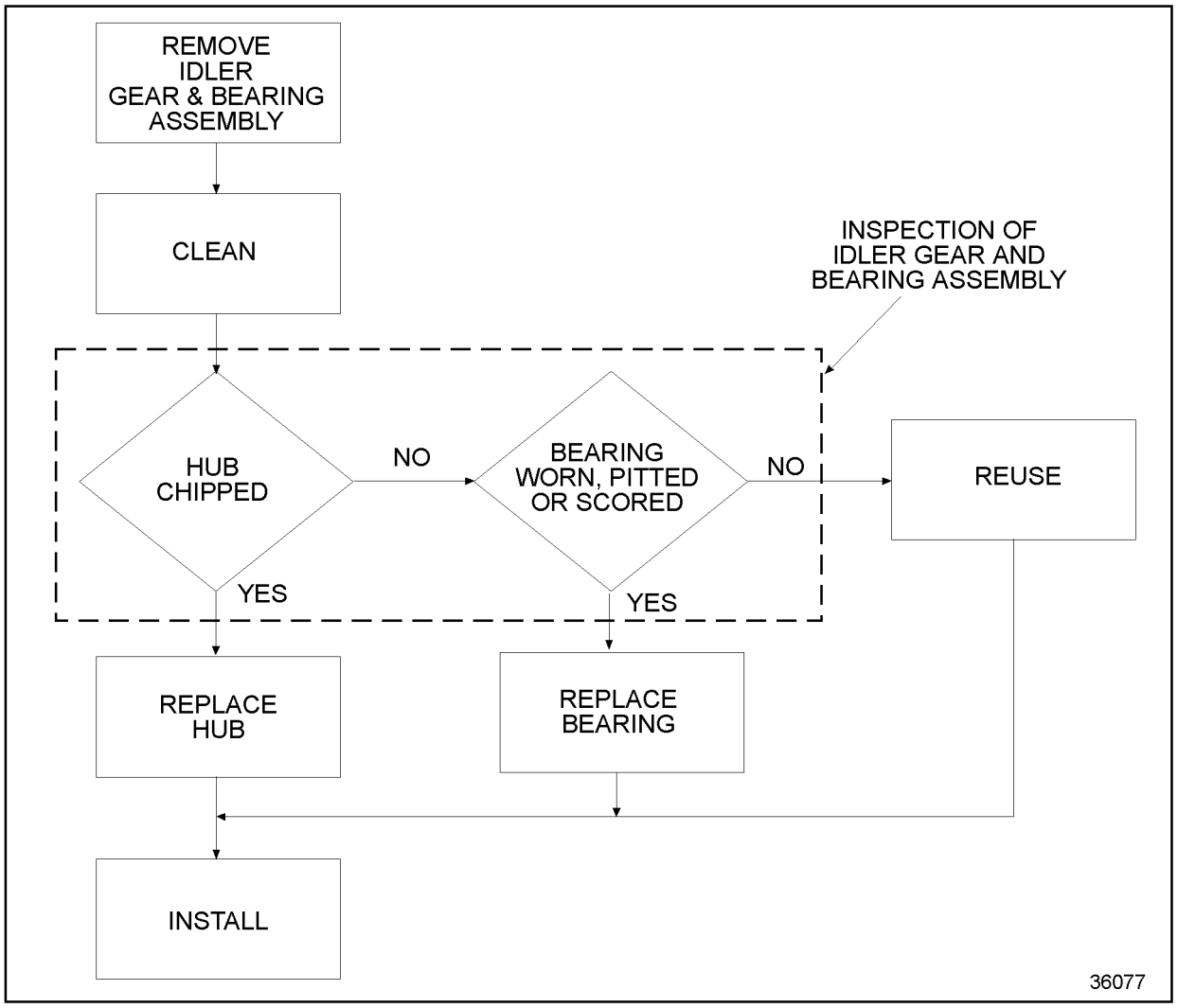


Figure 1-215 Flowchart for Repair or Replacement of Idler Gear and Bearing Assembly

1.28.2 Removal of Idler Gear and Bearing Assembly

Remove the idler gear, hub and bearing assembly as follows:

1. Remove the flywheel housing. Refer to section 1.19.2.

NOTE:
Before removing the idler gear, check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure is applied. Firmly grasp the gear rim with both hands, and rock the gear in relation to the bearing. The bearing must be replaced

if the gear wobbles or shakes. If the gear assembly is satisfactory, check the preload before installation.

2. Remove the idler gear hub to cylinder block bolt and special washer. Withdraw the assembly from the cylinder block rear end plate.
3. If necessary, remove the idler gear hole spacer (dummy hub).

1.28.3 Disassembly of Idler Gear and Bearing Assembly

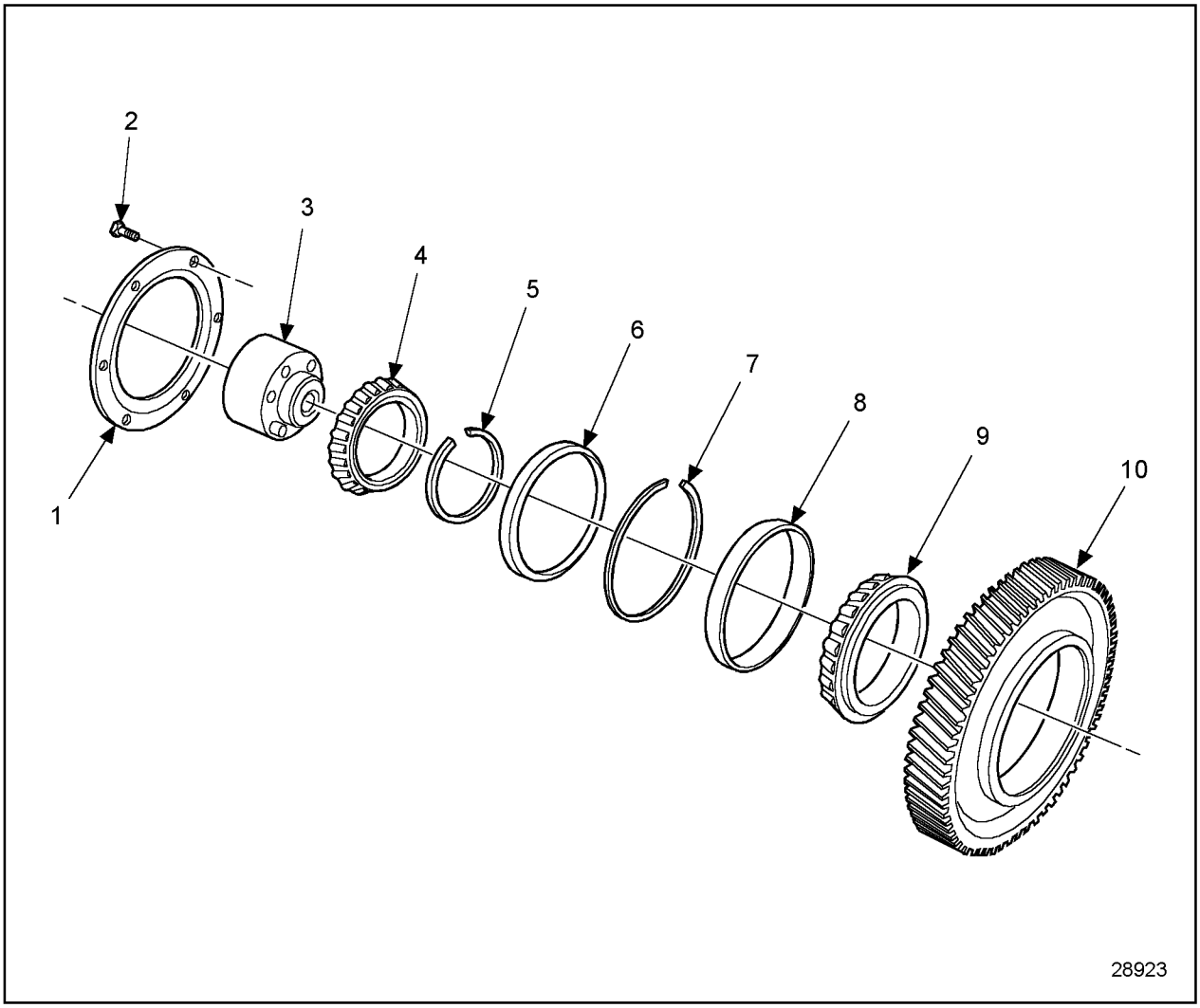
Disassemble the idler gear, hub, and bearing assembly as follows:

NOTICE:
Rotate the bearing to avoid the possibility of damaging it or brinelling the bearing cones.

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1. Remove the six bolts and three bolt locks, if used, that secure the bearing retainer to the idler gear. Remove the bearing retainer. See Figure 1-216.

NOTE:
Matchmark the parts during disassembly to ensure part reassembly in their original positions.



1. Bearing Retainer
2. Lock Bolt
3. Idler Gear Hub
4. Bearing Cone (Outer)
5. Spacer Ring (Inner)
6. Bearing Cup (Outer)
7. Spacer Ring (Outer)
8. Bearing Cup (Inner)
9. Bearing Cone (Inner)
10. Idler Gear

Figure 1-216 Disassembly of Idler Gear and Related Parts

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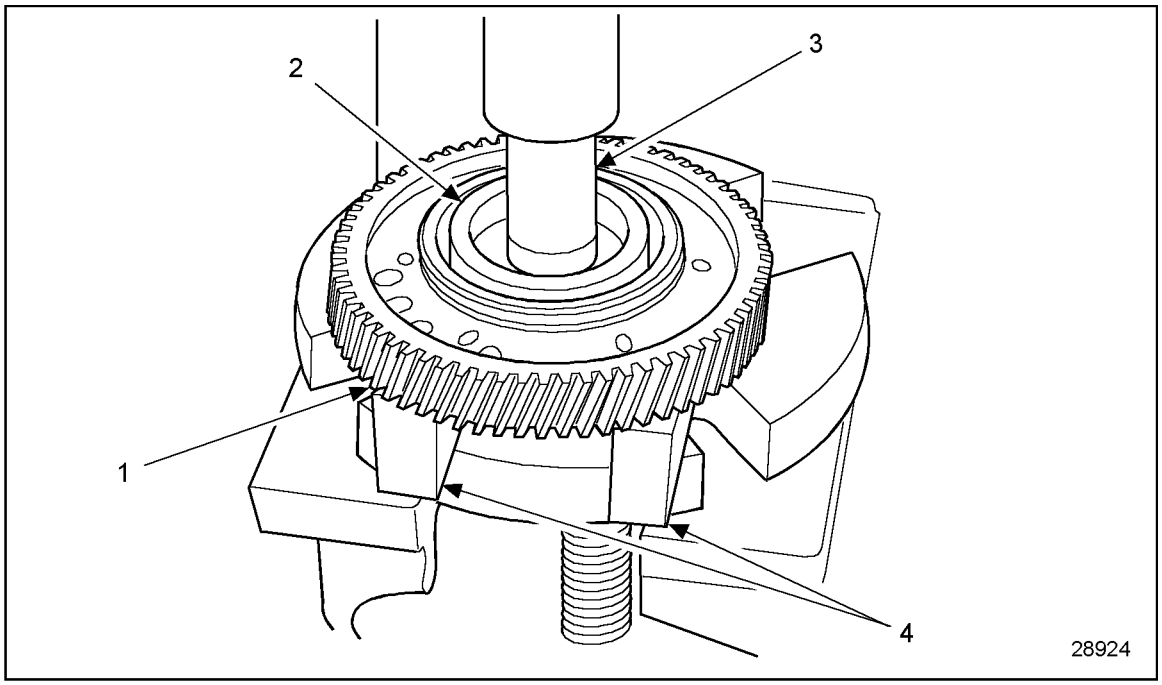
⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

⚠ 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. Clean the idler gear assembly with fuel oil, and dry it with compressed air.
3. Place the idler gear assembly in an arbor press, with the inner bearing cone supported on steel blocks. See Figure 1-217.



1. Idler Gear
2. Hub
3. Arbor Press
4. Support Blocks

Figure 1-217 Pressing Hub Out of Idler Gear Bearing

4. While rotating the idler gear assembly, press the hub out of the bearing.

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5. Remove the gear assembly from the arbor press, and remove the bearing cones and spacer rings.

NOTE:
Unless the bearing assembly is to be replaced, the inner and outer bearing cups should not be removed from the idler gear. If the cups are loose in the gear bore or the bore is worn, the bearing assembly and gear should be replaced.

6. Tap the bearing cups from the idler gear. Use a brass drift alternately at the four notches provided around the gear shoulder.

1.28.3.1 Cleaning of Idler Gear and Bearing Assembly

Prior to inspection, clean the idler gear, hub, and bearing components as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash the idler gear, hub, and bearing components 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 the parts with compressed air.

1.28.3.2 Inspection of Idler Gear and Bearing Assembly

Inspect the idler gear and bearing assembly as follows:

1. Visually inspect the idler gear hub for chips or foreign material in the holes.
   [a] If chipped, replace the idler gear hub.
   [b] If foreign material is in the holes, clean the idler gear hub.
   [c] If not chipped and no foreign material is in the holes, continue inspection.
2. Visually inspect the bearing for wear, pitting, scoring, or flat spots on the rollers or cones.
   [a] Replace the bearing if it is defective.
   [b] If none of the above conditions exist, continue inspection.
3. Visually inspect the gear teeth for scoring, pitting and wear.

[a] If severely damaged or worn, replace the gear.

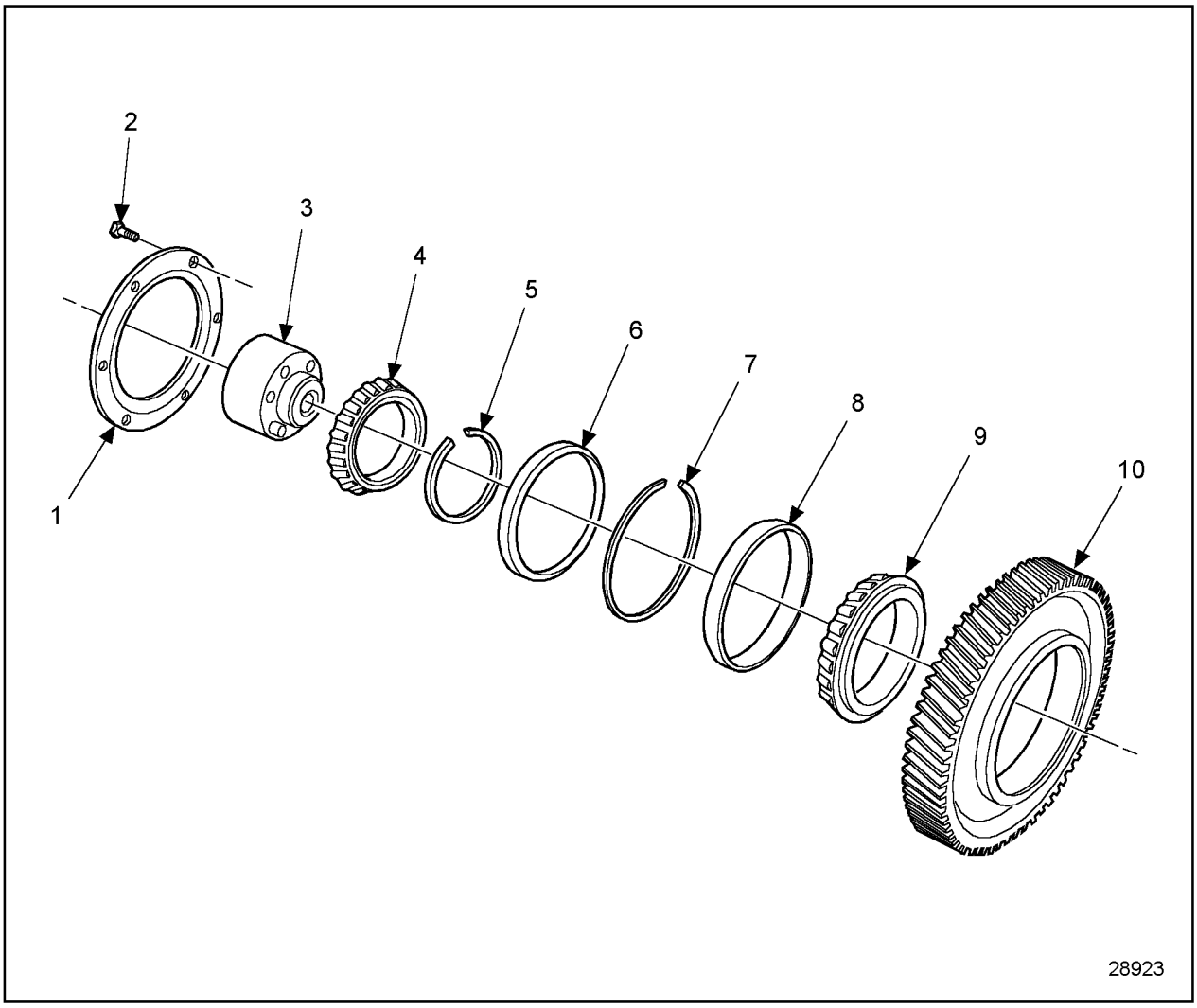
NOTE:
If a damaged gear is detected, refer to step 1 and repeat inspection procedure for the other gears in the gear train.

[b] If not scored, pitted, or worn, reuse the idler gear and bearing assembly. Refer to section 1.28.4.

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1.28.4 Assembly of Idler Gear and Bearing Assembly

Assemble the idler gear, hub, and bearing as follows. See Figure 1-218.



1. Bearing Retainer
2. Lock Bolt
3. Idler Gear Hub
4. Bearing Cone (Outer)
5. Spacer Ring (Inner)
6. Bearing Cup (Outer)
7. Spacer Ring (Outer)
8. Bearing Cup (Inner)
9. Bearing Cone (Inner)
10. Idler Gear

Figure 1-218 Idler Gear and Related Parts

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1. Assemble the bearing components in their original positions. Refer to the identification marks made during disassembly.

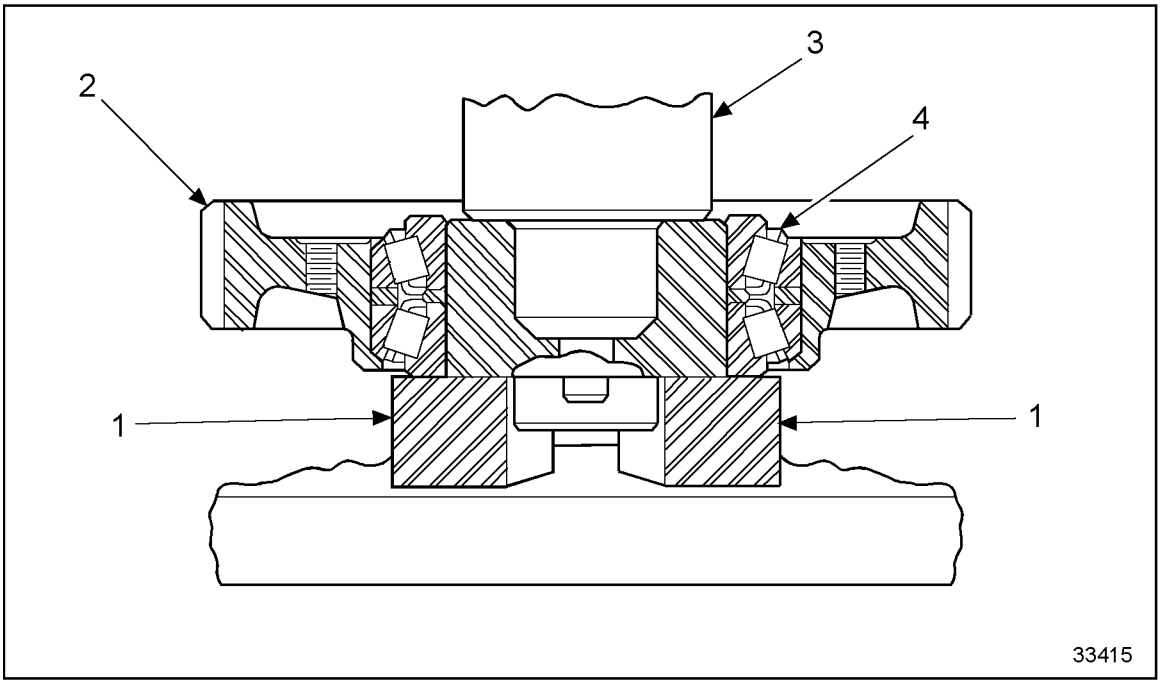
NOTE:
The idler gear bearing is a matched assembly. Do not mix the components with another bearing assembly.

2. Support the idler gear, shoulder down, on the bed of an arbor press.
3. Start one of the bearing cups, numbered side up, squarely into the gear bore.
4. Use the preload test plate between the ram of the press and the bearing cup to press the bearing cup against the gear shoulder.
5. Lay the outer spacer ring on the bearing cup face.
6. Start the other bearing cup, numbered side down, squarely into the gear bore.
7. Use the preload test plate between the press ram and the bearing cup to press the cup tightly against the spacer ring.
8. Use the preload test plate (with the large center hole) between the press ram and the bearing to press the inner bearing cone, numbered side up, on the idler gear hub, flush with the inner hub mounting face.
9. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180 degrees from the gap in the inner spacer ring.
10. Position the gear with both cups over the hub and the inner bearing cone.

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11. Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers between the cones.

NOTE:
The bearing cones must be supported so as not to load the bearing rollers during this operation. See Figure 1-219.



1. Parallel Bar
2. Hub Gear
3. Arbor Press Ram
4. Bearing Assembly

Figure 1-219 Pressing Hub into Idler Gear Bearing

1.28.4.1 Cleaning Idler Gear and Bearing Pre-Load

Prior to checking the idler gear and bearing preload clean components as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Clean and lubricate the idler gear bearing with light engine oil.
2. Idler gear assemblies that include new bearings should be "worked in" as follows:
   [a] Grasp the gear firmly in hand.
   [b] Rotate the gear back and forth several times.

3. Check the bearing to ensure that the gear may be rotated on its bearing without exceeding the maximum torque specifications. It should not permit the hub to tilt, wobble, or shake the gear.

1.28.4.2 Testing of Idler Gear and Bearing Assembly Pre-Load

The rollers in the bearing are loaded between the bearing cup and the bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be tightly held between the cones and the cup. A selected spacer ring between the bearing cones applies a slight preload to provide gear and bearing assembly rigidity when it is mounted on its hub. The effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones is the preload measure in terms of "pounds pull."

Any time an idler gear assembly has been removed from an engine for servicing or inspection, the preload should be measured.

If the mating crankshaft and camshaft gears are not already mounted on the engine, mount the idler gear on the engine to check the torque required to rotate the idler gear. Use a preload test plate against the hub and cone as follows:

1. Mount the idler gear assembly on the engine.
2. Install the center bolt and washer through the gear hub, and thread it into the cylinder block.
3. Tighten the bolt to 108-122 N·m (80-90 lb·ft) torque.

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4. Place the steel plate against the hub and bearing. See Figure 1-220.

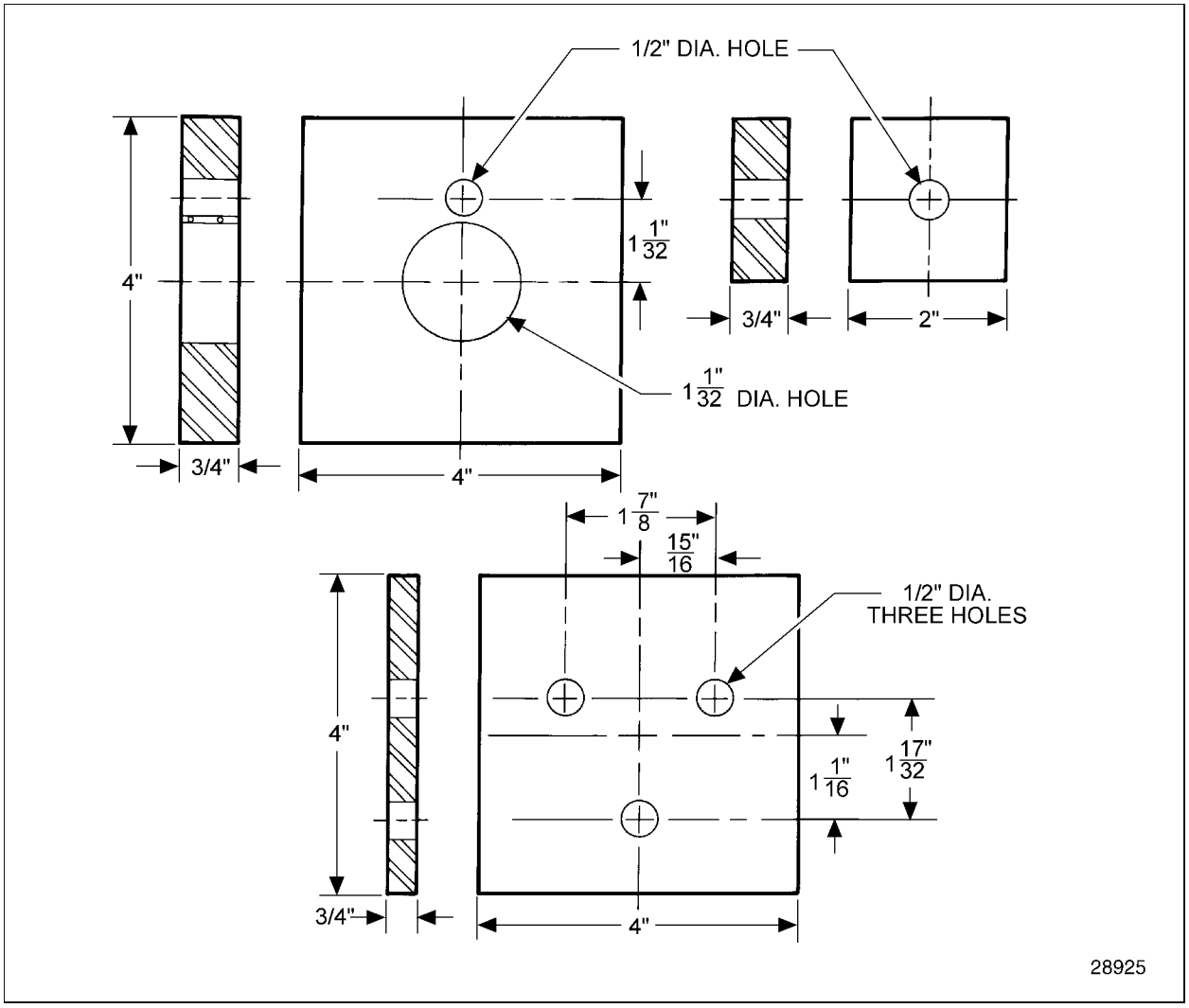
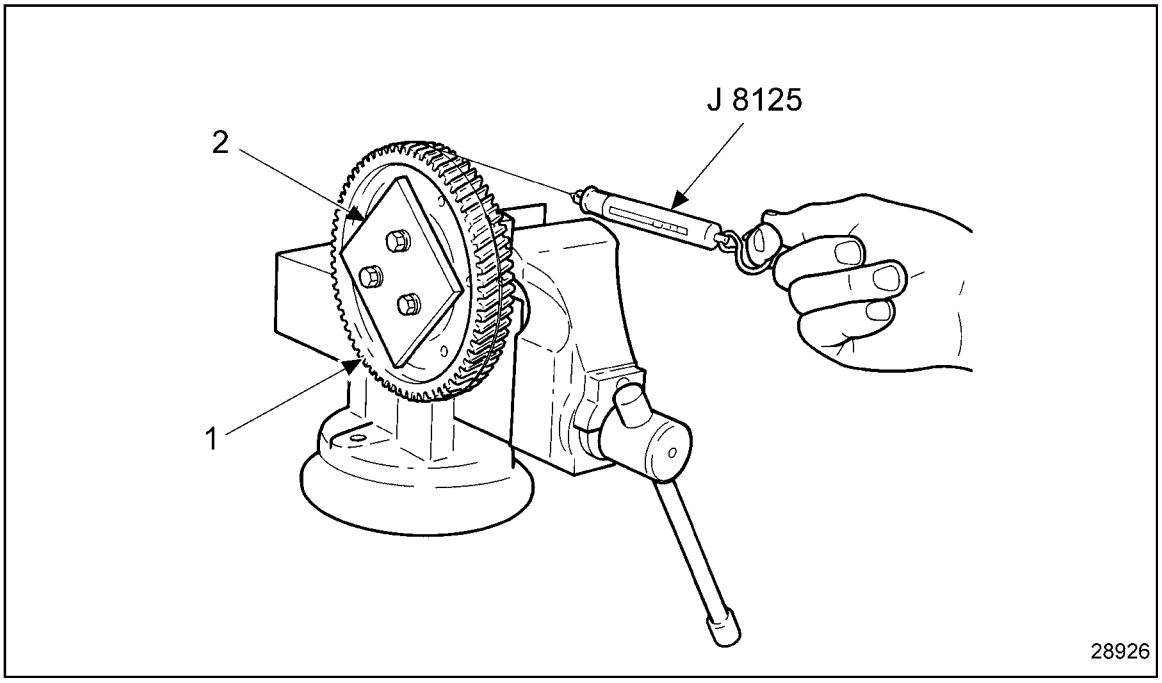


Figure 1-220 Plates for Bearing Test Fixture and Bearing Cone Installation

5. Insert three 3/8 in.-16 bolts through the plate, and thread them into the hub.
6. Tighten the bolts to 34-54 N·m (25-40 lb·ft) torque.
7. Tie one end of a piece of lintless 1/8 in. cord around a 1/8 in. round piece of wood or soft metal stock.
8. Place the wood between two of the gear teeth, and wrap the cord around the periphery of the gear several times.

9. Attach the other end of the cord to a spring scale J 8129. See Figure 1-221.



1. Idler Gear
2. Pre-Load Test Plate

Figure 1-221 Checking Idler Gear Pre-Load

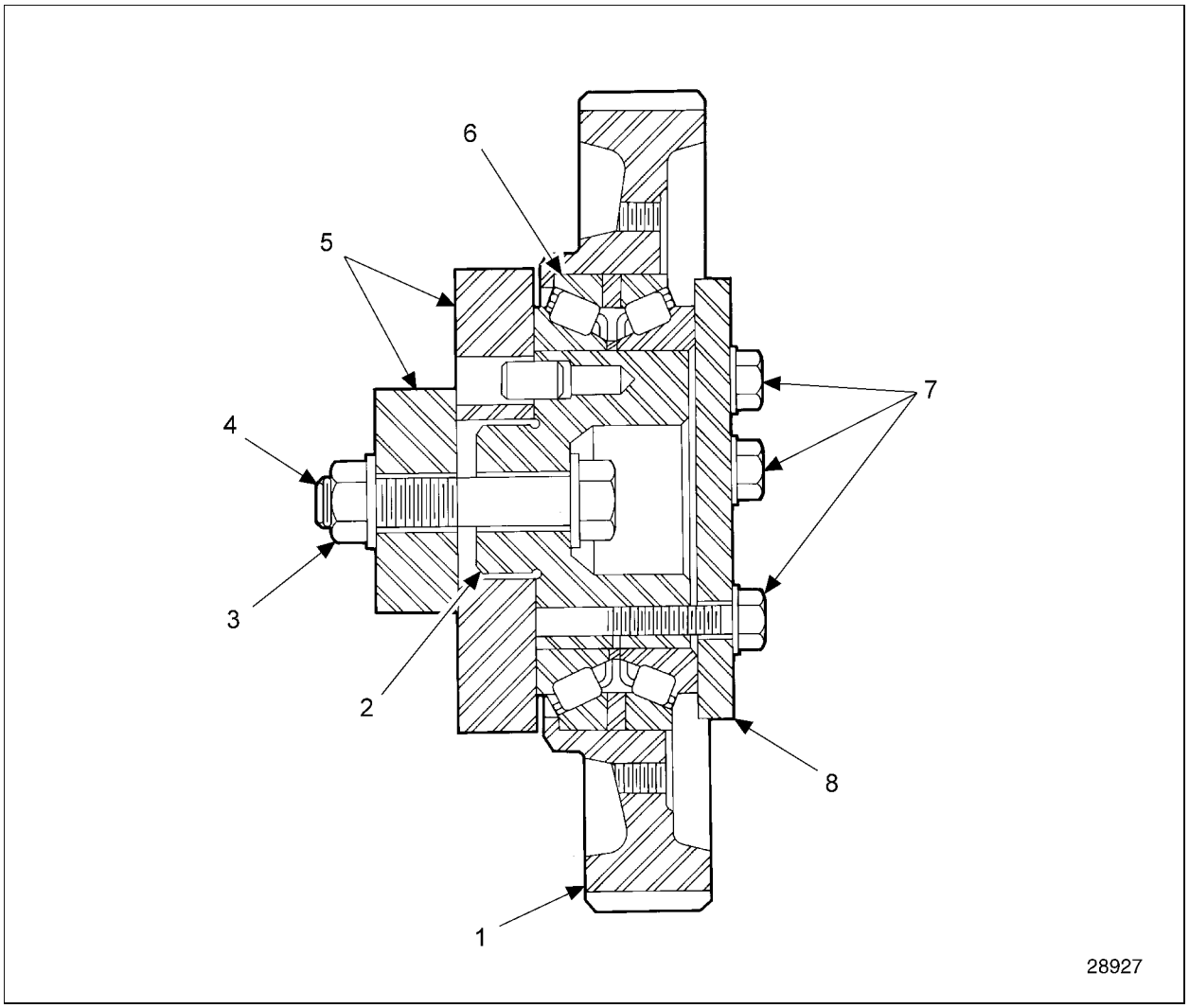
10. Maintain a straight steady pull on the cord and scale, 90 degrees to the axis of the hub.

NOTE:
Observe the pull, in pounds and ounces, required to start rotating the gear.

11. Make several checks to obtain an average reading.
12. If the pull is within 1/2 lb. minimum to 4 lbs. maximum, and does not fluctuate more than 2 lbs. 11 oz., the idler gear and bearing assembly are satisfactory for use.If the

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crankshaft and camshaft gears are mounted on the engine, make a suitable fixture that can be held in a vise as follows. See Figure 1-222.



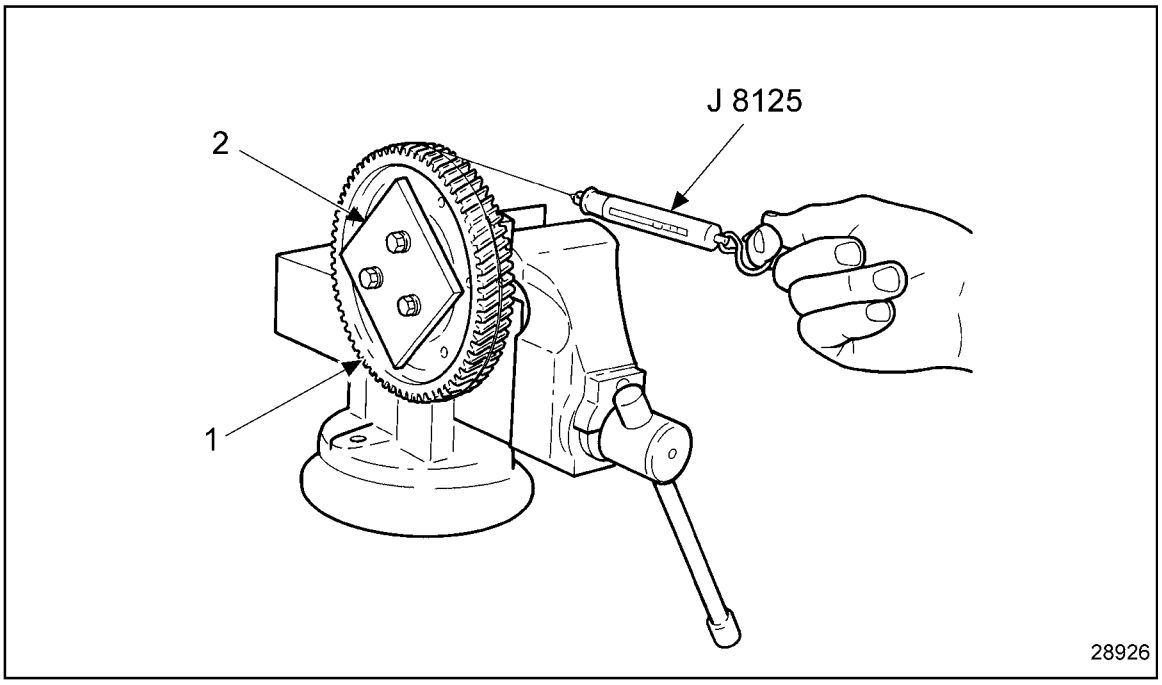
1. Idler Gear
2. Idler Gear Hub
3. Nut
4. Bolt
5. Clamp Plates
6. Bearing Assembly
7. Flywheel Housing-to-Hub Bolts
8. Clamp Plate

Figure 1-222 Fixture For Test Bearing Pre-Load

13. Use three plates, a 1/2 in.-13 x 2-3/4 in. bolt, and a plain washer with a 1/2 in.-13 nut and plain washer for mounting.

NOTE:
One of the plates is used to take the place of the flywheel housing, and the other two plates take the place of the cylinder block.

14. Tighten the nut to 108-122 N·m (80-90 lb·ft) torque, and tighten the three plate-to-hub attaching bolts to 34-54 N·m (25-40 lb·ft) torque to simulate "engine-mounted" conditions.Check the preload on the bearings, as follows:
15. Attach two upper plates to the idler gear hub with the 1/2 in.-13 bolt, washers, and nut.
16. Tighten the bolt to 107-120 N·m (80-90 lb·ft) torque.
17. Attach the third plate to the idler gear hub with three 3/8 in.-16 bolts.
18. Tighten the bolts to 34-54 N·m (25-40 lb·ft) torque.
19. Clamp the idler gear assembly and fixture in a vise. See Figure 1-223.



1. Idler Gear
2. Pre-Load Test Plate

Figure 1-223 Checking Idler Gear Pre-Load

20. Attach a cord to the idler gear and spring scale.
21. Tie one end of a piece of lintless 1/8 in. cord around a 1/8 in. round piece of wood or soft metal stock.
22. Place the wood between two of the gear teeth, and wrap the cord around the periphery of the gear several times.
23. Attach the other end of the cord to a spring scale J 8129.
24. Maintain a straight steady pull on the cord and scale, 90 degrees to the axis of the hub.

NOTE:
Observe the pull, in pounds and ounces, required to start rotating the gear.

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25. Make several checks to obtain an average reading.
26. If the pull is within 1/2 lb. minimum to 4 lbs. maximum, and does not fluctuate more than 2 lbs. 11 oz., the idler gear and bearing assembly are satisfactory for use.
27. If the scale reading is within the 1/2 to 4 lbs. specified, but fluctuates more than 2 lbs. 11 ounces, the idler gear and bearing assembly must NOT be installed on the engine.

NOTE:
Cones not concentric to each other, damaged cones or rollers, or dirt or foreign material within the bearings can cause fluctuations in scale readings. The bearing should be inspected for the fluctuation cause. Repair or replace the bearing. A scale reading that exceeds the specified maximum indicates bearing roller bind, or improperly installed rollers. When the scale reading is less than the specified minimum, the bearing is more likely worn and should be replaced.

After the preload check is completed, proceed as follows:

NOTICE:
Do not use standard bolts, and do not use the former bolt locks.

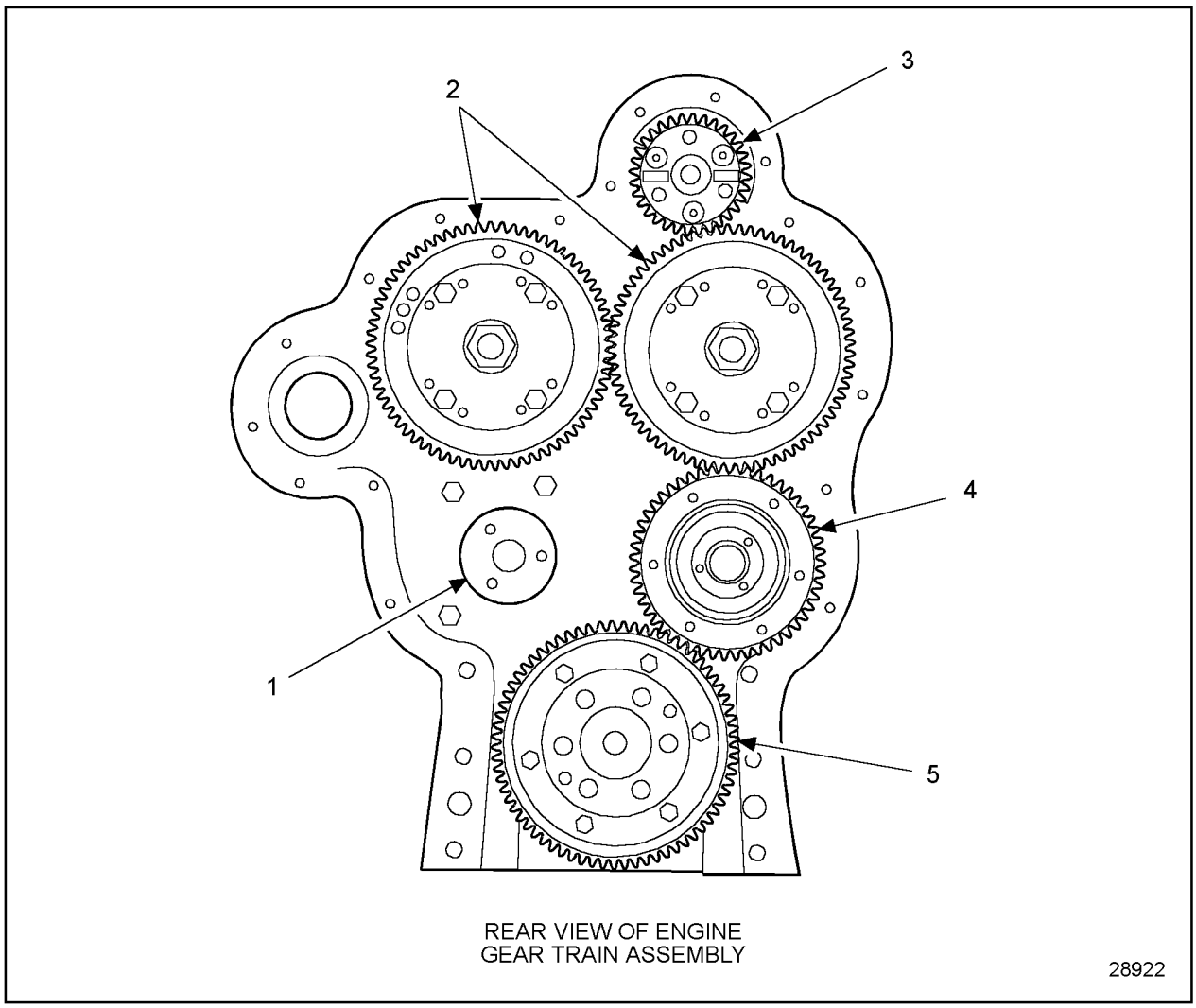
28. Remove the steel plates, and install the bearing retainer.
29. Attach the bearing retainer to the idler gear with six new lock bolts. Because the lock bolts are coated with a locking compound, always use new lock bolts when assembling the idler gear.
30. Tighten the bolts to 33-39 N·m (24-29 lb·ft) torque.

1.28.5 Installation of Idler Gear and Bearing Assembly

Install the idler gear, hub, and bearing assembly as follows:

1. Align the crankshaft gear and camshaft gear timing marks with those on the idler gear. Refer to section 1.29.7.
2. With these marks aligned, mesh the idler gear with the crankshaft gear and camshaft gear, and simultaneously rotate the gear hub so the dowel in the hub registers with the hole in the end plate.
3. Roll the idler gear into position, and align the hollow dowel with the oil hole in the end plate.
4. Tap the hub until it seats against the end plate.
5. After ensuring hub is tight against the end plate, secure the idler gear assembly with the 1/2 in.-13 bolt and special washer. Tighten the bolt to 108-122 N·m (80-90 lb·ft) torque.

6. If previously removed, install the idler gear hole spacer (dummy hub). See Figure 1-224.



1. Dummy Hub
2. Camshaft Gears
3. Blower Drive Gear
4. Idler Gear Assembly
5. Crankshaft Drive Gear

Figure 1-224 Location of Idler Gear and Dummy Hub

7. Secure the spacer to the cylinder block end plate and cylinder block with a 1/2 in.-13 bolt and special washer. Tighten the bolt to 108-122 N·m (80-90 lb·ft) torque.

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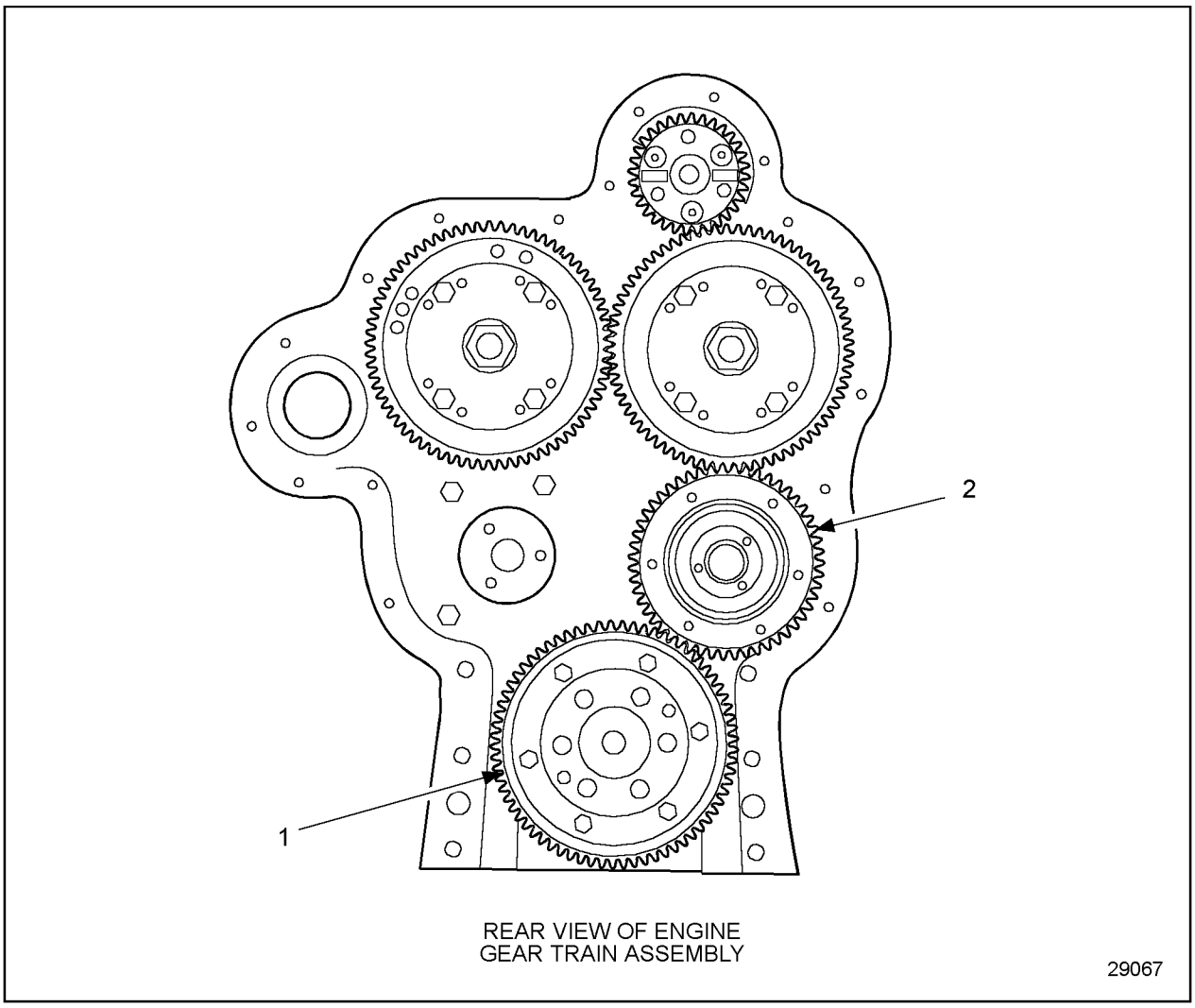
CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

8. Lubricate the idler gear bearing and gear teeth liberally with clean engine oil.
9. Check the backlash between the mating gears. The backlash must be 0.05-0.20 mm (0.002-0.008 in.) between new gears and must not exceed 0.25 mm (0.010 in.) between worn gears.
10. Install the flywheel housing. Refer to section 1.19.3.

1.29 CRANKSHAFT TIMING GEAR

The crankshaft timing gear is bolted to the flange at the rear end of the crankshaft and drives the camshaft gears and the blower drive gear through an idler gear. See Figure 1-225. On 12V and 16V engines, two crankshaft timing gears are on the crankshaft. The rear crankshaft gear is attached to the flange at the rear of the crankshaft. The lubricating oil pump drive gear is attached to the rear crankshaft gear. The front crankshaft gear assembly (gear and bushing) is attached to a damper assembly mounted on the flange at the front of the crankshaft.



1. Crankshaft Timing Gear
2. Idler Gear

Figure 1-225 Crankshaft Timing Gear Mounting (RH Rotation Engine Shown)

Since the two camshafts must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft gears. Refer to section 1.29.7.

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Current crankshafts and crankshaft timing gears replaced the former crankshafts and timing gears effective with engine serial numbers 6VF0123940, 8VF098671, 12VF002032, and 16VF006468. The current timing gears have a hole drilled in their bolt flanges. This hole provides clearance for a new 1/4 in. x 3/4 in. roll pin installed in the timing gear end of the current crankshafts. Refer to section 1.7. The pin permits only right-hand crankshaft timing gears to be installed on right-hand engine crankshafts, and only left-hand timing gears to be installed on left-hand engine crankshafts.

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

The roll pins can be removed from the new crankshafts to allow former crankshaft timing gear reuse. When reusing the former gears without the clearance hole, the proper rotation gear must be matched with the proper rotation crankshaft.

1.29.1 Repair or Replacement of Crankshaft Timing Gear

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-226.

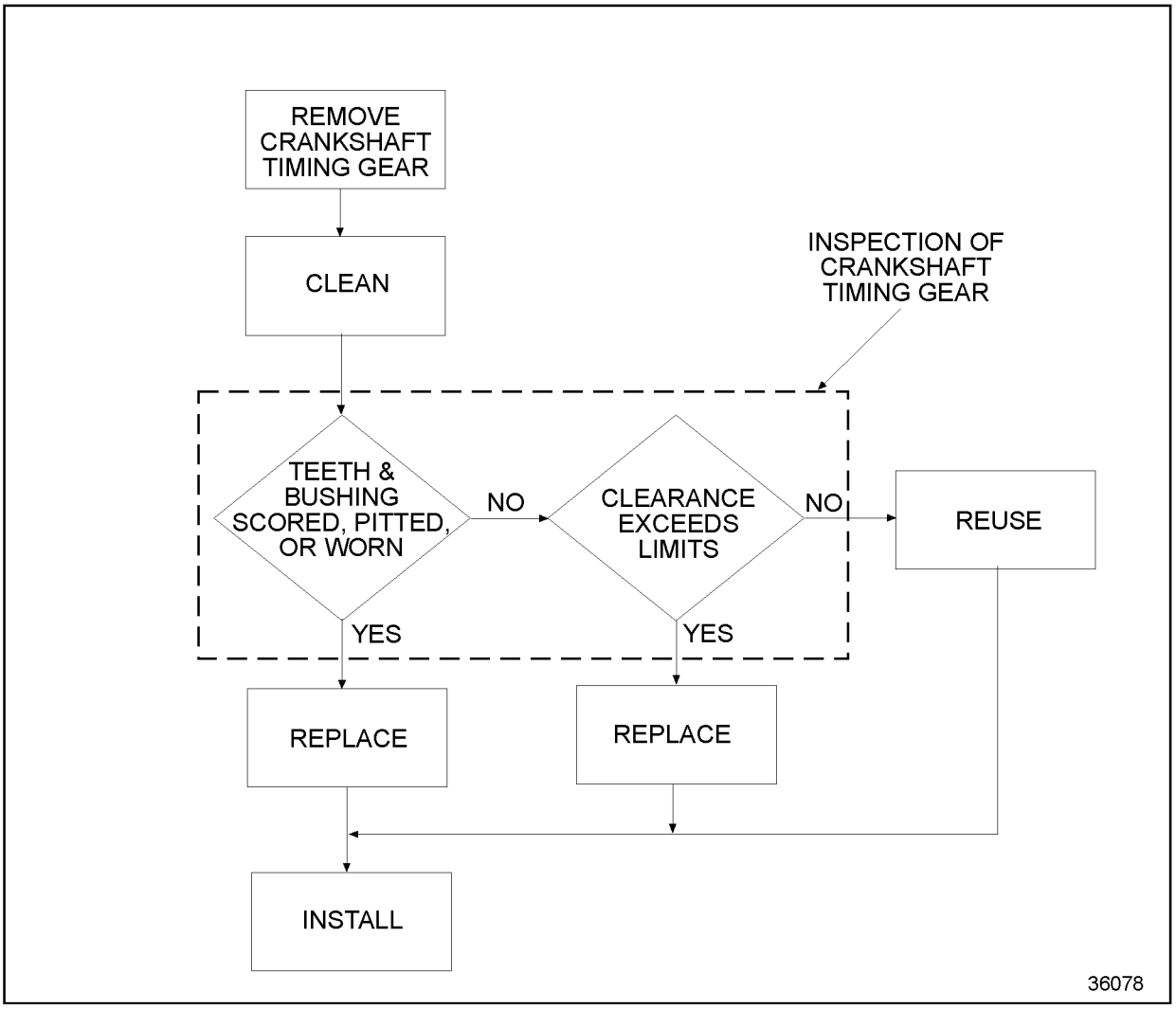


Figure 1-226 Flowchart for Repair or Replacement of Crankshaft Timing Gear

1.29.2 Removal of Crankshaft Timing Gear (6V and 8V)

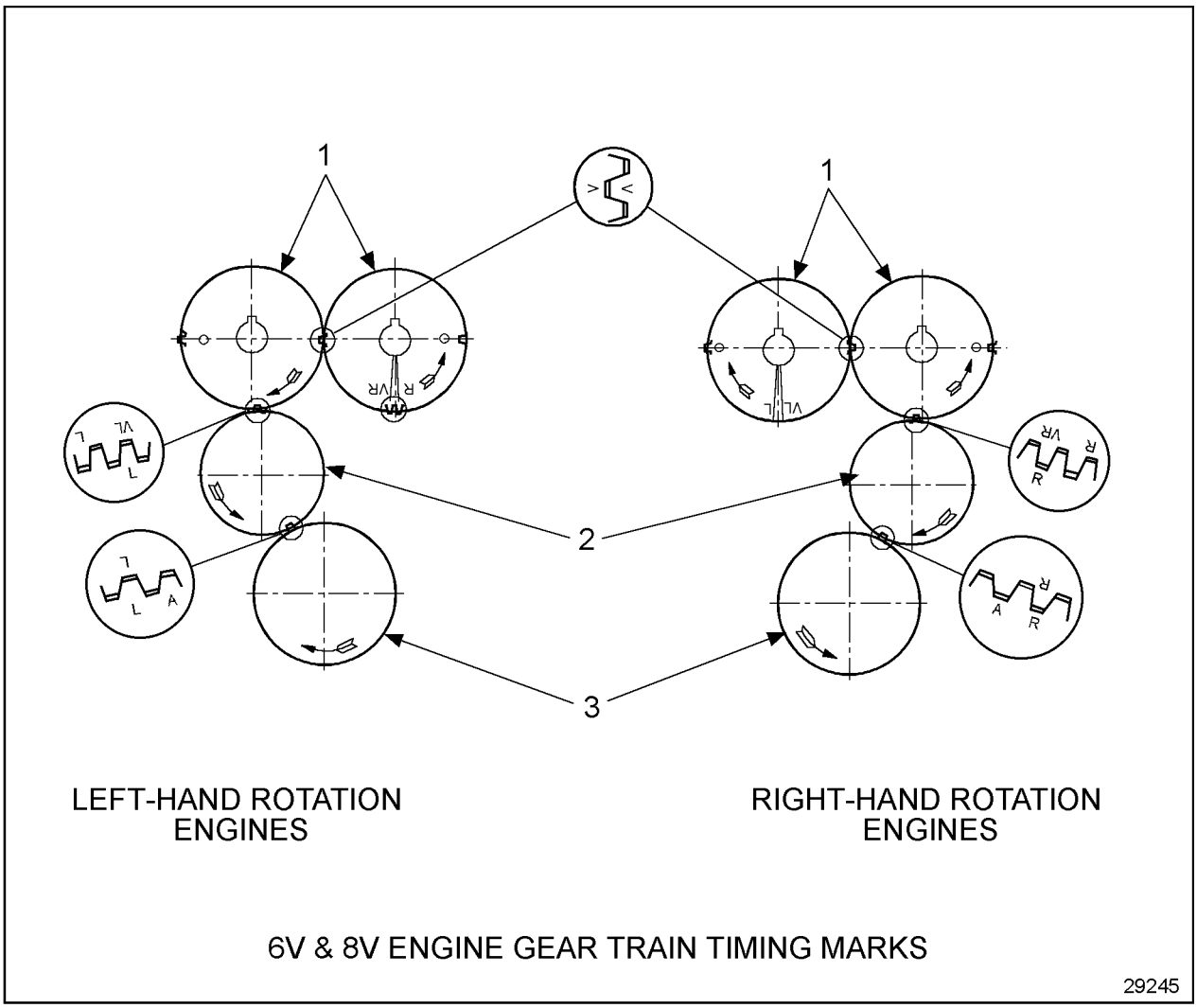
Remove the crankshaft timing gear as follows:

1. Remove the flywheel housing. Refer to section 1.19.2.

NOTE:
The crankshaft gear is a press fit on the crankshaft.

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2. Peen the outside diameter of the crankshaft rear oil sleeve until it can slip off crankshaft.



1. Camshaft Gears
2. Idler Gear
3. Crankshaft Gear

Figure 1-227 Gear Train and Timing Marks for 6V and 8V Engines

NOTE:
Before removing the crankshaft gear, align the timing marks of the gear train. Observe their location, so the gear can be installed in its original position. See Figure 1-227.

3. Remove the six bolts that secure the gear to the crankshaft.
4. Place a steel plate across the cavity in the end of the crankshaft to provide a base for the puller screw.
5. Remove the gear with a gear puller.

1.29.3 Removal of Crankshaft Timing Gear (12V and 16V)

Remove the crankshaft timing gear as follows:

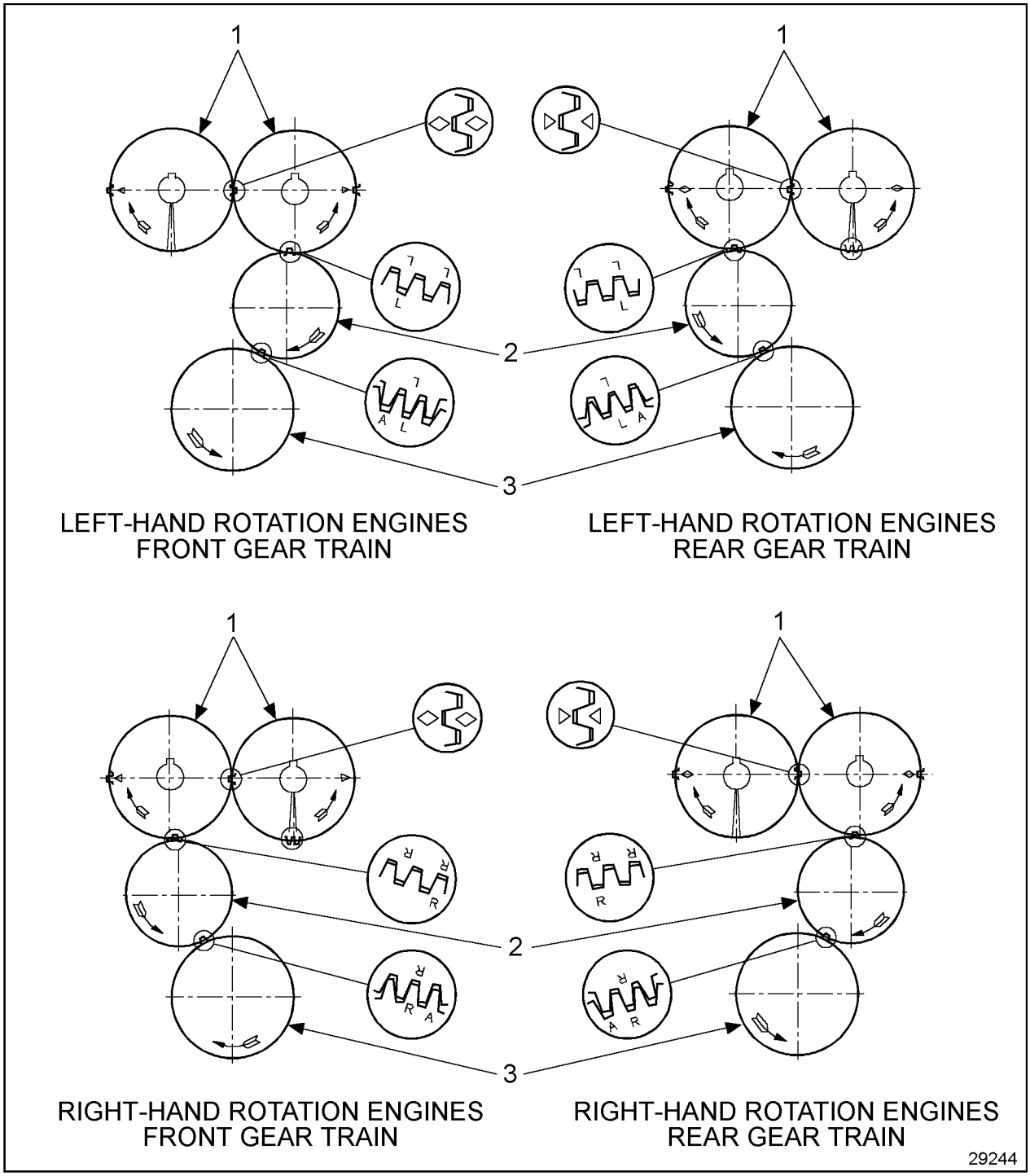
1. Remove the flywheel housing. Refer to section 1.19.2.

NOTE:
The crankshaft gear is a press fit on the crankshaft.

2. Peen the outside diameter of the crankshaft rear oil sleeve until it can slip off crankshaft.

NOTE:
Before removing the crankshaft gear, align the timing marks of the gear train. Observe their location, so the gear can be installed in its original position. See Figure 1-228.

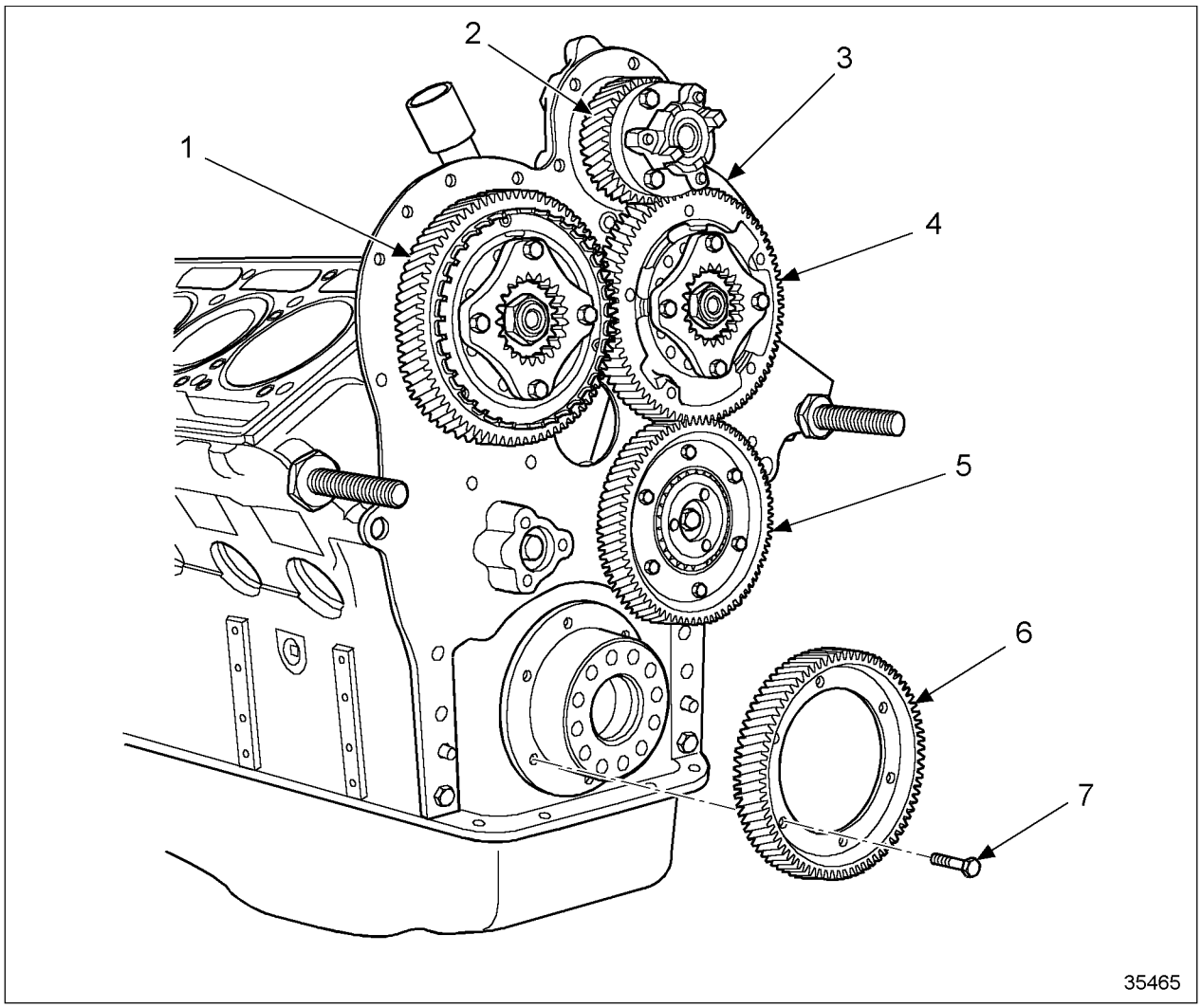
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1. Camshaft Gears
2. Idler Gear
3. Crankshaft Gear

Figure 1-228 Gear Train and Timing Marks for 12V and 16V Engines

3. Remove the six bolts that secure the rear timing gear to the crankshaft. See Figure 1-229.



1. Left Bank Camshaft Gear
2. Blower Drive Gear
3. Rear End Plate
4. Right Bank Camshaft Gear
5. Idler Gear
6. Crankshaft Timing Gear
7. Bolt (6)

Figure 1-229 Removal of Crankshaft Timing Gear

4. Remove the rear timing gear and oil pump drive gear as an assembly.
5. Place a steel plate across the cavity in the end of the crankshaft to provide a base for the puller screw.
6. Remove the gear with a gear puller.
7. Remove the six attaching bolts to separate the crankshaft and oil pump drive gears.
8. Remove the six bolts that secure the front crankshaft gear to the damper assembly.

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9. Withdraw the gear from the crankshaft.

1.29.4 Disassembly of Crankshaft Timing Gear

Disassemble the damper as follows:

1. Remove the bolts from the inner plate, spacers and the outer plate.
2. Remove the spacers from between the inner and outer plate.
3. Remove the springs.

1.29.4.1 Cleaning of Crankshaft Timing Gear

Prior to inspection, clean the crankshaft timing gear as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Clean the gear 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 gear with compressed air.

1.29.5 Inspection of Crankshaft Timing Gear

Inspect the crankshaft timing gear as follows:

1. Visually inspect the gear teeth and bushing for scoring, pitting or wear.
   [a] If severely scored, pitted, or worn, replace the gear or bushing. Refer to section 1.29.6.

NOTE:
If the gear is damaged, also check the other gears in the gear train.

   [b] If not scored, pitted, or worn, continue inspection.

2. Inspect the clearance between the bushing and the gear.

NOTE:
The clearance between the front crankshaft gear and the bushing is 0.03-0.08 mm (0.001-0.003 in.) with new parts and should not exceed 0.13 mm (0.005 in.) with used parts.

[a] If the clearance is not within specified limits, install a new gear and bushing.

[b] If the clearance is within the specified limits, reuse the gear and bushing.

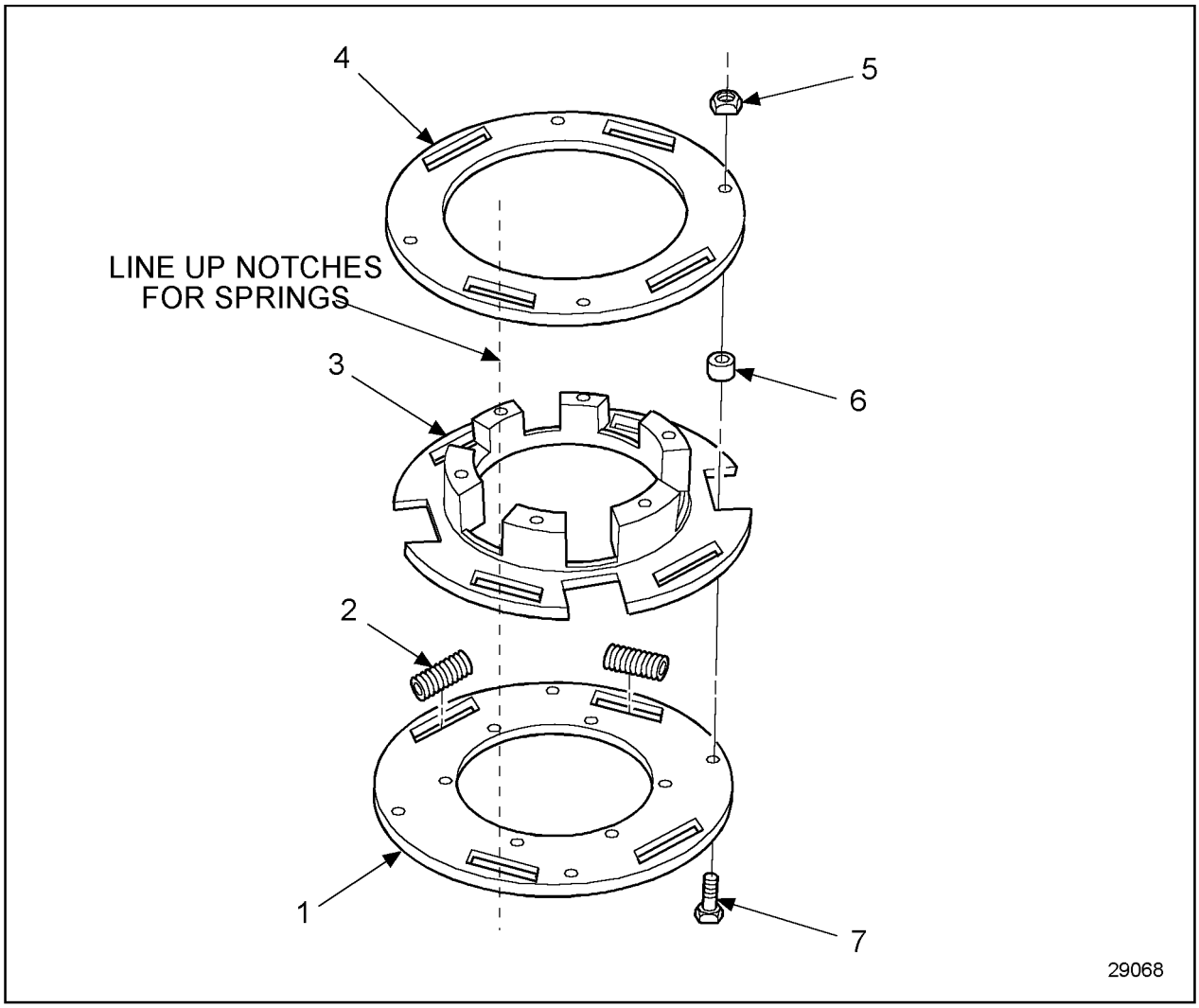
1.29.6 Assembly of Crankshaft Timing Gear

Assemble the damper as follows:

1. Lay the inner plate, flat side up, on a bench.
2. Place a spring in each slot of the damper.

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3. Place the hub on the inner plate with the notches in the hub and the inner plate. See Figure 1-230.



1. Inner Plate
2. Spring
3. Hub
4. Outer Plate
5. Nut
6. Spacer
7. Bolt

Figure 1-230 Proper Location of Notches and Assembly of Damper

4. Align the spring slots in the outer plate with the springs in the hub. Lay the outer plate on the hub.
5. Slide the spacers between the inner and outer plates. Align the spacers with the bolt holes in the plates.
6. Push the bolts through the inner plate, spacers, and the outer plate.

7. Install the nuts on the bolts. Torque the nuts to 41-47 N·m (30-35 lb·ft).

1.29.7 Installation of Crankshaft Timing Gear

Install the crankshaft timing gear as follows:

1. Align the bolt holes in the gear with the tapped holes in the crankshaft.

NOTE:
Since one bolt hole is offset, the gear can be attached in only one position.

2. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear. Refer to section 1.29.7.
3. Start the six 3/8 in.-24 bolts through the gear and into the crankshaft.
4. Draw the gear tight against the shoulder on the crankshaft. Tighten the bolts to 47-53 N·m (35-39 lb·ft) torque.
5. Check the backlash with the mating gear. The backlash should be 0.05-0.20 mm (0.002-0.008 in.) with new gears or 0.25 mm (0.010 in.) maximum with used gears.
6. Install a new crankshaft rear oil seal sleeve, if required. Refer to section 1.8.7.

1.29.8 Installation of the Crankshaft Timing Gear (12V and 16V)

Install the crankshaft timing gear on a 12V and 16V engine as follows:

1. Refer to section 1.29.7. Lay the rear crankshaft timing gear (timing mark side down) on a bench.
2. Place the oil pump drive gear (narrow side down) on the crankshaft gear.
3. Install the oil pump drive gear bolts. Tighten the bolts to 20-26 N·m (15-19 lb·ft) torque.
4. Slide the gear, oil pump gear first, on the rear end of the crankshaft. Align the bolt holes in the crankshaft gear with the tapped holes in the crankshaft.
5. Install and tighten the crankshaft gear bolts to 47-53 N·m (35-39 lb·ft) torque.
6. Align the timing mark on the crankshaft gear with the corresponding mark on the idler gear.
7. If removed, position the damper on the front end of the crankshaft. Install and tighten the damper-to-crankshaft bolts to 47-53 N·m (35-39 lb·ft) torque.
8. Align the timing marks, and attach the front crankshaft gear to the damper with six bolts. Tighten the bolts to 20-26 N·m (15-19 lb·ft) torque.
9. Check the gear backlash.

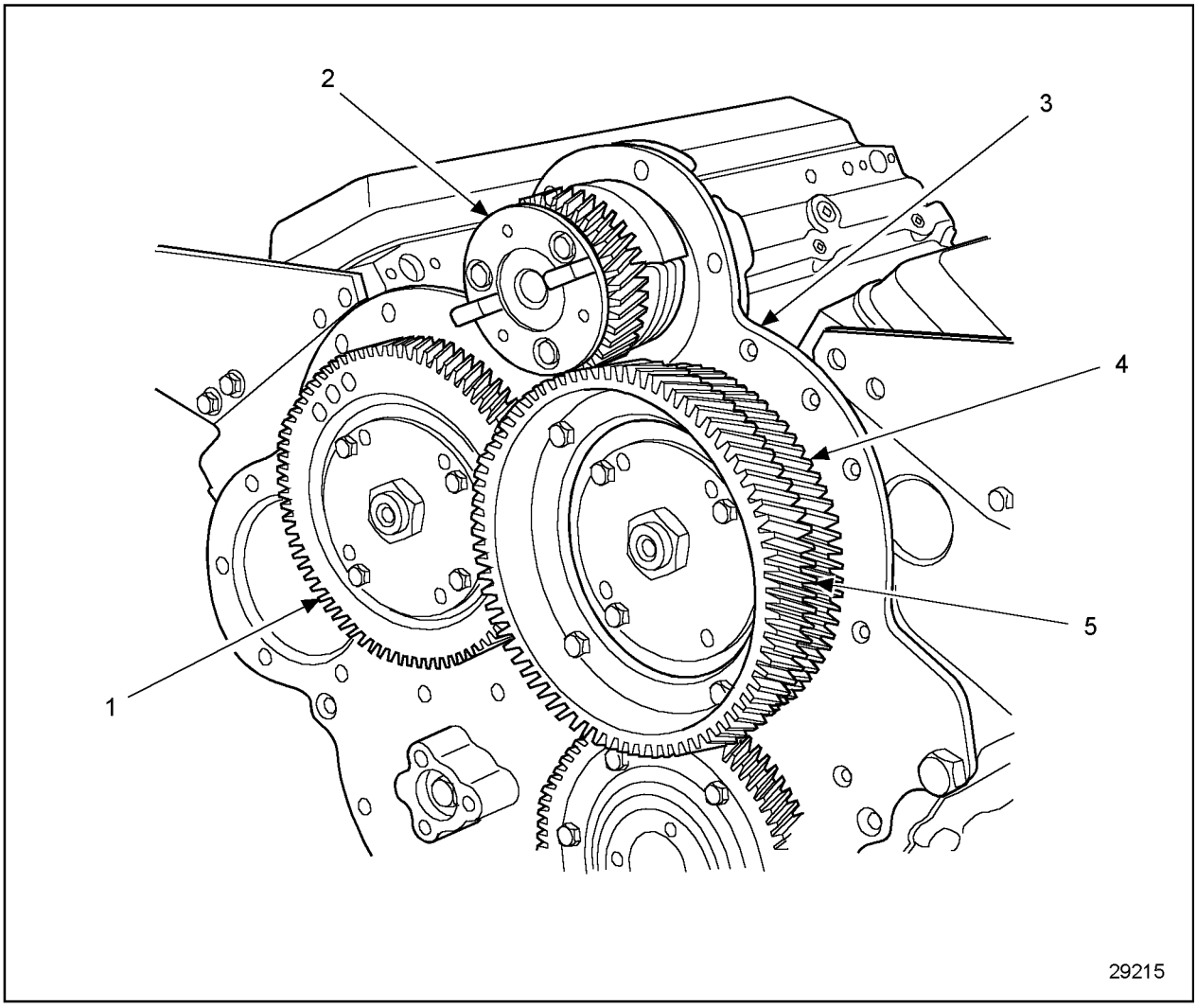
NOTE:
The backlash should be 0.05-0.20 mm (0.002-0.008 in.) with new gears, or 0.25 mm (0.010 in.) maximum with used gears.

10. Install a new crankshaft oil seal sleeve, if used, on the crankshaft. Refer to section 1.8.5.

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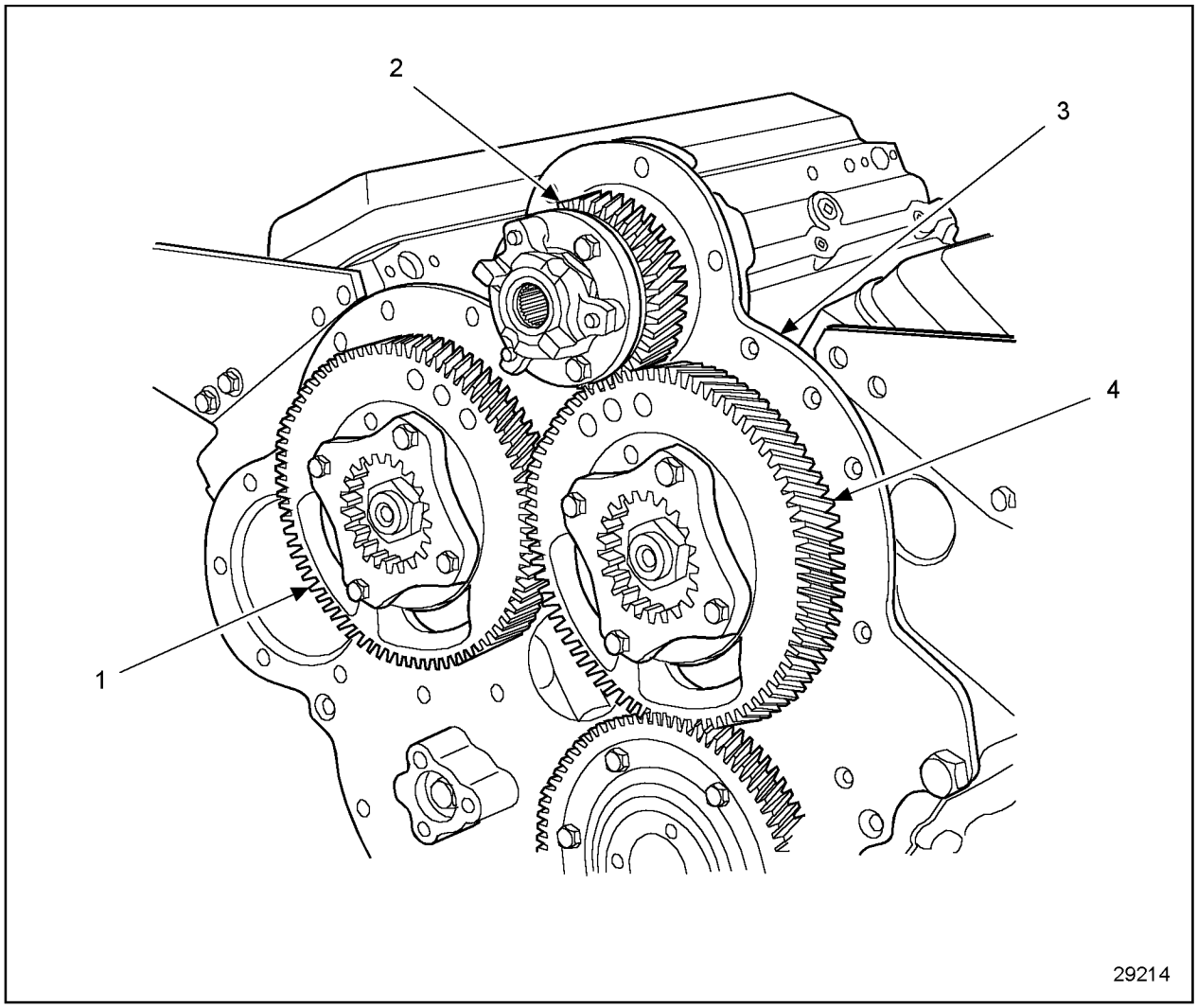
1.30 BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

A step-up gear, with 86 teeth, attached to the right cylinder bank camshaft gear drive the blower gear on non-turbocharged engines. See Figure 1-231. For turbocharged engines, the right cylinder bank camshaft gear drives the blower drive gear directly. See Figure 1-232.



1. LH Camshaft Drive Gear
2. Blower Drive Assembly
3. Rear End Plate
4. RH Camshaft Gear
5. Step-Up Gear

Figure 1-231 Blower Drive Gear Mounting (Non Turbocharged Engines)



1. LH Camshaft Gear
2. Blower Drive Gear
3. Rear End Plate
4. RH Camshaft Gear

Figure 1-232 Blower Drive Gear Mounting (Turbocharged Engines)

Two blower drive gear and support assemblies are used on the 12V and 16V engines. Both the front and the rear blower drive gears on the non-turbocharged 12V and 16V engines are the same and are driven the same. On the 12V and 16V turbocharged engines, however, the camshaft gear directly drives each blower drive gear. The blower drive gear and support assembly on turbocharged and non-turbocharged engines are not interchangeable.

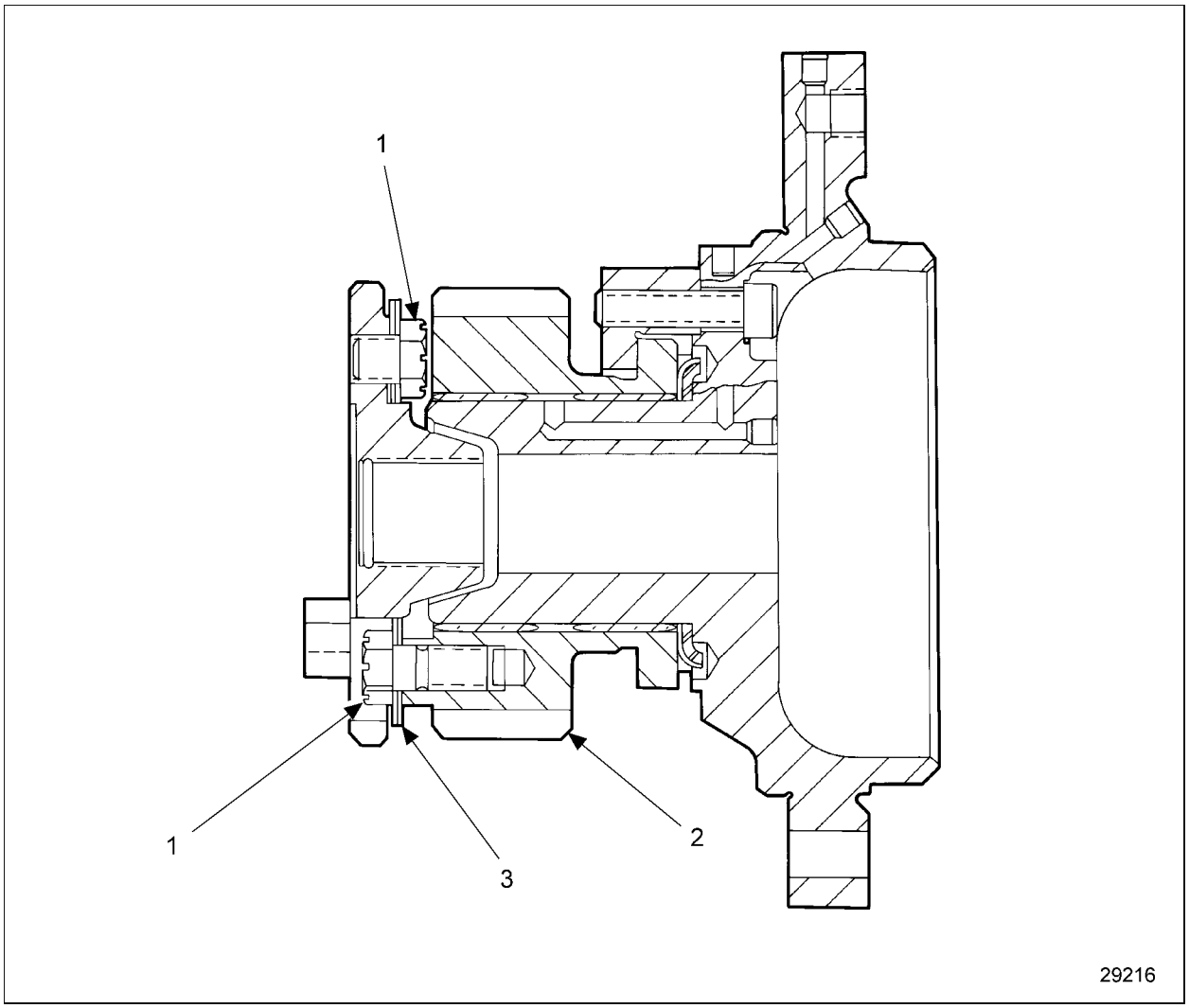
Since the camshaft gear runs at engine speed, the blower drive gear, that has about half as many teeth as the camshaft gear, runs at approximately twice the engine speed.

The blower to engine speed ratio for the 6V, 8V and 16V non-turbocharged and high output turbocharged engines is 2.60:1 (blower drive gear has 33 teeth). The blower to engine speed ratio for other turbocharged engines is 2.05:1 (blower drive gear has 38 teeth) or 1.95:1 (blower drive gear has 40 teeth) depending on the requirement.

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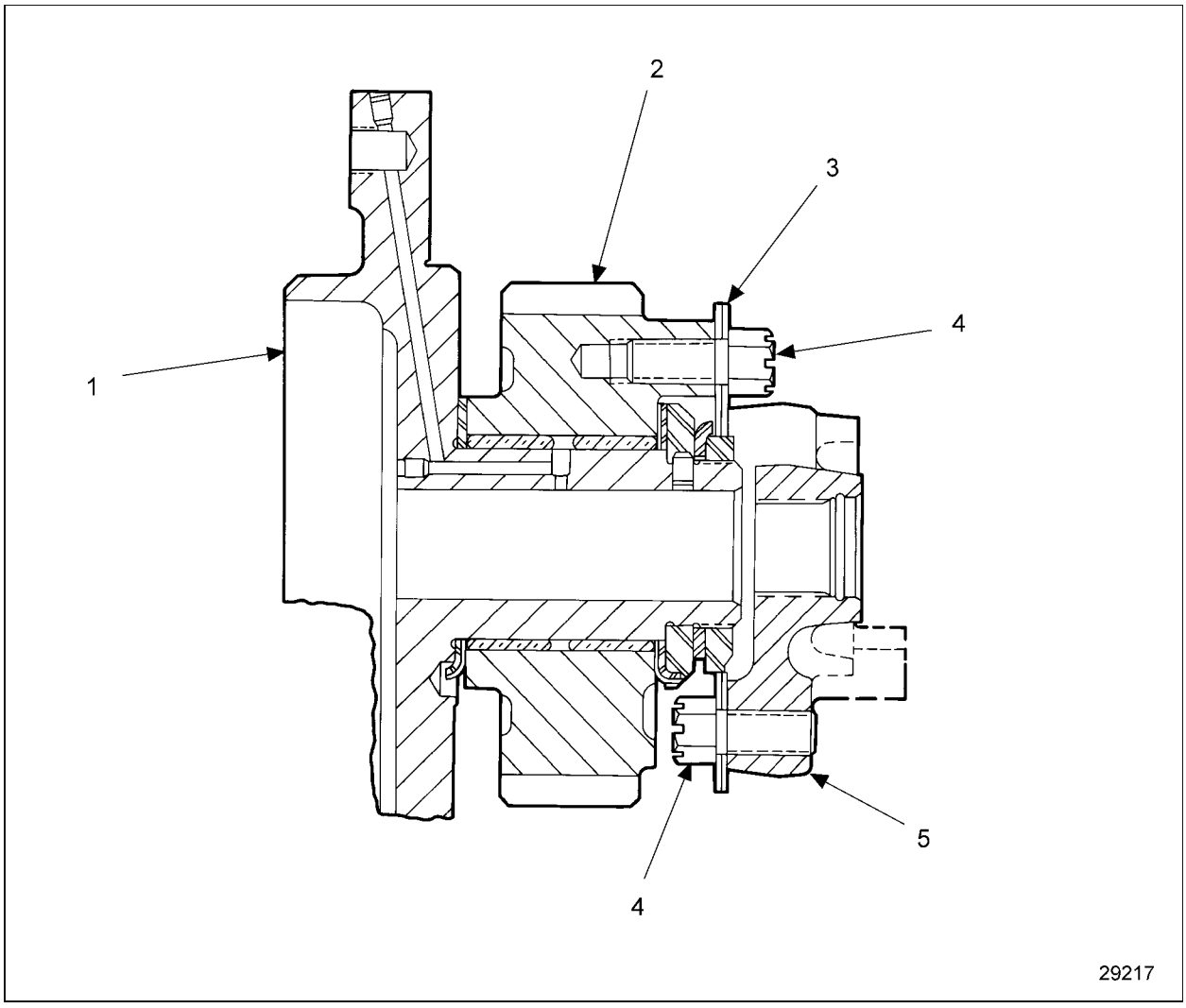
The blower drive gear is mounted on a support which that is attached to the cylinder block rear end plate. The blower drive gear bearings are pressure lubricated through an external line from the blower rear end plate to the blower drive support.

New blower drive shaft flex plates and type B hex lock bolts are now being used on engines that incorporate the large bearing blower. See Figure 1-233 and see Figure 1-234. The tumbled flex plates will continue to be used, as required. However, the thin hub spacers formerly used to protect the tumbled flex plates are no longer required and will not be serviced. The change to the new blower drive shaft flex plate attaching bolts become effective with engine serial numbers 6VF-092516, 8VF-077675, 12VF-001216 and 16VF-005875. Only the new flex plates and bolts should be used to service engines with large bearing blowers.



1. Lock Bolts
2. Gear Assembly
3. Plate

Figure 1-233 Rear Hub Assembly (Non Turbocharged Engines)



1. Rear Hub Support Assembly
2. Blower Drive Gear Assembly
3. Plate
4. Lock Bolts
5. Hub

Figure 1-234 Rear Hub Assembly (Turbocharged Engines)

Some former engines are equipped with thin hub spacers. They are not readily accessible and some mechanics may not be aware that they are behind the flex plate. When working on the blower hub assemblies, remove the flex plate attaching bolts carefully to avoid dropping the thin hub spacers into the gear train. If spacers are inadvertently dropped into the gear train, removal of the engine flywheel housing and/or oil pan may be required to retrieve them.

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1.30.1 Repair or Replacement of Blower Drive Gear and Support Assembly

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-235.

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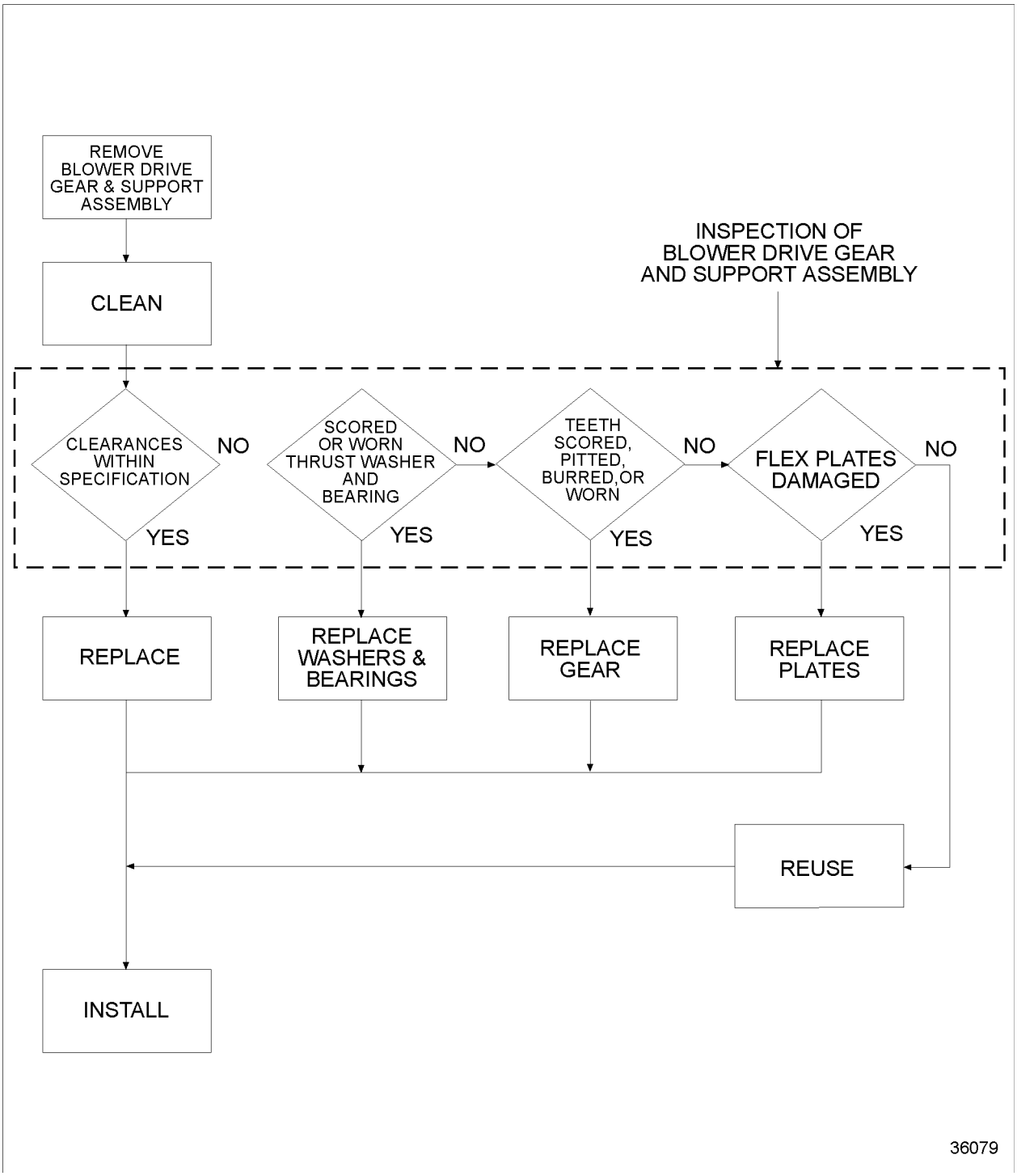


Figure 1-235 Flowchart for Repair of Replacement of Blower Drive Gear and Support Assembly

1.30.2 Removal of Blower Drive Gear and Support Assembly

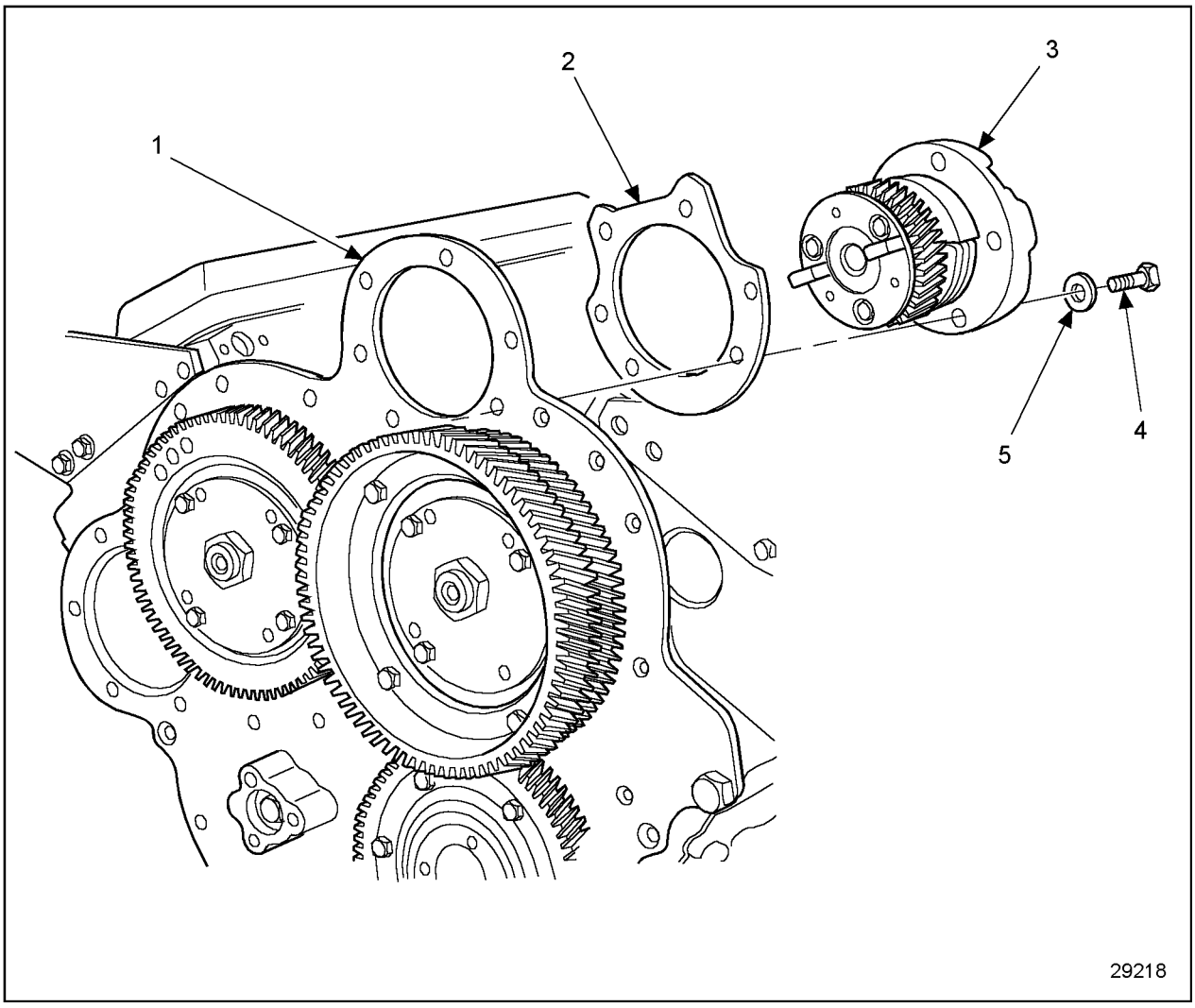
Remove the blower drive gear and support assembly as follows:

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1. Remove the flywheel housing. Refer to section 1.19.2.
2. Remove the flywheel. Refer to section 1.16.2.

NOTE:
It is not necessary to remove the flywheel housing when removing the blower drive gear. However, an inspection of the gear train is advisable when any one of the gears require service.

3. Remove the blower(s) and blower drive support lubrication tube. Refer to section 6.5.2.
4. Remove the two blower drive support-to-cylinder block rear end plate attaching bolts with copper washers. See Figure 1-236.



1. Rear End Plate
2. Gasket
3. Blower Drive Gear Assembly
4. Bolt
5. Copper Washer

Figure 1-236 Removal of Blower Drive Gear Assembly

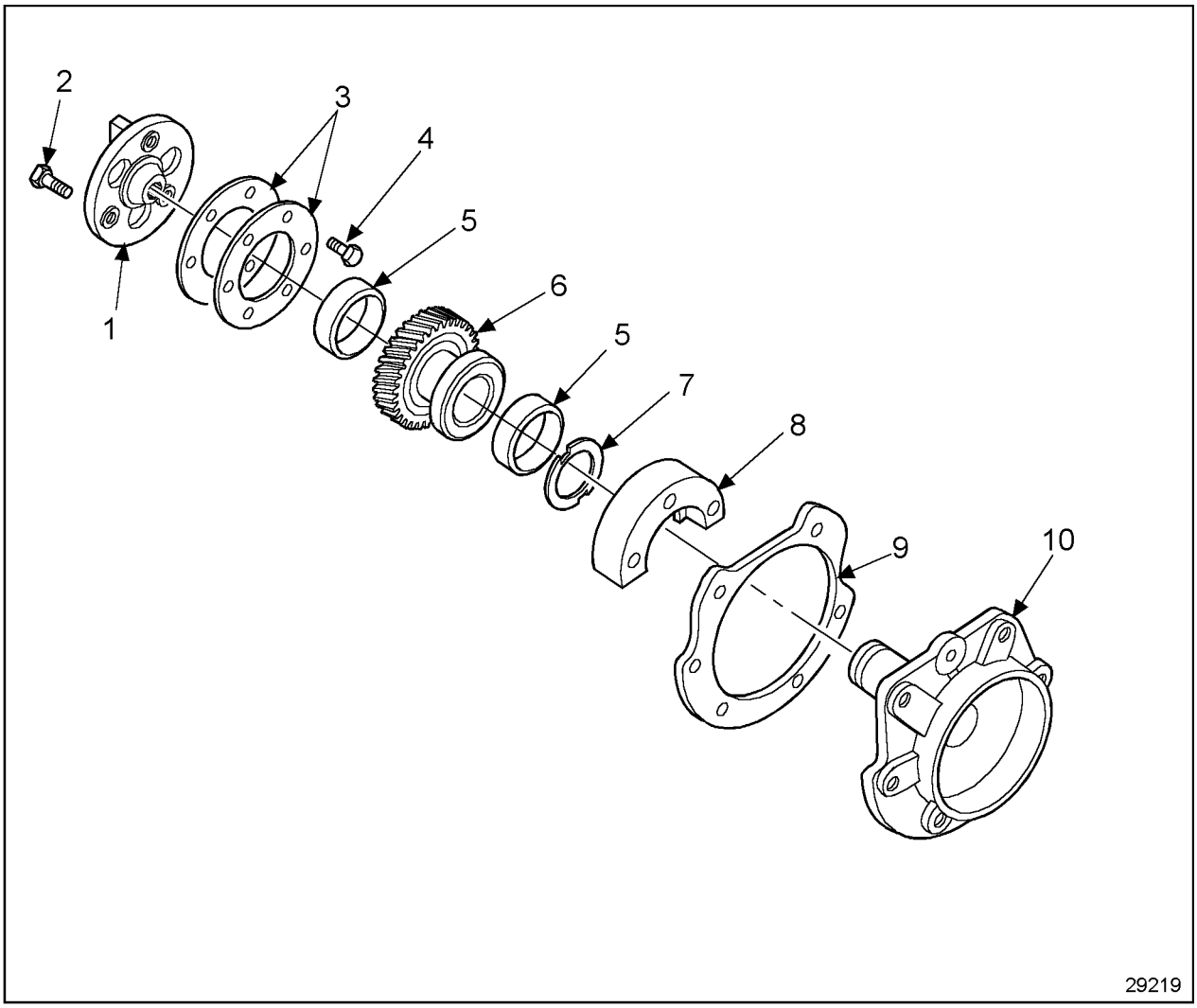
5. Tap the blower drive support to loosen it. Carefully withdraw the support from the cylinder block rear end plate so the blower drive gear teeth will not be damaged.
6. Discard the gasket.

1.30.3 Disassembly of Blower Drive Gear and Support Assembly

See Figure 1-237. On non-turbocharged engines, disassemble the blower drive gear and support assembly as follows:

NOTE:
At time of rebuild, or whenever the flex plates are removed, current type B lock bolts must be used. Do not attempt to reuse patch bolts.

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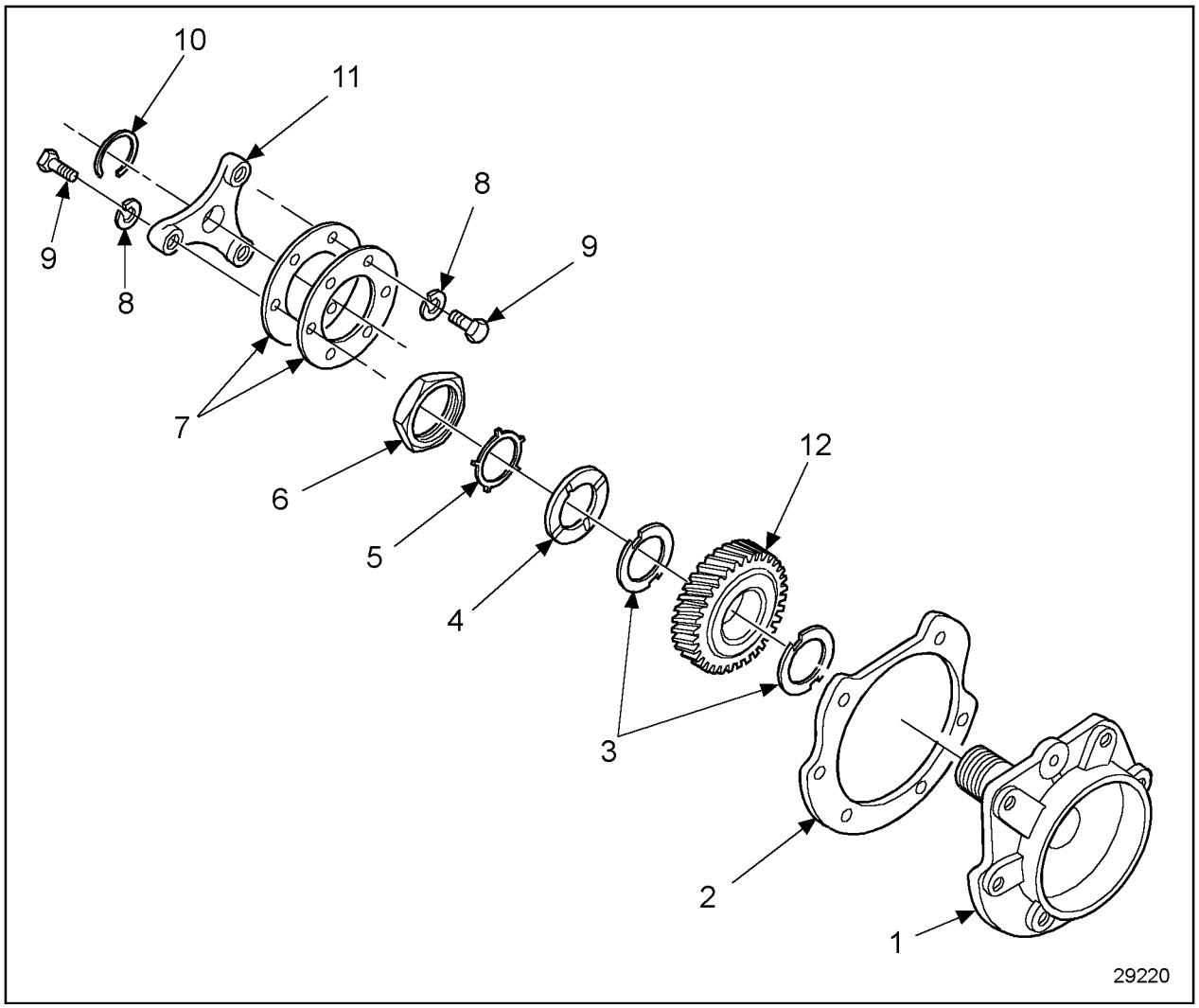
1. Driveshaft Hub
2. Bolt
3. Flex Plates
4. Bolt
5. Bearing
6. Drive Gear
7. Thrust Washer
8. Thrust Collar
9. Gasket
10. Blower Drive Support

Figure 1-237 Rear Hub, Blower Drive Gear, Support Assembly (Non Turbocharged Engines)

1. Secure the blower drive gear and support assembly in the soft jaws of a bench vise.
2. Remove the three lock bolts securing the drive gear hub and flex plates to the blower drive gear.
3. Remove the three lock bolts securing the flex plates to the drive gear hub, if required.
4. Remove three lock screws from the drive support, and lift the thrust collar from the drive gear flange.

5. Remove the blower drive gear and the thrust washer from the drive gear support hub.

See Figure 1-238. On turbocharged engines, disassemble the blower drive gear and support assembly as follows:



1. Blower Drive Support
2. Gasket
3. Thrust Bearings
4. Thrust Washer
5. Lock Washer
6. Nut
7. Flex Plates
8. Lock Washers
9. Bolt
10. Snap Ring
11. Blower Drive Shaft Hub
12. Blower Drive Gear

Figure 1-238 Rear Hub, Blower Drive Gear, Support Assembly (Turbocharged Engines)

1. Secure the blower drive gear and support assembly in a soft jawed bench vise.

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2. Remove the three bolts securing the drive gear hub and flex plates to the blower drive gear.
3. Remove the flex plates and blower drive gear hub as an assembly from the gear. If necessary, the flex plates may be removed from the hub.
4. Straighten the lugs on the lock washer, and remove the blower drive gear support nut.
5. Withdraw the lock washer, blower drive gear thrust washer, thrust bearings, and gear from the support.

1.30.3.1 Cleaning of Blower Drive Gear and Support Assembly

Prior to inspection, clean the blower drive gear and support assembly as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Clean the 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 with compressed air.

1.30.3.2 Inspection of Blower Drive Gear and Support Assembly

Inspect the blower drive gear and support assembly as follows:

1. Visually inspect the oil passage in the blower drive gear support for obstructions.
   [a] If plugged, clean passages out.
   [b] If not plugged, continue inspection.
2. Visually inspect the blower drive gear bushing inside diameter and the support hub outside diameter for wear or excessive heat damage.
   [a] If worn or heat damaged, replace the drive gear and support hub. Refer to section 1.30.5.
   [b] If not worn or damaged, proceed with inspection.
3. Check the clearance between the bushing and the support hub. Refer to section ADDITIONAL INFORMATION, specifications chart for blower drive gear.

[a] If the clearance exceeds the specified limits, replace the bushing and support hub. Refer to section 1.30.5.

[b] If the clearance does not exceed the specified limits, continue inspection.

NOTE:
If new bearings are installed, the outer end of each bearing must be pressed in flush to 0.25 mm (0.010 in.) below the gear face. The bearings must be reamed to size 41.300-41.313 mm (1.6260-1.6265 in.) inside diameter and to a finish of 20 micro-inches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within 0.08 mm (0.003 in.) total indicator reading and concentric with the pitch diameter of the gear teeth. The thrust washer retaining pin must extend approximately 2.03 mm (0.080 in.) above the threaded end of the hub.

4. Visually inspect the blower drive support thrust washer and thrust bearing for scoring and wear.

   [a] If excessively worn or scored, replace washers and bearings.

NOTE:
For new blower drive support thrust washers and thrust bearings thickness, refer to section ADDITIONAL INFORMATION.

   [b] If not excessively worn or scored, continue inspection.

5. Visually inspect the gear teeth for scoring, pitting, burring, and wear.

   [a] If excessively scored, pitted, burred, or worn, replace gear. Refer to section 1.30.5.

   [b] If not excessively scored, pitted, burred, or worn, continue inspection.

6. Visually inspect the flex plates for cracks or other damage.

   [a] If cracked or damaged, replace the plates. Refer to section 1.30.4.

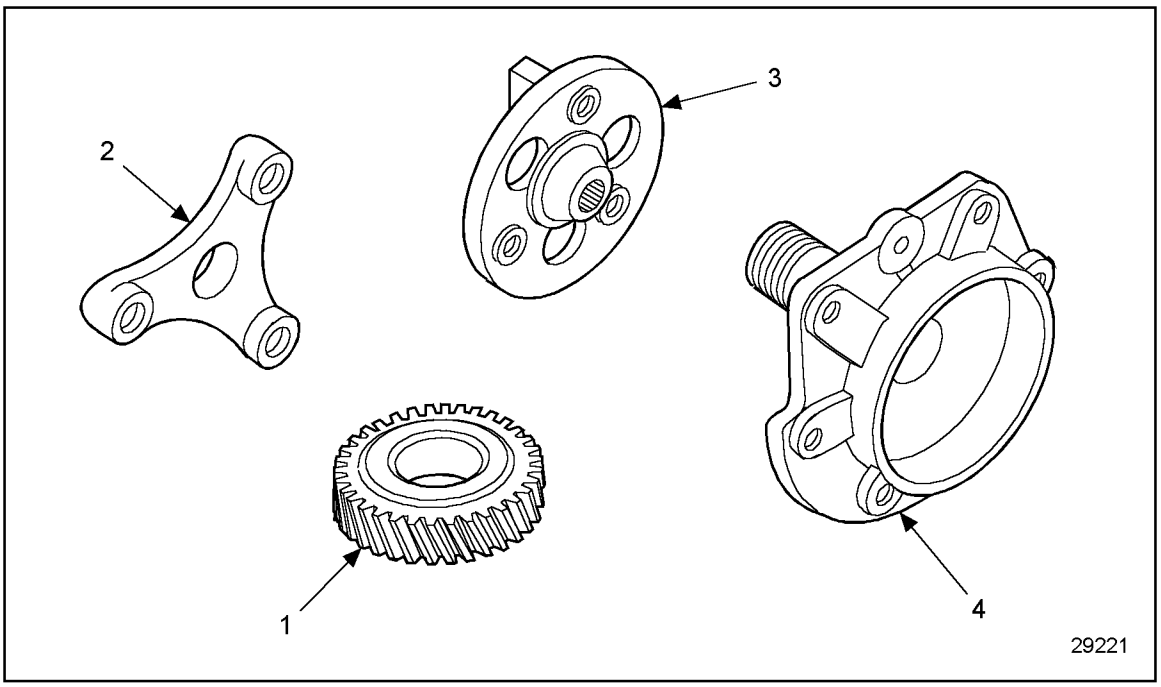
   [b] If not cracked or damaged, continue inspection.

7. Visually inspect the serrations in the blower drive shaft hub for wear or other damage.

NOTE:
To reduce spline wear, the blower drive shafts, blower drive couplings and accessory drive hubs have been replaced by specially heat treated parts, effective with engines 6VF-21492 and 8VF-19187. See Figure 1-239. DDC recommends that all of the subject

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components be replaced (including the flex plates) when any one or more of the parts require replacement on engines prior to the above serial numbers.



1. Blower Drive Gear
2. Blower Drive Shaft Hub (Turbocharged Engine)
3. Blower Drive Shaft Hub (Turbocharged Engine)
4. Blower Drive Shaft Support

Figure 1-239 Inspection of Blower Drive Shaft Hub, Support and Drive Gear

[a] If worn or damaged, replace the hub. Refer to section 1.30.4.

[b] If not worn or damaged, reuse the blower drive gear and support assembly.

1.30.4 Assembly of Blower Drive Gear and Support Assembly

On non-turbocharged engines, assemble the blower drive gear and support assembly as follows:

1. With the blower drive support clamped in a soft jawed bench vise, align the tangs on the blower drive gear thrust washer with the holes in the support.

NOTE:
The current thrust washer with two inner diameter keyways and the current locking washer with a longer tang must be used together for optimum nut locking performance.

2. Lubricate the drive support hub, the bushing in the drive gear, and the thrust washer face, and thrust collar with clean engine oil.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Slide the drive gear on the support hub with the flange end of the gear against the thrust washer.
4. Install the thrust collar over the flange end of the drive gear and against the drive support.
5. Secure the collar with three 5/16 in.-18 x 1-1/4 in. socket head lock bolts. Tighten the bolts to 22-28 N·m (16-21 lb·ft) torque.

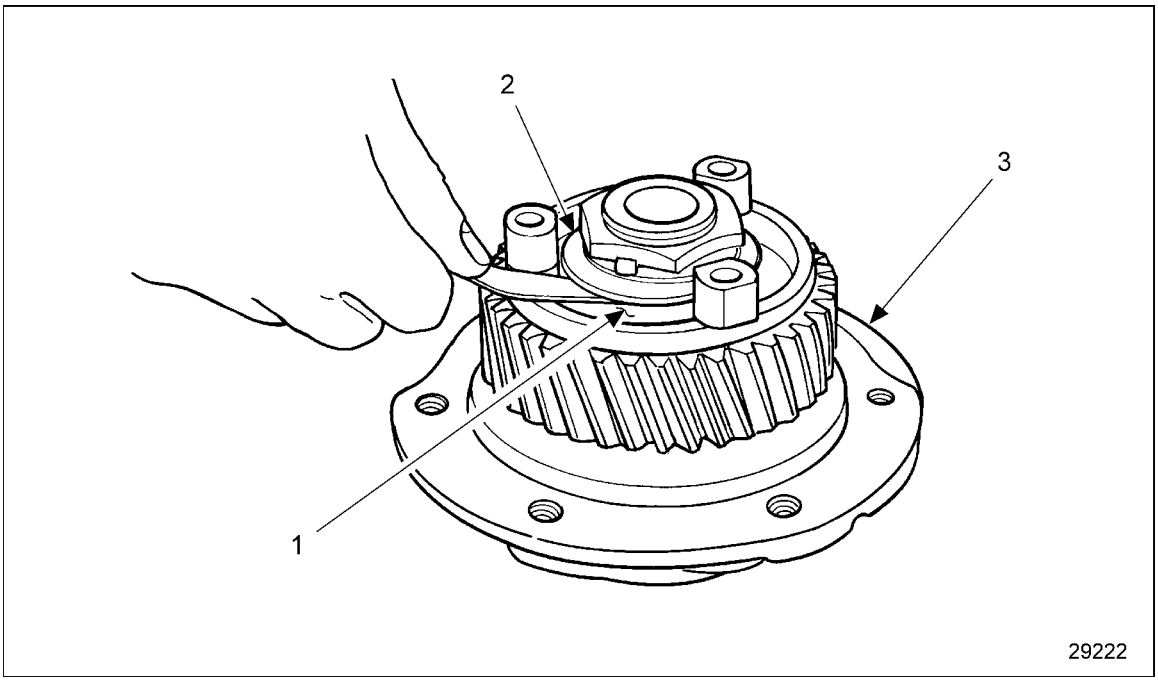
NOTE:
The thrust collar holds the drive gear on the support hub.

6. If the two flex plates were removed or replaced, secure them to the drive gear hub with the three special 3/8 in.-24 x 0.345 in. lock bolts. Tighten the bolts to 54-61 N·m (40-45 lb·ft) torque.
7. Secure the drive hub and flex plate assembly to the drive gear with three special 3/8 in.-24 x 0.925 in. lock bolts. Tighten the bolts to 47-53 N·m (35-39 lb·ft) torque.

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8. Check the clearance between the blower drive gear support thrust washer and the blower drive gear thrust bearing. See Figure 1-240.

NOTE:
The clearance should be 0.08-0.43 mm (0.003-0.017 in.) with new parts and should not exceed 0.48 mm (0.019 in.) between worn parts.



1. Thrust Bearing
2. Thrust Washer
3. Blower Drive Gear Assembly

Figure 1-240 Checking Clearance Between Drive Gear Support Thrust Washer and Thrust Bearing

On turbocharged engines, install the blower drive gear and support assembly as follows:

1. With the blower drive support clamped in a soft jawed bench vise, align the tangs on the blower drive thrust bearings with the support holes.

NOTE:
The new thrust washer with two inner diameter keyways and the new locking washer with a longer tang must be used together for optimum nut locking performance.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the support hub, the gear bushing, both thrust bearings, and the blower drive gear support thrust washer with clean engine oil.
3. Slide the gear, flat side down, on the hub.
4. Install the second thrust bearing, tangs up, on the support.
5. Align the blower drive support thrust washer slots with the bearing tangs.
6. Secure the gear on the support with a lock washer and nut. Tighten the nut to 68-81 N·m (50-60 lb·ft) torque, and bend the lock washer lugs against the nut flats to secure the nut.
7. Check the clearance between the blower drive gear support thrust washer and the blower drive gear thrust bearing.

NOTE:
The clearance should be 0.13-0.25 mm (0.005-0.010 in.) with new parts and should not exceed 0.30 mm (0.012 in.) between worn parts.

8. If the flex plates were removed from the blower drive gear hub, attach the spring plates to the hub with three special 3/8 in.-24 x 0.925 in. lock bolts. Tighten the bolts to 47-53 N·m (35-39 lb·ft) torque.

NOTICE:

Do not install the lock washers against the steel plates.

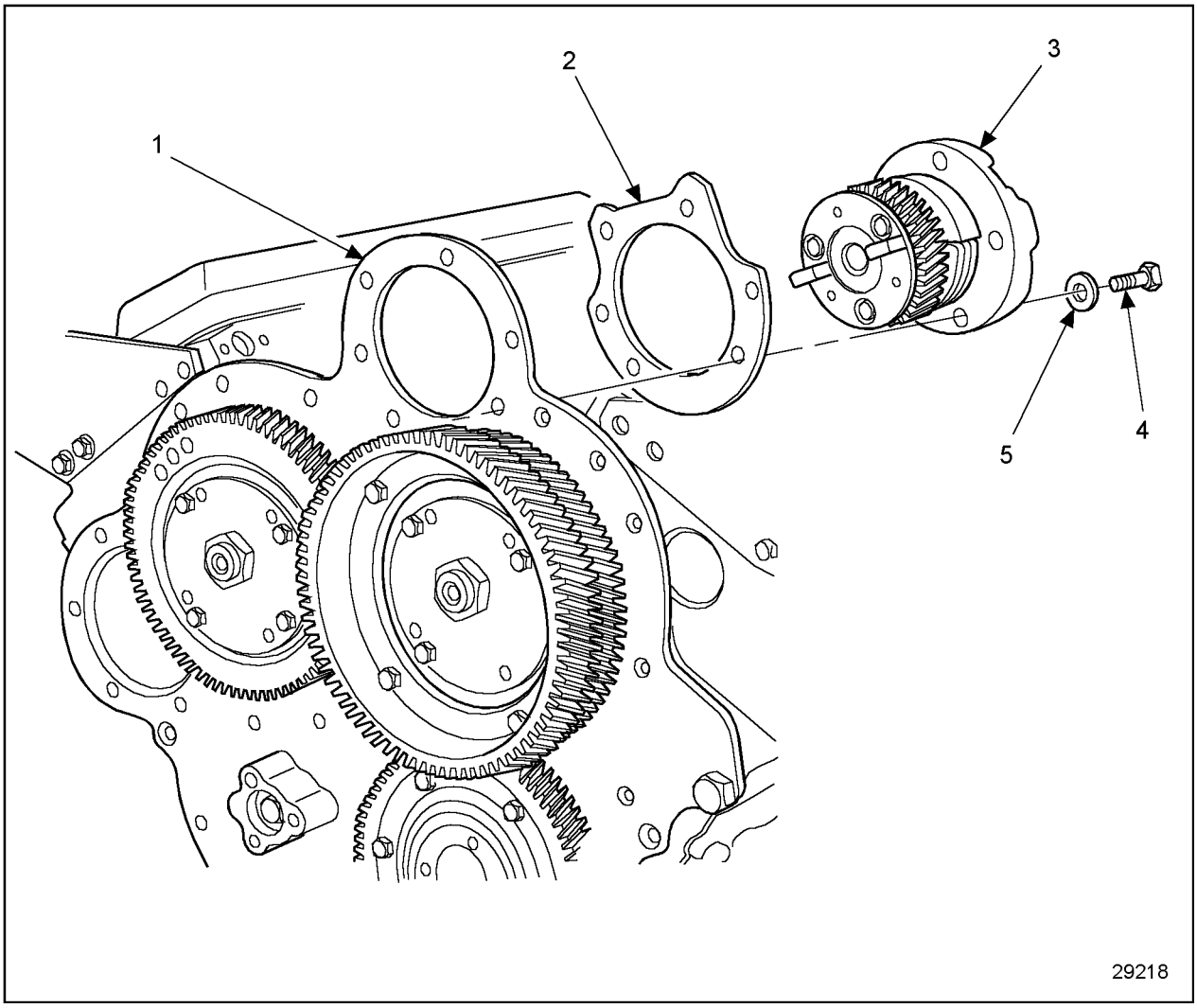
9. Assemble the flex plates and the hub to the gear with three special 3/8 in.-24 x 0.925 in. lock bolts. Tighten the bolts to 47-53 N·m (35-39 lb·ft) torque.

1.30.5 Installation of Blower Drive Gear and Support Assembly

Install the blower drive gear and support assembly as follows:

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1. Affix a new gasket to the blower drive gear support, and attach the gear and support assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 34-41 N·m (25-30 lb·ft) torque. See Figure 1-241.



1. Rear End Plate
2. Gasket
3. Blower Drive Gear Assembly
4. Bolt
5. Copper Washer

Figure 1-241 Installation of Blower Drive Gear Assembly

2. Check the gear backlash between the blower drive gear and the step-up gear attached to the camshaft (non-turbocharged engine) or the camshaft gear (turbocharged engine).

NOTE:
To accurately check the backlash, all of the flywheel housing attaching bolts must be tightened to their proper torque. Backlash should be 0.05-0.20 mm (0.002-0.008 in.) and should not exceed 0.25 mm (0.010 in.) with worn parts.

3. Remove the four flywheel housing-to-blower drive support bolts.
4. Install the blower(s). Refer to section 6.5.5.
5. Install the flywheel. Refer to section 1.16.5.
6. Install the flywheel housing. Refer to section 1.19.3.

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1.31 ACCESSORY DRIVE

Accessories such as an air compressor, hydraulic pump, or battery-charging alternator may be direct-driven or belt-driven from various locations on the engine.

Listed in Table 1-14 are the possible accessory drive location and rotation at a particular position. See Figure 1-242.

Accessory Drive Positions	Drive Ratio
1	1:1
2	1:1
*3	2.60:1 or 2.05
4	2.05:1
5	Not a Drive Position

* Depends upon engine application

Table 1-14 Accessory Drive Positions and Ratios

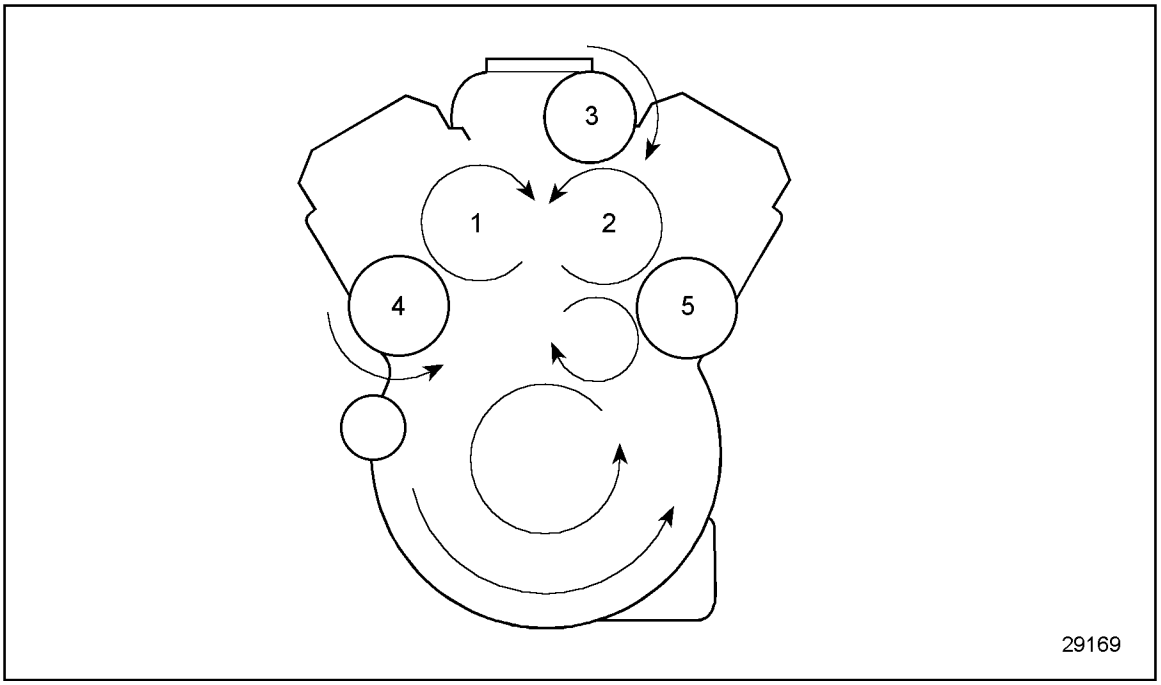
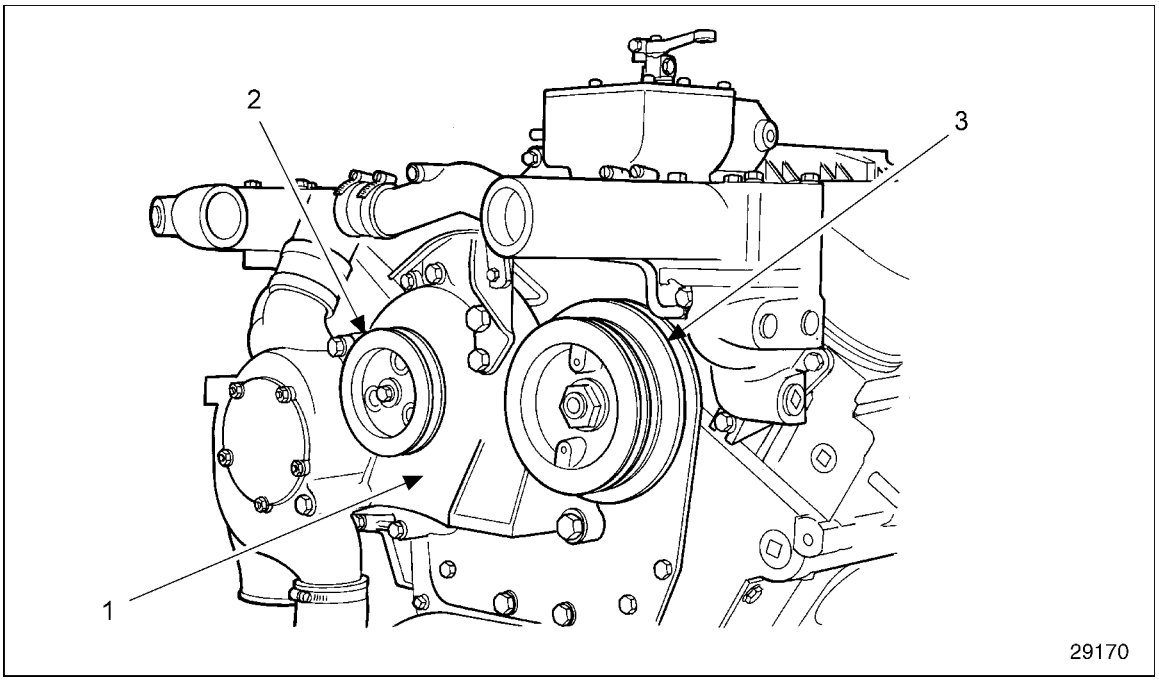


Figure 1-242 Accessory Drive Locations

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At the front of the engine, the left-bank camshaft pulley and the crankshaft pulley may be used to drive accessories. See Figure 1-243. On certain applications, an accessory drive pulley, that mounts on a shaft attached to the water pump drive gear, provides a drive for a high mounted battery-charging alternator.



1. Balance Weight Cover
2. Accessory Drive Pulley
3. Camshaft Pulley

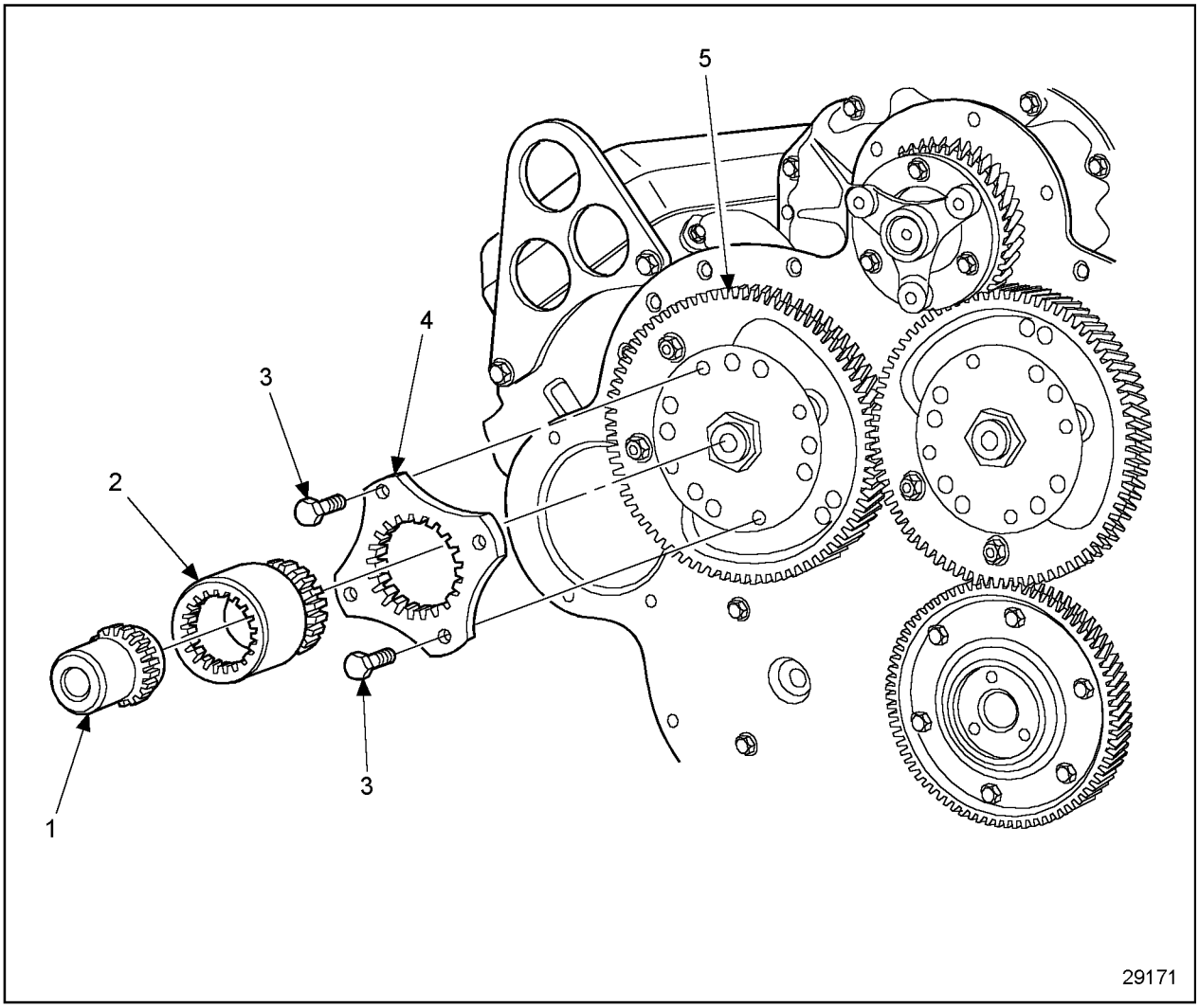
Figure 1-243 Front Mounted Accessory Drive Pulleys (6V and 16V)

The blower drive gear, left-bank accessory drive gear, or either camshaft gear may drive accessories.

The front accessory drive consists of a short drive hub bolted to the water pump drive gear and a pulley keyed to the hub. They are secured with a bolt, lock washer, and plain washer. An oil seal, pressed in the balance weight cover, prevents oil from seeping out where the shaft extends through the cover.

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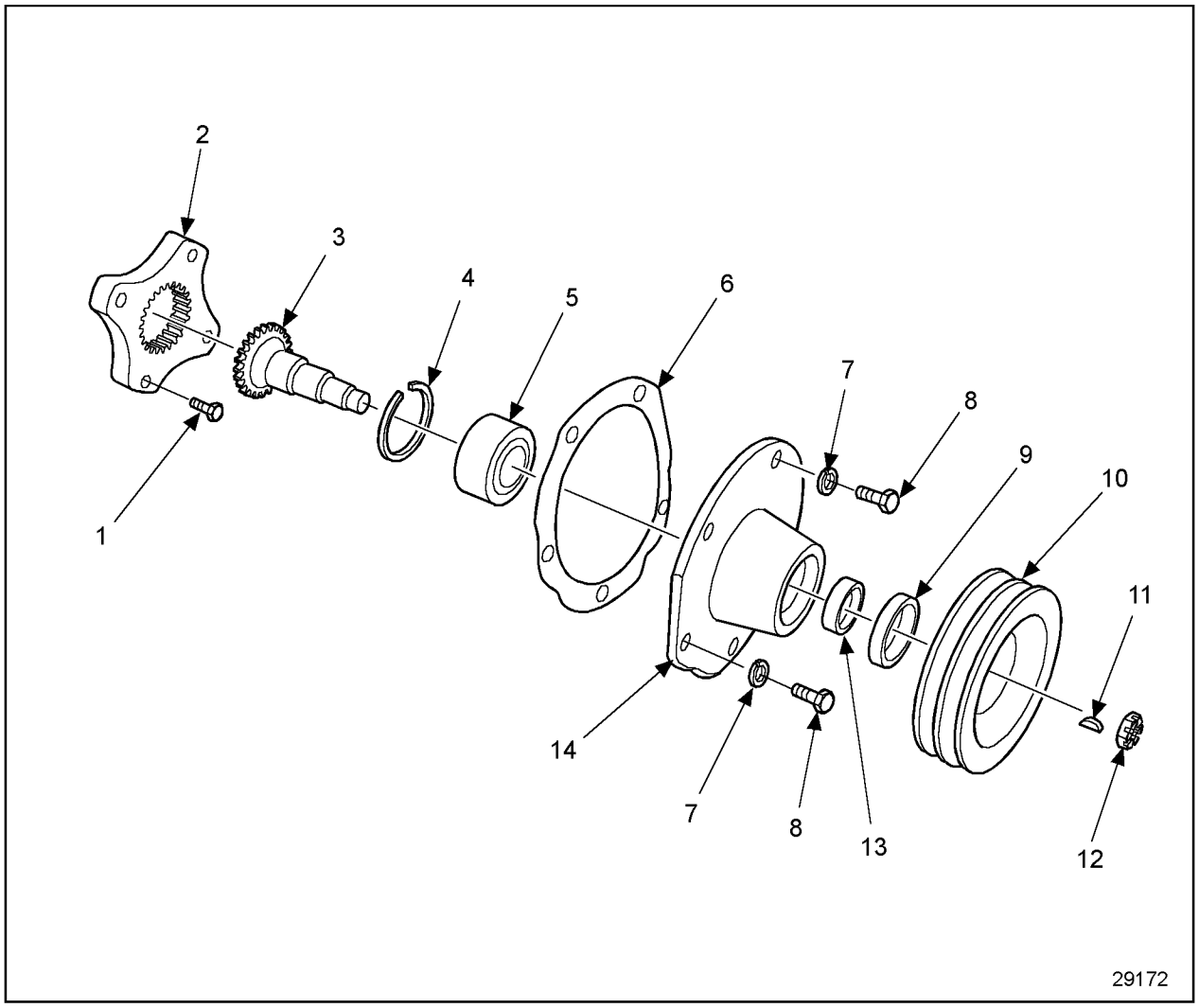
The camshaft driven accessory drive includes a drive plate bolted to either one of the camshaft gears. A direct-driven accessory is flange-mounted on the flywheel housing. A coupling splined to both the accessory drive plate and a drive hub on the accessory shaft drives the rear mounted camshaft accessory drive. See Figure 1-244.



1. Driven Hub (On Accessory)
2. Drive Coupling
3. Bolts
4. Drive Plate
5. Camshaft Gear

Figure 1-244 Components of Accessory Drive for Direct-Driven Applications

For a belt-driven accessory, a drive shaft is used in place of the drive coupling. One end of the drive shaft is splined to the drive plate and the other end is supported by a bearing in the accessory drive retainer, attached to the flywheel housing. See Figure 1-245. A drive pulley, attached to the outer end of the drive shaft, is connected by belts to the accessory drive pulley, mounted above the flywheel housing.

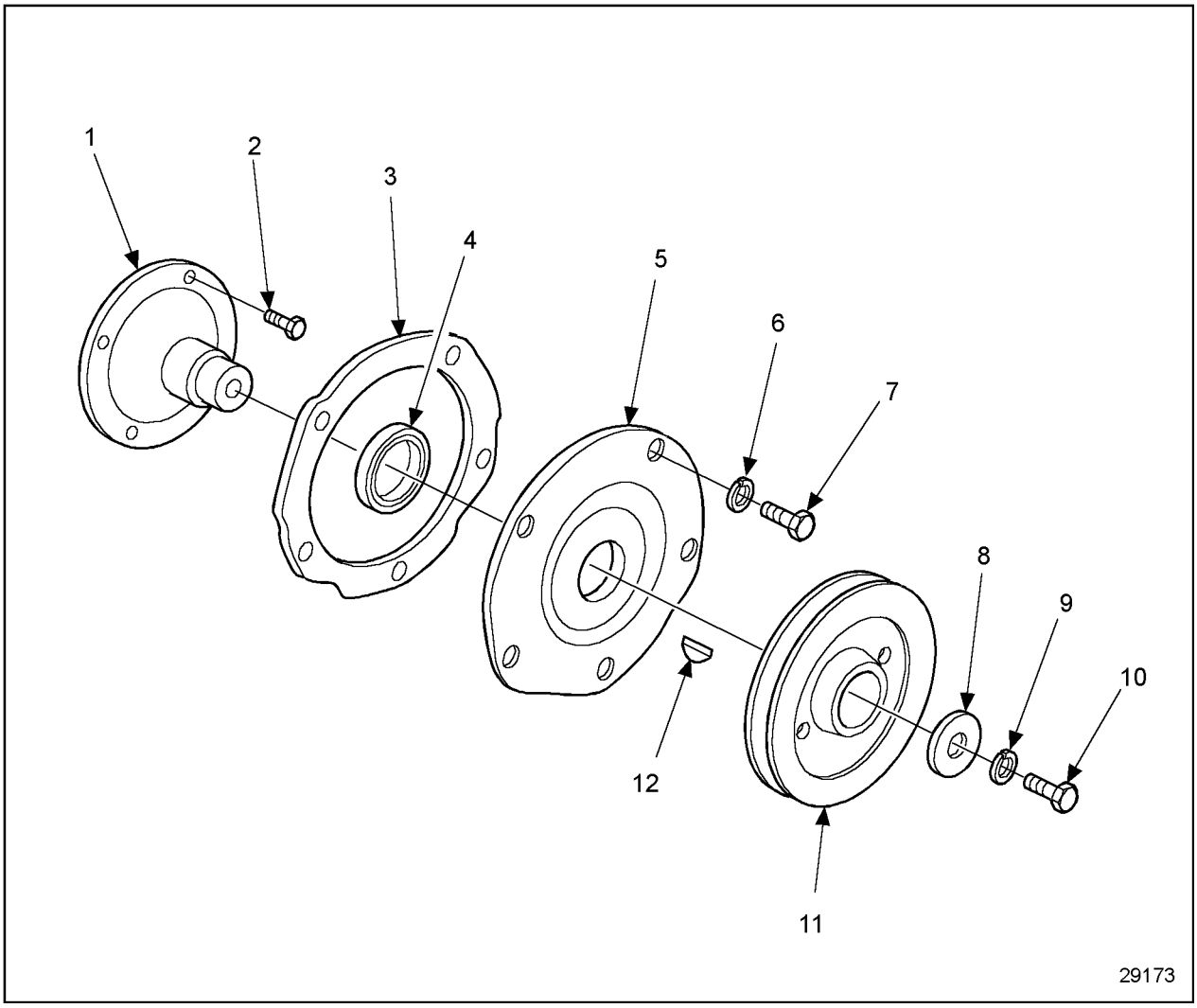


1. Bolt
2. Drive Plate
3. Drive Shaft
4. Lock Ring
5. Bearing
6. Gasket
7. Lock Washer
8. Bolt
9. Oil Seal
10. Pulley
11. Key
12. Nut
13. Spacer
14. Retainer

Figure 1-245 Components of Accessory Drive for Belt-Driven Accessory (Drive Plate Type)

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On some engines, an accessory drive hub is bolted directly to the camshaft gear. See Figure 1-246. An oil seal retainer is bolted to the flywheel housing and the pulley is keyed and secured to the hub with a bolt, lock washer, and plain washer.

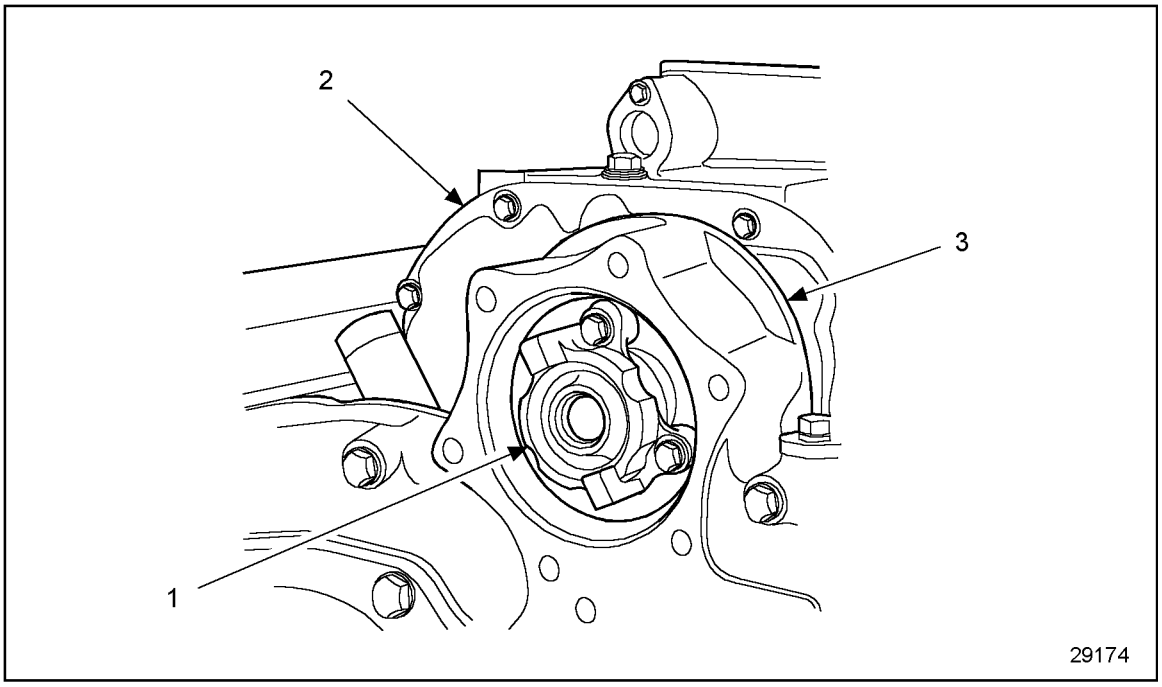


1. Drive Hub
2. Bolt
3. Gasket
4. Oil Seal
5. Retainer
6. Lock Washer
7. Bolt
8. Washer
9. Lock Washer
10. Bolt
11. Pulley
12. Key

Figure 1-246 Components of Accessory Drive for Belt-Driven Accessory (Drive Hub Type)

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Whenever an accessory is driven by the blower drive gear, a hub with two lugs replaces the standard hub in the blower drive assembly. See Figure 1-247. An accessory drive assembly consisting of a pulley, shaft double-row bearing, oil seal and oil seal spacer, and a driven hub and a housing is bolted to the flywheel housing.



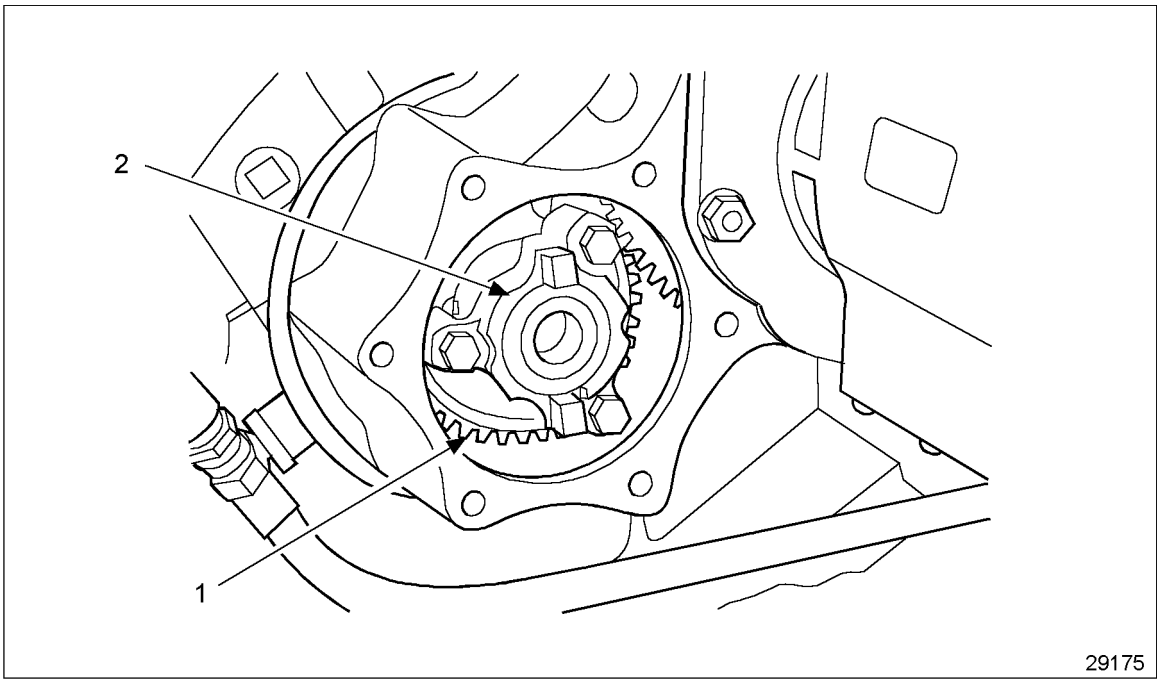
1. Accessory Drive Hub
2. Blower
3. Flywheel Housing

Figure 1-247 Accessory Drive Attached to Blower Drive Gear

A slotted coupling, that engages the lugs on the two hubs, provides the connection between the accessory drive and the blower drive gear.

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When required, an accessory drive gear is provided in the left-bank accessory pad in the flywheel housing. See Figure 1-248. The accessory drive assembly is similar to the blower drive gear and support assembly. The accessory drive gear, mounted on a support attached to the cylinder block rear end plate, is driven by the left-bank camshaft gear. The bushing-type bearings in the gear are pressure lubricated through an external oil line.



1. Accessory Drive
2. Drive Hub

Figure 1-248 Rear Left-Bank Drive Mounting

Detroit Diesel had released for service an improved coupling assembly for the 50DN alternator drive on 6V and 8V parlor and transit coach engines. This improved drive assembly provides for additional isolation of torque fluctuation on both cylinder banks and reduces camshaft bending loads. The installation of the current isolated drive gear assembly will require the removal of the alternator and power steering pump alternator plate to access the former drive gear without the need to remove the flywheel housing.

The current drive gear assembly replaced the former solid drive gear that has a drive ratio of 2.94:1. Also, the current drive gear assembly replaces the former solid drive gear that uses a drive ratio of 2.75:1. In addition, the former 20–tooth alternator pinion gear (for the 2.75:1 drive ratio) **must** be replaced with the current 18-tooth Delco Remy® pinion gear, available from Delco Remy.

Use service kit 23525790 for installation of the improved drive gear assembly.

1.31.1 Repair or Replacement of Accessory Drive

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-249.

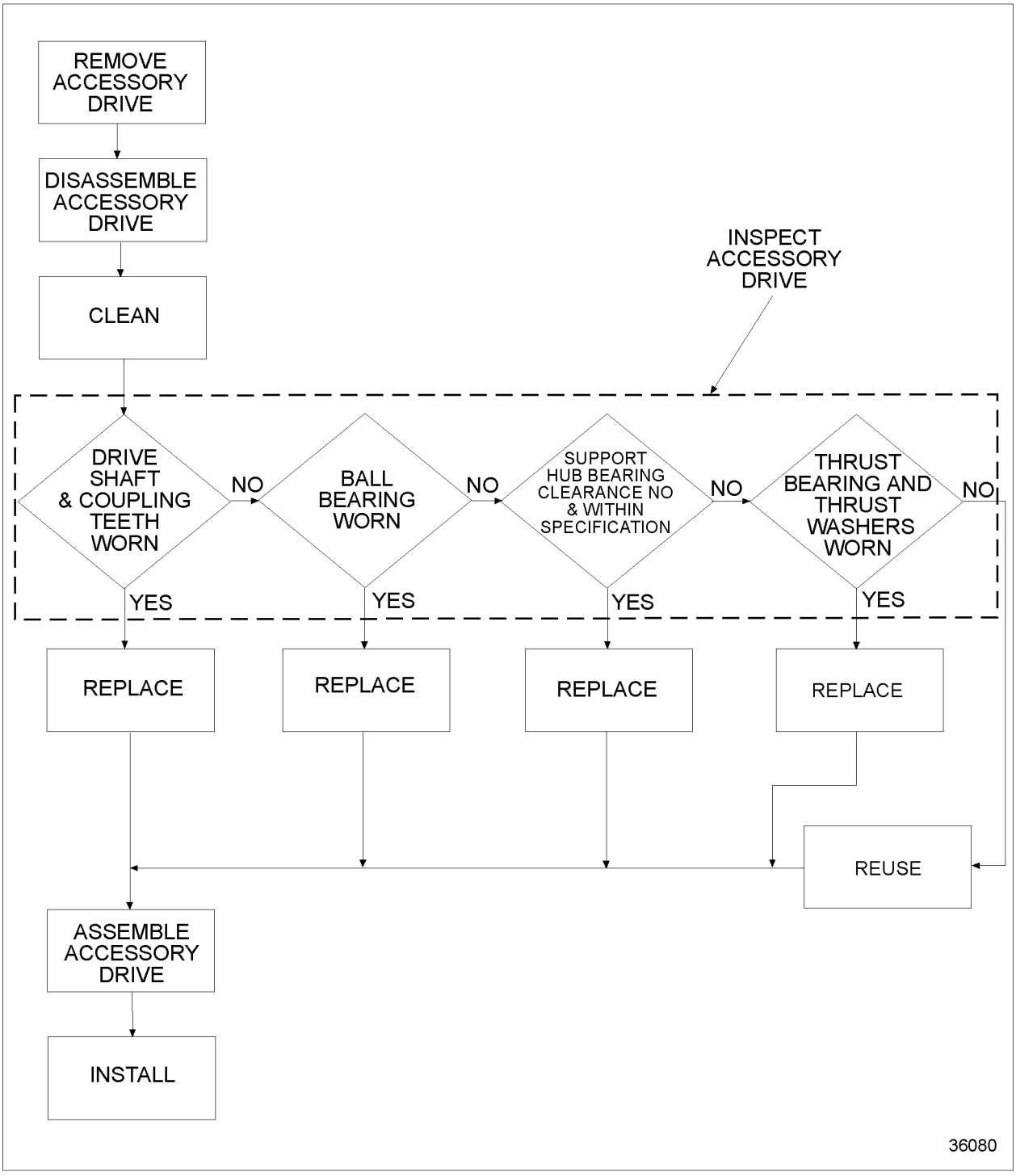


Figure 1-249 Flowchart for Repair or Replacement of Accessory Drive

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1.31.2 Removal of Front Accessory Drive

Remove front accessory drive as follows:

1. Loosen the alternator adjusting strap and alternator mounting bolts.
2. Remove the drive belt.
3. Remove any accessories necessary to provide access to the accessory drive pulley.
4. Remove the water pump. Refer to section 4.2.2.
5. Remove the pulley retaining bolt, lock washer, and plain washer.
6. Remove the pulley and the key.
7. Remove the balance weight cover. Refer to section 1.32.2.
8. Replace the oil seal in the balance weight cover, if necessary.
9. Remove the three bolts and lock washers, and withdraw the drive shaft from the water pump drive gear.

1.31.3 Removal of Direct-Drive Accessory Drive

Remove the accessory drive used with a direct-drive accessory as follows:

1. Disconnect any external piping or hoses at the accessory.
2. Remove the bolts and lock washers securing the accessory to the flywheel housing.
3. Pull the accessory straight out from the flywheel housing.
4. Remove the gasket.
5. Remove the drive coupling.

NOTE:
Place a clean, lintless cloth in the flywheel housing opening (under the accessory drive plate) to prevent bolts from accidentally falling into the gear train.

6. Remove the four shoulder bolts and lock washers, if used.
7. Withdraw the accessory drive plate.

1.31.4 Removal of Gear-Driven Accessory Drive

If a gear-driven accessory is used, remove the drive coupling as follows:

1. Remove the bolts and lock washers securing the accessory to the flywheel.
2. Pull the accessory straight out from the flywheel housing.
3. Remove and discard the gasket.

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1.31.5 Removal of Accessory Drive Hub

Remove the accessory drive hub as follows:

1. Slip the drive belt off the pulleys.
2. Remove the plain washer, lock washer, and bolt.
3. Remove the pulley.
4. Remove the key from the drive hub.
5. Remove the five attaching bolts and lock washers, and remove the retainer.
6. Remove and discard the gasket.
7. Remove and discard the oil seal.
8. Remove the four shoulder bolts.
9. Remove the drive hub.

1.31.6 Removal of Belt-Driven Accessory Drive

Remove the accessory drive used with a belt-driven accessory as follows:

1. Loosen the accessory mounting or adjusting bolts.
2. Remove the drive belts.
3. Remove the nut retaining the drive pulley on the accessory drive shaft.
4. Use a suitable gear puller, and withdraw the pulley from the shaft.
5. Remove the key from the shaft.
6. Remove the bolts and washers, and withdraw the accessory drive retainer assembly from the flywheel housing.
7. Remove the gasket.

NOTE:
Place a clean, lintless cloth in the flywheel housing opening under the accessory drive plate or drive hub to prevent bolts from falling into the gear train.

8. Remove the four shoulder bolts, and withdraw the accessory drive plate or drive hub.
9. Remove the accessory drive shaft from the retainer.
10. Remove the snap ring and ball bearing from the accessory drive retainer.

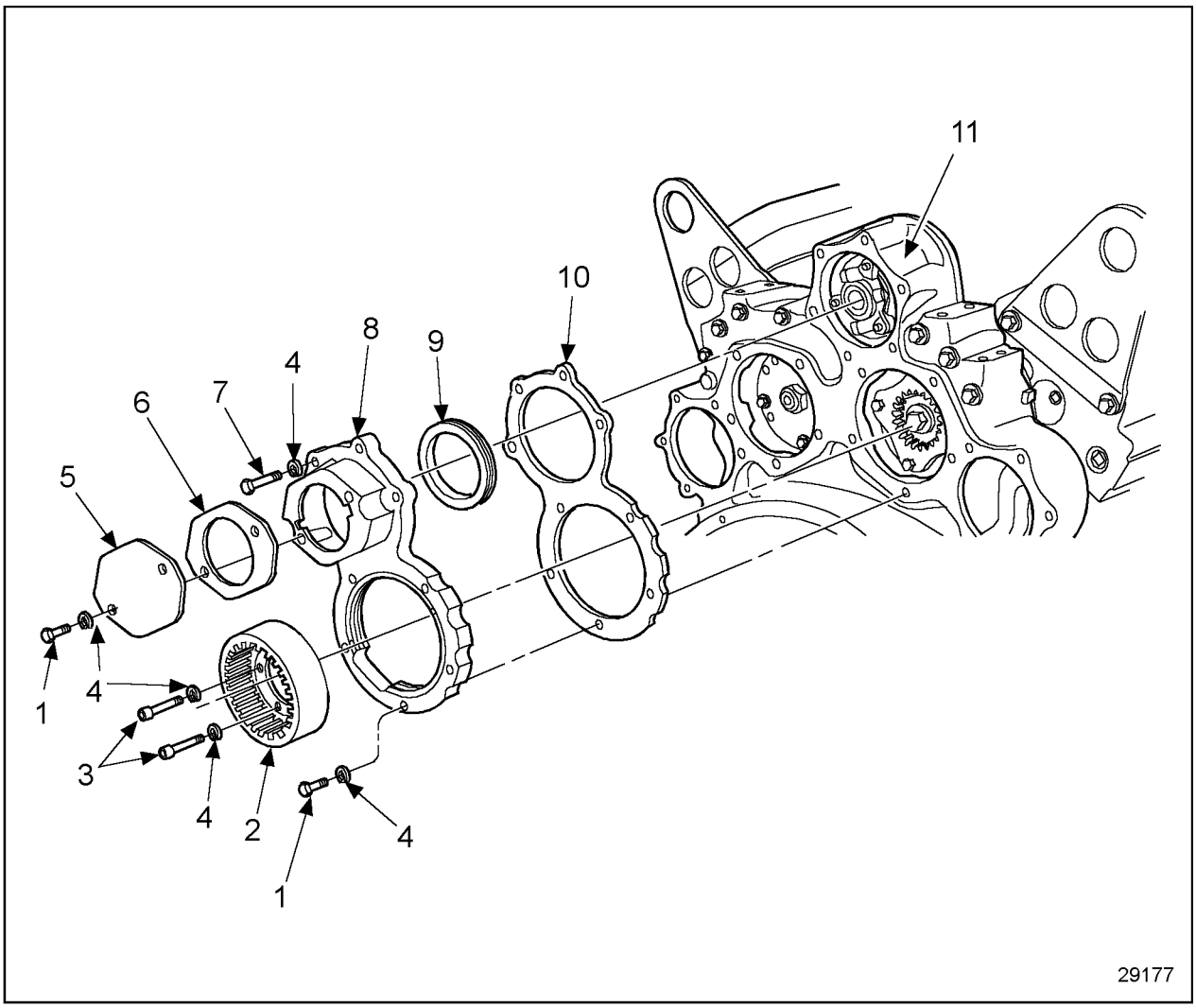
1.31.7 Removal of Accessory Drive Internal Step-Up Gear

If a step-up gear is used, remove it as follows:

1. Remove the flywheel housing small hole covers. Refer to section 1.19.2.
2. Remove the four upper adaptor bolts, and loosen the two set screws.

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3. Remove the figure "8" adaptor and the gasket. See Figure 1-250.



1. Bolt
2. Internal Step-Up Gear
3. Internal Step-Up Gear Set Screws
4. Lock Washer
5. Steering Pump Adaptor
6. Gasket
7. Upper Housing Bolt
8. Accessory Drive Adaptor
9. Adaptor Pilot Ring
10. Adaptor Gasket
11. Flywheel Housing

Figure 1-250 Rear Left-Bank Accessory Drive Assembly

1.31.8 Removal of Blower Accessory Drive

Remove the blower accessory drive as follows:

1. Loosen the alternator adjusting strap and alternator mounting bolts.

2. Remove the drive belts.
3. Remove the bolts and lock washers.
4. Withdraw the accessory drive assembly and the drive coupling.
5. Remove the blower drive shaft retaining ring.
6. Thread a No. 10-32 screw in the tapped hole and withdraw the blower drive shaft.
7. Remove the screw used to withdraw the shaft.
8. Remove the three bolts and lock washers, and withdraw the drive hub and two drive plates.

1.31.9 Removal of Left-Bank Accessory Drive

Remove the left-bank accessory drive as follows:

1. Remove the bolts and lock washers securing the hydraulic pump to the flywheel housing.
2. Withdraw the pump and gasket.
3. Remove the pump drive coupling.
4. Remove the three bolts and lock washers securing the accessory drive hub to the accessory drive gear.
5. Withdraw the drive hub.

1.31.10 Disassembly of Blower Accessory Drive

Disassemble the blower accessory drive as follows:

1. Remove the pulley retaining nut.
2. Remove the pulley and the retaining key.
3. Remove the old seal spacer.
4. Press the shaft and hub from the bearing.
5. Press the shaft from the hub, and remove the key from the shaft.
6. Remove the lock ring and bearing from the housing.
7. Press the oil seal from the housing with a suitable tool.

1.31.11 Disassembly of Rear Left-Bank Accessory Drive

Disassemble the rear left-bank accessory drive as follows:

If further disassembly is required, the flywheel housing, gear train, accessory drive lubrication tube, and cylinder block rear end plate must be removed first. Proceed as follows:

1. Remove the two bolts and copper washers securing the accessory drive support assembly to the rear end plate.
2. Withdraw the support assembly, and remove the gasket.

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3. Clamp the support assembly in a soft jawed vise.
4. Straighten the lugs on the lock washer and remove the gear retaining nut.
5. Withdraw the lock washer, thrust washer, thrust bearings, and accessory drive gear from the support.

1.31.11.1 Cleaning of Accessory Drive

Prior to inspection, clean the parts as follows:

NOTICE:
Shielded bearings must not be washed. Dirt may be washed in and the cleaning fluid might not be entirely removed from the bearing. Wipe the outside of the bearing.

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

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 with compressed air.

1.31.11.2 Inspection of Accessory Drive

Inspect the accessory drives as follows:

1. Visually inspect the drive plate and the drive coupling (or drive shaft) teeth for wear.
   [a] If worn, replace the parts. Refer to section 1.31.12.
   [b] If not worn, continue inspection.
2. Hold the ball bearing inner race, and slowly revolve the outer race to inspect for wear and free rolling.
   [a] If the bearing is worn or does not roll freely, replace the bearing. Refer to section 1.31.12.
   [b] If the bearing is not worn and rolls freely, continue inspection.

3. Check the inside diameter of the accessory drive gear bearings (bushing type) and the outside diameter of the hub on the gear support.

NOTE:
The clearance between the bearings and the support hub is 0.03-0.065 mm (0.001-0.0025 in.) with new parts.

NOTE:
If new bearings are installed, the outer end of each bearing must be pressed in flush to 0.25 mm (0.010 in.) below the face of the gear. The bearings must be reamed to size (41.300-41.313 mm 1.6260-1.6265 in. inside diameter) and to a finish of 20 micro-inches after installation. The bearing bores must also be square with the machined faces of the bolt bosses on the gear within 0.08 mm (0.003 in.) total indicator reading and concentric with the outside diameter of the gear. The thrust washer retaining pin must extend approximately 2.03 mm (0.080 in.) above the threaded end of the support hub.

   [a] Replace the parts when the clearance exceeds 0.13 mm (0.005 in.) on used parts. Refer to section 1.31.12.

   [b] If parts do not exceed specified clearances, continue inspection.

4. Remove and discard the oil seal. Inspect the drive shaft oil seal contact surface or drive hub for grooves.

   [a] If the shaft is grooved and cannot be "cleaned-up," replace it. Refer to section 1.31.20.

   [b] If not grooved or can be "cleaned-up," proceed with the inspection.

5. Inspect the drive hub for grooves and oil seal effectiveness.

   [a] If the drive hub is excessively grooved, and the oil seal is no longer effective, install a ring-type oil seal spacer to reposition the seal and provide a new sealing surface for the oil seal lip. Refer to section 1.31.18.

   [b] If the drive hub is not excessively grooved, and the oil seal is still effective, continue inspection.

6. Inspect the thrust bearings and thrust washers for scoring or wear.

   [a] If excessively worn or scored, replace the thrust bearings and thrust washer.

   [b] If not excessively worn or scored, reuse the thrust bearings and thrust washers.

1.31.12 Assembly of Blower Accessory Drive

Assemble the blower accessory drive as follows:

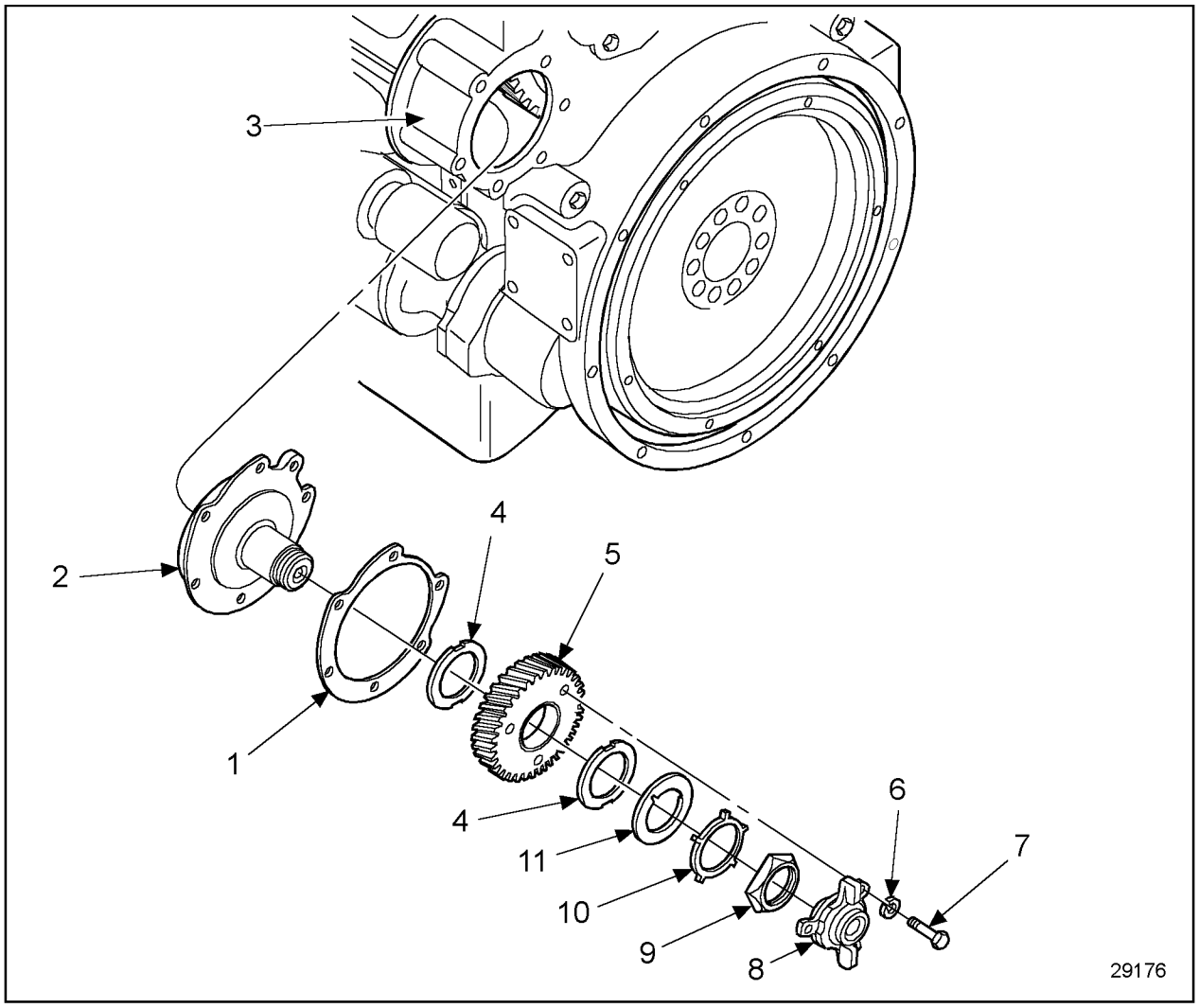
1. Install a key in the hub end of the shaft.
2. Lubricate the shaft, and press the hub tight against the shaft shoulder.
3. Install a new oil seal in the housing.
4. Install the bearing in the housing.

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5. Install the lock ring.
6. Use a sleeve to support the bearing inner race, lubricate the shaft, and press the hub and shaft assembly in the bearing until the shaft shoulder contacts the bearing inner race.
7. Install a key in the pulley end of the shaft.
8. Lubricate the shaft, and press the pulley on the shaft until it contacts the inner race of the oil seal spacer.
9. Install the 3/4 in.-16 pulley retaining nut. Tighten it to 163-190 N·m (120-140 lb·ft) torque.

1.31.13 Assembly of Rear Left-Bank Accessory Drive

See Figure 1-251. Assemble the rear left-bank accessory drive as follows:



1. Gasket
2. Accessory Drive Retainer
3. Flywheel Housing
4. Thrust Bearing (2)
5. Accessory Drive Gear
6. Lock Washer
7. Bolt
8. Drive Hub
9. Nut
10. Lock Washer
11. Thrust Washer

Figure 1-251 Rear Left-Bank Accessory Drive Assembly

1. Clamp the accessory drive support in a soft jawed vise.
2. Align the thrust bearing tangs with the support holes.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Lubricate the support hub, the gear bearings, both thrust bearings, and the thrust washer with clean engine oil.
4. Slide the gear on the hub, the flat side of the gear toward the support.
5. Install the second thrust bearing on the support, the bearing tangs facing away from the gear.
6. Align the thrust washer slots with the thrust bearing tangs.
7. Align the support hub pin with the washer bore slot.
8. Secure the gear, thrust bearings, and thrust washer with a lock washer and nut.

NOTE:
The new thrust washer with two inner diameter keyways and the new lock washer with a longer tang must be used together for optimal nut locking.

9. Tighten the nut to 68-81 N·m (50-60 lb·ft) torque. Bend the lock washer lugs against the nut flats.
10. Check the clearance between the thrust washer and the thrust bearing with a feeler gage.

NOTE:
The clearance must not exceed 0.30 mm (0.012 in.) with used parts. With new parts, the specified clearance is 0.13-0.25 mm (0.005-0.010 in.).

11. Affix a new gasket to the accessory drive gear.
12. Attach assembly to the cylinder block rear end plate with two bolts and copper washers. Tighten the bolts to 34-41 N·m (25-30 lb·ft) torque.
13. Install the rear end plate and gear train.
14. Check the backlash between the accessory drive gear and the camshaft gear.

NOTE:
The backlash must be between 0.05-0.20 mm (0.002-0.008 in.) with new gears and must not exceed 0.25 mm (0.010 in.) with worn gears.

15. Install the flywheel housing.
16. Install the accessory drive lubrication tube.

1.31.14 Installation of Front Accessory Drive

Install the front accessory drive as follows:

1. Attach the accessory drive shaft to the water pump drive gear with three 5/16 in.-24 x 7/8 in. bolts and lock washers. Tighten the bolts to 20-26 N·m (15-19 lb·ft) torque.
2. Install the balance weight cover. Refer to section 1.32.3.
3. Install the key in the shaft.
4. Install the pulley on the shaft, and secure it with a 3/8 in.-16 x 7/8 in. bolt, lock washer, and plain washer. Tighten the bolt to 34 N·m (25 lb·ft) torque.
5. Install the water pump. Refer to section 4.2.5.
6. Install any accessories removed to provide access to the accessory drive pulley.
7. Install the drive belt, and adjust the alternator to provide the proper belt tension. Tighten the alternator adjusting strap bolt and alternator mounting bolts.

NOTE:
When installing or adjusting accessory drive belts, ensure the bolt at the accessory adjusting pivot and the bolt in the adjusting slot is properly tightened. Refer to section 1.31.13.

1.31.15 Installation of Direct-Drive Accessory Drive

Install the accessory drive used with a direct-drive accessory as follows:

1. Align the bolt holes in the accessory drive plate with the tapped camshaft gear holes.
2. Secure the drive plate with the four special shoulder bolts. Tighten the bolts to 61-68 N·m (45-50 lb·ft) torque.
3. Remove the lintless cloth from the flywheel housing opening.
4. Install the drive coupling.
5. Install a new gasket.
6. Place the accessory straight on the flywheel housing, and secure with bolts and lock washers.
7. Connect any external piping or hoses to the accessory.

1.31.16 Installation of Gear-Driven Accessory Drive

If a gear-driven accessory is used, install the drive coupling as follows:

1. Affix a new gasket to the mounting flange on the accessory.
2. Place the accessory in position against the flywheel housing, and rotate it, if necessary, to align the teeth of the drive hub with those in the drive coupling.
3. Secure the accessory to the flywheel housing with bolts and lock washers.

1.31.17 Installation of Belt Driven Accessory Drive

If a belt-driven accessory is used, proceed as follows:

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1. Place the accessory drive retainer on a bench, mounting flange side up. Lubricate the outside diameter of the bearing with oil.
2. Press or tap the bearing, the protruding face of the inner race facing toward the retainer, straight in until it contacts the retainer shoulder.
3. Install the lock ring.
4. Turn the retainer over, and coat the bore with sealant.
5. Press a new oil seal into the retainer bore with the seal lip facing the bearing. Wipe any excess sealant from the retainer.
6. Turn the retainer over, bearing side up. Lubricate the drive shaft, and press it in the bearing until the shaft shoulder contacts the bearing.
7. Affix a new gasket to the retainer mounting flange.
8. Position the retainer and shaft assembly against the flywheel housing. Rotate the shaft slightly, if necessary, to permit the teeth of the shaft to mesh with the teeth in the accessory drive plate.
9. Secure the retainer to the flywheel housing with five bolts and lock washers. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.
10. Install the key in the shaft. Start the pulley on the shaft, and tap it into place.
11. Install the 3/4 in.-16 retaining nut. Tighten the nut to 163-190 N·m (120-140 lb·ft) torque.
12. Slip the drive belts over the pulleys. Position the accessory to provide the proper tension on the belts, and secure in place.

NOTE:
When installing or adjusting accessory drive belts, ensure the bolt at the accessory adjusting pivot point and the adjusting slot bolt is properly tightened.

1.31.18 Installation of Accessory Drive Hub

If an accessory drive hub is used, proceed as follows:

1. Align the drive hub bolt holes with the tapped holes in the camshaft gear. Secure the drive hub to the gear with four shoulder bolts. Tighten the bolts to 61-68 N·m (45-50 lb·ft) torque.
2. Use a dial indicator to check the run-out of the drive hub shaft.

NOTE:
The run-out must be within 0.25 mm (0.010 in.) total indicator reading.

3. Coat the retainer bore with sealant, and press a new oil seal in place.

NOTE:
The seal lip must face the engine when the retainer is installed.

4. Affix a new gasket to the retainer mounting flange.

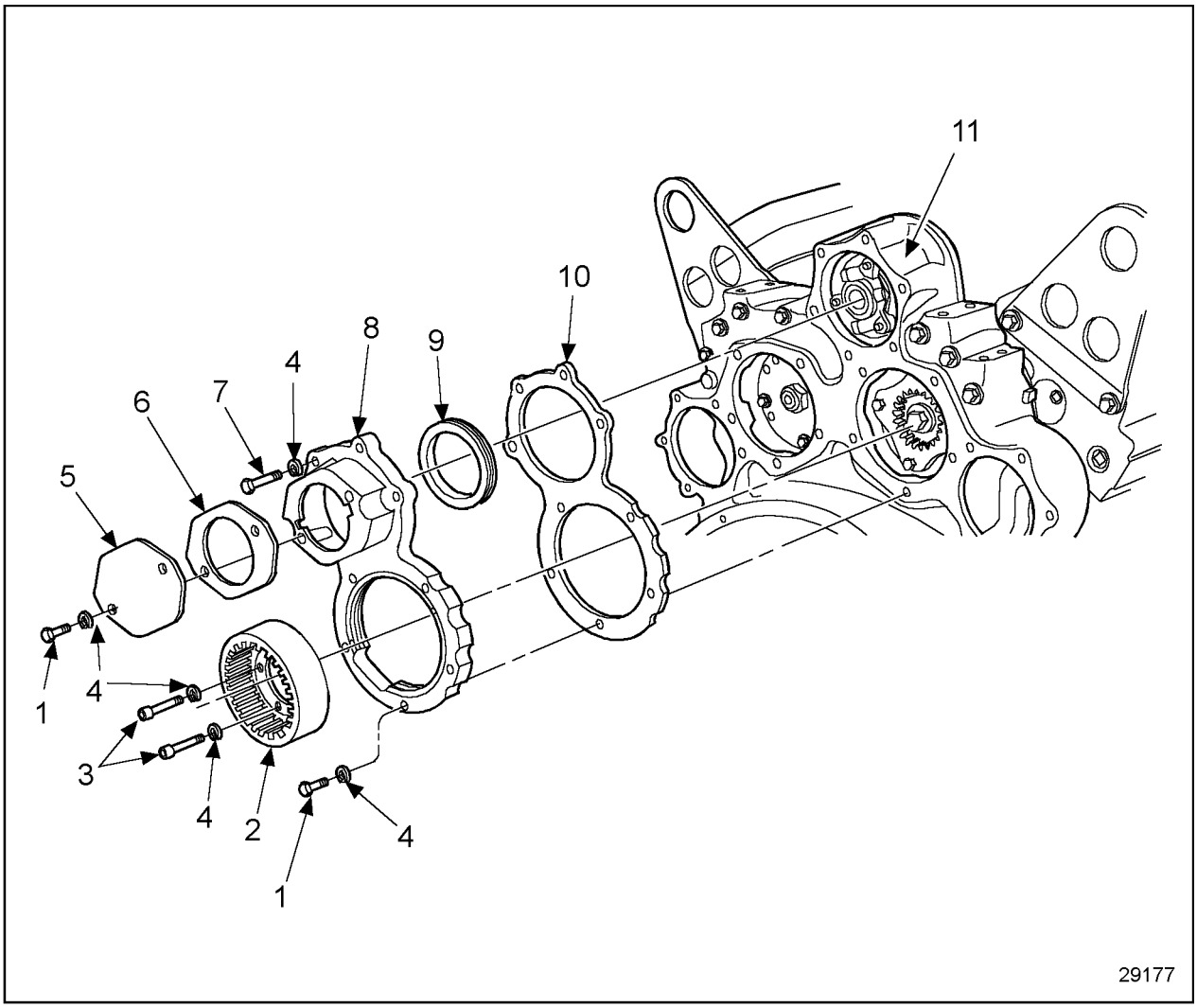
5. Place the retainer against the flywheel housing, and install the five attaching bolts and lock washers.
6. Before tightening the bolts, insert tool J 21166 over the shaft and into the retainer bore to align the oil seal with the shaft. Tighten the retainer bolts to 41-47 N·m (30-35 lb·ft) torque, and remove the oil seal aligning tool.
7. Install the key in the drive hub.
8. Start the pulley on the drive hub, and tap it into place.
9. Install the plain washer, lock washer, and bolt. Tighten the bolt to 47 N·m (35 lb·ft) torque.
10. Slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt, and secure it in place.

NOTE:
When installing or adjusting accessory drive belts, ensure the bolt at the accessory adjusting pivot point and the adjusting slot bolt is properly tightened. Refer to section 13.18.

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1.31.19 Installation of Step-Up Gear

If a step-up gear is used, see Figure 1-252. Proceed as follows:



1. Bolt
2. Internal Step-Up Gear
3. Internal Step-Up Gear Set Screws (2)
4. Lock Washer
5. Steering Pump Adaptor Cover
6. Gasket
7. Upper Housing Bolt
8. Accessory Drive Adaptor
9. Adaptor Pilot Ring
10. Adaptor Gasket
11. Flywheel Housing

Figure 1-252 Step-Up Gear Installation

1. Affix a new gasket to the figure "8" adaptor. Position the adaptor on the flywheel housing using a feeler gage, or equivalent, on the camshaft gear.

2. Install and tighten the four upper adaptor bolts. Adjust the two set screws until they are snug against the flywheel housing.
3. Place alignment gage J 29893 in the step-up gear, and secure it with the gage read point at the 8 o'clock set screw position.
4. Set the dial indicator on "0."

NOTICE:
When barring an engine, always turn clockwise. Ensure the crankshaft end bolt has not been loosened during the barring operation. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

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.

5. Bar the engine over.

NOTE:
The gage must travel clockwise until the read point is at the 2 o'clock position set screw (180 degrees).

6. If the dial indicator reads between the initial "0" setting and ± 0.002 in., remove the alignment gage.
7. If the dial indicator reads more than ± 0.002 in. from the initial setting of "0," loosen the four upper adaptor bolts. Back off the set screws on the adaptor, and readjust them until the dial indicator reading is one-half of the total variance.
8. Refer to step 6 and refer to step 7, to repeat the process until the proper readings are obtained or a maximum of three attempts have been made.
9. If the proper alignment readings cannot be obtained after three attempts, change the adaptor.
10. Remove the alignment gage.

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NOTICE:
Ensure alternator is properly fitted to the adaptor before it is bolted in place. Improper installation of the alternator can disturb adaptor alignment and cause gear train damage.

11. Install the flywheel housing small hole covers. Refer to section 1.19.3.

1.31.20 Installation of Rear Blower Accessory Drive

Install the rear blower accessory drive as follows:

1. Install the drive hub and the two drive plates on the blower drive gear.
2. Install the blower drive shaft, and secure it in place with the snap ring.
3. Place a new gasket on the accessory drive housing mounting flange.
4. Place the slotted drive coupling on the accessory drive assembly hub.
5. Align the coupling slots with the hub lugs attached to the blower drive gear.
6. Position the accessory drive against the flywheel housing. Secure the accessory drive assembly to the flywheel housing with bolts and lock washers.
7. Place the drive belts over the pulleys, and adjust the tension on the belts. Tighten the accessory mounting bolts.
8. Install the flywheel housing small hole covers if they were removed. Refer to section 1.19.3.

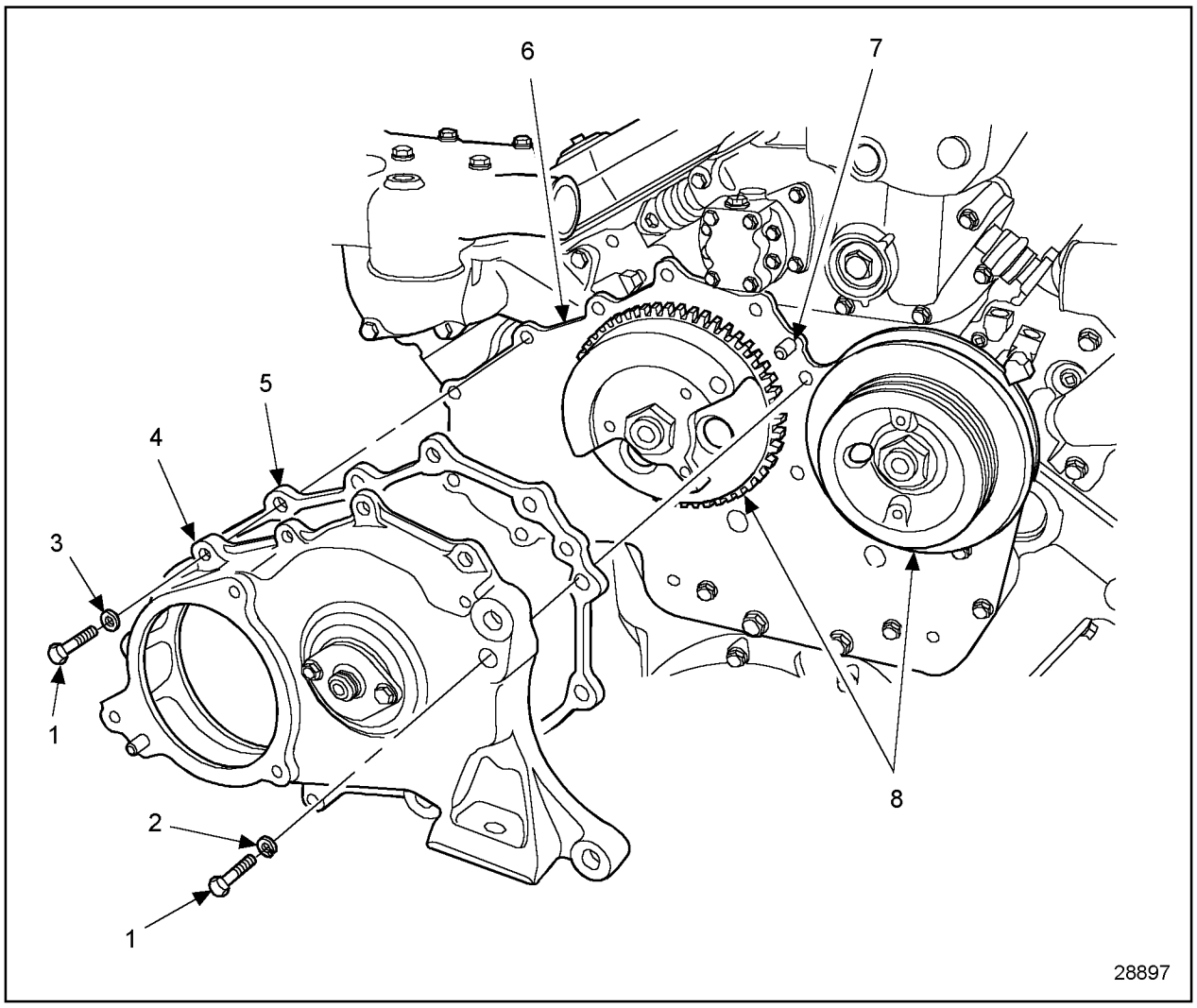
1.31.21 Installation of Left-Bank Accessory Drive

Install the left-bank accessory drive as follows:

1. Position the drive hub on the accessory drive gear, and secure it with three bolts and lock washers.
2. Affix a new gasket to the mounting flange on the hydraulic pump.
3. Place the slotted drive coupling on the pump driven hub. Align the coupling slots with the drive hub lugs.
4. Position the pump against the flywheel housing. Secure the pump to the flywheel housing with bolts and lock washers.
5. Install the flywheel housing small hole covers. Refer to section 1.19.3.

1.32 BALANCE WEIGHT COVER

The balance weight cover encloses the combination balance weight and water pump drive gear on the front end of the right cylinder bank camshaft. See Figure 1-253. This cover also serves to support the water pump.



1. Balance Weight Cover Bolts
2. Lock Washers
3. Plain Washers
4. Balance Weight Cover
5. Gasket
6. Front End Plate
7. Balance Weight Cover Alignment Dowel
8. Camshaft Balance Weight Assemblies

Figure 1-253 Typical Balance Weight Cover Assembly

The balance weight cover requires no servicing. When an engine is being completely reconditioned or the right-bank camshaft, camshaft bearings, or water pump drive gear need replacing, the balance weight cover must be removed.

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1.32.1 Repair or Replacement of Balance Weight Cover

The balance weight cover is not a serviceable item. Removal and installation procedures are listed below. See Figure 1-254.

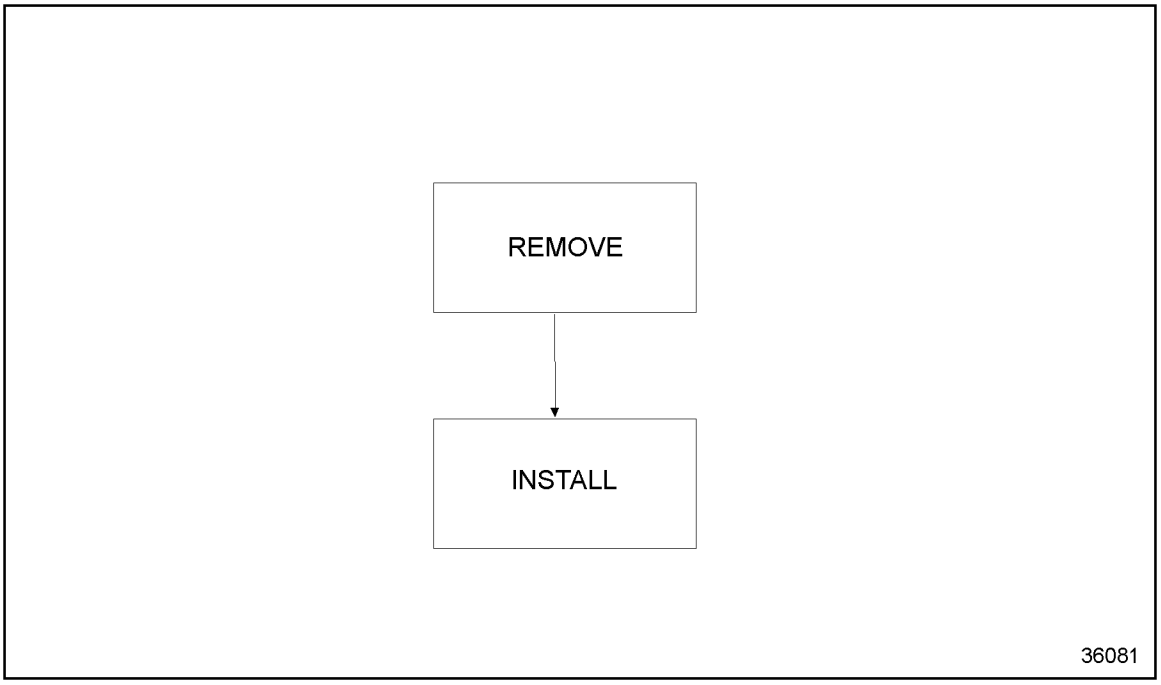


Figure 1-254 Flowchart for Repair or Replacement of Balance Weight Cover

1.32.2 Removal of Balance Weight Cover

Remove the balance weight cover as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Remove the water pump. Refer to section 4.2.2.
3. Remove any other parts required to remove the balance weight cover.
4. Remove the bolts, washers, and lock washers securing the balance weight cover to the front end plate and the cylinder block.

NOTE:
The cover is doweled to the end plate.

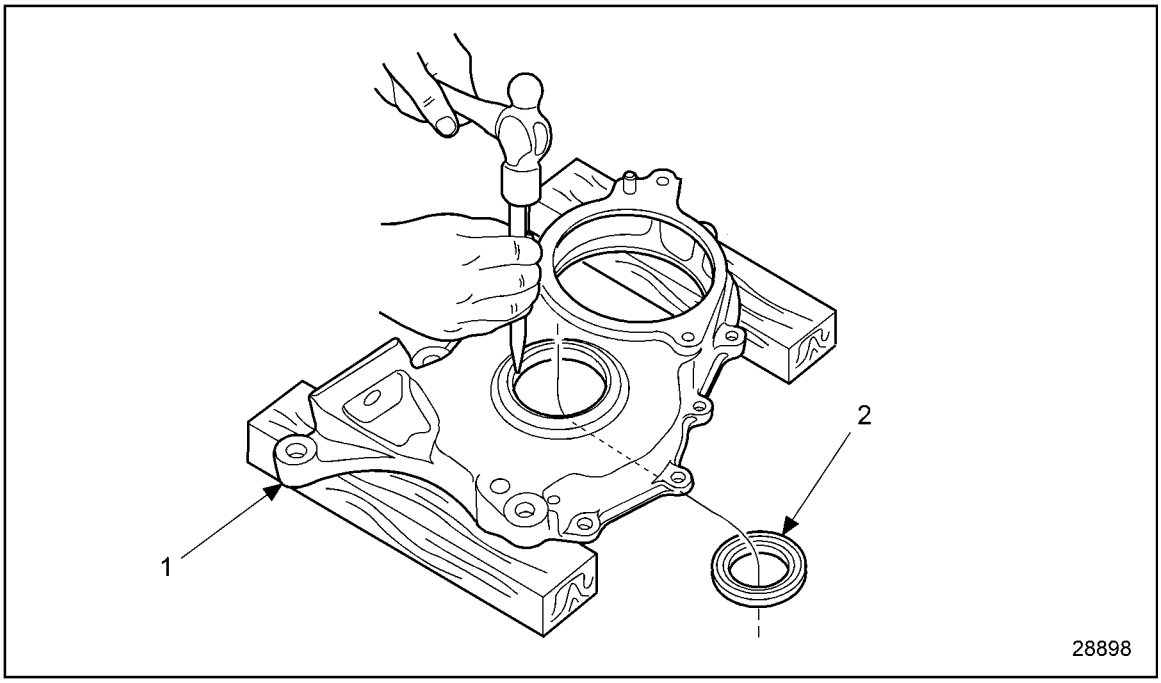
5. Tap the cover ends with a soft hammer to loosen it.
6. Remove all traces of the old gasket material from the cover and the end plate.

1.32.3 Installation of Balance Weight Cover

Install the balance weight cover as follows:

1. Affix a new gasket to the balance weight cover.
2. An accessory drive shaft oil seal is pressed into the balance weight cover on some engines.

See Figure 1-255. If necessary, replace the oil seal as follows:



1. Balance Weight Cover
2. Press Fit Oil Seal

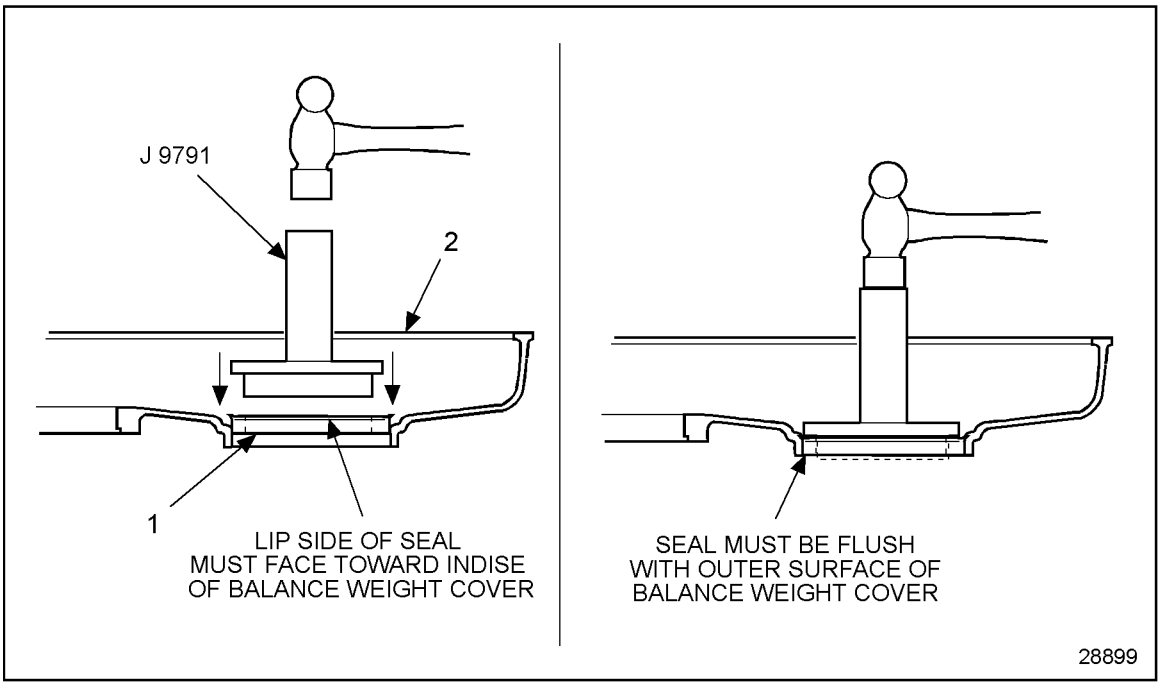
Figure 1-255 Removing Accessory Drive Balance Weight Cover Oil Seal

1. Drive the old oil seal out of the cover.

NOTE:
The new oil seal is plastic coated on the outside diameter for sealing purposes. Do not remove this coating.

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2. Position the seal with the sealing lip pointing toward the inner side of the cover. See Figure 1-256.



1. Oil Seal
2. Balance Weight Cover (Face Down)

Figure 1-256 Installation of Accessory Drive Oil Seal

3. Drive the seal in with installer J 9791 until it is flush with the outer surface of the cover.
4. Coat the seal lip with grease.

Complete installation as follows:

1. Install the balance weight cover on the engine, and secure it with bolts, nuts, lock washers, and plain washers.
2. Tighten the 3/8 in.-16 bolts to 41-47 N·m (30-35 lb·ft) torque, 3/8 in.-24 bolts and nuts to 47-53 N·m (35-39 lb·ft) torque, 1/2 in.-13bolts to 96-102 N·m (71-75 lb·ft) torque and the 5/8 in.-11 bolts to 186-200 N·m (137-147 lb·ft) torque.
3. Install the water pump. Refer to section 4.2.5.
4. Install any other parts that were removed.
5. Fill the cooling system. Refer to section 13.12.

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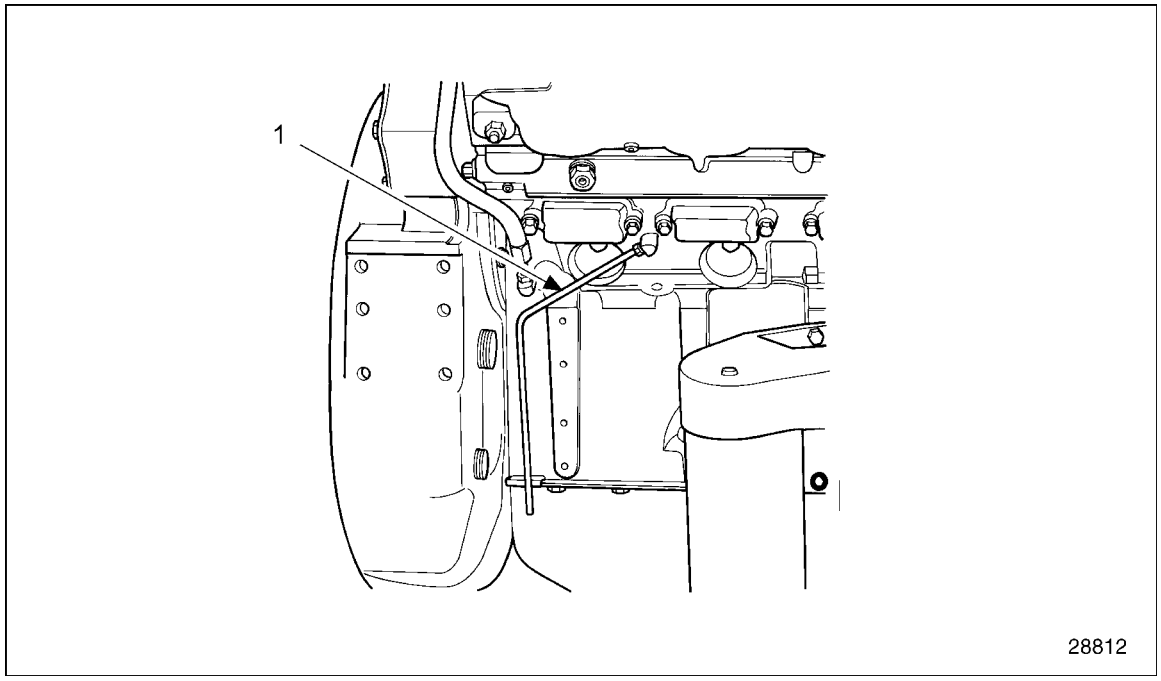
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SHOP NOTES

Shop notes for the Series 92 Engine:

AIR BOX DRAINS

During normal engine operation, water vapor, fuel fumes, and lubricating oil fumes condense on the bottom of the air box. The air box and air box drain tubes, mounted on the side of the cylinder block, remove the condensation. See Figure 1-257.

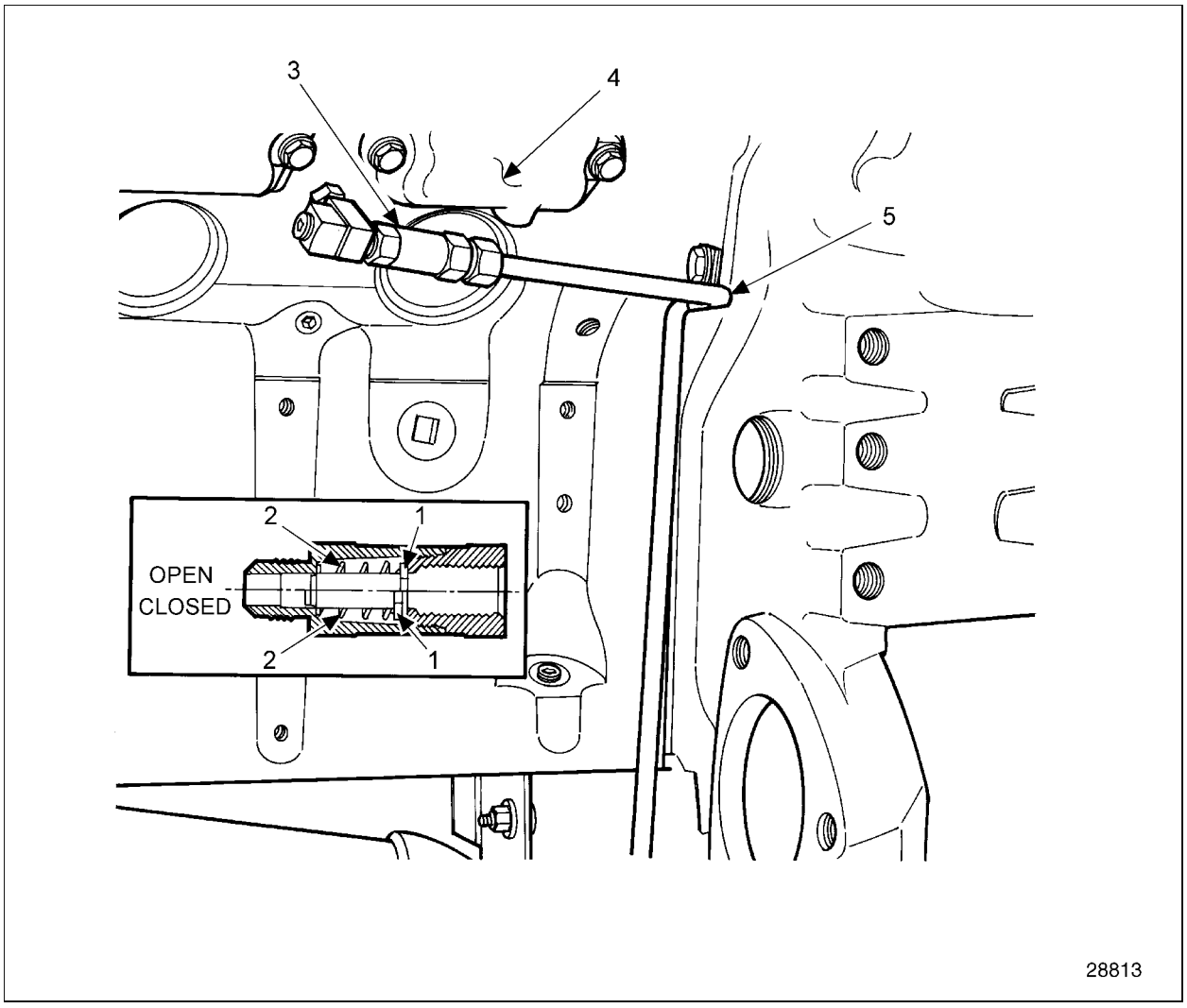


1. Air box Drains

Figure 1-257 Early Air Box Drain Tube

NOTE:
Early V-92 vehicle engines built without the air box drain check valves and engines built with drain tubes routed to the crankcase via the dipstick adaptor should be updated with the current open air box drain system. See Figure 1-258.

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1. Plunger
2. Spring
3. Check Valve
4. Air Box Cover
5. Air Box Drain

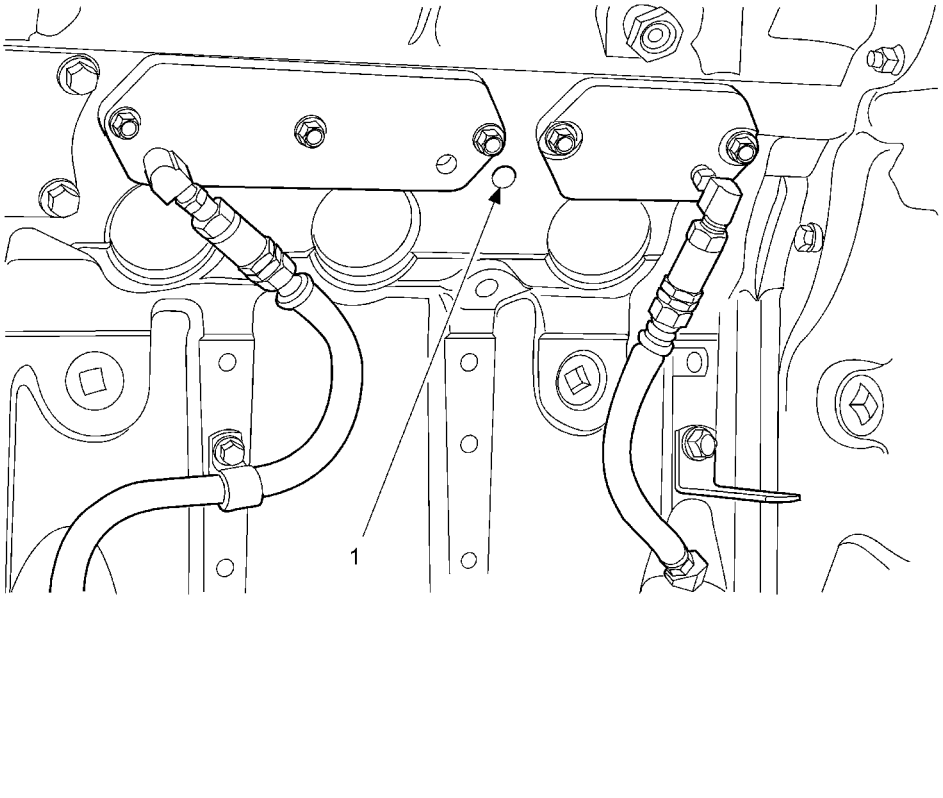
Figure 1-258 Open Air Box Drain Tube and Check Valve System

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

A check or control valve in the air box drain fitting allows drainage only at low air box pressure. The valve closes when air box pressure is increased.

The check valve cutaway shows the valve operating at engine idle speed. As the engine speed and air box pressure increase, the valve moves forward and seats, blocking air flow. Two valves with different pressure settings are available. See Figure 1-258.

NOTE:
Early V-92 vehicle engines built without the air box drain check valve and engines built with drain tubes routed to the crankcase via the dipstick adaptor should be updated with the current open air box drain system. See Figure 1-259.



1. Former Drain Opening

Figure 1-259 Left-Bank Air Box Drains and Covers (6V-92 Vee Drive Coach Engines)

NOTE:
DDC recommends retrofitting existing 6V vee drive coach engines with the new air box covers and drains because of the significant drainage improvement.

NOTE:
To ensure efficient air box drainage, install air box covers with the drilled drain openings down and the slot in the large cover facing inboard. Install check valves at an angle of 30 degrees to 45 degrees. Do not install check valves horizontally.

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Inspection of Check Valve

Inspect the check valve as follows:

1. Disconnect the drain tube between the check valve and the air box drain tube nut.
2. Run the engine, and note the air flowing through the valve at idle speed.
3. If the check valve is operating properly, there should be no airflow at engine speeds above 900-950 RPM. or 1400 RPM., depending on the valve used.
   [a] If airflow is present at engine speeds above 900-950 RPM. or 1400 RPM., replace the check valve.
   [b] If no airflow is present, reuse the check valve.

Inspect Air Box Pressure

To check air box pressures on an engine with drain tubes or hoses, proceed as follows:

1. Use an air box cover with a tapped hole for a fitting.
2. Remove the plug in the cover.
3. Install a fitting and a short drain tube.
4. Attach a manometer to the end of the drain tube.
5. Check the air box pressure. Refer to section 13.27.
   [a] If the air box pressure is not within specified limits, replace the air box.
   [b] If the air box pressure is within specified limits, reuse the air box.

CYLINDER BLOCK LINE BORING

To repair the main bearing saddles in a cylinder block damaged by spun main bearings, the damaged saddle must be machined to accept an insert. The insert and a new unfinished main bearing service cap are then line bored to the proper dimensions to accept standard main bearing shells.

Instructions for using the cylinder block line boring tool J 29005 are listed below:

NOTE:
To use this tool, two of the main bearing saddles must be undamaged, with one being the rear main saddle. The cylinder block assemblies of 12 and 16 cylinder engines must be separated and each "half block" line bored separately. If line boring performed in a suitably equipped machine shop, refer to “Dimensions for Machine Shop Line Boring Cylinder Block” in this section.

1. Remove all the plugs and main bearing caps, and clean the usable cylinder block.

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2. Determine which two undamaged main bearing saddles are to be used as alignment locations. Since the rear main bearing saddle cannot be repaired with this tool set, it must be one of the undamaged saddles. These saddles should be as far apart as possible.

NOTE:
In a block where the front and rear main bearing cap and saddle are serviceable, the journals in between can be repaired successively without removing the centering rings from the front and rear positions. When the only good main bearing bores are next to each other, the centering rings will have to be mounted there and marked for indexing. The closest bore will then be repaired first. The rear centering ring will remain in position and the other centering ring will be moved into the just repaired saddle so that the next damaged saddle can be repaired. The centering ring should be indexed identically when moved from saddle to saddle.

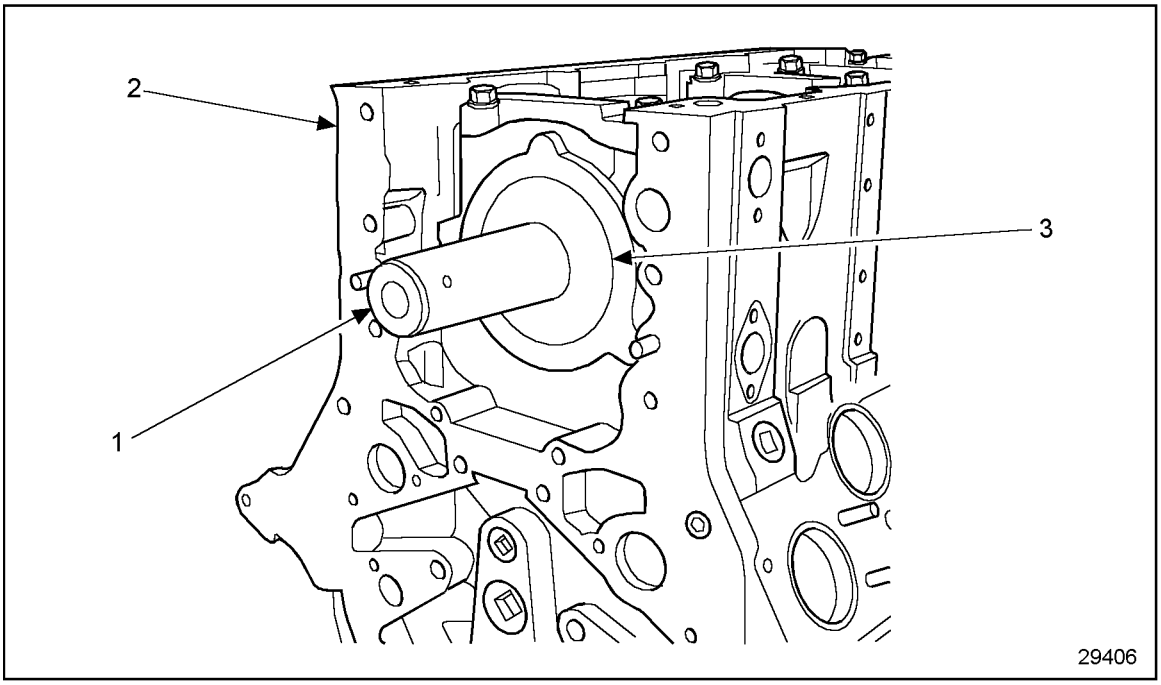
3. Set the centering rings (122.238 mm or 4.8125 in.) into the alignment saddles, and install the main bearing caps. Do not tighten the bolts.
4. Slide the boring bar through the centering rings.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

5. Lubricate the ring hole with clean engine oil during installation. The bar should rotate freely. See Figure 1-260.



1. Boring Bar
2. Cylinder Block
3. Centering Ring

Figure 1-260 Location of Boring Bar

6. Tighten the main bearing cap bolts on the caps holding the centering rings to the torque specified, 312-325 N·m (230-240 lb·ft).

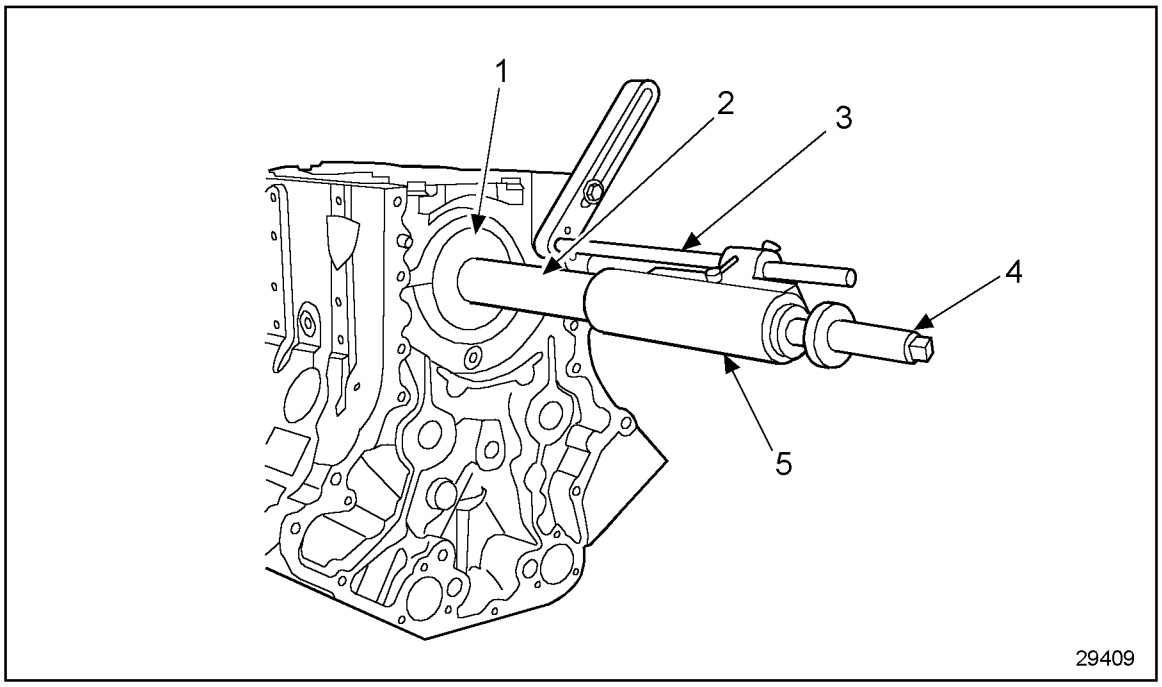
NOTE:
If the centering rings are loose in the saddle after tightening the bolts, use 0.001 in. paper shims, as necessary, between the ring and the main bearing cap and between the ring and the block.

7. Install the caps on all the remaining saddles, except the saddle to be machined, and hand tighten the bolts.

8. Install the insert hold-down bolts into the bolt holes of the saddle to be machined.

NOTE:
Do not tighten the bolts. This is only to keep chips out of the bolt holes.

9. Fasten the torsion bar and the hydraulic feed unit on either end of the cylinder block. Index the flat part of the feed rod into the boring bar. Snug the set screw. See Figure 1-261.

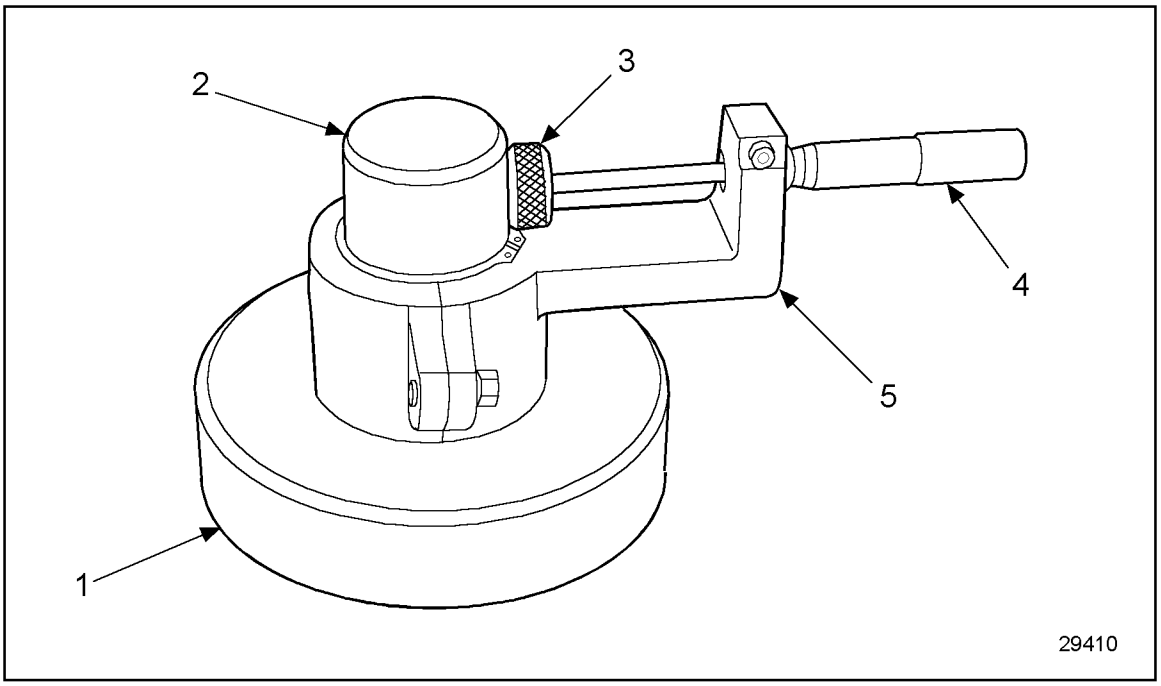


1. Centering Ring
2. Boring Bar
3. Torsion Bar
4. Feed Rod
5. Feed Unit

Figure 1-261 Location of Feed Rod and Unit

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10. Zero the micrometer with the test block supplied. See Figure 1-262. The micrometer is 0.050 in. per revolution, not 0.025 in. as normally seen on micrometers.



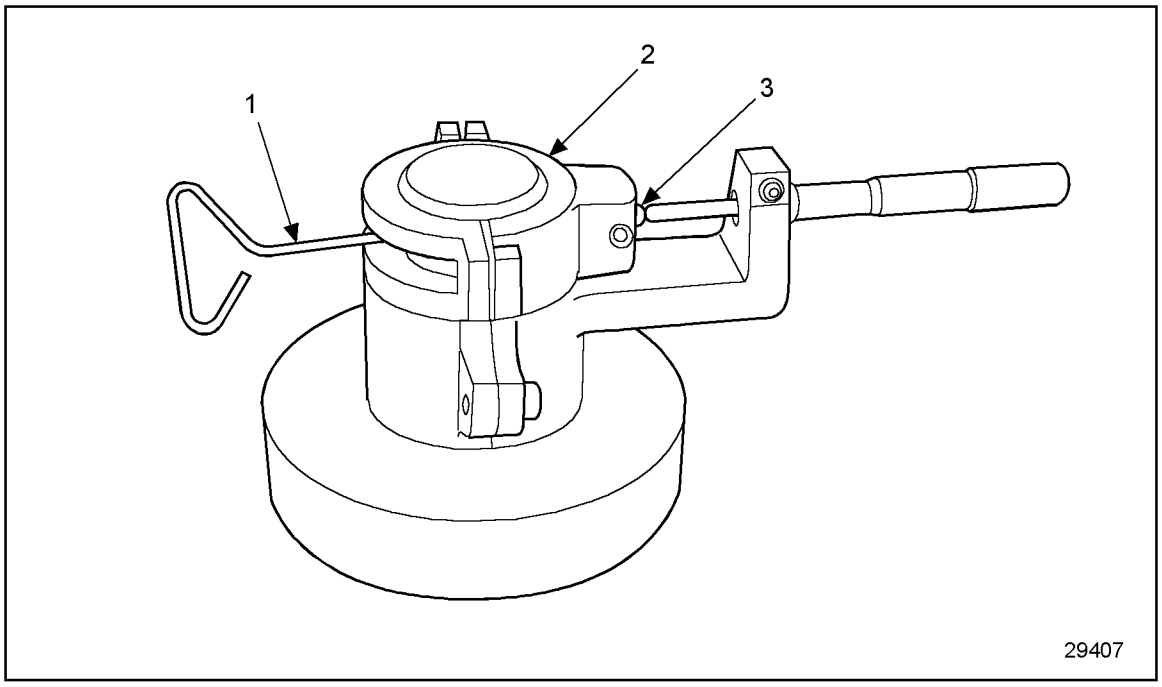
1. Base
2. Shaft
3. Test Block
4. Micrometer
5. Holder

Figure 1-262 Test Fixture and Micrometer

11. Install the cutting tool holder on the micrometer test fixture. Use only the straight Allen wrench supplied in the kit.

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12. Set the cutting tool for the first cut of 0.040 in. See Figure 1-263. The point of the cutting tool should be in the center of the micrometer barrel.



1. Cutter Bit Push Key
2. Cutting Tool
3. Cutting Tool Bit

Figure 1-263 Installing Cutting Tool Holder

NOTE:
Excessively tightening the Allen head screws is unnecessary.

13. Install the cutting tool on the boring bar.

Example:

Block: Bore Diameter First Cut 4.812 in. + 0.040 in. **Insert/Cap:** 4.712 in. + 0.040 in.

Block: Set Tool Second Cut 4.852 in. + 0.040 in. **Insert/Cap:** 4.752 in. + 0.040 in.

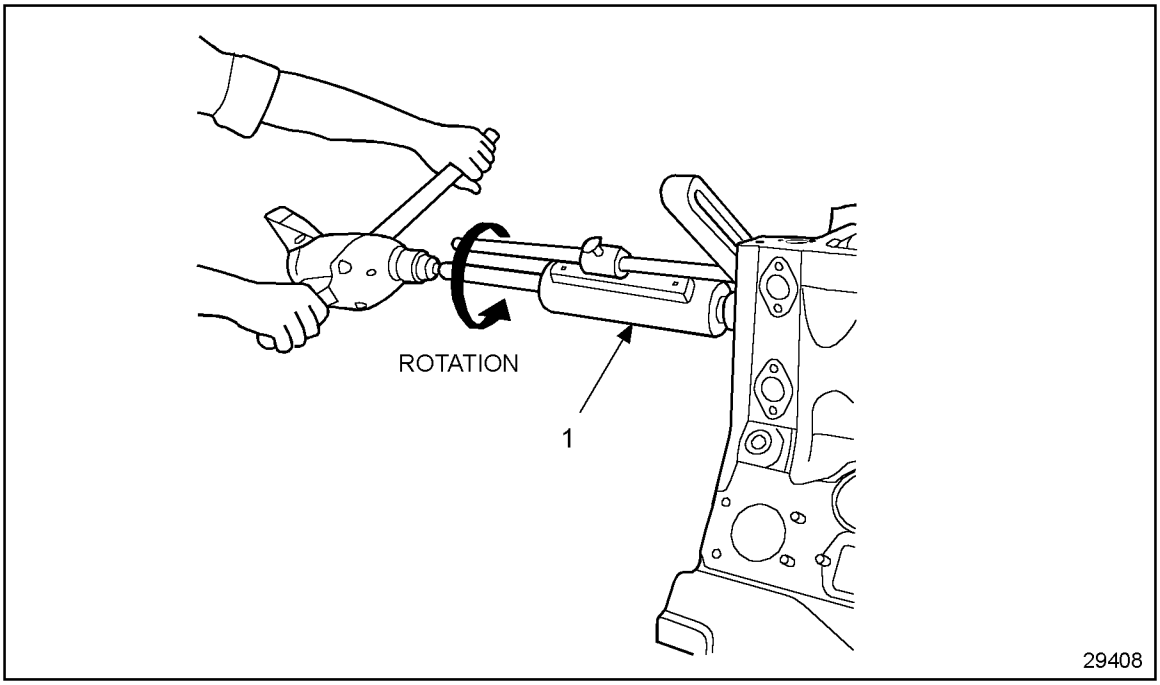
Block: Set Tool Final Cut 4.892 in. + 0.020 in. **Insert/Cap:** 4.792 in. + 0.020 in.

Final Block Dimension: Final Dimension 4.912 in. / 4.913

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Final Insert/Cap Dimension: Final Dimension 4.912 in. / 4.913

NOTE:
From the operator's viewpoint, the tool feeds away from him and rotates clockwise. See Figure 1-264.



1. Feed Unit

Figure 1-264 Use of Hydraulic Feed Unit

NOTE:
When installing the cutter, ensure the sharp portion of the bit is in the cutting position. See Figure 1-264.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

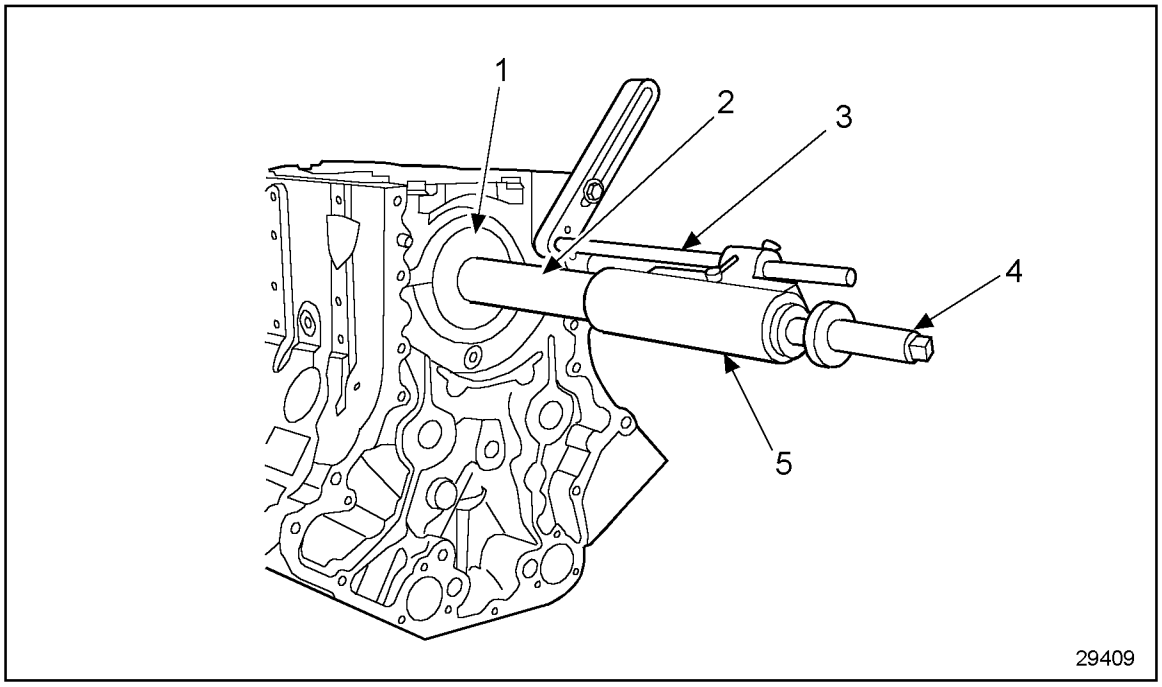
14. Lubricate the boring bar at the centering rings with clean engine oil before each cut.
15. Use a 1/2 in. drill motor of 300-400 RPM. Lubricate and install the universal drive in the drill chuck. Move the hydraulic feed unit lever to the "closed" position.
16. Line bore the distressed saddle using the three cuts and the dimensions given above.
17. If other bores are to be machined, remove the insert hold-down bolts and cover the machined saddle with a new unfinished service line bore cap. Hand tighten the bolts.

Machine the next saddle as follows:

1. Install the caps on all the remaining saddles, except the saddle to be machined, and hand tighten the bolts.
2. Install the insert hold-down bolts into the bolt holes of the saddle to be machined.

NOTE:
Do not tighten the bolts. This is only to keep chips out of the bolt holes.

3. Fasten the torsion bar and the hydraulic feed unit on either end of the cylinder block. Index the flat part of the feed rod into the boring bar. Snug the set screw. See Figure 1-265.

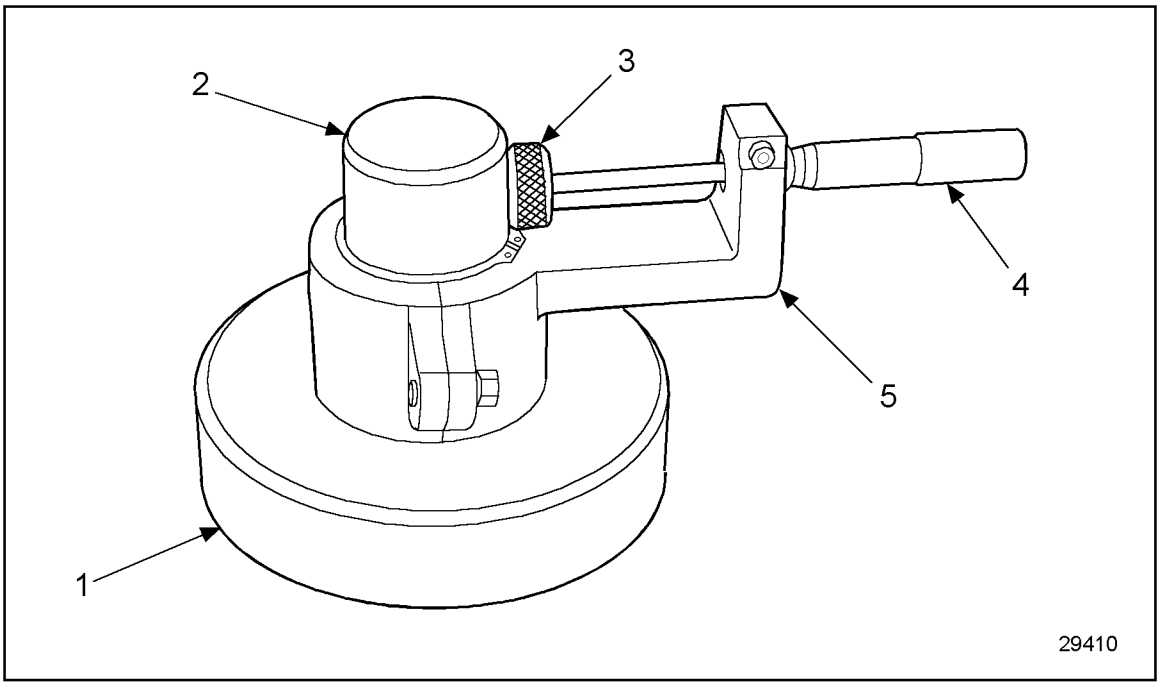


1. Centering Ring
2. Boring Bar
3. Torsion Bar
4. Feed Rod
5. Feed Unit

Figure 1-265 Location of Feed Rod and Unit

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4. Zero the micrometer with the test block supplied. See Figure 1-266. The micrometer is 0.050 in. per revolution, not 0.025 in. as normally seen on micrometers.

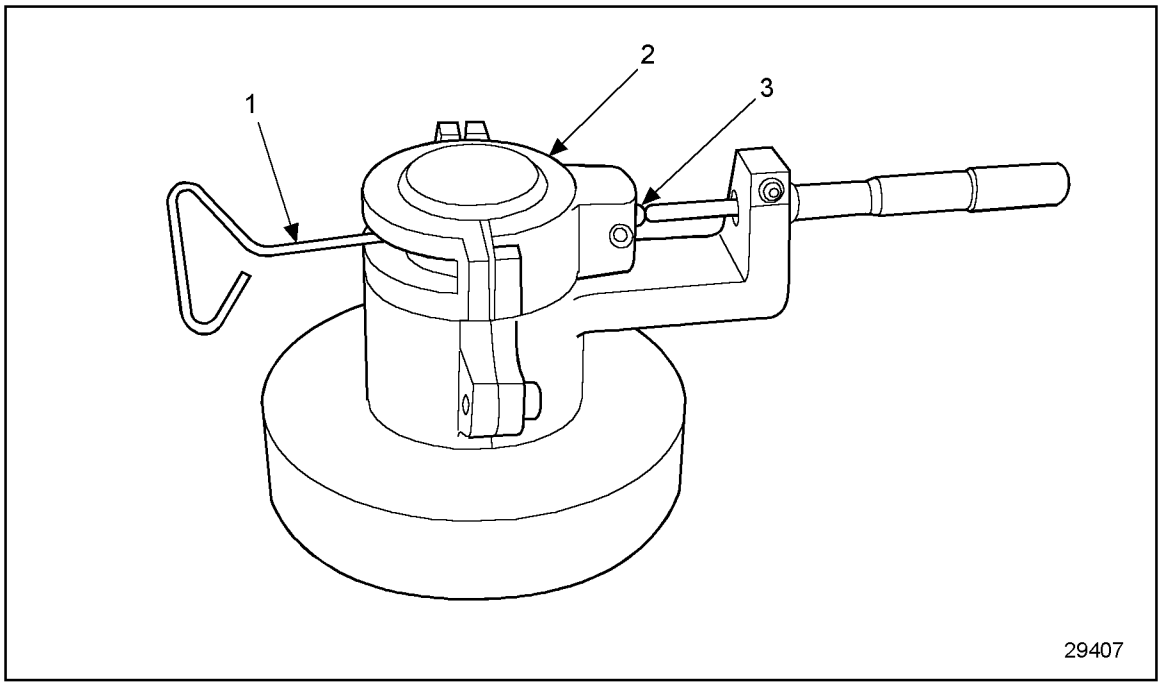


1. Base
2. Shaft
3. Test Block
4. Micrometer
5. Holder

Figure 1-266 Test Fixture and Micrometer

5. Install the cutting tool holder on the micrometer test fixture. Use only the straight Allen wrench supplied in the kit.

6. Set the cutting tool for the first cut of 0.040 in. See Figure 1-267. The point of the cutting tool should be in the center of the micrometer barrel.



1. Cutter Bit Push Key
2. Cutting Tool
3. Cutting Tool Bit

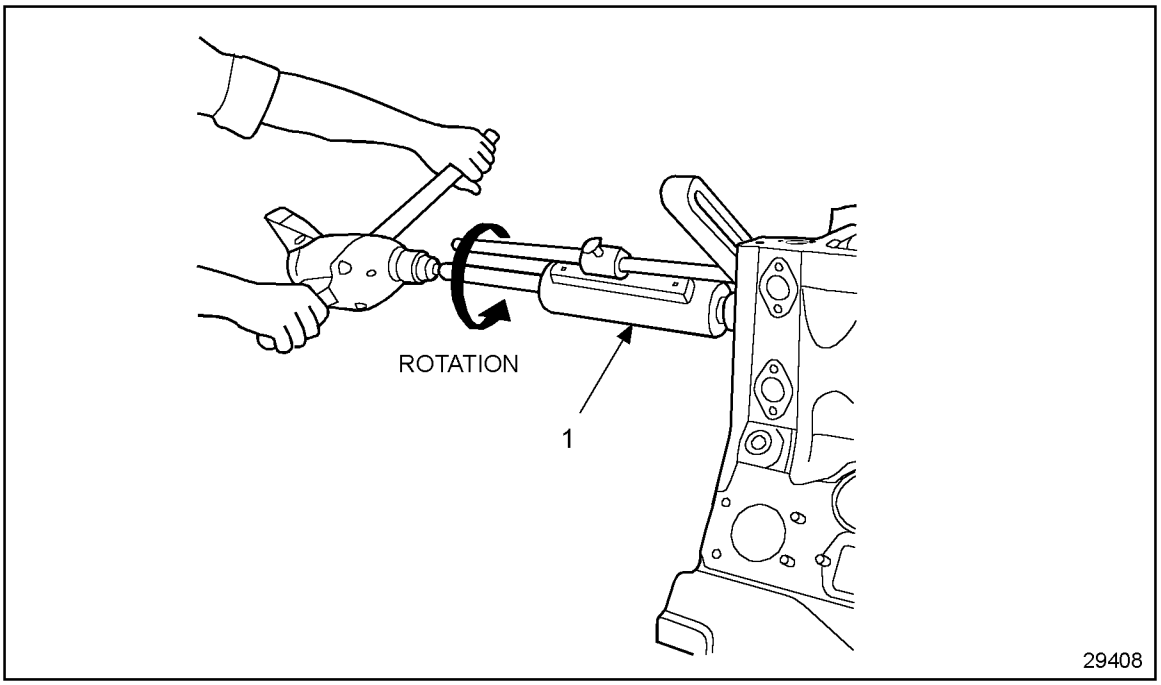
Figure 1-267 Installing Cutting Tool Holder

7. Install the cutting tool on the boring bar.

NOTE:
Excessively tightening the Allen head screws is unnecessary.

NOTE:
From the operator's viewpoint, the tool feeds away from him and rotates clockwise. See Figure 1-268.

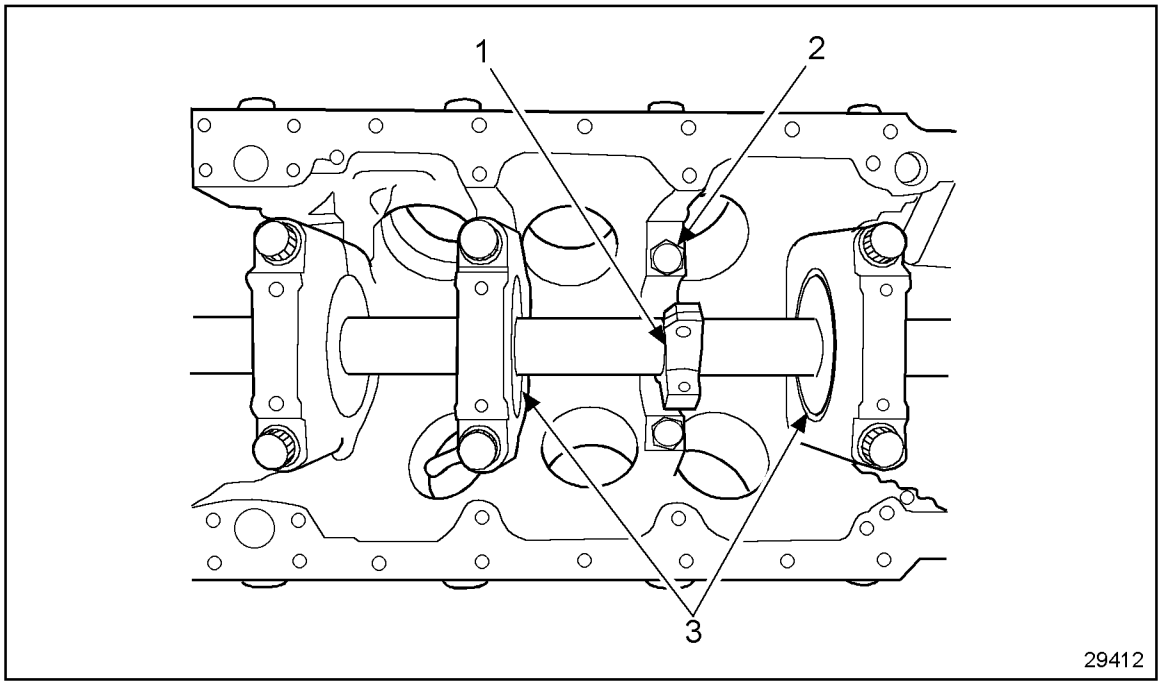
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1. Feed Unit

Figure 1-268 Use of Hydraulic Feed Unit

NOTE:
When installing the cutter, ensure the sharp portion of the bit is in the cutting position. See Figure 1-269.



1. Cutting Tool
2. Insert Hold-Down Bolt
3. Centering Rings

Figure 1-269 Position of Cutting Tool

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

8. Lubricate the boring bar at the centering rings with clean engine oil before each cut.
9. Use a 1/2 in. drill motor of 300-400 RPM. Lubricate and install the universal drive in the drill chuck. Move the hydraulic feed unit lever to the "closed" position.
10. Line bore the distressed saddle using the three cuts and the dimensions given above.

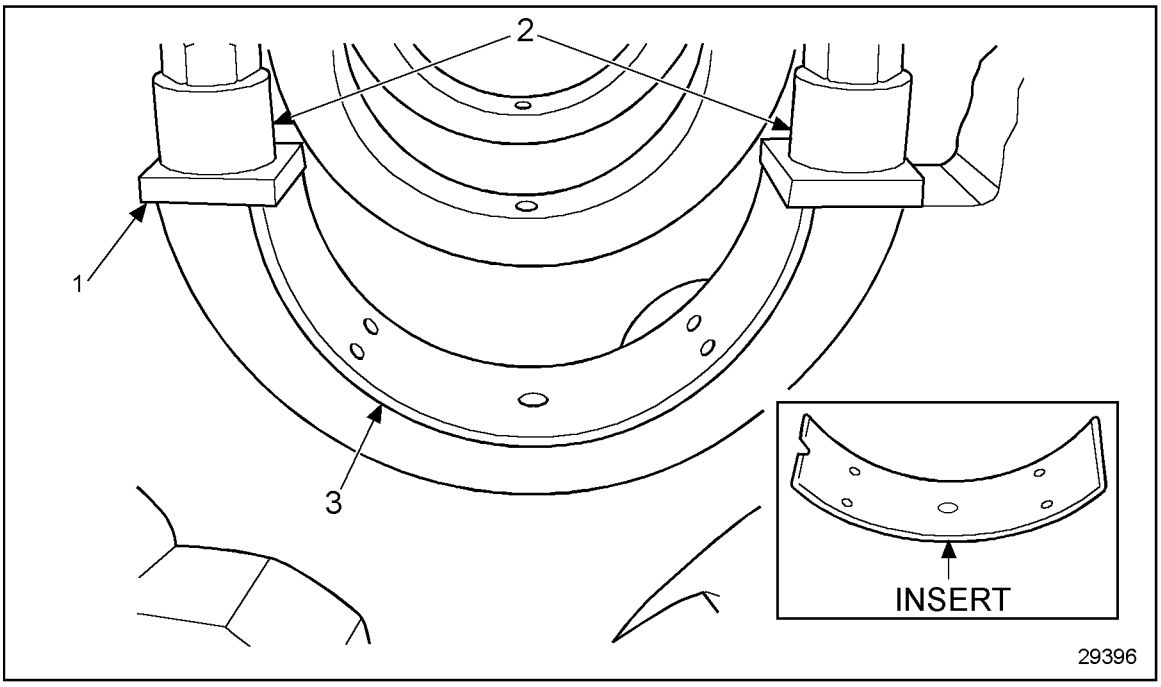
NOTE:
If other bores are to be machined, remove the insert hold-down bolts and cover the machined saddle with a new unfinished service line bore cap. Hand tighten the bolts.

Complete cylinder block line boring as follows:

1. Remove the boring bar, and clean the reworked saddles.
2. After the saddles have been reworked, inserts must be installed. Install and align the insert with the hold-down bolts and plates provided. Use the plate with a "step" on the

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side of the insert opposite the tang. Tighten the hold-down bolts to 27 N·m (20 lb·ft) torque. See Figure 1-270.

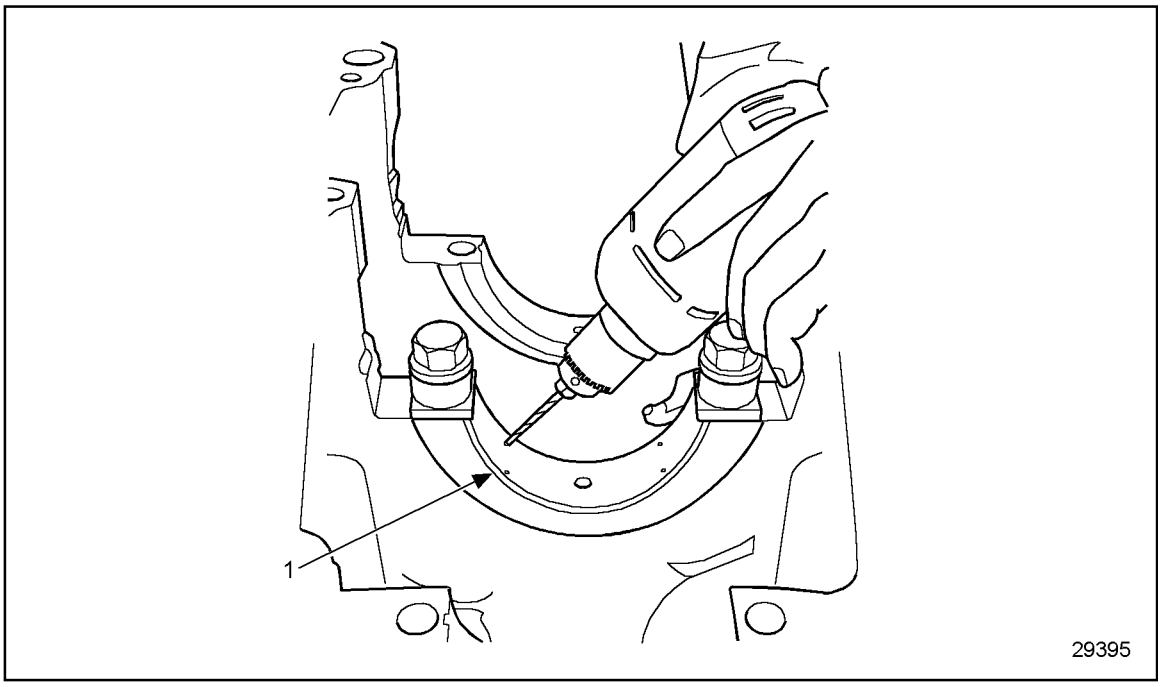


1. Holding Plate
2. Bushings
3. Bearing Insert

Figure 1-270 Position of Bushing and Hold Down Plate

3. Check the insert for alignment and fit.

4. Using a 1/8 in. drill bit, drill four holes in the saddle 1/4 in. deep through the four predrilled holes in the insert. See Figure 1-271.



1. Bearing Shell Insert

Figure 1-271 Drilling for Rivet Installation

CAUTION:

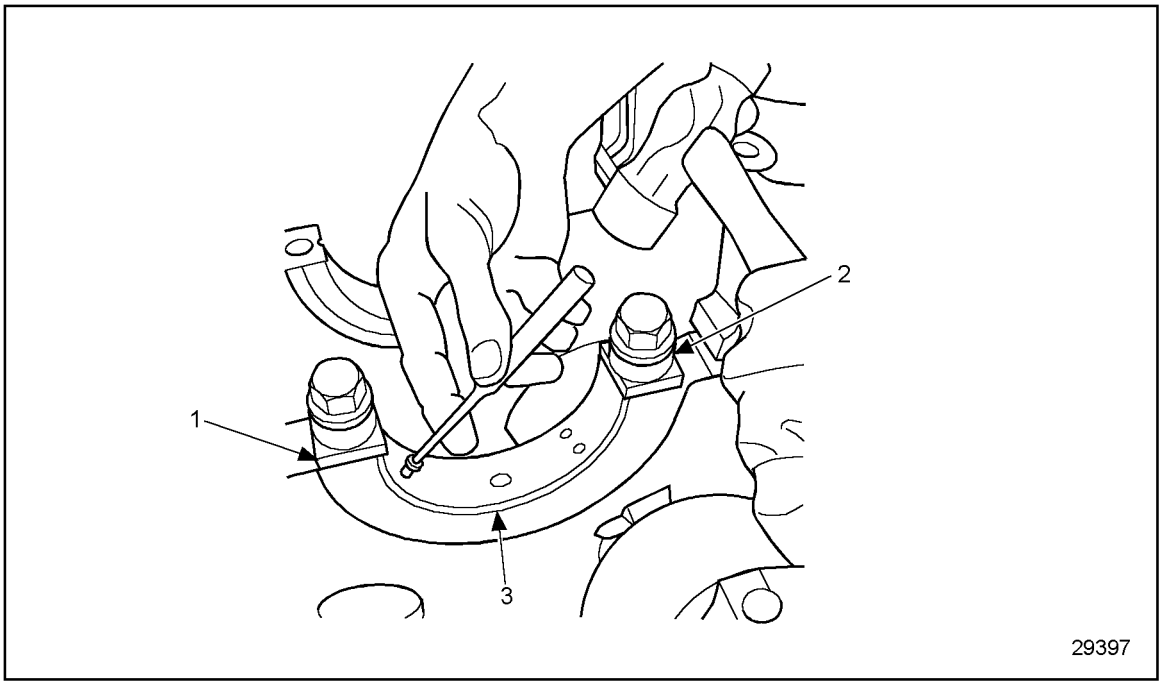
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

5. Clean the drilled holes with compressed air, and install the rivets.

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NOTICE:
Be careful not to strike the insert directly. The insert will distort. Two or three blows on the punch are usually sufficient to secure the rivet.

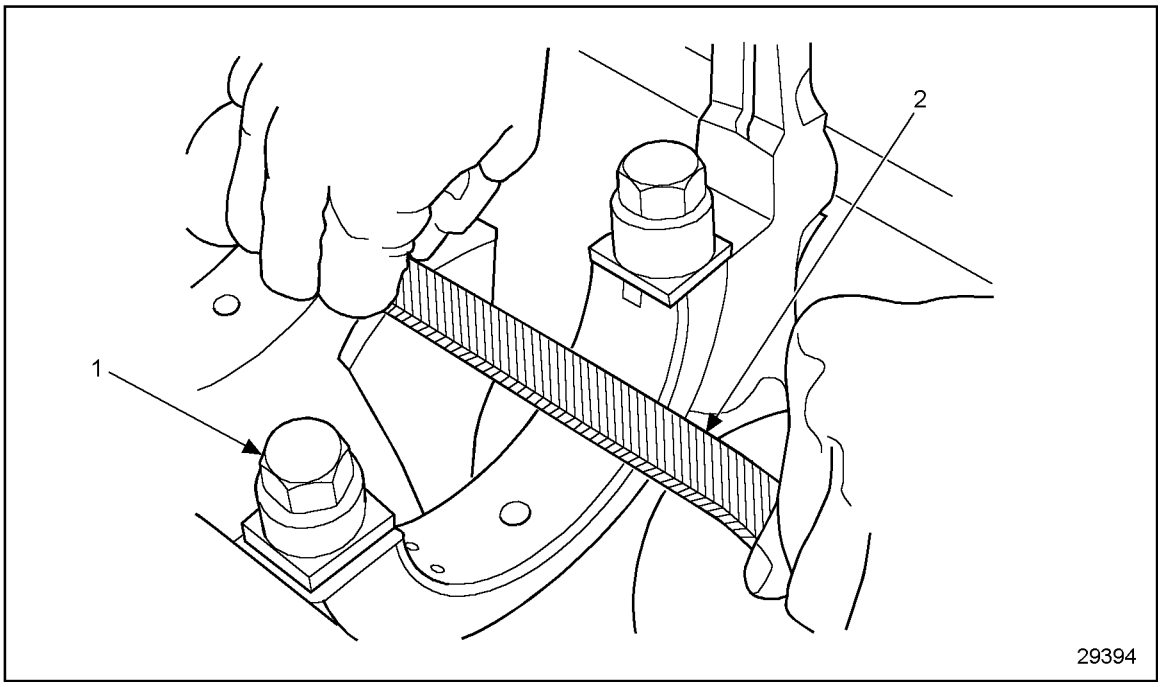
6. Secure the rivets with a hammer and punch. See Figure 1-272.



1. Holding Plate
2. Bushing
3. Bearing Shell Insert

Figure 1-272 Securing the Rivets

7. File off the excess rivet material. See Figure 1-273.



1. Bearing Shell Insert
2. File

Figure 1-273 Filing Excess Rivet Material

8. Remove both the insert hold-down bolts and plates, and file the excess material on the insert flush with the saddle-cap parting surface.

NOTE:
If the insert is loose, secure the rivets.

9. Install unfinished service bore caps on all repaired main bearing saddles. Torque the bolts to 312-325 N·m (230-240 lb·ft).
10. Line bore the unfinished cap and insert to the standard bore dimension using the previous procedure and dimensions.
11. Remove burrs and debris, and clean with a spray lubricant.

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12. Check the finished bore with the "Go-No-Go" test rings mounted on the boring bar. The "Go" ring should pass through the reworked saddle and cap bore with a slight drag.

NOTE:
If centering rings are removed during the line boring operation, mark the ring and saddle to insure proper installation alignment.

NOTE:
If the cylinder block is line bored properly, there will be no more than 0.03 mm (0.001 in.) overall misalignment from one end of the block to the other, or no more than 0.013 mm (0.0005 in.) between adjacent bores.

13. Clean the cylinder block, install the plugs and proceed with the rebuild.

Dimensions for Machine Shop Line Boring Cylinder Block

If the criteria for using tool J 29005 (two undamaged main bearing saddles, one of which must be the rear main saddle) cannot be met, or if you desire to salvage the cylinder block by line boring in a suitably equipped machine shop, critical dimensions must be maintained.

1. The cylinder block assembly of 12 and 16 cylinder engines must be separated and each "half-block" line bored separately.
2. Remove all plugs and main bearing caps, and clean the cylinder block.

NOTE:
The surface from which all critical dimensions are measured for line boring are the reamed locating holes (23.80-23.83 mm or 0.937-0.938 in.) at each end of the left-bank pan rail looking from the gear train end of the cylinder block. See Figure 1-274. The centerline of the crankshaft is 126.97-127.03 mm (4.999-5.001 in.) in from the centerline

of the reamed locating holes and 120.60-120.70 mm (4.748-4.752 in.) up from the pan rail surface.

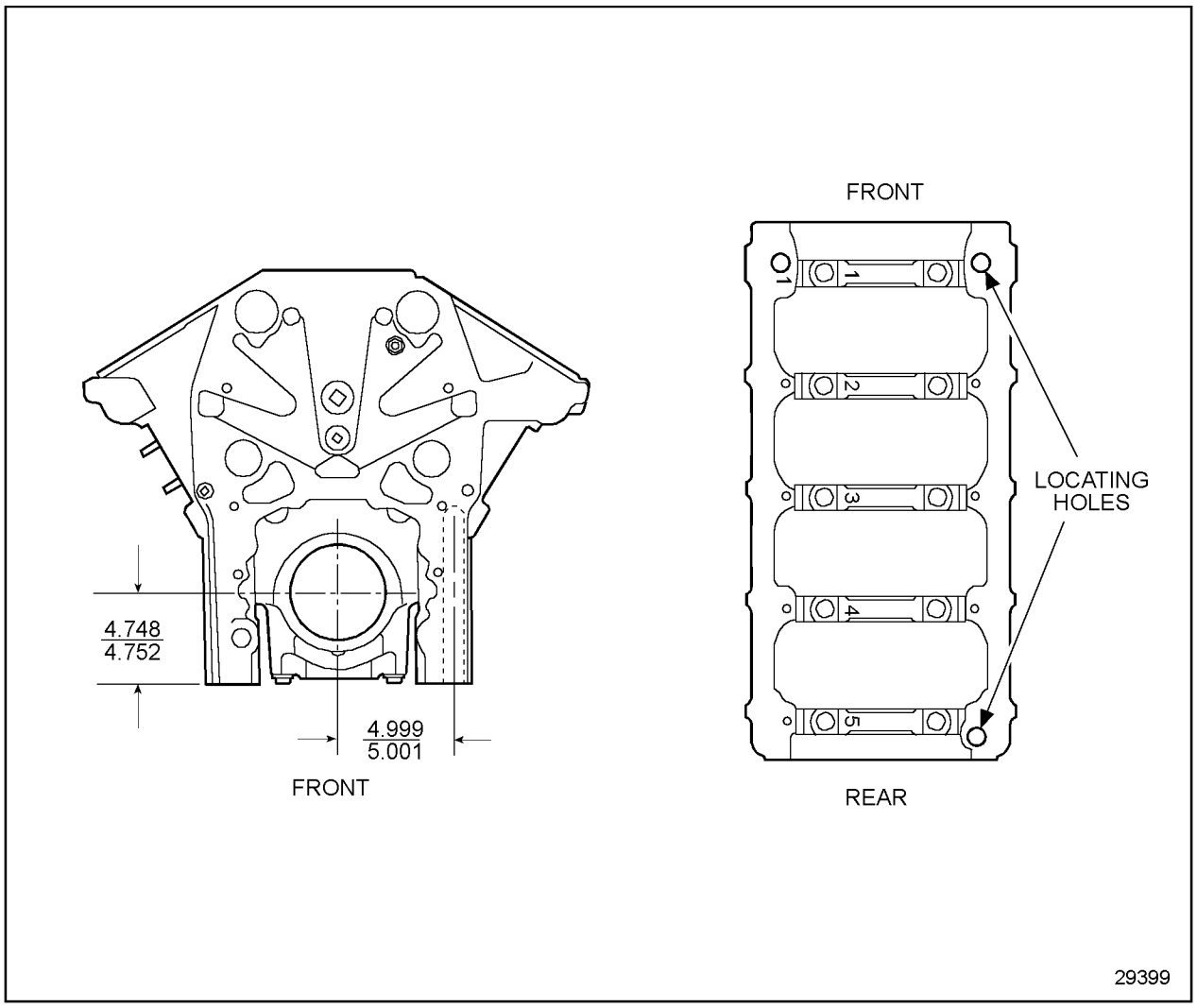
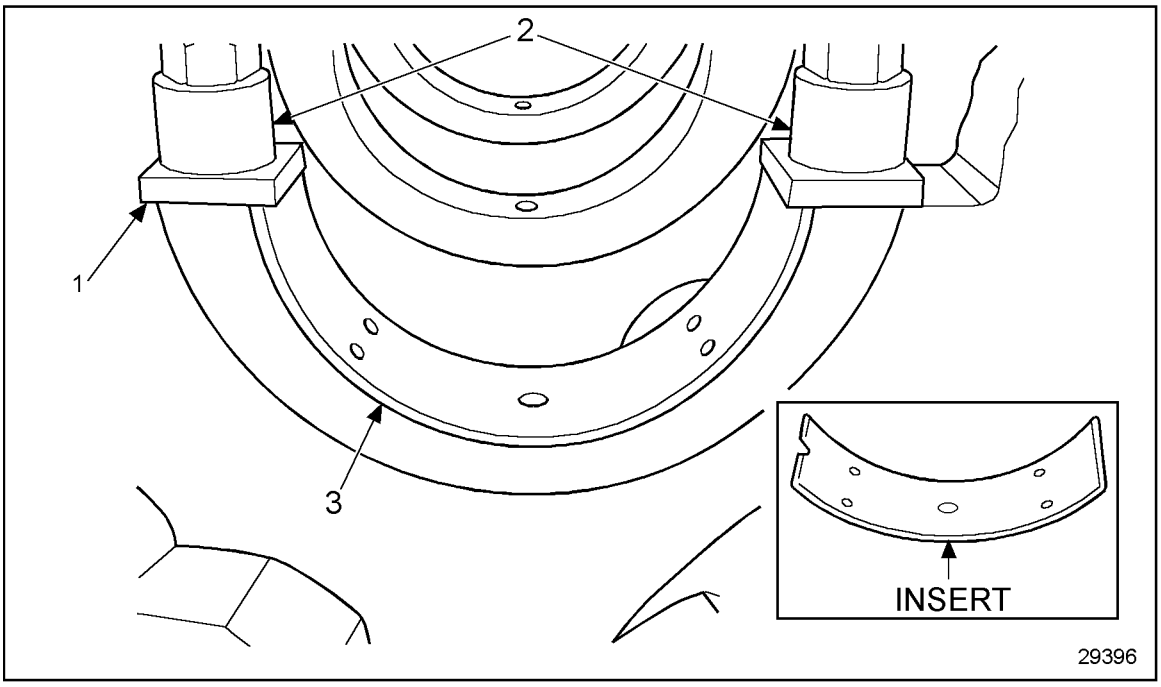


Figure 1-274 Line Boring Dimensions and Locating Holes

3. Machine the main bearing saddle bore(s) to the following dimension.
4. After the saddles have been reworked, inserts must be installed. Install and align the insert with the hold-down bolts and plates provided. Use the plate with a "step" on the

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side of the insert opposite the tang. Tighten the hold-down bolts to 27 N·m (20 lb·ft) torque. See Figure 1-275.



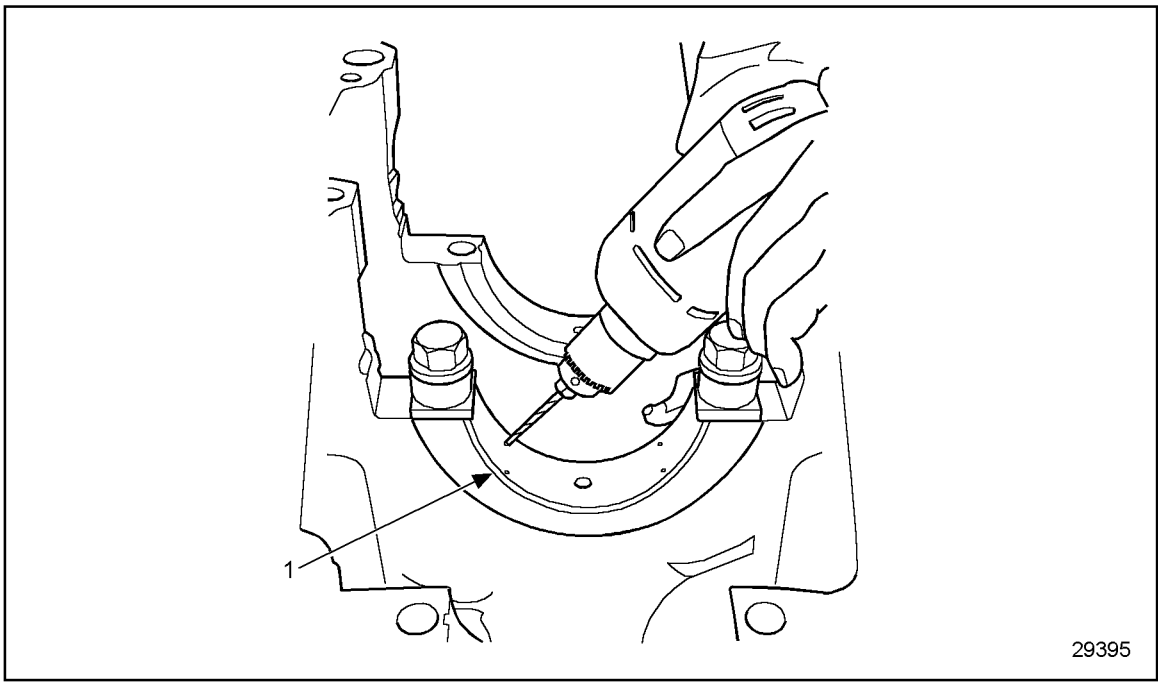
1. Holding Plate
2. Bushings
3. Bearing Insert

Figure 1-275 Position of Bushing and Hold Down Plate

5. Check the insert for alignment and fit.

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6. Using a 1/8 in. drill bit, drill four holes in the saddle 1/4 in. deep through the four predrilled holes in the insert. See Figure 1-276.



1. Bearing Shell Insert

Figure 1-276 Drilling for Rivet installation

CAUTION:

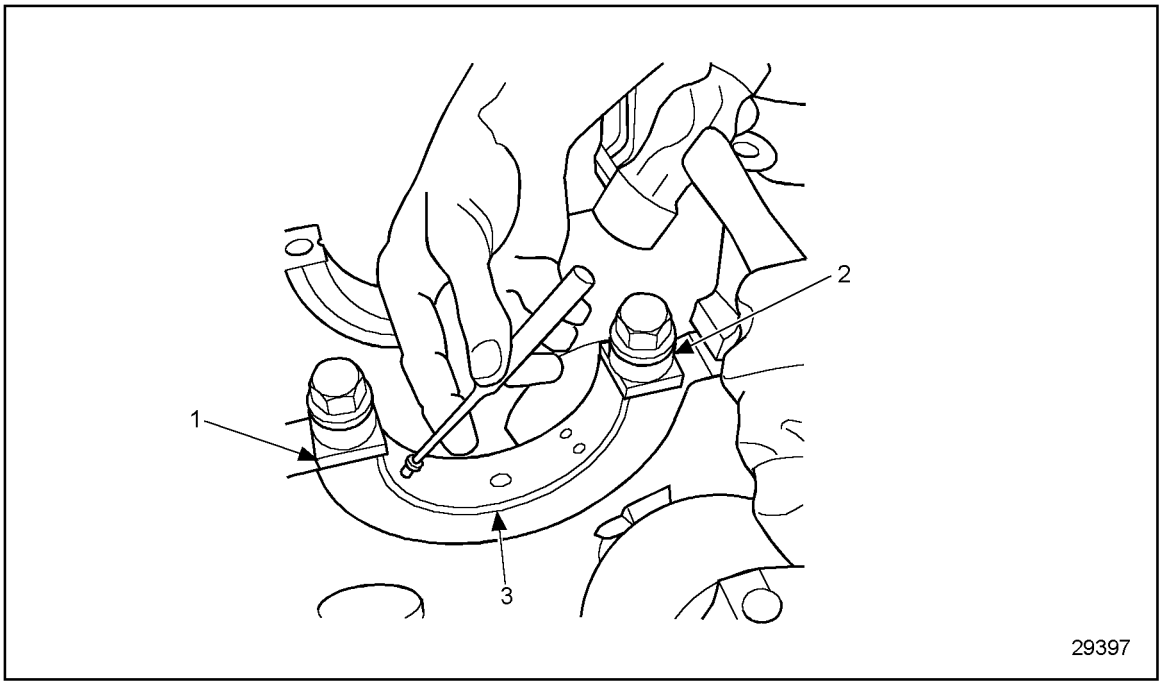
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

7. Clean the drilled holes with compressed air, and install the rivets.

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NOTICE:
Be careful not to strike the insert directly. The insert will distort. Two or three blows on the punch are usually sufficient to secure the rivet.

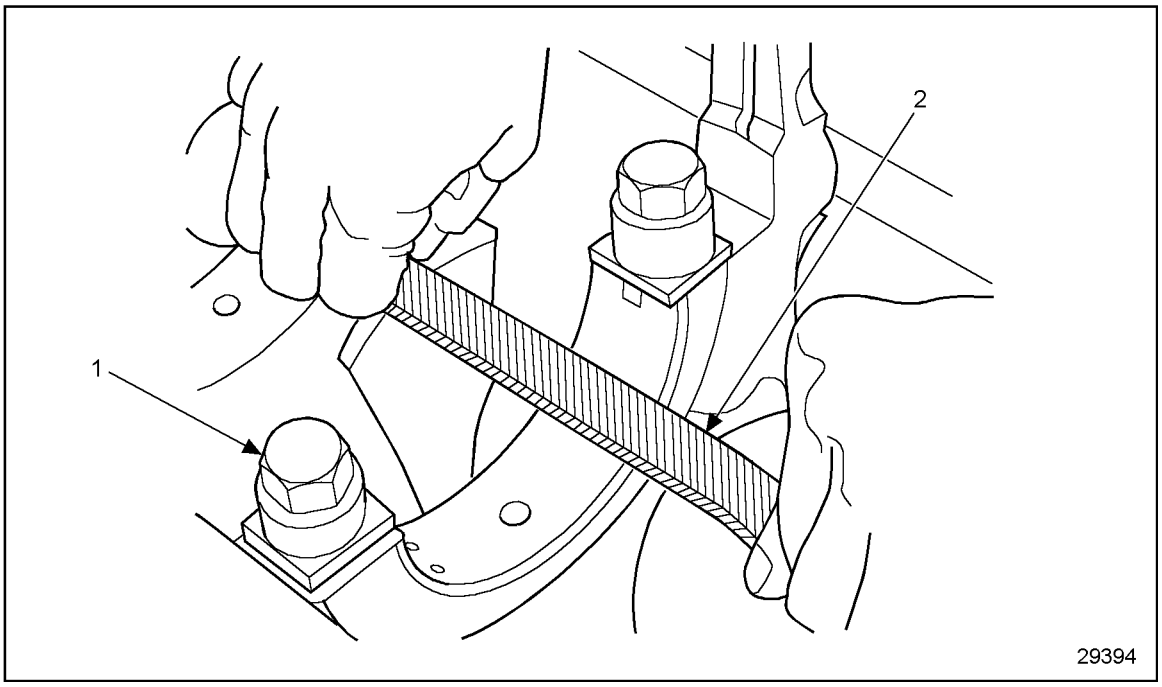
8. Secure the rivets with a hammer and punch. See Figure 1-277.



1. Holding Plate
2. Bushing
3. Bearing Shell

Figure 1-277 Securing the Rivets

9. File off the excess rivet material. See Figure 1-278.



1. Bearing Shell Insert
2. File

Figure 1-278 Filing Excess Rivet Material

10. Remove both the insert hold-down bolts and plates, and file the excess material on the insert flush with the saddle-cap parting surface.

NOTE:
If the insert is loose, secure the rivets.

11. Install unfinished service bore caps on all repaired main bearing saddles. Tighten the bolts to the specified torque 312-325 N·m (230-240 lb·ft).
12. Line bore the unfinished cap and insert to the standard bore dimension using the previous procedure and dimensions.
13. Remove burrs and debris, and clean with a spray lubricant.

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14. Check the finished bore with the "Go-No-Go" test rings mounted on the boring bar. The "Go" ring should pass through the reworked saddle and cap bore with a slight drag.

NOTE:
If centering rings are removed during the line boring operation, mark the ring and saddle to insure proper installation alignment.

NOTE:
If the cylinder block is line bored properly, there will be no more than 0.03 mm (0.001 in.) overall misalignment from one end of the block to the other, or no more than 0.013 mm (0.0005 in.) between adjacent bores.

15. Clean the cylinder block, install the plugs, and proceed with the rebuild.
16. Install new unfinished service line bore caps on the machined main bearing saddles. Tighten the bolts to the specified torque 312-325 N·m (230-140 lb·ft).

NOTE:
Main bearing cap bolts are specially designed and must not be replaced by ordinary bolts.

17. Line bore the installed inserts and unfinished service caps to the standard bore demotions.
18. The straightness of the finished bore must not vary more than 0.03 mm (0.001 in.) from end to end in the cylinder block or more than 0.013 mm (0.0005 in.) between adjacent bores.
19. Clean the cylinder block, and install the plugs.
20. Check and assemble the line bored block(s), and proceed with the rebuild.

METHODS OF INSPECTION FOR CYLINDER HEAD

The following describes the methods used for inspecting the cylinder block for cracks:

- **Magnetic Particle Method:** The Cylinder head is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which cause the magnetic particles in the powder or solution to gather there, effectively marking the crack.

NOTE:
The cylinder head must be demagnetized after the test

- **Fluorescent Magnetic Particle Method:** This method is similar to the magnetic particle method, but is more sensitive since it uses fluorescent magnetic particles which glow under a "Black Light."

NOTE:
Very fine cracks, especially on discolored or dark surfaces, that may be missed using the Magnetic Particle Method, will be disclosed under the "Black Light."

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- **Fluorescent Penetrant Method:** A Highly fluorescent liquid penetrant is applied to the area in question. Then, the excess penetrant is wiped off the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a "Black Light".
- **Non-Fluorescent Penetrant Method:** The test area being inspected is sprayed with "Spotcheck" or Dye Check. Allow one to thirty minutes to dry. Moisten cloths with cleaner to remove the excess surface penetrant. ***DO NOT flush surface with cleaner/remover because this will impair sensitivity.*** Repeat this procedure with additional wiping until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then, spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is five to fifteen minutes.

NOTE:
Refer to manufacture (MPSI) for inspection procedures.

MICRO PROCESSOR SYSTEMS, INC.

6405 Nineteen Mile Road

Sterling Heights, MI 48078

Phone: (313) 731-6410

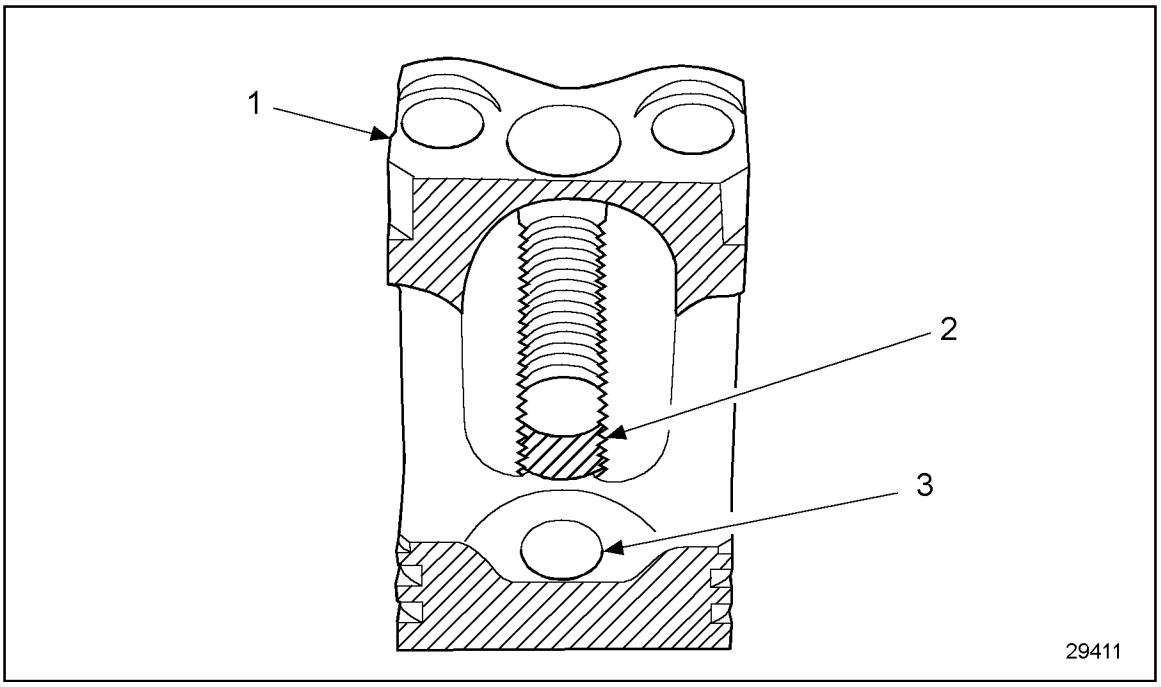
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REPLACING CYLINDER HEAD BOLT HOLE PLUG

The cylinder head bolt hole plugs are designed to seal the head bolt holes from the coolant passages. Replace a cylinder head bolt hole plug in the cylinder block, as follows. See Figure 1-279.



1. Cylinder Block
2. Plug
3. Water Jacket

Figure 1-279 Location of Cylinder Head Bolt Hole Plug

1. Remove the old plug, and clean the threads of all old sealant by running bottom tap J 25384 down the hole. The threads must be clean and dry before applying sealant.
2. Apply a sufficient quantity of Loctite 290 Sealant, or equivalent, to the threads in the block at the minimum depth of the stud plug (50.29 mm or 1.980 in.), as well as to the plug itself.

NOTE:
Some commonly used pipe sealants have been found to be ineffective for this application. Use Loctite 290.

3. Screw the plug in until the top of the plug is 50.29-52.58 mm (1.980-2.070 in.) maximum below the block surface for bolt clearance.

NOTICE:
Do not apply sealant to the top of the plug after installation.

4. Allow the sealant to set for twelve hours, and pressure check for five minutes at 276 kPa (40 lb/in.^{2}).

NOTICE:
Do not use power equipment to run the tap in. They could disturb the Loctite seal.

5. Run an 17.463 mm (0.6875 in.) bottom tap until it bottoms on the plug to remove excess Loctite from the bolt hole thread. Run the tap in by hand.
6. Inspect the bolt hole for debris.

TOOL MODIFICATION PROCEDURE

Existing J 22425-B expanders can be reworked to the revised expander configuration by removing the O-rings and carefully drilling the guide stud holes to a depth of 44.5 mm (1.75 in.). See Figure 1-280. Use the following procedure:

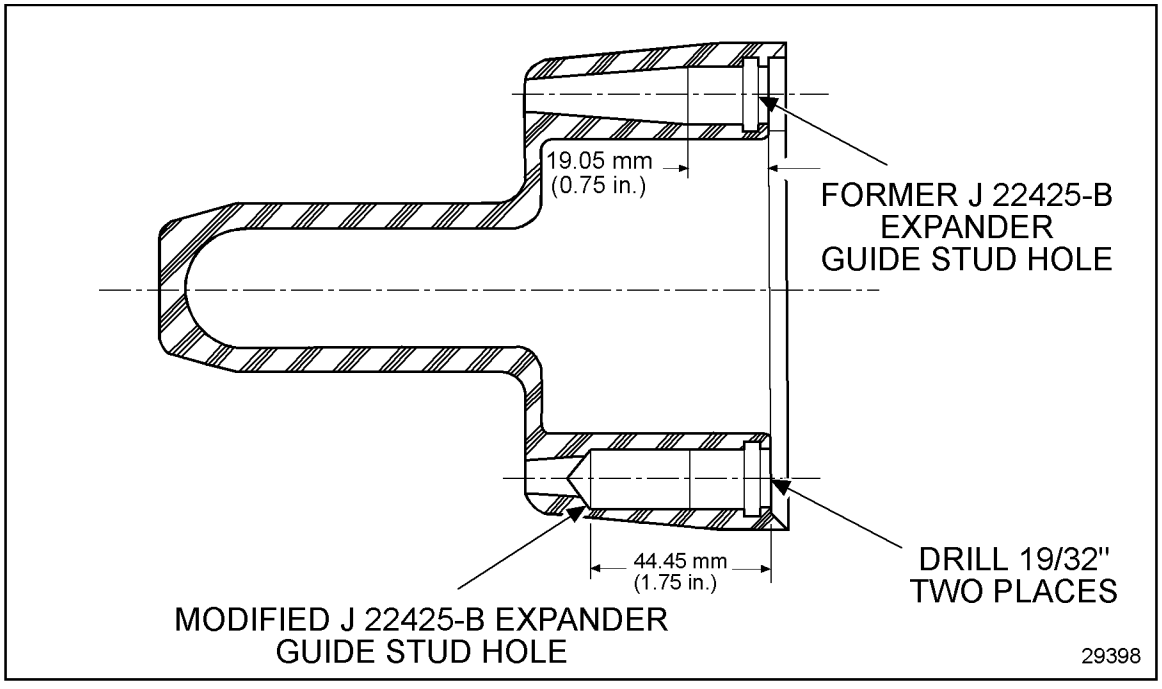


Figure 1-280 Comparison of Original and Reworked Expander J 22425-B

1. Remove the O-rings from expander J 22425-B.

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NOTICE:
Expander J 22425-B is made of hard plastic. To avoid damage, do not apply excessive pressure during the clamping operation.

2. Loosely clamp the expander on the table of a drill press.

NOTE:
Ensure that the expander is clamped straight.

3. Install a 15.0813 mm (0.59375 in.) drill bit into the drill press chuck.

NOTE:
Ensure that the cutting edges of the drill bit are free from burrs.

4. Set the required depth on the depth gage of the drill press.
5. Insert the drill bit into one of the expander guide stud holes.
6. Operate the drill press at a slow speed (75-100 RPM.) to center the drill in the existing 15.0813 mm (0.59375 in.) hole. Tighten the clamp.
7. Slowly deepen the guide stud hole from 19.1 mm (0.75 in.) - 44.5 mm (1.75 in.).

NOTE:
Drill at 75-100 RPM. to keep from drilling too deep.

8. Insert the drill bit into the other expander guide stud hole.
9. Operate the drill press at a slow speed (75-100 RPM.) to center the drill in the existing 15.0813 mm (0.59375 in.) hole. Tighten the clamp.
10. Slowly deepen the guide stud hole from 19.1 mm (0.75 in.) to 44.5 mm (1.75 in.).

NOTE:
Drill at 75-100 RPM. to keep from drilling too deep.

11. Remove the expander from the drill press and completely wash all cuttings from it with clean mineral spirits.

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

⚠ 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.

12. Dry with compressed air.
13. With an electric engraving pencil, re-identify the reworked expander to read "J 22425-B Modified." Cross out the former tool number "J 22425."

WELDING ENGINE CYLINDER HEADS

Welding has been used to salvage cylinder heads for several years. The resultant product, however, is not generally as good as a new casting. Furthermore, this procedure has caused some concern because of different ways of understanding precisely what the procedure involves.

The following explains Detroit Diesel Corporation's position on welded cylinder heads:

1. Welding is the process of elevating the original cylinder head casting to approximately 593°C (1100°F) (a temperature that is at least equivalent to stress relieving) and the addition of alloyed cast iron welding rod to the cracked area while in the molten state.

NOTE:
Low temperature, low voltage welding is considered a cosmetic salvage and should never be accepted as a structural repair.

2. Mechanical plugging is a salvage procedure that usually results in excessive installation stresses at the repaired area and should never be confused with or accepted as equivalent to welding. This procedure should never be used on cylinder heads.
3. If properly performed, welding performed outside the fire circle might salvage the cylinder head. Service life of a welded cylinder head is not equivalent to a new casting, even if the fire circle area of the original casting has not been welded.

NOTE:
A cracked casting is usually the result of overheating, and the casting may be damaged in areas other than the visible crack.

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NOTICE:
Do not weld in the fire circle. In order to eliminate future malfunctions on Detroit Diesel engines, cylinder heads cracked in the fire-circle should be destroyed.

4. Comparative testing indicates that welding inside the fire circle will result in a service life less than 50% of a new casting.

NOTICE:
The plug should not be inserted with a press fit. This will cause stresses that can cause the cylinder head to crack. To avoid damage use care to ensure that the small water nozzle hole has been drilled on the same centerline as the previous large water nozzle hole.

5. Update the large water nozzle to small water nozzle cylinder heads if a plug of the same material is used and the cylinder head, plug and welding rod are heated to a molten state. This ensures adequate fusion and complete weld penetration through the thickness of the firedeck.

NOTICE:
Secondary damage to other engine components could result from not checking these components.

6. Cylinder heads that have been welded should be checked for acceptability. Refer to section 1.3, refer to section 1.4 and refer to section 1.5. Check for cracks, cylinder head thickness, warping, camshaft follower clearance, and the press fit of all other components. These conditions can cause malfunctions of secondary components if these are not corrected. If any problem cannot be repaired, the part should not be used.
7. Components used with these cylinder heads should also be checked. Unacceptable components should not be used.

ISOLATE ECM COMPONENTS BEFORE WELDING

Damage may occur to ECM (Electronic Control Module) components if they are not isolated before welding is performed on the vehicle. To avoid ECM damage, Detroit Diesel recommends the following precautions:

1. Before welding, completely isolate the DDEC system from the vehicle. Disconnect the power and ground leads at the battery. Disconnecting the leads at the battery ensures that the DDEC system will remain isolated, along with any other component susceptible to welding damage.
2. Instruct personnel involved in vehicle welding that the battery leads must be removed before they weld on any vehicle.

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3. Apply precautionary labels in highly visible areas, such as the battery box cover, dashboard, sun visor, etc. Labels should read:

NOTICE:
Disconnect battery power and ground leads before welding. Otherwise, damage to electronic components may occur.

NOTICE:
Use of this precaution assumes an electronic component ground directly to the battery, as recommended by Detroit Diesel. If grounded otherwise, disconnecting the battery leads will not isolate the ECM system from the chassis ground. This could damage the system while welding.

REUSE CROSSHEAD PISTON ASSEMBLY COMPONENTS

Piston assembly components can, in certain instances, be reused. Undamaged piston pins, crowns and bushings that meet dimensional limits for used parts can be reused if installed within the same piston assembly from which they were removed.

Since the bushing takes the shape of the saddle area of the piston dome during engine operation, the crown, pin and bushing of a crosshead piston assembly should be considered matched. If a crown is replaced, the piston pin and bushing must also be replaced.

NOTICE:
Installing a used bushing in a new crown can result in uneven piston pin loading and possible piston pin damage.

If a bushing is replaced, a new pin must also be used. Conversely, if a new pin is required, the bushing must also be replaced. Before reusing any crosshead piston assembly components, see wear limits in this section.

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 0.03-0.08 mm (0.001-0.003 in.), type PR-1 (red) has a range of 0.05-0.15 mm (0.002-0.006 in.) and type PB-1 (blue) has a range of 0.10-0.23 mm (0.004-0.009 in.).

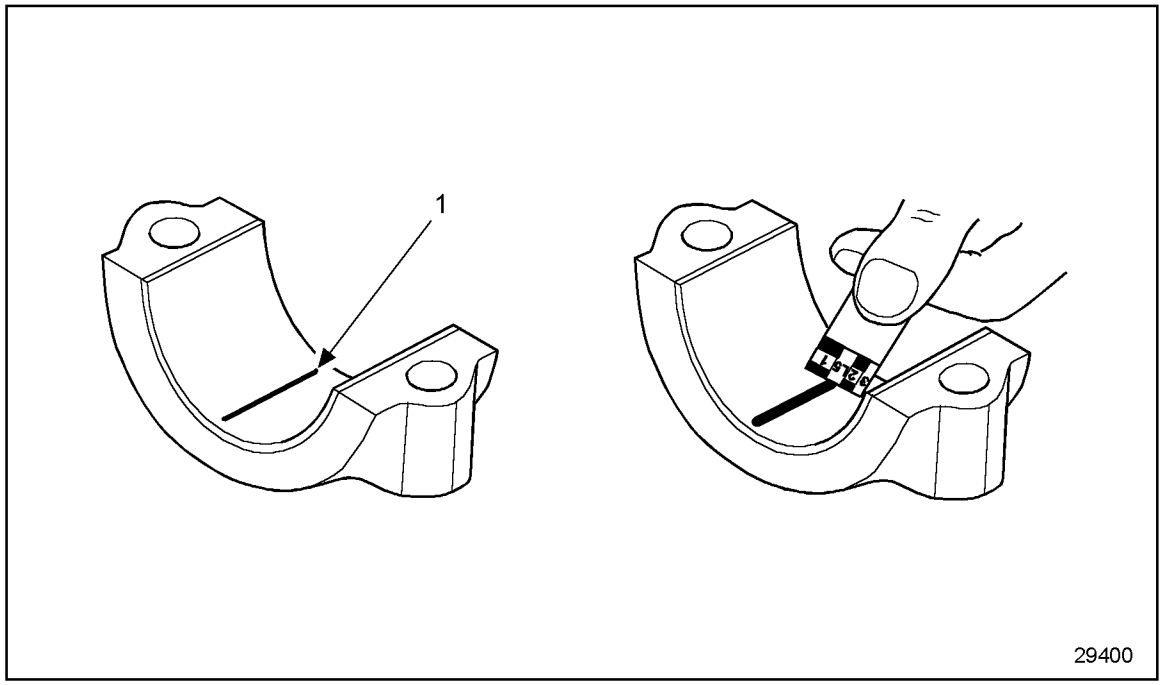
The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap, and wipe the oil from the bearing shell and the crankshaft journal.

NOTE:
Support the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

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2. Place a piece of the plastic strip the full width of the bearing shell, about 6.4 mm (0.25 in.) off center. See Figure 1-281.



1. Plastic Strip

Figure 1-281 Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

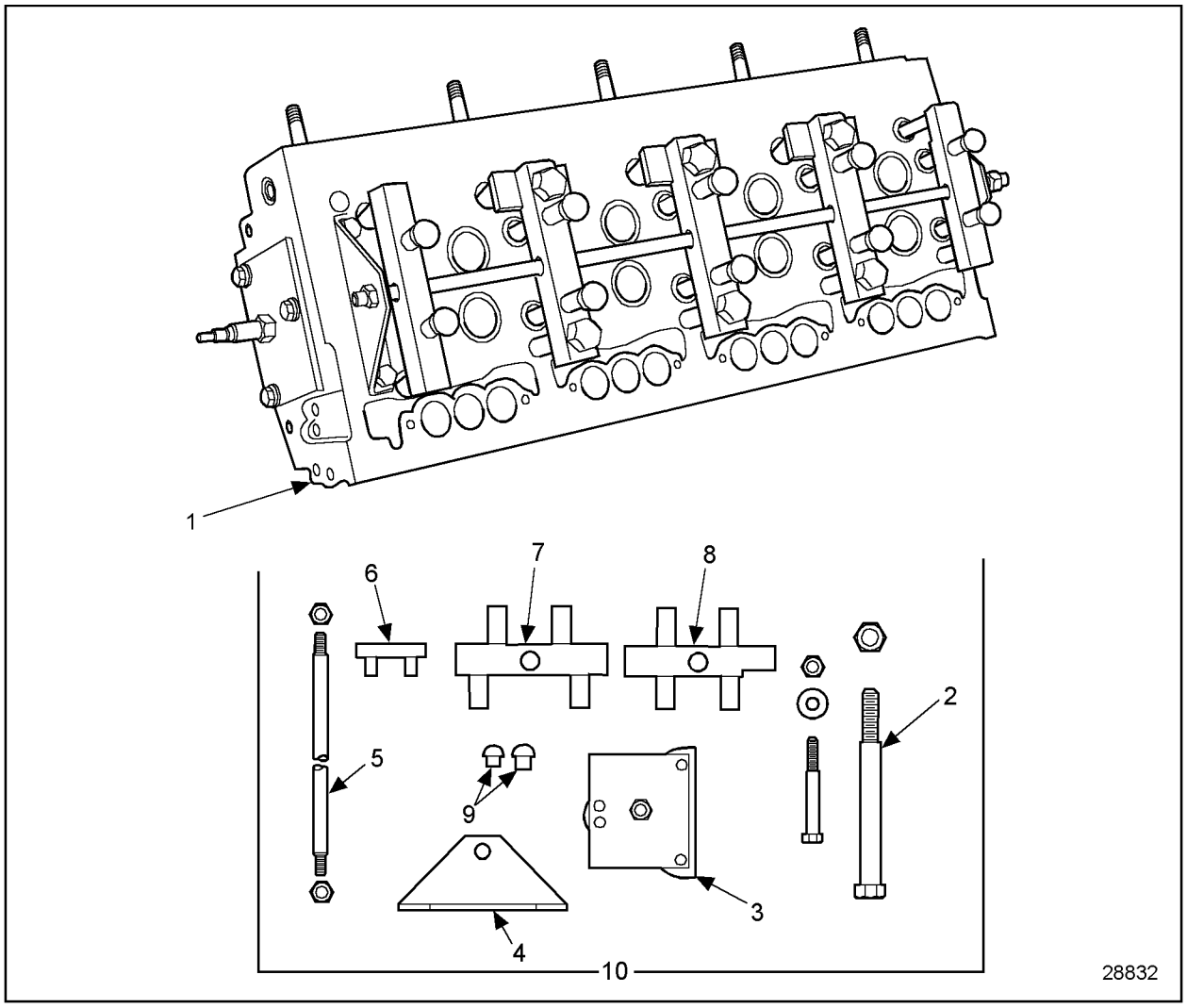
3. Rotate the crankshaft about 30 degrees from bottom dead center, and install the bearing cap. Tighten the bolts to the specified torque.
4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.
5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope. The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic. The difference between the readings is the approximate amount of taper.

PRESSURE TEST CYLINDER HEAD (CYLINDER HEAD DISASSEMBLED)

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

NOTICE:
If cracks are visible in the head, DO NOT use the pressure test method.

To seal off water holes in the cylinder head, assemble tool set J 28454, see Figure 1-282.



1. Cylinder Head
2. Hold Down Bolts and Nuts
3. Air Supply Plate
4. End Plates
5. Rod
6. Short Bridges
7. Long End Bridges
8. Long Center Bridges
9. Rubber Stoppers
10. Pressure Checking Tool Set J 28454

Figure 1-282 Cylinder Head Prepared for Pressure Testing using Tool J 28454

1. Install the large rubber stopper on the long center bridge feet.

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2. Install the small stoppers on all short bridges.
3. Install the necessary parts loosely on the cylinder head.

NOTICE:
Do not overtighten the hold down bolts. The rubber stopper could distort and seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak would not be detected.

4. Tighten the hold down bolts until the stoppers start to distort. A 7 N·m (5 lb·ft) torque is usually sufficient.

NOTICE:
Do not attach the pressure checking tool while moving the cylinder head from one location to another. This could result in permanent damage to the tool.

5. Install the air supply plate.
6. Install scrap or dummy injectors to ensure proper injector tube seating.

NOTE:
Dummy injectors can be made from old injector nuts and bodies. Injector spray tips are not necessary.

7. Tighten the injector clamp bolts to 27-34 N·m (20-25 lb·ft) torque.

⚠ 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. Apply 276 kPa (40 lb/in.^{2}) air pressure to the water jacket.

NOTE:
Perform this check at room temperature before immersing the cylinder head in the water tank. Do not perform this check in the hot water tank. The hot tank temperature could cause the nozzle to seal.

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⚠ 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. Immerse the cylinder head in a tank of water treated with Protech® 1650* or equivalent, previously heated to 82-93°C (180-200°F) for about twenty minutes to thoroughly heat the head.
10. Observe the water in the tank for bubbles indicating a leak or crack. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds and at the top and bottom of the cylinder head.
    [a] If air bubbles are visible, replace the cylinder head. Refer to section 1.3.5.
    [b] If no leaks are detected, proceed with inspection.
11. Relieve the air pressure, and remove the cylinder head from the water tank.
12. Remove the plates, gaskets and injectors.

⚠ 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.

13. Dry the head with compressed air.

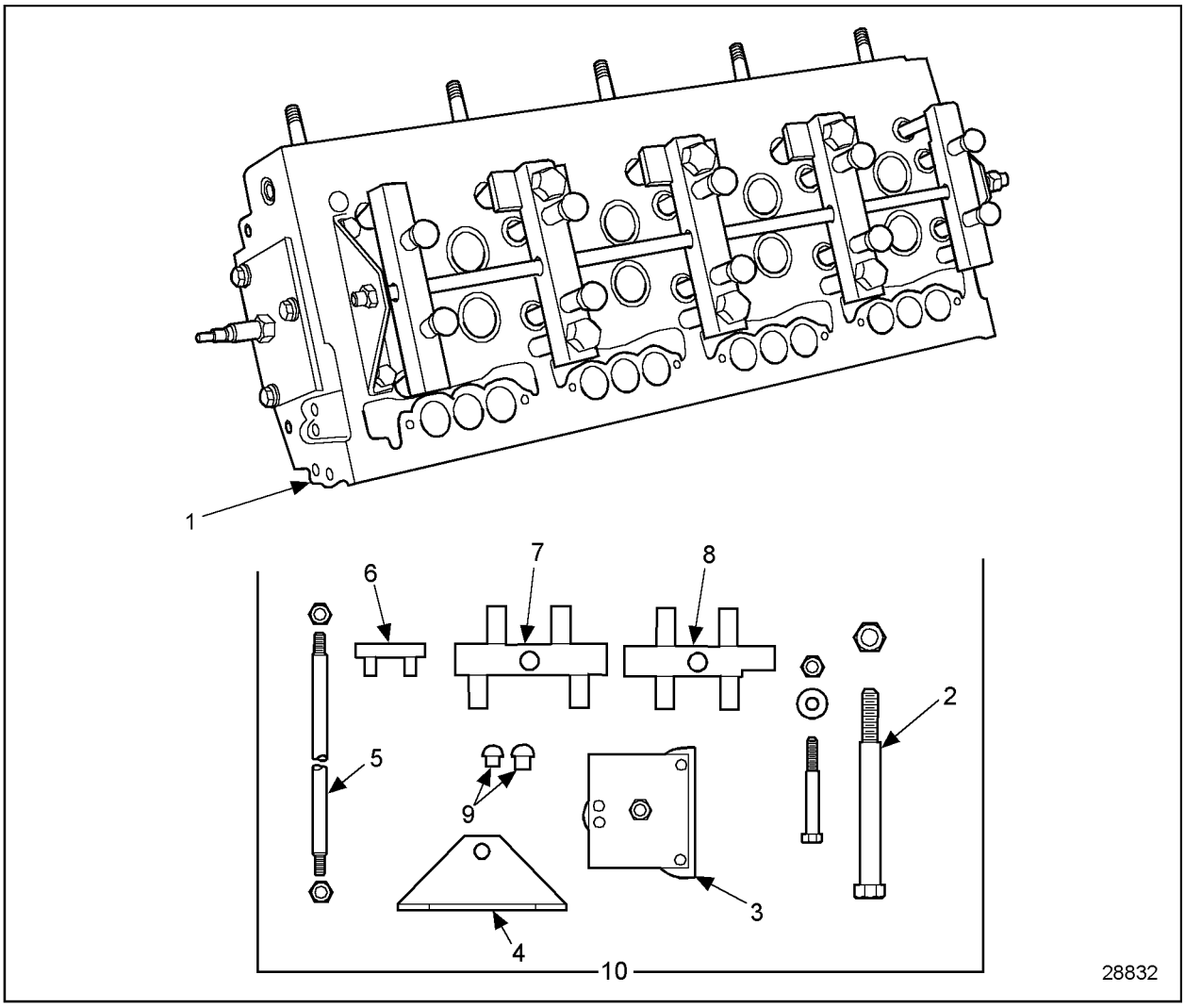
PRESSURE TEST CYLINDER HEAD (CYLINDER HEAD ASSEMBLED AND REMOVED FROM ENGINE)

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

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NOTICE:
If cracks are visible in the head, DO NOT use the pressure test method.

To seal off water holes in the cylinder head, assemble tool set J 28454, see Figure 1-283.



1. Cylinder Head
2. Hold Down Bolts and Nuts
3. Air Supply Plate
4. End Plates
5. Rod
6. Short Bridges
7. Long End Bridges
8. Long Center Bridges
9. Rubber Stoppers
10. Pressure Checking Tool Set J 28454

Figure 1-283 Cylinder Head Prepared for Pressure Testing using Tool J 28454

1. Install the large rubber stopper on the long center bridge feet.

2. Install the small stoppers on all short bridges.
3. Install the necessary parts loosely on the cylinder head.

NOTICE:
Do not overtighten the hold down bolts. The rubber stopper could distort and seal both the inner and outer diameter of the water nozzles. If the outer diameter is sealed, a leak would not be detected.

4. Tighten the hold down bolts until the stoppers start to distort. A 7 N·m (5 lb·ft) torque is usually sufficient.

NOTICE:
Do not attach the pressure checking tool while moving the cylinder head from one location to another. This could result in permanent damage to the tool.

5. Install the air supply plate to water jacket opening.

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. Apply 276 kPa (40 lb/in.^{2}) air pressure to the water jacket.
7. Check for leaks, using Leak Tek solution or equivalent, at the tops and bottoms of the injector tubes, oil gallery, exhaust ports, and fuel manifolds.
   [a] If air bubbles are visible, replace the cylinder head. Refer to section 1.3.5.
   [b] If no leaks are detected, proceed with inspection.
8. Relieve the air pressure slowly.
9. Remove the plates, gaskets and injectors.Check the bottom (fire deck) of the cylinder head for flatness as follows:
10. Use a heavy, accurate straight-edge and feeler gage, tool J 3172, to check for *transverse warpage* at each cylinder head end and between all cylinders.
    [a] If the *transverse warpage* warpage exceeds 0.011 mm (0.0040 in.), the cylinder head firedeck must be replaced. Refer to section 1.3.5.
    [b] If the *transverse warpage* warpage is less than 0.011 mm (0.0040 in.), proceed with inspection.

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11. Check for *longitudinal warpage* in six places. See Figure 1-284.

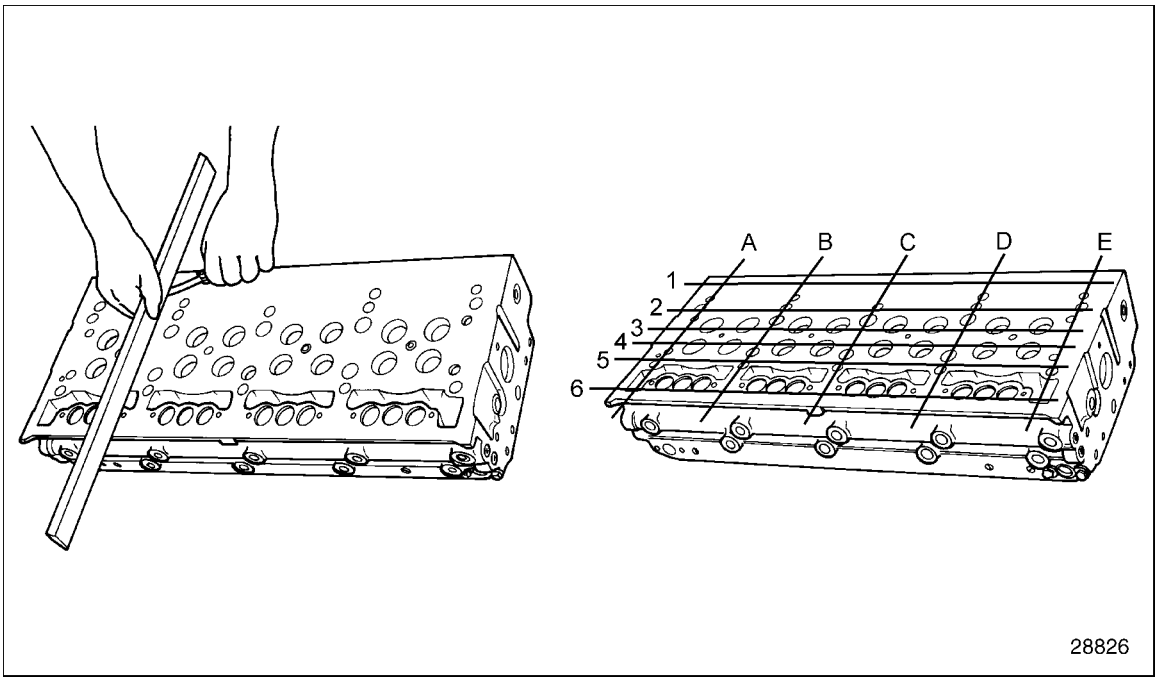


Figure 1-284 Checking Bottom Face of Cylinder Head

[a] If the *longitudinal warpage* exceeds 0.140 mm (0.0055 in.) on 6V engines or 0.203 mm (0.0080 in.) on 8V and 16V engines, the cylinder head firedeck must be replaced. Refer to section 1.3.5.

[b] If the *longitudinal warpage* warpage is less than 0.140 mm (0.0055 in.) on 6V engines or less than 0.203 mm (0.0080 in.) on 8V and 16V engines, proceed with inspection.

12. Examine the fire deck for pitting.

[a] If the fire deck is pitted, it must be replaced. Refer to section 1.3.4.

[b] If the fire deck is not pitted, proceed with examination of fire deck.

13. Use the measurements obtained and the limits as a guide to determine the advisability of reinstalling the head on the engine or of refacing it.

NOTE:
The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

NOTE:
If the cylinder head is to be refaced, remove the injector tubes prior to machining. Any machining of the fire deck can be done with the water nozzles in place. Do not remove

more metal from the fire deck of any cylinder head below the minimum distance of 89.81 mm (3.536 in.). See Figure 1-285.

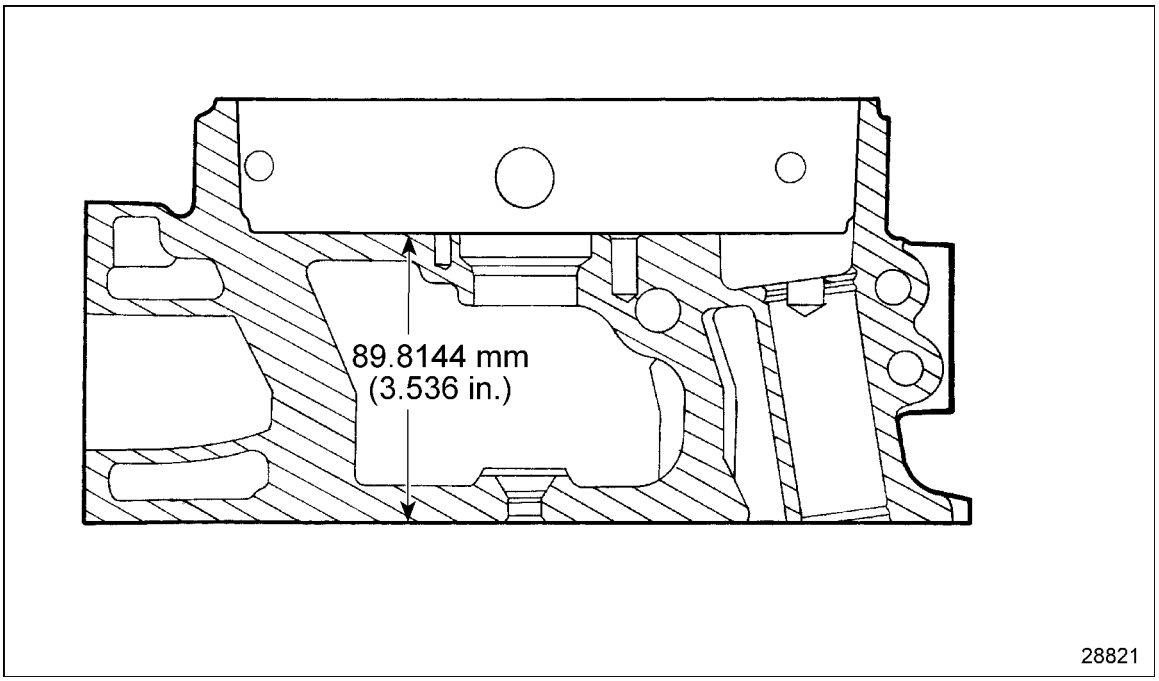


Figure 1-285 Minimum Distance Between Top and Bottom Faces of Cylinder Head

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

14. Install new injector tubes if the old tubes leaked or the cylinder head was refaced. Refer to section 2.4.2.

NOTE:
If the engine overheated, injector tubes in both cylinder heads must be replaced

15. Inspect the exhaust valves seat inserts and valve guides. Refer to section 1.5.6.2.

INSTALLATION OF NEW SOLID BLOCK PLUGS

Before beginning this operation, always check the face of the block plug to ensure the solid plug has not been previously installed. When installed, the new solid block plug has a convex (bowed-out) face. The former cup plug has a concave (recessed) face.

Install the new solid block plug in a former cylinder block as follows:

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1. Using a drift or punch and hammer, carefully remove the one-inch diameter cup plugs (if installed) from the front right bank and left bank of the cylinder block.
2. Clean out the block hole plug openings carefully to eliminate any corrosion, dirt, debris, or oil film.
3. Apply a liberal coating of Loctite 620 or equivalent anaerobic sealant/retaining compound to the O.D. of the plugs.
4. Using a 16 mm or 5/8 inch diameter socket as a driver, install the service plugs into the block until they bottom in the holes. When fully bottomed, plugs will emit a hollow "thud" when struck.

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)

See Figure 1-286 and see Figure 1-287 for cylinder block plugging instructions.

The identification of pipe plugs and other items for the 6V and 8V engines are listed in Table 1-15, and the standard pipe plug torque specifications are listed in Table 1-18.

NOTE:
Apply Loctite 567 pipe sealer with Teflon or equivalent prior to installation.

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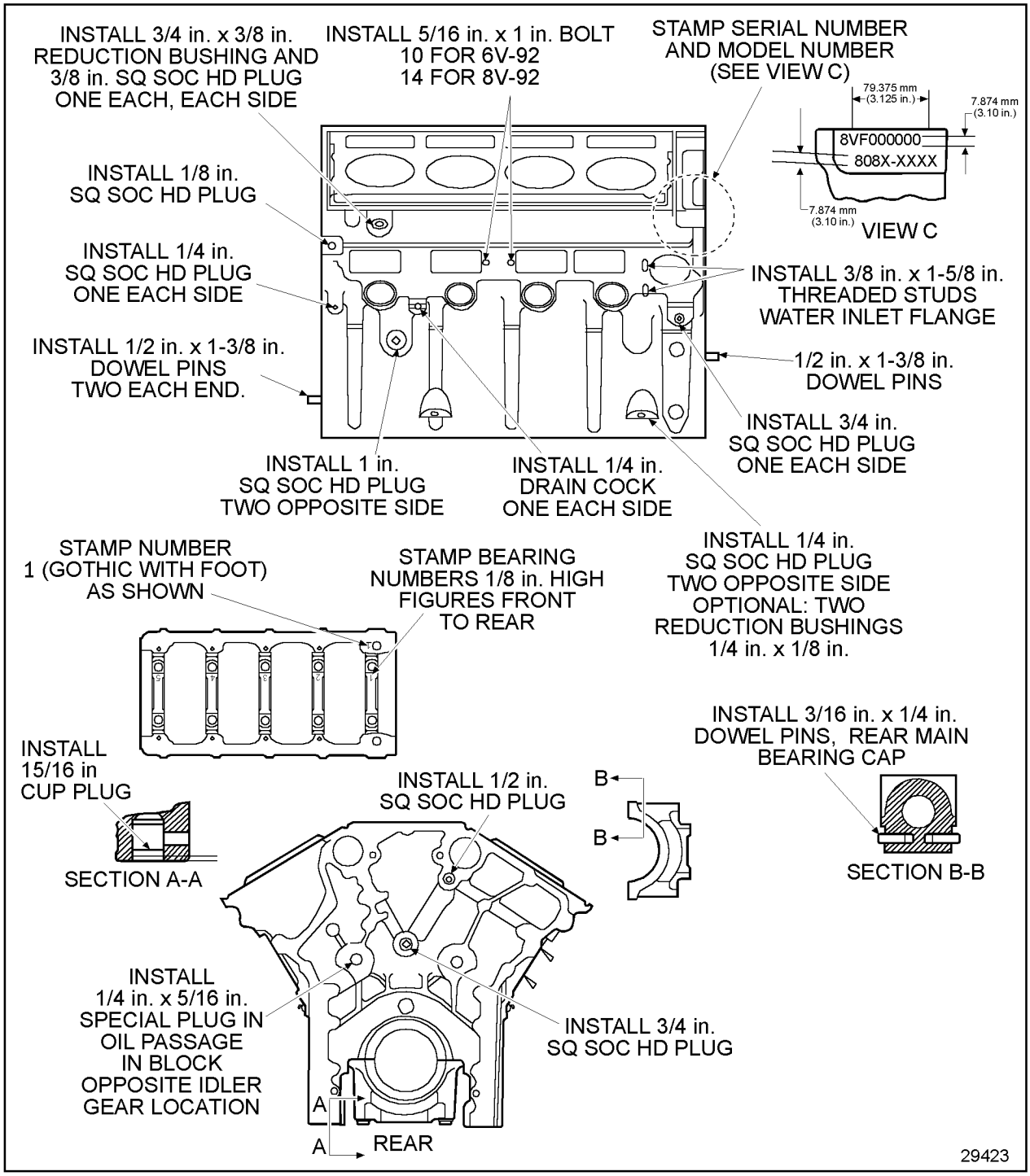


Figure 1-286 Cylinder Block Plugging (6V and 8V Engines)

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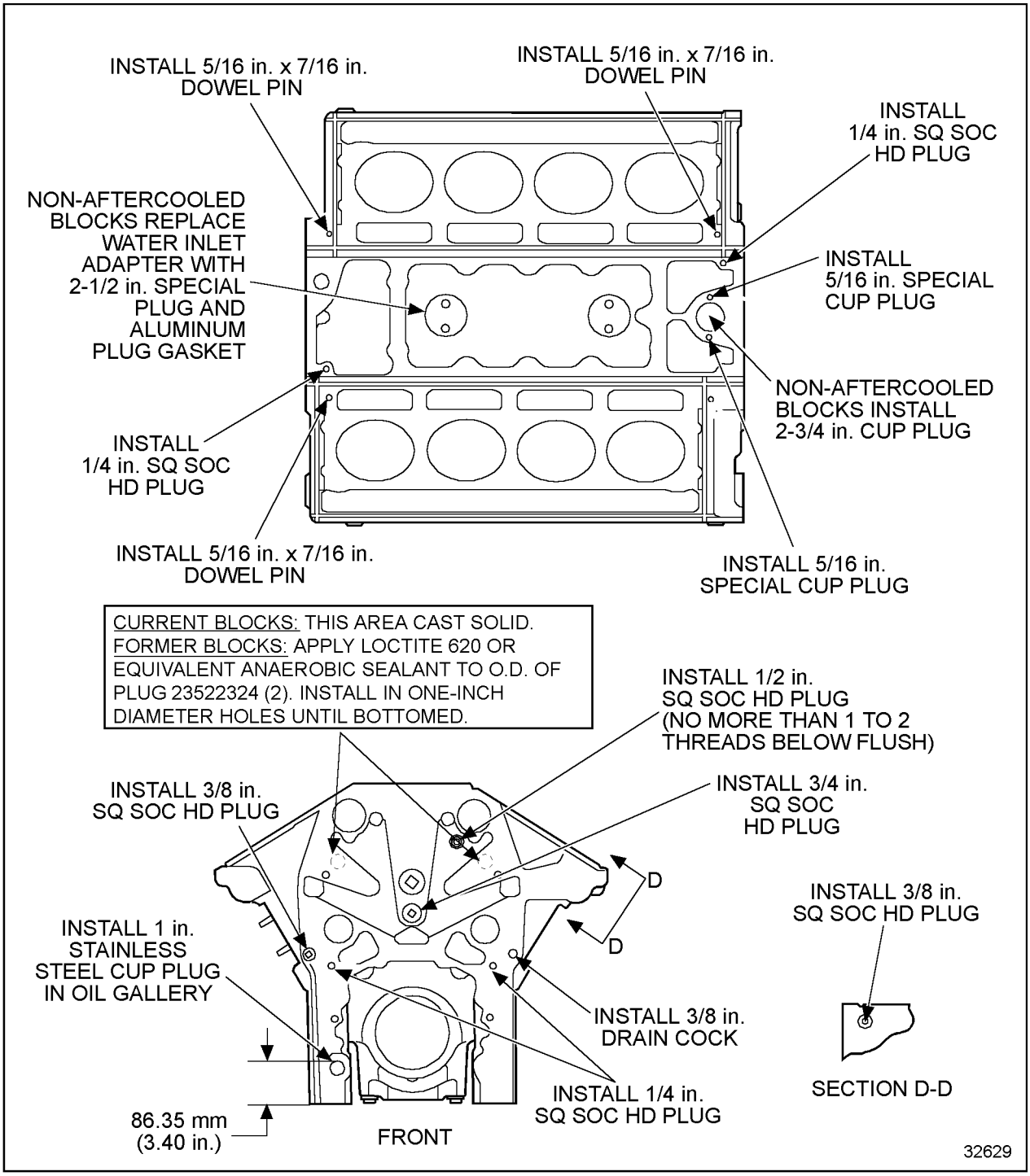


Figure 1-287 Cylinder Block Plugging (6V and 8V Engines)

The identification of pipe plugs are listed in Table 1-15, and the standard pipe plug torque specifications are listed in Table 1-18.

Description	Part Number	Installation*
Pipe Plugs †		
1/8 in. Squared Socket Head Pipe	8924380	-
1/4 in. Squared Socket Head Pipe	8923847	-
3/8 in. Squared Socket Head Pipe	8924517	-
1/2 in. Squared Socket Head Pipe	8923916	-
3/4 in. Squared Socket Head Pipe	8923313	Below Surface
1 in. Squared Socket Head Pipe	8924750	-
Other Plugs		
5/16 in. Special Cup	5123862	-
15/16 in. Cup	9428477	To 12 in. Below Surface
1 in. Solid	5139988	-
2-1/2 in. Special	5138646	-
2-3/4 in. Special Cup	5144559	-
1/4 in. x 5/16 in. Special	5154319	-
Other Items		
5/16 in. x 7/16 in. Dowel Pin	5103045	Flush With Surface
1/2 in. x 1-3/8 in. Dowel Pin	5151576	To 0.630 in. ± 0.030 in. Projection
3/16 in. x 1/4 in. Dowel Pin	141346	To 0.115 in. ± 0.030 in. Projection
3/8 in. x 1-5/8 in. Stud	5150362	To 1.00 in. ± 0.030 in. Projection
5/16 in. x 1 in. Bolt	8920631	To 1.00 in. ± 0.030 in. Projection
1/4 in. Drain Cock	8924140	-
3/8 in. Drain Cock	118536	-
3/4 in. x 3/8 in. Red Bush	5146913	-
1/4 in. x 1/8 in. Red Bush	8924142	-
Aluminum Plug Gasket	5138659	-

* Prevailed sealant

† Install plugs flush to below top of finished surfaces of block except where specific instructions are given.

Table 1-15 Identification Chart

CYLINDER BLOCK PLUGGING INSTRUCTIONS (12V AND 16V ENGINES)

See Figure 1-288 and see Figure 1-289 for cylinder block plugging instructions.

The identification of pipe plugs are listed in Table 1-16, and the standard pipe plug torque specifications are listed in Table 1-18.

NOTE:
Apply Loctite 567 pipe sealer with Teflon or equivalent prior to installation.

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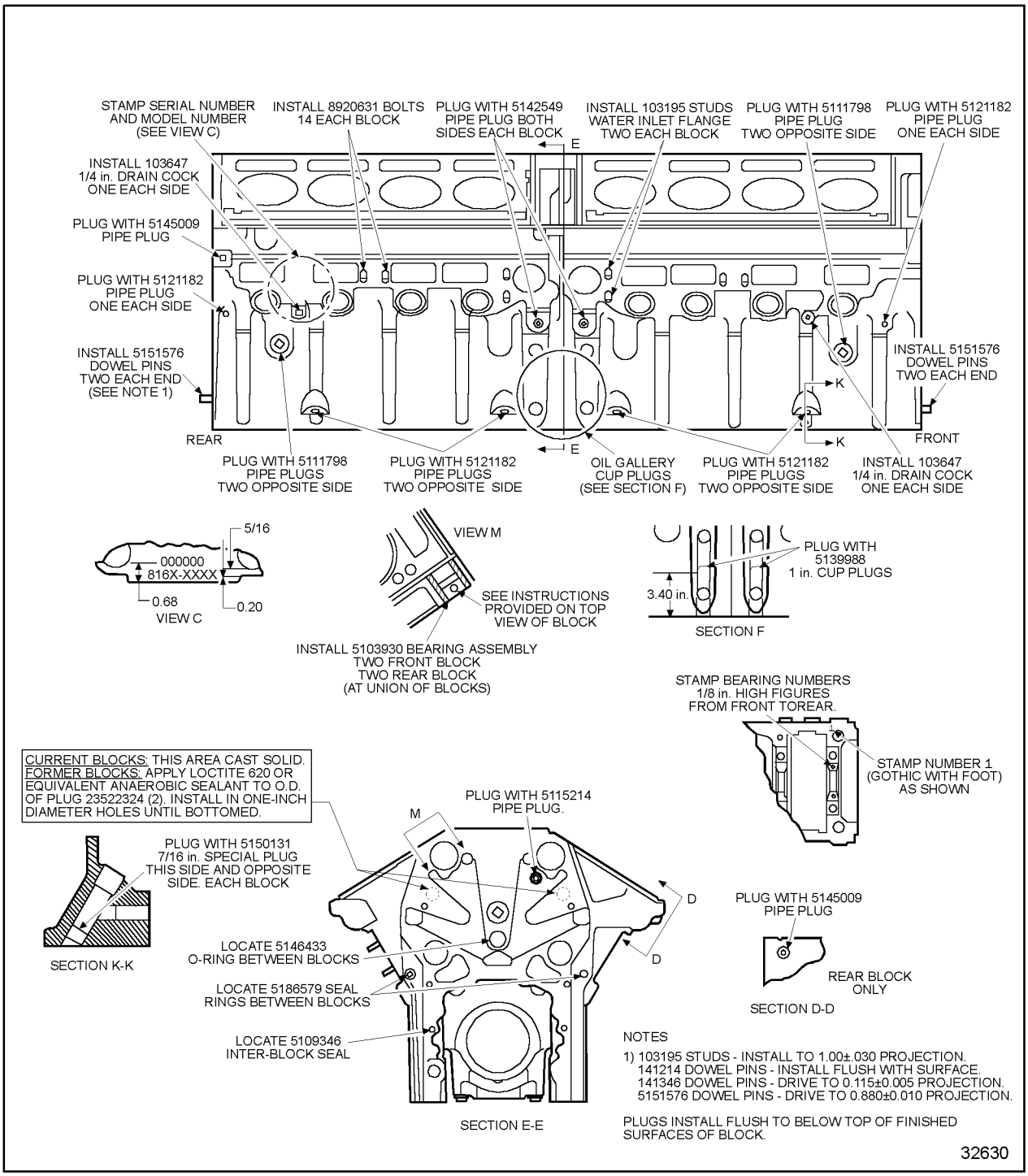


Figure 1-288 Cylinder Block Plugging (12V and 16V Engines)

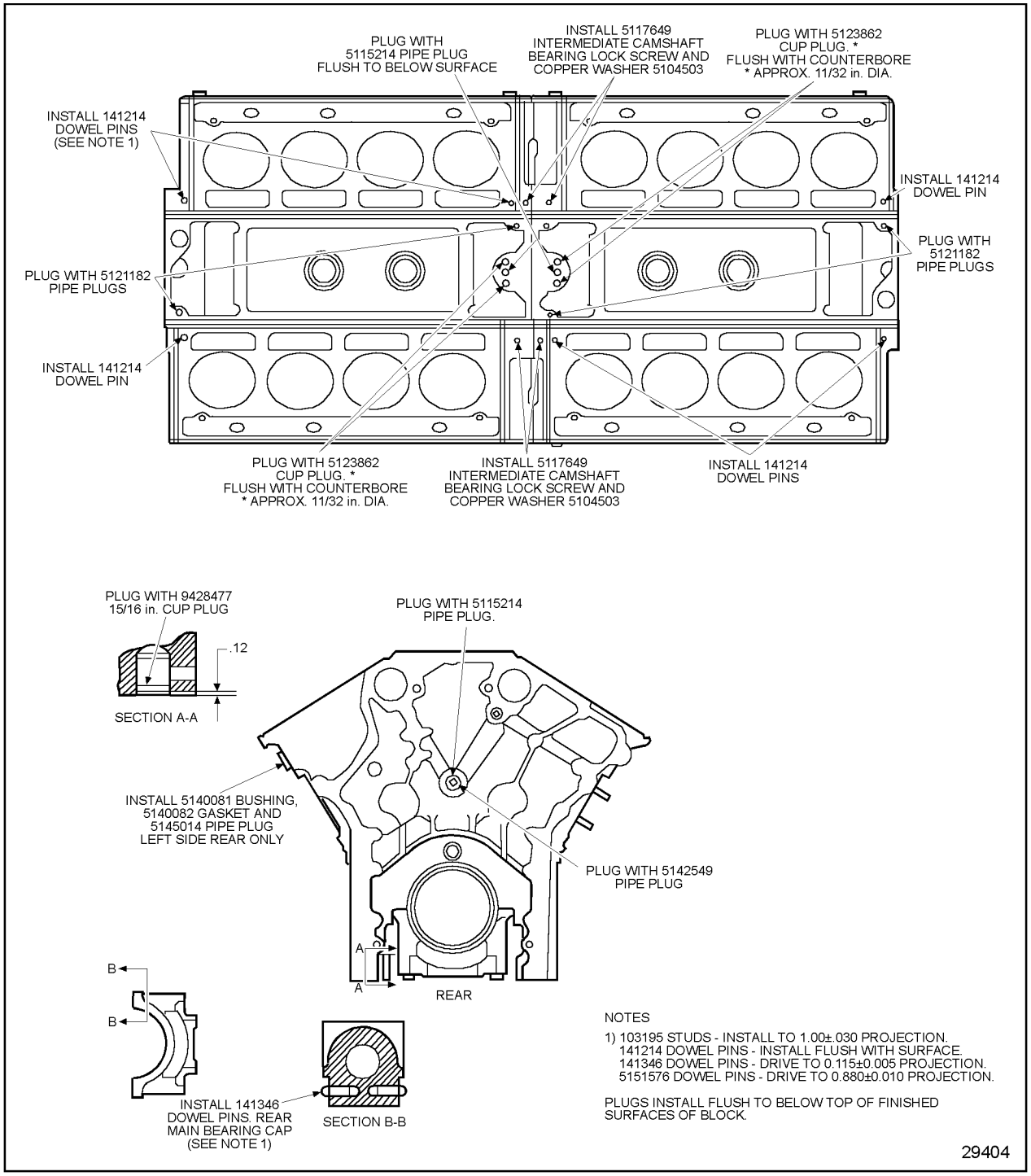


Figure 1-289 Cylinder Block Plugging (12V and 16V Engines)

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The identification of pipe plugs are listed in Table 1-16, and the standard pipe plug torque specifications are listed in Table 1-17.

Description	Part Number
1/8 in. Hex Socket Head	5145009
1/4 in. Hex Socket Head	5121182
3/8 in. Hex Socket Head	5145014
1/2 in. Hex Socket Head	5115214
3/4 in. Short Squire Socket Head	5142549
1 in. Socket Head	5111798

Table 1-16 Pipe Plug Identification Chart

Thread Size, NPTF *	Torque Specifications, N·m	Torque Specifications, lb·ft
1/8 in.	14-16	10-12
1/4 in.	19-22	14-16
3/8 in.	24-30	18-22
1/2 in.	31-37	23-27
3/4 in.	45-50	33-37
1 in.	102-115	75-85
1-1/4 in.	129-143	95-105
1-1/2 in.	150-177	110-130

*Use sealant such as Loctite 567 pipe plug sealant with Teflon (or equivalent) on all uncoated pipe plugs.

Table 1-17 Standard Pipe Plug Torque Specifications

CYLINDER HEAD PLUGGING INSTRUCTIONS

See Figure 1-290 and see Figure 1-291 for cylinder block plugging instructions.

The standard pipe plug torque specifications are listed in Table 1-18.

NOTE:
Apply Loctite 567 pipe sealer with Teflon or equivalent prior to installation.

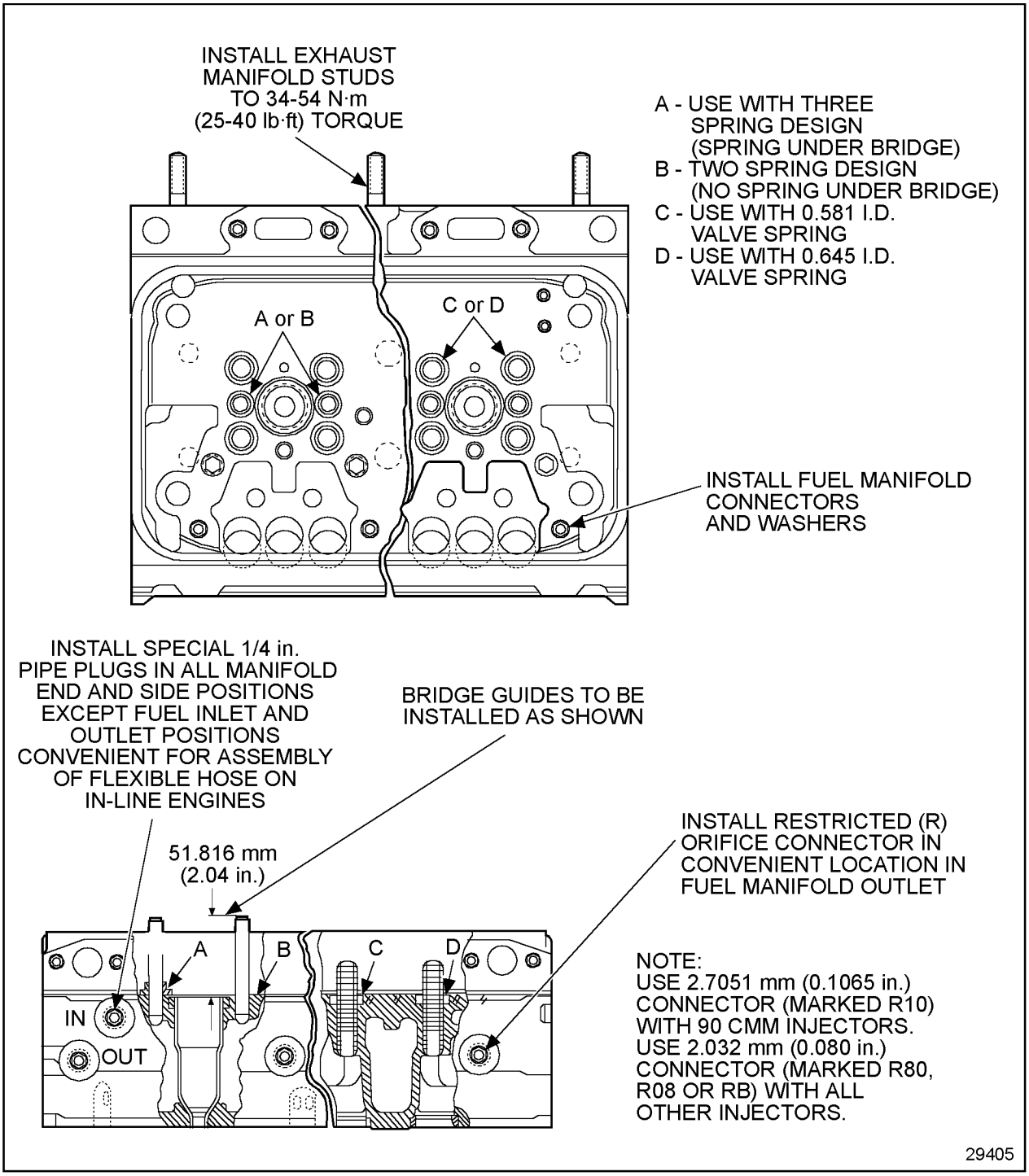


Figure 1-290 Cylinder Block Plugging

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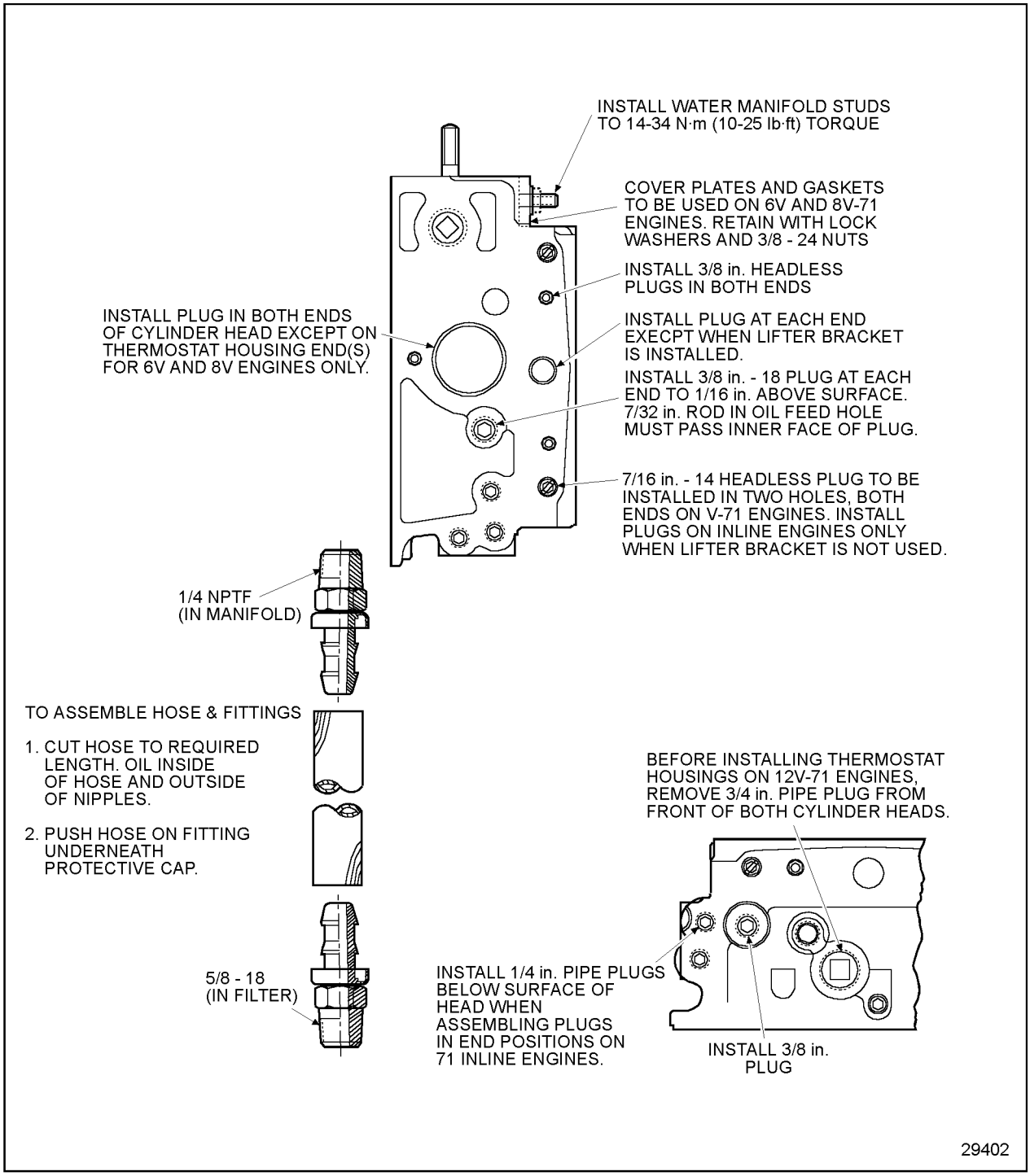


Figure 1-291 Cylinder Block Plugging

The standard pipe plug torque specifications are listed in Table 1-18.

Thread Size, NPTF *	Torque Specifications, N·m	Torque Specifications, lb·ft
1/8 in.	14-16	10-12
1/4 in.	19-22	14-16
3/8 in.	24-30	18-22
1/2 in.	31-37	23-27
3/4 in.	45-50	33-37
1 in.	102-115	75-85
1-1/4 in.	129-143	95-105
1-1/2 in.	150-177	110-130

*Use sealant such as Loctite 567 pipe plug sealant with Teflon (or equivalent) on all uncoated pipe plugs.

Table 1-18 Standard Pipe Plug Torque Specifications

EXHAUST VALVE ADJUSTMENT

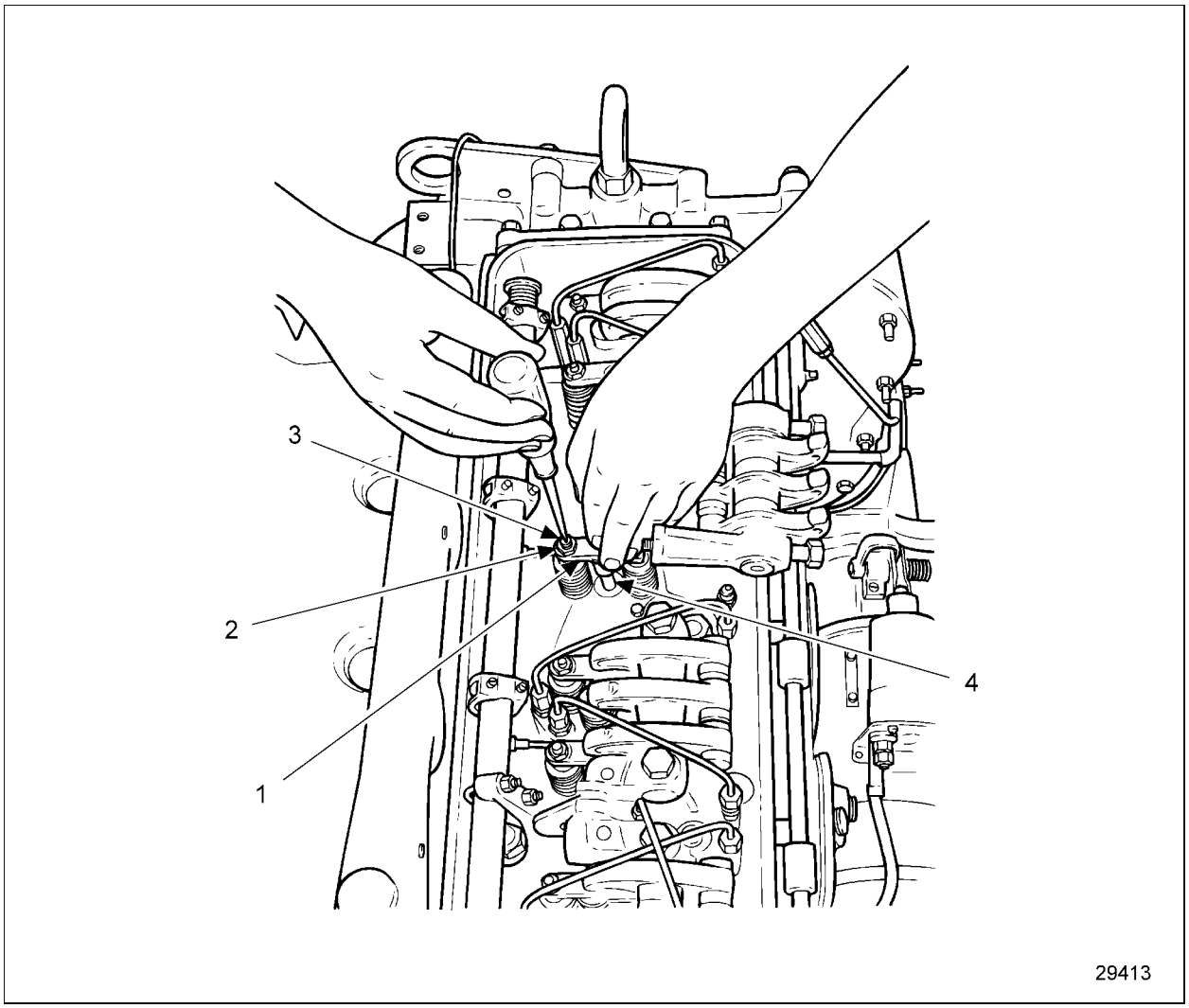
Adjust the exhaust valve bridges as follows:

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

1. Place the valve bridge in a vise or bridge holding fixture J 21772, and loosen the locknut on the bridge adjusting screw.
2. Install the valve bridge on the valve bridge guide.
3. While firmly pressing straight down on the pallet surface of the valve bridge, turn the adjusting screw clockwise until it just touches the valve stem.

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4. Turn the screw an additional 1/8 to 1/4 turn clockwise, and finger-tighten the locknut. See Figure 1-292.



1. Exhaust Valve Bridge
2. Locknut
3. Adjusting Screw
4. Valve Bridge Guide

Figure 1-292 Valve Bridge Adjustment

5. Remove the valve bridge, and place it in a vise.
6. Use a screw driver to keep the adjustment screw from turning.
7. Tighten the locknut to 27-34 N·m (20-25 lb·ft) torque.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

8. Lubricate the valve bridge guide and the valve bridge with engine oil.
9. Install the valve bridge in its original position.
10. Place a 0.038 mm (0.0015 in.) feeler gage J 23185 under each end of the valve bridge, or use a narrow strip cut from 0.038 mm (0.0015 in.) feeler stock, to fit in the bridge locating groove over the inner exhaust valve.
11. Both feeler gages must be tight while pressing down on the valve bridge pallet surface. If both of the feeler gages are not tight, readjust the adjusting screw.
12. Remove the valve bridge, and install it in its original position.
13. Adjust the remaining valve bridges in the same manner.
14. Swing the rocker arm assembly into position, making sure the valve bridges are properly positioned on the rear valve stems. This precaution is necessary to prevent valve damage from dislocated valve bridges.
15. Tighten the *rocker arm shaft bracket bolts* to the specified torque. For EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS, refer to section ADDITIONAL INFORMATION.

Installation of Valve Guide Oil Seal

Install the valve guide oil seal, if used, on the valve guide as follows:

1. Place a plastic seal installation cap on the end of the valve stem.
2. If the cap extends more than 1.588 mm (0.0625 in.) below the groove on the valve stem, remove the cap, and cut off the excess length.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Lubricate the installation cup with clean engine oil, and carefully start the seal over the valve stem.

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NOTICE:
The tool positions the seal so that it does not bottom out on the valve guide. If the seal is installed too far and contacts the top of the guide, it will distort and will not seal.

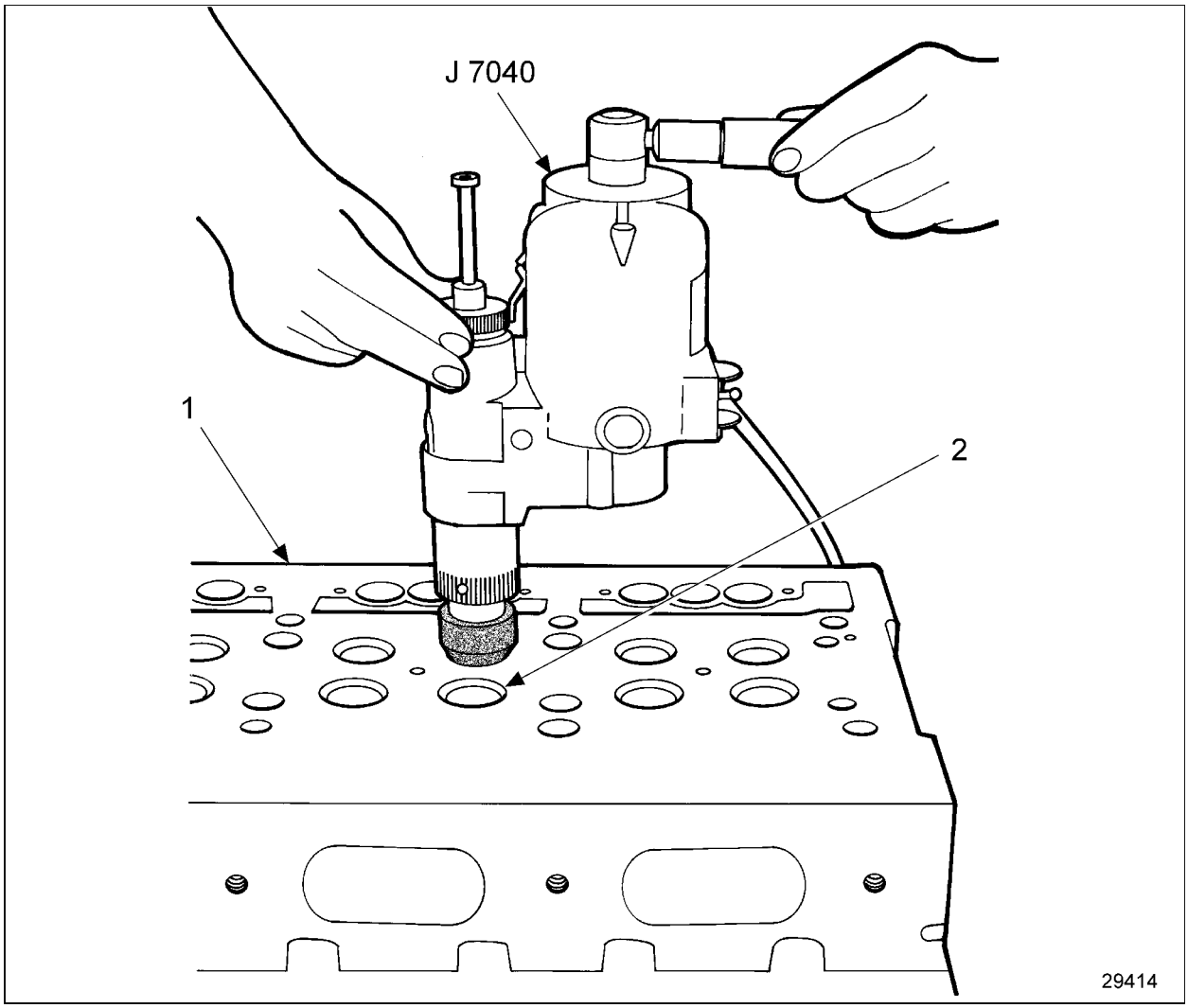
4. Using tool J 35373, push the seal down slowly until the tool bottoms on the cylinder head.
5. Remove the installation cap.

Reconditioning Exhaust Valve and Valve Seat

To reface a valve or valve seat, perform the following procedure:

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1. Use valve seat grinder set J 7040-A and adaptor set J 24566 to reface the valve seat inserts and head. See Figure 1-293.



1. Cylinder Head
2. Valve Seat

Figure 1-293 Grinding Valve Seat

2. Apply the 31 degree grinding wheel on the valve seat insert.
3. Use the 60 degree grinding wheel to open the throat of the insert.

NOTICE:
When grinding the inserts, do not permit the grinding wheel to contact the cylinder head. If the grinding wheel contacts the cylinder head, install a new insert.

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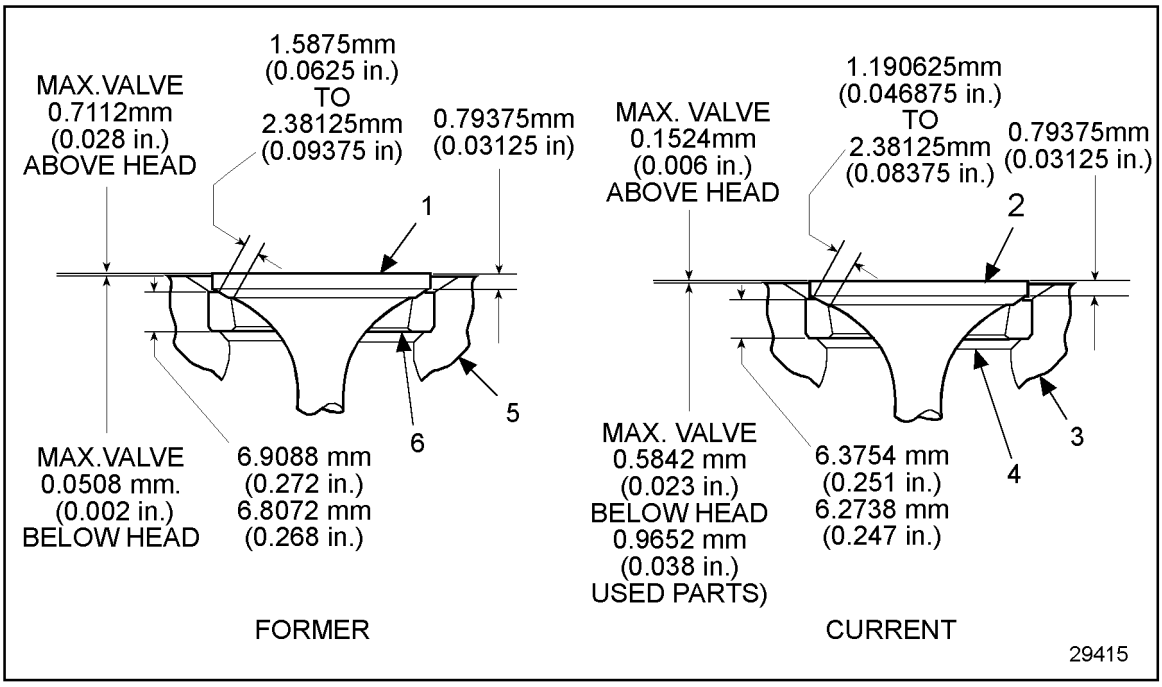
CAUTION:

To avoid injury from fire, keep a fire extinguisher near the grinding machine in case excessive heat should ignite the oil.

4. Grind the insert surface with the 15 degree wheel to narrow the seat width.

NOTE:
The 31 degrees insert face may be adjusted relative to the center of the valve face with the 15 degrees and 60 degrees grinding wheels.

NOTE:
See Figure 1-294 for valve protrusion measurements. If the valve has receded beyond the specified limits, replace the valve seat insert.



1. Valve
2. Valve
3. Cylinder Head
4. Valve Seat Insert
5. Cylinder Head
6. Valve Seat Insert

Figure 1-294 Exhaust Valve Protrusion Beyond Cylinder Head

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5. Dress the grinding wheel with J 24566, when necessary. See Figure 1-295.

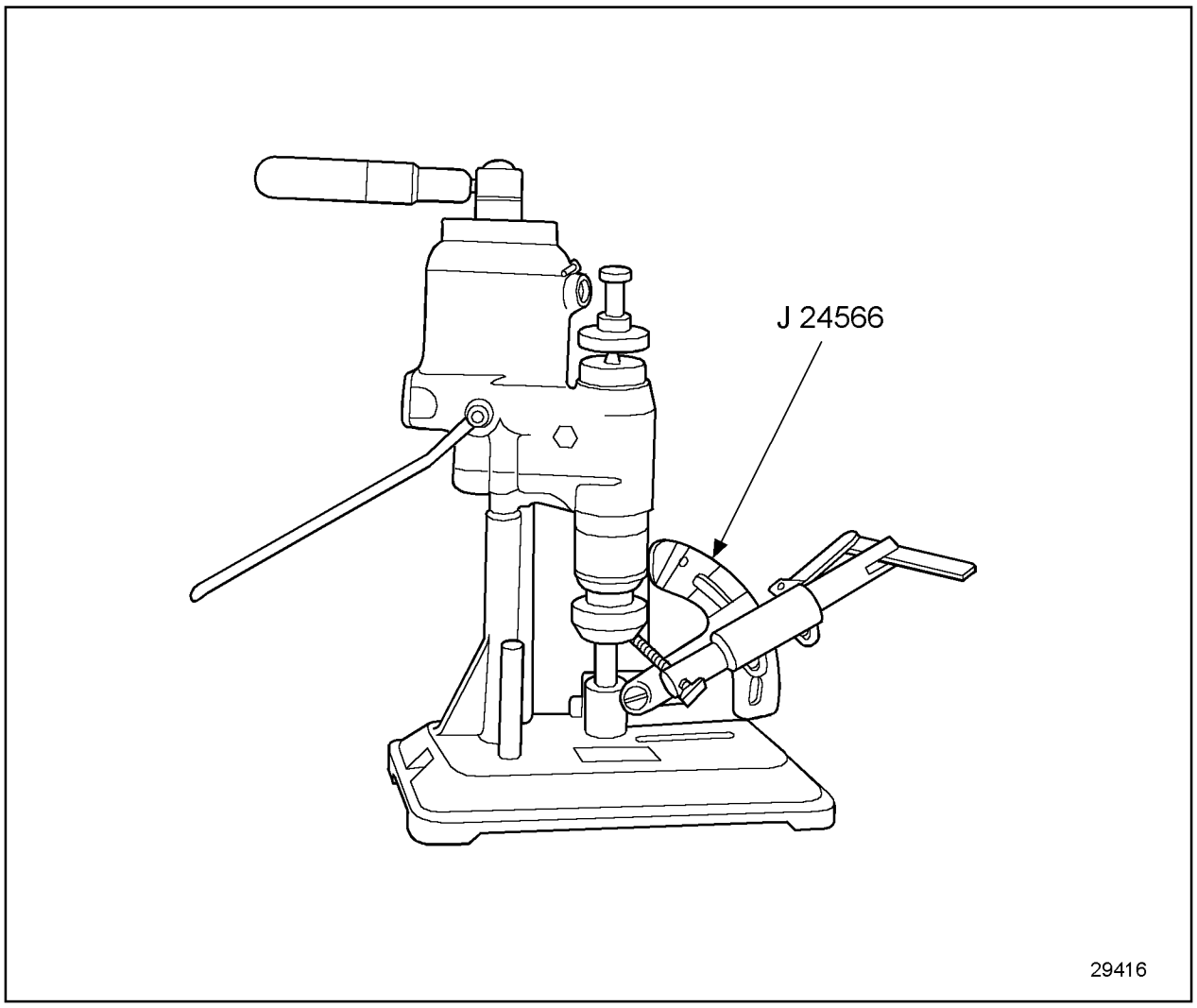


Figure 1-295 Grinding Wheel Dressing Tool Set J 24566

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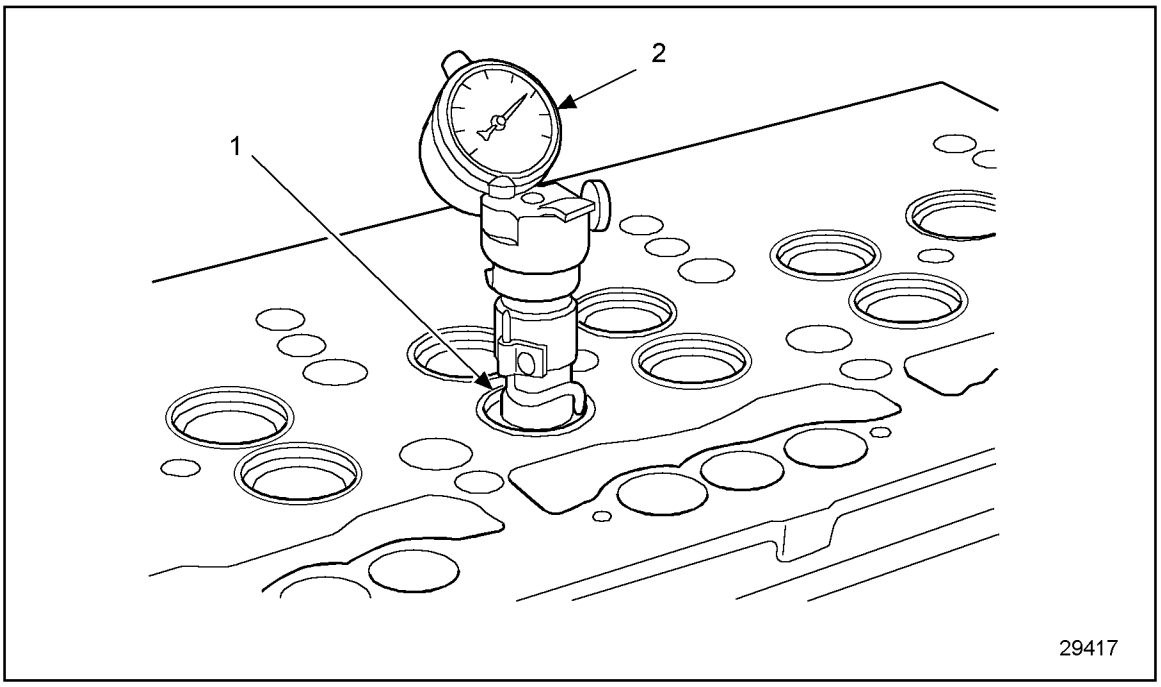
⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

⚠ 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. Clean the valve seat insert thoroughly with fuel oil. Dry with compressed air.
7. Position the dial indicator J 8165-2. See Figure 1-296.



1. Valve Seat Insert
2. Dial Indicator

Figure 1-296 Checking Relative Concentricity of Valve Seat Insert with Relation to Valve Guide

8. Rotate the dial indicator to determine valve seat insert concentricity relative to the valve guide. Total run-out should not exceed 0.05 mm (0.002 in.).
9. If run-out exceeds 0.05 mm (0.002 in.), check for a bent or worn valve guide before regrinding the insert.

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

1. Apply a light coat of Prussian blue, or similar paste, to the valve seat insert.
2. Lower the valve stem into the valve guide.
3. Bounce the valve on the insert. Do not rotate.

NOTE:
Do not use valve lapping compounds.

4. Observe the contact area on the valve face. The area of contact should be the center of the valve face.
   [a] If the contact area is not at the center of the valve face, replace the valve and valve seat.
   [b] If the contact area is centered, reuse the valve and valve seat.

REGRINDING CRANKSHAFT JOURNALS

Regrind the crankshaft journals as follows:

1. Confirm the dimensional requirements for journal axial profile, radial chatter, and oil hole washout with Gould 12000 Surface Analyzer, or equivalent.

NOTE:
Remanufactured crankshafts are available through the Detroit Diesel reliabilt® system and are made to the same quality specifications required of new original equipment crankshafts.

NOTE:
Remanufactured crankshafts procured from other than Detroit Diesel reliabilt sources must conform to Detroit Diesel specifications.

2. Polish according to Gould 1200, or equivalent, measurements.

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3. All used crankshafts that have not been reground must meet the dimensional specifications listed in Table 1-19 or be reground to reliabilt specifications.

Bearing Size	Connecting Rod Journal Diameter	Main Bearing Journal Diameter
Standard	76.16 mm / 76.21 mm (2.9985 in. / 3.0002 in.)	114.26 mm / 114.31 (4.4985 in. / 4.5002 in.)
0.010 in.	*75.91 mm / 75.95 mm (2.9885 in. / 2.9902 in.)	*114.01 mm / 114.10 (4.4885 in. / 4.4902 in.)
0.020 in.	*75.65 mm / 75.70 mm (2.9785 in. / 2.9802 in.)	*113.75 mm / 113.80 (4.4785 in. / 4.4802 in.)
0.030 in.	*75.40 mm / 75.65 mm (2.9685 in. / 2.9782 in.)	*113.50 mm / 113.54 (4.4685 in. / 4.4702 in.)

* Dimensions of reground crankshaft

Table 1-19 Dimensional Specifications

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

NOTE:
Crankshaft main bearing journals and/or connecting rod journals that exhibit discoloration from excessive overheating are not acceptable for rework.

4. If one or more main or connecting rod journals require grinding, grind all main journals or all connecting rod journals to the same required size listed in Table 1-19.

NOTE:
In addition to standard size crankshaft thrust washers, 0.13 mm and 0.25 mm (0.005 in. and 0.010 in.) oversized thrust washers are available. The dimensions listed in Table 1-20 apply to crankshafts with remanufactured thrust surfaces.

Nominal Size	Thrust Washer Thickness (Minimum)	Thrust Washer Thickness (Maximum)
Standard	0.1190 in.	0.1220 in.
0.005 in. Oversize	0.1240 in.	0.1270 in.
0.010 in. Oversize	0.1290 in.	0.1320 in.

Table 1-20 Dimensions for Oversize Thrust Washers

REPLACING FORMER DESIGN WATER NOZZLES

If the engine overheated, the former water nozzles must be replaced in both cylinder heads.

If necessary, replace the nozzles as follows:

1. Remove the old nozzles.

NOTICE:
The intermediate nozzle holes are reamed and must not be cleaned with a drill. This could result in water leaking into the lubricating oil. Use a soft bristle brush to clean the intermediate water nozzle holes.

2. Ensure the water inlet ports are clean and free of scale.
3. Install former water nozzles with installing tool J 24857-A. The current water nozzle should be pressed into place.
4. Position of the nozzles in the cylinder head.

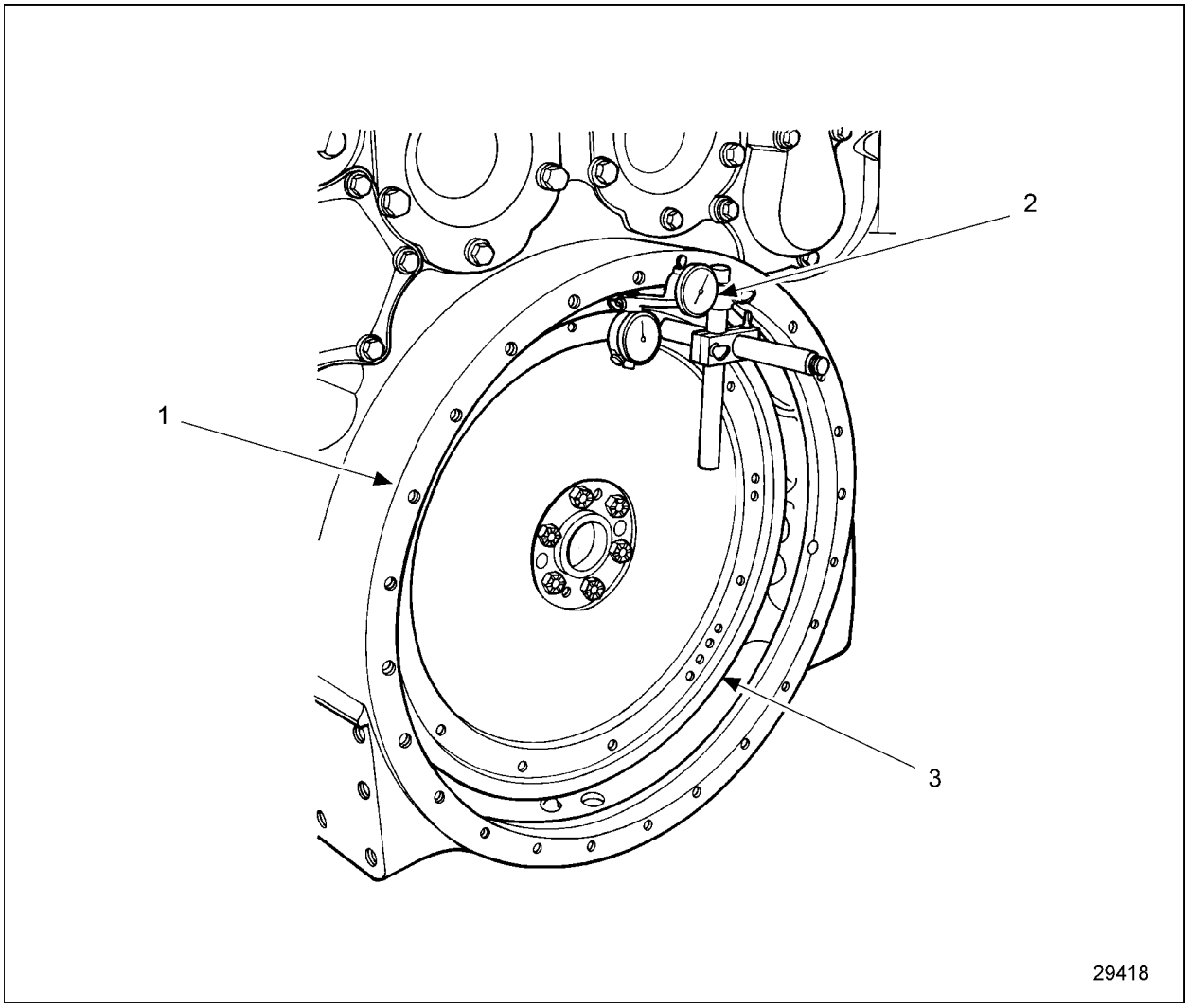
NOTE:
The former nozzles must be recessed 0.10 mm (0.004 in.) to flush with the bottom face of the cylinder head and the sealing area of the cylinder head around the nozzles must be flat within 0.05 mm (0.002 in.). The current water nozzles must be 0.38 mm (0.015 in.) recessed to flush.

FLYWHEEL HOUSING CONCENTRICITY AND BOLTING FLANGE FACE RUNOUT

Inspect the flywheel housing concentricity and bolting flange face run-out with tool set J 9737-D, as follows:

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1. Thread the base post J 9737-D tightly into one of the tapped holes in the flywheel. Assemble the dial indicators on the base post with the attaching parts provided in the tool set. See Figure 1-297.



1. Flywheel Housing
2. Dial Indicator
3. Flywheel

Figure 1-297 Checking Flywheel Housing Concentricity

2. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Ensure each indicator has adequate travel in each direction.
3. If the flywheel extends beyond the flywheel housing bell, the bore and face must be checked separately. Use the special adaptor in the tool set to check the housing bore.
4. Pry the crankshaft toward one end of the block to ensure that end play is in one direction only.
5. Adjust each dial indicator to read zero at the twelve o'clock position.

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:

The barring operation should ALWAYS be performed in a clockwise direction. The bolt must not be loosened. Serious engine damage may result if the vibration damper or pulley is not securely fastened to the crankshaft.

NOTE:
The hex head of the front crankshaft bolt may be used to turn the crankshaft.

6. Rotate the crankshaft one full revolution, recording readings at 90 degree intervals (4 readings each for the bore and the bolting flange face).
7. On "bossed" flywheel housings, position the dial indicators at a location where obstruction poses no problem.
8. To ensure accuracy, stop and remove the wrench or cranking bar before recording each reading.
9. Record the readings and interpret as listed in Table 1-21 and listed in Table 1-22:

3:00	9:00	Examples of Good	Examples of Bad
+	+	+0.002 in. +0.014 in. Difference = 0.012 in.	+0.002 in. +0.016 in. Difference = 0.014 in.
-	-	-0.002 in. -0.014 in. Difference = -0.012 in.	-0.002 in. -0.016 in. Difference = -0.014 in.

Table 1-21 Bore/Face Run-Out Values

3:00	9:00	Examples of Good	Examples of Bad
+	-	+0.002 in. -0.010 in. Total = 0.012 in.	+0.002 in. -0.012 in. Total = 0.014 in.
-	+	-0.002 in. +0.010 in. Total = 0.012 in.	-0.002 in. +0.012 in. Total = 0.014 in.

Table 1-22 Bore/Face Run-Out Values

Check bore face run-out as follows:

Check the value at six o'clock (6:00) position. This value cannot exceed ± 0.33 mm (0.013 in.).

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

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[a] Both readings "+" or "-". The difference must not exceed 0.33 mm (0.013 in.).

[b] Both readings different, "+/-" or "-/+." The total of dimensions must not exceed 0.33 mm (0.013 in.).

Check the bore diameter as follows:

Verification of bore diameter is required when 3:00 and 9:00 o'clock readings are both "+" or both "-". The total of dimensions must not exceed 0.76 mm (0.030 in.) as listed in Table 1-23.

3:00	9:00	Examples of Good	Examples of Bad
+	+	+0.014 in. +0.015 in. Total = 0.029 in.	+0.014 in. +0.017 in. Total = 0.031 in.
-	-	-0.014 in. -0.015 in. Total = -0.029 in.	-0.014 in. -0.017 in. Total = -0.031 in.

Table 1-23 Bore/Face Run-Out Values

10. If the bore or face run-out exceeds the maximum limits, remove the flywheel housing, and check for dirt or foreign material, such as old gasket material, between the end plate and flywheel housing or between the end plate and the cylinder block. If the bore diameter still exceeds limits, replace the flywheel housing.
11. Install the flywheel housing and the flywheel.
12. Tighten the attaching bolts in the proper sequence to the specified torque.
13. Recheck the bore and face run-out and the bore diameter. If necessary, replace the flywheel housing.

On 16V reinforced flywheel housings, check the flywheel housing concentricity and bolting flange face run-out with tool J 9737-D as follows:

1. Thread the base post J 9737-D tightly into one of the tapped holes in 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 and ensure each indicator has adequate travel in each direction.

NOTE:
If the flywheel extends beyond the flywheel housing bell, the housing bore and face must be checked separately. Use the special adaptor in tool set J 9737-D to check the housing bore.

4. Pry and hold the crankshaft in one direction to ensure end play is only in one direction.
5. Adjust each dial indicator to read zero at the twelve o'clock position.
6. Rotate the crankshaft one full revolution, taking readings at 45 degree intervals (8 readings each of the flywheel housing bore and the bolting face).

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7. Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed 0.33 mm (0.013 in.) for either the bore or face.
8. If the run-out exceeds the maximum limits, remove the flywheel and the flywheel housing.
9. Check for dirt or foreign material, such as old gasket material, between the end plate, flywheel housing, and new gasket (and between the end plate and the cylinder block).
10. Install the flywheel housing and secure the attaching bolts in the proper sequence and to the specified torque. Recheck the run-out.
11. If necessary, replace the flywheel housing.

PISTON-TO-LINER CLEARANCE

Measure clearance as follows:

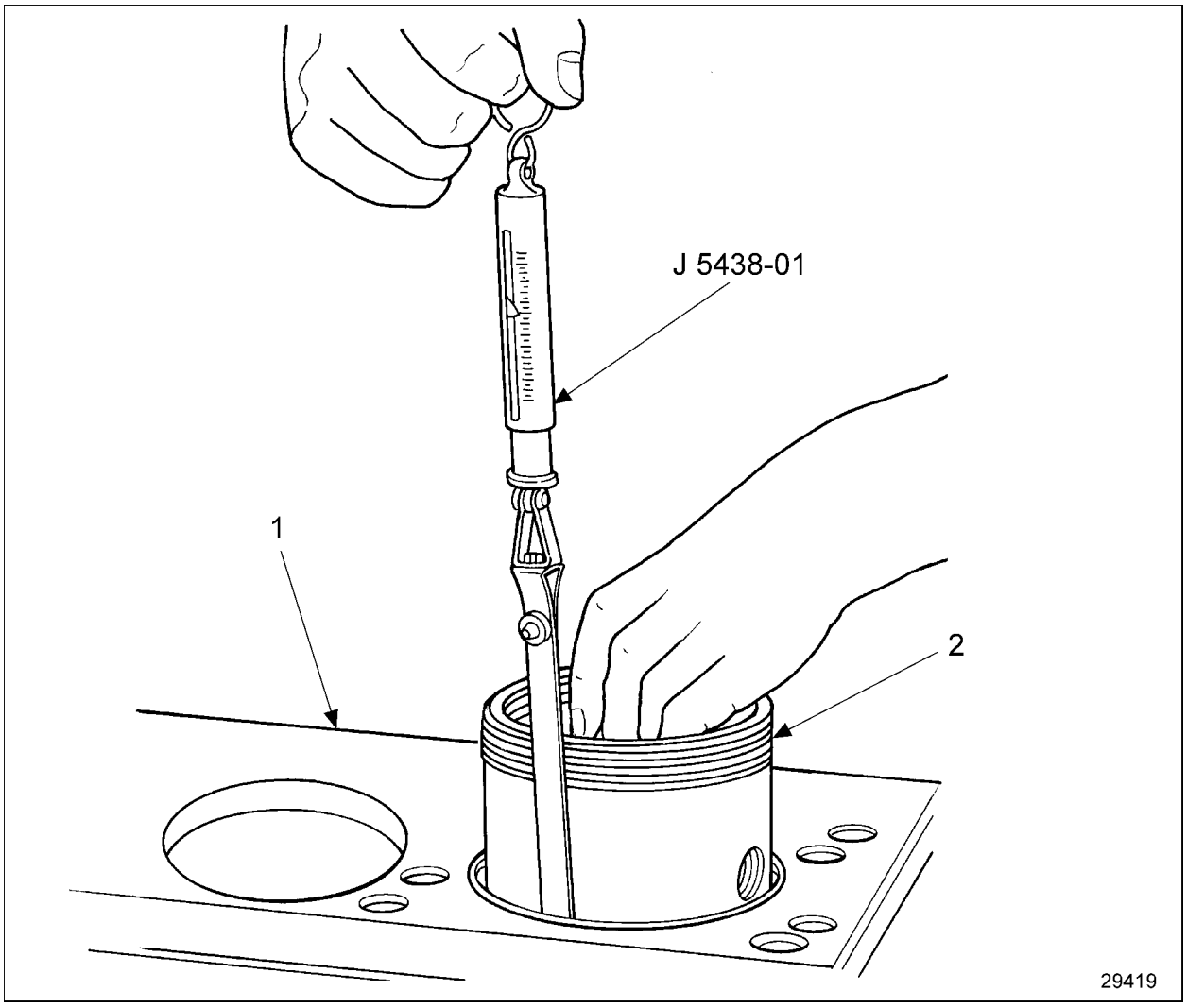
1. Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore.

NOTE:
Measurements should be taken at room temperature 70°F or (21°C).
Refer to section ADDITIONAL INFORMATION for specifications.

NOTE:
The piston-to-liner clearance, with new parts, will vary with the particular piston diameter. Refer to section ADDITIONAL INFORMATION. A maximum clearance of 0.30 mm (0.012 in.) is allowable with used parts. Specifications for the cross-head piston and rings are listed in Table 1-34. Current specifications may not be available at the time of publication. Refer to your local distributor, or Detroit Diesel Parts Technical for additional information.

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2. With the cylinder liner installed in the cylinder block, hold the piston skirt upside down in the liner and check the clearance in four places 90 degrees apart. See Figure 1-298.



1. Cylinder Block
2. Cylinder Liner

Figure 1-298 Measuring Piston-to-Liner with Tension Scale J 8129 (from set J 5438-01)

3. Use feeler gage J 8129 (from set J 5438-01) to check the clearance. The spring scale, attached to the proper feeler gage, is used to measure the force required to withdraw the feeler gage in pounds.

NOTE:
Select a feeler gage with a thickness that will require a pull of six pounds to remove. The clearance will be 0.03 mm (0.001 in.) greater than the thickness of the feeler gage used, i.e., a 0.10 mm (0.004 in.) feeler gage will indicate a clearance of 0.13 mm (0.005 in.) when it is withdrawn with a pull of six pounds. The feeler gage must be perfectly flat and free of nicks and bends.

4. If any bind occurs between the piston and the liner, examine the piston and liner for burrs.
   [a] If burred, remove burrs with a fine hone (a flat one is preferable), and recheck the clearance.
   [b] If not burred, continue checking clearance.

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

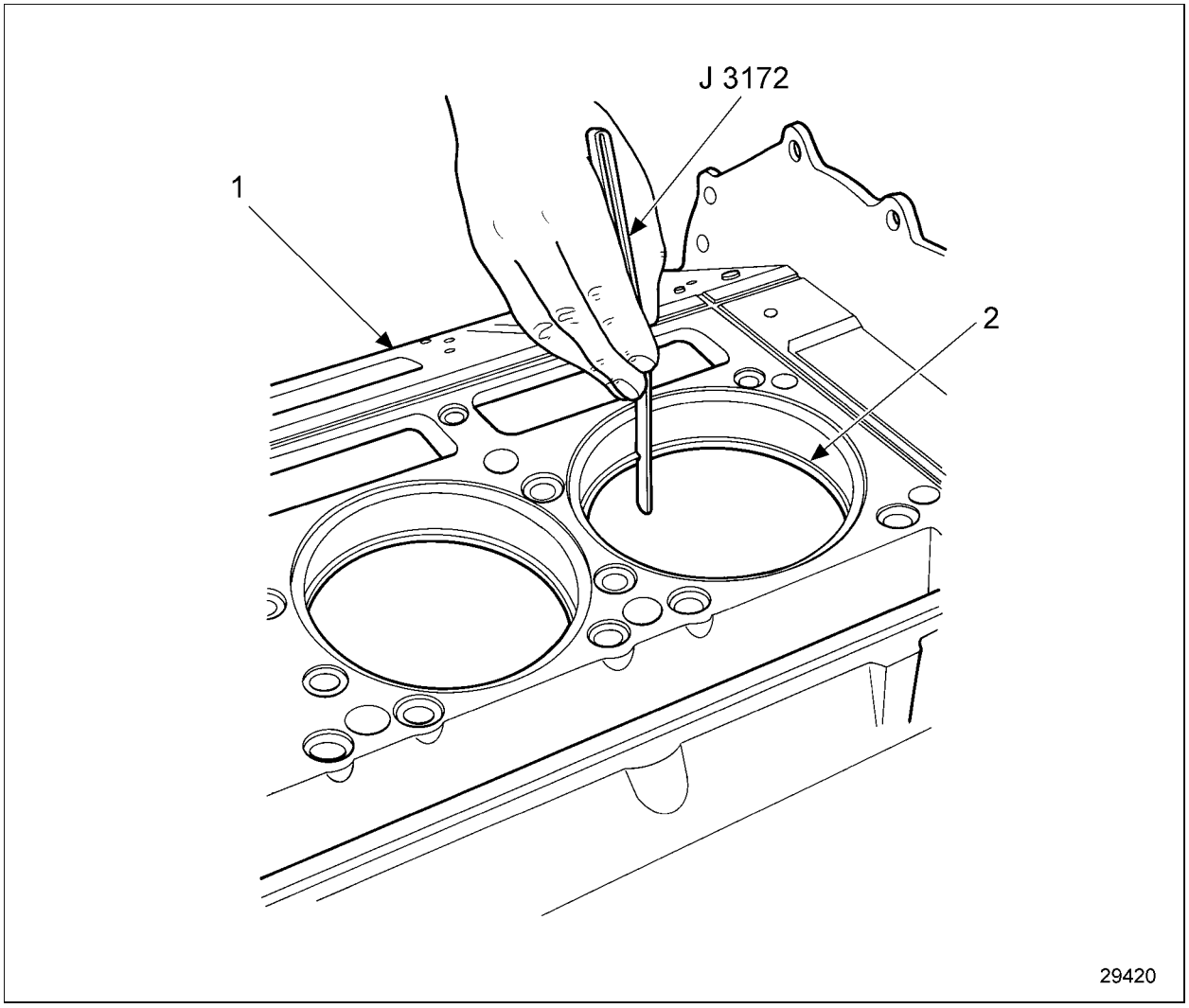
NOTE:
Current specifications may not be available at the time of publication. Refer to your local distributor, or Detroit Diesel Parts Technical for additional information.

5. Insert one ring at a time inside the cylinder liner and far enough down to be within the normal area of ring travel.
6. Use a piston skirt to push the ring down to ensure it is parallel with the top of the liner.

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7. Measure the ring gap with a feeler gage. See Figure 1-299.

NOTE:
Listed in Table 1-34 are ring gap specifications. Current specifications may not be available at the time of publication. Refer to your local distributor, or Detroit Diesel Parts Technical for additional information.



1. Cylinder Block
2. Piston Ring

Figure 1-299 Measuring Piston Ring Gap

8. If the gap on a compression ring is insufficient, file or stone both ends of the ring so the cutting action is from the outer surface to the inner surface.

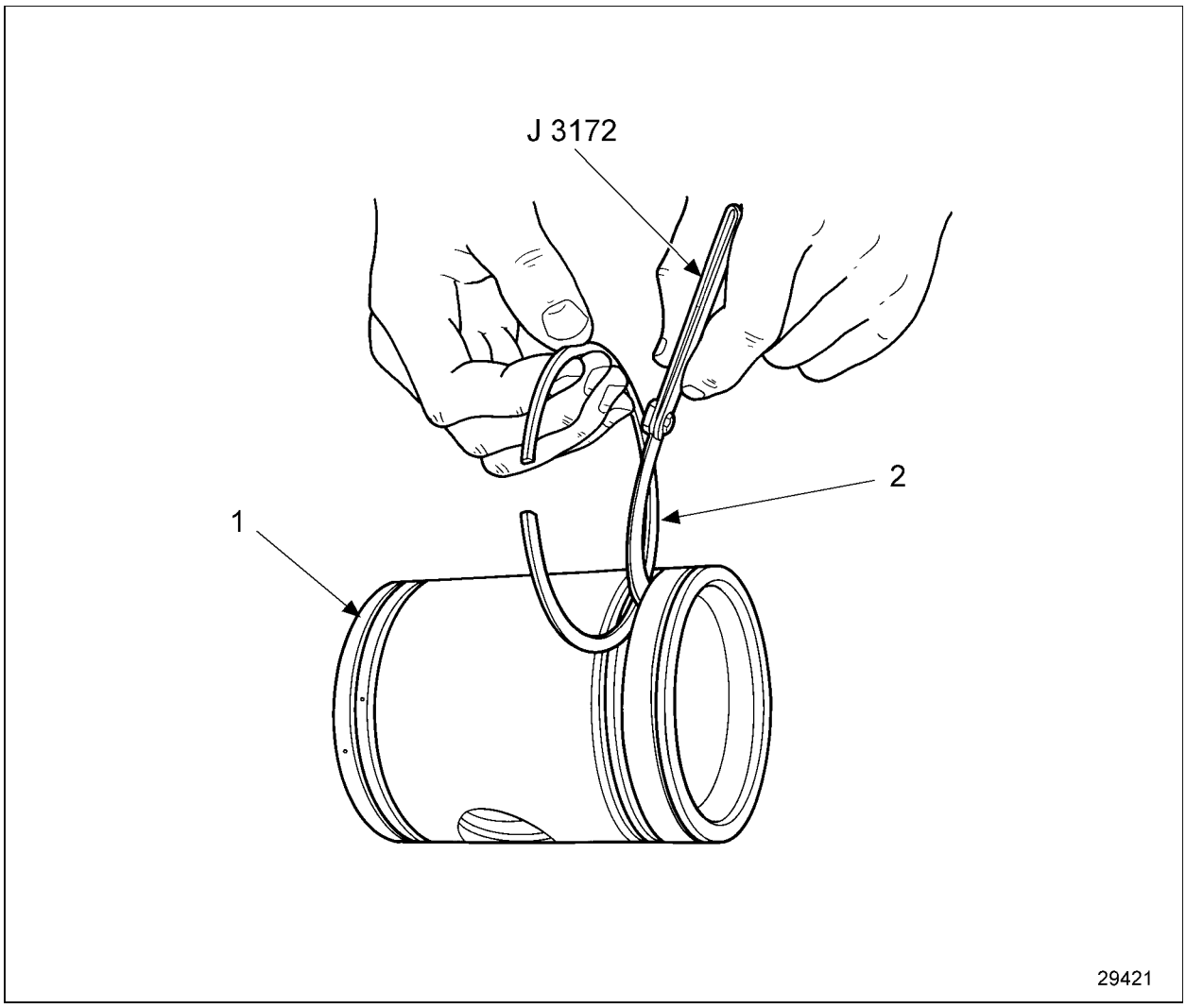
NOTE:
This will prevent the chrome plate on the ring from chipping or peeling. The ring ends must remain square and the chamfer on the outer edge must be approximately 0.38 mm (0.015 in.).

9. Check the ring side clearance. See Figure 1-300. Refer to section ADDITIONAL INFORMATION and listed in Table 1-34 for ring side clearances.

NOTE:
Current specifications may not be available at the time of publication. Refer to your local distributor, or Detroit Diesel Parts Technical for additional information.

[a] If the ring side clearance is not within specification, replace.

[b] If the ring side clearance is within specification, install the piston and piston ring.



1. Piston Assembly
2. Piston Ring

Figure 1-300 Measuring Piston Side Clearance

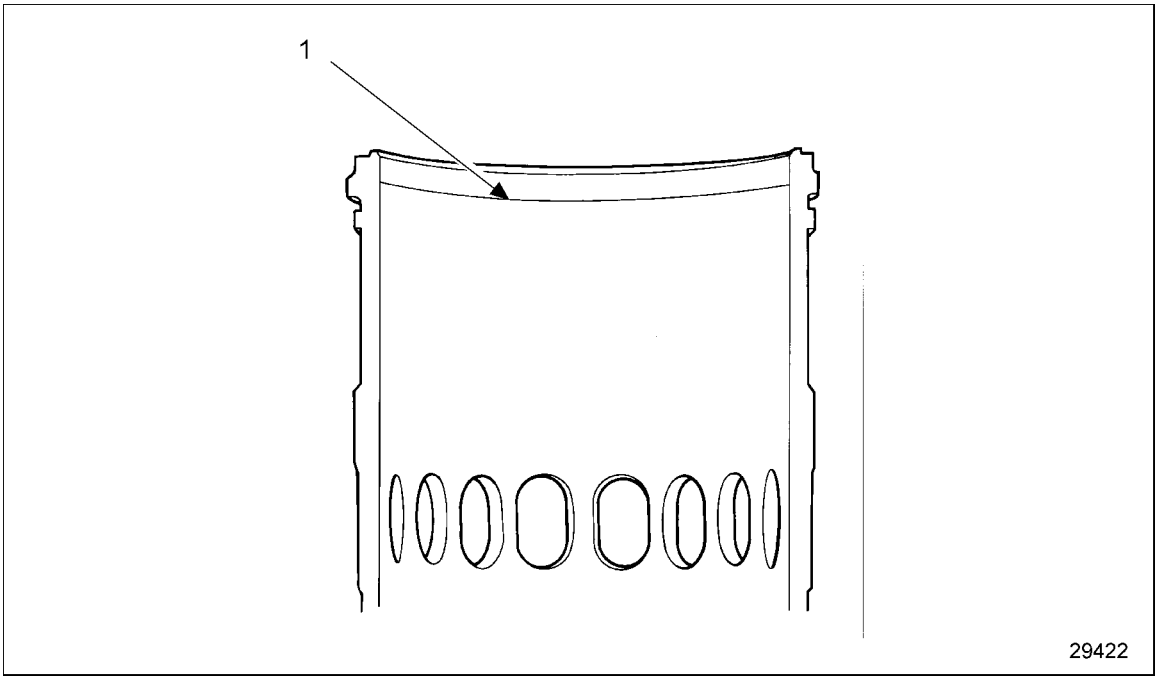
Hone The Cylinder Liner

Hone a used cylinder liner as follows:

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

Hone a used cylinder liner to break glaze resulting from piston ring rubbing after long operation periods and to remove the ridge formed at the top by the piston ring travel. See Figure 1-301.



1. Ridge

Figure 1-301 Cylinder Liner Ridge to Wear

1. Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture).

NOTE:
If it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

2. Work the hone J 5902-01, equipped with 120 grit stones J 5902-14 (from set J 5902-01), up and down (at 300-400 RPM.) the full length of the liner a few times in a criss-cross pattern to produce hone marks on a 45 degree axis.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Remove the liner from the fixture, and clean thoroughly 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.

4. Dry the liner with compressed air.
5. Inspect the entire surface for burrs.

NOTE:
After honing, the liner must conform to the same limits on taper and out-of-round as a new liner and the piston-to-liner clearance must be within the specified limits. For specifications listed in Table 1-37.

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 that 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.

Table of Specifications, New Part 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 92 Engine:

1. Cylinder block is listed in Table 1-24.
2. Cylinder heads are listed in Table 1-25.
3. Rocker arms and shafts are listed in Table 1-26.
4. Cam followers are listed in Table 1-27.
5. Exhaust valve seat inserts are listed in Table 1-28.

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6. Exhaust valves are listed in Table 1-29.
7. Valve guides are listed in Table 1-30.
8. Valve bridge guides are listed in Table 1-31.
9. Main bearings are listed in Table 1-32.
10. Crankshaft is listed in Table 1-33.
11. Cross-head piston and rings are listed in Table 1-34.
12. Cross-head piston pins are listed in Table 1-35.
13. Connecting rod bearings are listed in Table 1-36.
14. Cylinder liners are listed in Table 1-37.
15. Camshafts are listed in Table 1-38.
16. Camshaft bearings are listed in Table 1-39.
17. Camshaft gears are listed in Table 1-40.
18. Idler gear is listed in Table 1-41.
19. Crankshaft timing gear is listed in Table 1-42.
20. Blower drive step-up gear (non-turbo 2.6:1) is listed in Table 1-43.
21. Blower drive step-up gear (turbo 2.1:1) is listed in Table 1-44.
22. Blower drive step-up gear is listed in Table 1-45.
23. Left-bank accessory drive gear is listed in Table 1-46.

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Specifications for the cylinder block are listed in Table 1-24.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Block Bore:			
Diameter (Upper Pilot)-(A)	136.13 mm (5.3595 in.)	136.19 mm (5.3620 in.)	136.23 mm (5.3635 in.)
Diameter (Lower Two Seal Ring Lands)-(B)	135.55 mm (5.3365 in.)	135.60 mm (5.3385 in.)	135.62 mm (5.3395 in.)
Diameter (Water Jacket)-(C)	132.49 mm (5.2160 in.)	132.52 mm (5.2175 in.)	132.55 mm (5.2185 in.)
Diameter (Water Jacket)-(D)	132.49 mm (5.2160 in.)	132.54 mm (5.2180 in.)	132.55 mm (5.2185 in.)
Out-of-Round	-	0.03 mm (0.0010 in.)	-
Taper (Lower Bore)	-	0.03 mm (0.0010 in.)	-
Cylinder Liner Counterbore:			
Diameter	141.10 mm (5.5550 in.)	141.22 mm (5.5600 in.)	-
Depth (Standard)	12.08 mm (0.4755 in.)	12.12 mm (0.4770 in.)	-
Depth (.015 in. Deeper)	12.46 mm (0.4905 in.)	12.50 mm (0.4920 in.)	-
Main Bearing Bore:			
Inside Diameter (Vertical Axis)	122.22 mm (4.8120 in.)	122.25 mm (4.8130 in.)	-
Saddle-to-Main Bearing Cap	-	-	0.05 mm (0.0020 in.)
Top Surface of Block:			
Centerline of Main Bearing Bore to Top of Block	87.39 mm (16.1840 in.)	411.20 mm (16.1890 in.)	-
Flatness-Transverse (All)	-	-	0.08 mm (0.0030 in.)
Flatness-Longitudinal (6V and 12V)	-	-	0.15 mm (0.0060 in.)
Flatness-Longitudinal (8V and 16V)	-	-	0.18 mm (0.0070 in.)
Depth of Counterbores (Top Surface):			
Cylinder Head Seal Strip Groove	2.46 mm (0.0970 in.)	2.72 mm (0.1070 in.)	-
Combination Water and Oil Holes	2.13 mm (0.0840 in.)	2.26 mm (0.0890 in.)	-

Table 1-24 Cylinder Block

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Specifications for the cylinder head are listed in Table 1-25.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Flatness-Transverse	-	-	0.10 mm (0.0040 in.)
Flatness-Longitudinal (6V and 12V)	-	-	0.30 mm (0.0055 in.)
Flatness-Longitudinal (8V and 16V)	-	-	0.20 mm (0.0080 in.)
Surface Finish (with 1 mm Diameter Stylus)	-	90AA	-
Distance Between Top Deck and Firedeck	90.32 mm (3.5560 in.)	90.63 mm (3.5680 in.)	89.81 mm (3.5360 in.)
Water Nozzles (Former)	0.10 mm (0.0040 in. Recessed)	Flush	-
Water Nozzles (Current)	0.38 mm (0.0150 in. Recessed)	Flush	-
Cam Follower Bores	26.97 mm (1.0620 in.)	27.00 mm (1.0630 in.)	27.05 mm (1.0650 in.)
Exhaust Valve Insert Counterbore:			
Diameter	36.58 mm (1.4400 in.)	36.60 mm (1.4410 in.)	-
Depth	8.62 mm (0.3395 in.)	8.90 mm (0.3505 in.)	-

Table 1-25 Cylinder Heads

Specifications for the rocker arms and shafts are listed in Table 1-26.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Rocker Shaft Diameter	22.19 mm (0.8735 in.)	22.20 mm (0.8740 in.)	-
Rocker Arm Bushing Diameter (Inside)	22.23 mm (0.8750 in.)	22.25 mm (0.8760 in.)	-
Clearance (Shaft-to-Bushing)	0.03 mm (0.0010 in.)	0.06 mm (0.0025 in.)	0.10 mm (0.0040 in.)

Table 1-26 Rocker Arms and Shafts

Specifications for the cam followers are listed in Table 1-27.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Cam Follower Diameter	26.92 mm (1.0600 in.)	26.95 mm (1.0610 in.)	-
Clearance Follower-to-Head	0.03 mm (0.0010 in.)	0.08 mm (0.0030 in.)	0.15 mm (0.0060 in.)
Rollers and Pins:			
Clearance Pin-to-Bushing	0.03 mm (0.0013 in.)	0.05 mm (0.0021 in.)	0.25 mm (0.010 in. Horizontal)
Side Clearance Roller-to-Follower	0.28 mm (0.0110 in.)	0.58 mm (0.0230 in.)	0.58 mm (0.0230 in.)

Table 1-27 Cam Followers

Specifications for the exhaust valve seat inserts are listed in Table 1-28.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter	36.61 mm (1.4415 in.)	3.46 mm (1.4425 in.)	-
Seat Width	1.19 mm (0.0470 in.)	1.96 mm (0.0770 in.)	-
Valve Seat Run-out	-	0.05 mm (0.0020 in.)	0.05 mm (0.0020 in.)

Table 1-28 Exhaust Valve Seat Inserts

Specifications for the exhaust valves are listed in Table 1-29.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	7.87 mm (0.3100 in.)	7.89 mm (0.3108 in.)	7.85 mm (0.3090 in.)
Valve Head-to-Cylinder Head 30 Degrees	0.58 mm (0.023 in. Recess)	0.15 mm (0.006 Protrude)	0.97 mm (0.038 in.)

Table 1-29 Exhaust Valves

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Specifications for the valve guides are listed in Table 1-30.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Height Above Cylinder Head	17.02 mm (0.6700 in.)	18.03 mm (0.7100 in.)	-
Diameter-Inside	7.94 mm (0.3125 in.)	7.87 mm (0.3135 in.)	7.98 mm (0.3140 in.)
Clearance Valve-to-Guide	0.04 mm (0.0017 in.)	0.89 mm (0.0035 in.)	0.13 mm (0.0050 in.)

Table 1-30 Valve Guides

Specifications for the valve bridge guides are listed in Table 1-31.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Height Above Cylinder Head	51.82 mm (2.0400 in.)	51.82 mm (2.0400 in.)	-

Table 1-31 Valve Bridge Guides

Specifications for the main bearings are listed in Table 1-32.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter (Vertical Axis)	114.34 mm (4.5016 in.)	114.40 mm (4.5040 in.)	-
Bearing-to-Journal Clearance	0.04 mm (0.0014 in.)	0.14 mm (0.0055 in.)	0.14 mm (0.0055 in.)
Bearing Thickness 90 Degrees From Parting Line	3.92 mm (0.1545 in.)	3.94 mm (0.1552 in.)	-

Table 1-32 Main Bearings

Specifications for the crankshaft are listed in Table 1-33.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Journal Diameter-Main Bearing	114.26 mm (4.4985 in.)	114.31 mm (4.5002 in.)	-
Journal Diameter-Connecting Rod Bearing	76.16 mm (2.9985 in.)	76.21 mm (3.0002 in.)	-
Journal Out-of -Round	-	0.01 mm (0.0005 in.)	0.01 mm (0.0005 in.)
Journal Taper:			
Main Bearing	-	0.01 mm (0.0004 in.)	0.01 mm (0.0004 in.)
Connecting Rod (Full Length)	-	0.02 mm (0.0008 in.)	-

Connecting Rod (Half Length)	-	0.01 mm (0.0004 in.)	-
***Run-out on Journals-Total Indicator Reading: 6V (Mounted on Number 1 and 4 Journals):**			
At Number 2 and Number 3 Journals	-	0.05 mm (0.0020 in.)	-
8V (Mounted on Number 1 and 5 Journals):			
At Number 2 and Number 4 Journals	-	0.05 mm (0.0020 in.)	-
At Number 3 Journal	-	0.10 mm (0.0040 in.)	-
12V (Mounted on Number 1 and 8 Journals):			
At Number 2 and Number 7 Journals	-	0.05 mm (0.0020 in.)	-
At Number 3 and Number 6 Journals	-	0.10 mm (0.0040 in.)	-
At Number 4 and Number 5 Journals	-	0.15 mm (0.0060 in.)	-
16V (Mounted on Number 1 and 10 Journals):			
At Number 2 and Number 9 Journals	-	0.05 mm (0.0020 in.)	-
At Number 3 and Number 8 Journals	-	0.10 mm (0.0040 in.)	-
At Number 4 and Number 7 Journals	-	0.15 mm (0.0060 in.)	-
At Number 5 and Number 6 Journals	-	0.20 mm (0.0080 in.)	-
Thrust Washer Thickness	3.02 mm (0.1190 in.)	3.10 mm (0.1220 in.)	-
End Play (End Thrust Clearance)	0.10 mm (0.0040 in.)	0.28 mm (0.0110 in.)	0.46 mm (0.0180 in.)

* Run-out tolerance given for guidance when regrinding crankshaft. When run-out on adjacent journals is in opposite direction, the sum must not exceed 0.08 mm (0.003 in.) total indicator reading. When run-out on adjacent journals is in the same direction, the difference must not exceed 0.08 mm (0.003 in.) total indicator reading. When high spots of run-out on adjacent journals are at right angles to each other, the sum must not exceed 0.10 mm (0.004 in.) total indicator reading, or 0.05 mm (0.002 in.) on each journal.

Table 1-33 Crankshaft

Specifications for the cross-head piston and rings are listed in Table 1-34.

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Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Piston Crown Saddle-to-Crown Distance:			
NA Piston (19:1 Compression Ratio)	68.64 mm (2.7025 in.)	68.82 mm (2.7095 in.)	-
T Piston (17:1 Compression Ratio)	68.64 mm (2.7025 in.)	68.82 mm (2.7095 in.)	-
Diameter:			
At Top	122.18 mm (4.8104 in.)	122.26 mm (4.8134 in.)	-
Below Both Compression Rings	122.61 mm (4.8273 in.)	122.69 mm (4.8303 in.)	-
Above and Below Seal Ring Groove	113.41 mm (4.4650 in.)	113.67 mm (4.4750 in.)	-
Above and Below Bearing Saddle	82.19 mm (3.2360 in.)	82.22 mm (3.2370 in.)	-
Compression Rings:			
Gap (Top-Fire Ring)	0.64 mm (0.0250 in.)	1.14 mm (0.0450 in.)	1.52 mm (0.0600 in.)
Gap (Number 2 and 3)	0.64 mm (0.0250 in.)	1.14 mm (0.0450 in.)	1.52 mm (0.0600 in.)
Clearance Ring-to-Groove:			
* Top (Keystone Fire Ring)	0.03 mm (0.0010 in.)	0.13 mm (0.0050 in.)	0.18 mm (0.0070 in.)
Number 2 (Rectangular Section)	0.25 mm (0.0100 in.)	0.33 mm (0.0130 in.)	0.56 mm (0.0220 in.)
Number 3 (Rectangular Section)	0.10 mm (0.0040 in.)	0.18 mm (0.0070 in.)	0.33 mm (0.0130 in.)
Seal Ring:			
Gap (In Skirt Counterbore)	0.05 mm (0.0020 in.)	0.43 mm (0.0170 in.)	-
Clearance	0.01 mm (0.0005 in.)	0.08 mm (0.0030 in.)	0.10 mm (0.0040 in.)
Piston Skirt:			
† Diameter (Includes Tin)	122.77 mm (4.8333 in.)	122.84 mm (4.8361 in.)	-
Clearance Skirt-to-Liner	0.07 mm (0.0029 in.)	0.21 mm (0.0082 in.)	0.30 mm (0.0120 in.)
Seal Ring Bore	114.30 mm (4.5000 in.)	114.38 mm (4.5030 in.)	-
Piston Pin Bore	38.16 mm (1.5025 in.)	38.19 mm (1.5035 in.)	38.20 mm (1.5040 in.)
Oil Control Rings:			
Gap (Two Rings in Lower Groove)	0.25 mm (0.0100 in.)	0.64 mm (0.0250 in.)	1.09 mm (0.0430 in.)
Gap (Two Rings in Upper Groove-Turbo)	0.18 mm (0.0070 in.)	0.43 mm (0.0170 in.)	0.89 mm (0.0350 in.)

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Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Gap (Two Rings in Upper Groove-Non-Turbo)	0.25 mm (0.0100 in.)	0.64 mm (0.0250 in.)	1.09 mm (0.0430 in.)
Clearance	0.04 mm (0.0015 in.)	0.14 mm (0.0055 in.)	0.20 mm (0.0080 in.)

Note: Current specifications may not be available at the time of publication. Refer to your local distributor, or Detroit Diesel Parts Technical for additional information.

* Measured with keystone fire ring flush with outside diameter of piston crown.

† Diameter above and below the piston pin may be 122.63 mm (4.8280 in.)

Table 1-34 Cross-Head Piston and Rings

Specifications for the cross-head piston pins are listed in Table 1-35.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Diameter	38.09 mm (1.4996 in.)	38.10 mm (1.5000 in.)	38.05 mm (1.4980 in.)
Slipper Bearing (Bushing):			
Thickness at Center	2.21 mm (0.0870 in.)	2.24 mm (0.0880 in.)	2.18 mm (0.0860 in.)
Clearance (Edge of Bushing-to-Groove in Piston)	0.01 mm (0.0005 in.)	0.27 mm (0.0105 in.)	0.30 mm (0.0120 in.)

Table 1-35 Cross-Head Piston Pins

Specifications for the connecting rod bearings are listed in Table 1-36.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter (Vertical Axis)	76.21 mm (3.0005 in.)	76.29 mm (3.0035 in.)	-
Bearing-to-Journal Clearance	0.02 mm (0.0008 in.)	0.11 mm (0.0045 in.)	0.11 mm (0.0045 in.)
Bearing Thickness 90 Degrees From Parting Line	3.15 mm (0.1240 in.)	3.16 mm (0.1245 in.)	-

Table 1-36 Connecting Rod Bearings

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Specifications for the cylinder liners are listed in Table 1-37.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter (Upper Surface)	136.09 mm (5.3577 in.)	136.13 mm (5.3595 in.)	-
Outside Diameter (Seal Ring Surface)	135.50 mm (5.3347 in.)	135.55 mm (5.3365 in.)	-
Outside Diameter (Lower Surface)	132.44 mm (5.2142 in.)	132.49 mm (5.2160 in.)	-
Inside Diameter	122.91 mm (4.8390 in.)	122.97 mm (4.8415 in.)	-
Out-of-Round Inside Diameter	-	0.05 mm (0.0020 in.)	0.06 mm (0.0025 in.)
Taper Inside Diameter	-	0.04 mm (0.0015 in.)	0.06 mm (0.0025 in.)
Depth of Flange BELOW Block	1.06 mm (0.0418 in.)	1.07 mm (0.0482 in.)	-
Variation in Depth Between Adjacent Liners	-	0.04 mm (0.0015 in.)	-

Table 1-37 Cylinder Liners

Specifications for the camshafts are listed in Table 1-38.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Diameter (at Bearing Journals):			
Front and Rear (6V and 12V engines)	38.02 mm (1.4970 in.)	38.04 mm (1.4975 in.)	-
Front and Rear (8V and 16V engines)	38.00 mm (1.4960 in.)	38.01 mm (1.4965 in.)	-
Center and Intermediate	38.05 mm (1.4980 in.)	38.06 mm (1.4985 in.)	-
Run-out at Center Bearing (When Mounted on End Bearings)	-	0.05 mm (0.0020 in.)	-
End Thrust	0.08 mm (0.0030 in.)	0.38 mm (0.0150 in.)	0.46 mm (0.0180 in.)
Thrust Washer Thickness	3.02 mm (0.1190 in.)	3.10 mm (0.1220 in.)	-

Table 1-38 Camshafts

Specifications for the camshaft bearings are listed in Table 1-39.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter:			
Front and Rear	38.10 mm (1.5000 in.)	38.13 mm (1.5010 in.)	-
Center and Intermediate	38.13 mm (1.5010 in.)	38.18 mm (1.5030 in.)	-
Clearance Bearing-to-Shaft:			
Front and Rear (6V, 12V and 16V engines)	0.06 mm (0.0025 in.)	0.10 mm (0.0040 in.)	0.15 mm (0.0060 in.)
Front and Rear (8V engines)	0.09 mm (0.0035 in.)	0.13 mm (0.0050 in.)	0.15 mm (0.0060 in.)
Center and Intermediate	0.06 mm (0.0025 in.)	0.13 mm (0.0050 in.)	0.23 mm (0.0090 in.)
Outside Diameter:			
Front and Rear	55.56 mm (2.1875 in.)	11.82 mm (2.1880 in.)	-
Center and Intermediate	55.47 mm (2.1840 in.)	55.52 mm (2.1860 in.)	-
Diameter of Cylinder Block Bore	54.69 mm	(2.1889 in.)	-
Clearance Bearings-to-Block:			
Front and Rear	0.01 mm (0.0005 in. Press)	0.04 mm (0.0014 in. Loose)	-
Intermediate	0.04 mm (0.0015 in.)	0.11 mm (0.0045 in.)	-

Table 1-39 Camshaft Bearings

Specifications for the camshaft gears are listed in Table 1-40.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter	30.14 mm (1.1865 in.)	2.85 mm (1.1875 in.)	-
Clearance Gear-to-Shaft	0.04 mm (0.0015 in. Press)	-	-
Backlash	0.05 mm (.00020 in.)	0.20 mm (0.0080 in.)	0.25 mm (0.0100 in.)

Table 1-40 Camshaft Gears

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Specifications for the idler gears are listed in Table 1-41.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Backlash	0.05 mm (0.0020 in.)	0.20 mm (0.0080 in.)	0.25 mm (0.0100 in.)
Pre-Load-Variation on Pull 2lbs. 11oz.	1/2 lb.	4 lb.	-

Table 1-41 Idler Gear

Specifications for the crankshaft timing gears are listed in Table 1-42.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter	133.32 mm (5.2490 in.)	133.38 mm (5.2510 in.)	-
Clearance Gear-to-Shaft	0.03 mm (0.001 in. Press)	0.03 mm (0.001 in. Loose)	-
Backlash	0.05 mm (0.0020 in.)	0.20 mm (0.0080 in.)	0.25 mm (0.0100 in.)

Table 1-42 Crankshaft Timing Gears

Specifications for the blower drive step-up gear (non-turbo 2.6:1) are listed in Table 1-43.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter (Support Bushing)	46.92 mm (1.8770 in.)	47.70 mm (1.8780 in.)	-
Hub Diameter (AT Bearing)	47.61 mm (1.8745 in.)	47.64 mm (1.8755 in.)	-
Hub-to-Support Bushing Clearance	0.04 mm (0.0015 in.)	0.09 mm (0.0035 in.)	-
Thrust Washer Thickness	0.64 mm (0.1190 in.)	5.33 mm (0.1210 in.)	-
End Thrust	0.08 mm (0.0030 in.)	17.78 mm (0.0170 in.)	0.48 mm (0.0190 in.)

Table 1-43 Blower Drive Step-Up Gear (Non-Turbo 2.6:1 Ratio)

Specifications for the blower drive step-up gear (turbo 2.1:1) are listed in Table 1-44.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Backlash	0.05 mm (0.0020 in.)	0.20 mm (0.0080 in.)	0.25 mm (0.0100 in.)
Inside Diameter (Support Bushing)	40.65 mm (1.6260 in.)	40.65 mm (1.6260 in.)	-
Hub Diameter (at Bearing)	41.25 mm (1.6240 in.)	41.27 mm (1.6250 in.)	-
Hub-to-Support Bushing Clearance	0.03 mm (0.0010 in.)	0.06 mm (0.0025 in.)	0.13 mm (0.0050 in.)
Thrust Washer Thickness	5.97 mm (0.2350 in.)	6.22 mm (0.2450 in.)	-
Thrust Bearing Thickness	1.50 mm (0.0590 in.)	1.55 mm (0.0610 in.)	-
End Thrust	0.13 mm (0.0050 in.)	0.25 mm (0.0100 in.)	0.30 mm (0.0120 in.)

Table 1-44 Blower Drive Gear (Turbo 2.1:1 Ratio)

Specifications for the blower drive step-up gear are listed in Table 1-45.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Backlash	0.05 mm (0.0020 in.)	0.20 mm (0.0080 in.)	0.25 mm (0.0100 in.)

Table 1-45 Blower Drive Step-Up Gear

Specifications for the left-bank accessory drive gear are listed in Table 1-46.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Backlash	0.05 mm (0.0020 in.)	0.20 mm (0.0080 in.)	0.25 mm (0.0100 in.)
Inside Diameter (Support Bushing)	41.30 mm (1.6260 in.)	41.31 mm (1.6265 in.)	-
Hub Diameter (at Bearing)	41.25 mm (1.6240 in.)	41.27 mm (1.6250 in.)	-
Hub-to-Support Bushing Clearance	0.25 mm (0.0010 in.)	0.06 mm (0.0025 in.)	0.13 mm (0.0050 in.)
Thrust Washer Thickness	5.97 mm (0.2350 in.)	0.59 mm (0.2450 in.)	-
Thrust Bearing Thickness	1.50 mm (0.0590 in.)	1.55 mm (0.0610 in.)	-
End Thrust	0.13 mm (0.0050 in.)	0.25 mm (0.0100 in.)	0.30 mm (0.0120 in.)

Table 1-46 Left-Bank Accessory Drive Gear (2.1:1 Ratio)

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EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS

Listed in Table 1-47 are exceptions to standard fastener torque specifications supporting the Series 92 Engines.

Section	Fastener	Size	N·m	lb·ft	lb·in
Refer to section 1.4.8 Refer to step 16	Cam Follower Guide Bolt	1/4 in.-20	16-20	12-15	-
Refer to section 1.3.2 Refer to step 16	Injector Control Shaft Bracket Bolt	1/4 in.-20	14-16	10-12	-
Refer to section ADDITIONAL INFORMATION	Air Box Cover Bolt	5/16 in.-18	11-16	8-12	-
Refer to section 1.30.3 Refer to step 4	Blower Drive Gear Support-to-Thrust Collar Bolt	5/16 in.-18	22-28	16-21	-
Refer to section 3.11.3 Refer to step 8	Oil Pan Bolts (Lower Pan)	5/16 in.-18	14-16	10-12	-
Refer to section ADDITIONAL INFORMATION Refer to step 7	Exhaust Valve Bridge Adjusting Screw Locknut	5/16 in.-24	27-34	20-25	-
Refer to section 1.31.18 Refer to step 6	Idler Gear Bearing Retainer Bolts	5/16 in.-24	33-39	24-29	-
Refer to section 1.26.2 Refer to step 18	Camshaft End Bearing Bolts	3/8 in.-16	47-54	35-40	-
Refer to section 1.11.3 Refer to step 5	Engine Front Cover Bolts	3/8 in.-16	31-41	25-30	-
Refer to section 1.11.2 Refer to step 8	Engine Front Cover Bolts (16V)	3/8 in.-16	54-64	40-45	-
Refer to section 1.19.2 Refer to step 7	Flywheel Housing Bolts	3/8 in.-16	34-41	25-30	-
Refer to section 1.31.14 Refer to step 4	Front Accessory Drive Pulley Bolt	3/8 in.-16	34	25	-
Refer to section ADDITIONAL INFORMATION Refer to step 1	Front End Plate Bolt (Into Water Jacket Plug)	3/8 in.-16	27-34	20-25	-
Refer to section 1.19.3 Refer to step 11	Idler Gear Hub and Spacer Bolts (Hex Head)	3/8 in.-16	54-61	40-45	-
Refer to section 1.19.3 Refer to step 11	Idler Gear Hub and Spacer Bolts (Flange Hex Head)	3/8 in.-16	41-47	30-35	-
Refer to section ADDITIONAL INFORMATION Refer to step 7	Injector Clamp Bolts	3/8 in.-16	27-34	20-25	-
Refer to section 1.19.4 Refer to step 16	Oil Pan Bolts (Upper)	3/8 in.-16	20-27	15-20	-
Refer to section 1.3.3.3 Refer to step 2	Water Manifold Cover Bolt	3/8 in.-16	27-34	20-25	-

Section	Fastener	Size	N·m	lb·ft	lb·in
Refer to section 1.31.4 Refer to step 1	Accessory Drive Disc-to-Camshaft Gear Bolt	3/8 in.-24	61-68	45-50	-
Refer to section 1.31.4 Refer to step 1	Accessory Drive Hub-to-Camshaft Gear Bolt	3/8 in.-24	61-68	45-50	-
Refer to section 1.24	Balance Weight-to-Camshaft Gear Bolt	3/8 in.-24	20-24	15-18	-
Refer to section 1.30.3 Refer to step 2	Blower Drive Gear Hub-to-Spring Plate Bolt	3/8 in.-24	54-61	40-45	-
Refer to section 1.19.3 Refer to step 6	Blower Drive Step-Up Gear Bolt	3/8 in.-24	68-81	50-60	-
Refer to section 1.30.5 Refer to step 3	Blower Drive Support Bolts and Nuts (T Engines)	3/8 in.-24	34-41	25-30	-
Refer to section 1.26.3 Refer to step 15	Camshaft Intermediate Bearing Lock Screw	3/8 in.-24	20-27	15-20	-
Refer to section 1.11.2 Refer to step 2	Engine Front Cover Bolts (16V-Threaded Into Plug Nuts)	3/8 in.-24	34-41	25-30	-
Refer to section 7.2.3	Exhaust Manifold Outlet Flange Nuts (Brass)	3/8 in.-24	27-34	20-25	-
Refer to section 1.19.2 Refer to step 9	Flywheel Housing Bolts (Threaded Into Plug Nuts)	3/8 in.-24	34-41	25-30	-
Refer to section 1.2.5	Flywheel Housing Cover (Small Cover) Stud Nut	3/8 in.-24	27-34	20-25	-
Refer to section 1.19.2 Refer to step 8	Flywheel Housing Cover (Small Hole) Bolt	3/8 in.-24	41-47	30-35	-
Refer to section 1.3.5 Refer to step 28	Fuel Pipe Nuts (Uncoated)	3/8 in.-24	18.3	-	160
Refer to section 1.3.5 Refer to step 28	Fuel Pipe Nuts (Endurion)	3/8 in.-24	14.69	-	130
Refer to section 1.3.5 Refer to step 28	Fuel Pipe Nuts (Jacobs Brake)	3/8 in.-24	13.6	-	120
Refer to section 1.3.5 Refer to step 28	Fuel Pipe Nuts (Load Limiting Device)	3/8 in.-24	18.3	-	160
Refer to section 1.3.5 Refer to step 28	Fuel Pipe Nuts (DDEC Engines)	3/8 in.-24	15.6	-	145
Refer to section ADDITIONAL INFORMATION Refer to step 7	Injector Clamp Nut	3/8 in.-24	27-34	20-25	-
Refer to section 1.31.9 Refer to step 1	Left-Bank Accessory Drive Support Bolts and Nuts	3/8 in.-24	34-41	25-30	-
Refer to section 1.3.3.3 Refer to step 2	Water Manifold Cover Nuts	3/8 in.-24	27-34	20-25	-

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Section	Fastener	Size	N·m	lb·ft	lb·in
Refer to section 1.19.3 Refer to step 18	Flywheel Housing Cover (Large Hole)	7/16 in.-14	41-47	30-35	-
Refer to section 1.31	Generator Drive Bearing Retaining Bolt	7/16 in.-14	41-47	30-35	-
Refer to section 1.31	Generator Drive Oil Seal Retaining Bolt	7/16 in.-14	41-47	30-35	-
Refer to section 1.31	Rear Accessory Drive Pulley Bolt	7/16 in.-14	47	35	-
Refer to section 1.22.3 Refer to step 7	Connecting Rod Nut (Lubrite)	7/16 in.-20	81-95	60-70	-
Refer to section 1.20.4 Refer to step 7	Cross-Head Piston Pin-to-Connecting Rod Bolt	7/16 in.-20	75-81	55-60	-
Refer to section 1.3.3.3 Refer to step 2	Exhaust Manifold Nuts	7/16 in.-20	41-47	30-35	-
Refer to section 1.3.3.3 Refer to step 4	Fuel Manifold Connector Nuts	7/16 in.-20	41-47	30-35	-
Refer to section 1.14.2 Refer to step 4	Vibration Damper Hub Bolt (8V Engine)	7/16 in.-20	102-115	75-85	-
Refer to section 1.31.8 Refer to step 8	Alternator Drive Bearing Retaining Bolt	1/2 in.-13	41-47	30-35	-
Refer to section 1.31	Alternator Drive Oil Seal Retaining Bolt	1/2 in.-13	41-47	30-35	-
Refer to section 1.8.4.2 Refer to step 2	Crankshaft Front Cover and Trunnion Bolts (16V)	1/2 in.-13	122-136	90-100	-
Refer to section 1.7.2 Refer to step 19	Crankshaft Front Cover Bolts	1/2 in.-13	108-122	80-90	-
Refer to section 1.19.2 Refer to step 7	Flywheel Housing Bolts	1/2 in.-13	122-136	90-100	-
Refer to section 1.19.3 Refer to step 19	Flywheel Housing Cover (Large Hole) Bolt	1/2 in.-13	41-47	30-35	-
Refer to section 1.19.3 Refer to step 6	Idler Gear Hub and Dummy Hub Bolt	1/2 in.-13	108-122	80-90	-
Refer to section 1.4 Refer to step 24	* Rocker Shaft Bolts	1/2 in.-13	122-136	90-100	-
Refer to section 1.18	Engine Drive Shaft Flexible Coupling Bolt	1/2 in.-20	130-156	96-115	-
Refer to section 1.19.3 Refer to step 7	† Camshaft Gear Bolt (Right-Bank-300M)	9/16 in.-18	244-258	180-190	-
Refer to section 1.16.2 Refer to step 1	† Flywheel Bolts	9/16 in.-18	-	-	-
Refer to section 1.14	† Vibration Damper Bolt	9/16 in.-18	211-224	155-165	-

Section	Fastener	Size	N·m	lb·ft	lb·in
Refer to section 1.3.2 Refer to step 18	† Cylinder Head Bolts	11/16 in.-11	312-325	230-240	-
Refer to section 1.10.3 Refer to step 6	† Main Bearing Bolts (Assembly) (Captured Washer)	11/16 in.-11	312-325	230-240	-
Refer to section 1.7.6 Refer to step 10	† Main Bearing Bolts (Former)	11/16 in.-11	339-352	250-260	-
Refer to section 1.10.3 Refer to step 6	† Main Bearing Bolts (Bolting) (Captured Washer)	11/16 in.-11	312-325	230-240	-
Refer to section 1.7.6 Refer to step 11	† Main Bearing Bolts (Bolting) (Former)	11/16 in.-11	339-352	250-260	-
Refer to section 1.31	Accessory Drive Pulley Nut	3/4 in.-16	163-190	120-140	-
Refer to section 1.14.4 Refer to step 9	Crankshaft End Bolt	1/4 in.	393-421	290-310	-
Refer to section 1.2.2	Camshaft End Bolt	1 1/8 in.-18	407-441	300-325	-
Refer to section 1.30.4	Blower Drive Gear Hub Nut (T Engines)	1 7/16 in.-16	68-81	50-60	-
Refer to section 1.31	Left-Bank Accessory Drive Gear Nut	1 7/16 in.-16	68-81	50-60	-

* 102-115 N·m (75-85 lb·ft) torque on the two bolts attaching load limit or power control screw bracket (if used) to the rocker arm shaft bracket.

† Lubricate threads with International Compound No. 2, or equivalent.

Table 1-47 Exceptions to Standard Fastener Torque Specifications

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Special Plug Torque Specifications

Listed in Table 1-48 are special plug torque specifications supporting the Series 92 Engines.

Section	Fastener	* Plug Size	Assembly
Refer to section 1.1.4 Refer to step 2	Oil Gallery Plug	3/8 in. Dryseal PTF Thread	† Assemble Flush to 1.59 mm (0.0625 in.) Protrusion From Surface
Refer to section 1.3	Cylinder Head (Side)	3/8-16 in.	Assemble Flush to 1.59 mm (0.0625 in.) Protrusion From Surface
Refer to section 1.3	Cylinder Head (End)	3/4 in. Dryseal PTF-SAE Short	Flush to 3.18 mm (0.1250 in.) Recessed
Refer to section 1.1.2	Core Hole Plug (Air Box Floor)	2 1/2 in. -16	312-366 N·m (230-270 lb·ft) Torque
Refer to section 1.1.6 Refer to step 8	Oil Drain Plug (Nylon Washer)	18 mm	34-47 N·m (25-35 lb·ft) Torque

* Apply sealing compound to plugs used without gaskets or Teflon.

† After installation, a 1.2187 in. diameter rod inserted in oil line must pass inner face of plug.

Table 1-48 Special Plug Torque Specifications

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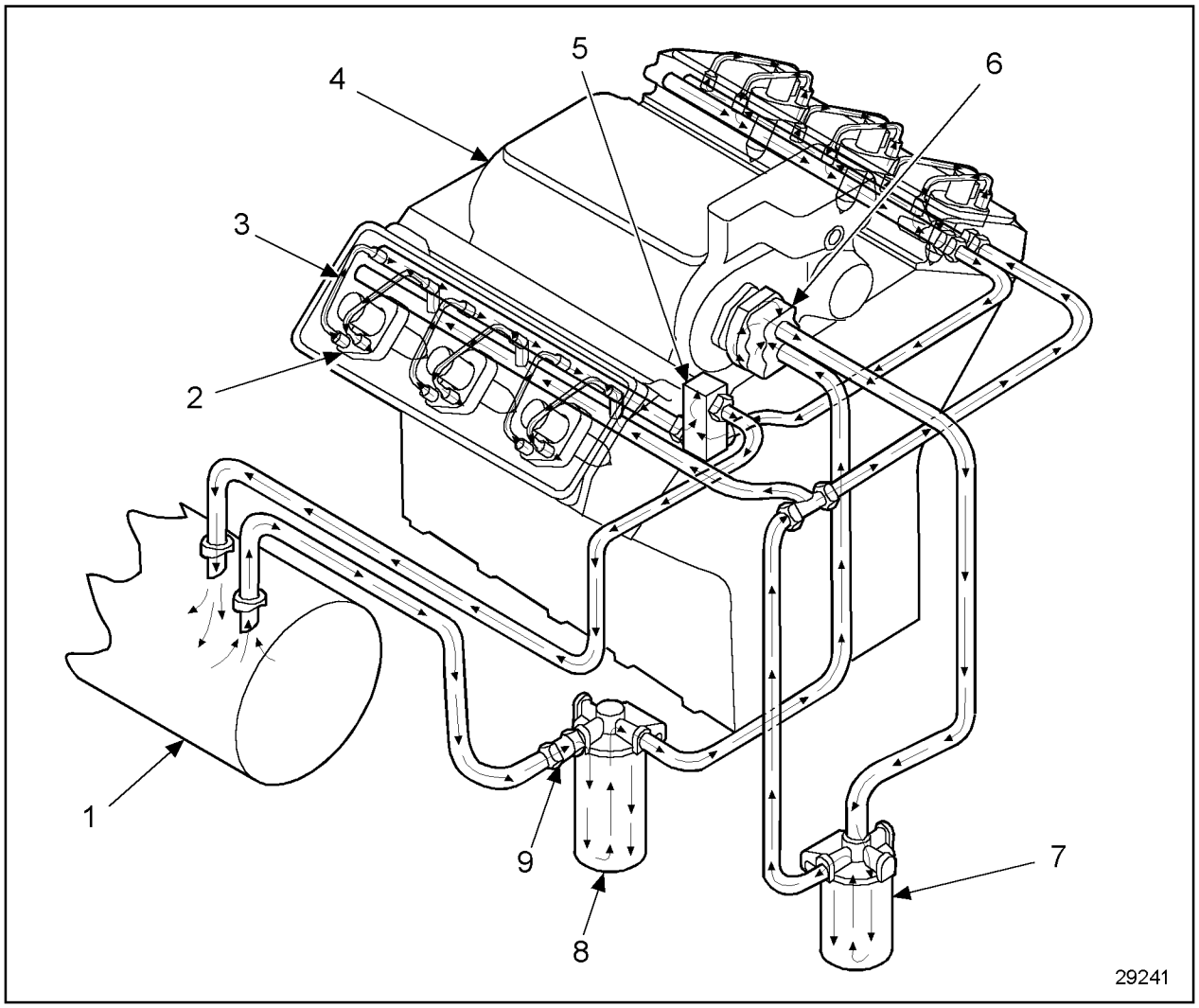
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2.1 FUEL SYSTEM

The fuel system includes the following components:

- ☐ MUI Fuel Injectors
- ☐ EUI Fuel Injectors
- ☐ Fuel Crossover Tubes (Inlet and Outlet)
- ☐ Fuel Manifolds (Integral with the Cylinder Head)
- ☐ Fuel Pump
- ☐ Fuel Strainer
- ☐ Fuel Filter
- ☐ Fuel Lines
- ☐ DDEC II
- ☐ DDEC III
- ☐ DDEC IV
- ☐ EUI Electrical Wiring Harness (Injector Harness)

Fuel is drawn from the supply tank through the fuel strainer, entering the fuel pump at the inlet side. See Figure 2-1.



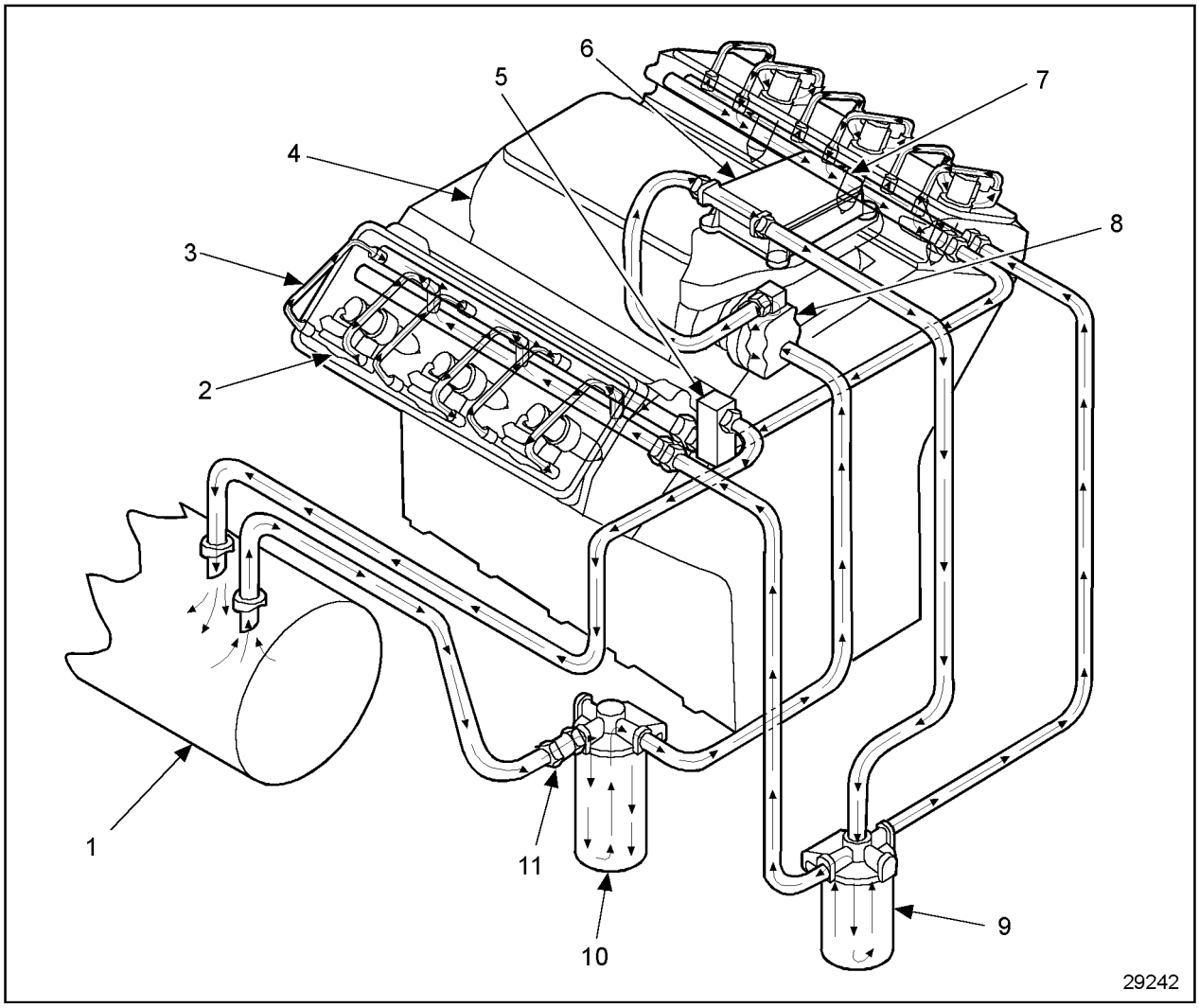
1. Fuel Tank
2. MUI Fuel Injector
3. Fuel Crossover Tubes
4. Blower
5. Restricted Tee Fitting
6. Fuel Pump
7. Fuel Filter
8. Fuel Strainer
9. Check Valve (When Required)

Figure 2-1 Schematic Diagram of a Typical Fuel System (Non-DDEC)

The fuel system for a MUI and DDEC engine are similar, except that DDEC units circulate fuel through a cold plate to cool the ECM. See Figure 2-2. It leaves the pump under pressure, and is forced through the fuel filter, through the inlet fuel manifold, through fuel crossover tubes, and into the inlet side of each fuel injector.

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On DDEC engines fuel is routed differently. Fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage), which are stamped in several places. This aids fuel line installation. See Figure 2-2.



1. Fuel Tank
2. EUI Fuel Injector
3. Fuel Crossover Tubes
4. Blower
5. Restricted Tee Fitting
6. DDEC Cold Plate
7. DDEC-ECM
8. Fuel Pump
9. Fuel Filter
10. Fuel Strainer
11. Check Valve (When Required)

Figure 2-2 Schematic Diagram of a Typical Fuel System (DDEC)

Surplus fuel returns from the outlet side of the injectors, to the fuel return manifold, and back to the supply tank.

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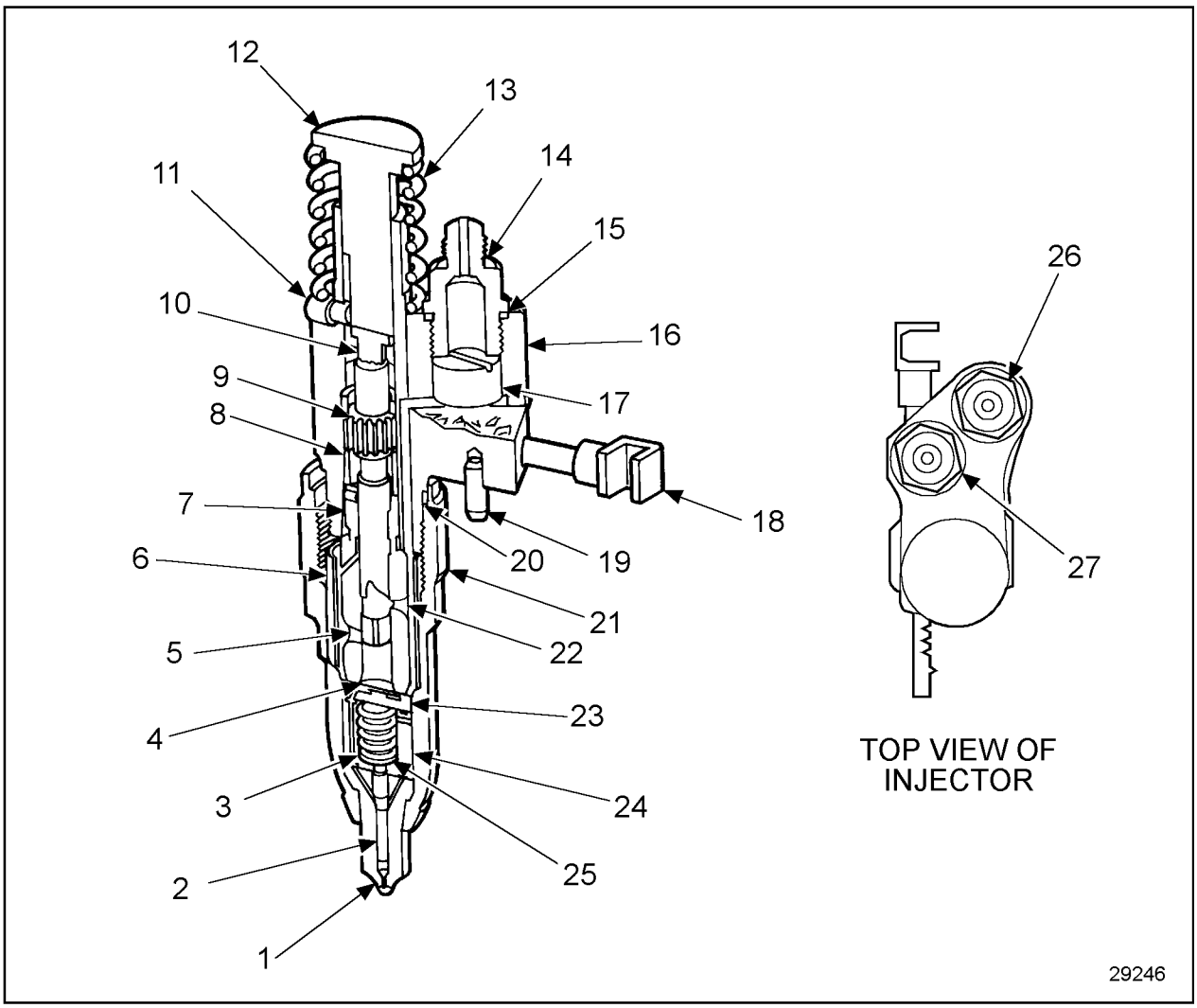
All engines are equipped with a restrictive fitting in the fuel outlet manifold on 6V and 8V engines (two of the cylinder heads of 12V and 16V engines) to maintain the fuel system pressure. Refer to section 11.6 for engine run-in procedures.

A check valve will be required for some applications. The check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back to the supply tank when the engine is shut down.

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2.2 MECHANICAL UNIT INJECTOR

The fuel injector is a lightweight, compact unit that enables quick and easy starting directly on diesel fuel. It permits the use of a simple open type combustion chamber. No high pressure fuel lines, air-fuel mixing, or vaporizing devices are required. See Figure 2-3.



1. Spray Tip
2. Needle Valve
3. Valve Spring
4. Check Valve
5. Lower Port
6. Spill Deflector
7. Bushing
8. Gear Retainer
9. Gear
15. Gasket
16. Injector Body
17. Filter
18. Control Rack
19. Dowel
20. Seal
21. Injector Nut
22. Upper Port
23. Check Valve Cage

10. Plunger
11. Stop Pin
12. Follower
13. Follower Spring
14. Filter Fitting
24. Spring Cage
25. Spring Seat
26. Outlet
27. Inlet

Figure 2-3 Cutaway of Mechanical Unit Injector

The fuel injector performs the following four functions:

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber
3. Meters and injects the required amount of fuel to maintain engine speed and load.
4. Creates the high pressure required for proper fuel injection.

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

Fuel injection metering and timing is accomplished by an upper and lower helix machined in the lower end of the injector plunger.

Fuel is metered from no load to full load by rotation of the plunger in the bushing. See Figure 2-4.

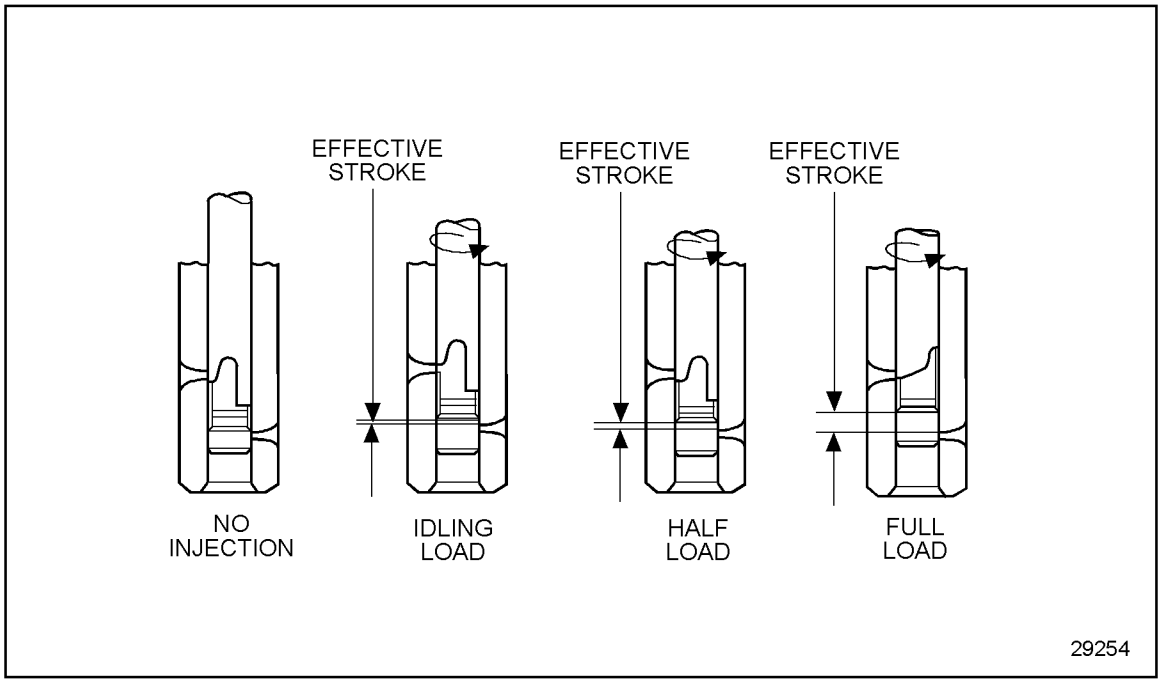


Figure 2-4 Fuel Metering from No Load to Full Load

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The phases of injector operation by vertical travel of the injector plunger are shown in the following illustration.

The continuous fuel flow through the injector prevents air pockets in the fuel system and cools injector parts subject to high combustion temperatures.

Engine power output is varied by the injector output (fuel output). Injector fuel output is varied by the effective stroke of the plunger and the flow rate of the spray tip.

NOTICE:
Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If different types of injectors are mixed in an engine, erratic operation will result, damaging the engine or the equipment it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes.

The governor, by means of a tube, controls the injector operation by actuating the injector rack. Each lever must be adjusted independently, thus permitting a uniform setting or fine tuning of all injector racks.

The fuel injector combines all parts necessary to provide complete and independent fuel injection at each cylinder.

Fuel, under low pressure, enters the injector at the inlet side through the fitting filter. From the filter, the fuel passes through a drilled passage into the supply chamber. The supply chamber is the area between the plunger bushing and the spill deflector and the area under the injector plunger within the bushing wall. The plunger operates up and down in the bushing. Fuel is supplied through the two funnel-shaped ports in the bushing wall.

The motion if the injector rocker arm is transmitted to the plunger by the follower. In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear that meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger. See Figure 2-5 and see Figure 2-6.

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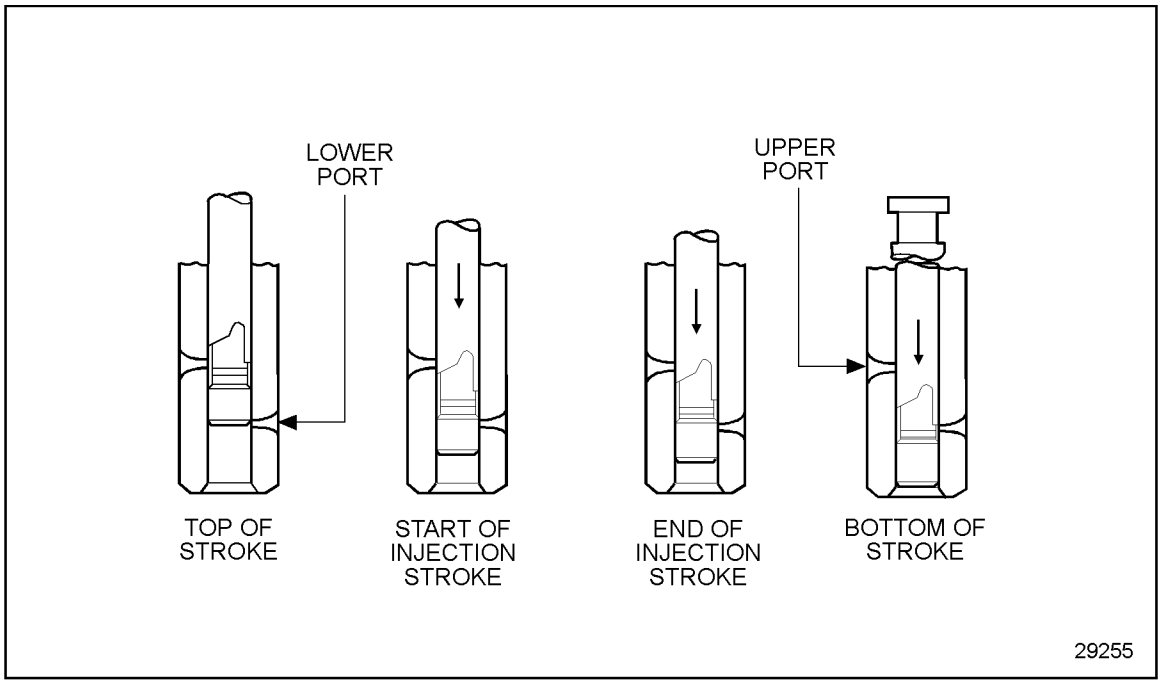
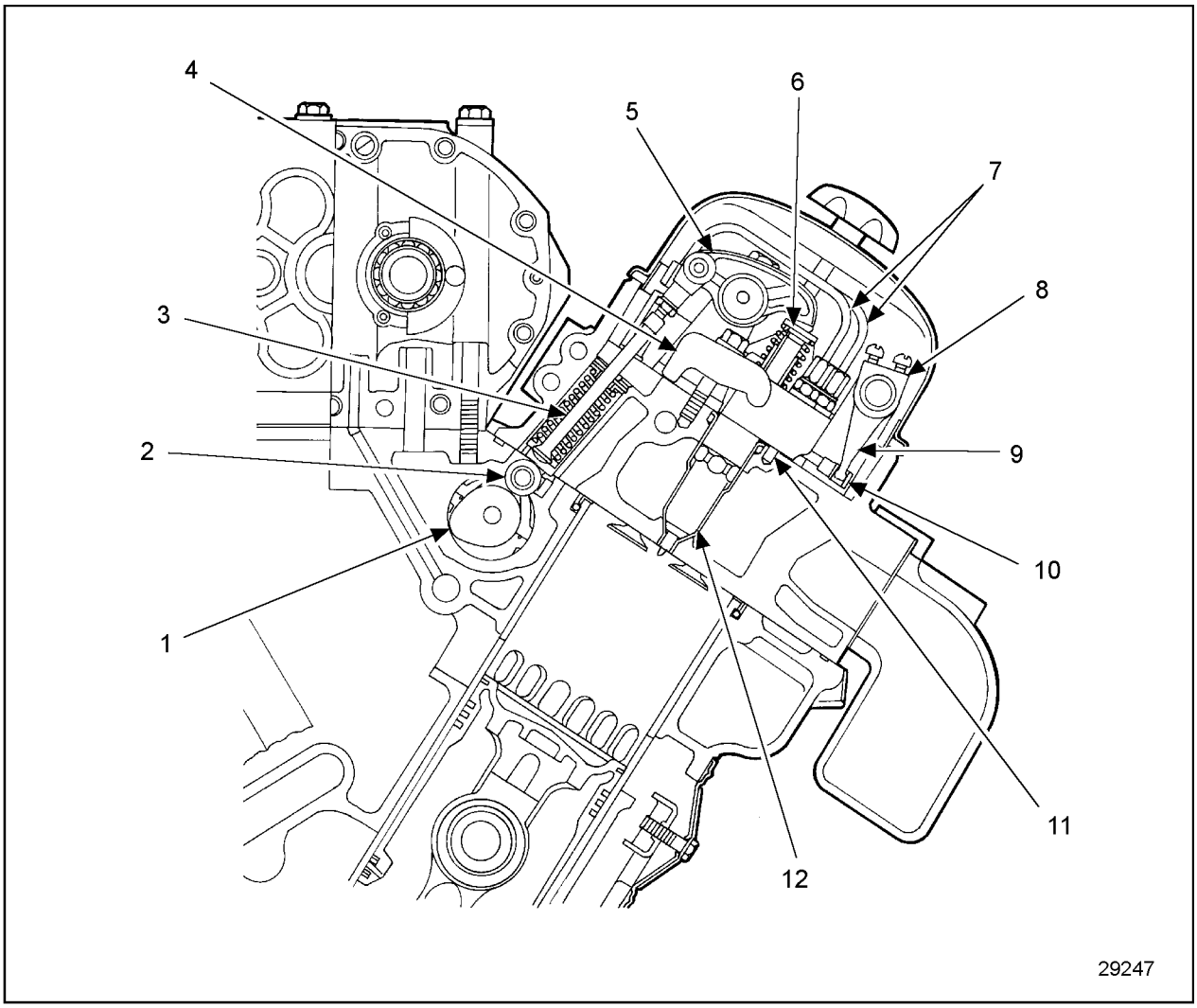


Figure 2-5 Phase of Injector Operation Through Vertical Travel of Plunger

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1. Camshaft
2. Cam Follower
3. Push Rod
4. Injector Clamp
5. Rocker Arm
6. Mechanical Unit Injector
7. Fuel Crossover Tubes
8. Control Tube
9. Rack Control Lever
10. Injector Control Rack
11. Dowel Pin
12. Injector Tube

Figure 2-6 Mechanical Unit Injector Mounting

As the plunger moves downward, under pressure of the injector rocker arm, some fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is obtained, it opens the flat check valve. The fuel in the check valve cage, spring cage, tip passages, and tip cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off its seat (beginning of injection), the fuel is forced through small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved, and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed-off of fuel by passing the needle pilot in the tip assembly.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of debris. The injector plunger is then returned to its original position by the injector follower spring.

On the return upward movement of the plunger, the high pressure within the cylinder and the bushing is again filled with fuel through the ports. The constant circulation of fresh, cool fuel through the injector renews the fuel supply in the chamber, helping cool the injector and effectively removing all traces of air that may otherwise accumulate in the system and interfere with accurate metering of the fuel.

Changing the position of the helices by rotating the plunger retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all fuel is forced back into the supply chamber and no fuel injection takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From the no injection position to full injection position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

Effective April, 1988, new fuel pipes (jumper lines), similar to those currently used on electronic unit injectors in DDEC engines, are now used on the mechanical unit injectors in Series 92 marine engines.

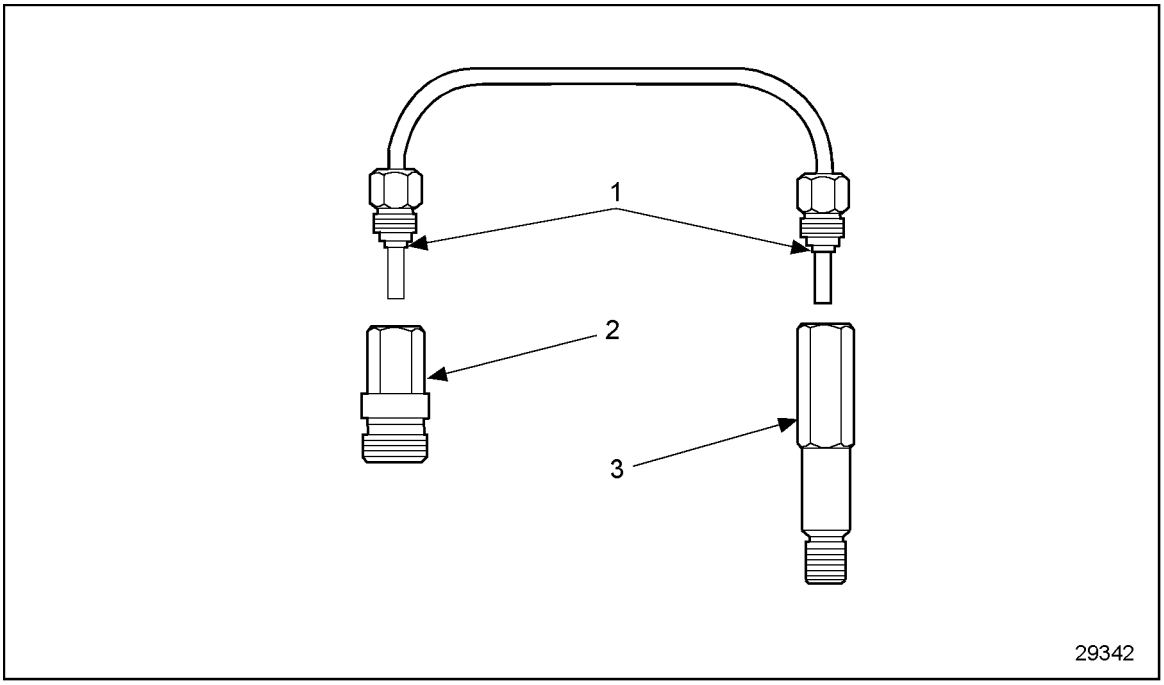
⚠ CAUTION:

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.

The new fuel pipes feature a three-piece connector at both ends. The primary sealing element is the replaceable fluoroelastomer (Viton) O-ring seal.

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To conform with the fuel pipe change, new connectors are installed in the cylinder head, and new fuel injectors, with redesigned filter caps, are used. The connectors and caps incorporate a 1/2 in. - 20 female thread to accept the 1/2 in. - 20 male thread on the fuel pipe nuts. See Figure 2-7.



1. O-ring Seal
2. Injector Filter Cap
3. Connector

Figure 2-7 New Marine Engine Fuel Pipes, Connectors, and Injector Filter Caps

General Instructions for Injector Care and Overhaul:

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerance of various injector parts, extreme cleanliness and strict adherence to service instructions is mandatory. Perform all injector repairs in a clean, well-lighted room with a dust-free atmosphere.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors and prevent damage. Protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.
2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only when completely disassembling and overhauling the injector.
3. Whenever an injector has been removed and installed or replaced, make the following adjustments. Refer to section 12.3.
   [a] Time the injector.
   [b] Position the injector control rack.
4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive. Refer to section 14.1 and refer to section 5.3.

NOTE:
Ensure a new filter has been installed in a reconditioned injector that is to be placed in stock. This precaution will prevent dirt particles from entering the injector.

NOTE:
Do not test new or *reliabilt* remanufactured unit injectors prior to installation in the engine. The Kent-Moore® POP stand should only be used as a diagnostic tool on fuel injectors that have been *removed* from an engine.

5. When a reconditioned injector is to be placed in stock, fill it with injector rack test oil J 26400-5B. Do not use fuel oil. Install shipping caps on both filter caps immediately after filling. Store the injector in an upright position to prevent test oil leakage.

2.2.1 Repair or Replacement of Mechanical Unit Injector

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-8.

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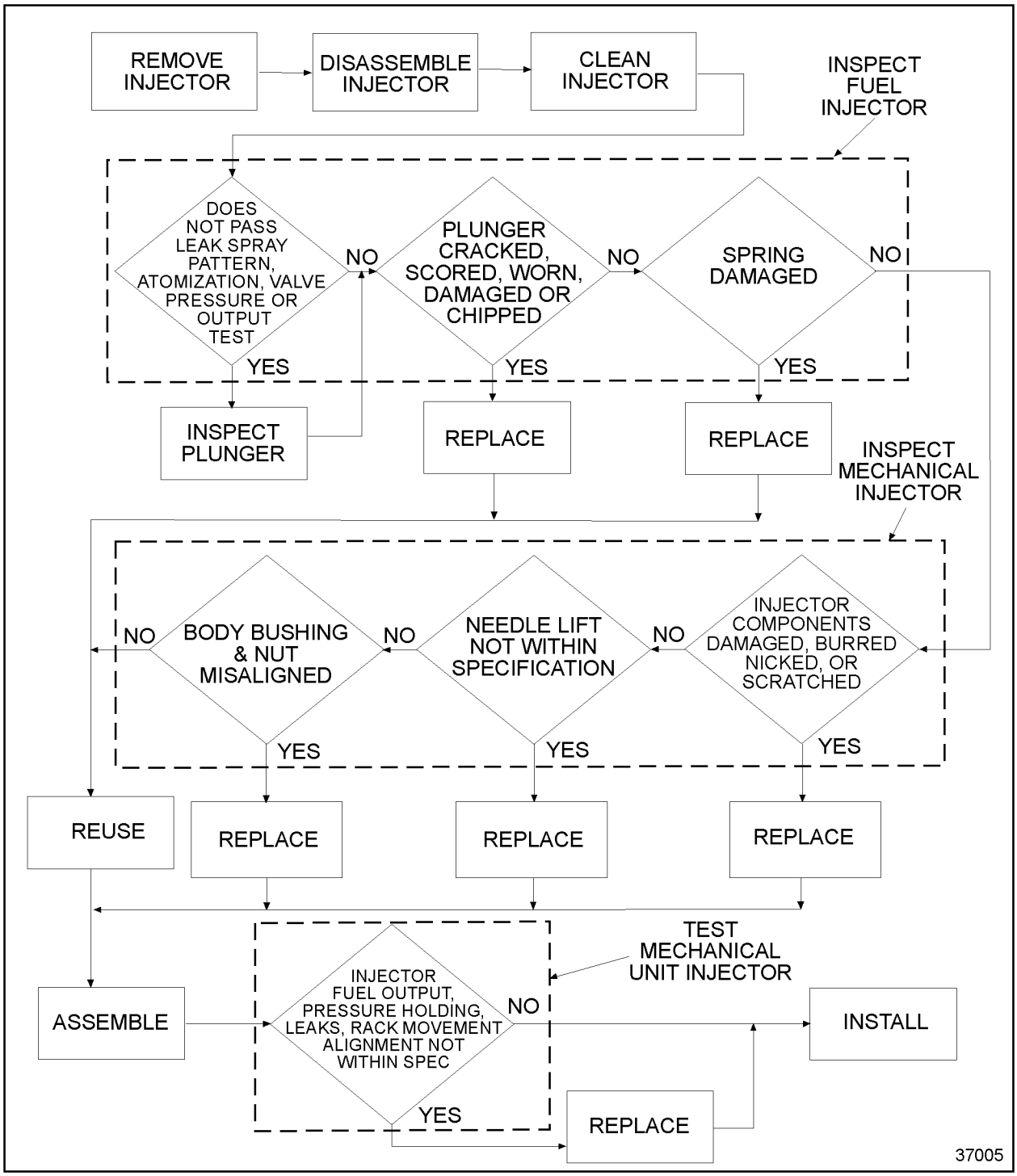


Figure 2-8 Flowchart Repair or Replacement of Mechanical Unit Injector

2.2.2 Removal of Mechanical Unit Injector

Remove the injector as follows:

1. Clean and remove the valve rocker cover. Discard the gasket.

NOTICE:
Immediately after removing the fuel pipes (jumper lines) from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Protect the fuel pipes and fuel connectors from dirt or foreign material entry.

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

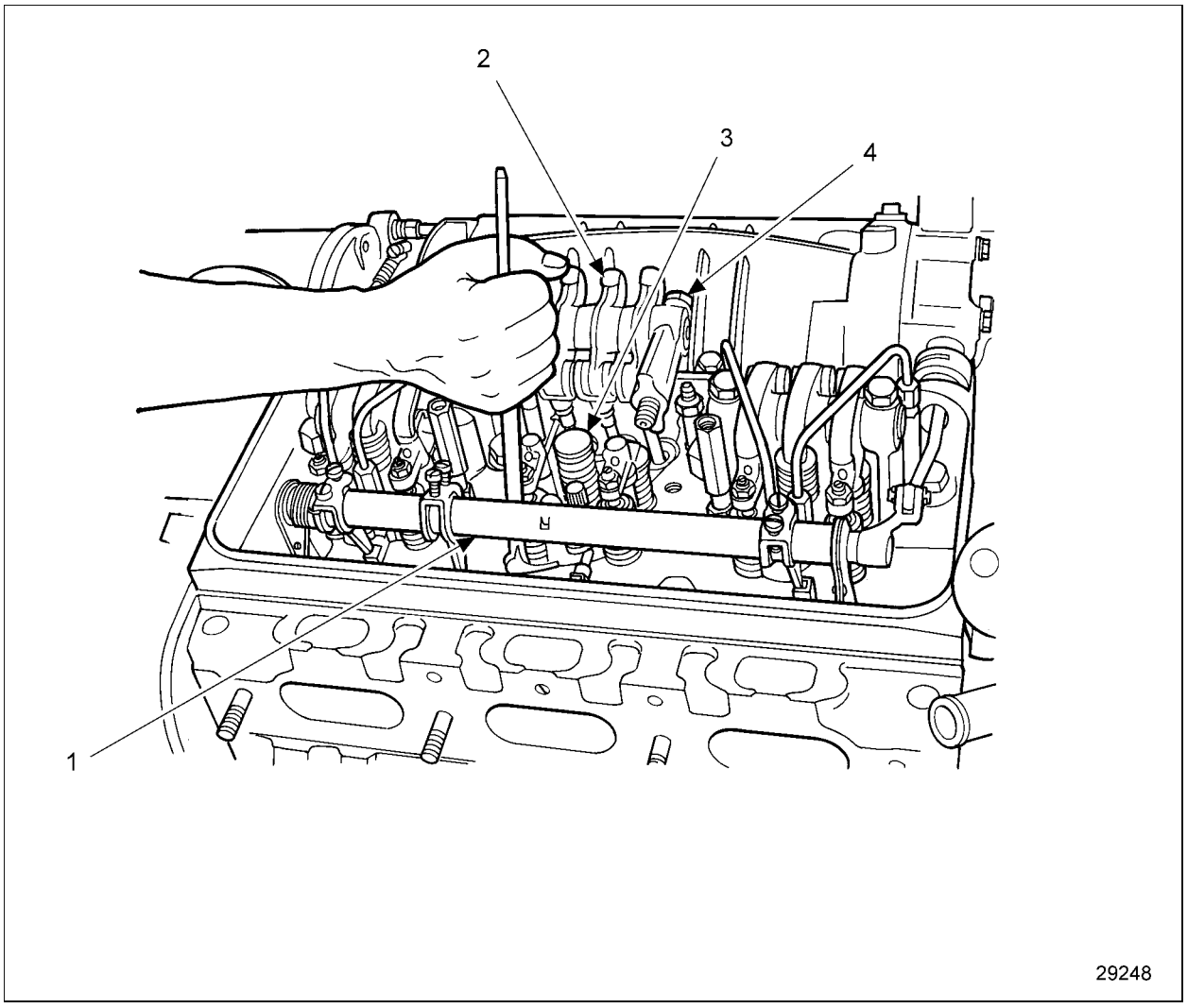
CAUTION:
To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms horizontally in line.

NOTE:
If a wrench is used on the front crankshaft bolt, do not turn the crankshaft to the left. This could loosen the bolt.

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4. Remove the two rocker shaft bracket bolts, and swing the rocker arms away from the injector and valves. See Figure 2-9.



1. Injector Control Tube
2. Rocker Arm Assemblies
3. Mechanical Unit Injector
4. Rocker Arm Shaft Bolt

Figure 2-9 Removing Mechanical Unit Injector from Cylinder Head

5. Remove the injector clamp bolt, washer, and clamp.
6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever. Slide the lever away from the injector.
7. Lift the injector from its seat in the cylinder head.
8. Cover the injector hole in the cylinder head to keep foreign material out.

⚠ 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.

9. Clean the exterior of the injector with clean solvent. Dry it with compressed air.

NOTICE:

To avoid fuel leaks, always use new O-ring seals when replacing the fuel pipes. Do not reuse seals. The new fuel pipes are not compatible with Jacobs Brakes used in automotive applications and should not be used on engines equipped with them.

NOTICE:

Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

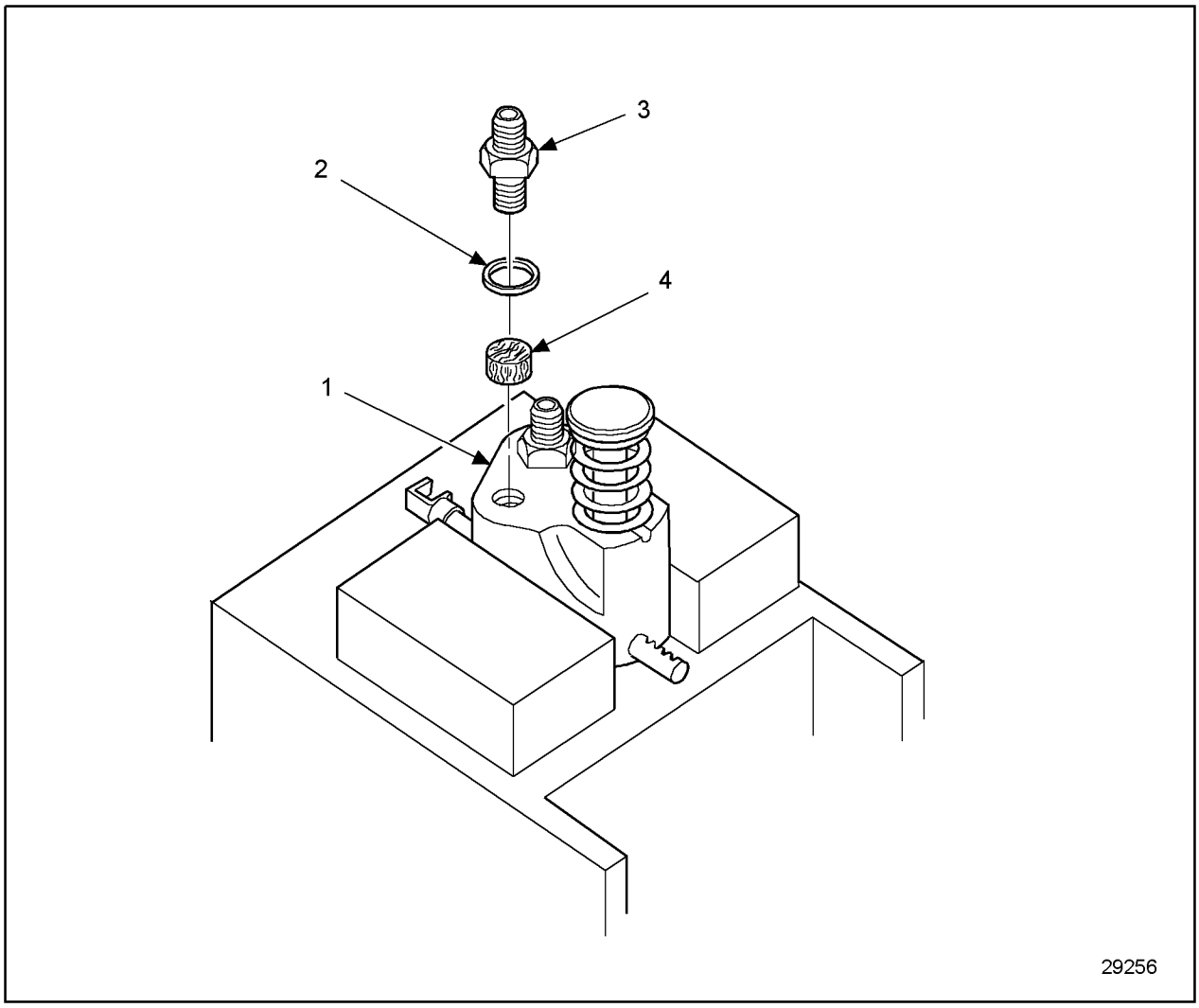
NOTE:
DDC recommends installing the new flared end fuel pipes to replace the originals. When installing flared end fuel pipes, use fuel line nut wrench J 8932-B and "clicker" type torque wrench J 24405 (calibrated in inch-pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to General Information for torque specifications.

2.2.3 Disassembly of Mechanical Unit Injector

Disassemble the injector as follows:

1. Support the injector upright in injector holding fixture J 22396-A, and remove the filter cap, gasket, and filter element. See Figure 2-10.

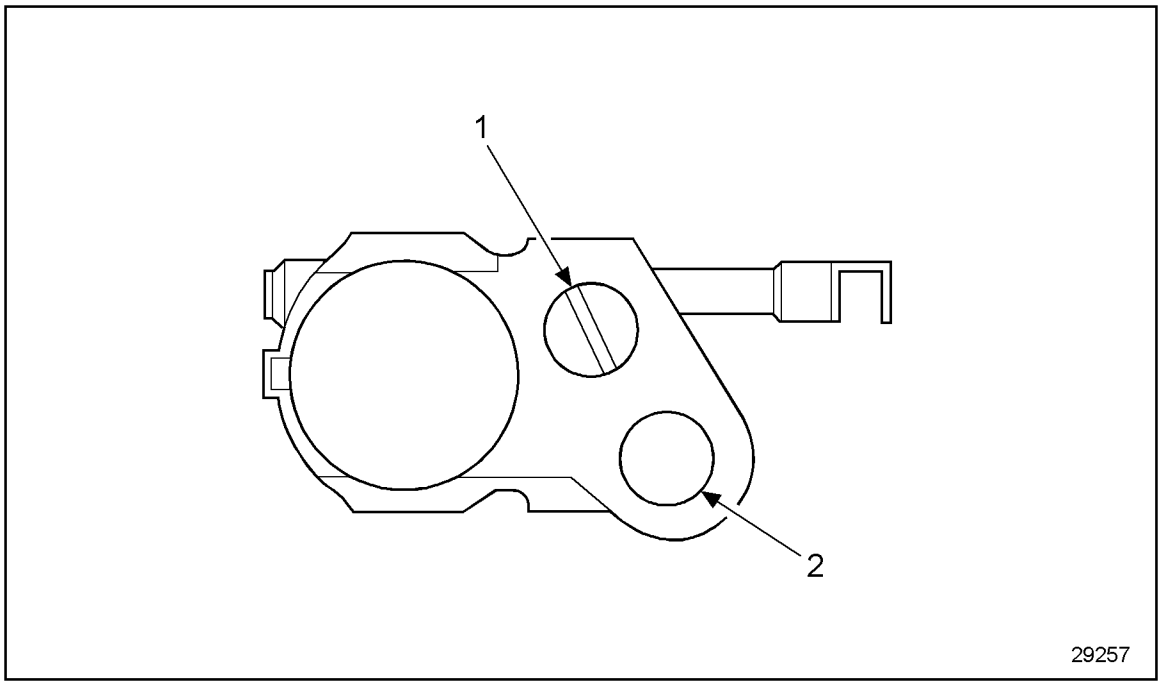
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1. Mechanical Unit Injector
2. Gasket
3. Filter Cap
4. Filter Element

Figure 2-10 Removing Filter Cap and Filter Element

NOTE:
Whenever a fuel injector is disassembled, discard the old filters and gaskets, and replace them with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side. See Figure 2-11.



1. Inlet
2. Outlet

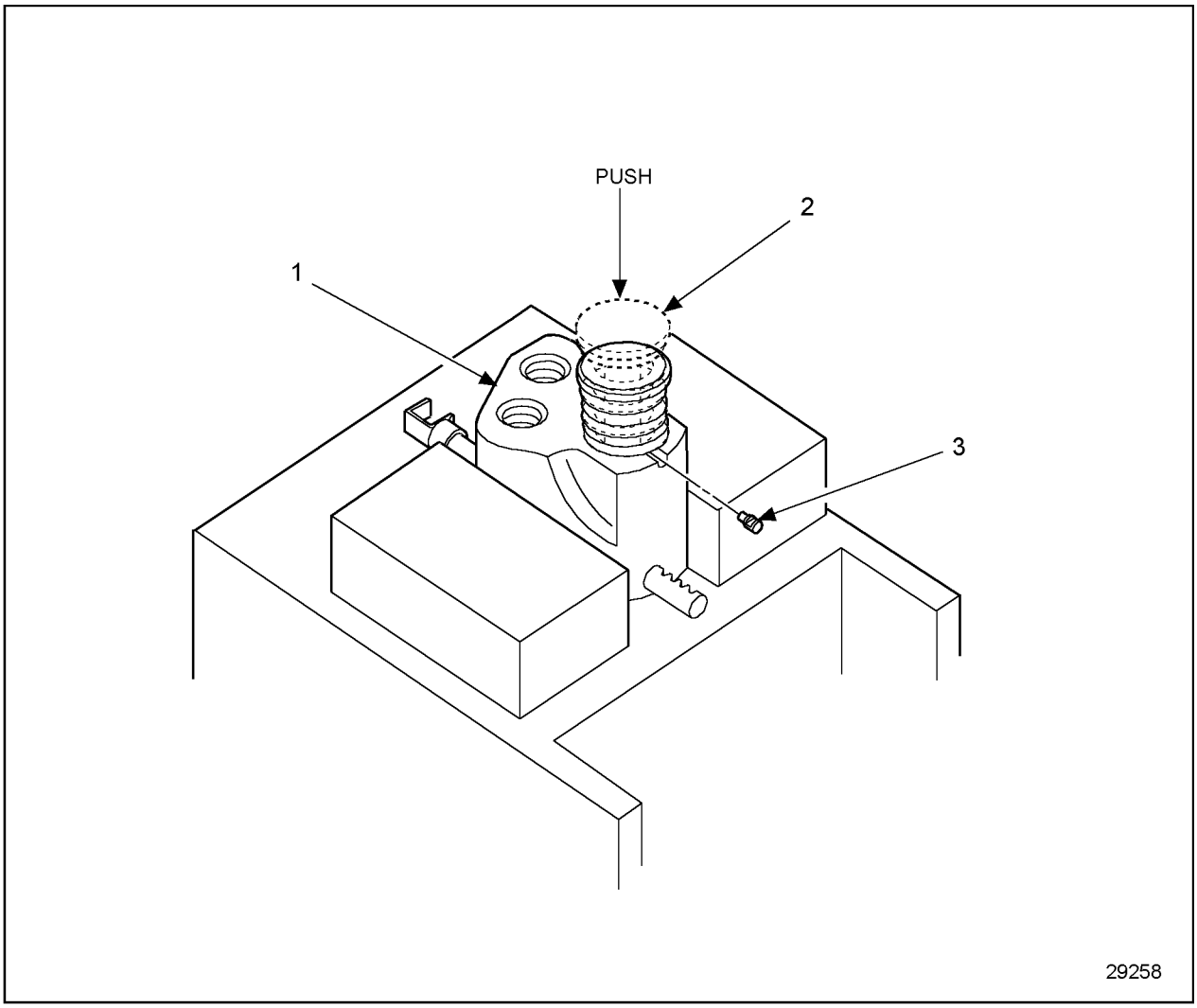
Offset injector filter required on inlet side only (above control rack)

Figure 2-11 Location of Injector Filter (Offset Injector)

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2. Compress the follower spring. See Figure 2-12. Raise the spring above the stop pin with a screwdriver, and withdraw the pin.

NOTE:
Allow the spring to rise gradually.

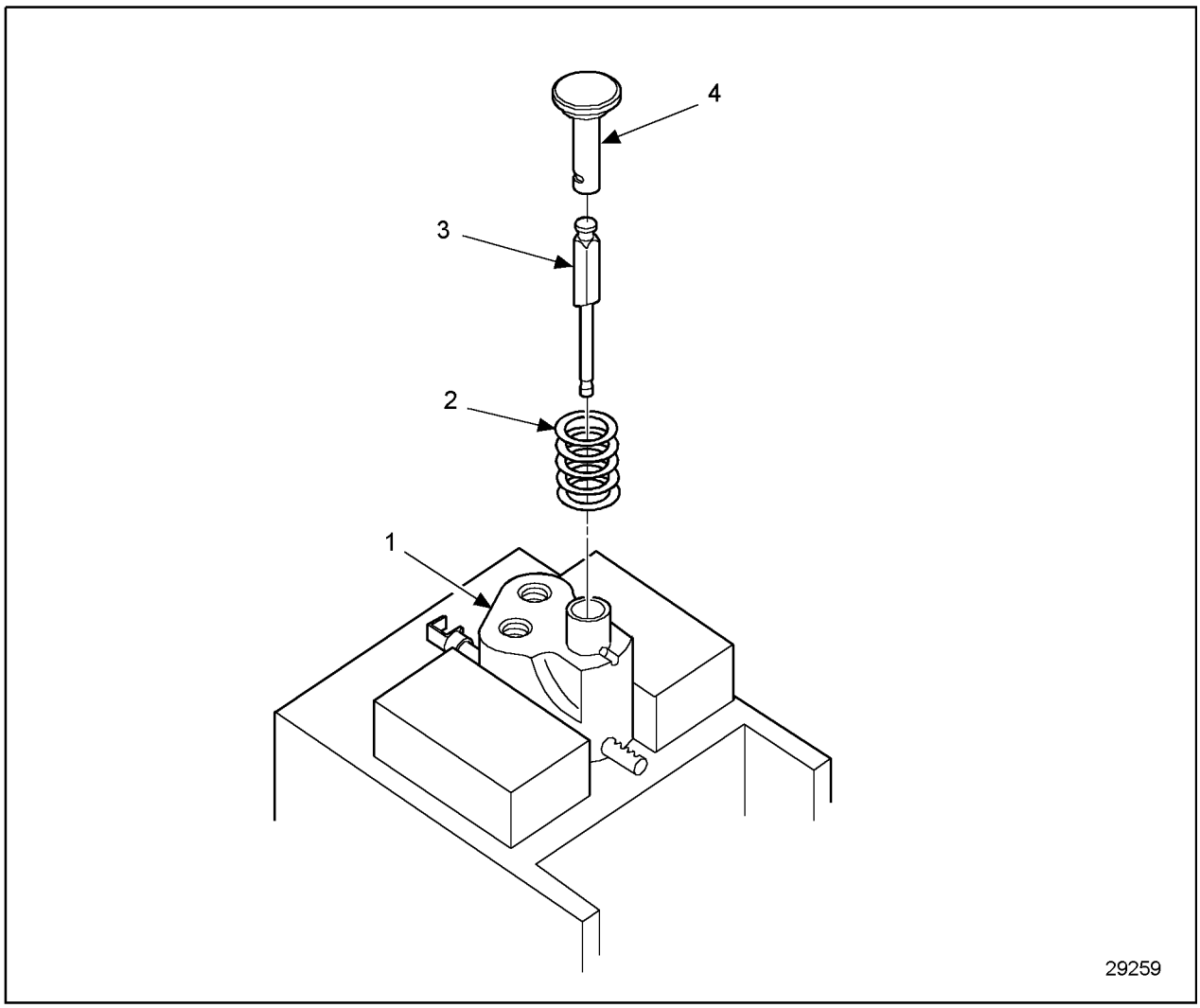


1. Fuel Injector
2. Follower
3. Stop Pin

Figure 2-12 Removing Injector Follower Stop Pin

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3. Remove the plunger follower, plunger, and spring as an assembly. See Figure 2-13.

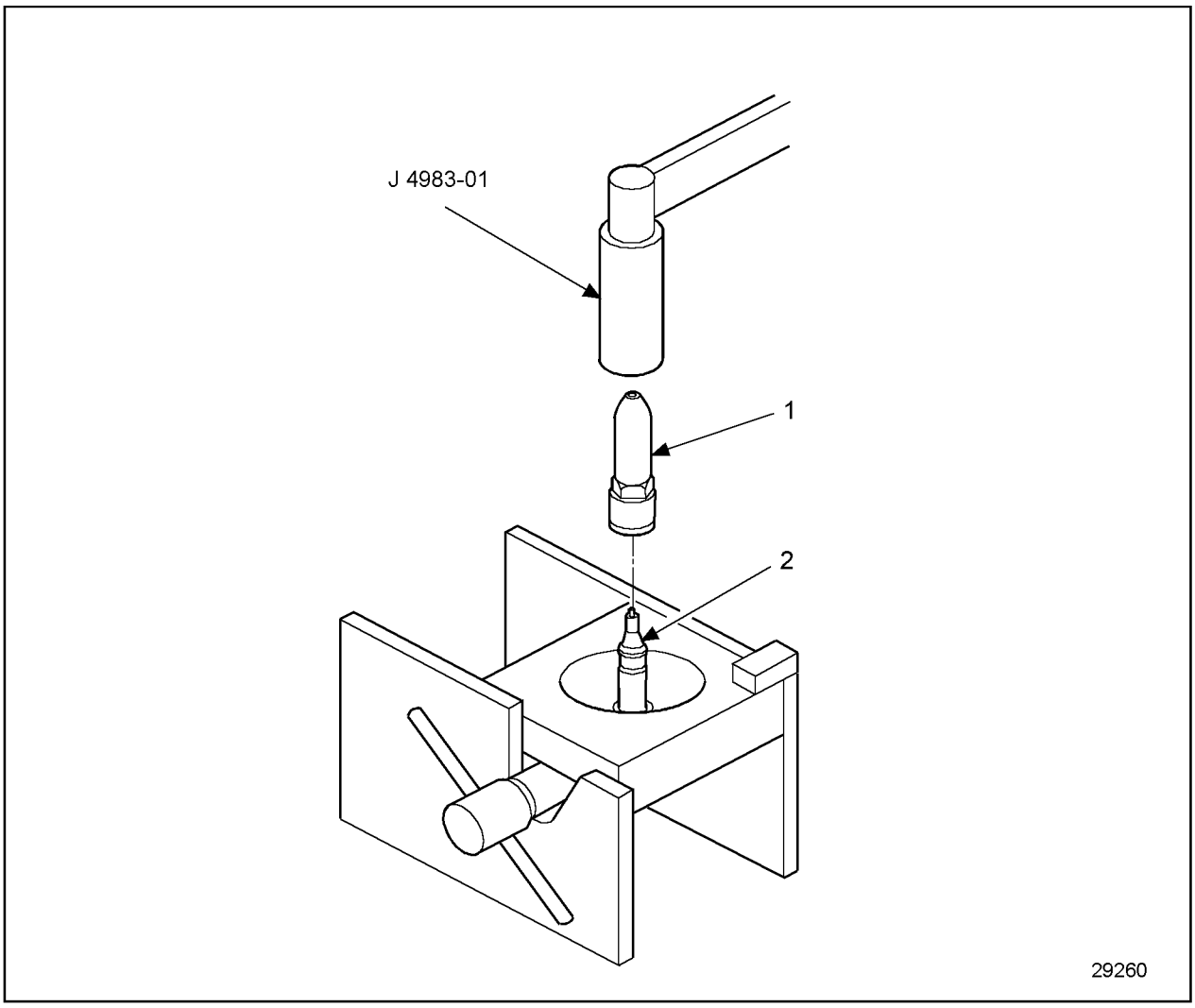


1. Fuel Injector
2. Spring
3. Plunger
4. Plunger Follower

Figure 2-13 Removing or Installing Plunger Follower, Plunger, and Spring

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4. Using socket J 4983-01, loosen the nut on the injector body. See Figure 2-14.



1. Injector Nut
2. Spray Tip and Valve Assembly

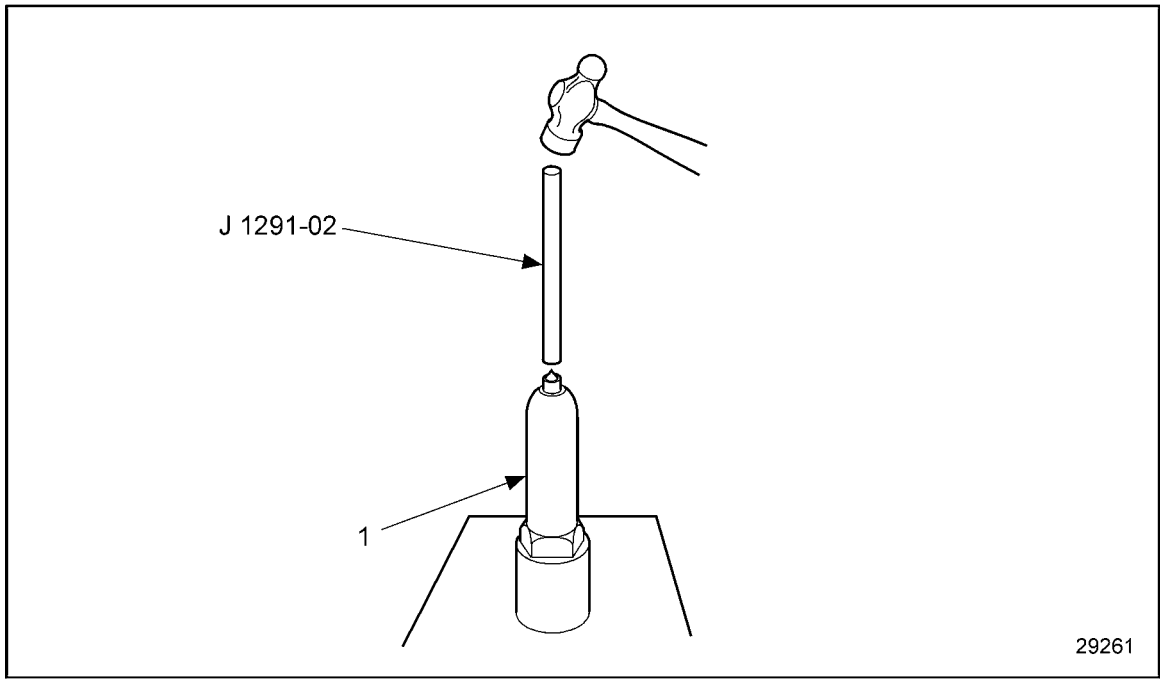
Figure 2-14 Removing Injector Nut using Tool J 4983-01

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5. Lift the injector nut straight up. Remove the spray tip, spring cage, valve spring, spring seat, check valve cage, and check valve.

NOTE:
Do not dislodge the spray tip and valve parts.

NOTE:
When an injector has been in use for some time, the spray tip may not be pushed readily from the nut. In this case, support the nut on a wood block, and drive the tip down through the nut, using tool J 1291-02. See Figure 2-15.

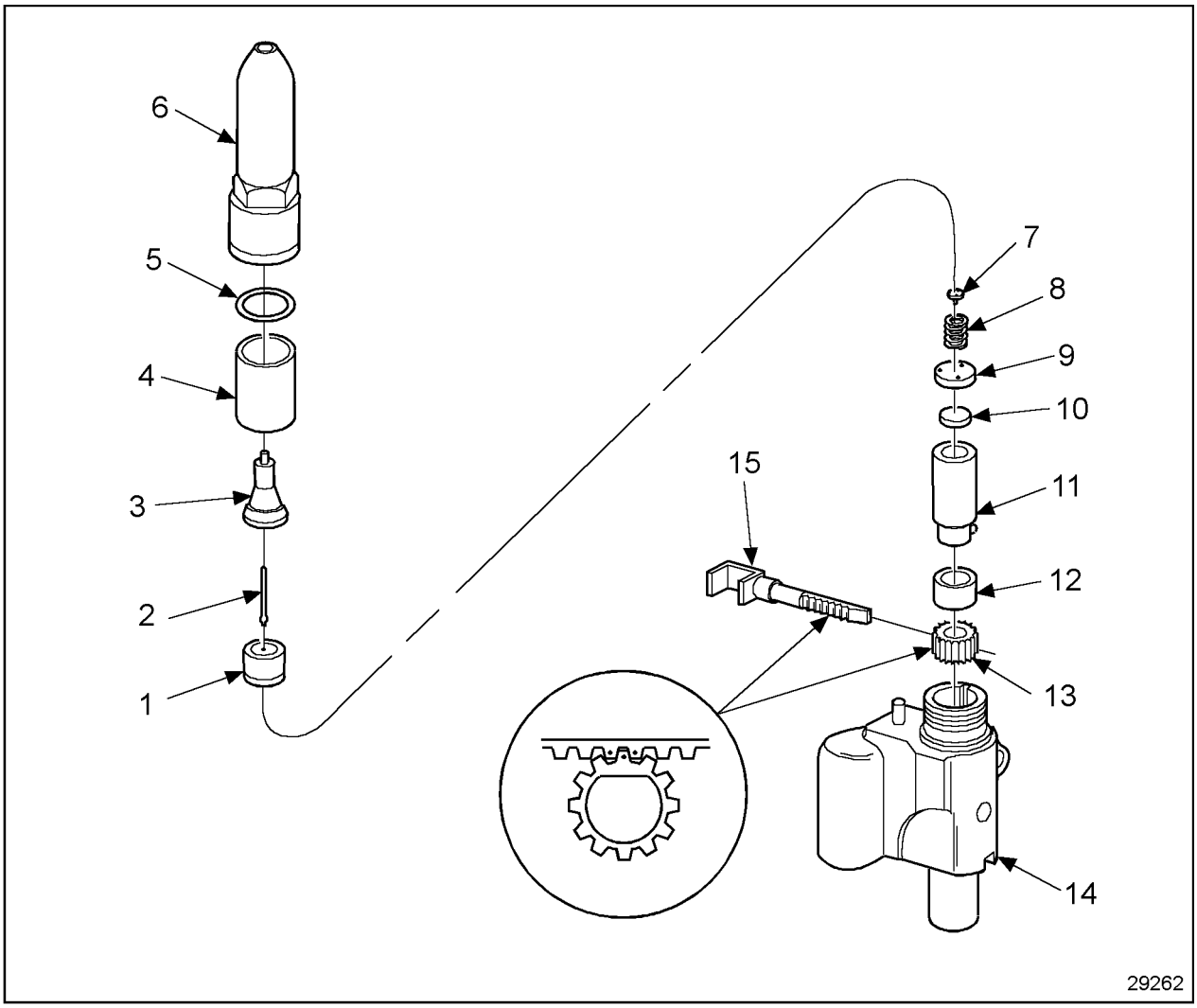


1. Injector Nut

Figure 2-15 Removing Spray Tip from Injector Nut using J 1291-02

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6. See Figure 2-16. Remove the spill deflector, and lift the bushing straight out of the injector body.



1. Spring Cage
2. Needle Valve
3. Spray Tip
4. Spill Deflector
5. Seal Ring
6. Injector Nut
7. Spring Seat
8. Valve Spring
9. Check Valve Cage
10. Check Valve
11. Bushing
12. Gear Retainer
13. Gear
14. Injector Body
15. Control Rack

Figure 2-16 Injector Rack, Gear, Spray Tip, and Valve Assembly

7. Remove the injector body from the holding fixture. Turn the body upside down, and catch the gear retainer and gear as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Remove the seal ring from the body.

2.2.3.1 Cleaning of Mechanical Unit Injector

Clean the fuel injector as follows:

NOTE:
Provide the injector repair room with a supply of filtered, dry, compressed air for drying the injector parts after they have been cleaned. Use rust-proof wash pans. They should be deep enough to permit complete submersion of all injector parts in wire baskets of 16 mesh wire screen. Use baskets that will keep the parts from contacting dirt at the bottom of the pans.

NOTE:
Since most injector problems result from dirt particles, a clean area must be provided for injector parts after cleaning and 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.

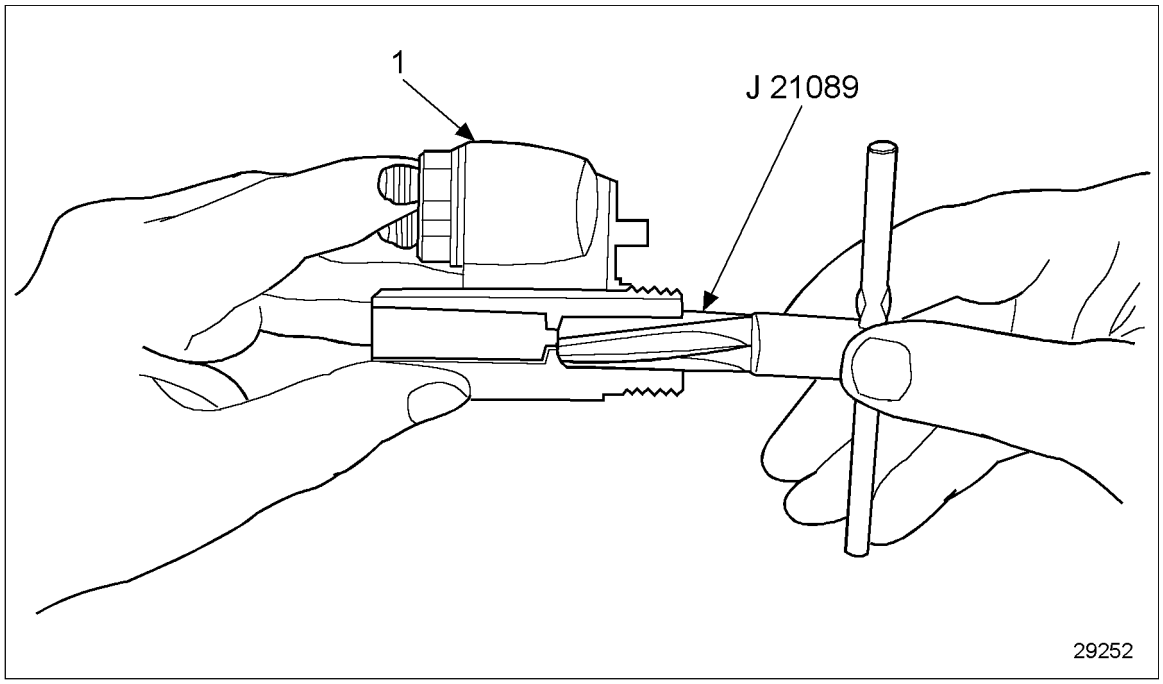
1. Wash all parts with a suitable cleaning solvent. Dry them with clean, filtered compressed air.
2. Wipe the parts with lint-free tissue. Clean out the passages, drilled holes, and slots in all injector parts.

NOTE:
Since lint or other particles will clog the injector once it is assembled, rags should never be used for cleaning or drying.

3. Soak the spray tip for approximately fifteen minutes in a sonic cleaner.

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4. Insert reamer J 21089 in the injector body. See Figure 2-17. Turn it clockwise a few times.



1. Injector Body

Figure 2-17 Cleaning Injector Body with Tool J 21089

5. Remove the reamer, and check the ring face for reamer contact over the entire surface.

NOTE:
If necessary, repeat the reaming procedure until the reamer makes contact with the entire ring face.

6. Clean the opposite side of the ring in the same manner.

NOTICE:
Do not damage the injector body ring during this operation. This spiral ring forms part of the injector body and is not serviced. If the ring is damaged, the injector body must be replaced.

7. Insert reamer J 21089 carefully into the ring bore of the injector body. Turn the reamer clockwise to remove any burrs.

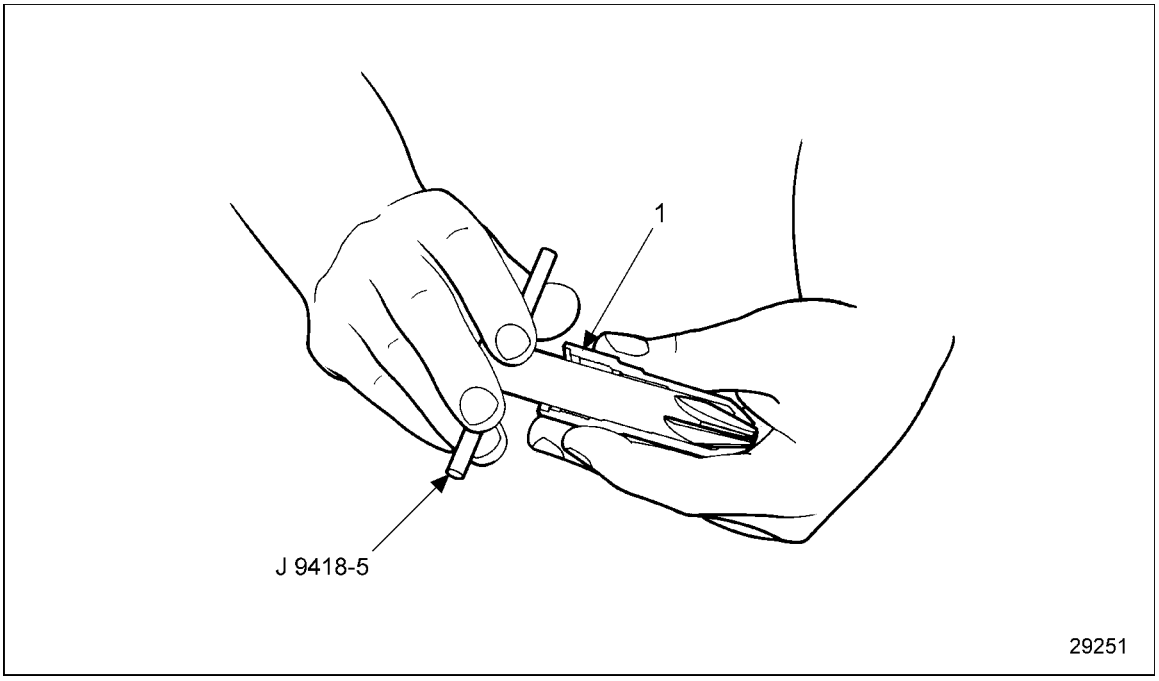
NOTE:
Do not dislodge the ring.

⚠ 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. Wash the injector body in clean solvent, and dry with compressed air.
9. Remove the carbon deposits from the lower end of the injector nut with reamer J 9418-5 from set J 9418. See Figure 2-18.

NOTE:
Remove only enough metal to produce a clean uniform seat.



1. Injector Nut

Figure 2-18 Cleaning Injector Nut Lower End with Tool J 9418-5 from Set J 9418

NOTE:
Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and fuel leakage.

10. Clean the tip seat with reamer J 9418-1 from set J 9418.

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⚠ 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. Wash the injector nut in clean solvent, and dry it with 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.

12. Wash the plunger and bushing with clean solvent, and dry them with compressed air.

NOTICE:

Ensure high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing during engine operation, causing oil dilution.

NOTE:
When handling the injector plunger, do not touch the finished plunger surfaces.

NOTE:
Since they are matched parts, keep the plunger and bushing together.

13. After washing, submerge the parts in a clean receptacle containing clean test oil.

NOTE:
Keep the parts of each injector assembly together.

2.2.3.2 Inspection of Mechanical Unit Injector

Inspect the injector as follows:

1. Check the injector for leaks using tester J 34760-150A (from set J 34760-B). Refer to section ADDITIONAL INFORMATION.
   [a] If the injector leaks, inspect the plunger. Refer to step 4.
   [b] If the injector does not leak, proceed with the inspection.
2. Check the spray pattern, atomization, and valve opening pressure using tester J 34760-150A (from set J 34760-B).
   [a] If the injector does not pass the tests, inspect the plunger. Refer to step 4.

[b] If the injector passes the tests, continue inspection.

3. Perform injector fuel output test using calibrator J 22410.

NOTE:
If calibrator J 22410 is not available use updated calibrator J 39300. Tools used on these machines ***are not interchangeable***.

[a] If the injector does not pass the test, inspect the plunger. Refer to step 4.

[b] If the injector passes the test, continue inspection.

4. Visually inspect the plunger for scratches, scoring, wear, damage, and helix chipping.

[a] If scratched, scored, worn, damaged, or chipped, replace the plunger. Refer to section 2.2.4.

[b] If not scratched, scored, worn, damaged, or chipped, continue inspection.

NOTE:
Injector components manufactured after January 1, 1988 may or may not be blued. Bluing has no effect on a part's performance or service life.

5. Measure between the top of the follower and the slot.

[a] If this dimension is not within 41.834 ± 0.05 mm (1.647 ± 0.002 in.), replace follower. See Figure 2-19.

[b] If this dimension is within specified limits, proceed with inspection.

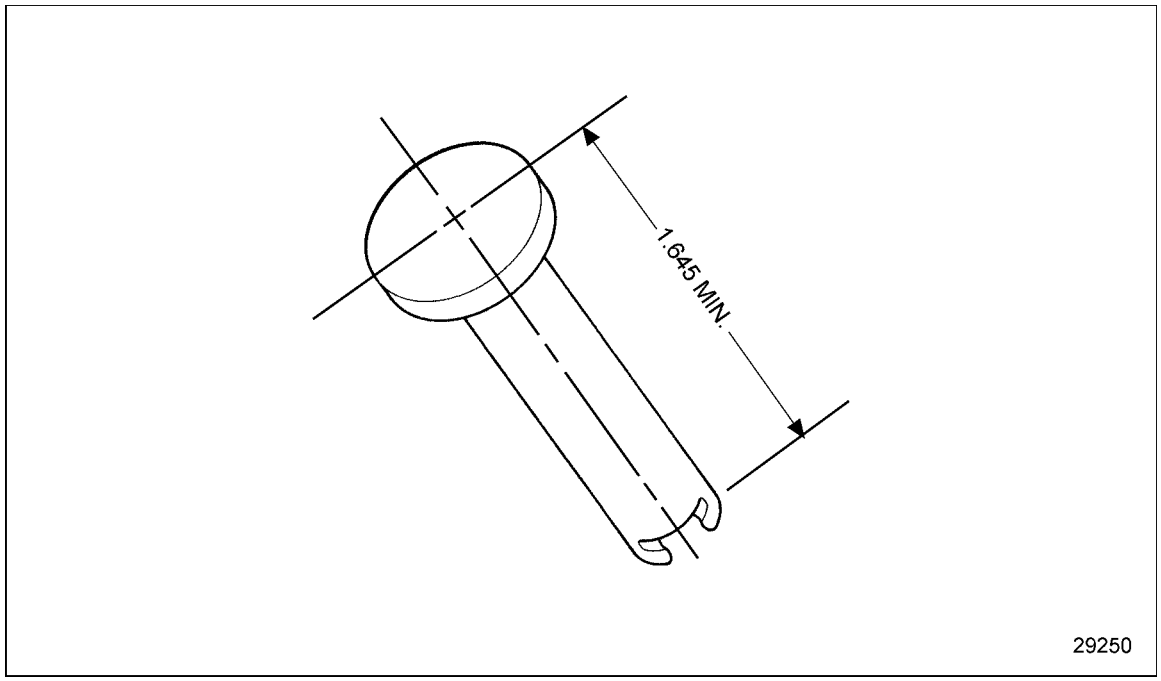


Figure 2-19 Injector Follower Measurements

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6. Visually inspect the stop pin groove in the side of the follower for damage.
   [a] If not smooth, replace the follower. Refer to section 2.2.4.
   [b] If smooth, continue inspection.
7. Examine the outside diameter of the follower spring coils for wear from the rocker arms contacting the coils.
   [a] If worn, replace the follower spring. Refer to section 2.2.4.
   [b] If not worn, continue inspection.
8. Visually inspect the follower spring for rust, pitting, nicks, or notches in the coils, broken coils, broken coil ends, and notches under the coil ends.
   [a] If rusted, pitted, nicked, notched, or broken, replace the follower spring. Refer to section 2.2.4.
   [b] If not rusted, pitted, nicked, notched, or broken, continue inspection.
9. Visually inspect the spring for damage or wear and check the follower spring tension with spring tester J 29196. Refer to section ADDITIONAL INFORMATION.

NOTE:
The current injector follower spring 3.61 mm (0.142 in.) diameter wire has a free length of approximately 38.202 mm (1.504 in.) and should be replaced when a load of less than 70 lbs. will compress it to 26.11 mm (1.028 in.). The former spring wire was 3.05 mm (0.120 in.) diameter.

NOTE:
DDC recommends that at the time of overhaul, all injectors in an engine need to be the same spring type.

   [a] If the spring is damaged, worn, or fails to meet test specifications, replace it. Refer to section 2.2.4.
   [b] If not damaged or worn and meets test specifications, continue inspection.
10. Visually inspect the injector body threads, the bushing seating surface, and the filter cap gasket sealing surfaces for damage, wear, rust, and corrosion.
    [a] If excessively damaged, worn, rusted, corroded, or more than 10 percent of the threads are damaged, replace the injector body. Refer to section 2.2.4.
    [b] If not damaged, worn, rusted, or corroded, continue inspection.
11. Visually inspect the rack hole, body seal ring sealing surface, clamp radius, and dowel pin for damage and wear.
    [a] If worn or damaged, replace the injector body. Refer to section 2.2.4.
    [b] If not worn or damaged, continue inspection.
12. Visually inspect the filter cap jumper line sealing surfaces, the copper gasket sealing surfaces, the threads, and the fuel passage.

[a] If the threads or sealing surfaces are damaged, replace the filter cap. Refer to section 2.2.4.

[b] If the fuel passages are plugged, clean them and remove burrs. Refer to section ADDITIONAL INFORMATION.

[c] If the threads and sealing surfaces are not damaged and the fuel passages are not plugged, continue inspection.

13. Visually inspect the control rack for nicks, burrs, rust, and hardness.

[a] If nicked, burred, rusted, or hard, replace the control rack. Refer to section 2.2.4.

[b] If not nicked, burred, rusted, or hard, continue inspection.

14. Inspect the control rack teeth for wear.

[a] If worn, replace the control rack. Refer to section 2.2.4.

[b] If not worn, continue inspection.

15. Check the rack for straightness.

NOTE:
A 6.35 mm (0.250 in.) inside diameter bushing may be used to check the rack for straightness.

[a] If bent, replace the rack. Refer to section 2.2.4.

[b] If not bent, proceed with the inspection.

16. Inspect the notch width in the clevis.

NOTE:
The notch in the clevis should be 7.938-7.988 mm (0.3125-0.3145 in.).

[a] If the width is not within the specified limits, replace the rack. Refer to section 2.2.4.

[b] If the width is within specified limits, continue inspection.

17. Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

[a] If burred, remove burrs from teeth. Refer to section ADDITIONAL INFORMATION.

[b] If excessively worn, burred, rusted, or cracked, replace the gear. Refer to section 2.2.4.

[c] If not worn, burred, rusted, or crooked, continue inspection.

18. Visually inspect the bushing lapped sealing surface for scratches and the bushing internal diameter for scoring.

[a] If scratched or scored, replace the plunger and bushing assembly. Refer to section 2.2.4.

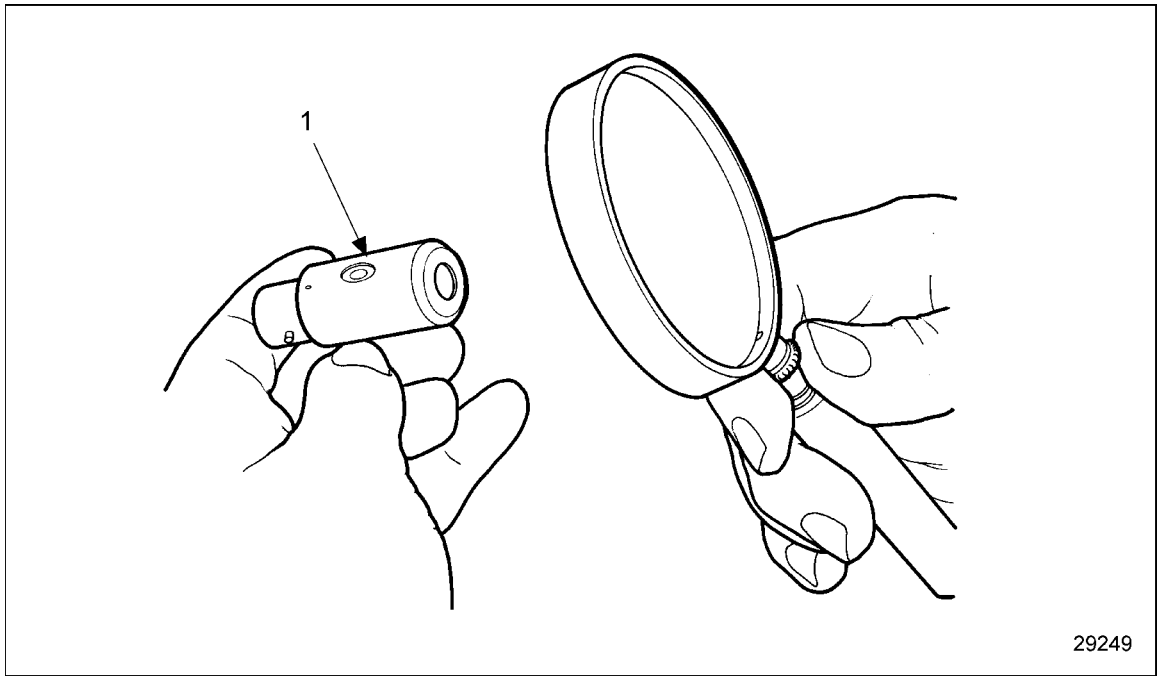
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NOTICE:
Do not attempt to interchange the plunger between bushings. Since components of plunger and bushing assemblies are supplied as matched sets, any attempt to mix them can result in plunger and bushing seizure and serious injector damage.

NOTE:
Revised plunger and bushing assemblies are interchangeable with early plunger and bushing assemblies. Because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.

[b] If not scratched or scored, continue inspection.

19. Visually inspect the dowel pin for damage.
    [a] If damaged, replace the plunger and bushing assembly. Refer to section 2.2.4.
    [b] If not damaged, continue inspection.
20. Inspect the entire bushing for corrosion or varnish. See Figure 2-20.
    [a] Clean the bushing, and remove varnish.
    [b] If not varnished or corroded, continue inspection.



1. Bushing

Figure 2-20 Examining Sealing Surface with a Magnifying Glass

21. Inspect the plunger for corrosion, varnish, scoring, scratches, wear, and chips along the edge of the helix. See Figure 2-21.

    [a] If scored, cracked, chipped and scratched, varnish cannot be removed, replace the plunger and bushing assembly. Refer to section 2.2.4.

    [b] Clean the plunger, and remove varnish. See Figure 2-21.

    [c] If not scored, cracked, chipped, scratched, and varnish can be removed, continue inspection.

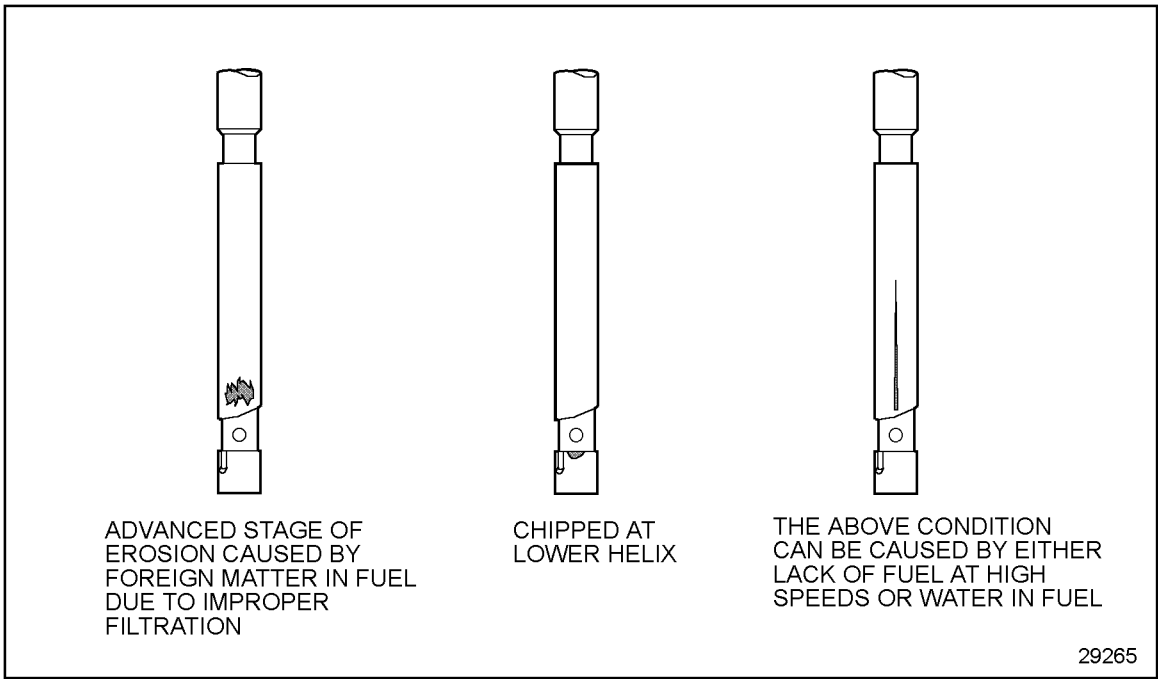


Figure 2-21 Unusable Injector Plungers

22. Inspect the check valve for corrosion, varnish, and cracks and scratches on the lapped surfaces.

    [a] If scratched, cracked, corroded, or varnish cannot be removed, replace the check valve. Refer to section 2.2.4.

    [b] Clean the check valve, and remove varnish.

    [c] If not scratched, cracked, corroded, and varnish can be removed, continue inspection.

23. Inspect the check valve cage for corrosion, varnish, wear, and cracks and scratches on the lapped surfaces.

    [a] Clean the check valve cage, and remove varnish.

    [b] If corroded, worn, cracked, scratched, or varnish cannot be removed, replace the check valve cage. Refer to section 2.2.4.

    [c] If not corroded, worn, cracked, scratched, and varnish can be removed, continue inspection.

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24. Inspect the injector valve spring for worn, broken, and notched coil ends.
    [a] If worn, broken, and notched, replace the injector valve spring. Refer to section 2.2.4.
    [b] If not worn, broken, or notched, continue inspection.
25. Visually inspect for corrosion, nicks, and cavitation erosion on the inside of the spring at approximately 1-1/2 coils from the end.
    [a] If corroded, replace the spring. Refer to section 2.2.4.
    [b] If not corroded, proceed with the inspection.
26. Inspect the spring seat surfaces for wear.
    [a] If the surfaces are excessively worn, replace the spring seat. Refer to section 2.2.4.
    [b] If the surfaces are not excessively worn, continue inspection.

NOTE:
To ensure proper operation, the high valve opening pressure spring and seat must be used together. Do not mix injectors containing standard springs and seats with injectors having high valve opening pressure springs and seats in the same engine. A high valve opening pressure valve spring and seat are used in certain high output engine injectors. The high valve opening pressure spring is made of a thicker diameter wire than the standard valve spring and has a smaller inside diameter (4.42 mm ID vs. 4.68 mm ID or 0.174 in. ID vs 0.184 in. ID). The high valve opening pressure spring seat can be distinguished from the standard spring seat by the smaller diameter post and the groove on the end of this post.

27. Inspect the spring cage for cracks, corrosion or varnish, and scratches on the lapped sealing surfaces.
    [a] If cracked, corroded, scratched, or varnish cannot be removed, replace the spring cage. Refer to section 2.2.4.
    [b] Clean the spring cage, and remove the varnish.
28. Inspect the spring seat surface and the needle valve seating surface for wear.
    [a] If excessively worn, the spring cage must be replaced. Refer to section 2.2.4.
    [b] If not excessively worn, continue inspection.
29. Inspect the spray tip for cracks, enlarged spray holes, corrosion on the outside diameter taper, and oxide scale on the spray hole end.
    [a] If tips are cracked, holes are enlarged, outside taper is corroded, and oxide scale is on the spray hole end, replace the injector. Refer to section 2.2.5.
    [b] If none of these conditions exist, continue inspection.
30. Inspect the seal ring seating area, the spray tip seating area, and the spray tip hole for corrosion.
    [a] If corroded, replace the necessary parts.
    [b] If not corroded, proceed with the inspection.

31. Visually inspect the nut-to-tip sealing surface and the lapped sealing surface for scratches.
    [a] If scratched, replace the injector. Refer to section 2.2.5.
    [b] If not scratched, continue inspection.
32. Visually inspect the spray tip needle valve for erosion at the seat shoulder, scratches and discoloration from overheating.
    [a] If eroded, scratched, or discolored, replace the needle valve. Refer to section 2.2.4.
    [b] If not eroded, scratched, or discolored, continue inspection.
33. Visually inspect the nut for damaged threads or loosening.
    [a] If threads are damaged, replace the nut. Refer to section 2.2.4.
    [b] If loosened, hand tighten the nut.
    [c] If not damaged or loose, continue inspection.
34. Inspect both ends of the spill deflector for smoothness, cracks, and burrs.
    [a] If burred, remove the burrs.
    [b] If burrs cannot be removed, deflector is cracked, or edges are rough and uneven, replace the spill deflector. Refer to section 2.2.4.
    [c] If none of these conditions exist, continue inspection.
35. Inspect the thickness of spray tip shoulder, check valve cage, check valve, and valve spring cage. The minimum parts thickness is listed in Table 2-1.
    [a] Parts failing to meet specified minimum dimensions must be replaced. Refer to section 2.2.4
    [b] If the parts meet specified minimum dimensions, continue inspection.

Part Name	Minimum Thickness
Spray Tip (Shoulder)	5.0546 mm (0.199 in.)
Check Valve Cage	4.1402-4.191 mm (0.163-0.165 in.)
Check Valve	0.5588 mm (0.022 in.)
Valve Spring Cage	15.2908 mm (0.602 in.)

Table 2-1 Minimum Thickness (Used Parts)

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2.2.3.3 Inspection of Needle Valve Lift

Measure the needle valve lift, using tool J 9462-02 as follows. See Figure 2-22:

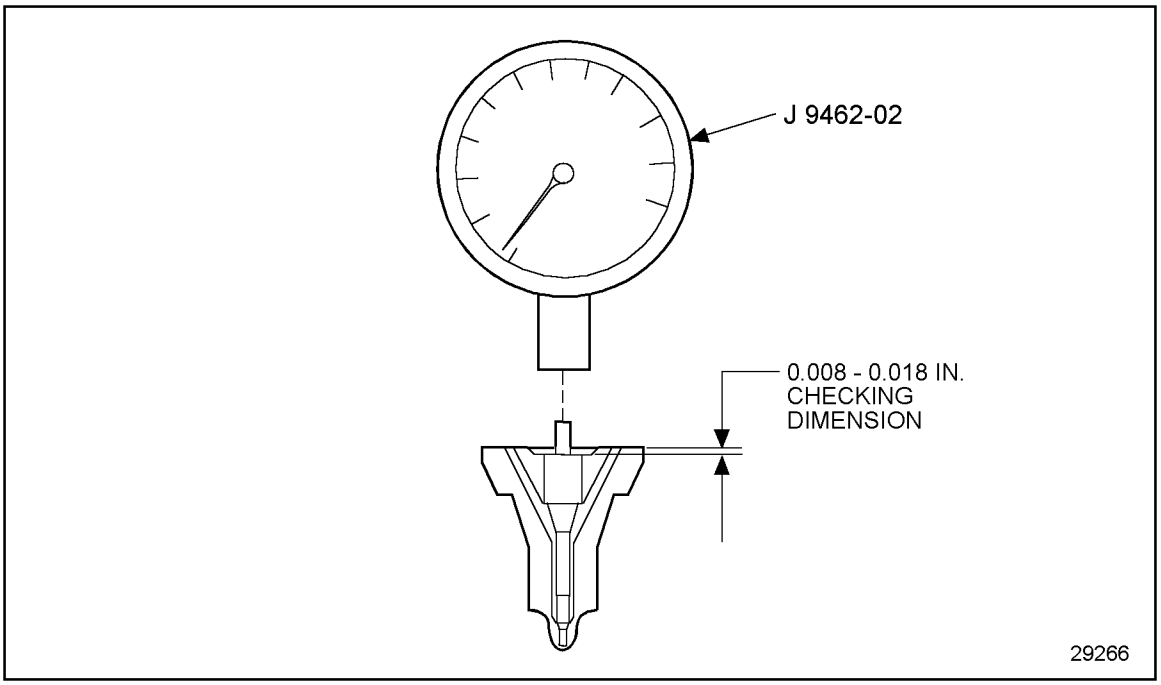


Figure 2-22 Checking Needle Valve Lift with Tool J 9462-02

1. Place the bottom surface of the plunger assembly on a flat surface, and zero the indicator dial.
2. Place the spray tip and needle valve assembly against the bottom of the gage with the needle valve quill in the plunger hole.
3. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator.

NOTE:
The lift should be 0.20-0.46 mm (0.008-0.018 in.).

[a] If the lift exceeds 0.46 mm (0.018 in.), the tip assembly must be replaced. Refer to section 2.2.4.

[b] If the lift is less than 0.20 mm (0.008 in.), inspect for foreign material between the needle valve and the tip seat. If present, remove the foreign material.

[c] If the needle valve lift is within limits, install a new needle valve spring, and recheck the valve opening pressure and valve action. Refer to section 2.2.4.

[d] The spray tip and needle valve assembly should be replaced if low valve opening pressure or poor atomization occurs with the new spring and seat.

4. Match the plunger/bushing assembly with the proper tip using flow gage J 25600-B. Refer to section ADDITIONAL INFORMATION.

2.2.3.4 Inspection of Mechanical Unit Injector with Tester J 29584

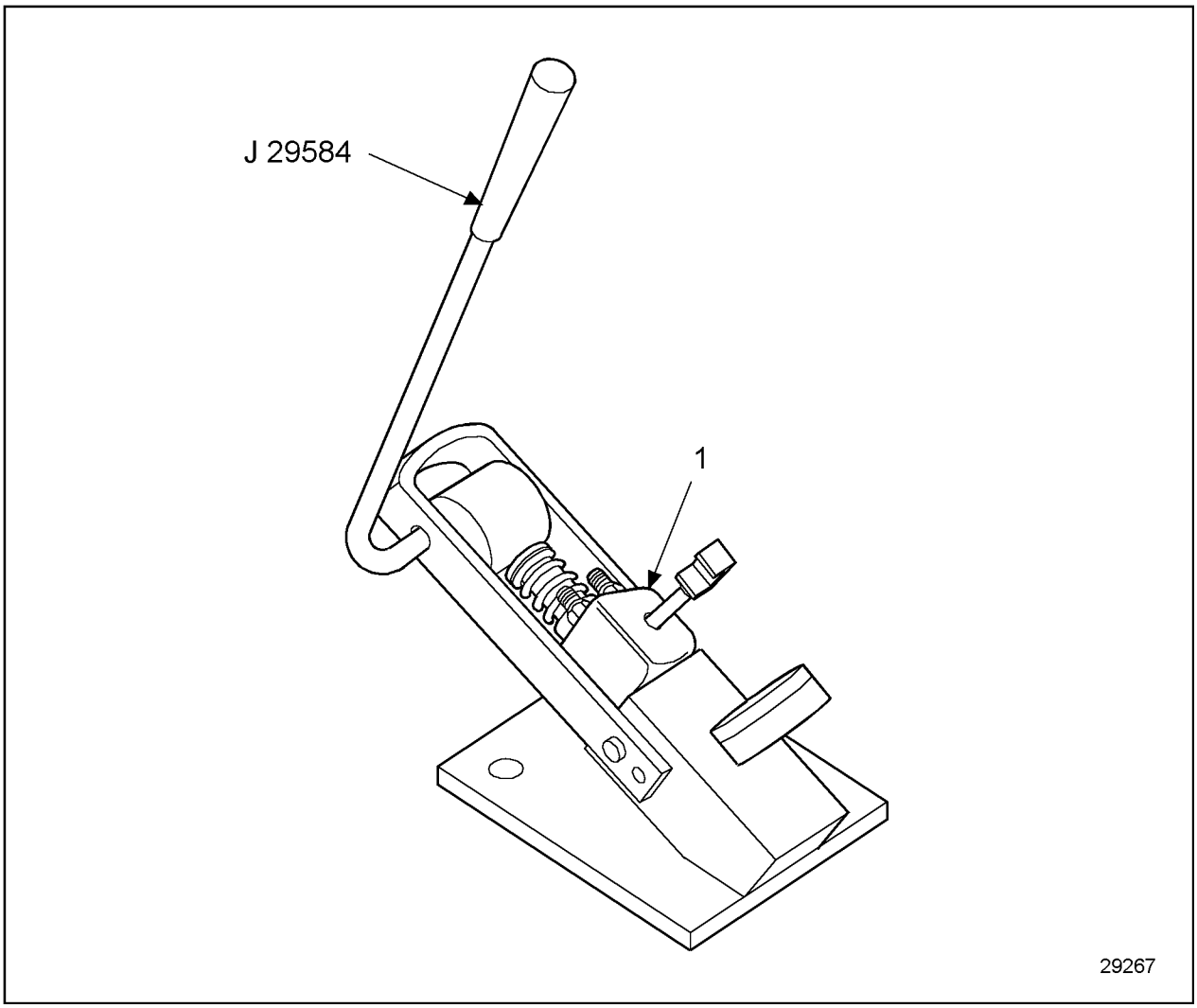
Check the rack and plunger for freedom of movement with tester J 29584 as follows:

1. With the injector control rack held in the no-fuel position, operate the handle to depress the follower to the bottom of its stroke.

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2. Very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel.

NOTE:
If the rack falls without restriction, the injector passes the test. If the injector fails the test, either the plunger is scored or the plunger and bushing assembly or the body and nut is misaligned due to dirty parts. See Figure 2-23.



1. Mechanical Unit Injector

Figure 2-23 Inspecting Injector with Tester J 29584

[a] If the plunger is scored, replace the rack and plunger. Refer to section 2.2.4.

[b] If the body, bushing, or nut is misaligned, clean dirty parts or replace damaged parts. Refer to section 2.2.4.

[c] If the injector passes the test, continue inspection.

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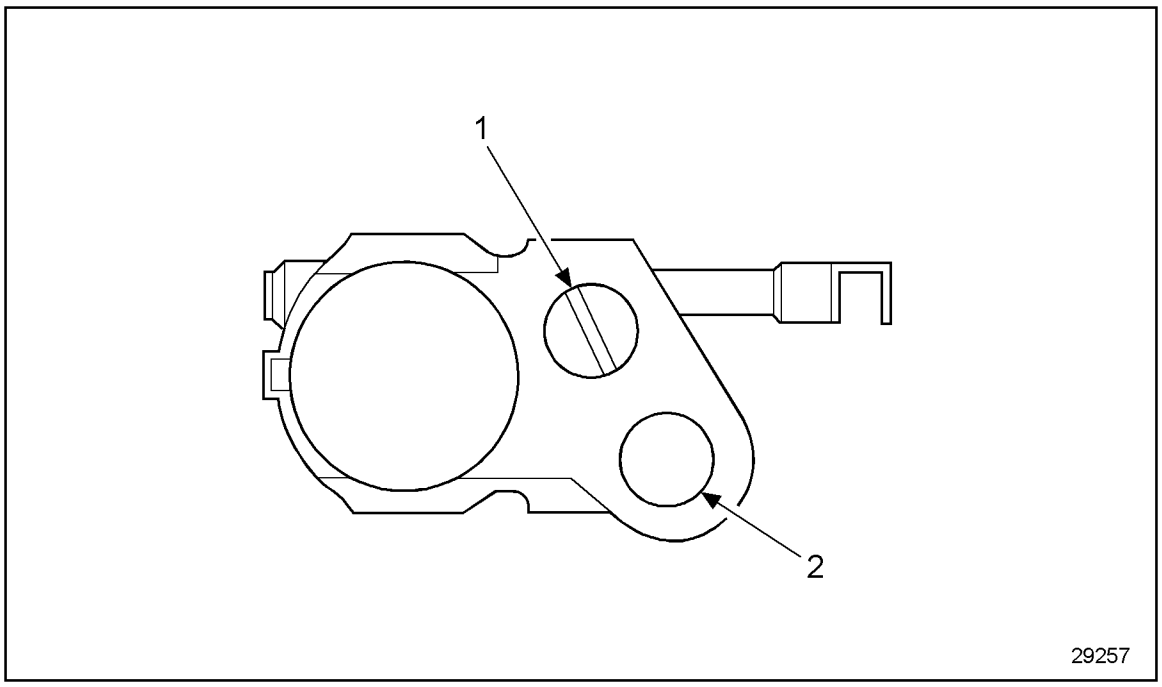
2.2.4 Assembly of Injector

Assemble the injector as follows:

1. Secure the body in vise J 22396-A.
2. Insert new filter in the top of the body.

NOTE:
The current production filter is installed dimple end down, slotted end up.

3. Insert a new filter in the inlet side of an offset injector. No filter is required at the outlet side. See Figure 2-24.



1. Inlet
2. Outlet

Offset injector filter required on inlet side only (above control rack)

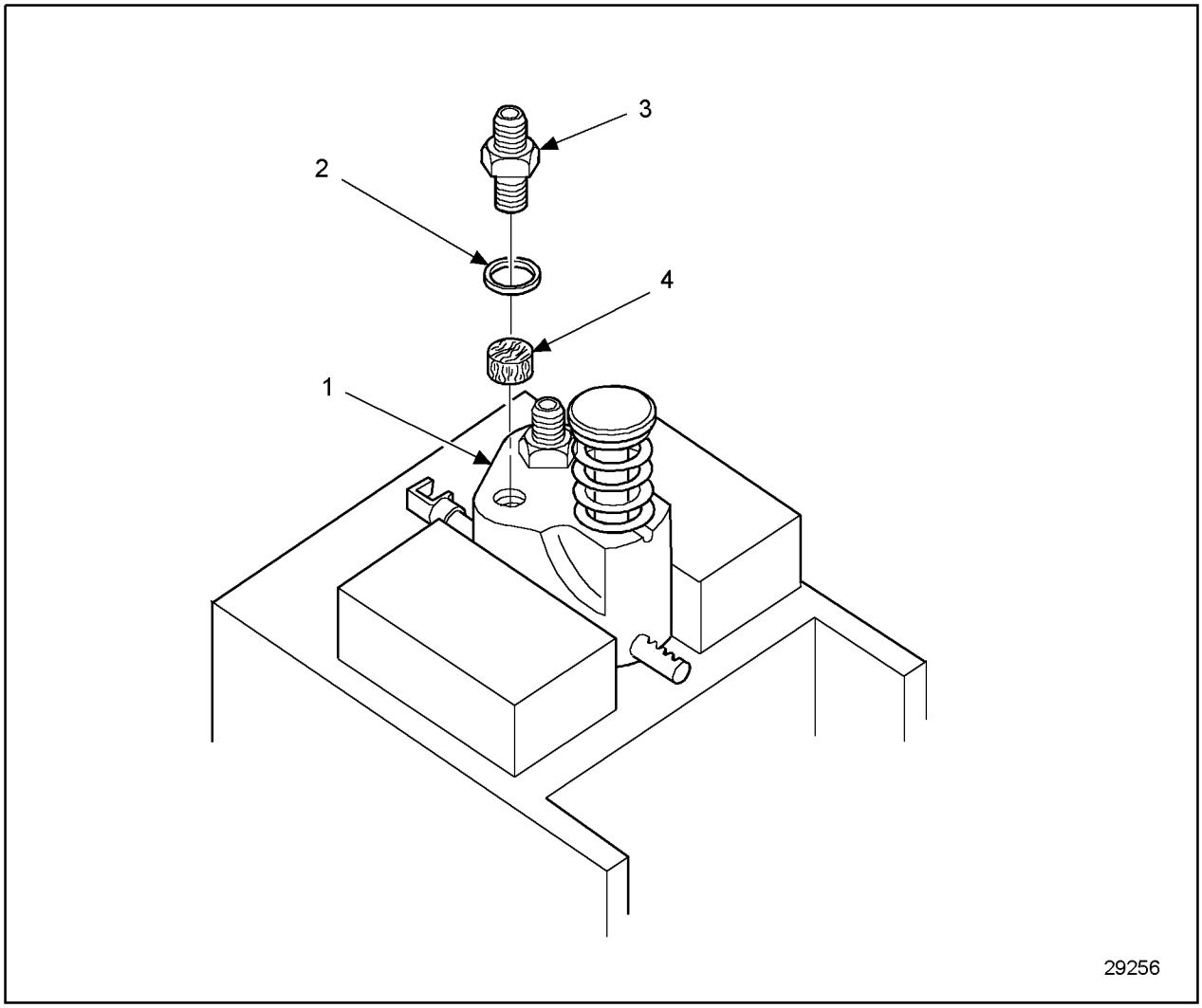
Figure 2-24 Location of Filter in Injector Body

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4. Place a new gasket on each filter cap. Lubricate the threads, and install the filter caps. Tighten the filter caps to 81-95 N·m (60-70 lb·ft) torque with a 9/16 in. deep socket. Listed in Table 2-2. See Figure 2-25.

Blued	Non-Blued	Mixed
81-95 N·m (60-70 lb·ft)	81-95 N·m (60-70 lb·ft)	81-95 N·m (60-70 lb·ft)

Table 2-2 Injector Components



1. Fuel Injector
2. Gasket
3. Filter Cap
4. Filter Element

Figure 2-25 Installing Filter Cap and Filter Element

5. Install clean shipping caps to protect the sealing surfaces and prevent dirt from entering the injector.

6. Lubricate the injector nut seal ring installer J 29197 with injector test oil.
7. Remove the injector from the vise, and hold the injector body, bottom end up. Place the installer over the threads of the injector body.
8. Lubricate the new seal ring. Place the new seal over the protector nose and onto the shoulder of the injector body.

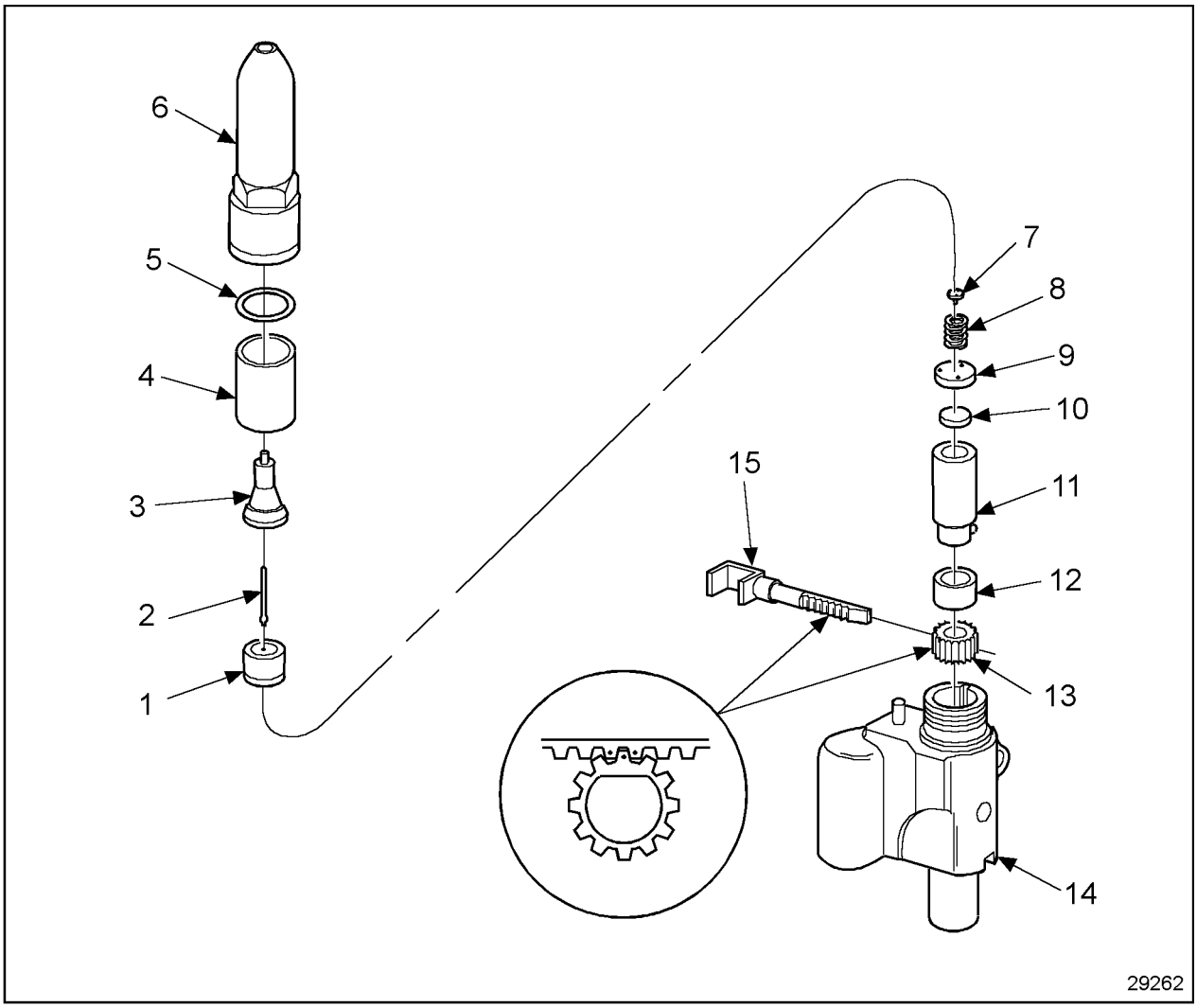
NOTE:
Do not allow the seal to roll or twist.

NOTE:
A new round (in cross-section) injector nut seal ring has replaced the former diamond-shaped ring. Only the round seal is serviced.

9. Remove the protector (J 29197).
10. Slide the control rack into the injector body.

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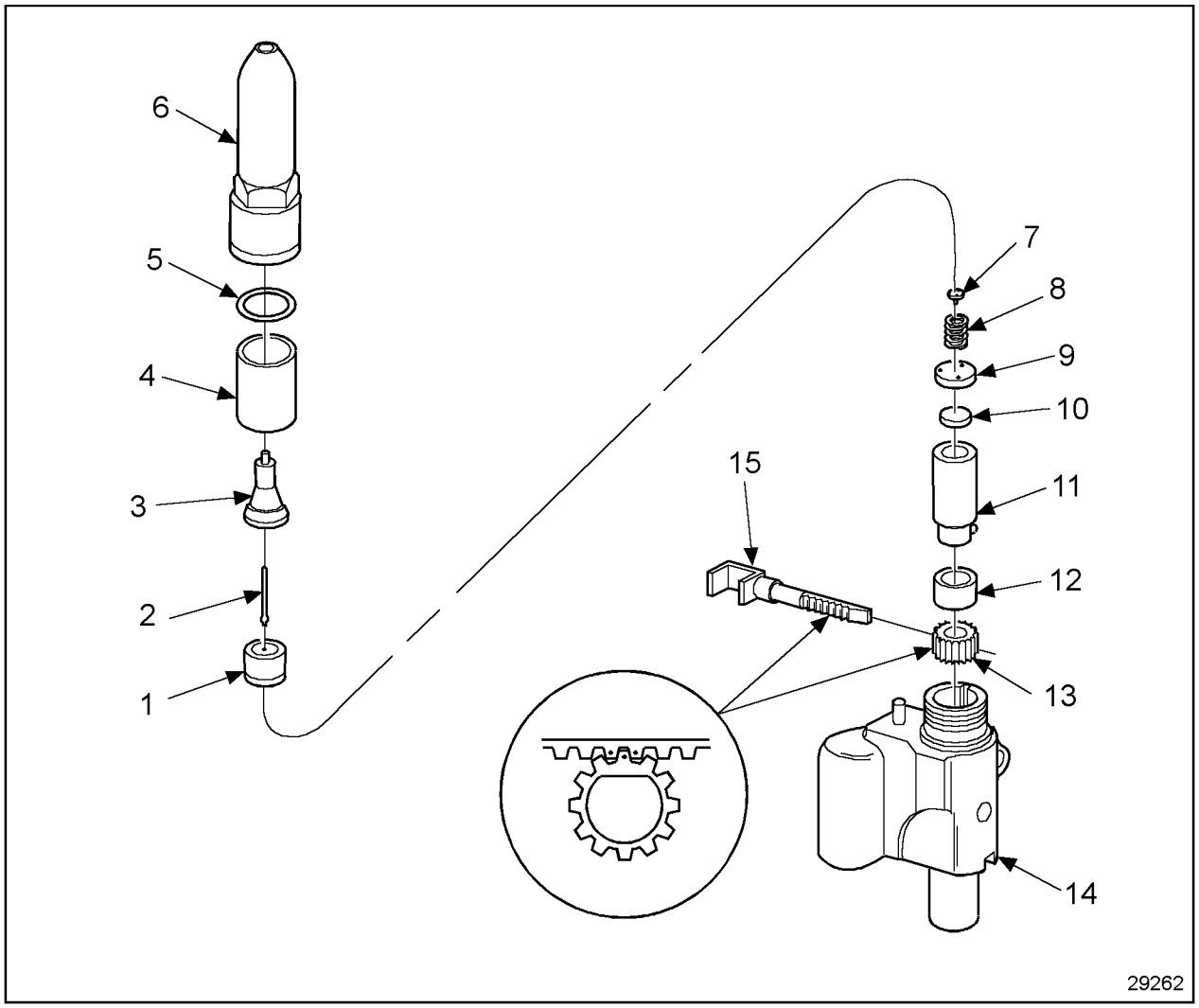
11. Observe the marked teeth on the control rack and gear. Look into the body bore, and move the rack until the drill marks are visible. Hold the rack in this position. See Figure 2-26.



1. Spring Cage
2. Needle Valve
3. Spray Tip
4. Spill Deflector
5. Seal Ring
6. Injector Nut
7. Spring Seat
8. Valve Spring
9. Check Valve Cage
10. Check Valve
11. Bushing
12. Gear Retainer
13. Gear
14. Injector Body
15. Control Rack

Figure 2-26 Injector Rack, Spray Tip and Valve Assembly

12. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack. See Figure 2-27.



1. Spring Cage
2. Needle Valve
3. Spray Tip
4. Spill Deflector
5. Seal Ring
6. Injector Nut
7. Spring Seat
8. Valve Spring
9. Check Valve Cage
10. Check Valve
11. Bushing
12. Gear Retainer
13. Gear
14. Injector Body
15. Control Rack

Figure 2-27 Injector Rack, Spray Tip and Valve Assembly

13. Place the gear retainer on top of the gear.

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14. Align the locating pin in the bushing with the slot in the injector body. Slide the end of the bushing into place.
15. Support the injector body, bottom end up, in injector vise J 22396-A.
16. Install the spill deflector over the bushing barrel.
17. Perform the spray tip test using injector tip tester J 22640-A before proceeding with the injector assembly. Refer to section ADDITIONAL INFORMATION.
18. Place the check valve [without the 0.25 mm (0.010 in.) hole] centrally on the top of the bushing. Place the check valve cage over the check valve and against the bushing.

NOTE:
The check valve cage must not rest on the check valve.

19. Insert the spring seat in the valve spring. Insert the assembly into the cage, spring seat first.
20. Place the spring cage, spring seat, and valve spring assembly (valve spring down) on top of the check valve cage.
21. Put the needle, tapered end down, into the spray tip. Place the spray tip assembly on top of the spring cage with the needle valve quill end in the spring cage hole.
22. Lubricate the threads in the injector nut, and hand thread the nut on the injector body.
23. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body.
24. Tighten the nut as tight as possible by hand.

NOTE:
There should be sufficient force on the spray tip to make it impossible to turn with finger.

25. Place injector in fixture tool J 4983-01.

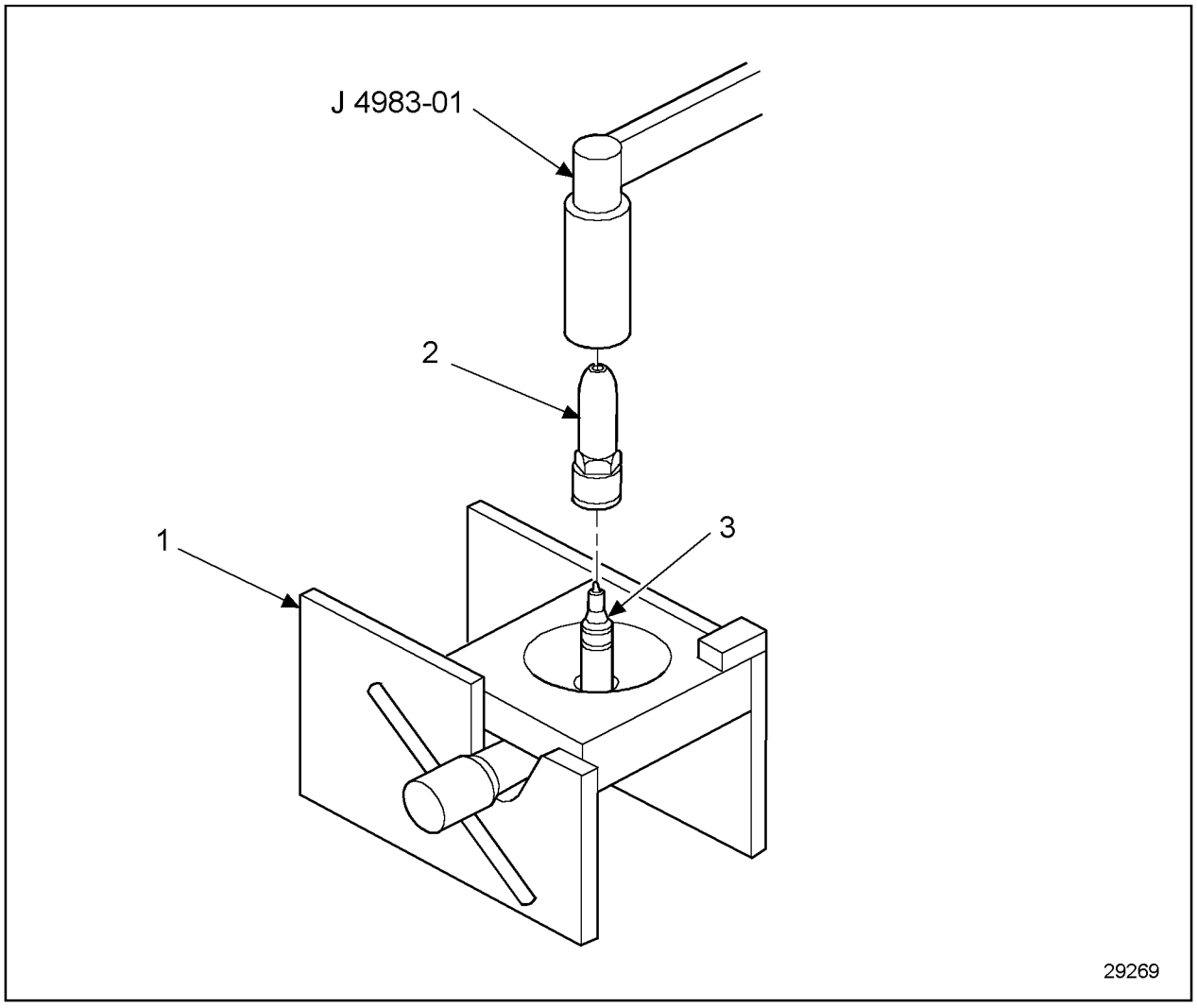
NOTICE:
Do not exceed the specified torque. The nut may be stretched and lapped surfaces will seal improperly in a subsequent injector overhaul.

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26. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 102-115 N·m (75-85 lb·ft) torque. Listed in Table 2-3 are the injector components. See Figure 2-28 for illustration.

Blued	Non-Blued	Mixed
95-115 N·m (70-85 lb·ft)	61-75 N·m (45-55 lb·ft)	95-115 N·m (70-85 lb·ft)

Table 2-3 Injector Components



1. Holding Fixture
2. Injector Nut
3. Spray Tip Assembly

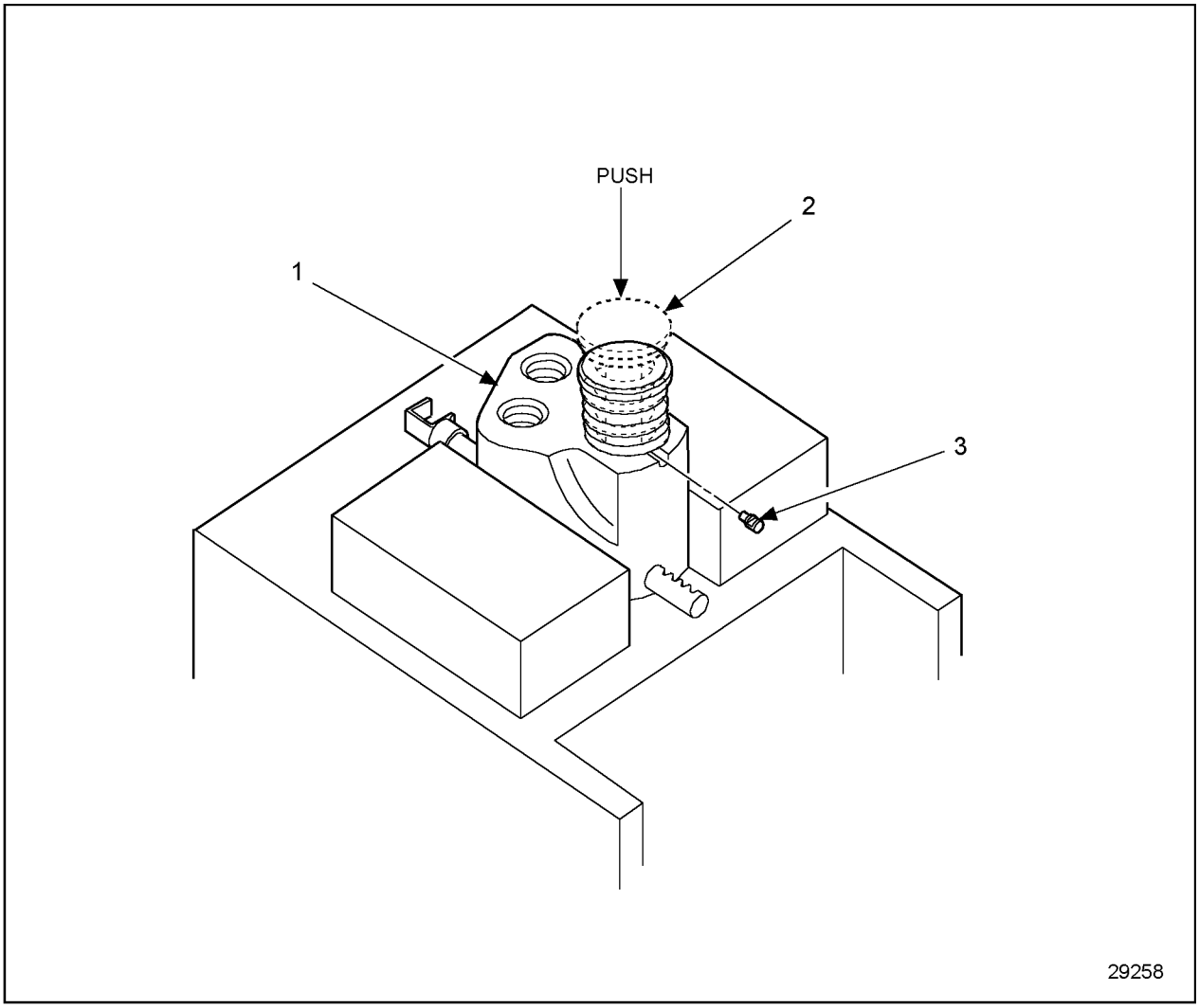
Figure 2-28 Torquing Injector Nut to Injector Body with Tool J 4983-01

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27. After assembling the fuel injector, check the area between the nut and the body.

NOTE:
If the seal is still visible after the nut is assembled, try another nut and a new seal that permits assembly without seal extrusion.

28. Turn the injector over, and push the rack in all the way.
29. Place the follower spring on the injector body.
30. Place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. See Figure 2-29.



1. Fuel Injector
2. Follower
3. Stop Pin

Figure 2-29 Installing Injector Follower Stop Pin

31. Slide the head of the plunger into the follower.

32. Align the slot in the follower with the stop pin hole in the injector body.
33. Align the flat side of the plunger with the flat in the gear.
34. Insert the free end of the plunger into the injector body. Press down on the follower, and simultaneously press the stop pin into position.

NOTE:
When in place, the spring will hold the stop pin in position.

2.2.4.1 Test Injector Fuel Output

Perform the injector fuel output test using calibrator J 22410. Refer to section ADDITIONAL INFORMATION.

NOTE:
If calibrator J 22410 is not available use updated calibrator J 39300. Tools used on these machines ***are not interchangeable***.

2.2.4.2 Test Injector Atomization and Spray

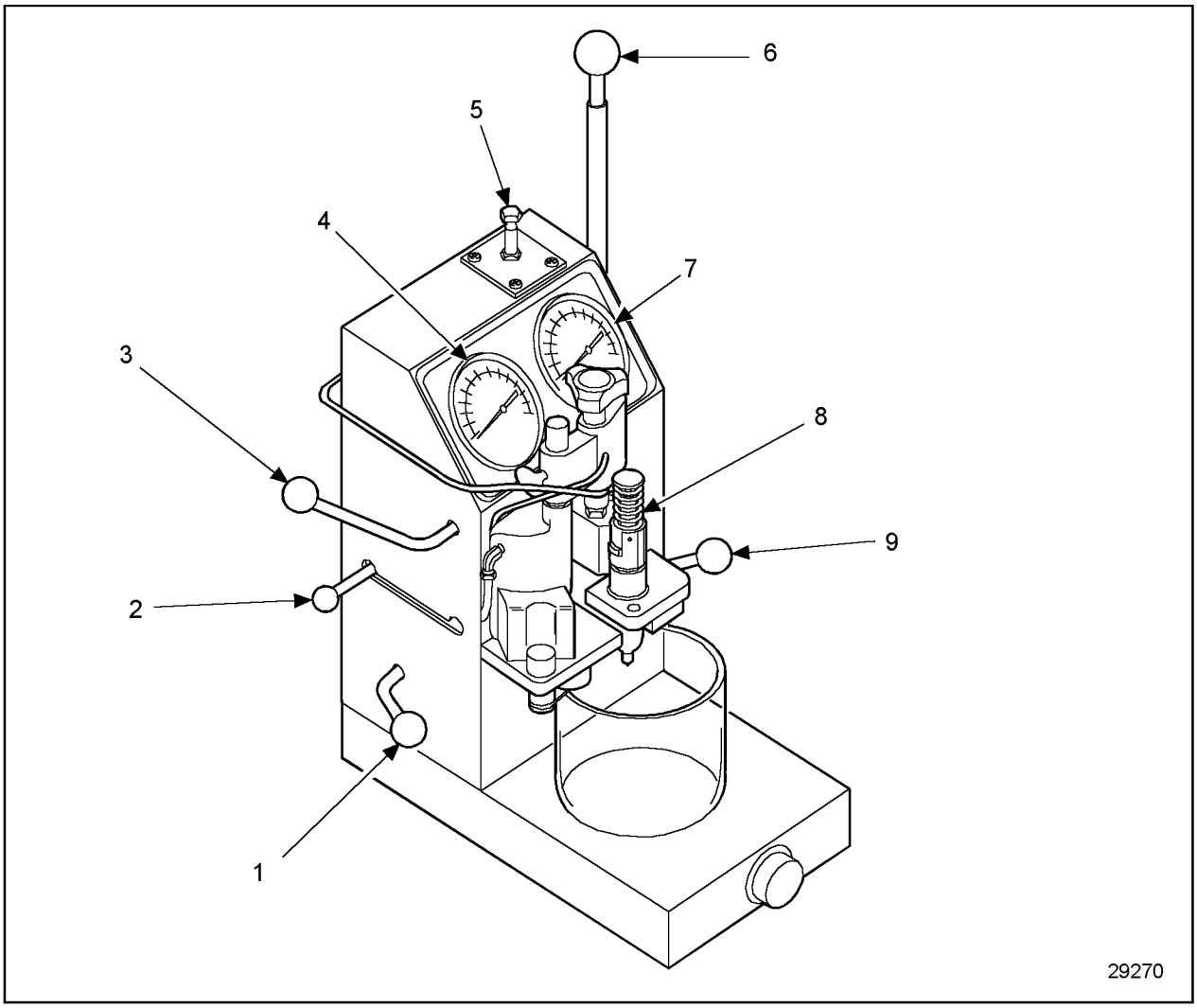
Test the injector atomization and spray using tool J 34760–150A from set J 34760-B as follows:

1. Clamp the injector, and purge the air from the system. See Figure 2-30.

NOTE:
Ensure a new filter has been installed in a reconditioned injector that is to be placed in stock. This precaution will prevent dirt particles from entering the injector.

NOTE:
Do not test new or *reliabilt* remanufactured unit injectors prior to installation in the engine. The Kent-Moore POP stand should only be used as a diagnostic tool on fuel injectors that have been *removed* from an engine.

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1. Lever 4 Up-Flow to Clamp; Down-Flow to Injector
2. Rocker Arm Engagement-Lever 3
3. Plunger Position Lever 2
4. Gage 1
5. Gage Dampening Valve
6. Pump Lever 1
7. Gage 2
8. Mechanical Unit Injector
9. Lever 5 Up-Valve Closed for Clamping; Down-Valve Open to Release Clamp

Figure 2-30 Injector in Position for Testing with Tester J 34760-150A

2. Move lever 4 down.
3. Position the injector rack in the full-fuel position.
4. Place pump lever 1 in the vertical position.
5. Move lever 3 to the forward position.

6. Using pump lever 1, depress the injector follower at 40 to 80 strokes per minute to simulate engine operation. Observe the spray pattern.

NOTE:
All spray orifices should be open and dispersing the test oil evenly. The beginning and ending of injection should be sharp, and the test oil should be finely atomized with no drops forming on the end of the tip.

2.2.4.3 Test Injector Pressure Holding and Leaks

Perform the pressure holding and leak test as follows:

NOTE:
This test determines if the body-to-bushing mating surfaces in the injector are sealing properly and indicates proper plunger-to-bushing fit.

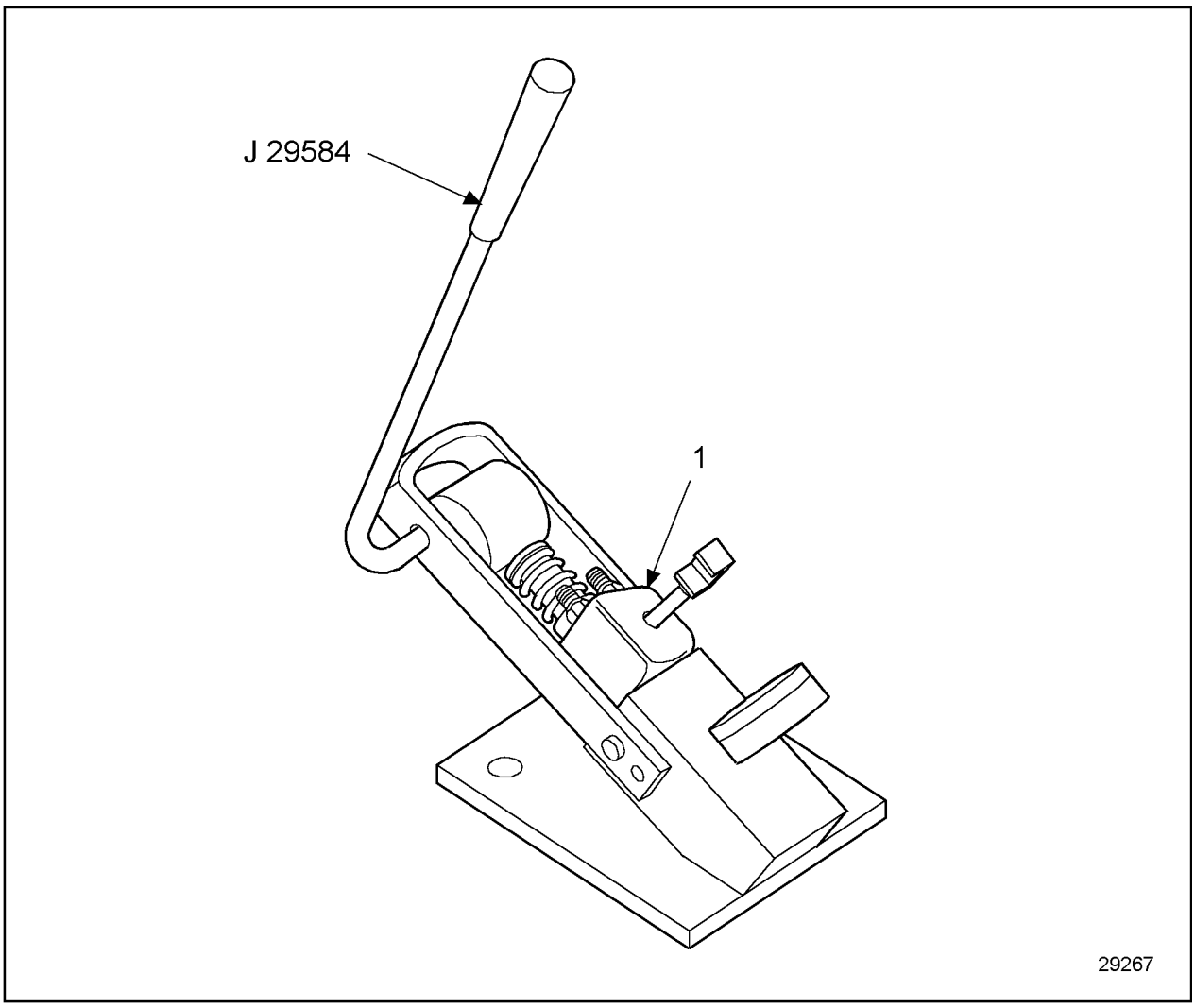
1. Clamp the injector into tester J 34760-150A (from set J 34760-B). Purge the air from the system.
2. Close the thru-flow valve, but do not over tighten.
3. Move lever 2 to the rear, horizontal position.
4. Operate pump lever until gage 1 reads approximately 4823 kPa (700 lb/in.^{2}), and time pressure drop between 3100-1723 kPa (450-250 lb/in.^{2}).
   [a] If pressure drop occurs in less than 15 seconds, leakage is excessive. Replace injector. Refer to section 2.2.5.
   [b] If the fuel injector passes the above tests, proceed with the fuel output test. Refer to section ADDITIONAL INFORMATION.
5. Unclamp the injector.
6. Open the thru-flow valve to release system pressure.
7. Move lever 5 down to release the clamping pressure.
8. Swing out the adaptor plate, and remove the injector after the nylon seals and the clamping head are free and clean of the injector filter caps.
9. Carefully return lever 5 to the up (horizontal) position.

2.2.4.4 Test of Injector Rack Movement

Test rack movement as follows:

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1. Place the injector in tester J 29584. See Figure 2-31. Check rack for freedom of movement.



1. Mechanical Unit Injector

Figure 2-31 Testing Injector with Tester J 29584

2. With the injector control rack held in the no-fuel position, operate the handle to depress the follower to the bottom of its stroke.
3. Very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel.
   [a] If the rack falls freely, the injector passes the test.
   [b] If the rack does not fall freely, loosen the injector nut, turn the tip, and tighten the nut. Loosen and tighten the nut a couple of times, if necessary.

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[c] If the rack does not move freely, change the injector nut. Refer to section 2.21.

NOTE:
It may be necessary to disassemble the injector to eliminate the cause of the misaligned parts, remove dirt or carbon in the nut or tip.

2.2.4.5 Test of Injector Spray Tip Alignment

Test the spray tip alignment as follows:

1. Place the injector in tester J 29584, and adjust the dial indicator to zero.
2. Rotate the injector 360 degrees, and note the total run-out indicated on the dial.
3. If the total run-out exceeds 0.20 mm (0.008 in.), remove the injector from the gage.
4. Loosen the injector nut, center the spray tip, and tighten the nut to 102-115 N·m (75-85 lb·ft) torque. Listed in Table 2-4 are the injector components.

Blued	Non-Blued	Mixed
95-115 N·m (70-85 lb·ft)	61-75 N·m (45-55 lb·ft)	95-115 N·m (70-85 lb·ft)

Table 2-4 Injector Components

5. Recheck the spray tip.
   [a] If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut. Refer to section 2.2.4.
   [b] If the spray tip passes the test, install the injector. Refer to section 2.2.5.

2.2.5 Installation of Mechanical Unit Injector

Prior to injector installation, perform the following steps:

NOTE:
Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will ensure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

1. Clean the injector tube.

NOTE:
Exercise care to remove ONLY the carbon, so that the proper tip protrusion is maintained.

2. Pack the reamer flutes with grease to retain the carbon removed from the tube.
3. The fuel injector must be filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

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1. Insert the injector into the injector tube with the dowel pin in the injector body registering with the cylinder head locating hole.
2. Slide the injector rack control lever over so that it registers with the injector rack.

NOTE:
Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

3. Install the injector clamp, washer (with curved side toward injector clamp), and bolt. Tighten the bolt to 27-34 N·m (20-25 lb·ft) torque.

NOTE:
Ensure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

NOTICE:
On four valve cylinder heads, exhaust valves may be damaged if the exhaust valve bridge is not resting on the ends of the exhaust valves when the rocker shaft bracket bolts are tightened. Refer to section 1.4. Note the position of the exhaust valve bridge before, during, and after tightening the rocker shaft bolts.

4. Move the rocker arm assembly into position. Tighten the bolts to secure the rocker arm brackets to the cylinder head. Refer to *General Information* for torque specifications.
5. Remove the shipping caps. Align the fuel pipes, and connect them to the injectors and the fuel connectors.

NOTE:
Because of their low friction surface, Endurion-coated nuts on fuel jumper lines must be tightened from 14.69-18.1 N·m (130-160 lb·in) torque, instead of the 18.3 N·m (160 lb·in) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix nuts on the same cylinder head. Jake Brake jumper lines and jumper lines used with load-limiting devices do not have coated nuts.

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6. Tighten fuel pipe nuts on jumper lines to the single values listed in Table 2-5. Use fuel line nut wrench J 8932-B and "clicker" type torque wrench J 24405 (calibrated in inch-pounds).

Jumper Line Usage	Torque
Endurion-coated	14.69-18.1 N·m (130-160 lb·in)
Uncoated	18.3 N·m (160 lb·in)
*Jacobs Brakes	13.6 N·m (120 lb·in)
Load Limiting Devices	18.3 N·m (160 lb·in)
DDEC Engines	16.16 N·m (143 lb·in)

* Not Serviced. Available from Jacobs Manufacturing Company.

Table 2-5 Torque Specifications for Jumper Line Usage

NOTE:
Low lubricating oil pressure or fuel odor coming from crankcase breather or an open filler cap might indicate fuel leaks at the fuel injector supply lines and connector nut seals. When these are detected, remove the valve rocker cover. Under normal conditions, lubricating oil should coat the cylinder head area and collect where the fuel pipes contact the connectors and the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, fuel oil is leaking and washing off the lubricating oil.

7. To correct, remove and replace the leaking fuel pipes and/or connectors.
8. Use a new gasket, and install the rocker cover.
9. Drain the lubricating oil, and change the oil filter elements.
10. Refill the crankcase to the proper level with the recommended grade of oil. Refer to section 13.5.1.
11. Refer to section 12.1 for complete engine tune-up.

NOTE:
If only one injector has been removed and replaced, and the other injectors and the governor adjustment have not been disturbed, only adjust the valve clearance, and time the injector for the one cylinder. Position the injector rack control lever.

12. Refer to section 12.3 for injector installation verification.

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2.3 ELECTRONIC UNIT INJECTOR

The Series 92 Electronic Unit Injector is a lightweight, compact unit that injects diesel fuel directly into the combustion chamber. See Figure 2-32. The amount of fuel injected and the beginning of injection timing is determined by the Electronic Control Module (ECM). The ECM sends a command pulse that activates the injector solenoid.

NOTE:
These modifications do not apply to the ethanol, methanol, or compressed natural gas engines.

The EUI performs four functions:

- Creates the high fuel pressure required for efficient injection.
- Meters and injects the precise amount of fuel required for engine load.
- Atomizes the fuel for mixing with the air in the combustion chamber.
- Permits continuous fuel flow to cool components.

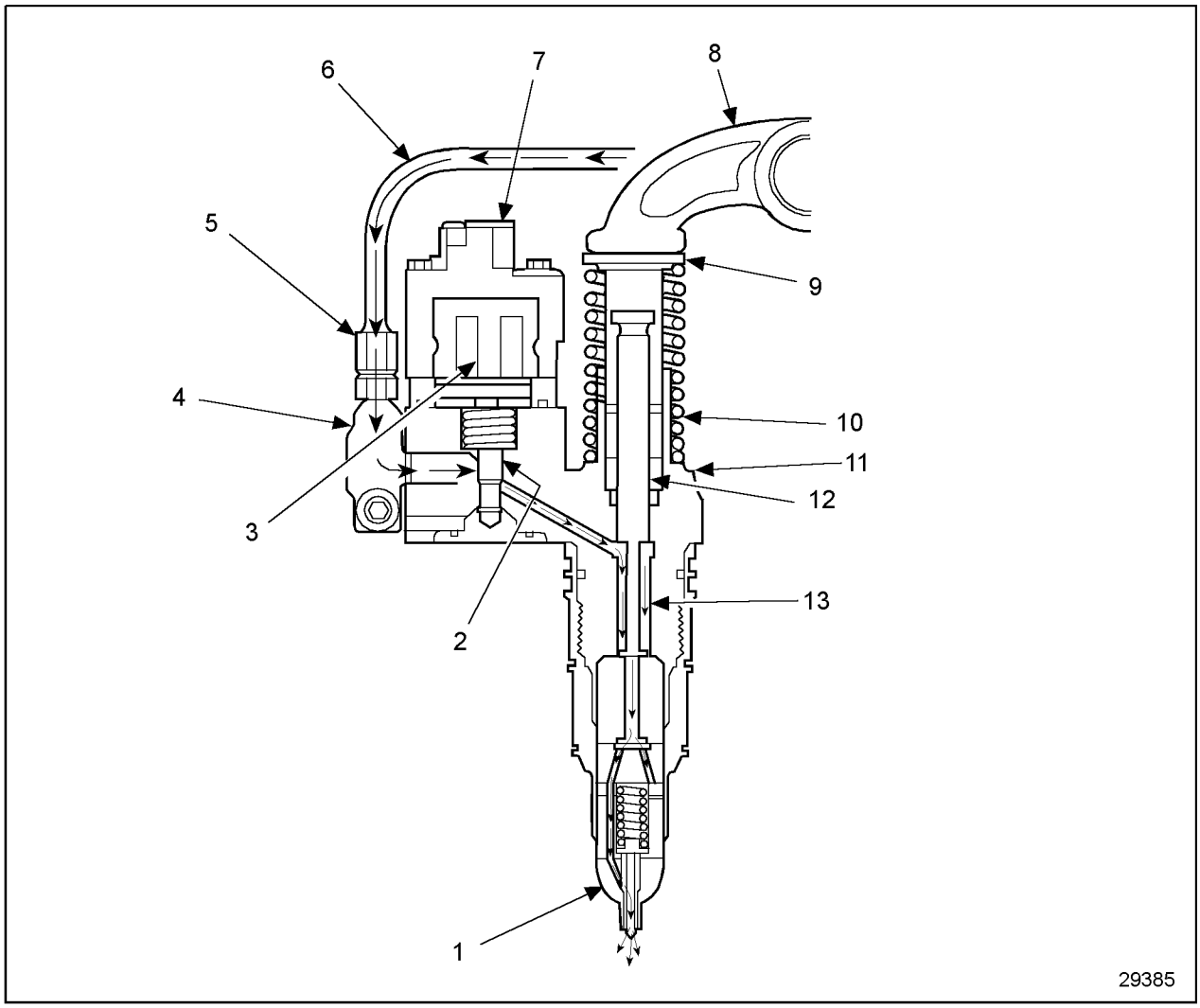
Engine combustion is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder. Metering and timing of the fuel is accomplished by the ECM, that actuates the solenoid poppet valve to stop the free flow of fuel through the injector. When the solenoid poppet valve closes, fuel is trapped in the injector body below the plunger. The continuous fuel flow through the injector prevents the formation of air pockets in the fuel system in addition to cooling those injector parts subjected to high combustion temperatures.

The EUI combines in a single unit, all of the parts necessary to provide complete and independent fuel injection at each cylinder.

NOTE:
Do not test new or *reliabilt* remanufactured electronic unit injectors prior to installation in the engine. The Kent-Moore POP stand should only be used as a diagnostic tool on fuel injectors that have been *removed* from an engine.

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After entering the inlet manifold, the fuel passes through a drilled passage into the poppet control valve and plunger area. See Figure 2-32.



1. Injector Nut and Spray Tip Assembly
2. Poppet Control Valve
3. Armature
4. Fuel Inlet/Outlet Manifold
5. Fuel Inlet/Outlet Fittings
6. Fuel Crossover Tube
7. Injector Solenoid
8. Rocker Arm
9. Injector Follower
10. Follower Spring
11. Injector Body
12. Plunger
13. Fuel Supply Chamber

Depicts only the fuel flow path of the combustible fuel. The fuel used for cooling the injector is not shown.

Figure 2-32 Cross Section of Electronic Unit Injector (Fuel Flow Operation)

The plunger operates up and down in the injector body bore. The motion of the rocker arm is transmitted to the plunger and follower that bears against the follower spring.

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On the compression stroke (during engine operation), as the piston moves approximately two-thirds of the way up in the cylinder, the injector cam lode begins to lift. This causes the injector rocker arm to push down on the follower and plunger. Just prior to injection, the ECM sends an electric pulse, that activates the injector solenoid. The energized solenoid creates a magnetic force that 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 high pressure cylinder gases from blowing back into the injector and fuel system.

This fuel pressure acts on the needle valve. When it creates a force high enough to overcome the needle valve spring force holding the needle valve 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 in the cylinder.

After the "pulse width" time has passed (measured in degrees of crankshaft rotation), 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 fuel pressure within the injector. When the pressure is low enough, the needle valve closes and ends injection.

The beginning of injection and fuel metering 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, is derived from fuel tables stored in the calibrating software of the ECM. The amount of pulse width 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 plunger cavity for another injection cycle. The constant circulation of fuel through the injector renews the fuel supply in the chamber and helps cool the injector.

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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 2-33.

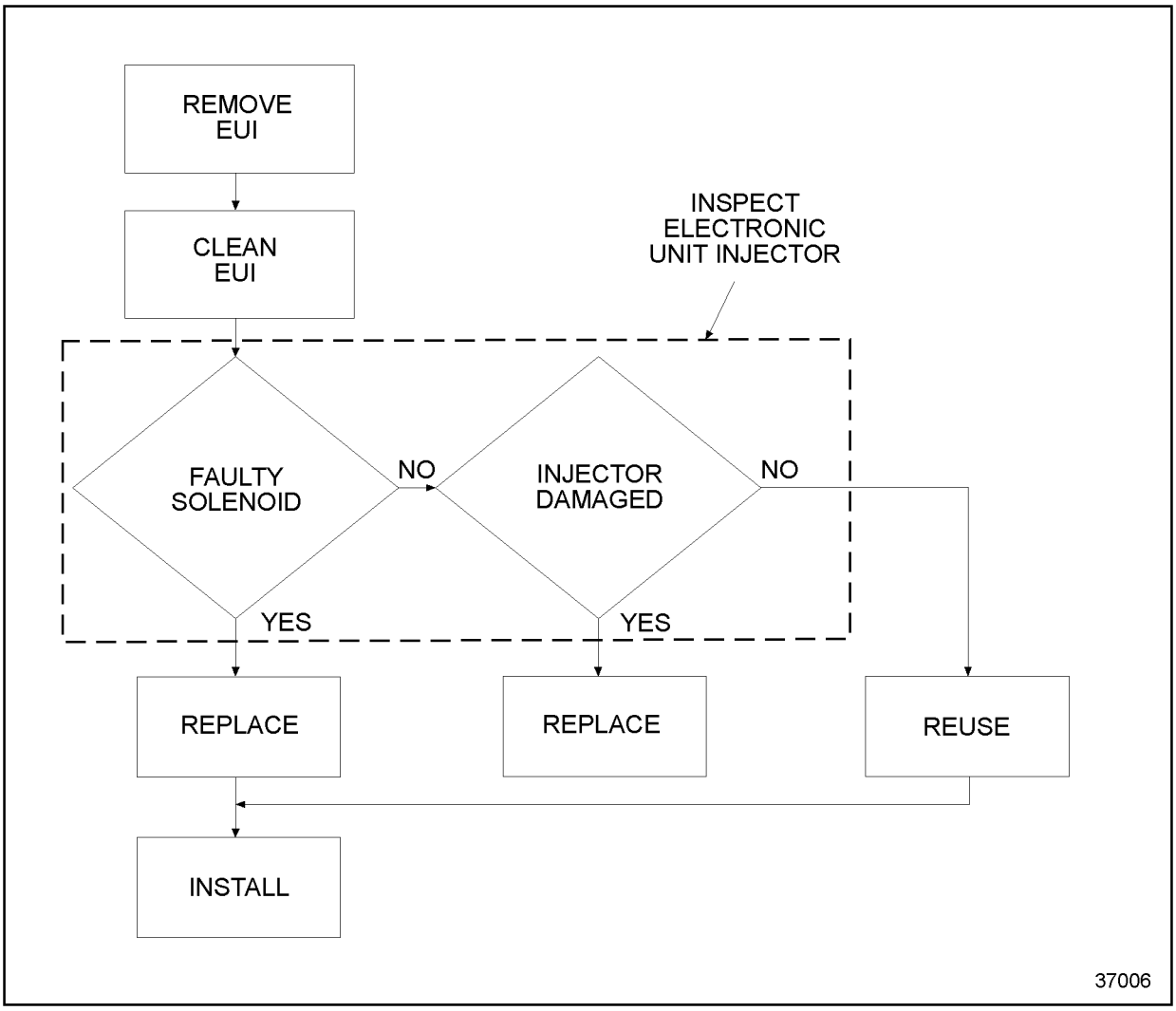


Figure 2-33 Flowchart for Repair or Replacement of Electronic Unit Injector

2.3.2 Removal of Electronic Unit Injector

Remove the electronic unit injector as follows:

1. Clean and remove the valve rocker cover. Refer to section 1.6.

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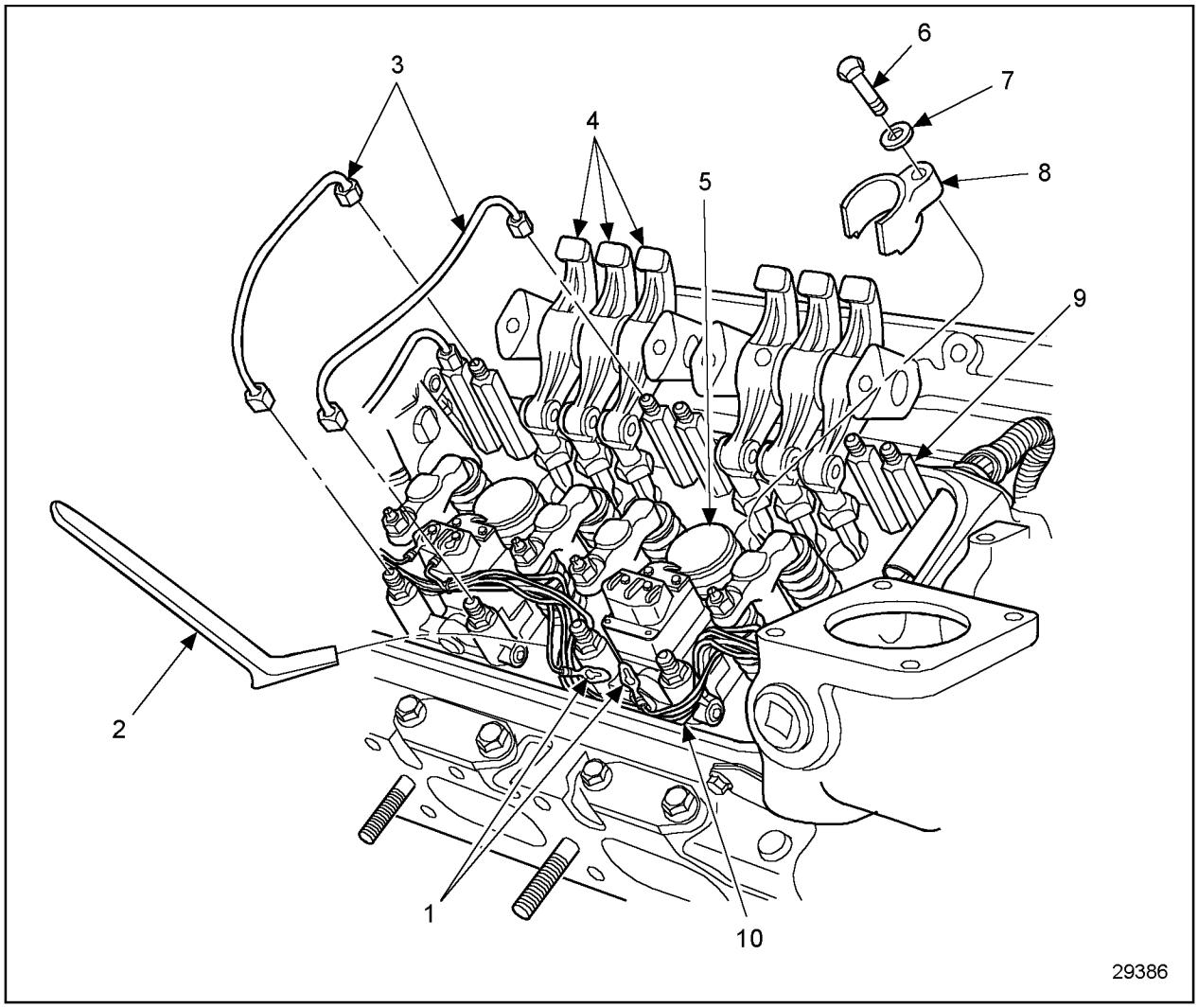
NOTICE:
Use caution to prevent damage to the fuel stand pipes and crossover lines during removal.

2. Remove the fuel inlet and outlet crossover lines from the injector and fuel stand pipes in the cylinder head.
3. Remove the two rocker shaft thru-bolts. Push the rocker shaft assembly back, away from the injector.
4. Loosen the injector wire terminal screws two full turns, and remove the terminal wires.

NOTICE:
Extreme care should be used when handling the EUI to avoid costly damage by dropping or mishandling the injector.

NOTICE:
Do not remove the terminal screws from the injector. The wire terminals have keyhole slots to fit over the screw head. Turning the screws too far will damage the threads in the injector solenoid housing.

5. Lift the injector from its seat in the cylinder head by inserting a pry bar under the injector body. See Figure 2-34.



1. Solenoid Terminal Leads
2. Pry Bar
3. Fuel Crossover Tubes
4. Rocker Arm Assemblies
5. Electronic Unit Injector
6. Hold Down Bolt
7. Washer
8. Hold Down Crab
9. EUI Electrical Harness
10. Fuel Stand Pipe

Figure 2-34 Removing Electronic Unit Injector

NOTE:
After removing an injector, cover the injector tube cavity in the cylinder head to keep out foreign material.

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2.3.2.1 Cleaning of Electronic Unit Injector

Clean the EUI as follows:

NOTICE:
To avoid damaging them, do not wire brush the spray holes.

1. Using wire buffing wheel J 7944, remove carbon from the injector exterior, where the injector tip joins the nut.
2. Clean the injector exterior with clean solvent.

⚠ 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 it with compressed air.

2.3.3 Disassembly of Electronic Unit Injector

On a Series 92 EUI, only the injector solenoid and seal rings *are not serviceable*. The injector must not be disassembled.

2.3.3.1 Inspection of Electronic Unit Injector

Inspect the EUI as follows:

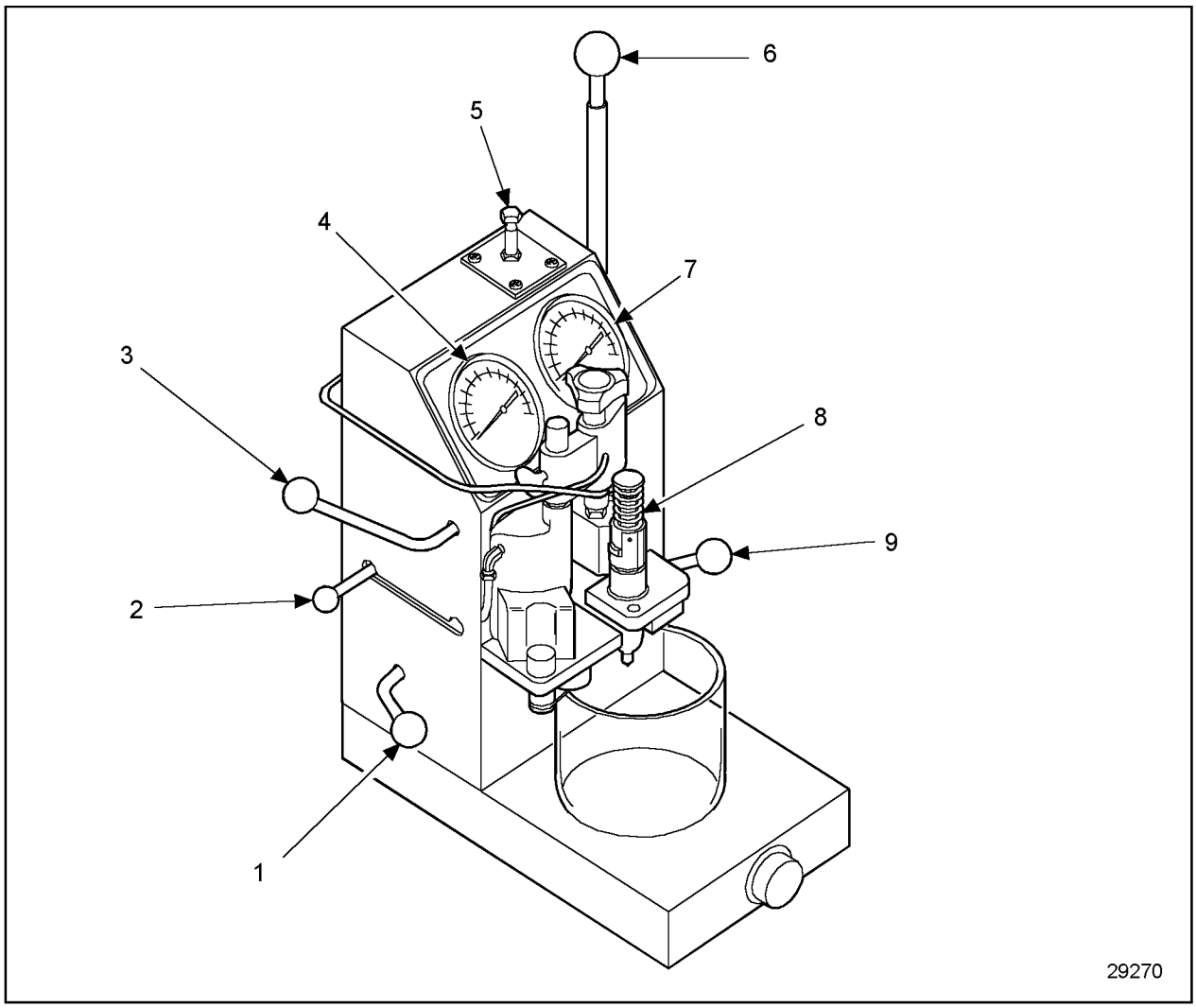
1. Install tool J 34760-147A (from set J 34760-B) injector pop-n-fixture, and test the injector. See Figure 2-35.

NOTE:
Do not test new or *reliabilt* remanufactured electronic unit injectors prior to installation in the engine. The Kent-Moore POP stand should only be used as a diagnostic tool on fuel injectors that have been *removed* from an engine.

[a] If necessary, replace the solenoid. Refer to section 2.3.4.

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[b] If the injector is performing satisfactorily, it may be reused. Proceed with inspection.



1. Lever 4 Up-Flow to Clamp; Down-Flow to Injector
2. Rocker Arm Engagement-Lever 3
3. Plunger Position-Lever 2
4. Gage 1
5. Gage Dampening Valve
6. Pump Lever 1
7. Gage 2
8. Electrical Unit Injector
9. Lever 5 Up-Valve Closed for Clamping; Down-Valve Open to Release Clamp

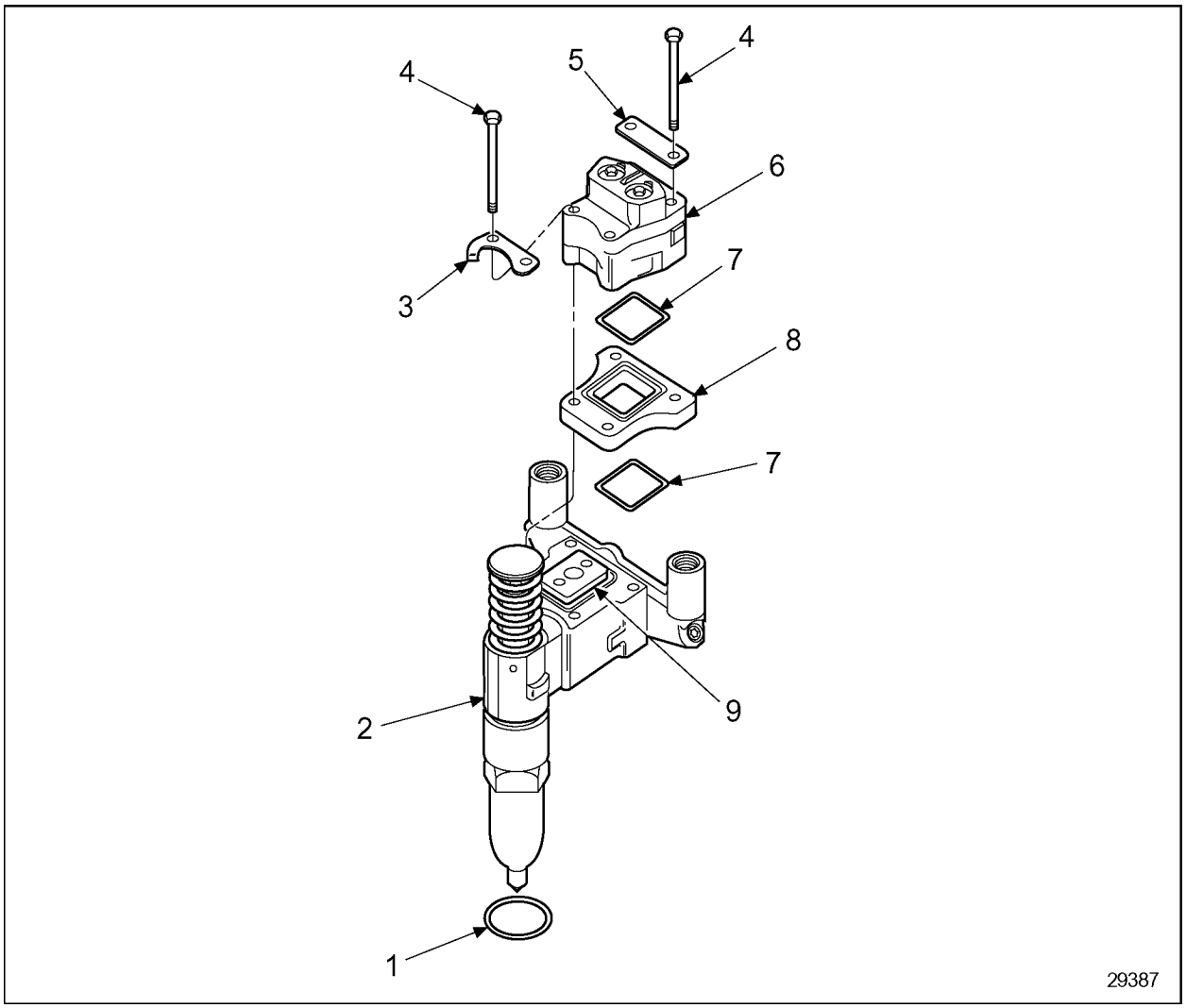
Figure 2-35 Injector in Position for Testing with Tester J 34760-147A from Set J 34760-B

2. Visually inspect the O-ring for damage, cuts, nicks or deterioration. See Figure 2-36.

[a] If damaged, replace the O-ring. Refer to section 2.3.4.

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[b] If undamaged, the O-ring may be reused. Proceed with inspection.



1. O-ring Seal
2. Electronic Unit Body
3. Follower Spring Stop
4. Solenoid Bolts (4)
5. Load Plate
6. Solenoid
7. Solenoid Seal (2)
8. Spacer Plate
9. Armature

Figure 2-36 Inspection of Electronic Unit Injector

3. Visually inspect the injector tubes in the cylinder head for evidence of coolant leaks or damage at the injector seat.

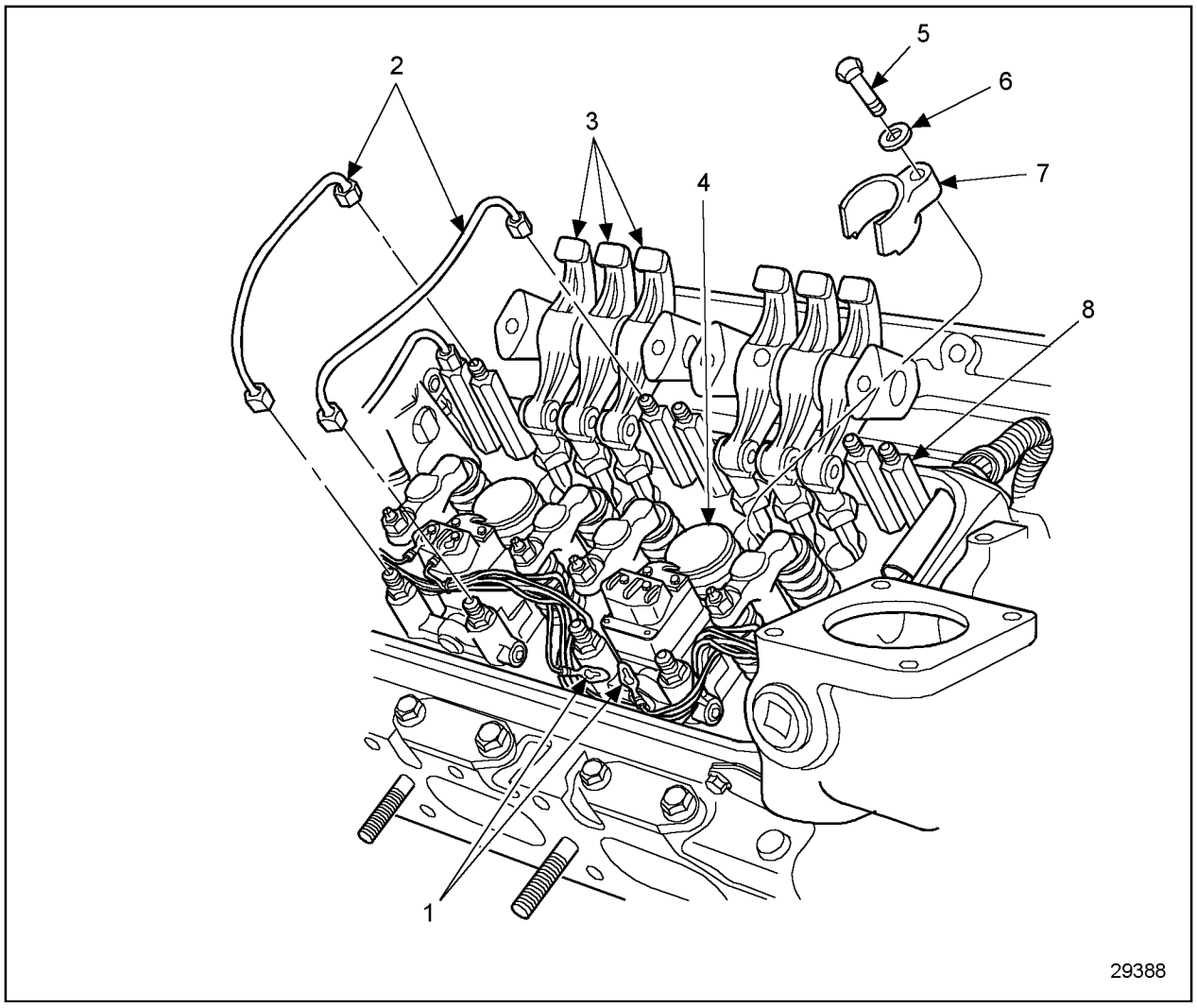
   [a] If damaged, replace the injector tubes. Refer to section 2.4.3.

   [b] If undamaged, the injector may be installed.

2.3.4 Installation of Electronic Unit Injector

Install the electronic unit injector as follows:

1. Insert the injector into the appropriate injector tube bore. See Figure 2-37.



1. Solenoid Terminal Leads
2. Fuel Crossover Tubes
3. Rocker Arm Assemblies
4. Electronic Unit injector
5. Hold Down Bolt
6. Washer
7. Hold Down Crab
8. Fuel Stand Pipe

Figure 2-37 Installation of Electronic Unit Injector

2. Visually align the injector body for equal clearance between the valve springs.

NOTE:
There is no locating dowel pin on the underside of the EUI.

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3. After aligning the injector, seat the injector by pressing down on the top of the injector with the heel of your hand.
4. Tighten the injector crab bolt to 27.12-33.9 N·m (20-25 lb·ft).
5. Tighten the rocker shaft bolts to 122-135.6 N·m (90-100 lb·ft).
6. Tighten the jumper tube nuts to 16.16 N·m (143 lb·in.).

NOTE:
Make sure O-ring seals are in place at the end of each jumper tube nut.

7. Set the injector timing. Refer to section 12.3.
8. Adjust valve clearances. Refer to section 12.2.
9. Install the EUI terminal wires by positioning the keyhole in the terminal over the screw in the injector solenoid housing.
10. Pull the terminal end down so that the screw rests in the smaller slot in the terminal.
11. Tighten the screws to 1.36-1.92 N·m (12-17 lb·in).

NOTE:
Do not bend the terminals down after installation.

12. With rocker arms in place, install the rocker arm shafts. Refer to section 1.4.9.
13. Adjust the intake and exhaust valve clearances and injector height. Refer to section 12.2.
14. Install the rocker cover. Refer to section 1.6.5.

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2.4 FUEL INJECTOR TUBE

The bore in the cylinder head (for the fuel injector) is directly through the cylinder head water jacket. See Figure 2-39.

NOTICE:
Only ethylene glycol base antifreeze should be used in Detroit Diesel engines. Methyl alcohol base antifreeze has an adverse effect on the fluoroelastomer seal rings in the cylinder head.

To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create watertight and gastight joints at the top and bottom.

The large Inside diameter (30.4292-30.5054 mm vs. 29.972-30.0482 mm or 1.198-1.201 in. vs. 1.180-1.183 in.), the Detroit Diesel logo, and the number "606" stamped on the top flange distinguishes the injector hole tube from the former.

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2.4.1 Repair or Replacement of Fuel Injector Tube

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-38.

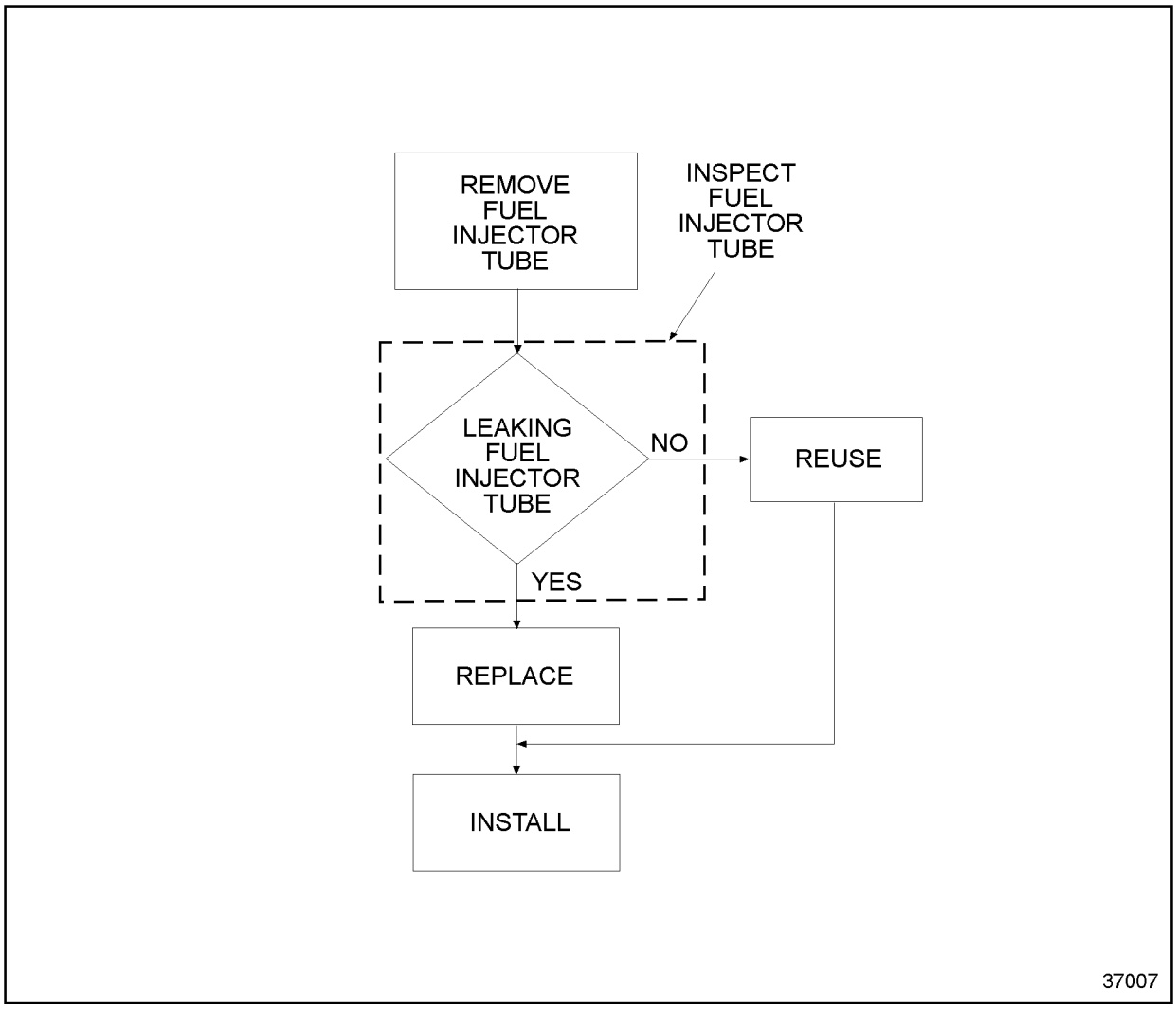


Figure 2-38 Flowchart for Repair or Replacement of Fuel Injector Tube

2.4.2 Removal of Fuel Injector Tube

Use injector tube service tool set J 22525-B to remove the injector tube as follows:

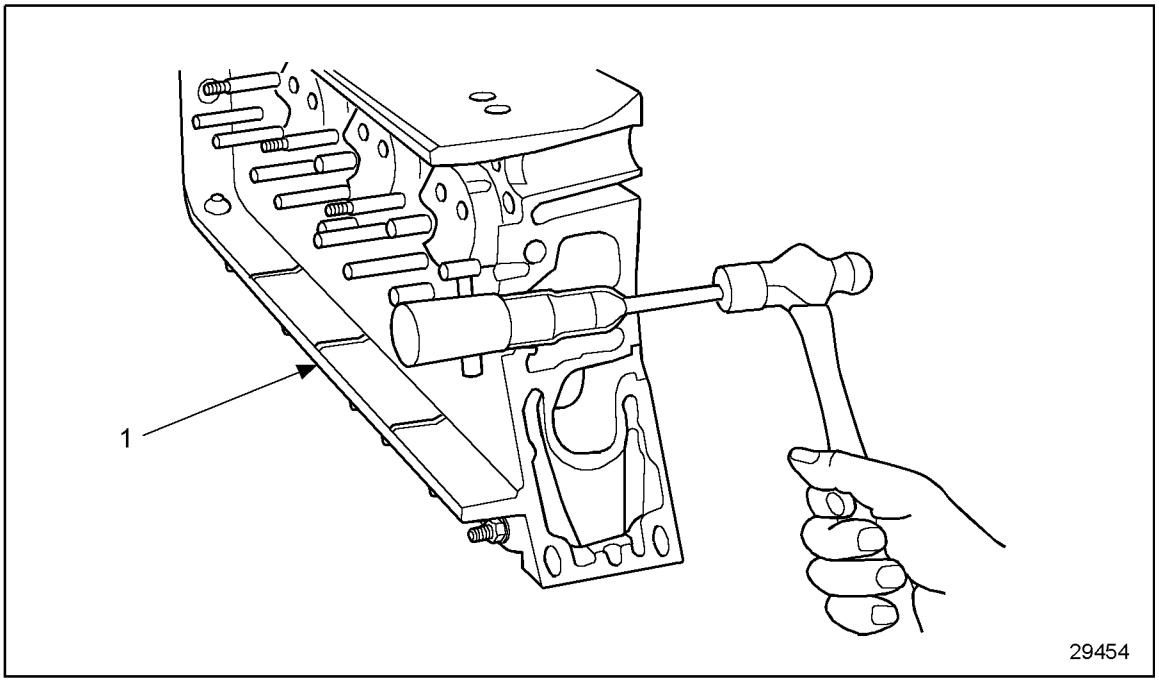
1. Remove, disassemble, and clean the cylinder head. Refer to section 1.3.

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2. Place the injector tube installer J 5286-4C (from set J 22525-B in the injector tube.

NOTE:
This tool or installer J 5286-4C (from set J 22525-B) may be used with semi-finished, service-only injector hole tubes (identified by the number "606" stamped on the top flange).

3. Insert the pilot J 5286-5 (from set J 22525-B) through the small opening of the injector tube, and thread the pilot into the tapped hole in the end of the installer. See Figure 2-39.



1. Cylinder Head

Figure 2-39 Removing Injector Tube with Tools J 5286-4C and J 5286-5 from Set J 22525-B

4. Tap the end of the pilot to loosen the injector tube.
5. Lift the injector tube, installer, and pilot from the cylinder head.

2.4.2.1 Inspection of Fuel Injector Tube

Inspect the fuel injector tube as follows:

1. Inspect the fuel injector tube for leaks.
   [a] If a leak is detected, seal the injector tube leak. Refer to section ADDITIONAL INFORMATION.
   [b] If no leaks are detected, reuse the fuel injector tube.

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2.4.3 Installation of Fuel Injector Tube

Install the fuel injector tube as follows:

1. Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end.

NOTICE:

DO NOT lubricate the outside of the injector tube or inside the cylinder head injector tube bore. Lubricant will cause the tube to turn during reaming or rolling operations and possibly damage the injector tube or reamers.

⚠ CAUTION:

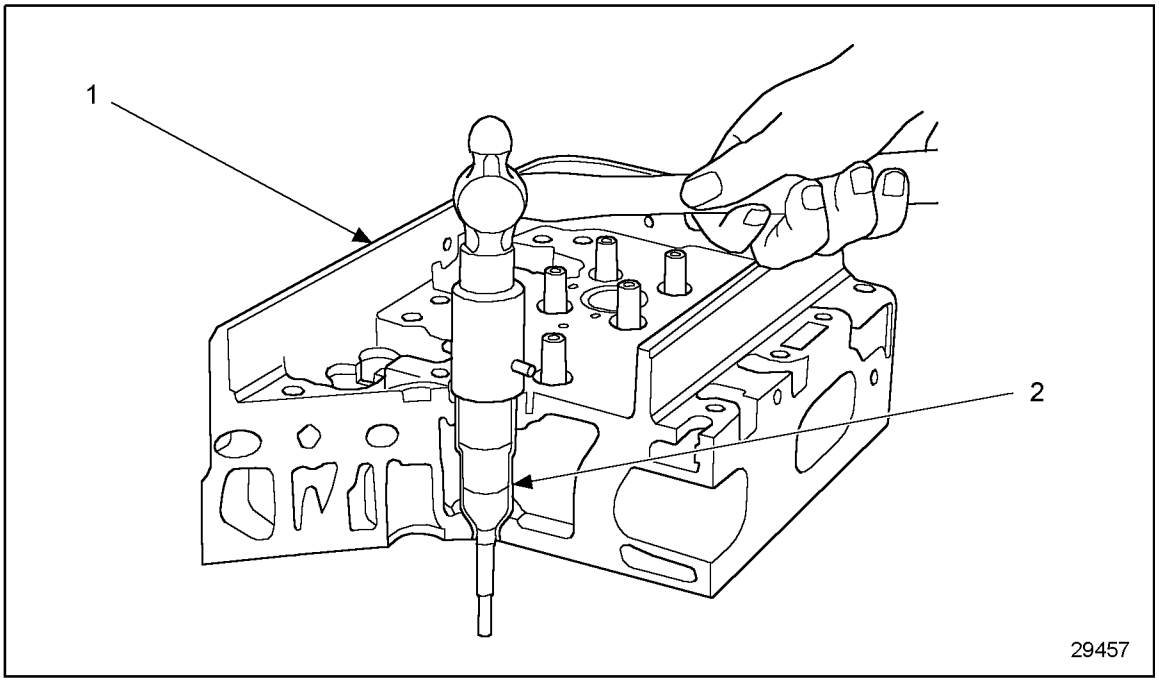
To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

2. Lubricate the new injector tube seal ring with engine oil, and place it in the counterbore in the cylinder head.

3. Place the installer J 5286-4C (from set J 22525-B) in the injector tube. Insert the pilot J 5286-6 (from set J 22525-B) through the small opening of the injector tube, and thread it into the tapped end of the installer. See Figure 2-40.



1. Cylinder Head
2. Fuel Injector Tube

Figure 2-40 Installing Injector Tube with Tools J 5286-4C and J 5286-5 from Set J 22525-B

NOTE:
For proper installation of any injector tube, the tool must contact the tube at the bottom before it touches the flange at the top. The clearance at the top, between the flange and the tool, should be 0.025-0.254 mm (0.001-0.010 in.).

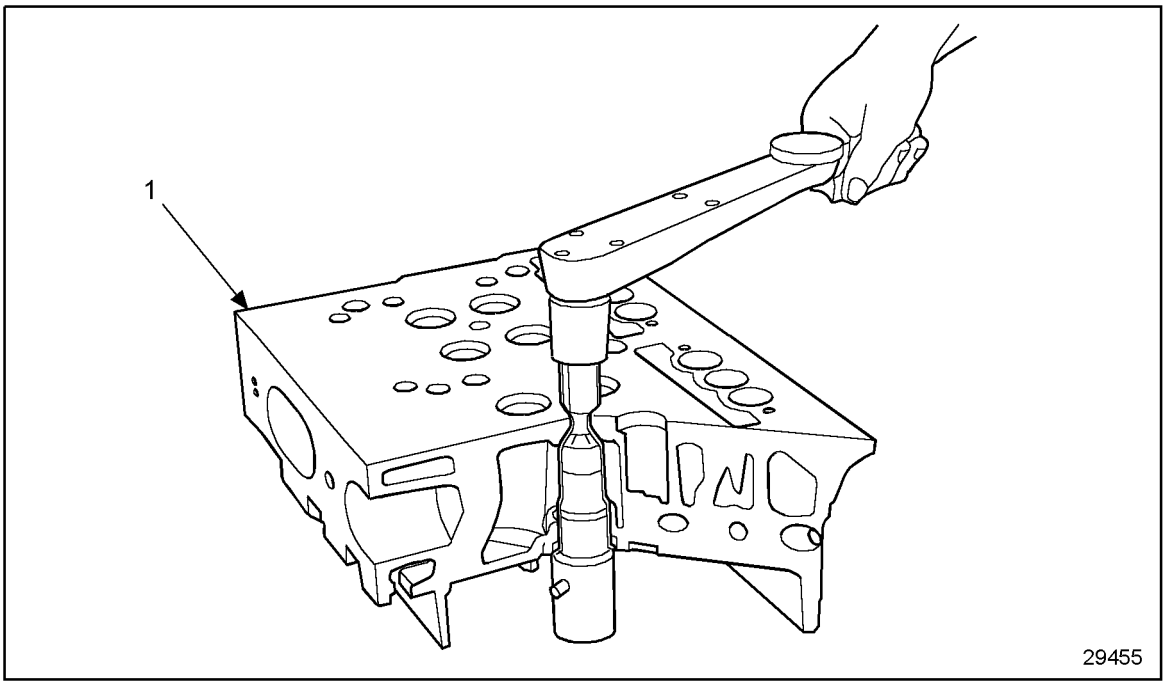
4. Slip the injector tube into the injector bore, and drive it in place.

NOTE:
Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is used to retain the seal ring.

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NOTICE:
During installation, the tube will stretch slightly before the tool contacts the flange, allowing the tool to properly install the tube. If there is no clearance at the flange, the tube will buckle slightly during installation until the tool contacts the tube at the lower end. The buckling causes compressive stress, that will allow the tube to crack during engine operation, subsequently causing engine damage.

5. Turn the cylinder head bottom side up, remove the pilot J 5286-5 (from set J 22525-B), and thread tool J 5286-6 (from set J 22525-B) into the tapped end of the installer J 5286-4C (from setJ 22525-B). See Figure 2-41.



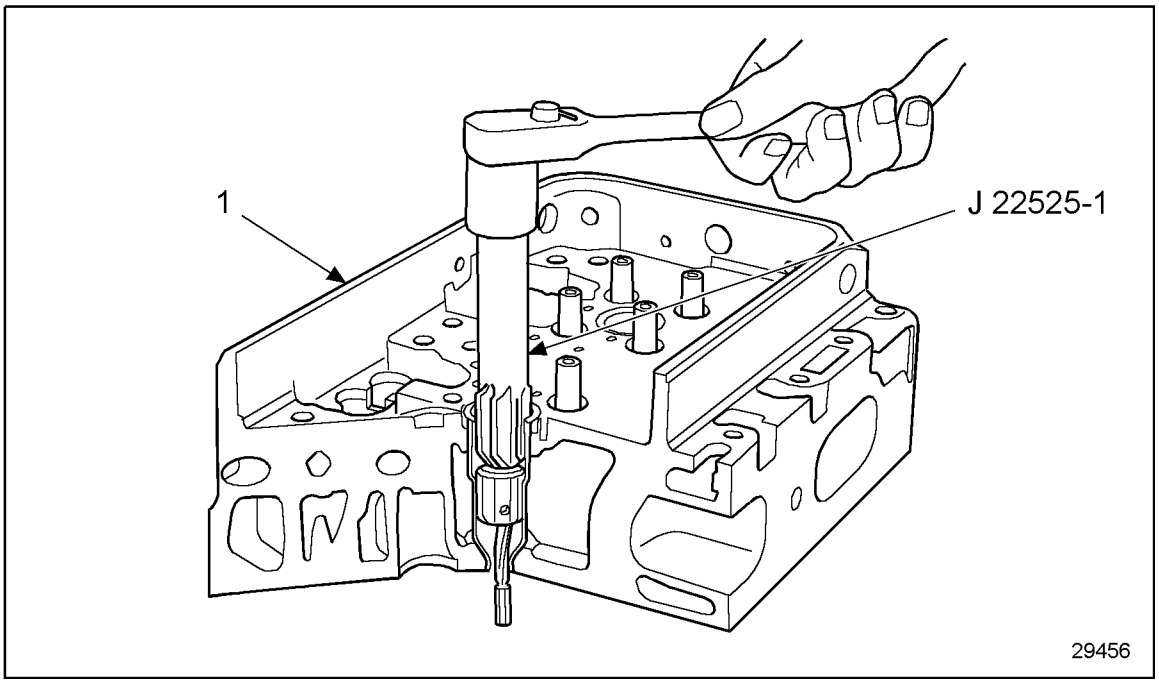
1. Cylinder Head

Figure 2-41 Upsetting Injector Tube with Tools J 5286-4C and J 5286-6 from Set J 22525-B

6. Using a socket and torque wrench, apply approximately 41 N·m (30 lb·ft) torque on the die.
7. Remove the installing tools.

NOTICE:
The current tube takes less time to install than the former tube because the large inside diameter of the new tube does not require reaming. Reaming is only necessary at the small inside diameter and the injector nut seat. To avoid cutting through the thin wall of the injector tube, do not ream forcefully or rapidly.

NOTE:
With the cylinder head right side up and the injector tube free from dirt, hand ream to receive the injector body nut and spray tip. See Figure 2-42.



1. Cylinder Head

Figure 2-42 Reaming Injector Tube for Injector Body Nut and Spray Tip with Tool J 22525-1 from Set J 22525-B

8. Place a few drops of light cutting oil on the reamer flutes, and position the reamer J 22525-1 (from set J 22525-B) in the injector tube.

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NOTICE:
The reamer should be turned in a clockwise direction only, both when inserting and when withdrawing the reamer. Movement in the opposite direction will dull the cutting edges of the flutes.

9. Turn the reamer clockwise (withdrawing the reamer frequently for chip removal) until the lower shoulder of the reamer contacts the injector tube.
10. Clean out all of the chips.
11. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 (from set J 22525-B) into the small hole of the injector tube.
12. Place a few drops of cutting oil on the tool. Using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to 0.13 mm (0.005 in.) below the finished surface of the cylinder head.
13. Wash the interior of the injector tube with clean solvent.

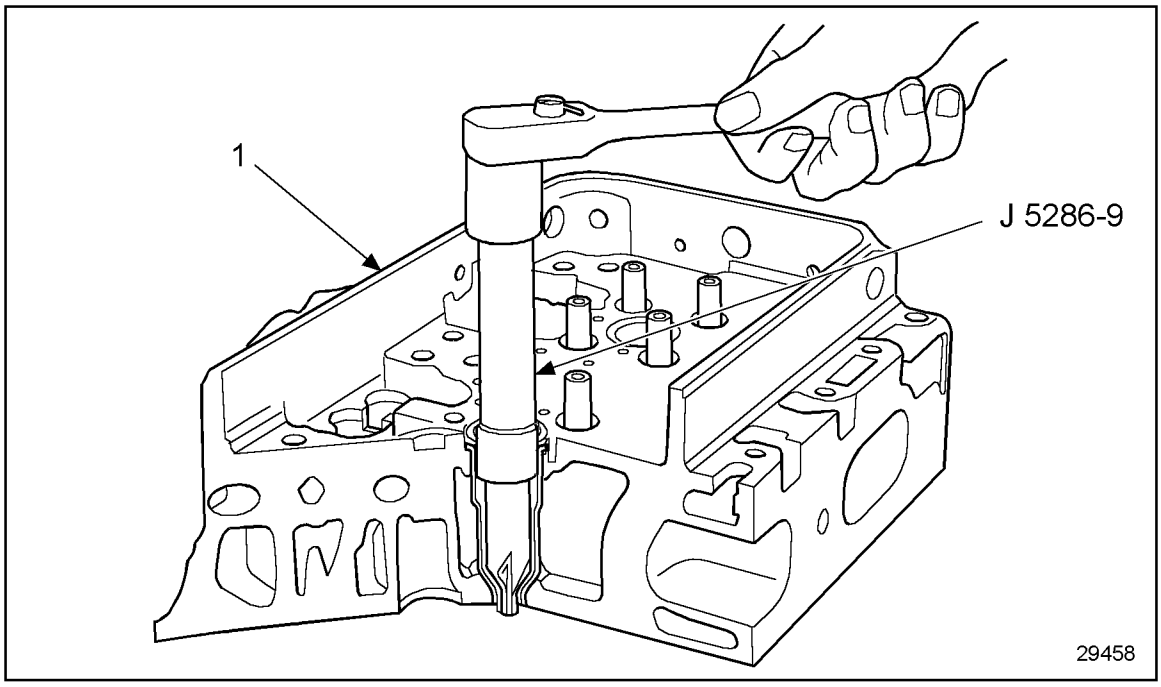
⚠ CAUTION:

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.

14. Dry it with compressed air.

NOTE:
Any firedeck resurfacing work must be done prior to final injector tube seat gaging. Refer to section 1.3.3.1 for resurfacing instructions.

NOTE:
Hand ream the tube to provide a good seating surface for the bevel and the lower end of the injector nut. See Figure 2-43.



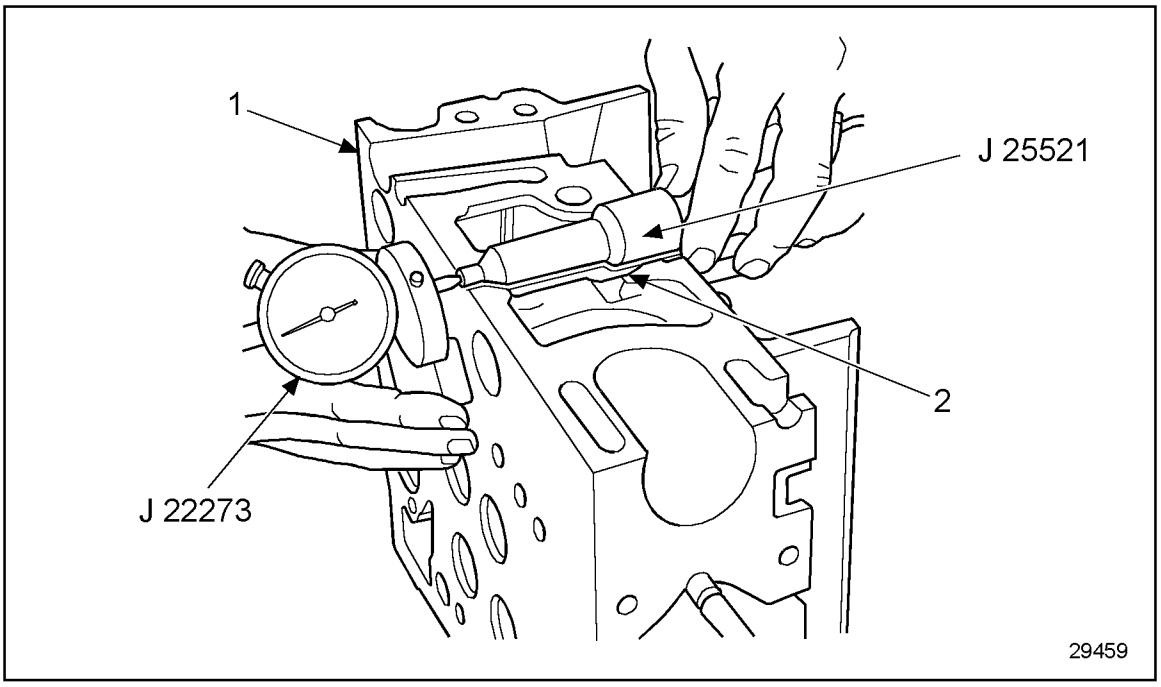
1. Cylinder Head

Figure 2-43 Reaming Injector Tube for Injector Nut with Tool J 5286-9C from Set J 22525-B

15. 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

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the injector tip in the combustion chamber. Determine the amount of stock that must be reamed from the bevel seat of the tube. See Figure 2-44.

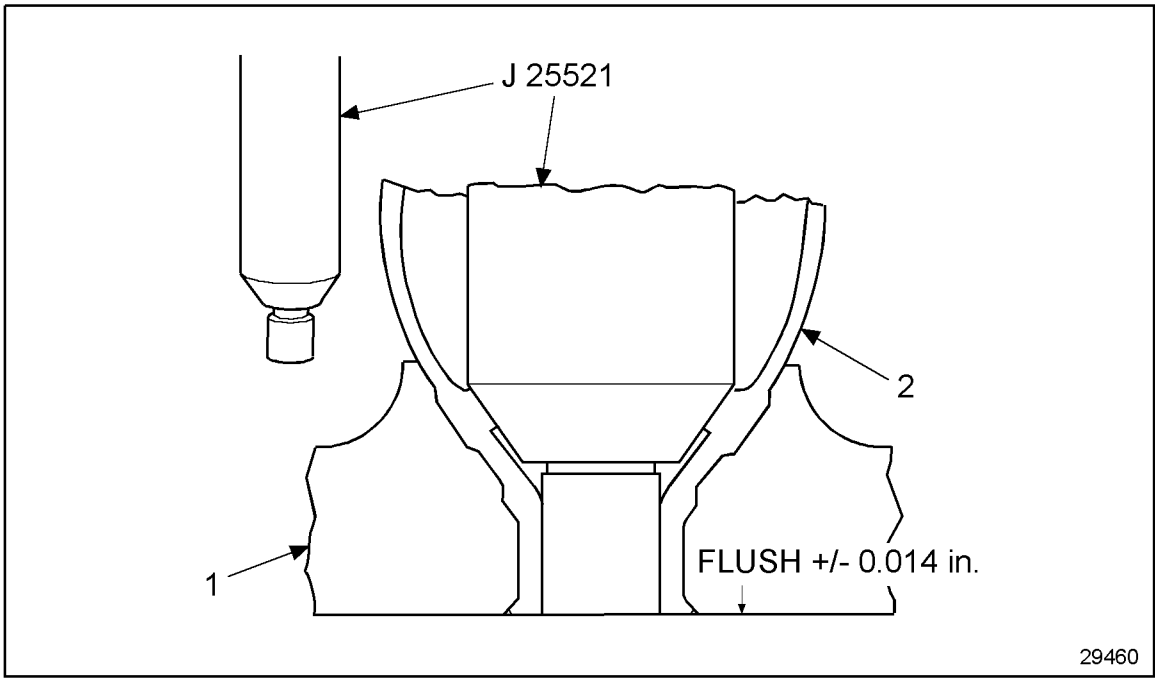


1. Cylinder Head
2. Injector Tube

Figure 2-44 Measuring Relationship of Injector Tube Bevel Seat to Cylinder Head Firedeck with Tool J 25521 (from set J 22525-B) and Gage J 22273-01

16. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower the reamer J 5286-9C (from set J 22525-B) into the injector tube until it contacts the bevel seat.
17. Without applying any downward force on the reamer, turn it steadily to make a trial cut.
18. Remove the reamer, and blow out the chips.
19. Check the bevel seat to find what portion of the seat has been cut.
20. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the progress.
21. Remove the chips from the injector tube.

22. Zero the sled gage dial indicator J 22273-01 to the firedeck, and continue the reaming operation until the shoulder of the spray tip is flush to ± 0.356 mm (± 0.014 in.) with the firedeck of the cylinder head. See Figure 2-45.



1. Cylinder Head
2. Injector Tube

Figure 2-45 Measuring Relationship of Gage to Cylinder Head Firedeck with Tool J 25521 (from set J 22525-B)

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.

23. Wash the interior of the injector tube with clean solvent, and dry it with compressed air.
24. Assemble and install the cylinder head. Refer to section 1.3.4, and refer to section 1.3.5.

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2.5 ELECTRONIC ENGINE CONTROLS

Detroit Diesel Electronic Controls (DDEC) determine the timing and amount of fuel injected by the Electronic Unit Injectors (EUI). DDEC also monitors several engine functions via electrical sensors that send electrical signals to the Electronic Control Module (ECM). The ECM processes incoming data and determines the proper fuel output and timing to ensure optimum engine performance. The ECM also displays warnings or shuts down the engine to prevent serious engine damage in the case of low oil pressure, low coolant level/pressure, or high oil and/or coolant temperature.

NOTE:
This engine is equipped with DDEC software. This software generally assures optimal engine performance. The installation of software upgrades may cause minor changes in features and engine performance.

Some Series 92 engines feature DDEC I (not pictured) or DDEC II electronic controls. Later model engines have the third generation system, DDEC III. See Figure 2-46.

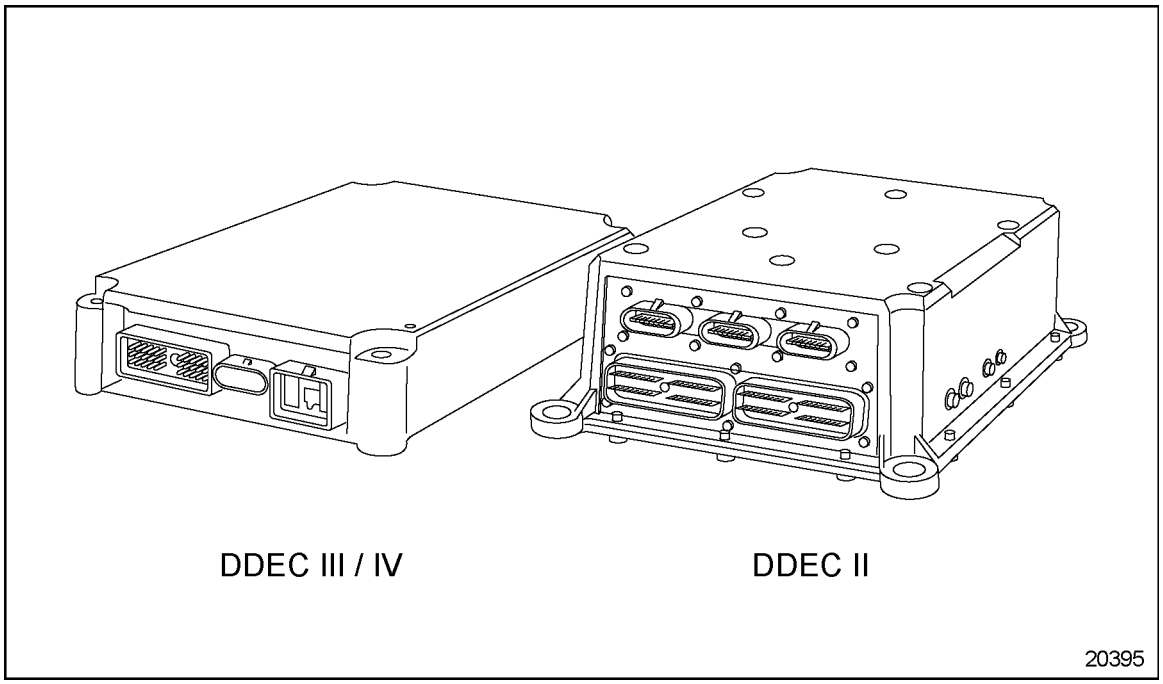


Figure 2-46 Detroit Diesel Electronic Control Modules (DDEC)

2.5.1 DDEC Diagnostic Procedures

Before attempting any diagnosis of the DDEC Control System, refer to the *DDEC II Troubleshooting Guide*, 6SE489. Basic mechanical checks should be made first to verify the problem is not fuel or air delivery related, and that the problem is electrical. If basic mechanical checks fail to locate the problem, start the DDEC diagnosis with the Troubleshooting Charts printed in the *DDEC II Troubleshooting Guide*, 6SE489 or *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497.

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The hand-held DDR is used on DDEC II and DDEC III controlled engines to display engine description, diagnostic data, fault codes, and to program the ECM. A printout of the information displayed on the DDR can be obtained by attaching a printer. See Figure 2-47 for the diagnostic data reader kit J 38500-H, includes a reader, cable, carrying case, DDEC cartridge, manual, and a 6-pin adaptor. Refer to section 2.7 for additional DDEC III information.

NOTE:
There are a number of DDR software cartridges available for the DDR. Contact your nearest Detroit Diesel authorized distributor for information on the correct software cartridge available for your current engine application needs.

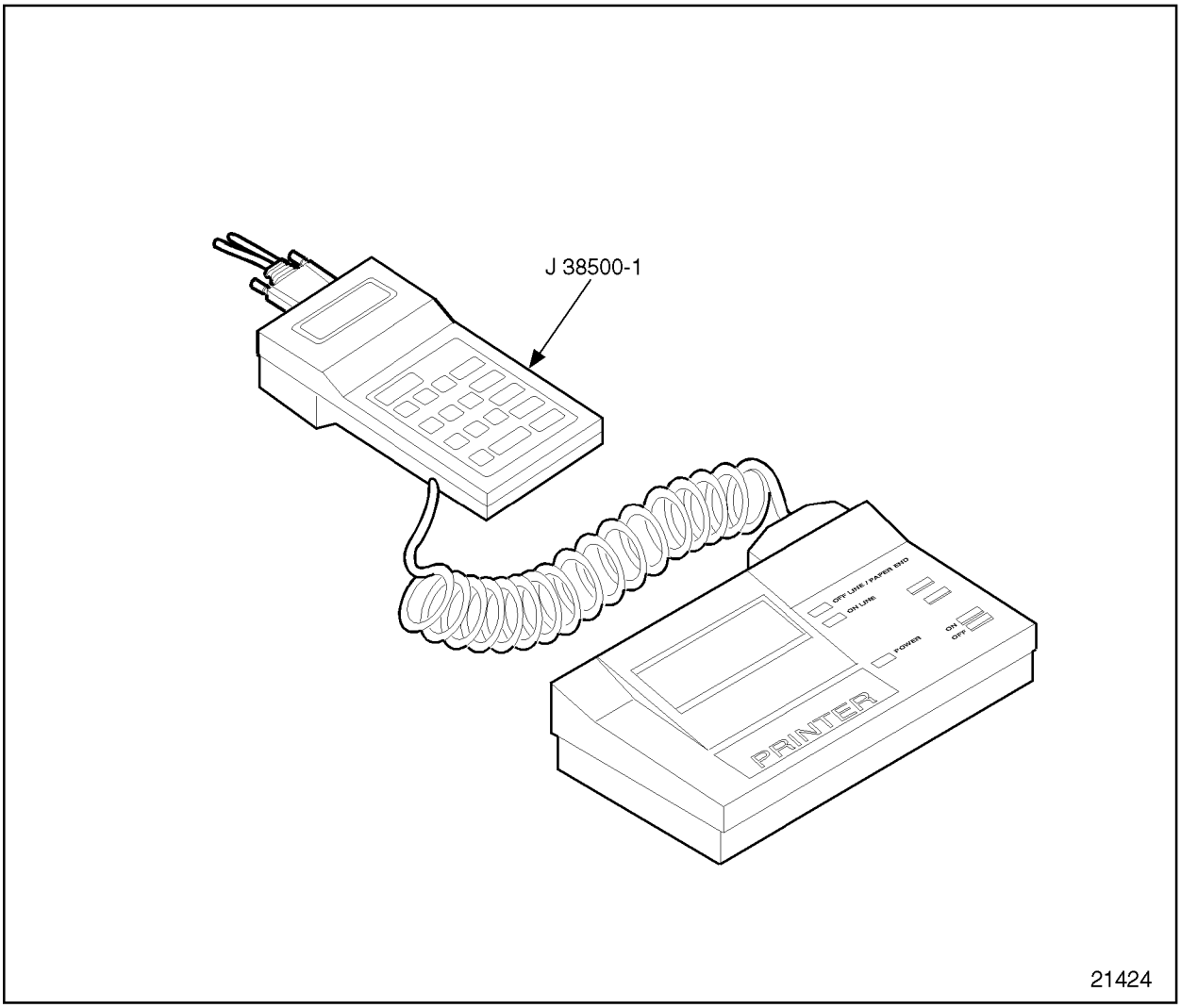


Figure 2-47 Diagnostic Data Reader (DDR)

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⚠ CAUTION:

To avoid injury from engine shutdown in an unsafe situation, ensure the operator knows how to override the stop engine condition on a DDEC-equipped unit.

⚠ 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.

If a DDR is not available, the following procedure can be used to read the fault codes using the "Check Engine" light.

If the vehicle or vessel 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*.

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If there is no diagnostic switch, locate the 12-pin Diagnostic Data Link (DDL) connector. See Figure 2-48.

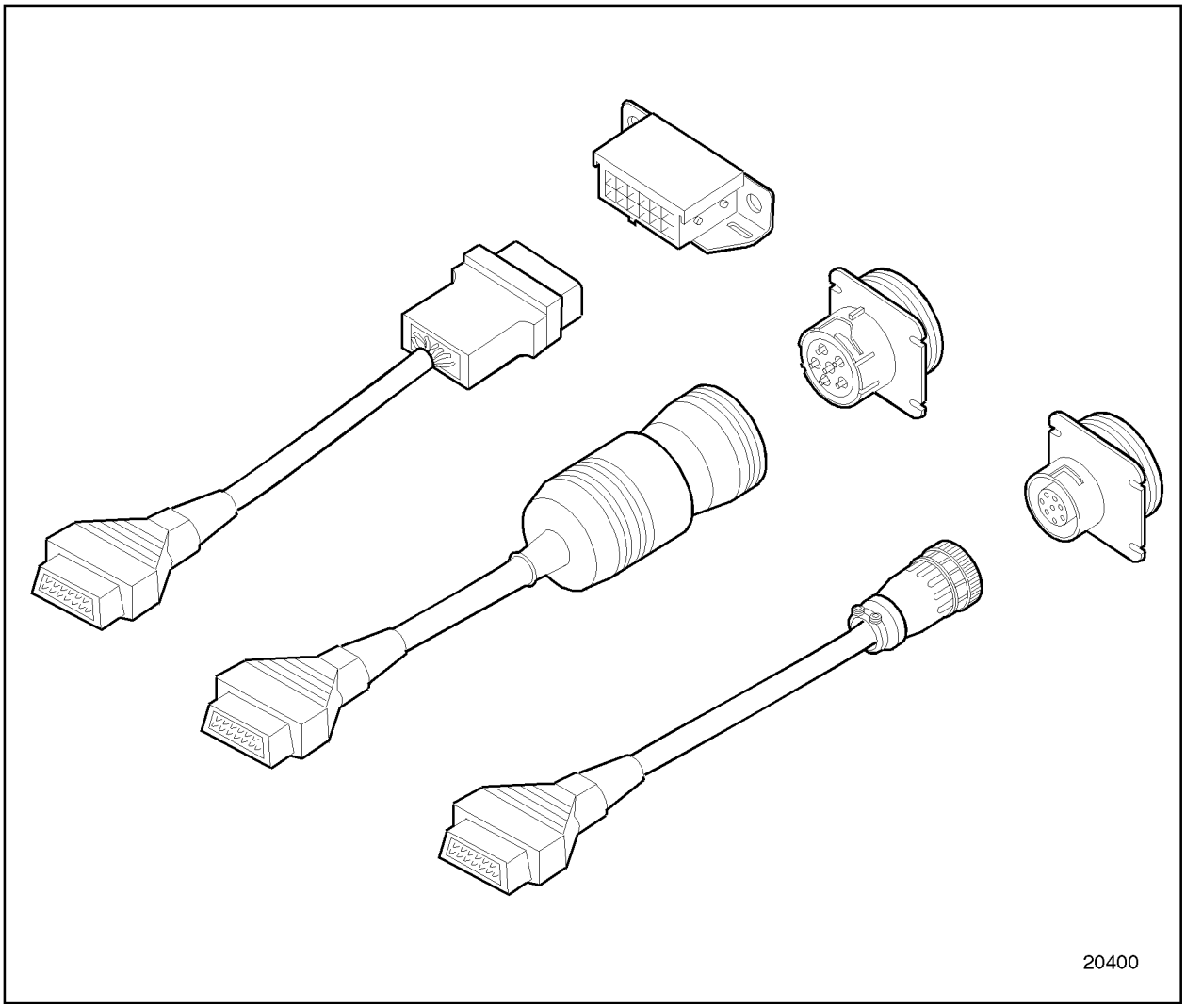


Figure 2-48 Diagnostic Data Link (DDL)

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NOTICE:
If the machinery (vehicle or vessel) is equipped with an OEM supplied diagnostic switch, the switch must NOT be switched on when the vehicle, vessel or machine is in operation. If this is done, the diagnostic mode line will be grounded, and the throttle will be forced to the idle position, affecting equipment 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 (DDEC II engines only).

If a code other than code 25 is read, refer to the correct chart in the *DDEC II Troubleshooting Guide*, 6SE489, or in the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497, for repair instructions.

Fault codes can be cleared from the DDEC system only with a diagnostic reader (DDR). To clear codes, follow the instructions provided with the reader.

NOTE:
Before beginning any repair procedures, the ignition switch must be in the "OFF" position.

Basic replacement procedures for DDEC components follow. Components should not be replaced unless they have been correctly identified as defective using the *DDEC II Troubleshooting Guide*, 6SE489 or in the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497.

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2.6 DDEC II

The DDEC II ECM is packaged in a die-cast aluminum housing with sealed connectors.

The ECM is a microprocessor. It is the control center for the DDEC II and DDEC III systems. See Figure 2-49 and see Figure 2-50 for the single block DDEC II and DDEC III configurations and see Figure 2-51 for the multi-block DDEC III configuration.

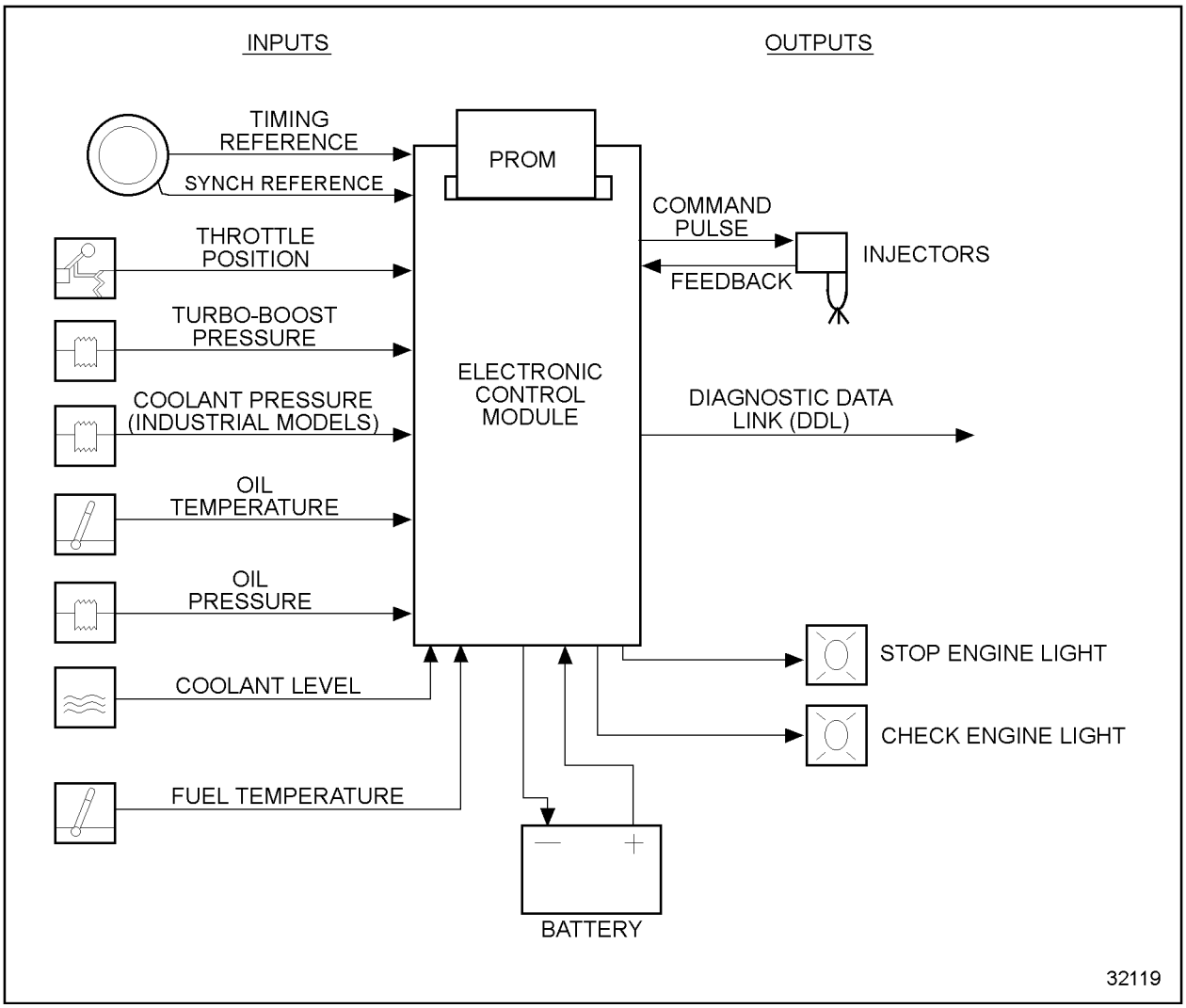


Figure 2-49 DDEC II Schematic (6V and 8V)

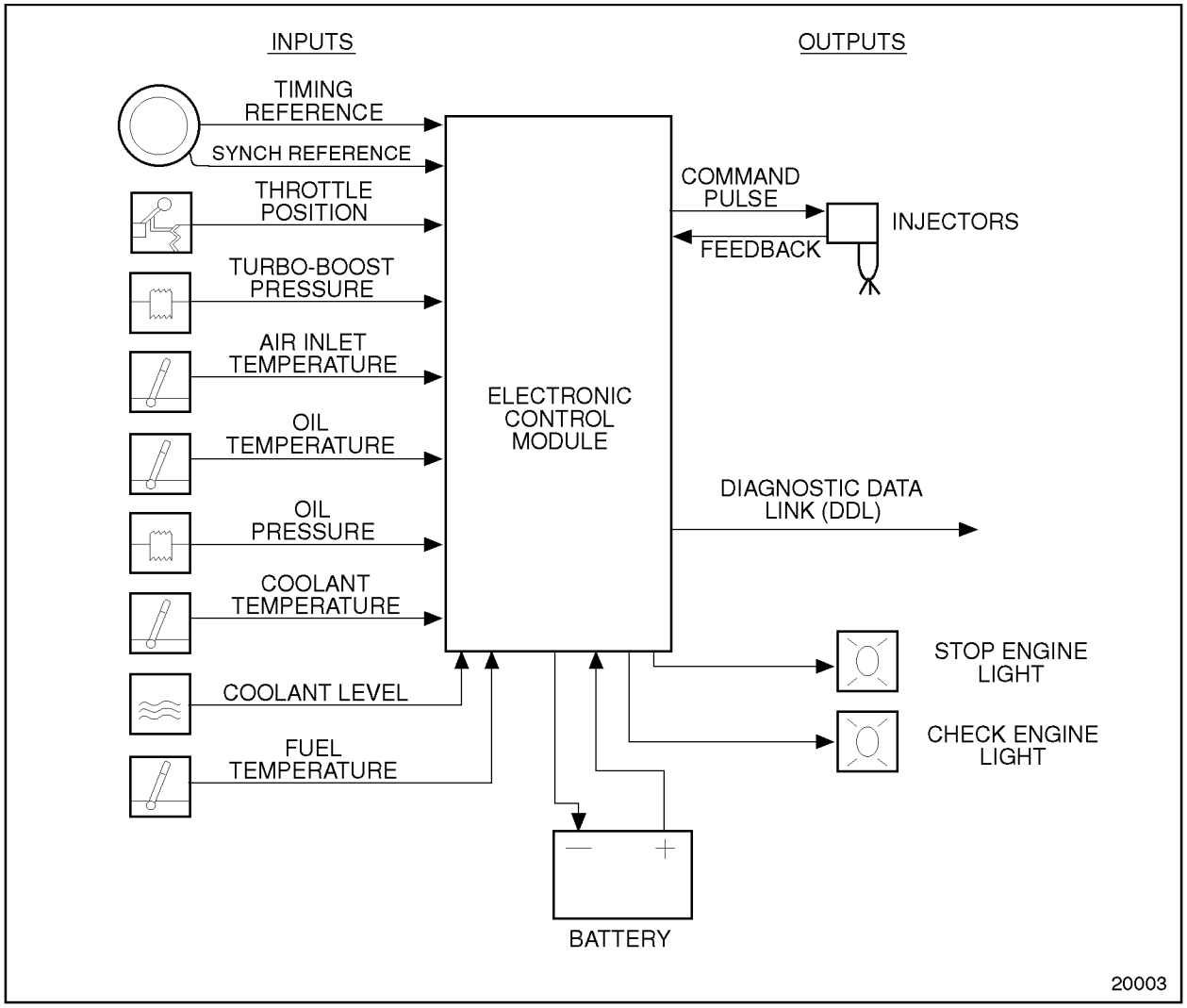


Figure 2-50 DDEC III Schematic

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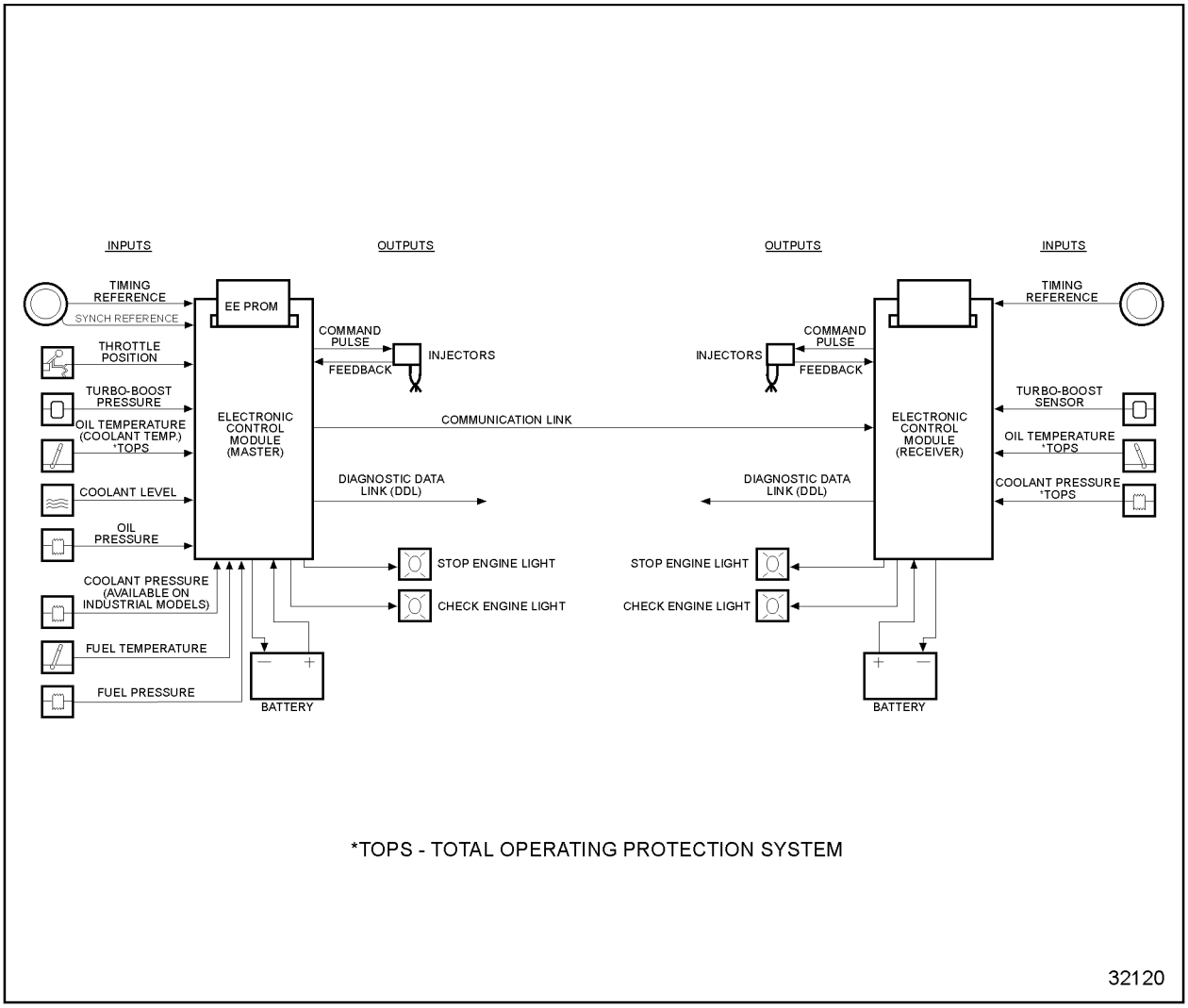


Figure 2-51 DDEC III Schematic (12V and 16V)

The DDEC II system consists of the following components:

- DDEC II ECM
- Replaceable EEPROM
- Connections to Various Sensors:
  - Engine Sensors (Engine Harnesses)
  - Operational Displays (Vehicle Harnesses)
  - Power (Power Harness)
  - Fuel Injectors (Injector Harnesses)

2.6.1 Repair or Replacement of the DDEC II ECM

The DDEC II ECM is a sealed, non-serviceable unit. It should be tagged for recore.

2.6.2 Removal of the DDEC II ECM

Remove the ECM as follows:

1. Carefully disengage the lock on the power harness and injector harness connections.
2. Remove the five wire harness connections at the ECM.
3. Remove the thru - bolts holding the ECM to the engine.

NOTICE:
Failure to seal the cooler plate openings after disconnecting them may allow foreign material to enter the fuel system. This could lead to serious fuel system damage and engine malfunction.

4. Remove the ECM and cold plate (if applicable) from the engine.
5. Remove the screws securing the cold plate to the ECM (if applicable). Remove the cold plate.

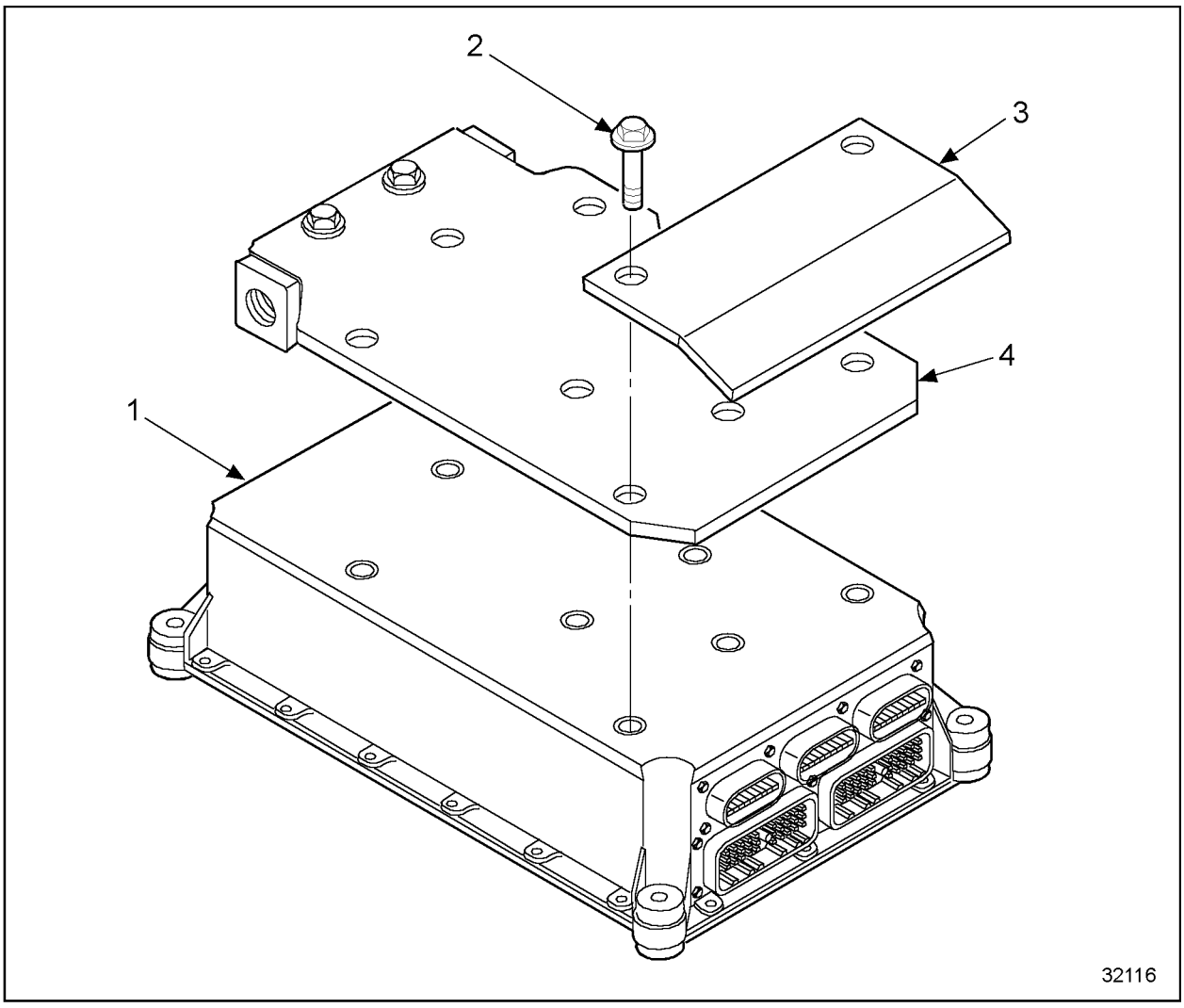
2.6.3 Installation of the DDEC II ECM

Install the ECM as follows:

NOTE:
ECM cooler plate corrosion has occurred at work sites using high pressure engine washing techniques. Prior to installing the ECM, apply DDC silver acrylic enamel

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paint (5149996-12 oz spray can) to the ECM mating surface of the cooler plate. See Figure 2-52.



1. DDEC II ECM
2. Cooler/Heat Shield-to-ECM Self Tapping Bolts (8)
3. Harness Heat Shield (Used on Series 92 Only)
4. Cooler Plate

Figure 2-52 ECM and Cooler Plate Assembly (DDEC II)

NOTE:
If fuel leaks have occurred, install a new cooler plate.

1. Install the cold plate on the ECM (if applicable). Use Loctite 262, or equivalent, and torque the screws to 114-144 N·m (84-106 lb·in.).
2. Apply anti - seize compound or equivalent on the cold plate - to - ECM screws. Torque screws to 16 - 20 N·m (12 - 15 lb·ft).

NOTICE:
The ECM isolators must be installed. Failure to install the isolators may lead to ECM damage caused by excessive vibration, or erratic engine operation caused by electrical potential difference.

3. Inspect the ECM isolators for damage. Replace, if necessary.
4. Mount the ECM and cold plate (if applicable) to the engine.
5. Secure the ECM to the engine with thru - bolts. Torque the ECM-to-engine bolts to 23-27 N·m (17-20 lb·ft).
6. Torque the ECM connector hold-down screws to 24-30 kg·cm (21-26 lb·in.).
7. Engage the lock tab on the power harness and injector harness connectors.
8. Turn the ignition to the "ON" position. Read any diagnostic codes. If any code other than a code 25 is obtained, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or in the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497
9. Start the engine, and check for fuel leaks.

For information on the 18SP479–Installation instructions for the 6V-92 EUI 0.10 g/bhp–hr PM US EPA-Approved Emission Upgrade Kit, refer to installation instructions provided in upgrade kit or refer to section ADDITIONAL INFORMATION for a brief summery.

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2.7 DDEC III

DDEC III constantly monitors engine performance, with electronic sensors transmitting essential engine data to the ECM. See Figure 2-53.

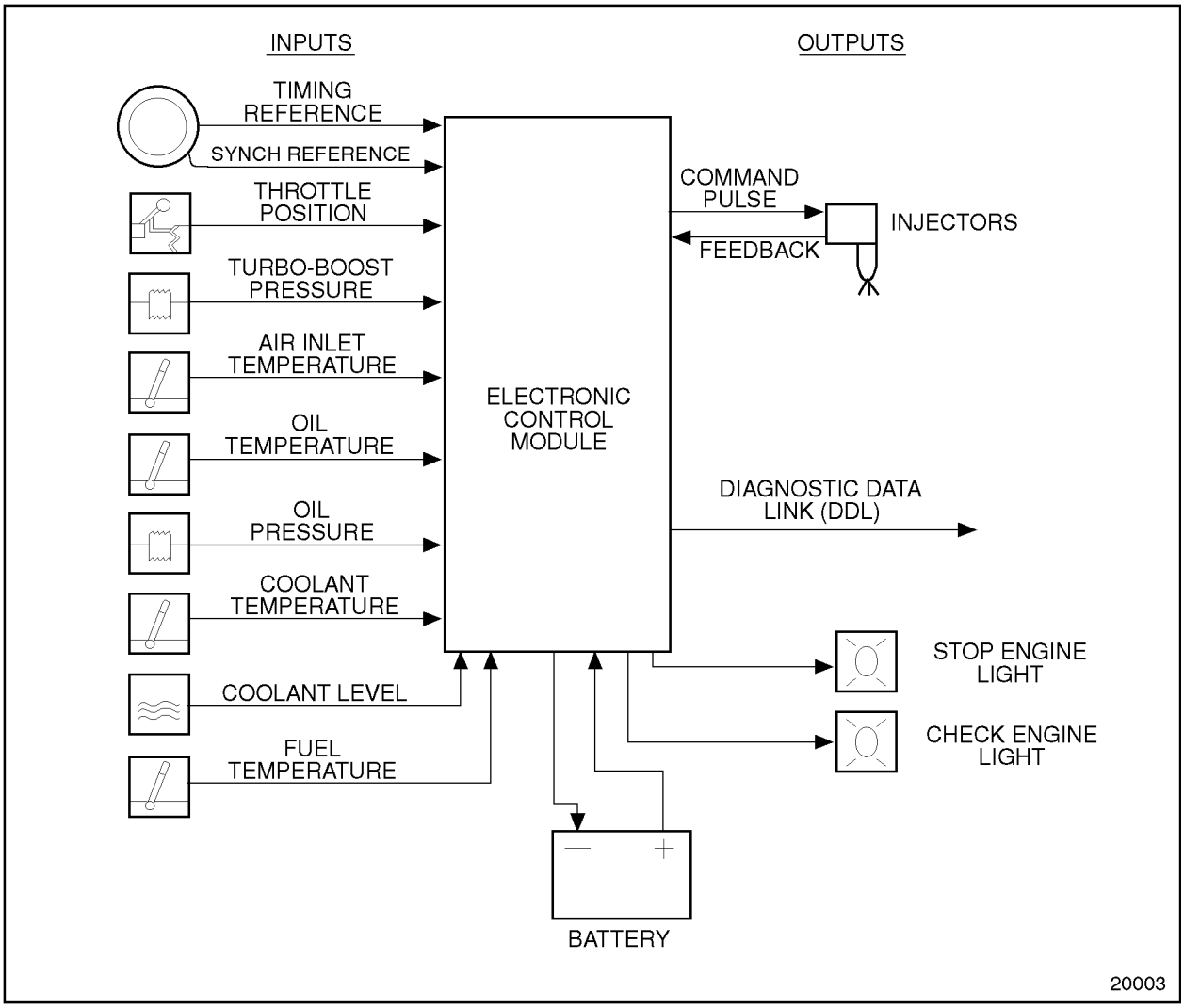


Figure 2-53 DDEC III Schematic

The DDEC III system consists of the following components:

- ☐ DDEC III ECM
- ☐ Connections to Various Sensors:
  - ☐ Engine Sensors (Engine Harnesses)
  - ☐ Operational Displays (Vehicle Harnesses)
  - ☐ Power (Power Harness)
  - ☐ Fuel Injectors (Injector Harnesses)
- ☐ Programmable inputs and outputs

Any faults that occur are stored as codes in the memory of the ECM. These codes may be accessed in three ways:

⚠ CAUTION:

To avoid injury from engine shutdown in an unsafe situation, ensure the operator knows how to override the stop engine condition on a DDEC-equipped unit.

⚠ 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.

- A Diagnostic Data Reader (DDR) can be used to read the codes.
- A personal computer (PC) may be connected to the ECM through a translator device that converts J1708 to RS232 protocol.
- The Check Engine Light (CEL) or the Stop Engine Light (SEL) indicate engine conditions.

If the CEL, a panel mounted yellow indicator light, is illuminated, this indicates a condition that should be diagnosed as soon as convenient.

NOTICE:

If both the CEL and SEL, a panel mounted red indicator light, are illuminated, a major engine fault has occurred and immediate attention is required to avoid potential serious engine damage.

An automatic engine shutdown feature is available. A shutdown override switch is required to allow the engine to be operated during automatic shutdown or rampdown.

2.7.1 Repair or Replacement of DDEC III ECM

The DDEC III ECM is a sealed, non-serviceable unit. It should be tagged for recore.

2.7.2 Removal of 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 all the wire harness connections at the ECM.
3. Remove the thru - bolts holding the ECM to the engine.

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NOTICE:
Failure to seal the cooler plate openings after disconnecting them may allow foreign material to enter the fuel system. This could lead to serious fuel system damage and engine malfunction.

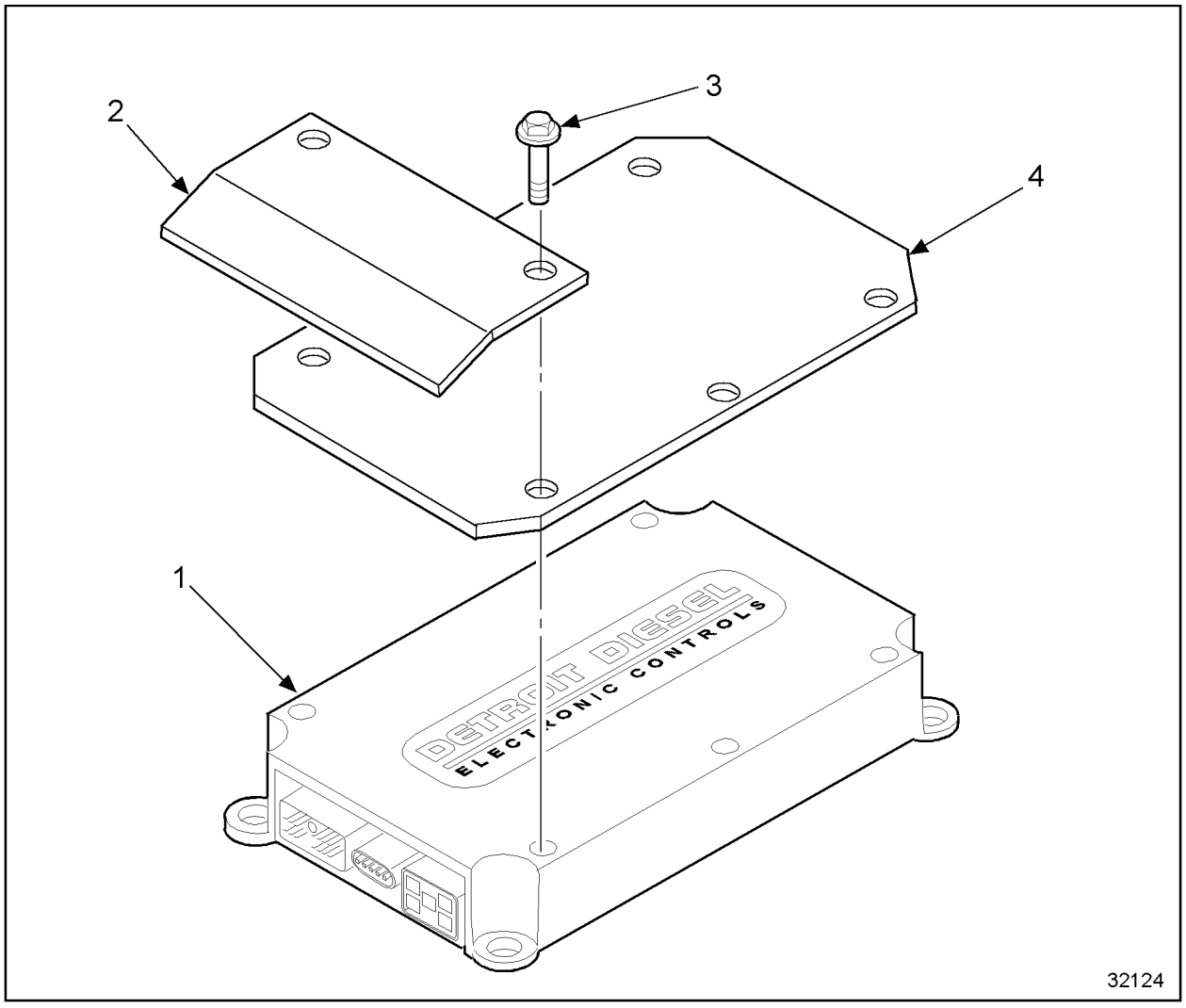
4. Remove the ECM and cold plate (if applicable) from the engine.
5. Remove the screws securing the cold plate to the ECM (if applicable). Remove the cold plate.

NOTE:
All electrical connector cleaning must be kept to a minimum. When cleaning is required, DDC recommends using LPS Electro Contact Cleaner. For areas that require CFC-free products, LPS No Flash Electro Contact Cleaner is available in a 16 oz. spray can under part number 03416. For the name of the distributor in your area, contact the manufacturer at: LPS Laboratories 4647 Hugh Howell Road Tucker, GA 30084 Phone: (800) 241-8334 Fax: (404) 493-9206 Toll free for US and Canada

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2.7.3 Installation of DDEC III ECM

See Figure 2-54 and install the ECM as follows :



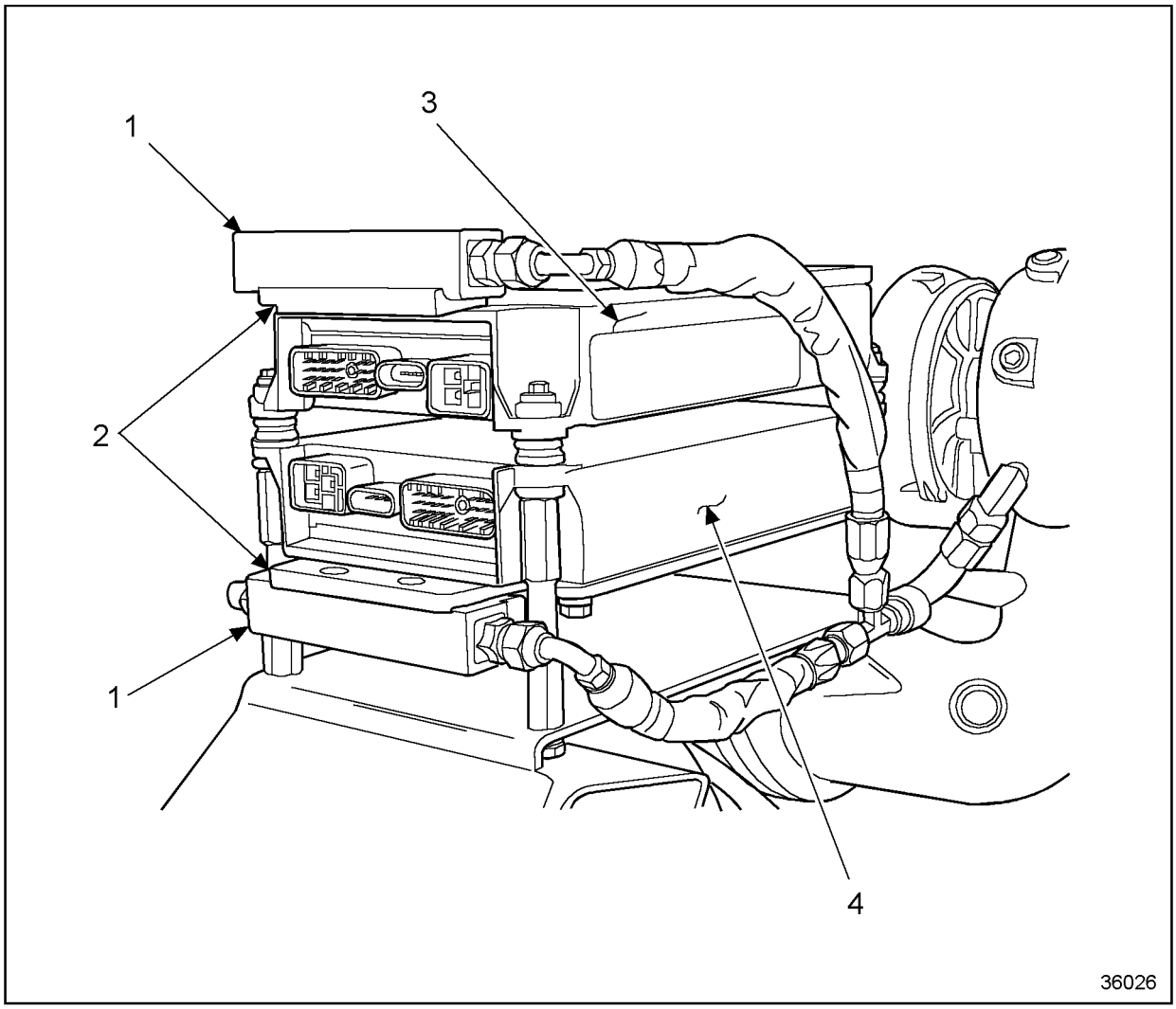
1. DDEC III ECM
2. Harness Heat Shield (Used on Series 92 Only
3. Cooler/Heat Shield-to-ECM Self Tapping Bolts (8) (Series 92 Only)
4. Cooler Plate

Figure 2-54 ECM and Cooler Plate Assembly (DDEC III)

NOTE:
If fuel leaks have occurred, install a new cooler plate.

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Engines having more than 8 cylinders require 2 or more ECMs to handle the additional injectors. See Figure 2-55.



1. Fuel Coolers
2. Cooler Plate
3. Master ECM
4. Receiver ECM

Figure 2-55 Dual ECM and Cooler Plate Assembly (DDEC III)

1. Install the cold plate on the ECM (if applicable). Use Loctite 262, or equivalent, and torque the screws to 114-143 N·m (84-106 lb·in.).

NOTICE:
The ECM isolators must be reinstalled. Failure to reinstall the isolators may lead to ECM damage caused by excessive vibration, or erratic engine operation caused by electrical potential difference.

2. Inspect the ECM isolators for damage. Replace, if necessary.
3. Mount the ECM and cold plate (if applicable) 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).
5. Torque the ECM connector hold-down screws to 24-30 kg cm (21-26 lb·in.).
6. Connect the two-wire and three-wire harness and injector harness connectors.
7. Engage the lock tab on the power harness and injector harness connectors.
8. Turn the ignition to the "ON" position. Read any diagnostic codes. If any code other than a code 25 is obtained, refer to the *DDEC II Troubleshooting Guide*, 6SE489, or in the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497, for repair instructions.
9. Start the engine, and check for fuel leaks.

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2.8 DDEC IV

DDEC IV constantly monitors engine performance, with electronic sensors transmitting essential engine data to the ECM. See Figure 2-56.

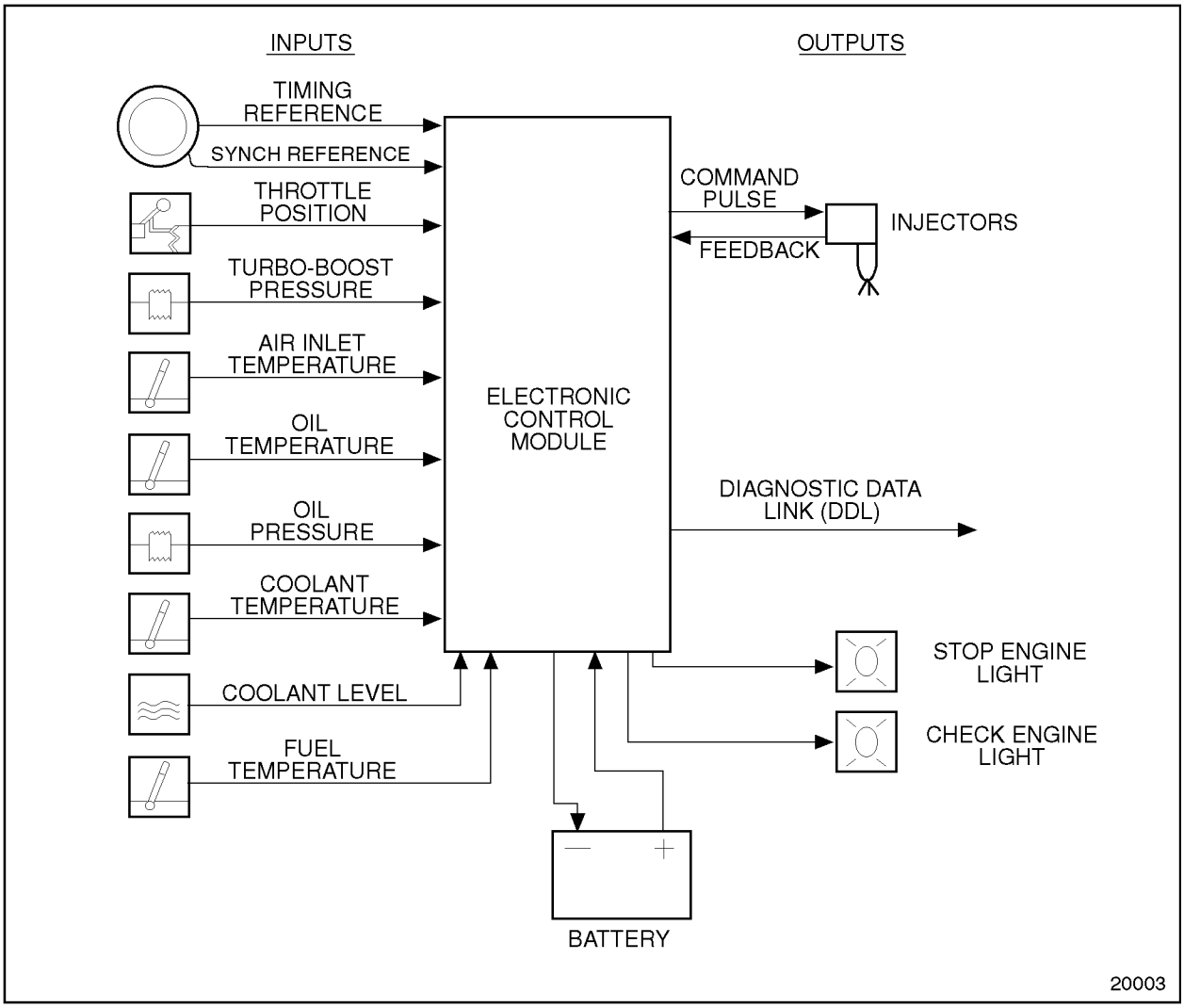


Figure 2-56 DDEC IV Schematic

The DDEC IV system consists of the following components:

- ☐ DDEC IV ECM
- ☐ Connections to Various Sensors:
  - ☐ Engine Sensors (Engine Harnesses)
  - ☐ Operational Displays (Vehicle Harnesses)
  - ☐ Power (Power Harness)
  - ☐ Fuel Injectors (Injector Harnesses)
- ☐ Programmable inputs and outputs

Any faults that occur are stored as codes in the memory of the ECM. These codes may be accessed in three ways:

⚠ CAUTION:

To avoid injury from engine shutdown in an unsafe situation, ensure the operator knows how to override the stop engine condition on a DDEC-equipped unit.

⚠ 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.

- ☐ A Diagnostic Data Reader (DDR) can be used to read the codes.
- ☐ A personal computer (PC) may be connected to the ECM through a translator device that converts J1708 to RS232 protocol.
- ☐ The Check Engine Light (CEL) or the Stop Engine Light (SEL) indicate engine conditions.

If the CEL, a panel mounted yellow indicator light, is illuminated, this indicates a condition that should be diagnosed as soon as convenient.

NOTICE:

If both the CEL and SEL, a panel mounted red indicator light, are illuminated, a major engine fault has occurred and immediate attention is required to avoid potential serious engine damage.

An automatic engine shutdown feature is available. A shutdown override switch is required to allow the engine to be operated during automatic shutdown or rampdown.

2.8.1 Repair or Replacement of DDEC IV ECM

The DDEC IV ECM is a sealed, non-serviceable unit. It should be tagged for recore.

2.8.2 Removal of DDEC IV ECM

Perform the following steps for ECM removal:

1. Carefully disengage the lock tab on the power harness and injector harness connectors.
2. Remove all the wire harness connections at the ECM.
3. Remove the thru - bolts holding the ECM to the engine.

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NOTICE:
Failure to seal the cooler plate openings after disconnecting them may allow foreign material to enter the fuel system. This could lead to serious fuel system damage and engine malfunction.

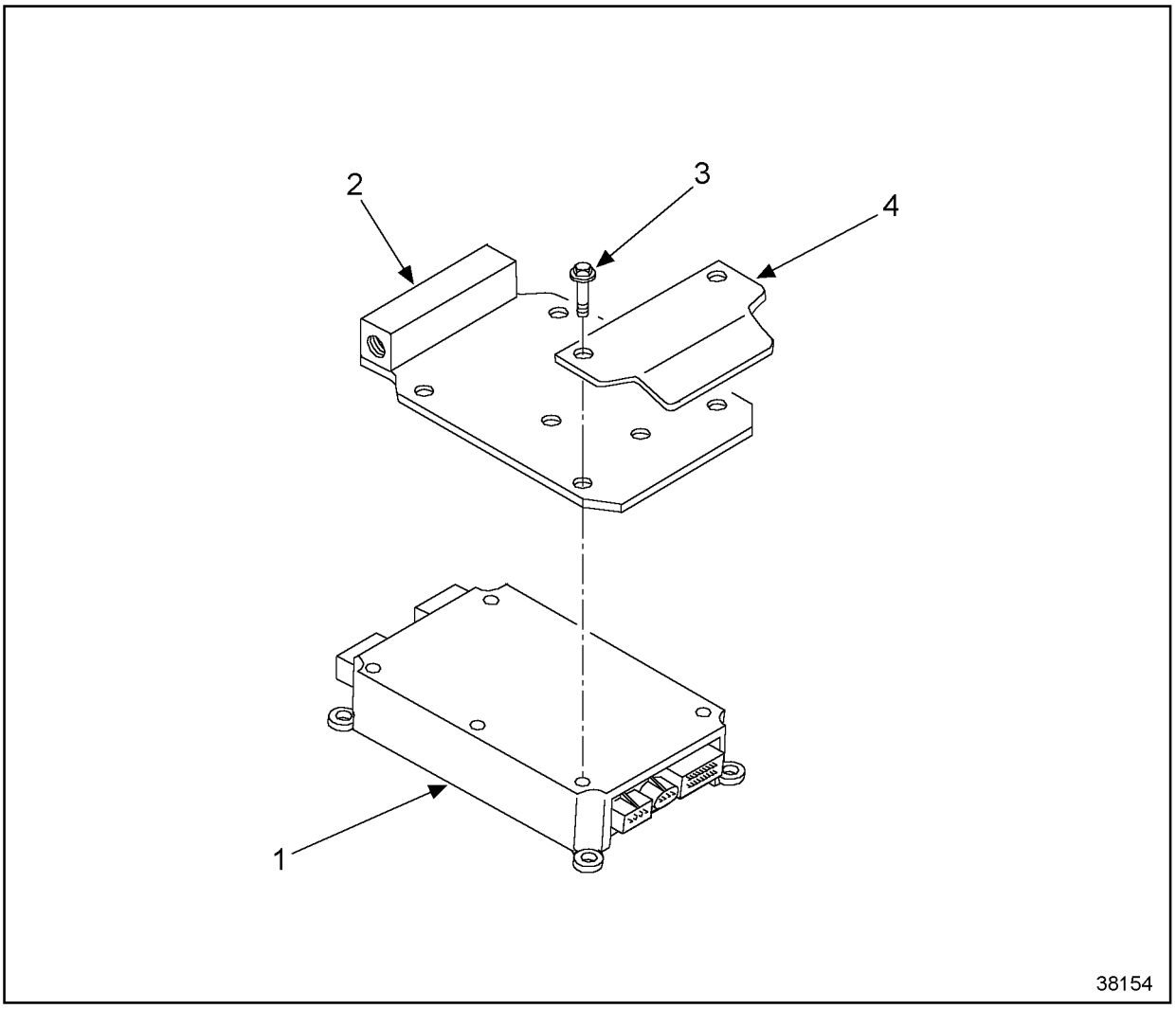
4. Remove the ECM and cold plate (if applicable) from the engine.
5. Remove the screws securing the cold plate to the ECM (if applicable). Remove the cold plate.

NOTE:
All electrical connector cleaning must be kept to a minimum. When cleaning is required, DDC recommends using LPS Electro Contact Cleaner. For areas that require CFC-free products, LPS No Flash Electro Contact Cleaner is available in a 16 oz. spray can under part number 03416. For the name of the distributor in your area, contact the manufacturer at: LPS Laboratories 4647 Hugh Howell Road Tucker, GA 30084 Phone: (800) 241-8334 Fax: (404) 493-9206 Toll free for US and Canada

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2.8.3 Installation of DDEC IV ECM

Install the ECM as follows, see Figure 2-57:



1. DDEC IV ECM
2. Cooling Plate
3. Self Tapping Bolt
4. Heat Shield

Figure 2-57 ECM and Cooler Plate Assembly (DDEC IV)

NOTE:
If fuel leaks have occurred, install a new cooler plate.

Engines having more than 8 cylinders require 2 or more ECMs to handle the additional injectors.

1. Apply DDC/Loctite anti-seize compound or equivalent, to the cold plate-to-ECM screws. Place cold plate on ECM, install screws, and torque to 16–20 N·m (12–15 lb·ft). Install ECM heat shield.

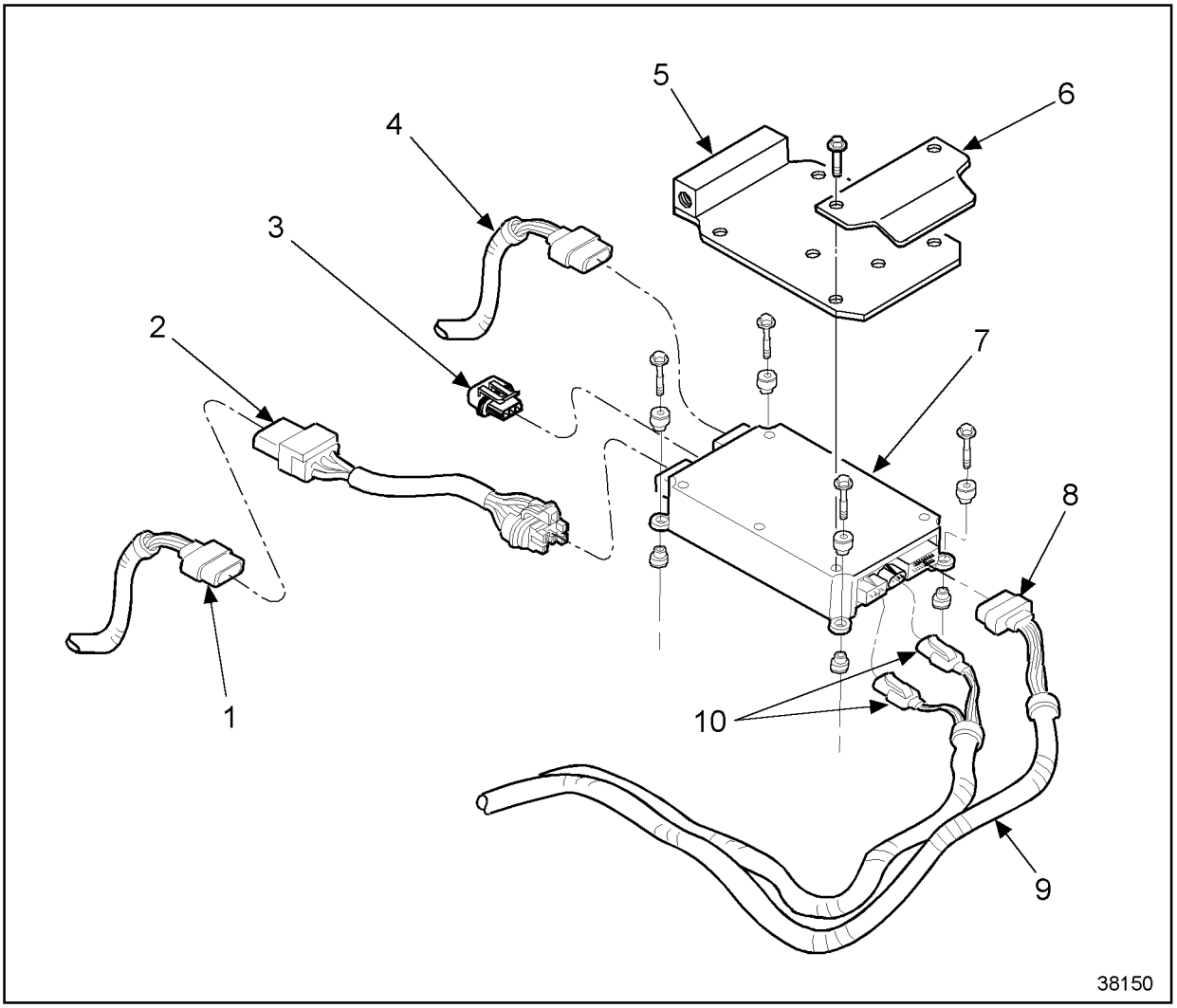
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NOTICE:
The ECM isolators must be reinstalled. Failure to reinstall the isolators may lead to ECM damage caused by excessive vibration, or erratic engine operation caused by electrical potential difference.

2. Inspect the ECM isolators for damage. Replace, if necessary.
3. Secure the ECM mounting bracket to the engine.
4. Secure the ECM to the bracket, torque to 23-27 N·m (17-20 lb·ft).
5. Install the 9/16 in. –18 elbow in the fuel block.

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6. Install the engine sensor harness. See Figure 2-58.



1. Power Harness Assembly
2. Power Harness Adaptor
3. Communication Harness Cover
4. Vehicle Harness (30 Pin)
5. Cooling Plate
6. Heat Shield
7. DDEC IV ECM
8. Engine Harness (30 Pin)
9. DDC-Supplied Engine and Injector Harnesses
10. Injector Harnesses

Figure 2-58 Location of Engine Harness

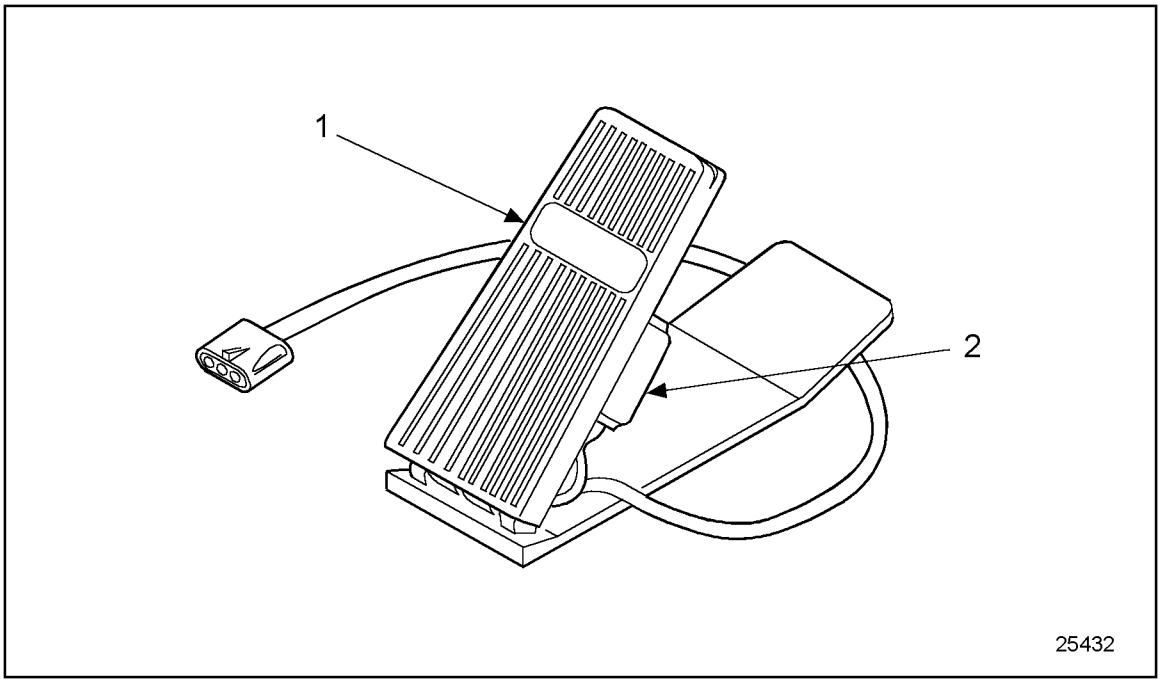
7. Torque the ECM connector hold-down screws to 24-30 kg-cm (21-26 lb·in.).
8. Connect the two-wire and three-wire harness and injector harness connectors.
9. Engage the lock tab on the power harness and injector harness connectors.

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10. For information on the 6V-92 EUI 0.10 g/bhp-hr PM US EPA–approved upgrade kit, refer to section ADDITIONAL INFORMATION, or the 18SP479 installation instructions provided with upgrade kit.
11. Turn the ignition to the "ON" position. Read any diagnostic codes. If any code other than a code 25 is obtained, refer to the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497 for repair instructions.
12. Start the engine, and check for fuel leaks.

2.9 ELECTRONIC FOOT PEDAL ASSEMBLY

The Electronic Foot Pedal Assembly (EFPA) connects the accelerator pedal to the Throttle Position Sensor (TPS). The Throttle Position Sensor (TPS) sends an electrical signal, varying in voltage according to the amount the pedal is depressed, to the ECM. The system is installed in place of the mechanical foot pedal. The travel of the foot pedal is limited by the manufacturer, no adjustment is required. See Figure 2-59.



1. Electronic Foot Pedal Assembly
2. Throttle Position Sensor

Figure 2-59 Electronic Foot Pedal Assembly

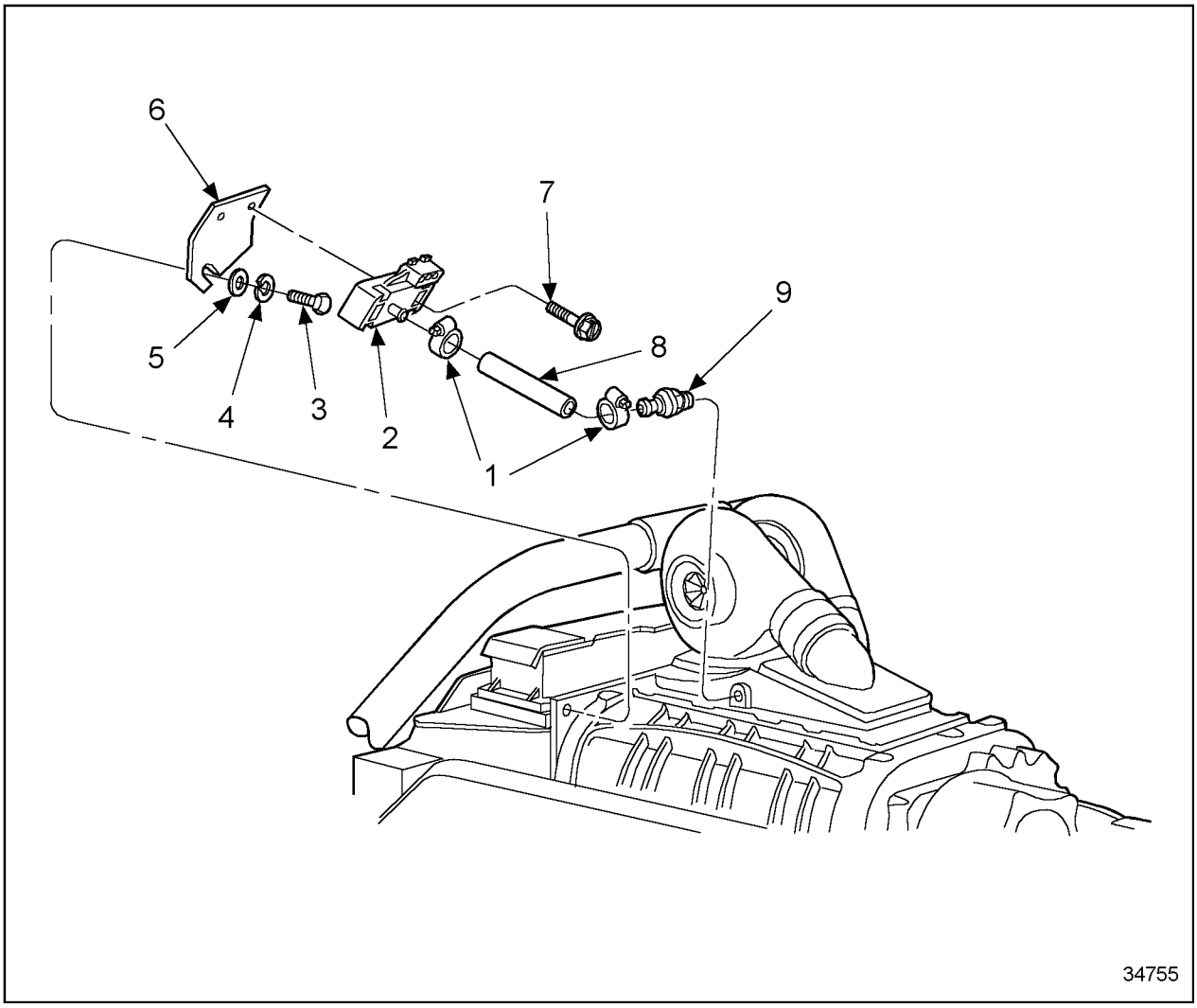
2.9.1 Repair or Replacement of Electronic Foot Pedal Assembly

The EFPA assembly is supplied by the vehicle manufacturer. Refer to the Original Equipment Manufacturer for the service procedure.

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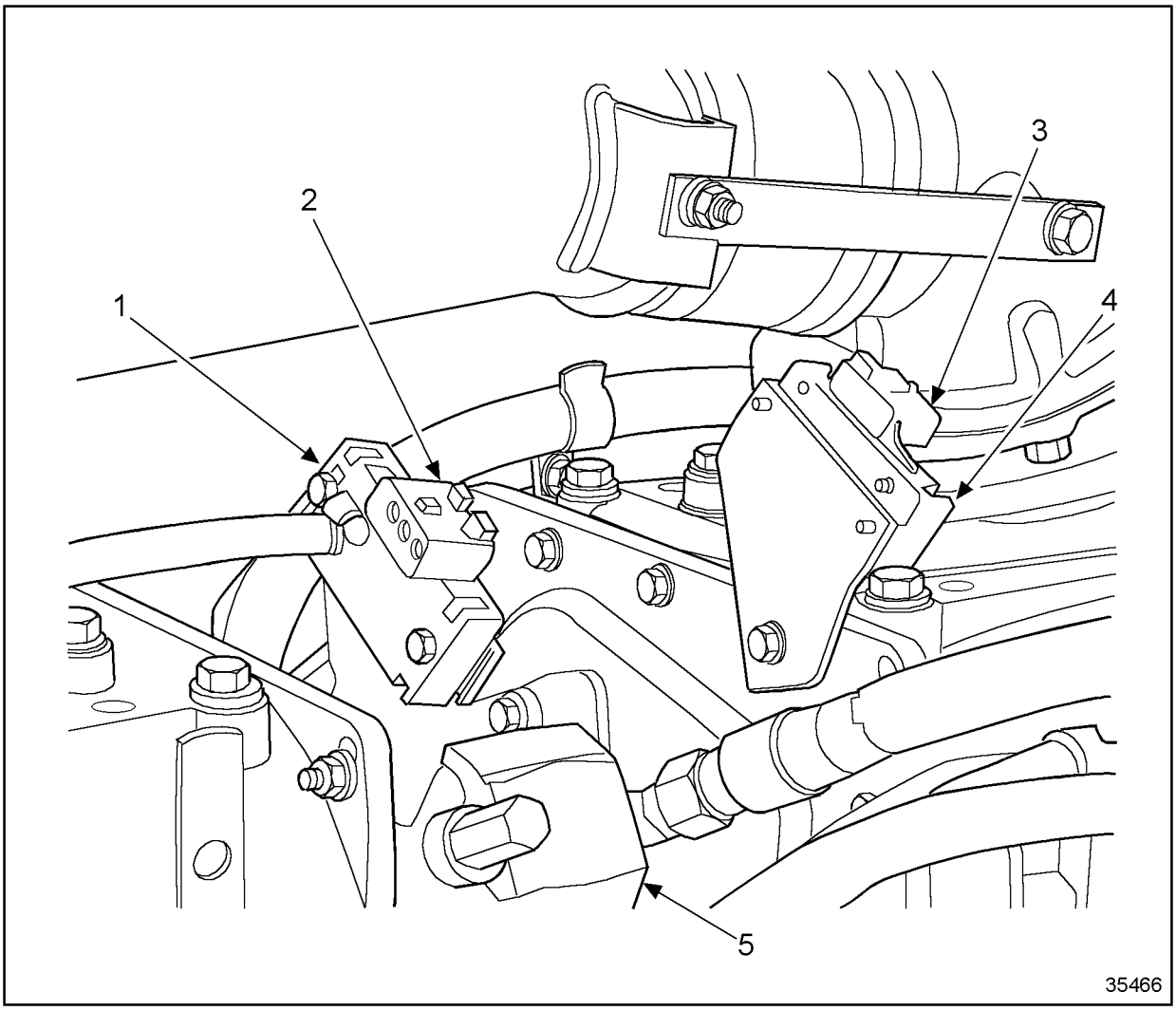
2.10 TURBO BOOST SENSOR

The Turbo Boost Sensor (TBS) is bracket-mounted to the engine. A short hose runs from the sensor to the air inlet housing. See Figure 2-60 and see Figure 2-61.



1. Clamps (2)
2. Turbo Boost Sensor
3. Bolt
4. Lock Washer
5. Plain Washer
6. Bracket
7. Locking Bolt
8. Hose
9. Adaptor

Figure 2-60 Turbo Boost Sensor and Mounting Hardware Assembly



1. Turbo Boost Sensor
2. Turbo Boost Sensor Connector
3. Turbo Boost Sensor Connector
4. Turbo Boost Sensor
5. Fuel Pump

Figure 2-61 Turbo Boost Sensor (12V and 16V)

The TBS sends an electrical signal to the ECM. The ECM uses the TBS signal to compute the amount of air entering the engine. The information obtained by the TBS is used by the ECM to regulate the fuel supply which controls engine smoke.

2.10.1 Repair or Replacement of Turbo Boost Sensor

The TBS is non-serviceable and must be replaced as an assembly. No adjustment is required.

2.10.2 Removal of Turbo Boost Sensor

With the engine (ignition) off remove the TBS as follows:

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1. Disengage the locking tang on the TBS connector body.
2. Grasp the terminal body, and gently pull it from the sensor.
3. Remove the hose from the TBS.
4. Remove the two bolts that secure the TBS to the bracket.
5. Remove the TBS.

2.10.3 Installation of Turbo Boost Sensor

With the engine (ignition) off install the TBS as follows:

NOTICE:
The TBS is an electronic component. Use care when installing to prevent damage.

1. Place TBS on engine.
2. Install the two bolts that secure the TBS to the bracket. Torque to 2.35-2.94 N·m (21-26 lb·in).
3. Attach the hose to the TBS.
4. Place the terminal body on the sensor.
5. Engage the locking tang on the TBS connector body.
6. 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.
7. Check for air leaks.

2.11 OIL PRESSURE SENSOR

The Oil Pressure Sensor (OPS) is installed in the main engine oil gallery. See Figure 2-62 and see Figure 2-63.

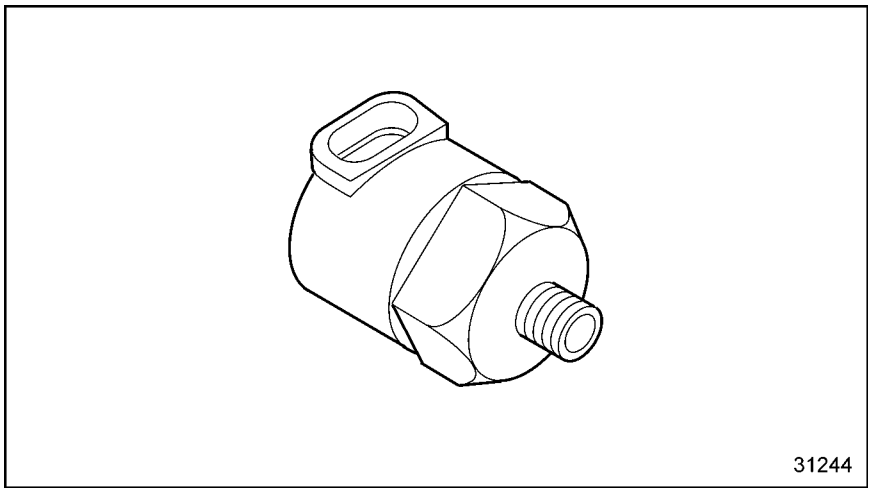
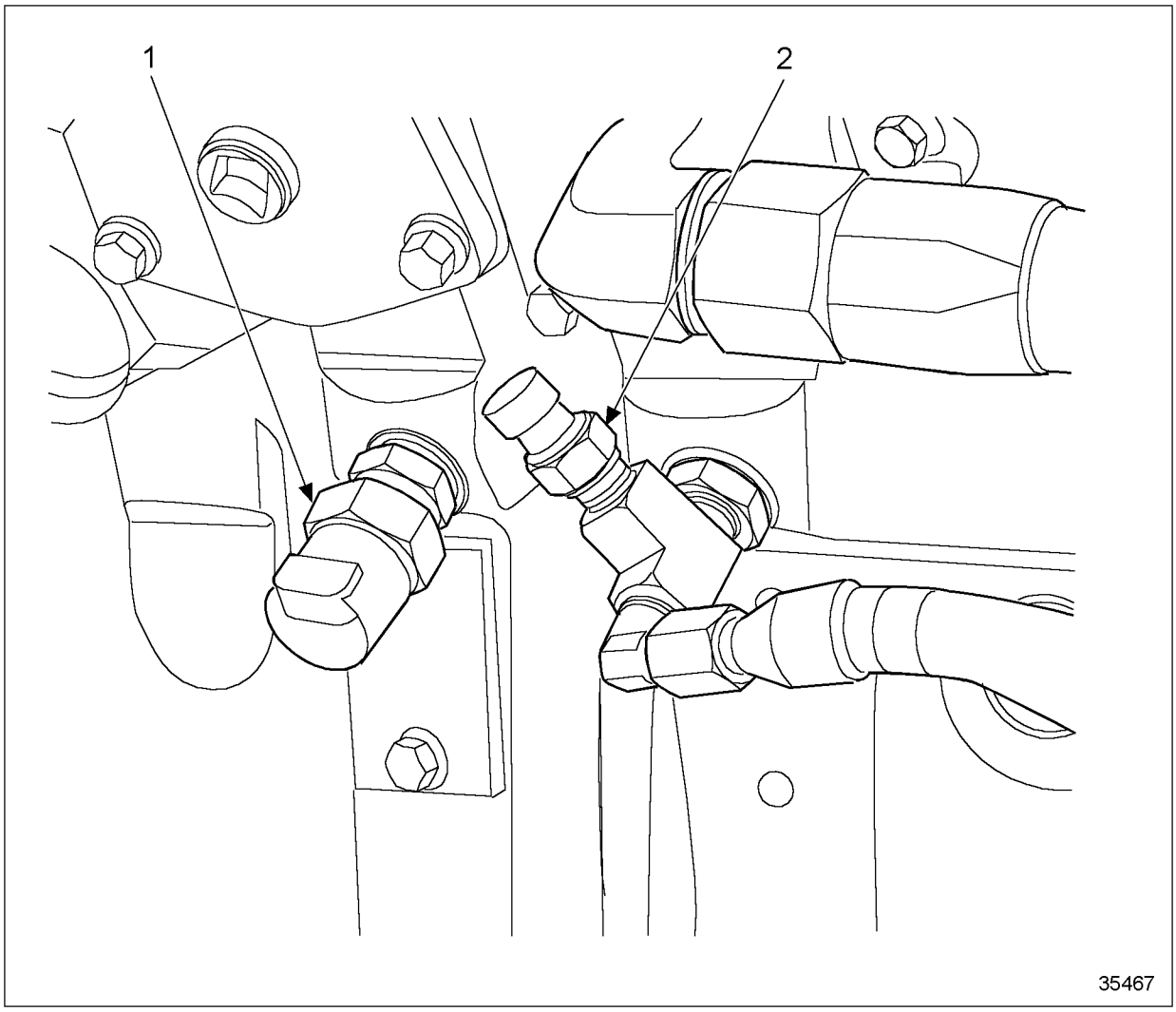


Figure 2-62 Oil Pressure Sensor

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1. Oil Pressure Sensor
2. Oil Temperature Sensor

Figure 2-63 Oil Pressure Sensor and Oil Temperature Sensor (12V and 16V)

The OPS electronically signals the ECM what the engine oil pressure is at any given speed. If the ECM receives a low oil pressure signal exceeding seven seconds, it will initialize the stop engine or warning function. Shutdown is calculated as a function of engine RPM & Pressure.

2.11.1 Repair or Replacement of Oil Pressure Sensor

The OPS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.11.2 Removal of Oil Pressure Sensor

With the engine (ignition) off remove the OPS as follows:

1. Disengage the locking tang on the three-wire connector.

2. Grasp the connector body, and gently pull it free of the OPS.
3. Unscrew the hex end of the OPS with the appropriate wrench.

2.11.3 Installation of Oil Pressure Sensor

With the engine (ignition) off install the OPS as follows:

NOTICE:
The OPS is an electronic device. Use care when installing to prevent damage.

1. To prevent leaks, apply Loctite 567 pipe sealant with Teflon, (or equivalent) on all but the first two threads of the OPS.

NOTE:
Effective September 1991 the new OPS does not require Loctite. Use a 1.25 in. deep well socket.

2. Screw the OPS onto the engine with a hex wrench.
3. Attach the connector body to the OPS.
4. Engage the locking tang on the three-wire connector.
5. Turn the ignition to the "ON" position. Read any diagnostic codes. If any code other than 25 is obtained, refer to the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497.
6. Check for oil leaks. Refer to section 13.5.3.

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2.12 OIL TEMPERATURE SENSOR

The Oil Temperature Sensor (OTS) is installed in the main engine oil gallery. The OTS electronically signals the ECM, indicating engine oil temperature. The ECM modifies engine speed for better cold weather starts and faster warm-ups based on the OTS signals. Oil temperatures exceeding programmed specification for two seconds or more will initialize the stop engine or warning function. See Figure 2-64 and see Figure 2-65.

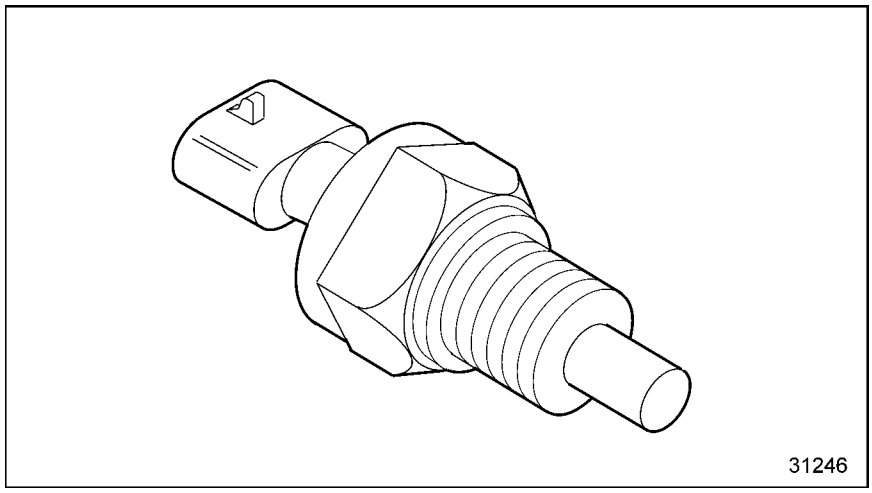
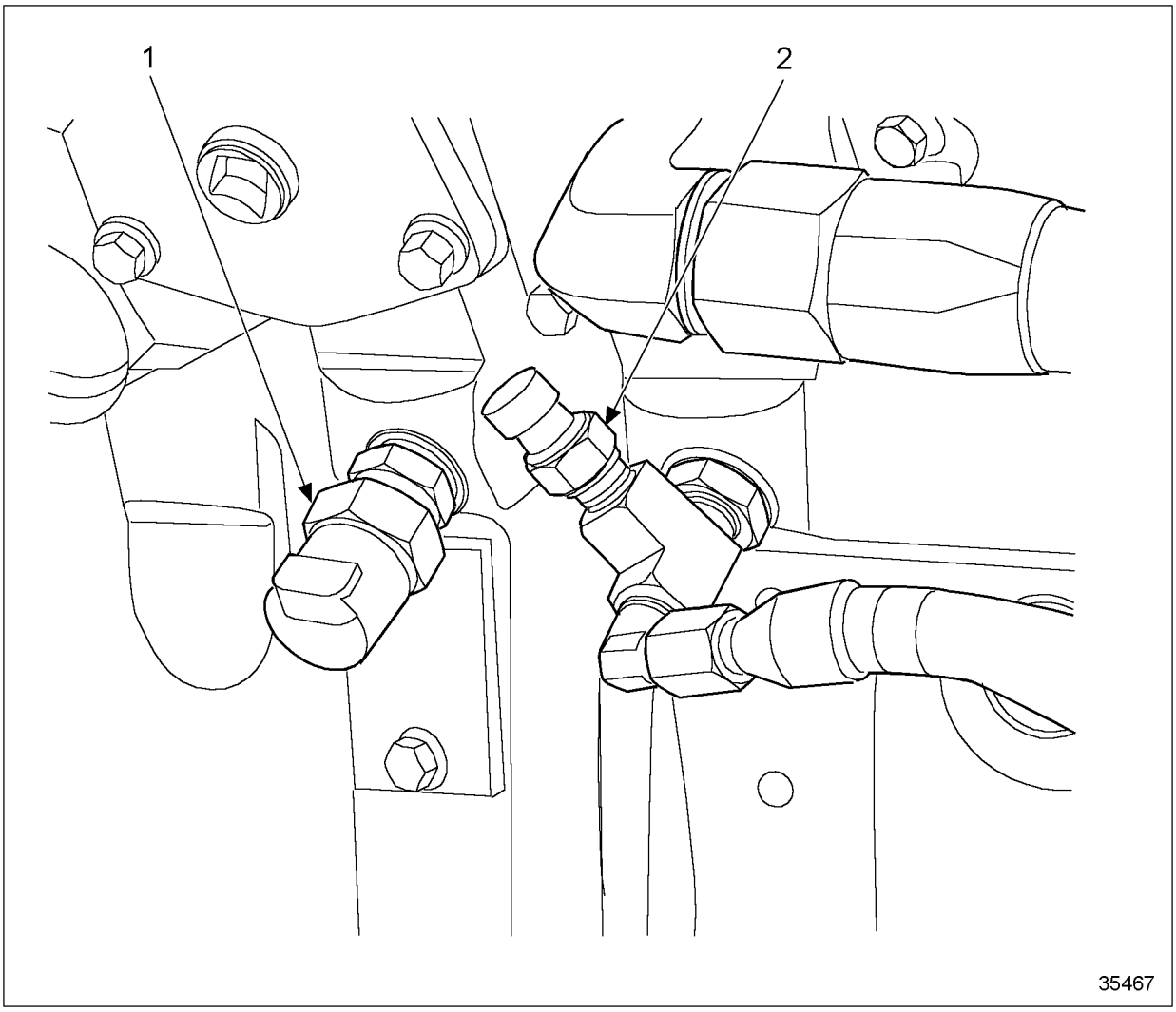


Figure 2-64 Oil Temperature Sensor



1. Oil Pressure Sensor
2. Oil Temperature Sensor

Figure 2-65 Oil Temperature Sensor and Oil Pressure Sensor (12V and 16V)

2.12.1 Repair or Replacement of Oil Temperature Sensor

The OTS is non-serviceable and must be replaced as a unit. No adjustment is required.

2.12.2 Removal of Oil Temperature Sensor

With engine (ignition) off remove the OTS as follows:

1. Disengage the locking tang on the two-wire connector.
2. Grasp the connector body, and gently pull it from the socket.
3. Unscrew the hex portion of the sensor with the appropriate wrench.

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2.12.3 Installation of Oil Temperature Sensor

With engine (ignition) off install the OTS as follows:

NOTICE:
The Oil Temperature Sensor is an electronic device. Use care when installing to prevent damage.

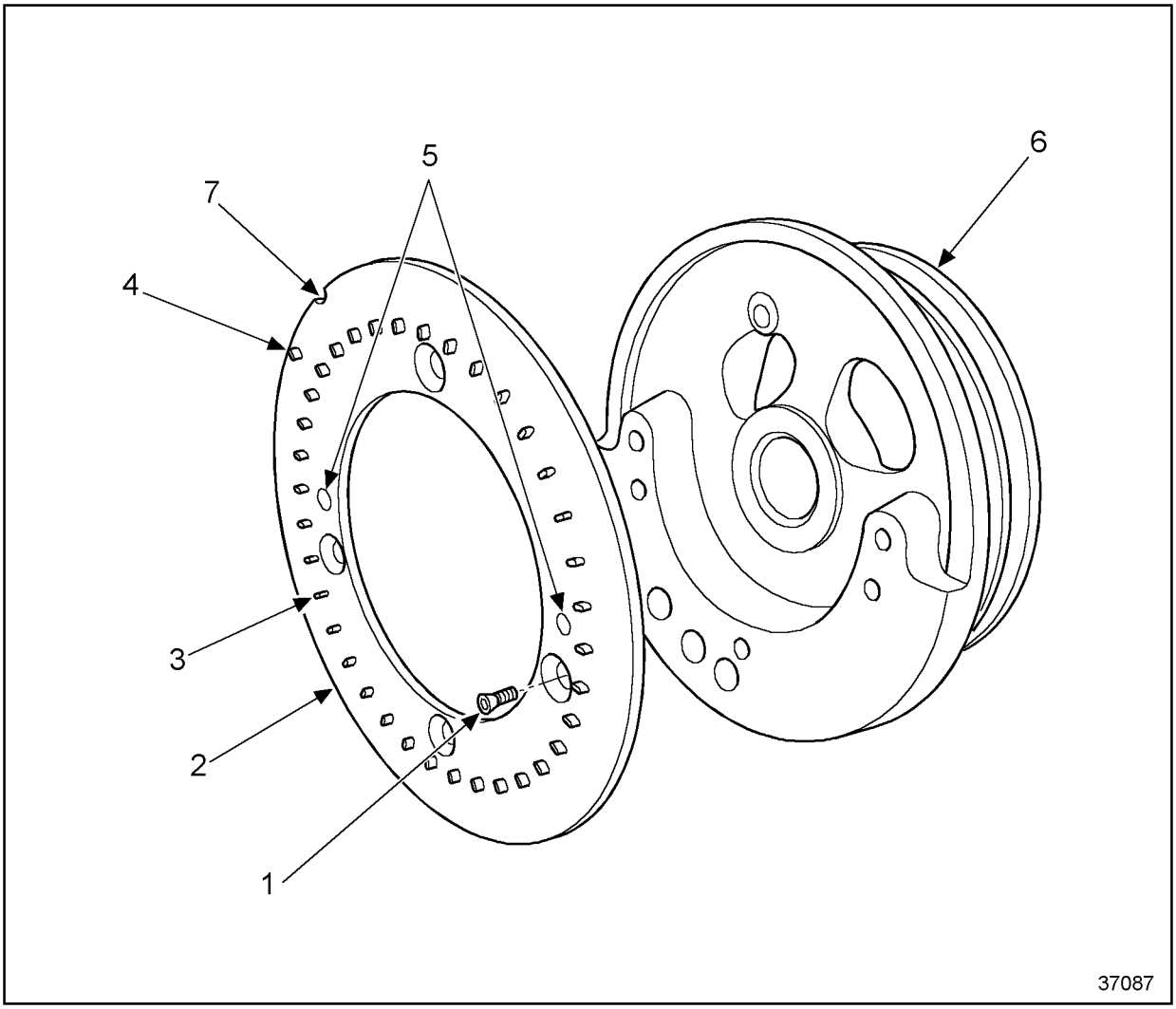
1. To prevent leaks, apply Loctite pipe sealer with Teflon 567 (or equivalent) on all but the first two threads of the OTS.
2. Install the OTS sensor with a hex wrench.
3. Press the connector body into the socket.
4. Engage the locking tang on the two-wire connector.
5. Turn the ignition to the "ON" position. 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.
6. Check for oil leaks.

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2.13 PULSE WHEEL DDEC III AND II (6V AND 8V ENGINES)

The following is an overview of the DDEC III pulse wheel. An overview for the DDEC II pulse wheel will follow. Procedures in this section apply to both DDEC II an III.

The pulse wheel is a metal disc that is mounted to the rear of the left camshaft pulley. See Figure 2-66.



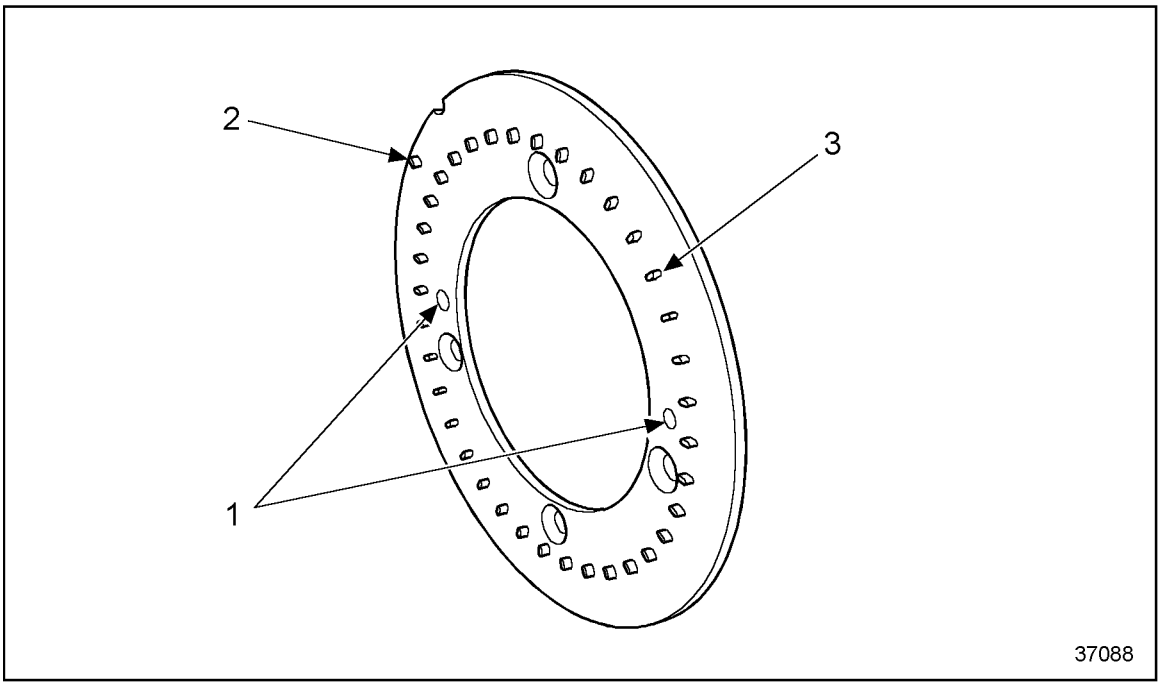
1. Allen Screw (Tapered Head)
2. Pulse Wheel
3. Timing Reference Sensor Signal Teeth (36)
4. Synchronous Reference Sensor Tooth (1)
5. Dowel Holes
6. Camshaft Pulley
7. Notch

Figure 2-66 Pulse Wheel and Camshaft Pulley DDEC III (6V and 8V-92)

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The raised metal teeth generate a signal in the Synchronous Reference Sensor (SRS) and Timing Reference Sensor (TRS). The ECM uses these signals to determine engine speed to locate the number one cylinder and to determine the piston positions for fuel injection.

For DDEC III and IV, one wheel is used for the 6V and 8V-92 engines regardless of rotation. The pulse wheel is used on all 6V and 8V-92 engines. See Figure 2-67. A groove is machined on the outer edge of the wheel. This corresponds to the TRS pin used for proper timing of the TRS sensor.



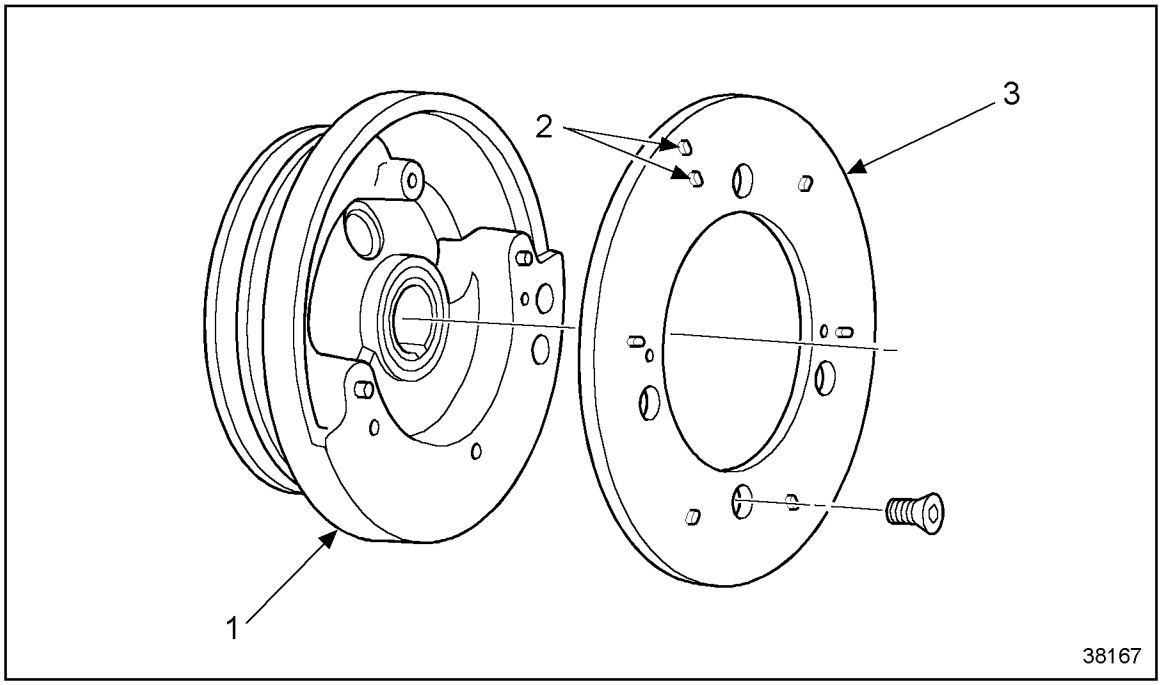
1. Dowel Holes
2. Synchronous Reference Sensor Signal Tooth (1)
3. Timing Reference Sensor Signal Teeth (36)

Figure 2-67 Pulse Wheel DDEC III (6V and 8V-92)

This wheel has a total of 37 raised metal teeth. Two holes are provided that mate with dowels at the rear of the cam pulley. A staggered bolt pattern prohibits improper installation.

DDEC II Pulse Wheel Overview

The pulse wheel is a metal disc that is mounted to the rear of the left camshaft pulley. See Figure 2-68.



1. Camshaft Pulley
2. Teeth
3. Pulse Wheel

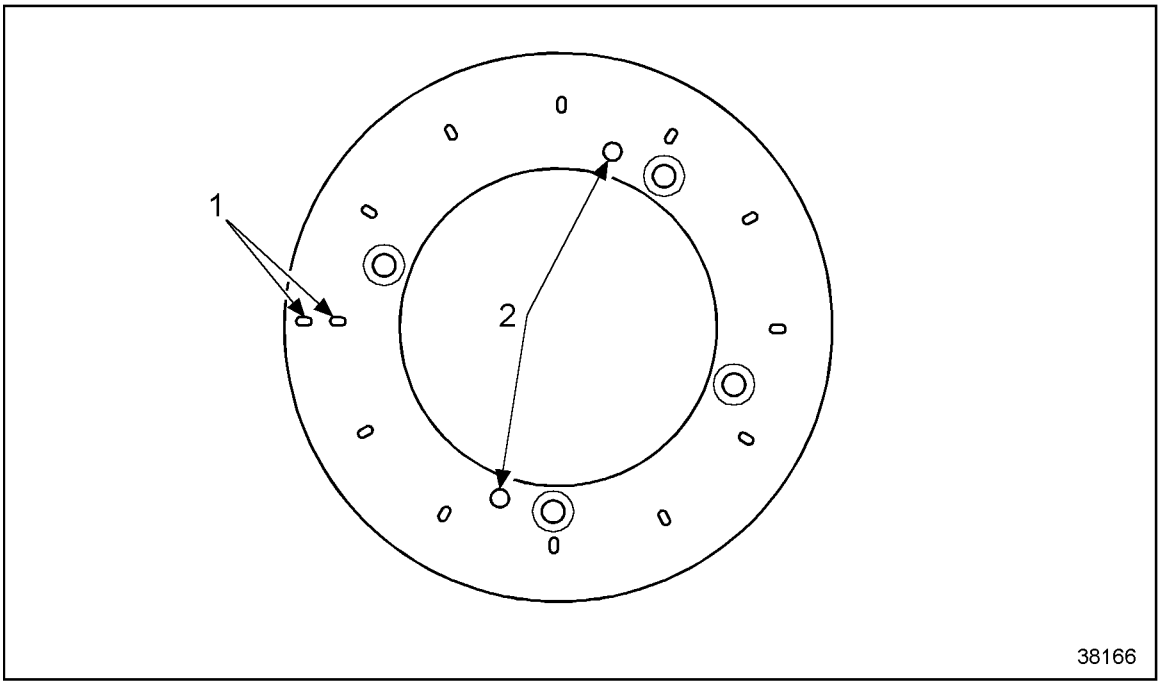
Figure 2-68 Pulse Wheel and Camshaft Pulley DDEC II (6V-92)

The raised metal teeth generate a signal in the Synchronous Reference Sensor (SRS) and Timing Reference Sensor (TRS). The ECM uses these signals to determine engine speed to locate the number one cylinder and to determine the piston positions for fuel injection.

One of three different wheels may be installed in DDEC II, depending on engine rotation and number of cylinders.

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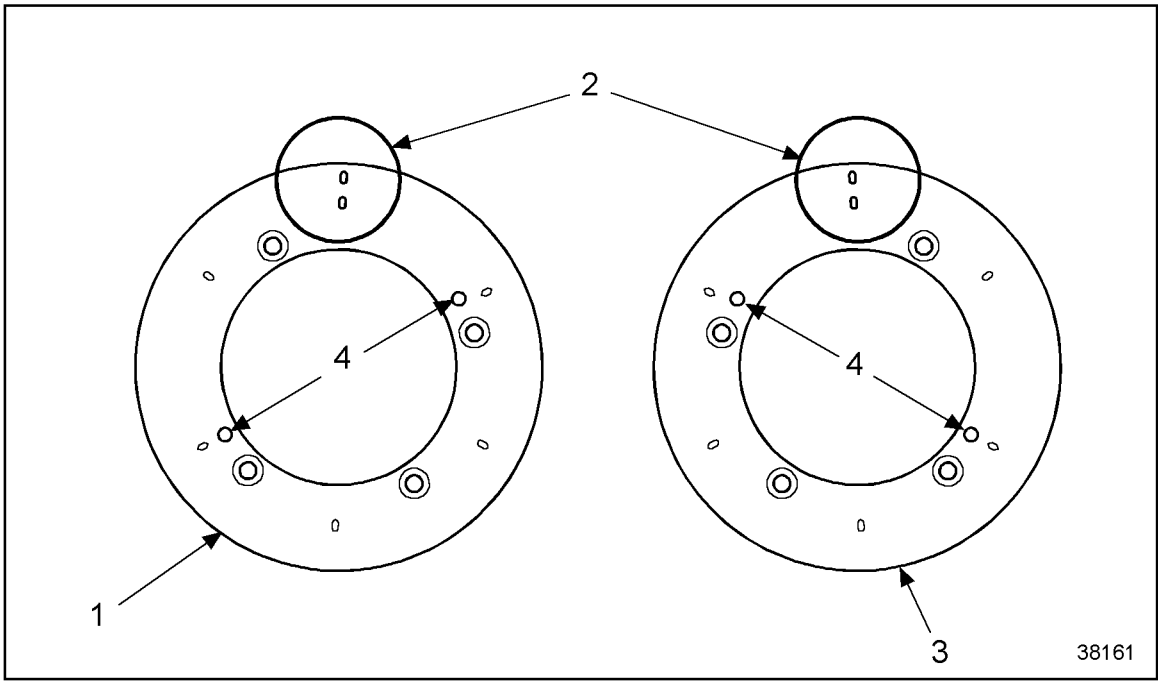
See Figure 2-69. This wheel has a total of thirteen raised teeth. Two holes are provided that mate with dowels at the rear of the cam pulley. A staggered bolt pattern prohibits improper installation.



1. Teeth
2. Dowel Holes

Figure 2-69 Pulse Wheel DDEC II (8V-92)

Two different pulse wheels are used on 6V-92 engines, depending on the direction of rotation of the engine. With the double row of teeth on the pulse wheel at the twelve o'clock position, note the location of the dowel holes. See Figure 2-70.



1. Left-Hand Rotation
2. Double Teeth
3. Right-Hand Rotation
4. Dowel Holes

The direction of engine rotation is determined by viewing the engine from the front or fan end. On right-hand rotation engines, the crank pulley rotates clockwise. On left-hand rotation engines, the crank pulley rotates counterclockwise.

Figure 2-70 Pulse Wheel DDEC II (6V-92) Depicting Engine Rotation

2.13.1 Repair or Replacement of Pulse Wheel

The pulse wheel is non-serviceable.

2.13.2 Removal of Pulse Wheel

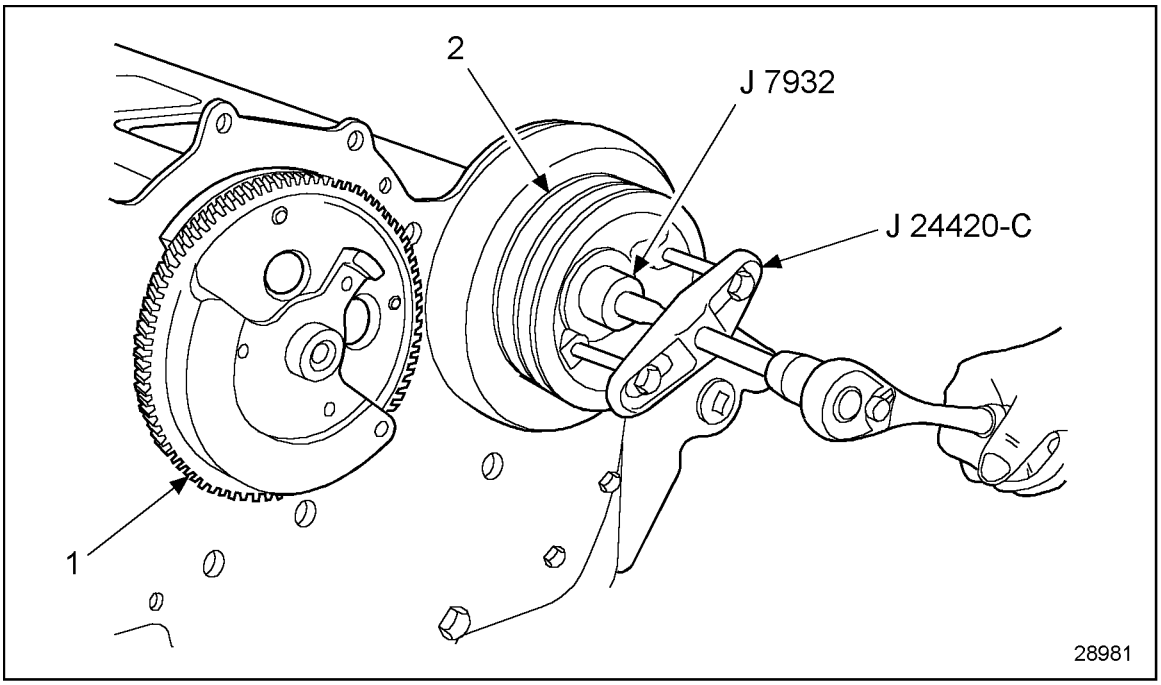
The replacement of the pulse wheel will require adjustment of the Synchronous Reference Sensor (SRS) and Timing Reference Sensor (TRS). Refer to section 2.15.3.1. Remove the pulse wheel as follows:

1. Loosen and remove the drive belt(s) from the left camshaft pulley, if equipped.
2. Loosen and remove the nut and washer securing the left cam pulley to the end of the camshaft.

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NOTICE:
Do not pry the pulse wheel to remove it. You may bend the pulse wheel or damage the teeth.

3. Attach puller J 24420-C to the camshaft pulley.
4. Use adaptor J 7932 between the end of the camshaft and the puller screw to protect the end of the camshaft. See Figure 2-71.



1. RH Balance Weight and Camshaft Assembly 2. LH Camshaft Pulley

Figure 2-71 Puller J 24420-C and Adaptor J 7932

5. Remove the four Allen-type flat head screws that retain the pulse wheel to the cam pulley. Remove the pulse wheel.

2.13.2.1 Inspection of Pulse Wheel

Inspect the pulse wheel as follows:

1. Inspect the pulse wheel for damage:
   [a] If the pulse wheel is bent or deformed, or if teeth are bent or missing, replace pulse wheel.
   [b] If the wheel is not bent, and not teeth are missing, refer to section 2.13.3.

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2.13.3 Installation of Pulse Wheel

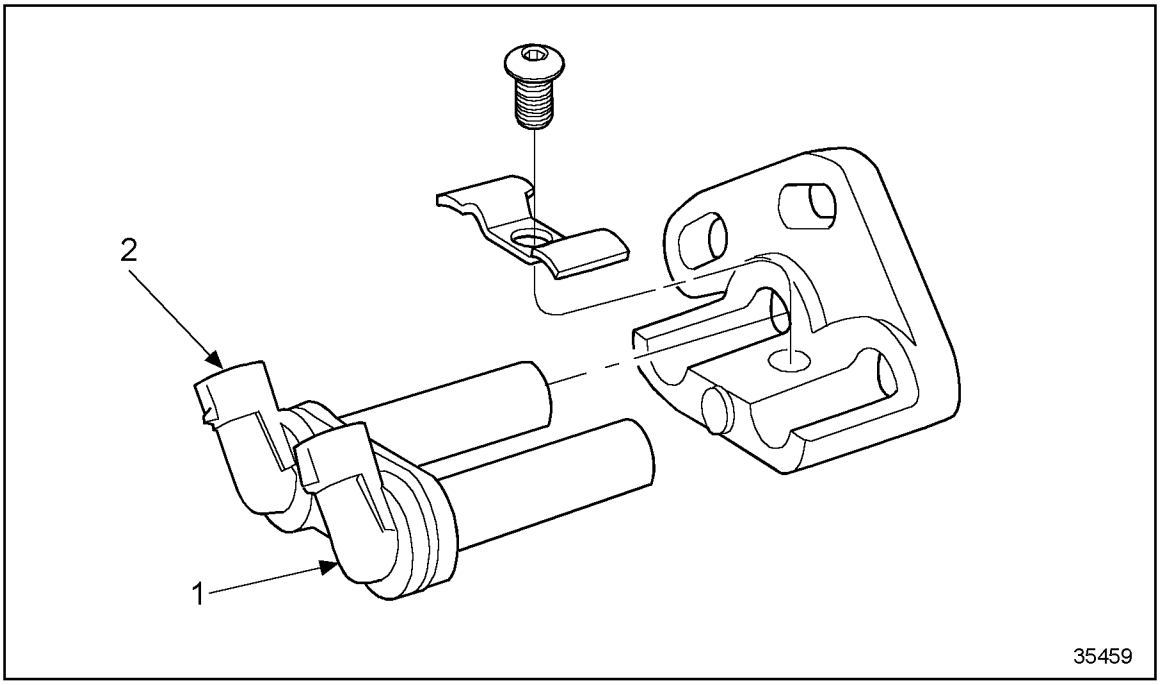
Install the pulse wheel as follows:

1. Locate the two small holes in the pulse wheel over the dowels in the rear of the cam pulley.
2. Use Loctite 262, or equivalent, on the four Allen-type flat head screws, and secure the pulse wheel to the cam pulley.
3. If removed, replace the Woodruff key to the slot in the camshaft.
4. Index the slot on the cam pulley to the Woodruff key, and start the pulley on the end of the camshaft.
5. Use a fiber mallet or plastic hammer to lightly tap the cam pulley onto the end of the camshaft.
6. Install the nut and lock washer to the end of the camshaft, and tighten to 407-441 N·m (300-325 lb·ft.) torque.
7. Adjust the SRS/TRS to pulse wheel air gap. Refer to section 2.15.3.1.
8. Install the drive belts.
9. Adjust the belt tension. Refer to section 13.18.

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2.14 SYNCHRONOUS REFERENCE SENSOR (6V AND 8V)

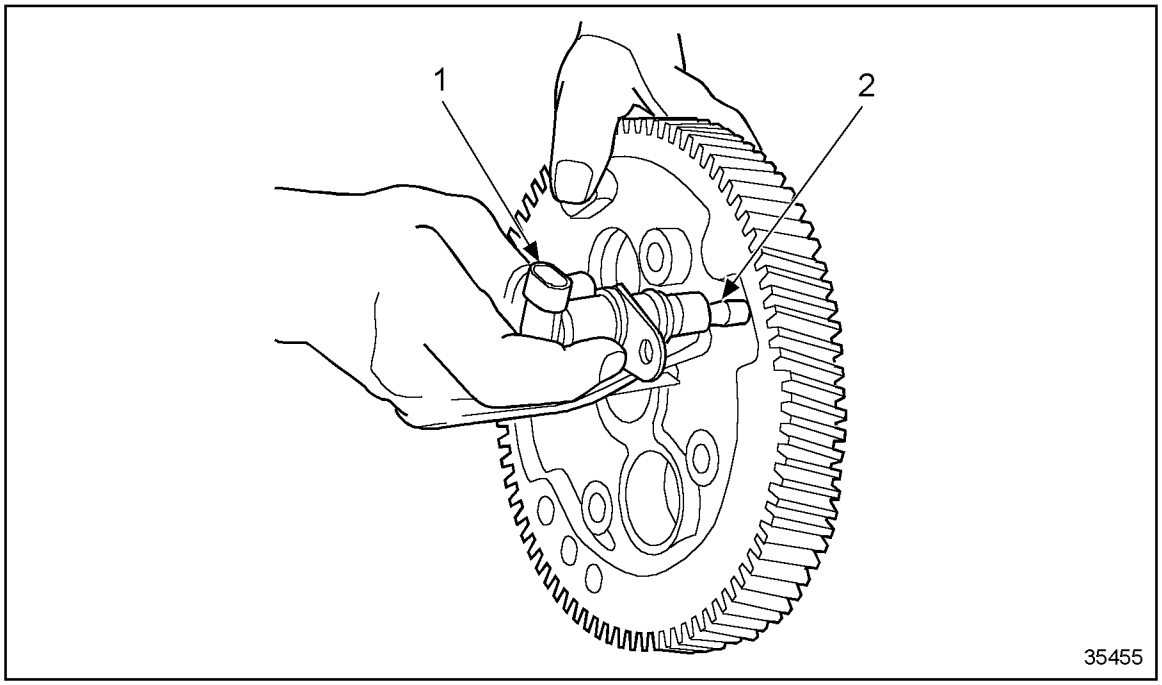
The Synchronous Reference Sensor (SRS) is an electronic component that sends a signal to the Electronic Control Module (ECM). See Figure 2-72 and see Figure 2-72.



1. Timing Reference Sensor
2. Synchronous Reference Sensor

Figure 2-72 SRS/TRS Reference Sensor (6V and 8V)

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1. Synchronous Reference Sensor
2. Once Per Revolution Pin

Figure 2-73 Synchronous Reference Sensor (12V and 16V)

The SRS references firing position for the number one piston. The SRS assembly is mounted through the engine front end plate at the top, left corner of the engine. See Figure 2-74.

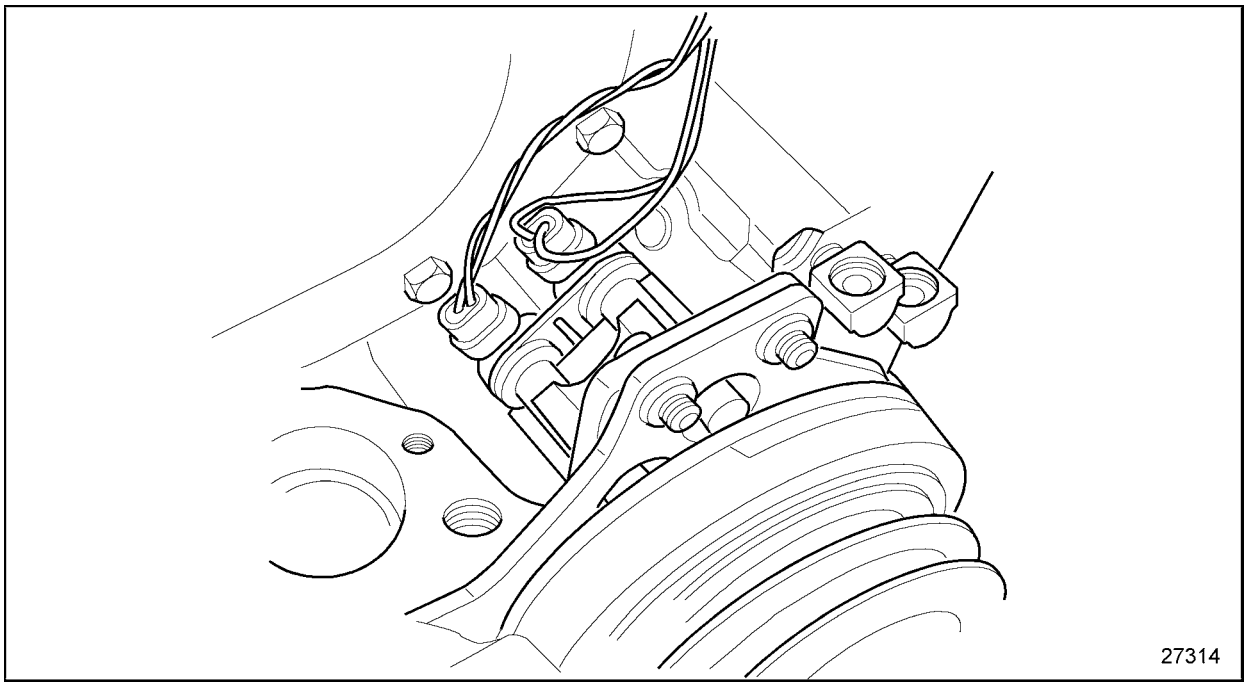


Figure 2-74 Location of SRS and TRS

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A tooth on the timing wheel, that is bolted to the left bank camshaft gear, passes the SRS once per revolution, signalling the ECM to determine engine speed.

2.14.1 Repair or Replacement of Synchronous Reference Sensor

The SRS is non-serviceable and must be replaced as a unit.

2.14.2 Removal of Synchronous Reference Sensor

Remove the SRS as follows:

1. Remove the heat shield, cold plate, and ECM. Refer to section 2.6.2(DDEC II), refer to section 2.7.2(DDEC III), or refer to section 2.8.2(DDEC IV).
2. Loosen and remove the four bolts and washers retaining the ECM bracket to the engine.
3. Loosen and remove the two bolts and washers retaining the ECM bracket to the blower end plate.
4. Remove the ECM bracket from the engine.
5. Remove any hoses or fuel lines necessary to gain access to the sensors.
6. Disengage the locking tang on the SRS connector.
7. Grasp the connector bodies, and gently pull them apart.
8. Remove the SRS retaining screw and clip.
9. Remove the sensor assembly.
10. If the pulse wheel or engine front end plate has been removed or replaced, loosen the two sensor-retaining socket head screws.

2.14.3 Inspection of Synchronous Reference Sensor

Inspect the SRS as follows:

1. Inspect sensor contact for damage.
   [a] If contact damage to the pulse wheel or pin at the harness connector is found, replace the SRS sensor. Refer to section 2.14.4.
   [b] If no sensor damage is found, refer to section 2.14.4.

2.14.4 Installation of Synchronous Reference Sensor

Install the SRS as follows:

NOTICE:

The SRS is an electronic component. Use care when installing, to prevent damage

CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

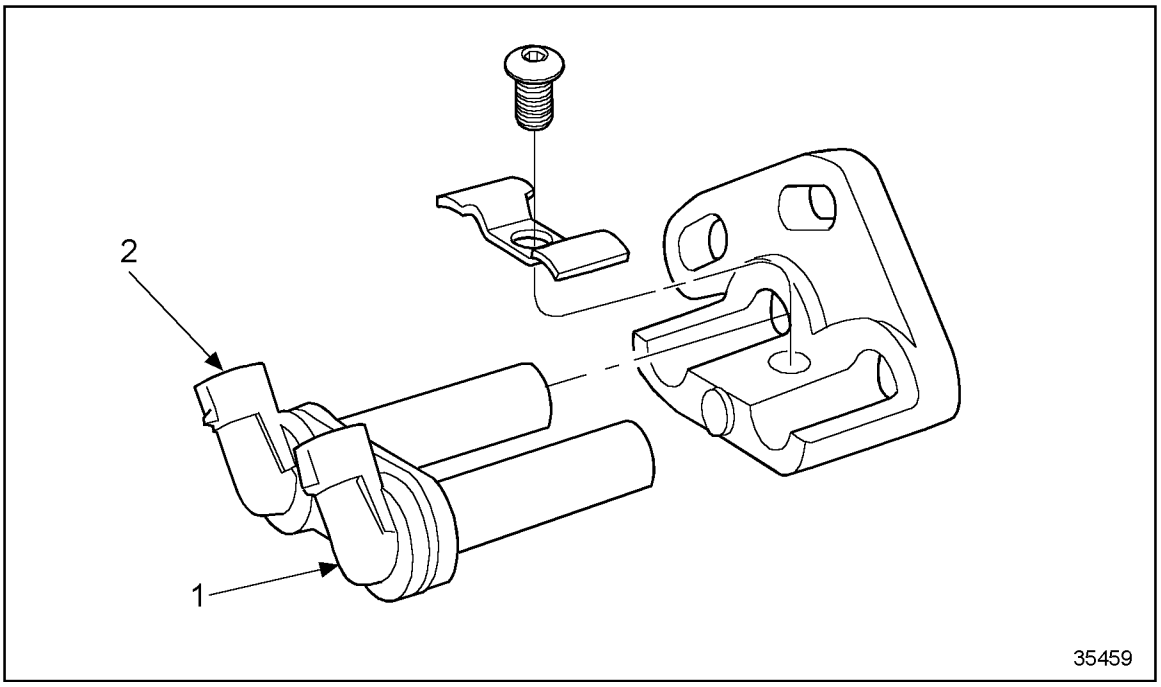
Diesel fuel is relatively harmless at ambient temperatures.

1. If the pulse wheel or engine front end plate has been removed or replaced, tighten the two sensor-retaining socket head screws. Refer to section 2.15.3.1.
2. Install the sensor assembly.
3. Attach the SRS retaining screw and clip.
4. Press the connector bodies together.
5. Engage the locking tang on the SRS connector.
6. Replace any hoses or fuel lines previously removed.
7. Install the ECM bracket.
8. Install and tighten the two bolts and washers connecting the ECM bracket to the blower end plate.
9. Install and tighten the four bolts and washers connecting the ECM bracket to the engine.
10. Refer to section 2.6.3(DDEC II), refer to section 2.7.3(DDEC III), or refer to section 2.8.3(DDEC IV) for ECM installation. Install the heat shield, cold plate, and ECM.
11. Adjust the SRS. Refer to section 2.15.3.1.

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2.15 TIMING REFERENCE SENSOR

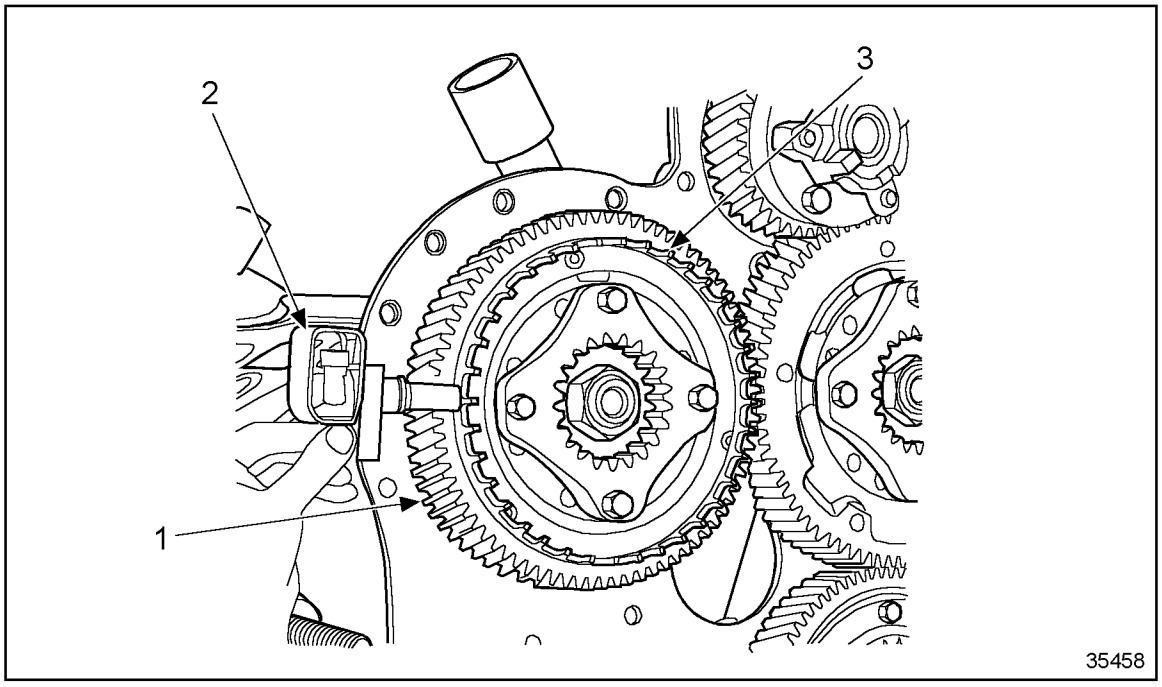
The Timing Reference Sensor (TRS) is an electronic component that sends a signal to the Electronic Control Module (ECM) to indicate the firing position for each piston. See Figure 2-75 and see Figure 2-76.



1. Timing Reference Sensor
2. Synchronous Reference Sensor

Figure 2-75 SRS/TRS Reference Sensor (6V and 8V)

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1. Left Bank Camshaft Gear
2. Timing Reference Sensor
3. Pulse Wheel

Figure 2-76 Timing Reference Sensor and Pulse Wheel Installed on Camshaft Gear (12V and 16V)

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The assembly is mounted through the engine front end plate at the top, left corner of the engine. See Figure 2-77.

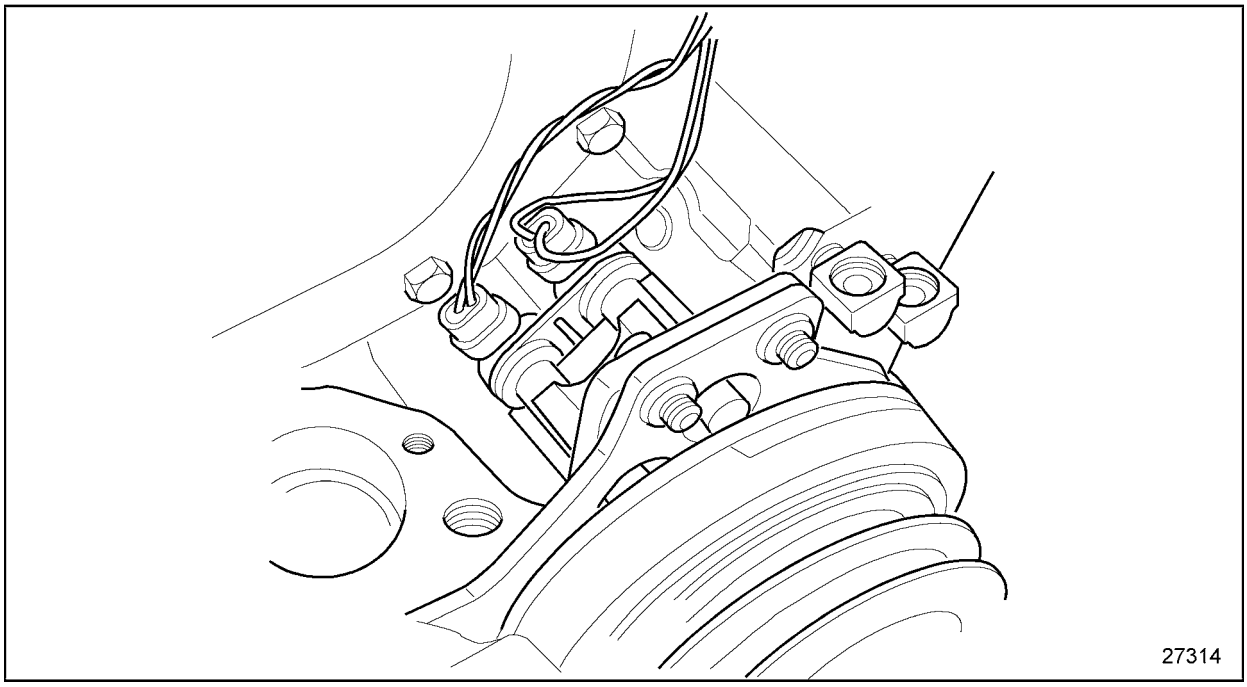


Figure 2-77 Location of SRS and TRS

2.15.1 Repair or Replacement of Timing Reference Sensor

The TRS is non-serviceable and must be replaced as a unit.

2.15.2 Removal of Timing Reference Sensor

Remove the TRS as follows:

1. Refer to section 2.6.2(DDEC II), refer to section 2.7.2(DDEC III), or refer to section 2.8.2(DDEC IV) and remove the heat shield, cold plate, and ECM.
2. Loosen and remove the four bolts and washers retaining the ECM bracket to the engine.
3. Loosen and remove the two bolts and washers retaining the ECM bracket to the blower end plate.
4. Remove the ECM bracket from the engine.
5. Remove any hoses or fuel lines necessary to gain access to the sensors.
6. Disengage the locking tang on the TRS connector.
7. Grasp the connector bodies, and gently pull them apart.
8. Remove the TRS retaining screw and clip.
9. Remove the sensor assembly.

10. If the pulse wheel or engine front end plate has been removed or replaced, loosen the two sensor-retaining socket head screws.

2.15.2.1 Inspection of Timing Reference Sensor

Inspect the TRS as follows:

1. Inspect sensor contact for damage.
   [a] If damage to the pulse wheel or pin at the harness connector is found, replace the TRS sensor. Refer to section 2.14.4.
   [b] If no sensor damage is found, refer to section 2.14.4.

2.15.3 Installation of Timing Reference Sensor

Install the TRS as follows:

NOTICE:
The TRS is an electronic component. Use care when installing, to prevent damage

1. If the pulse wheel or engine front end plate has been removed or replaced, tighten the two sensor-retaining socket head screws. Refer to section 2.15.3.1.
2. Install the sensor assembly.
3. Attach the TRS retaining screw and clip.
4. Press the connector bodies together.
5. Engage the locking tang on the TRS connector.
6. Replace any hoses or fuel lines previously removed.
7. Install the ECM bracket.
8. Install and tighten the two bolts and washers connecting the ECM bracket to the blower end plate.
9. Install and tighten the four bolts and washers connecting the ECM bracket to the engine.
10. Refer to section 2.6.3(DDEC II), refer to section 2.7.2(DDEC III), or refer to section 2.8.3(DDEC IV) for ECM installation. Install the heat shield, cold plate, and ECM.
11. Adjust the TRS. Refer to section 2.15.3.1.

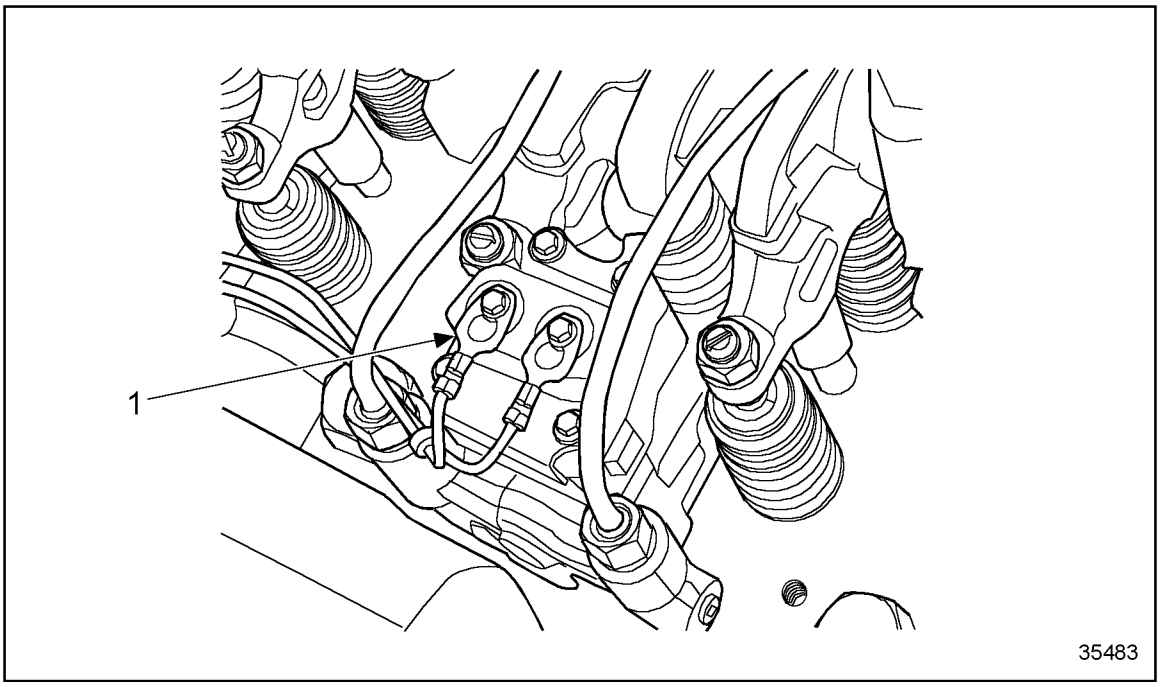
2.15.3.1 Adjustment of Synchronous Reference Sensor and Timing Reference Sensor

Whenever a sensor assembly is installed, align it in relationship to the teeth on the pulse wheel.

1. Refer to section 2.3.2(EUI Removal). See Figure 2-78.

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- For **DDEC II** remove the 1R for right-hand rotation engines. Remove 1L for left-hand rotation engines.
- For **DDEC III and IV**, remove the 1R injector. The 1R injector location is to be used for all configurations.



1 Injector

Figure 2-78 EUI Injector Location

2. Position the piston for the cylinder at top-dead-center using crankshaft position timing tool J 34930-A as follows:

NOTICE:
Failure to insert the spacer could result in damage to the dial indicator if the piston is already at the top of travel when the tool is installed.

[a] Install the slotted spacer on the chain between the dial indicator and the top of the holder. Tighten the clamp screw.

[b] Insert dial indicator tool into the injector bore, install injector hold-down crab, and tighten bolt.

[c] Turn the crankshaft slowly in the direction of rotation, and note indicator movement.

[d] Stop turning when the dial hand just stops.

[e] Turn the crankshaft slowly, opposite the direction of rotation, until the dial indicator hand just starts to move. The piston is now at top-dead-center.

NOTE:
Before piston downward travel can be measured, the dial indicator must be "zeroed".

[f] Loosen the clamp screw, and remove the slotted spacer.

[g] Lower the dial indicator until the smaller indicator hands are at "0" and the larger hand is near "0". See Figure 2-79.

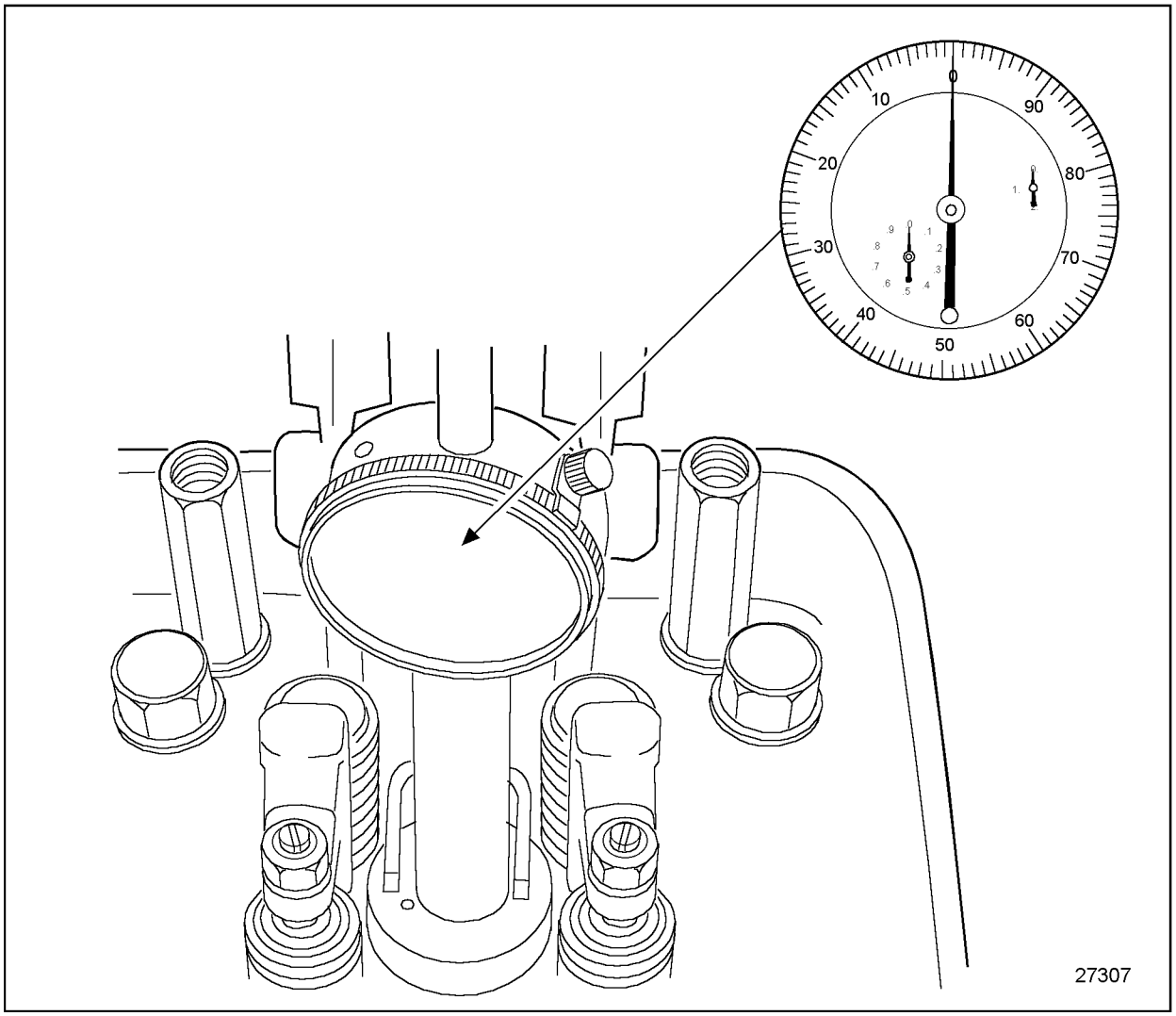


Figure 2-79 Reading Dial Indicator

[h] Tighten the clamp screw, and turn the outer ring of the dial face to "0" the large hand.

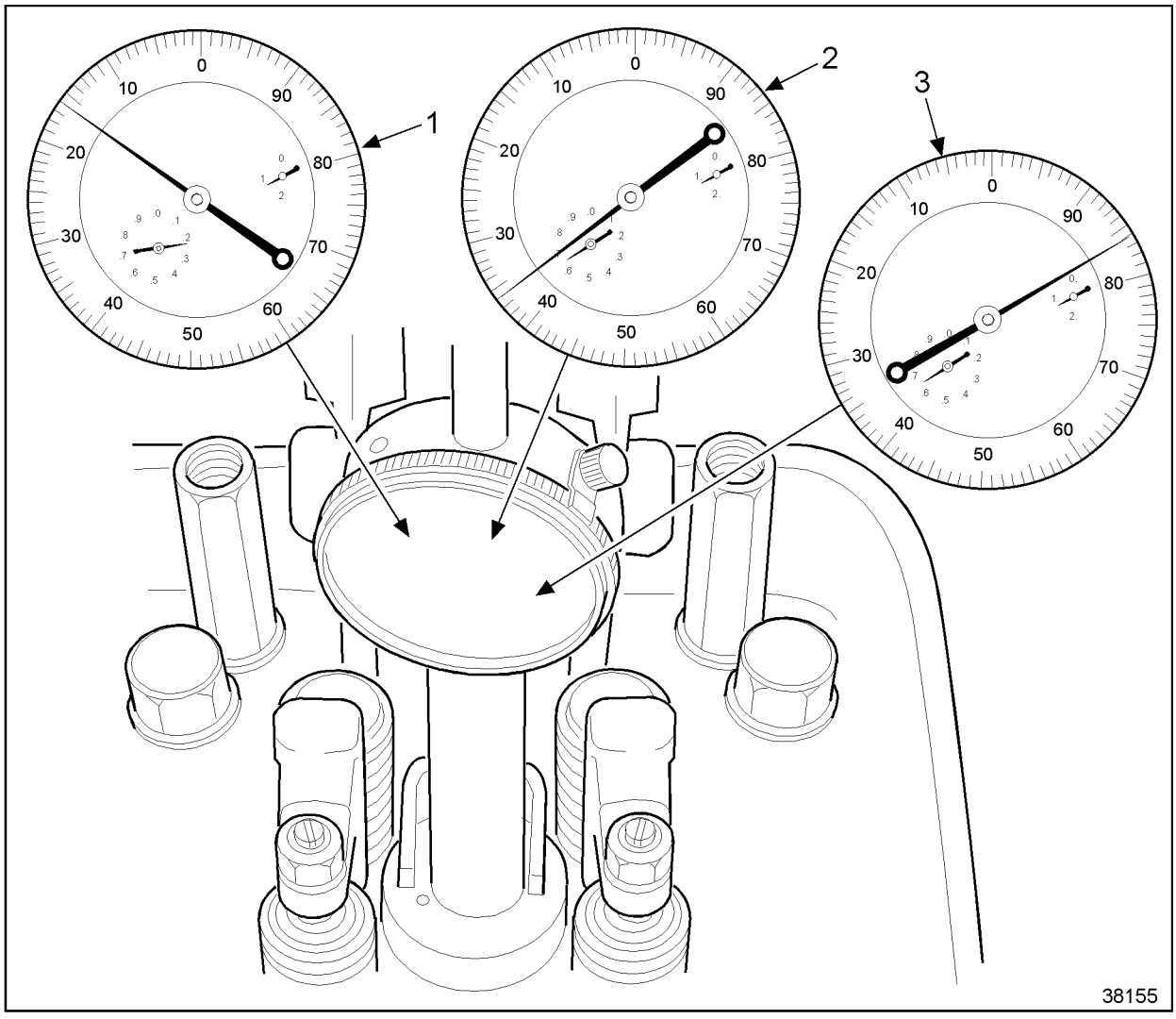
[i] Tighten the bezel screw so the outer ring will not turn.

DDEC II – Turn the crankshaft slowly in the direction of rotation until the dial indicator pointer reads exactly 30.8864 mm (1.216 in.) See Figure 2-80.

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DDEC III – Turn the crankshaft slowly in the direction of rotation until the dial indicator pointer reads exactly 41.5544 mm (1.636 in.) for RH 6V engines, 37.719 mm (1.485 in.) for LH 6V engines, or 54.5084 mm (2.146 in.) for RH 8V engines. See Figure 2-80.

DDEC IV – Turn the crankshaft slowly in the direction of rotation until the dial indicator pointer reads exactly 46.685 mm (1.838 in.) for RH 6V engines or 42.774 mm (1.684 in.) for LH 6V engines. See Figure 2-80.



1. DDEC II
2. DDEC III
3. DDEC IV

Figure 2-80 Measuring Piston Travel on Dial Indicator

3. Check the torque of the SRS/TRS upon completion of the positioning procedure. Refer to section 2.15.3.1 for torque procedures.

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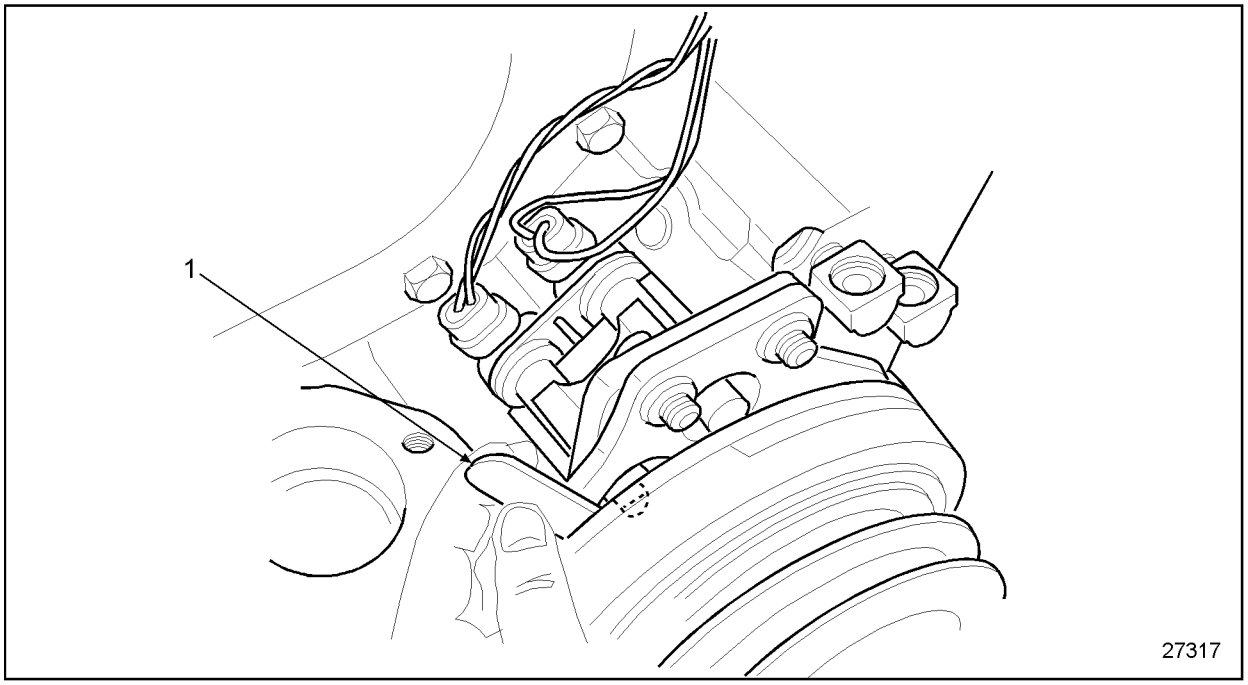
NOTICE:
If the crankshaft pulley retaining bolt has loosened during the timing procedure, tighten it to the specified torque upon completion of the SRS/TRS positioning procedure. Failure to maintain required bolt torque may lead to crankshaft pulley loosening, resulting in severe engine damage.

NOTE:
At this point the teeth on the rear of the pulse wheel, located on the rear cam pulley, are in the proper location for positioning the sensors. The sensor bracket must be positioned correctly in relation to the engine front end plate. Use SRS/TRS timing tool J 39815 to accomplish this task.

4. Tap the end of the camshaft pulley with a fiber mallet or rubber hammer to take up the camshaft end play.

Perform the following steps for DDEC II (for DDEC III and IV proceed to step 15.)

5. Insert the SRS/TRS timing tool between the double teeth on the pulse wheel and the TRS so that the groove at the rear of the tool slides over the teeth in the Pulse Wheel. See Figure 2-81.



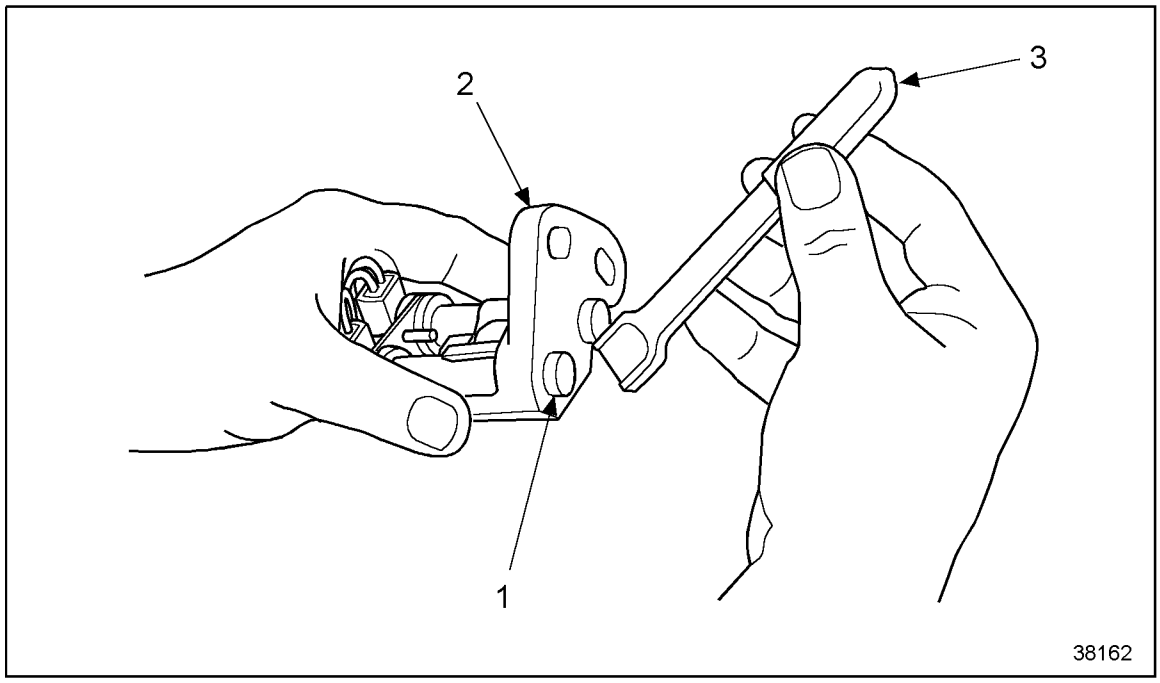
1. Timing Tool

Figure 2-81 SRS/TRS Timing Tool Insertion Point (DDEC II)

6. This operation is necessary if the sensor bracket has been loosened from its original mounting position. If the sensor bracket has not been loosened, proceed to step 8. Position

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the SRS/TRS bracket so that the round end of the TRS is located in the half moon portion at the front of the timing tool. See Figure 2-82.



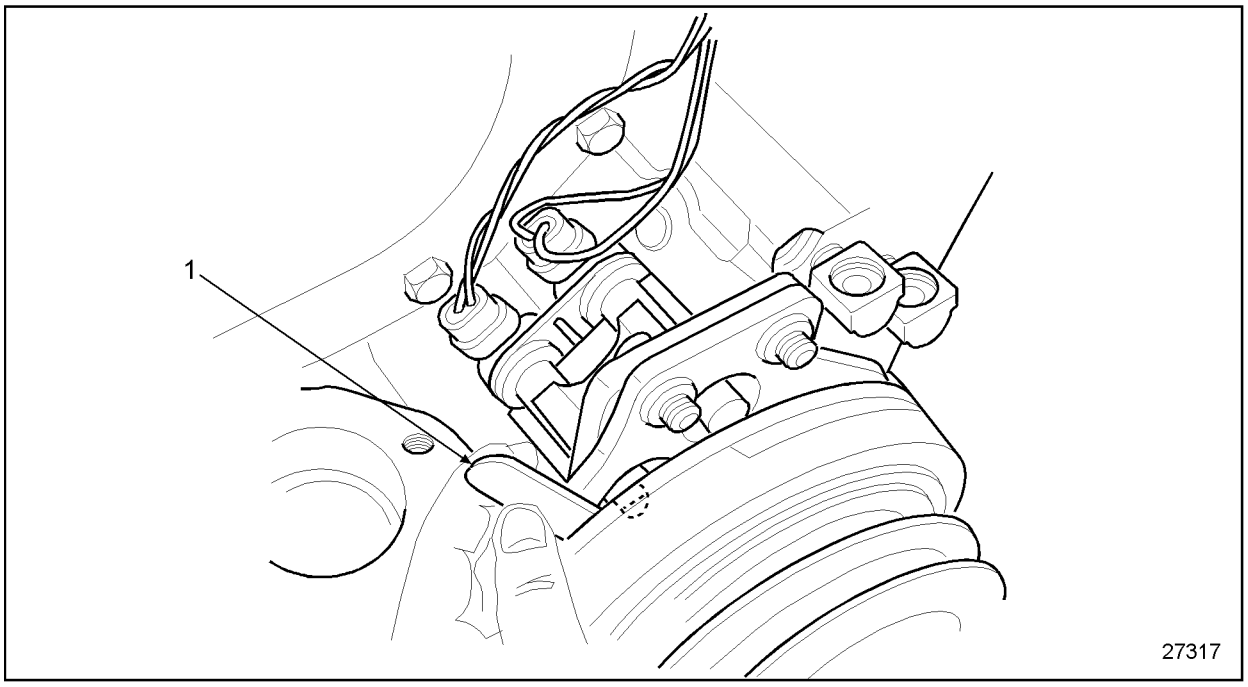
1. TRS
2. SRS/TRS Bracket
3. Timing Tool

Figure 2-82 SRS/TRS Bracket Position (DDEC II)

7. Tighten the two Allen bolts securing the SRS/TRS bracket to the engine front end plate.

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8. Push gently on the end of the TRS so that the timing tool is in direct contact with the TRS and the raised metal teeth of the Pulse wheel. See Figure 2-83.



1. Timing Tool

Figure 2-83 Timing Tool Position (DDEC II)

9. Tighten the sensor retaining clip socket head screw. If this adjustment has been done correctly, the resulting air gap between the pulse wheel teeth and the sensor will be 0.020 in. (± 0.002 in.)
10. Loosen and remove the injector crab hold-down bolt.
11. Remove the injector crab.
12. Remove the timing tool.
13. Remove the dial indicator.
14. Install the EUI previously removed and the front cover and related parts. Refer to section 2.3.4.

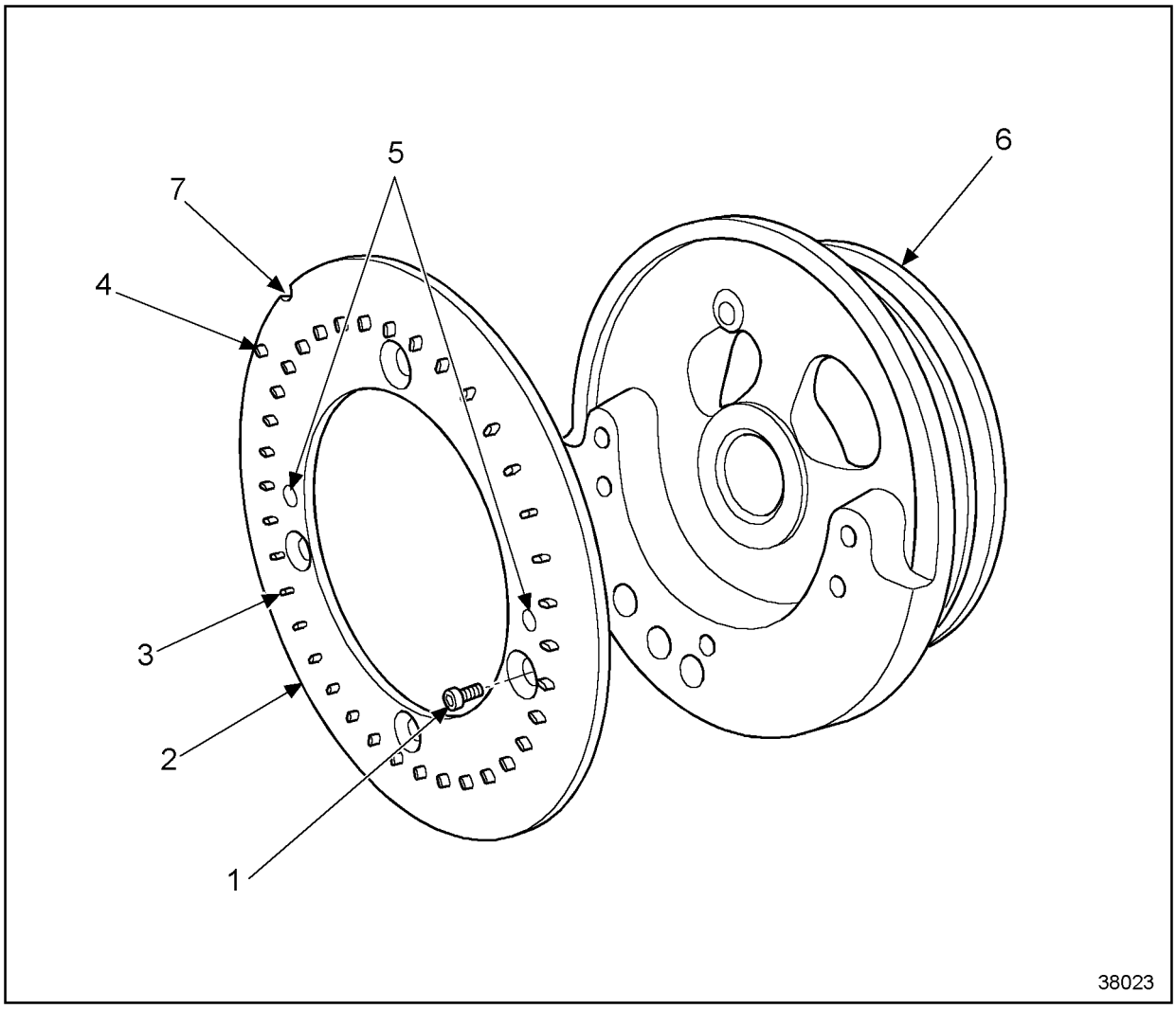
Perform the following steps for DDEC III and IV

15. Insert the TRS timing tool J 39815 into the bracket where the TRS sensor was removed from.

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16. Slide the tool through the bracket and cover so the slot in the tool engages with the TRS timing pin on the pulse wheel.

NOTE:
There are 36 TRS pins and 1 SRS pin. The TRS timing tool must be inserted over the No. 1 TRS pin. Slide the tool through the bracket and cover so that the slot in the tool engages with the TRS timing pin on the pulse wheel. The correct TRS pin corresponds to the notch found on the outer edge of the pulse wheel. See Figure 2-84.



1. Allen Screw (Tapered Head)
2. Pulse Wheel
3. Timing Reference Sensor Signal Teeth (36)
4. Synchronous Reference Sensor Tooth (1)
5. Dowel Holes
6. Camshaft Pulley
7. Notch

Figure 2-84 DDEC III Pulse Wheel Installation

17. Adjust the bracket to provide the proper alignment. See Figure 2-85.

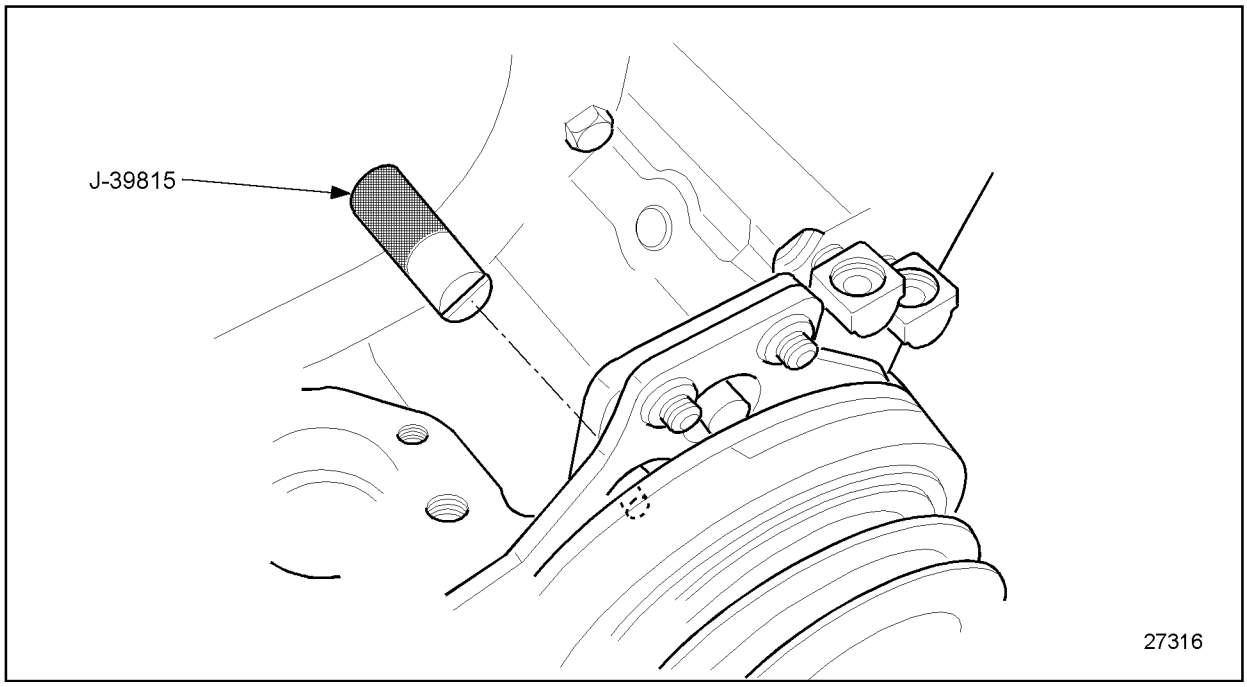


Figure 2-85 Use of TRS Timing Tool J 39815

18. Tighten the two Allen bolts to secure the SRS/TRS bracket to the front end plate with the TRS timing tool located into the TRS pin on the pulse wheel.
19. Remove the timing tool.
20. Tap the end of the camshaft pulley with a fiber or rubber mallet to take up the camshaft end play.
21. Gently slide the SRS/TRS assembly into the bracket.
22. Position a 0.50 mm (0.020 in.) feeler gage between the TRS sensor and the TRS pin on the pulse wheel.
23. Tighten the sensor retaining clip socket head screw.

NOTE:
If the adjustment is correct, the air gap between the pulse wheel teeth and the end of the sensor should be 0.457- 0.559 mm (0.018-0.022 in.).

24. Loosen and remove the injector crab hold-down bolt.
25. Remove the injector crab.
26. Remove the dial indicator.
27. Install the EUI previously removed and the front cover and related parts. Refer to section 2.3.4.

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2.16 COOLANT LEVEL SENSOR

The Coolant Level Sensor (CLS) is a two-piece sensor. See Figure 2-86. The sensor probe (supplied by the vehicle manufacturer) is mounted in the radiator top tank or overfill tank. The sensor module is attached to the engine sensor harness. The module sends an electrical signal to the ECM to indicate coolant level. Low coolant will activate the stop engine function or warning function. Both the CLS sensor probe and module are non-serviceable and should be replaced as necessary.

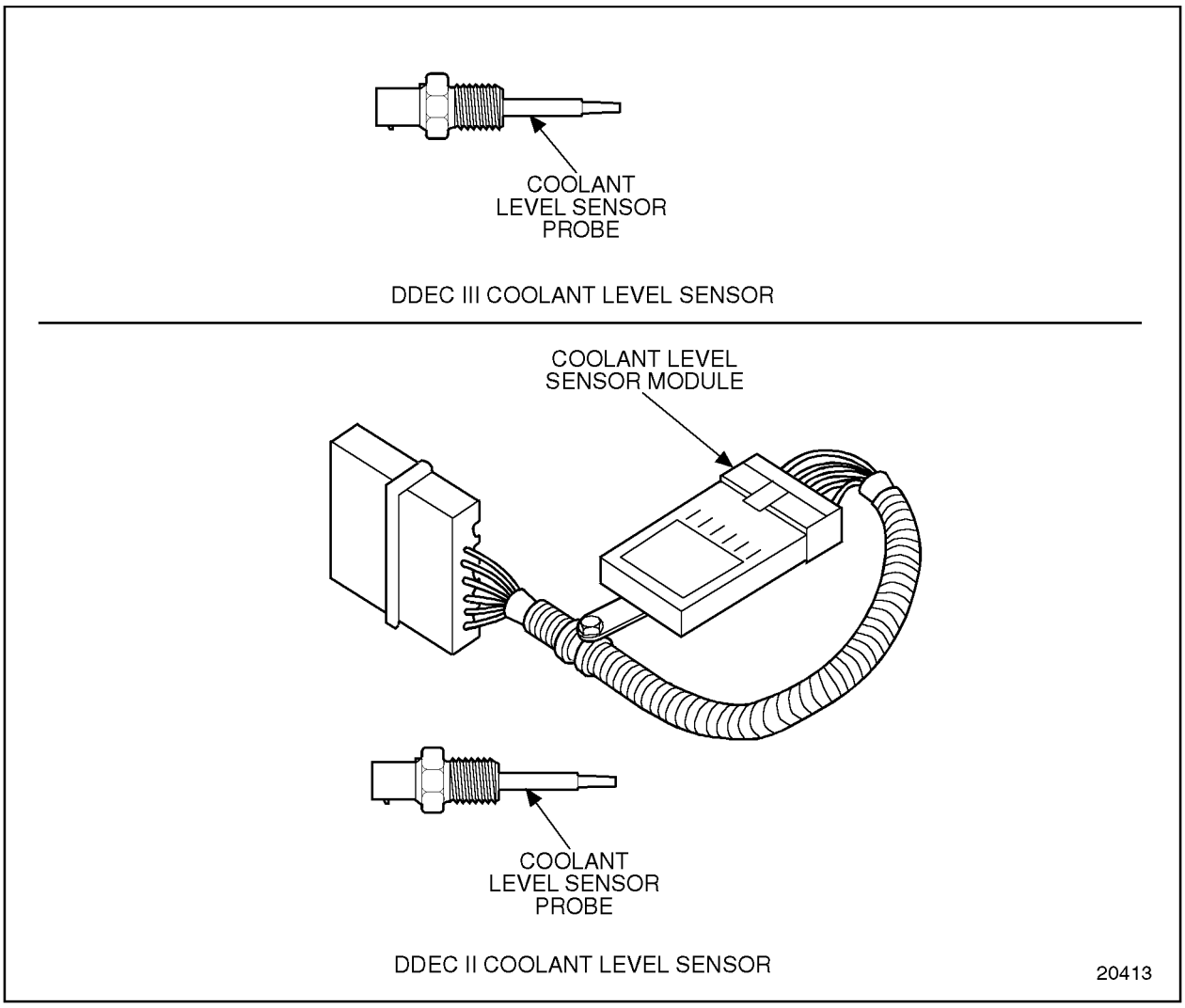


Figure 2-86 Two-piece Coolant Level Sensor

NOTE:
The coolant level sensor should be checked every 2 years, refer to section 13.12.7 for maintaining procedures.

The DDEC II and DDEC III coolant level sensors are different in the following ways:

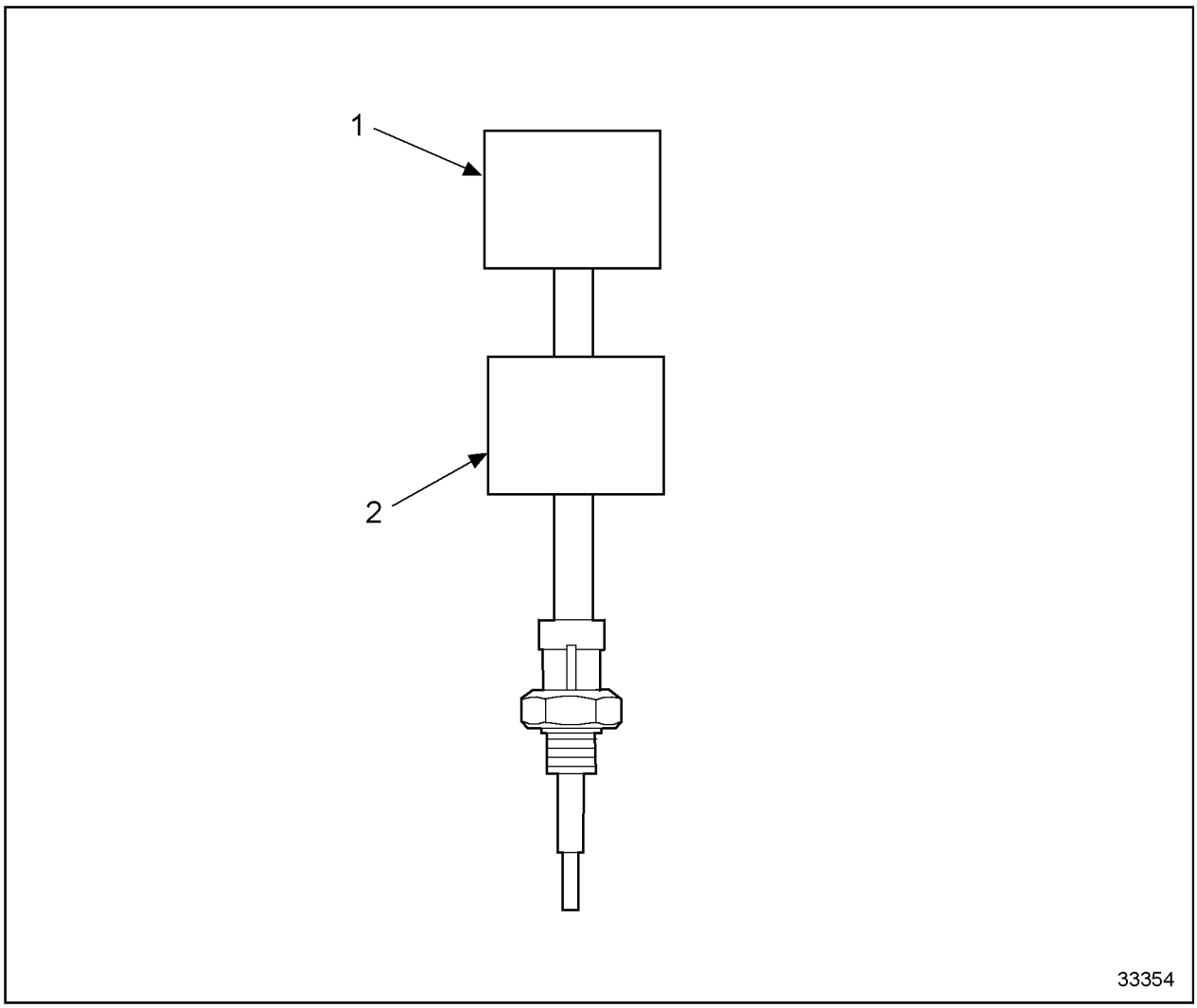
NOTICE:
To avoid possible engine damage, do not use DDEC II coolant level sensors on DDEC III applications. DDEC III sensors can be used in DDEC II applications.

- Externally, the sensors psychically look the same.
- The sensor used for DDEC II has a black colored connector.
- The sensor used for DDEC III has an off-white colored connector.

NOTE:
The DDEC III Coolant Level Sensor (CLS) has an internal resistor where the DDEC II (CLS) does not. The DDEC III (CLS) can be used in place of the DDEC II (CLS). However, the DDEC II (CLS) cannot be used in place of a DDEC III (CLS) on DDEC III units. In addition, DDEC III (CLS) used in place of the DDEC II (CLS) still requires module.

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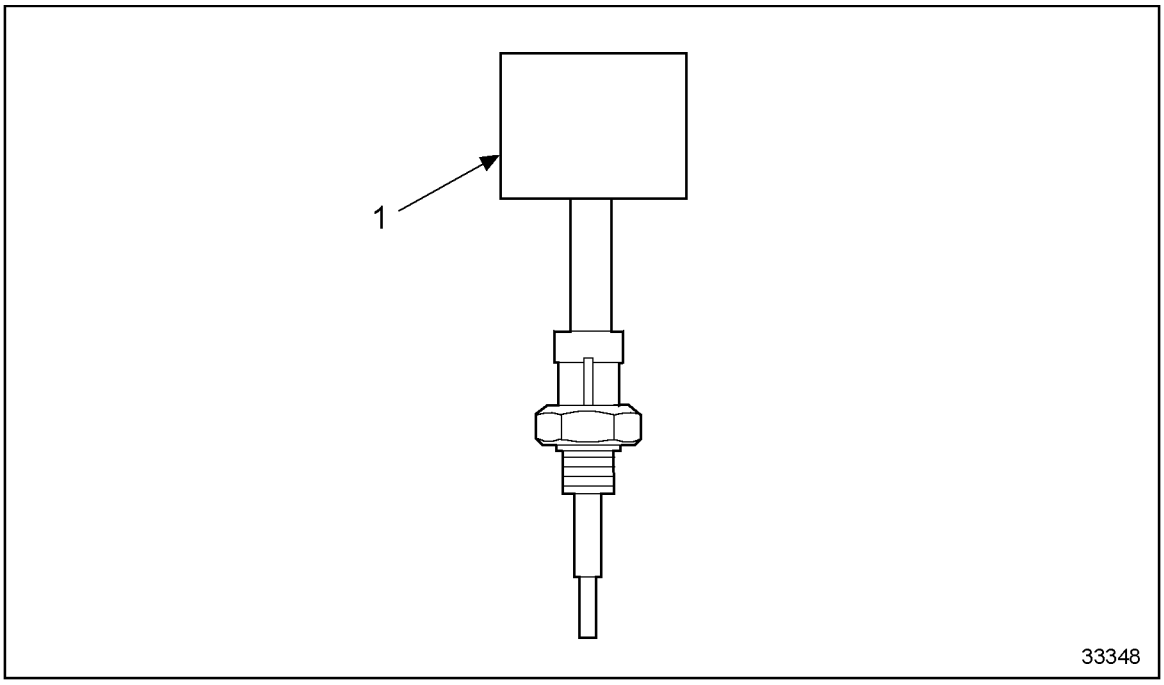
☐ A coolant level module must be used with all DDEC II CLS applications. See Figure 2-87.



1. DDEC II ECM
2. Coolant Level Module

Figure 2-87 Connector Assembly (DDEC II)

- All DDEC III applications, except Volvo®, do not require a coolant level module. See Figure 2-88.



1. DDEC III ECM

Figure 2-88 Connector Assembly (DDEC III)

2.16.1 Repair or Replacement of Coolant Level Sensor

The CLS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.16.2 Removal of Coolant Level Sensor Probe

Remove the CLS probe 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.
3. Use the appropriate wrench on the hex portion of the sensor and unscrew it from the radiator.

2.16.3 Removal of Coolant Level Sensor Module

Remove the CLS module as follows:

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1. Disengage the locking tang on the CLS module connector. Grasp the connector bodies and gently pull them apart.
2. Remove the CLS module from harness.

2.16.3.1 Inspection of Coolant Level Sensor Module

Inspect the CLS module as follows:

NOTICE:
Operating an engine with a coolant level probe connector that is not correctly wired may prevent the sensor from detecting a low coolant condition, eventually causing engine damage.

1. Inspect the wires on the metri-pak probe connector for incorrect wiring.

NOTE:
The yellow wire should be connected to the "A" terminal and the black wire should be connected to the "B" terminal.

[a] If the wires are reversed, remove and reposition the wires in the connector or splice a new connector to the harness

[b] If properly wired, use the connector.

2.16.4 Installation of Coolant Level Sensor Module

Install the CLS module as follows:

1. Position the CLS module on harness.

NOTICE:
Use care upon installation of the CLS module. It is an electronic component and easily damaged.

2. Grasp the connector bodies and gently push them together. Engage the locking tang on the CLS module connector.

2.16.5 Installation of Coolant Level Sensor Probe

Install the CLS probe as follows:

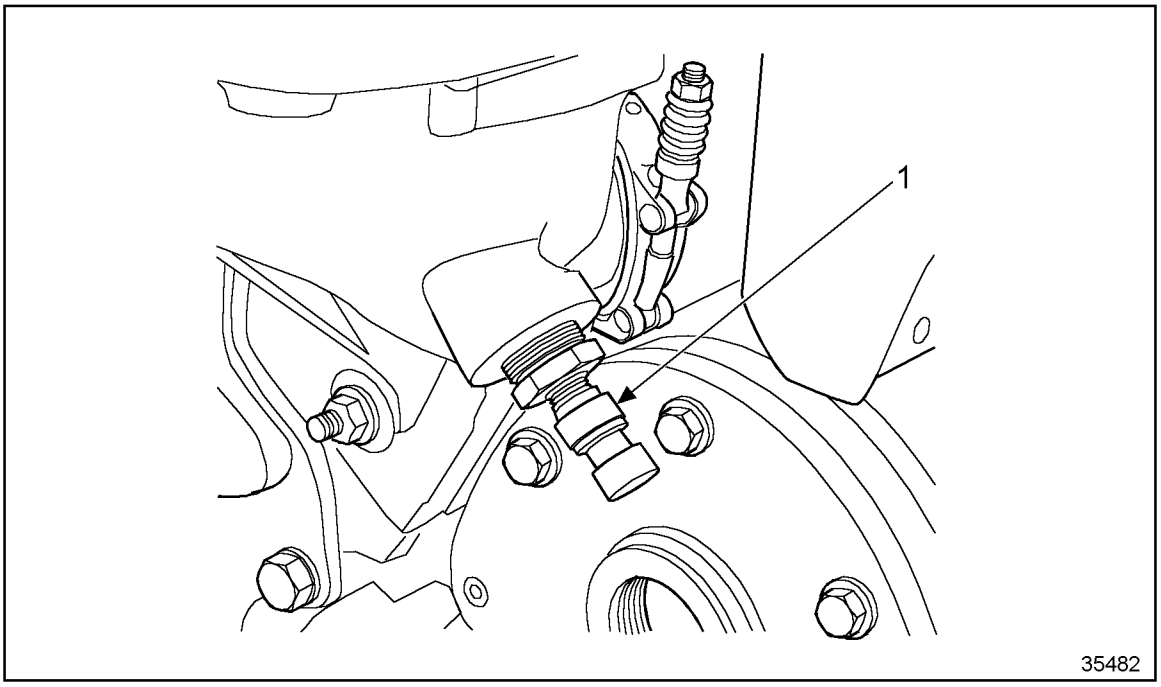
1. Position the CLS probe in the radiator. Use the appropriate wrench on the hex portion of the sensor and screw it into the radiator.
2. Install the nut on the sensor lead of probe and tighten the nut. Install the sensor lead. Install the ground wire and ground wire screw on the side of probe.
3. Ensure the drain cock at the bottom of the radiator is closed.

4. Fill the cooling system. Refer to section 13.12.2.
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.
6. Start the engine and check for leaks.

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2.17 COOLANT TEMPERATURE SENSOR

The Coolant Temperature Sensor (CTS) sends an electrical signal to the ECM indicating the engine coolant temperature. The CTS activates engine protection if coolant temperature exceeds the specified limits. See Figure 2-89.



1. Coolant Temperature Sensor

Figure 2-89 Coolant Temperature Sensor (12V and 16V)

2.17.1 Repair or Replacement of Coolant Temperature Sensor

The CTS is non-serviceable, and is replaced as a unit. No adjustment is required.

2.17.2 Removal of Coolant Temperature Sensor

Remove the coolant temperature sensor as follows:

1. Disengage locking tang on two wire connector.
2. Grasp 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 from the cylinder head.

2.17.3 Installation of Coolant Temperature Sensor

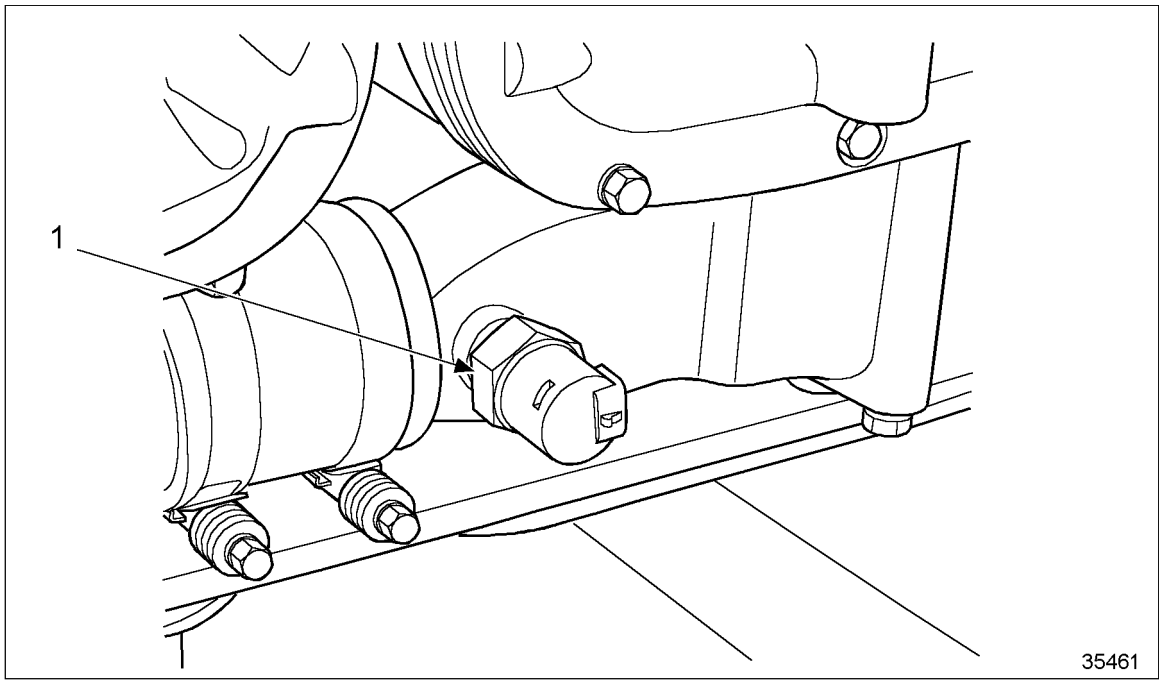
Install the coolant temperature sensor as follows:

1. Apply Loctite 567 pipe sealant with Teflon or equivalent on all but first two threads.
2. Install CTS to the cylinder head.
3. Tighten to 102-127 N·m (75-94 lb·ft)
4. Carefully fasten two-wire connector onto sensor and engage locking tang.

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2.18 COOLANT PRESSURE SENSOR (12V AND 16V)

On 12V and 16V cylinder engines a coolant pressure sensor (CPS) is mounted beneath the two oil coolers. If coolant pressure gets too low, a signal is sent to the ECM to turn on the Check Engine Light (CEL) and warn the operator. See Figure 2-90.



1. Coolant Pressure Sensor

Figure 2-90 Coolant Pressure Sensor (12V and 16V)

2.18.1 Repair or Replacement of Coolant Pressure Sensor

The CPS is non-serviceable, and is replaced as a unit. No adjustment is required.

2.18.2 Removal of Coolant Pressure Sensor

With the engine (ignition) off remove the coolant pressure sensor as follows:

1. Disconnect the engine harness and remove the connector.

NOTE:
Observe where each wire lead on the harness is connected.

2. Remove the old sensor.

2.18.3 Installation of Coolant Pressure Sensor

With the engine (ignition) off install the coolant pressure sensor as follows:

NOTICE:
The CPS is an electronic device. Use care when installing to prevent damage.

1. Install the new sensor into the engine port.Listed in Table 2-6 are the coolant pressure/intercooler coolant pressure sensor connections.

Sensor Pigtail	Engine Harness	Connector Cavity	Wire Number	Description
Black	Black	A	452	Ground
Green	Dark Green	B	976	Signal
Red	Gray	C	416	Supply

Table 2-6 Coolant Pressure/Intercooler Coolant Pressure Sensor Connections

2. Strip each wire from the harness and splice it to the appropriate wire on the sensor pigtail.

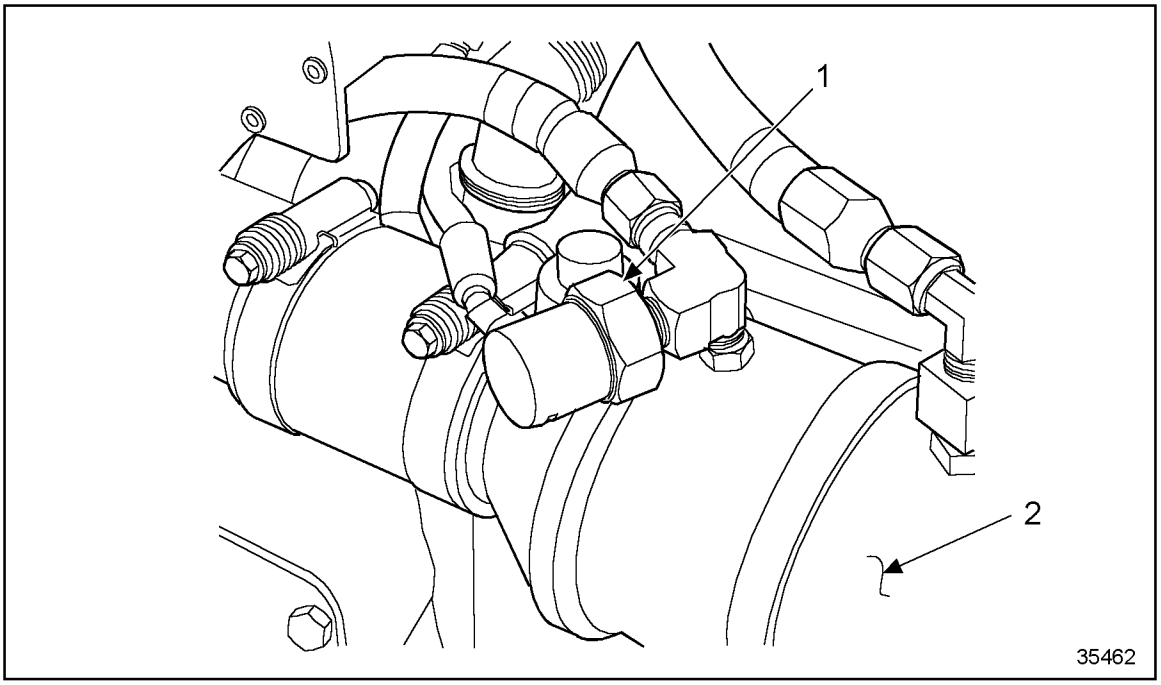
NOTE:
Solder splicing is preferred, but crimp splices are acceptable.

3. Cover each wire splice with heat shrink tubing, preferably the self-adhesive type, so that no bare wire is exposed.
4. Cover all spliced wires with an overall heat shrink tube.
5. Reconnect the engine harness.
6. Start the engine and check for proper sensor operation.
7. Turn the ignition to the "ON" position. Read any diagnostic codes. If any code other than 25 is obtained, refer to the *DDEC III/IV Single ECM Troubleshooting Guide*, 6SE497.
8. Check for coolant leaks. Refer to section 13.12.

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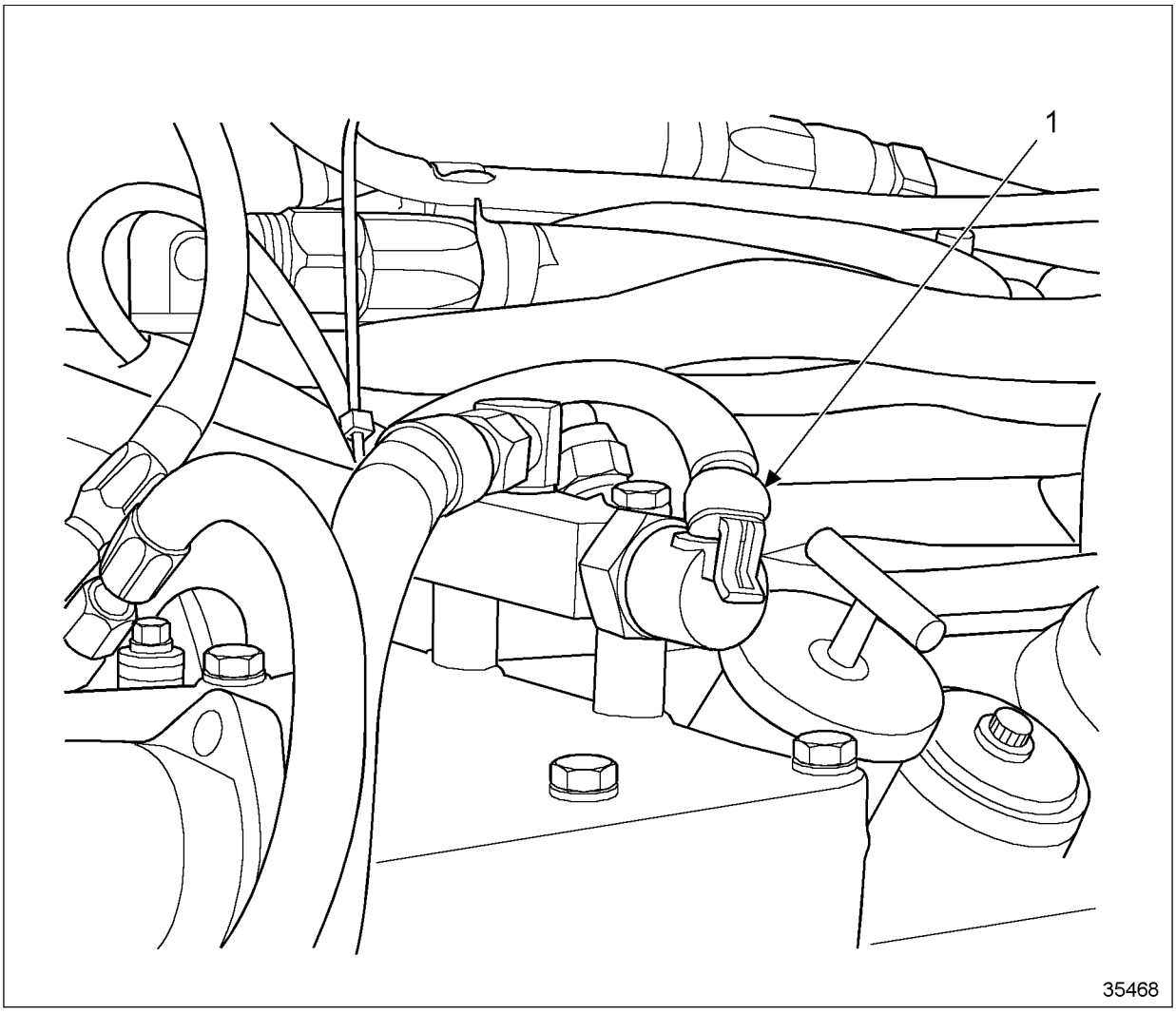
2.19 FUEL PRESSURE SENSOR

The fuel pressure sensor (FPS) is installed into the fuel block mounted at the rear of the engine. See Figure 2-91 and see Figure 2-92.



1. Fuel Pressure Sensor
2. Fuel Cooler

Figure 2-91 Fuel Pressure Sensor (6V and 8V Marine)



1. Fuel Pressure Sensor

Figure 2-92 Fuel Pressure Sensor (12V and 16V)

The FPS sends an electrical signal to the ECM indicating engine fuel pressure at a given speed.

2.19.1 Repair or Replacement of Fuel Pressure Sensor

The FPS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.19.2 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 an appropriate wrench on the hex end of the FPS to unscrew it from the fuel block.

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2.19.3 Installation of Fuel Pressure Sensor

Install the FPS as follows:

NOTICE:
The FPS is an electronic device. Use care while installing to prevent damage.

1. Apply Loctite 567 pipe sealant with Teflon, (or equivalent) on all but the first two threads. Use an appropriate wrench to screw the FPS into the fuel block.
2. Turn the ignition to the "ON" position. If any diagnostic code other than code 25 is obtained, refer to the *DDEC II Troubleshooting Guide*, 6SE489.
3. Check for fuel leaks.

2.20 FUEL TEMPERATURE SENSOR

The fuel temperature sensor (FTS) mounts in the fuel block at the rear of the engine. See Figure 2-93 and see Figure 2-94.

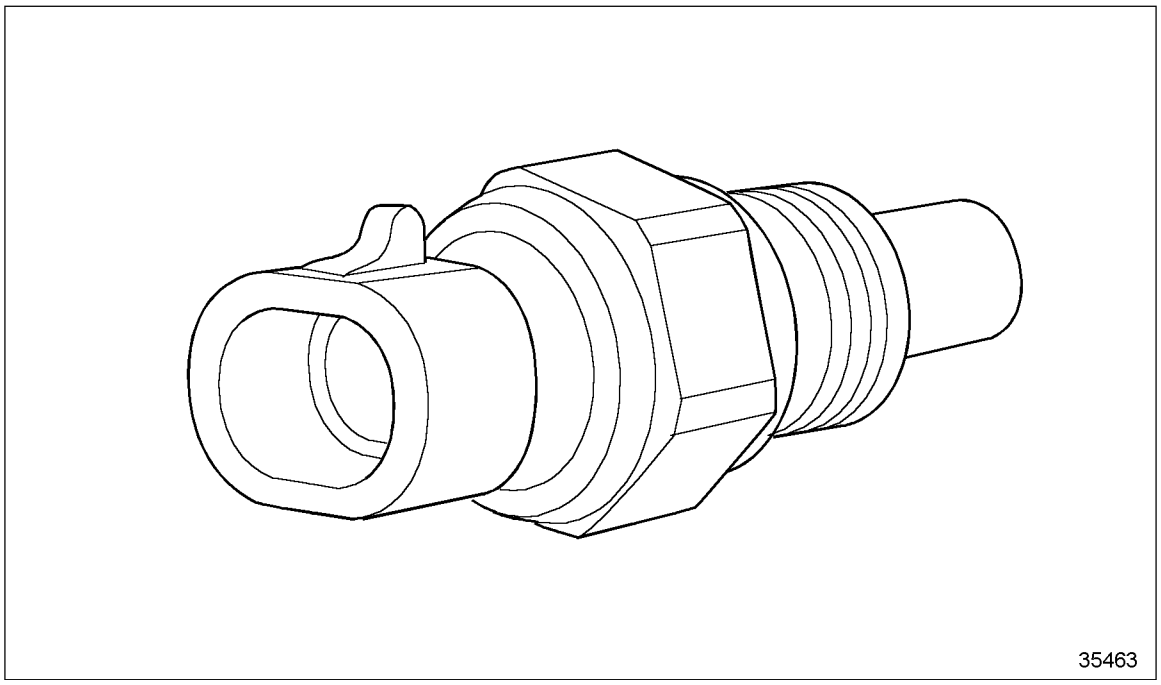
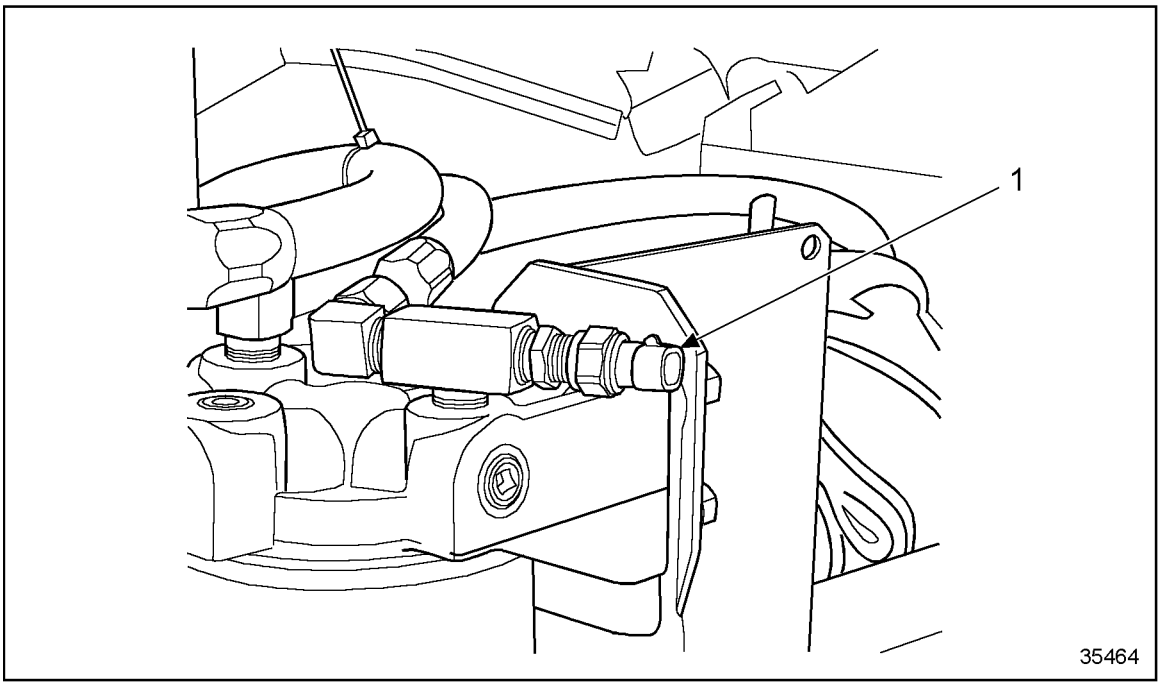


Figure 2-93 Fuel Temperature Sensor

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1. Fuel Temperature Sensor

Figure 2-94 Fuel Temperature Sensor (12V and 16V)

The FTS signals the ECM indicating fuel inlet temperature. From this the ECM calculates fuel consumption.

2.20.1 Repair or Replacement of Fuel Temperature Sensor

The FTS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.20.2 Removal of Fuel Temperature Sensor

Remove the FTS as follows:

1. Disengage the locking tang on the two-wire connector.
2. Grasp the connector body, and gently pull it from the socket.
3. Unscrew the sensor from the fuel block with an appropriate hex wrench.

2.20.3 Installation of Fuel Temperature Sensor

Install the FPS as follows:

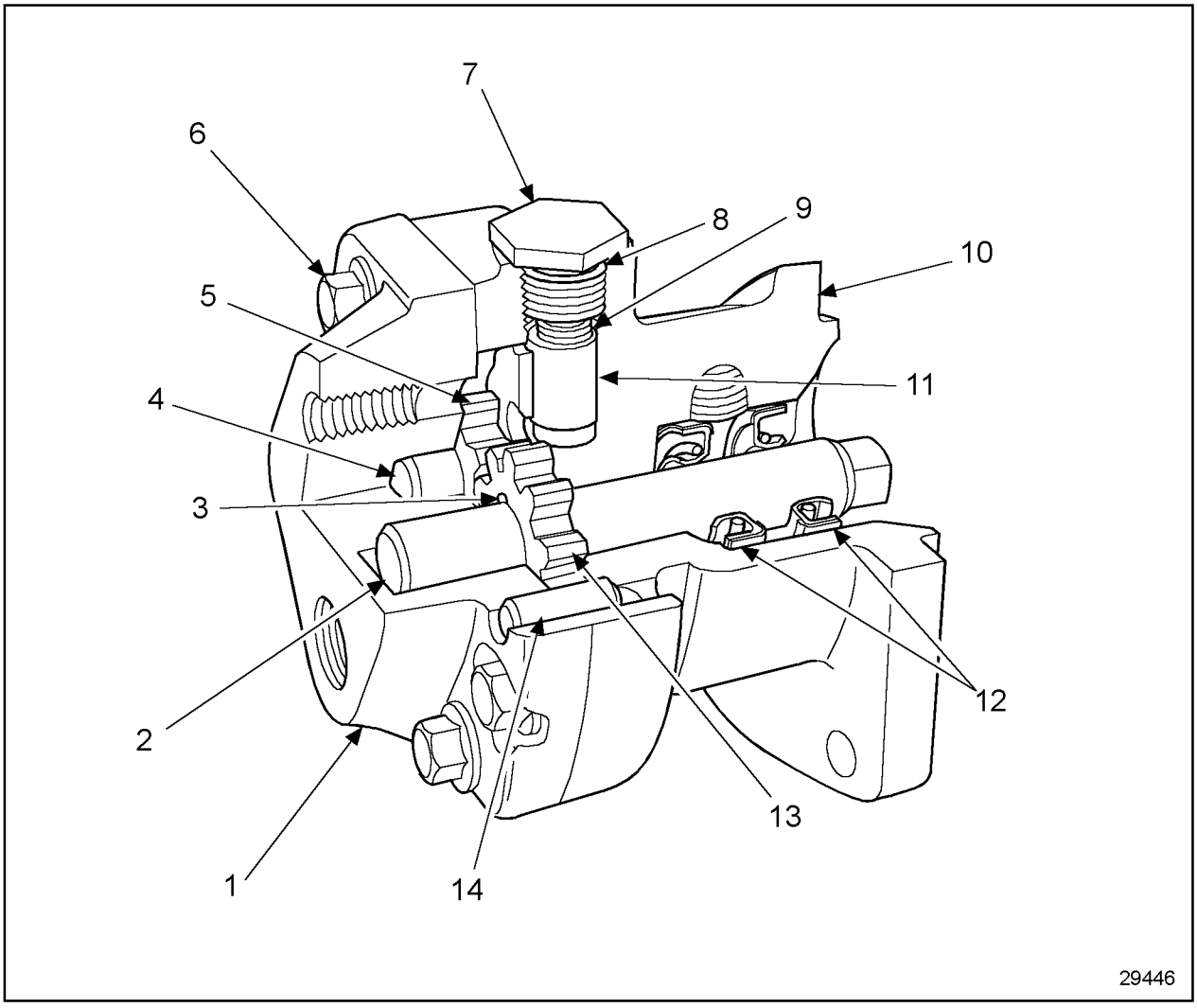
NOTICE:
The FTS is an electronic device. Use care while installing to prevent damage.

1. Apply Loctite 567 pipe sealant with Teflon (or equivalent) on all but the first two threads.
2. Install the sensor to the fuel block with the appropriate wrench.
3. Press the connector body into the socket.
4. Engage the locking tang on the two-wire connector.
5. Turn the ignition to the "ON" position. If any diagnostic code other than code 25 is obtained, refer to *DDEC II Troubleshooting Guide*, 6SE489.
6. Check for fuel leaks.

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2.21 FUEL PUMP

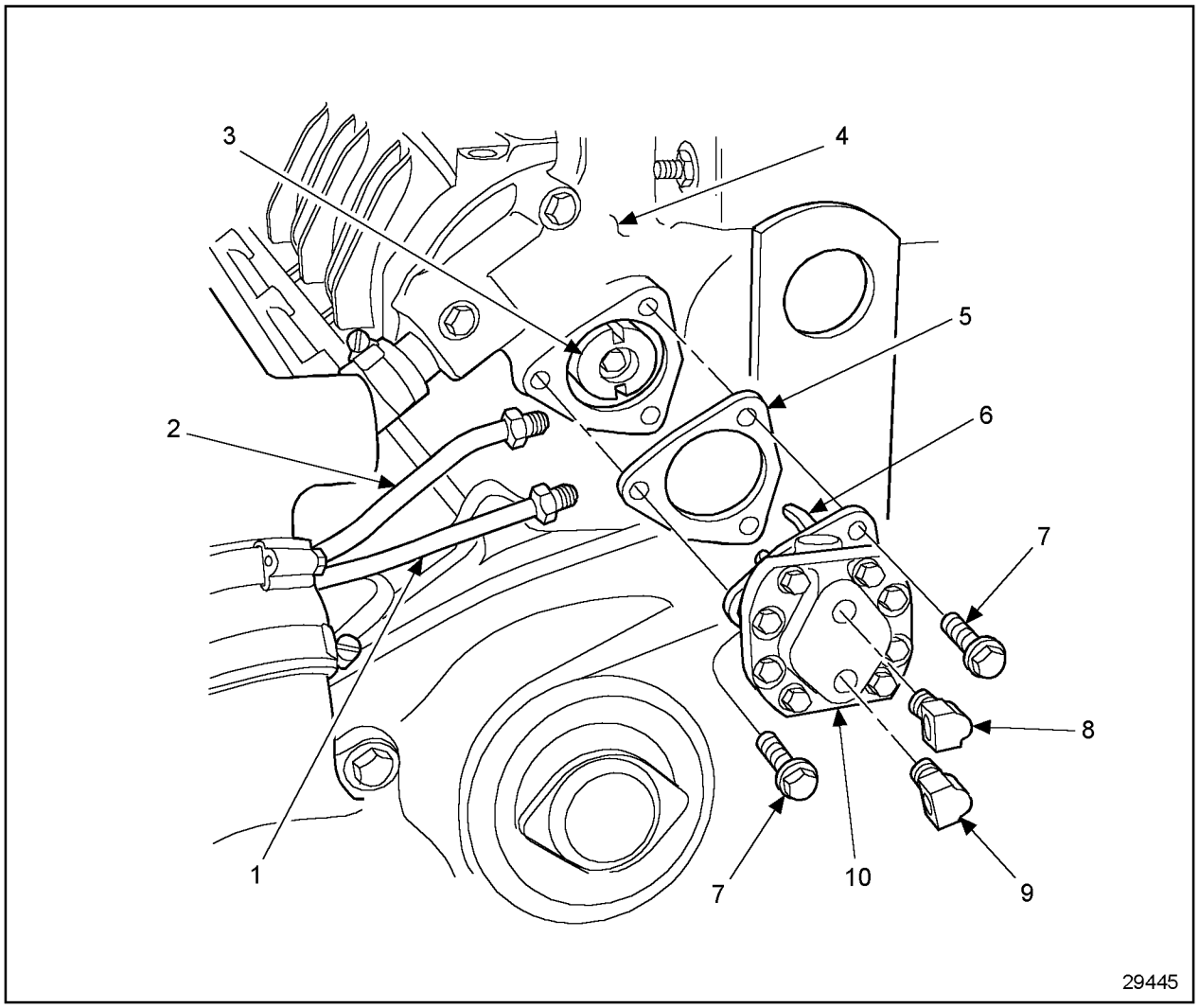
The positive displacement gear-type fuel pump transfers fuel from the supply tank to the fuel injectors. See Figure 2-95. The fuel pump circulates the fuel supply to the injectors, purging the air from the system and cooling the injectors. A fuel return manifold and fuel return line returns the unused fuel to the fuel tank.



1. Fuel Pump Cover
2. Drive Shaft
3. Steel Ball
4. Driven Shaft
5. Driven Gear
6. Bolt
7. Plug
8. Gasket
9. Spring
10. Fuel Pump Body
11. Relief Valve
12. Oil Seals
13. Drive Gear
14. Alignment Dowel

Figure 2-95 Cutaway of Typical Fuel Pump Assembly

The fuel pump is attached to the housing with three nylon patch bolts that prevent the oil in the housing from seeping out around the bolt threads. A drive coupling fork, attached to the end of the pump drive shaft and mating with a drive disc attached to the blower rotor, drives the pump from the end of the blower rotor. See Figure 2-96 and see Figure 2-97. Regardless of engine rotation, the pump will always rotate to the left.



1. Inlet Fuel Line
2. Outlet Fuel Line
3. Blower Drive Coupling
4. Governor Housing
5. Gasket
6. Bolt and Lock Washer Assembly
7. Outlet Fuel Fitting
8. Inlet Fuel Fitting
9. Fuel Pump Assembly
10. Drive Fork

Figure 2-96 Fuel Pump Assembly (Typical Pump Installation 6V and 8V)

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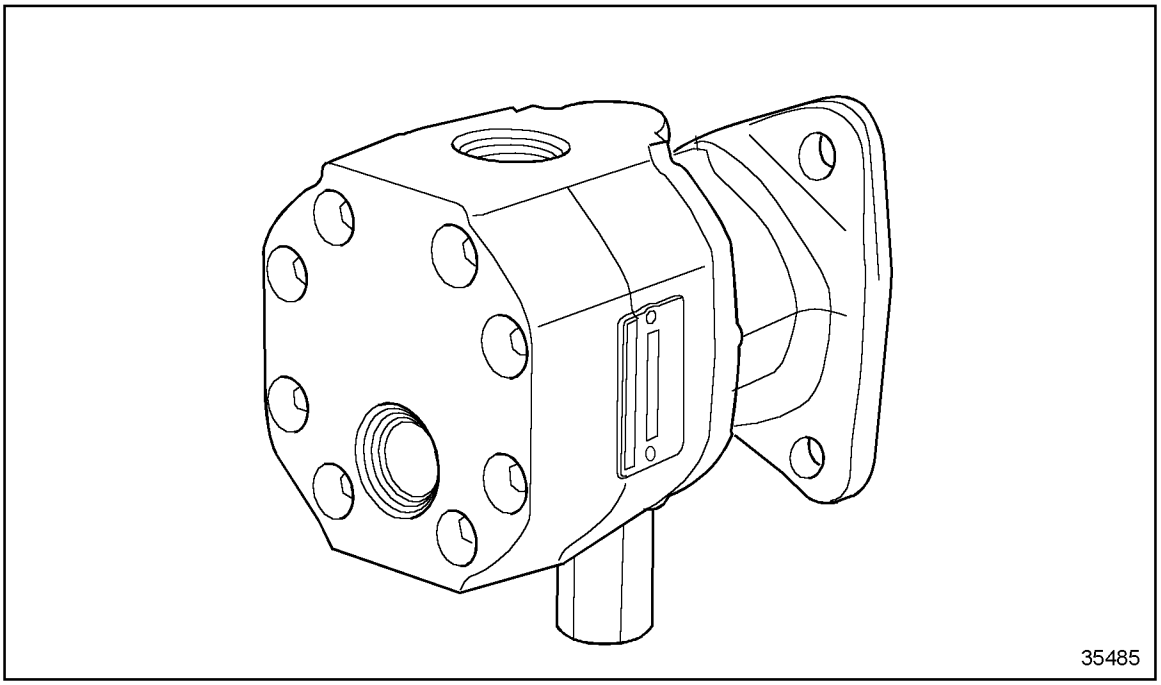
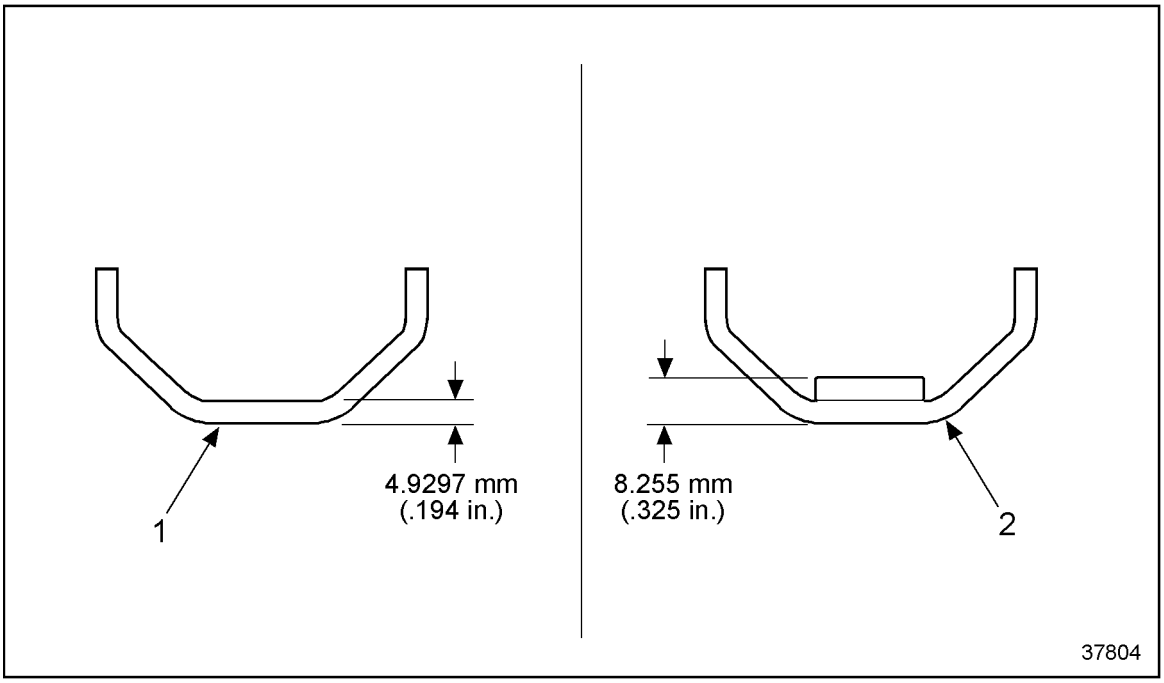


Figure 2-97 Typical Fuel Pump (12V and 16V)

For all DDEC engine applications the fuel pump drive coupling fork has been improved. The center section thickness of the fork has been increased by 3.33 mm (0.131 in.). See Figure 2-98.



1. Former
2. Current

Figure 2-98 Fuel Pump Drive Couplings (Former and Current)

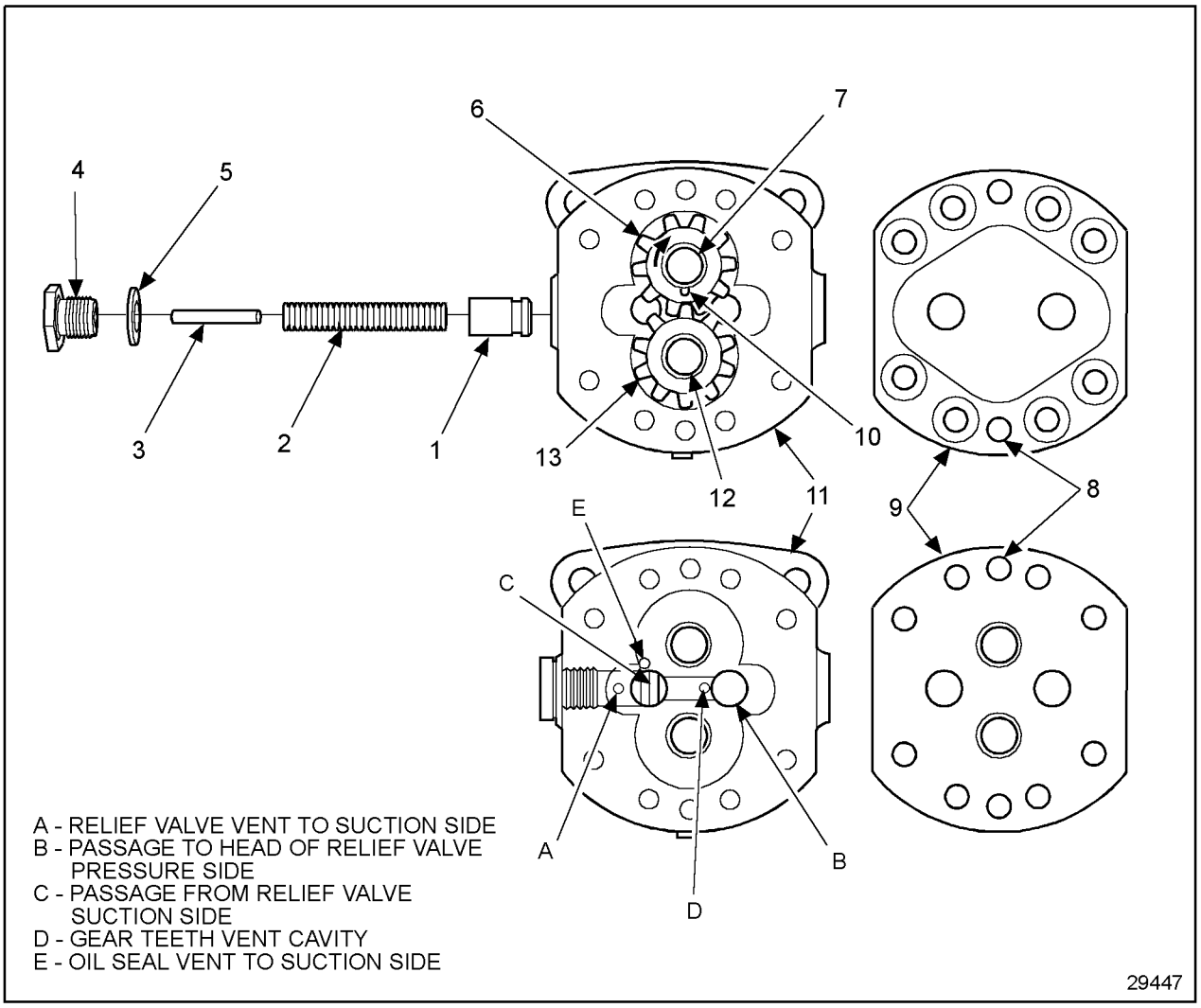
This additional material keeps the coupling fork in constant contact with the blower drive shaft, preventing the coupling from sliding back and disengaging from the blower drive shaft.

Certain engine applications use a high-capacity fuel pump with 3/8 in. wide gears to increase fuel flow and reduce fuel spill temperature. The high-capacity fuel pump and the standard fuel pump, with 1/4 in. wide gears, are not completely interchangeable. When replacing a standard pump with a high-capacity pump, the appropriate fuel lines and connections must be used.

Two dowels position the fuel pump cover and body. The dowels aid in maintaining gear shaft alignment. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearance is set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The recessed fuel pump body provides running space for the pump gears. See Figure 2-99. Recesses are also provided at the inlet and outlet positions of the gears. Hole "A" permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock, that would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole "B" and relieves excess discharge pressure. When the discharge pressure is great enough to move the relief valve back from its seat, fuel re-enters the inlet side of the pump through hole "C". Cavity "D" 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. 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.

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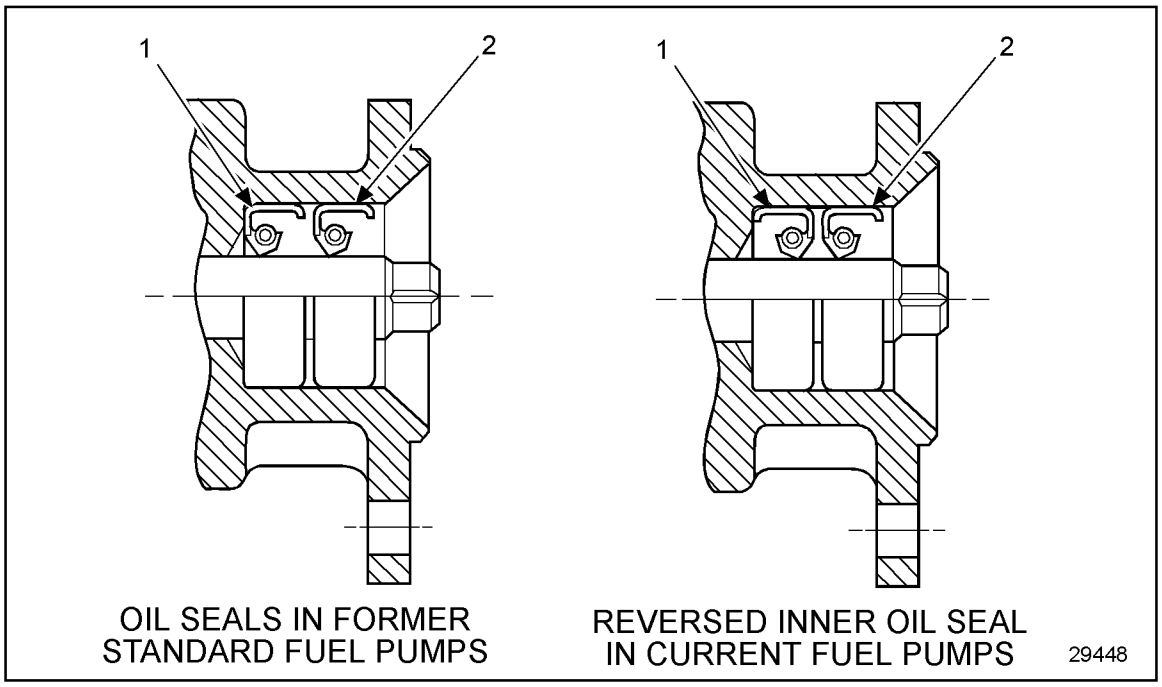
1. Relief Valve
2. Spring
3. Pin
4. Plug
5. Gasket
6. Drive Gear
7. Drive Shaft
8. Dowel Pin
9. Cover
10. Steel Ball
11. Fuel Pump Body
12. Driven Shaft
13. Driven Gear

Figure 2-99 Fuel Pump Valve and Rotation

NOTE:
Since the standard and high capacity fuel pumps are used in other Detroit Diesel product lines, three tapped holes are available for the purpose of preventing fuel oil from being retained between the seals. The orientation of the fuel pump will determine which hole should be used as a vent. The vent should be located on the bottom side of the pump. The remaining holes need to be plugged to protect debris from falling into the bearing area of the pump and causing damage to the bearing seals.

Two oil seals are pressed into the flanged side of the pump body bore to retain the fuel oil in the pump and the lubricating oil in the governor housing.

A higher temperature material lip type seal is now being used in the fuel pumps. The current fuel pump seal is made of a polyacrylate material. The former seal is made of nitrile. The current fuel pump seals are installed with the seal lips facing opposite of each other. The former fuel pumps have the nitrile seals installed with both seal lips facing the pump mounting flange. Both the polyacrylate and nitrile seals are interchangeable. Only the polyacrylate seals and fuel pumps with polyacrylate seals are serviced. See Figure 2-100.

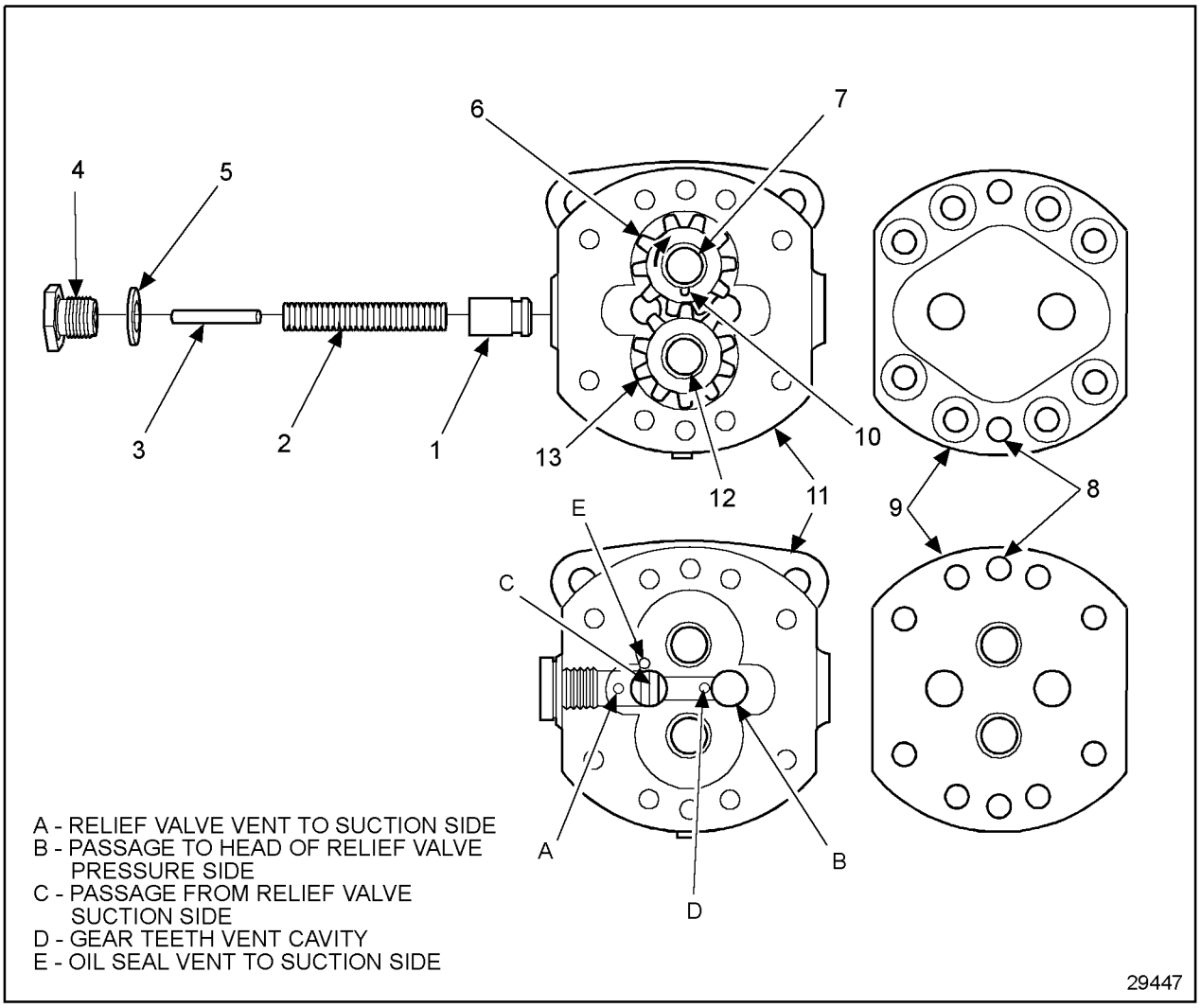


1. Inner Seal
2. Outer Seal

Figure 2-100 Fuel Pump Oil Seal Arrangement Former and Current

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Hole "E" serves as a vent passageway in the body between the inner oil seal and the suction side of the pump, preventing fuel oil pressure build up around the shaft ahead of the inner seal. See Figure 2-101.



1. Relief Valve
2. Spring
3. Pin
4. Plug
5. Gasket
6. Drive Gear
7. Drive Shaft
8. Dowel Pin
9. Cover
10. Steel Ball
11. Fuel Pump Body
12. Driven Shaft
13. Driven Gear

Figure 2-101 Fuel Pump Valve and Rotation

Expect some fuel oil leakage around the fuel pump seals when the engine is running and immediately after the engine has been shut down. This occurs with a new fuel pump and/or new pump seals. The seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some leakage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could dilute the engine oil with fuel. The drainage of the excess fuel is mandatory. If leakage exceeds one drop per minute, replace the seals.

The drive and driven gears are a line-to-line to 0.03 mm (0.001 in.) press fit. The drive gear is provided with a gear retaining ball to locate the gear on the shaft.

A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 448 kPa (65 lb/in.^{2}).

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 carry the fuel oil to the discharge side of the pump. As the gear teeth mesh in the center of the pump, the fuel is forced out 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 at the fuel inlet manifold. Refer to section 11.5.

NOTE:
Current standard fuel pumps (with 1/4 in. wide gears) incorporate a 1/8 in. shorter pump body with three drain holes, a 1/8 in. shorter drive shaft, and a cover with a 3/8 in. inlet opening. When replacing a former pump, a 3/8 in. x 1/4 in. reducing bushing is required for the inlet opening. The upper unused drain holes must be plugged. The drain hole must be left open to allow fuel to drain in the event if a seal failure

NOTE:
Certain engine applications use a high-capacity fuel pump with 3/8 in. wide gears to increase fuel flow and reduce fuel spill temperature. The high-capacity fuel pump and the standard fuel pump with 1/4 in. wide gears may not be completely interchangeable; therefore, when a high-capacity pump is being used, the appropriate fuel lines and connections must be utilized.

2.21.1 Repair or Replacement of Fuel Pump

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-102.

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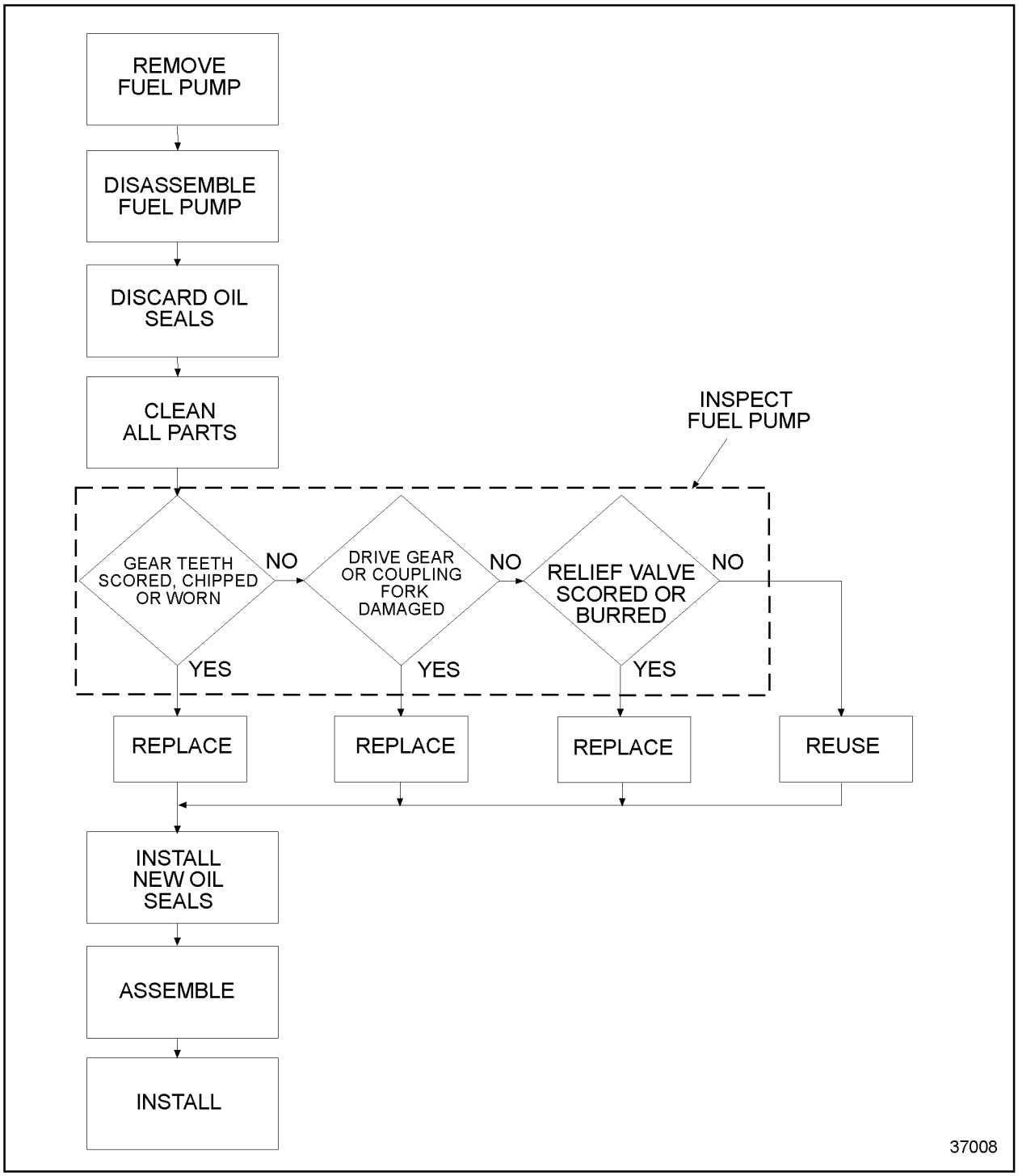


Figure 2-102 Flowchart for Repair or Replacement of Fuel Pump

2.21.2 Removal of Fuel Pump

Remove the fuel pump as follows:

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.

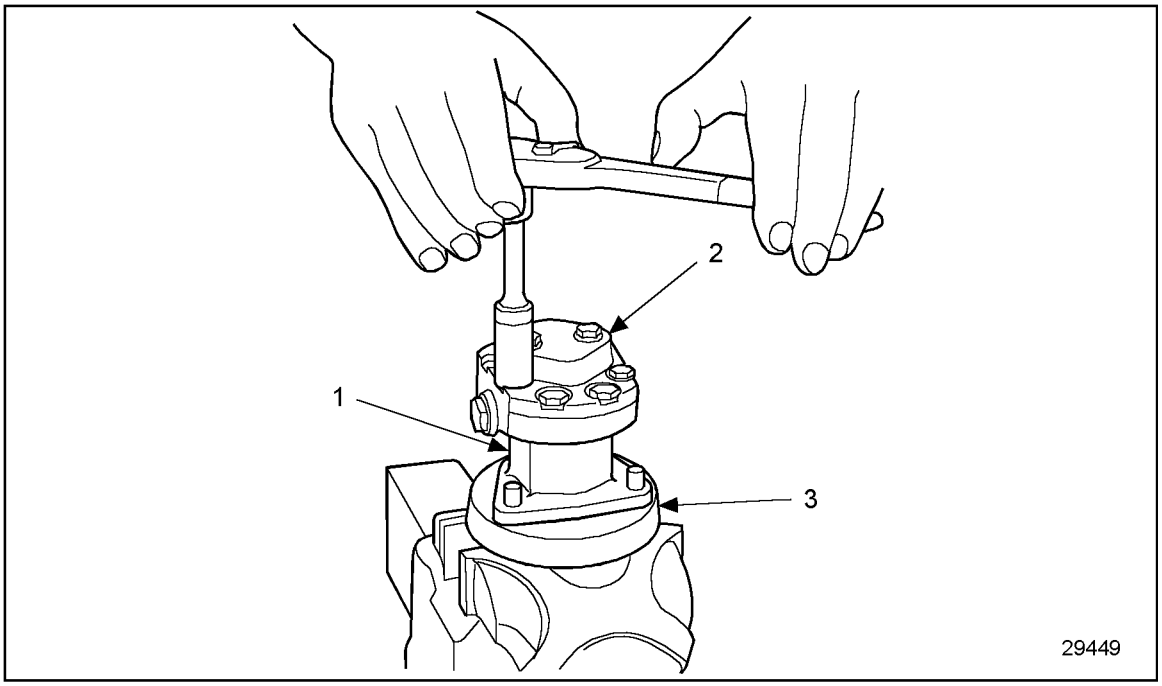
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2. Disconnect the drain tube, if used, from the fuel pump.
3. Remove the three pump attaching bolts, and withdraw the pump from the housing.

2.21.3 Disassembly of Fuel Pump

Disassemble the fuel pump as follows:

1. Mount the fuel pump in holding fixture J 1508-10A (from set J 1508-E). See Figure 2-103.



1. Fuel Pump Assembly
2. Fuel Pump Cover
3. Holding Fixture

Figure 2-103 Removing Fuel Pump Cover

NOTICE:
Remove the cover with care to avoid damaging the finished faces of the pump body and cover.

2. Remove the eight cover bolts, and withdraw the pump cover from the pump body.
3. Withdraw the drive shaft, drive gear, and gear retaining ball from the pump body as an assembly.

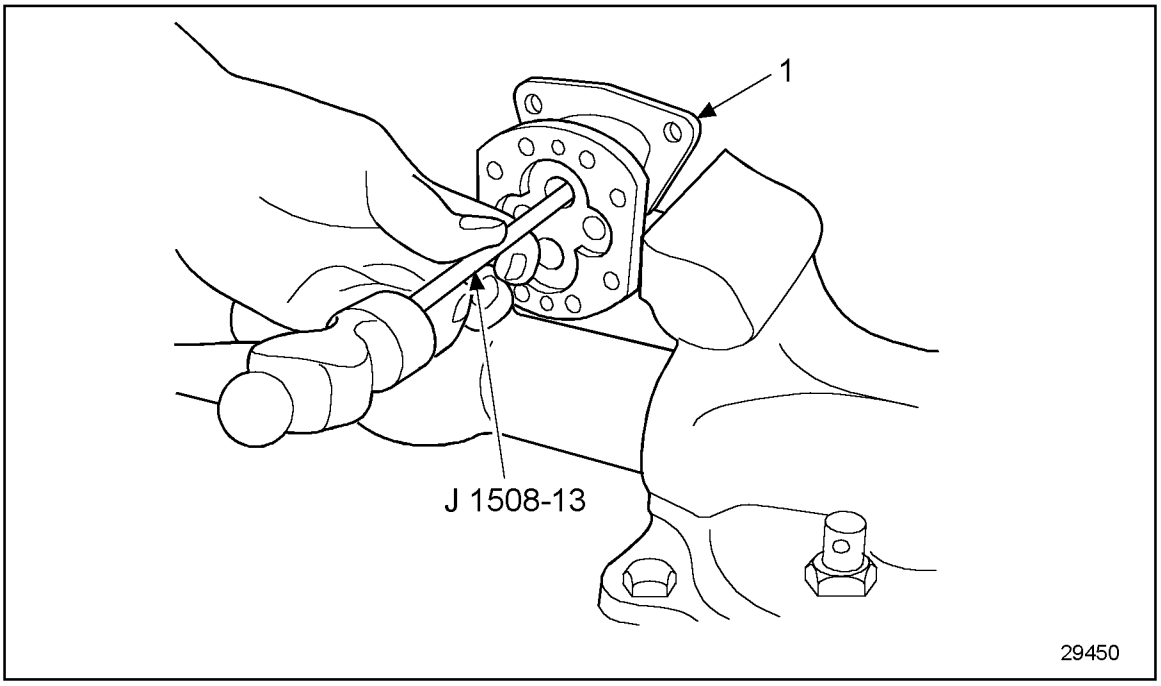
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NOTICE:
Do not press the squared end of the shaft through the gear. Slight score marks will damage the oil seal contact surface.

4. Press the drive shaft far enough to remove the steel locking ball. Invert the shaft and gear assembly, and press the shaft from the gear.
5. Remove the driven shaft and gear from the pump body as an assembly.

NOTE:
Do not remove the gear from the shaft. The driven gear and shaft are serviced as an assembly only.

6. Remove the relief valve plug and copper gasket.
7. Remove the valve spring, pin, and relief valve from the valve cavity in the pump body.
8. If the oil seals need to be replaced, remove them with oil seal remover J 1508-13 (from set J 1508-E). See Figure 2-104. Clamp the pump body in a soft jaw bench vise, and tap the end of the tool with a hammer to remove the outer and inner seals.



1. Fuel Pump Assembly

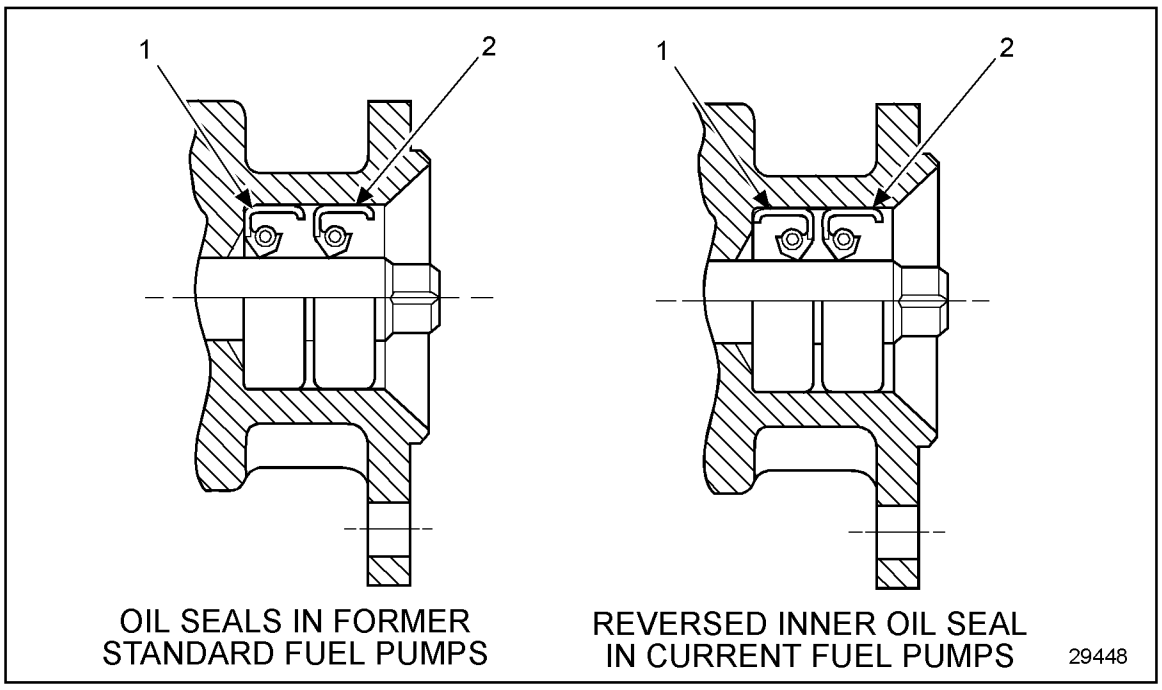
Figure 2-104 Removing Oil Seals using Tool J 1508-13 (from SetJ 1508-E)

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9. When installing new seals ensure they are installed in the new position.

NOTE:
Once oil seals are removed from the pump body they must be discarded and replaced with new seals.

NOTE:
When replacing the seals ensure new design seals are used and are installed in the proper position See Figure 2-105.



1. Inner Seal (Nitrile)
2. Outer Seal (Nitrile)
3. Inner Seal (Polyacrylate)
4. Outer Seal (Polyacrylate)

Figure 2-105 Fuel Pump Oil Seal Arrangement Former and Current

2.21.3.1 Cleaning of Fuel Pump

Clean the fuel pump as follows:

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean all 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 them with compressed air.

2.21.3.2 Inspection of Fuel Pump

Inspect the fuel pump as follows:

1. Visually inspect the pump gear teeth for scoring, chipping, or wear.
   [a] If scored, chipped, or worn, replace the gear. Refer to section 2.21.4.
   [b] If not scored, chipped, or worn, continue inspection.
2. Visually inspect the ball slot in the drive gear for wear.
   [a] If excessively worn, replace the gear. Refer to section 2.21.4.
   [b] If not excessively worn, continue inspection.
3. Visually inspect the drive coupling fork.
   [a] If broken or excessively worn, replace it. Refer to section 2.21.4.
   [b] If not broken or excessively worn, continue inspection.
4. Visually inspect the drive and driven shafts for scoring or wear.
   [a] If scored or worn, replace the shafts. Refer to section 2.21.4.

[b] If not scored or worn, continue inspection.

NOTE:
The driven shaft is serviced as a gear and shaft assembly only.

5. Visually inspect the pump cover and body. The mating faces must be flat and smooth and fit tightly together.

NOTICE:
The mating faces of the pump body and cover must be flat, smooth and fit together. Any scratches or slight damage may result in pressure leaks.

[a] If warped, scratched, or damaged, replace the pump cover or body. Refer to section 2.21.4.

[b] If not warped, scratched, or damaged, proceed with the inspection.

6. Visually inspect pump cover and body for wear at areas that come in contact with the gears and shafts.

[a] If worn, replace the pump cover or body. Refer to section 2.21.4.

[b] If not worn, proceed with the inspection.

7. Visually inspect the relief valve for score marks, burrs, and fit in the pump body.

[a] If slightly scored or burred, clean with fine emery cloth or crocus cloth.

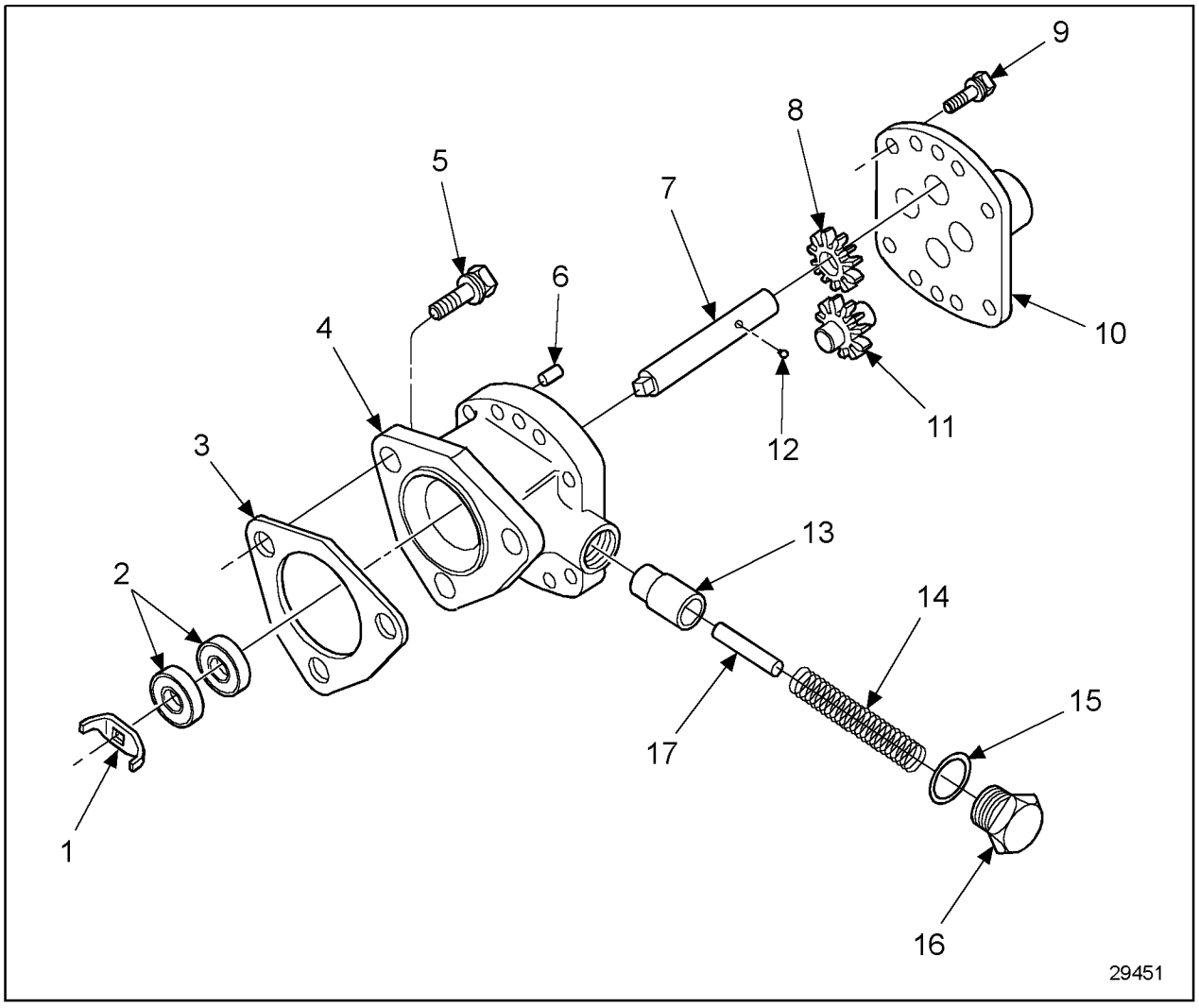
[b] If excessively scored and burred and does not fit in the pump body, replace the valve. Refer to section 2.21.4.

[c] If not scored and burred and fits properly in the pump body, reuse the relief valve.

2.21.4 Assembly of Fuel Pump

See Figure 2-106. Assemble the fuel pump as follows:

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1. Drive Coupling
2. Oil Seals
3. Gasket
4. Fuel Pump Body
5. Pump Body Mounting Bolts (3)
6. Dowel Pins (2)
7. Drive Shaft
8. Drive Gear
9. Cover Bolts (8)
10. Pump Cover
11. Driven Gear and Shaft
12. Steel Ball
13. Relief Valve
14. Spring
15. Gasket Seal
16. Plug
17. Pin

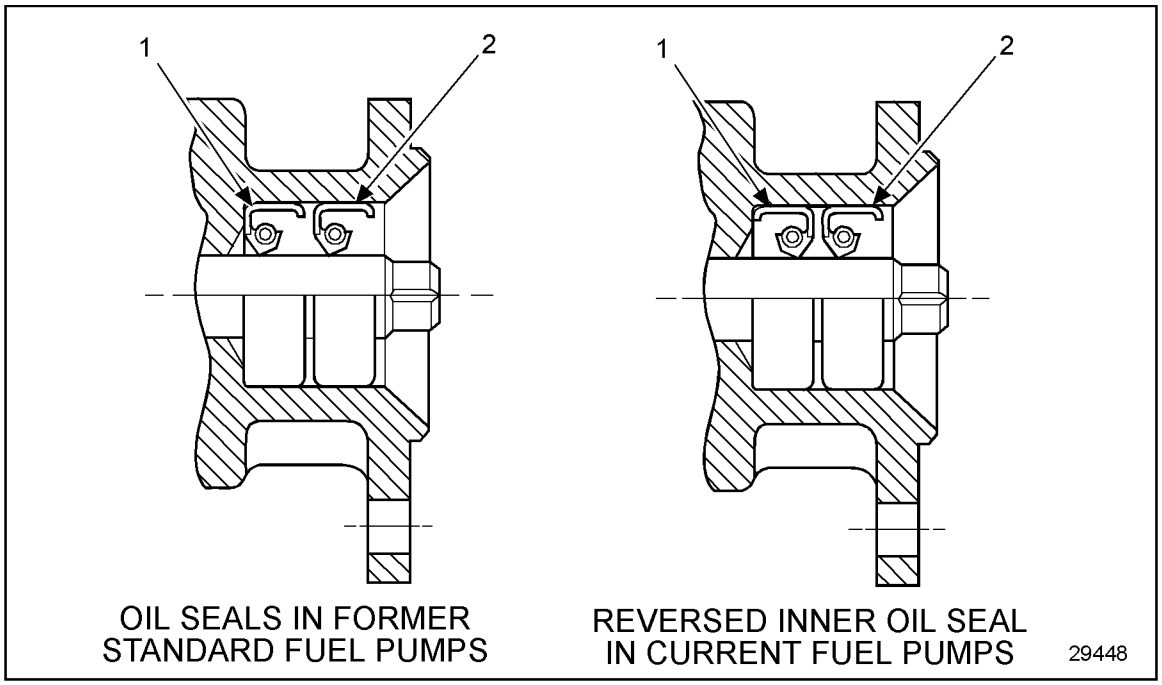
Figure 2-106 Typical Fuel Pump

1. Lubricate the lips of the oil seals with a light coat of vegetable shortening.

NOTICE:
The inboard seal facing "IN" requires greater care at assembly or service to prevent seal lip damage.

2. Place the inner oil seal on the pilot of the installer handle J 1508-8 (from set J 1508-E) so the seal lip faces toward the shoulder on the tool.

NOTE:
When replacing the former nitrile fuel pump seals with the current polyacrylate seals, install them with the seal lips facing each other. See Figure 2-107.

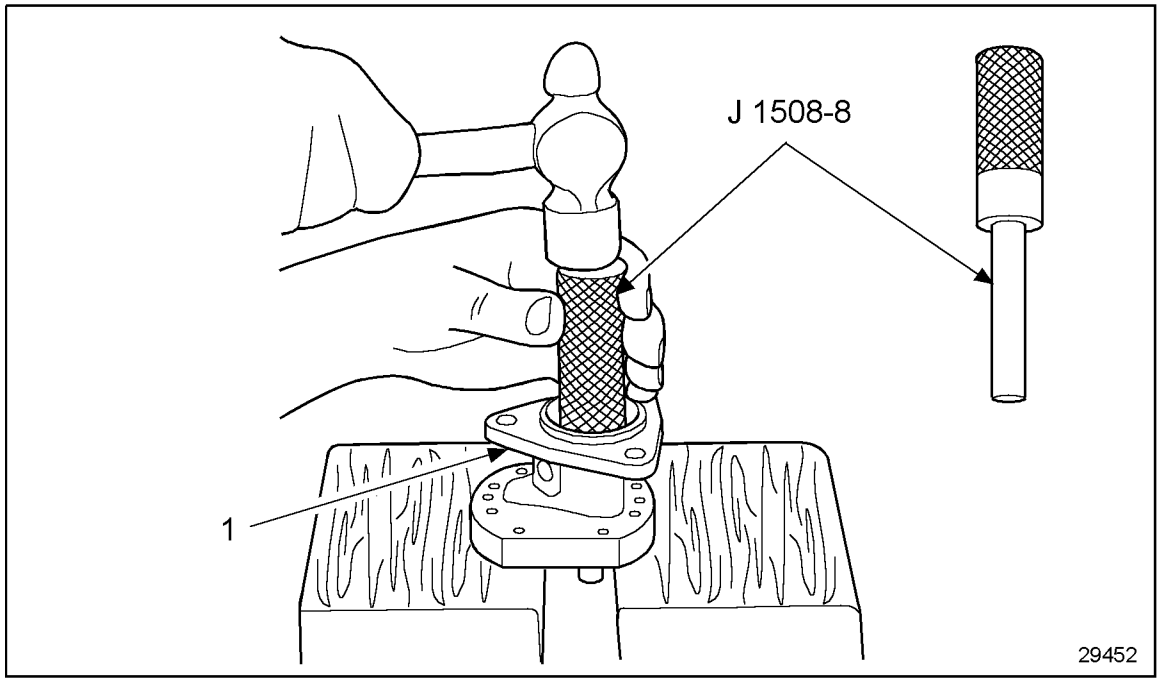


1. Inner Seal (Nitrile)
2. Outer Seal (Nitrile)
3. Inner Seal (Polyacrylate)
4. Outer Seal (Polyacrylate)

Figure 2-107 Fuel Pump Oil Seal Arrangement Former and Current

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3. With the pump body supported on wood blocks, insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange. Drive the seal in until it bottoms. See Figure 2-108.



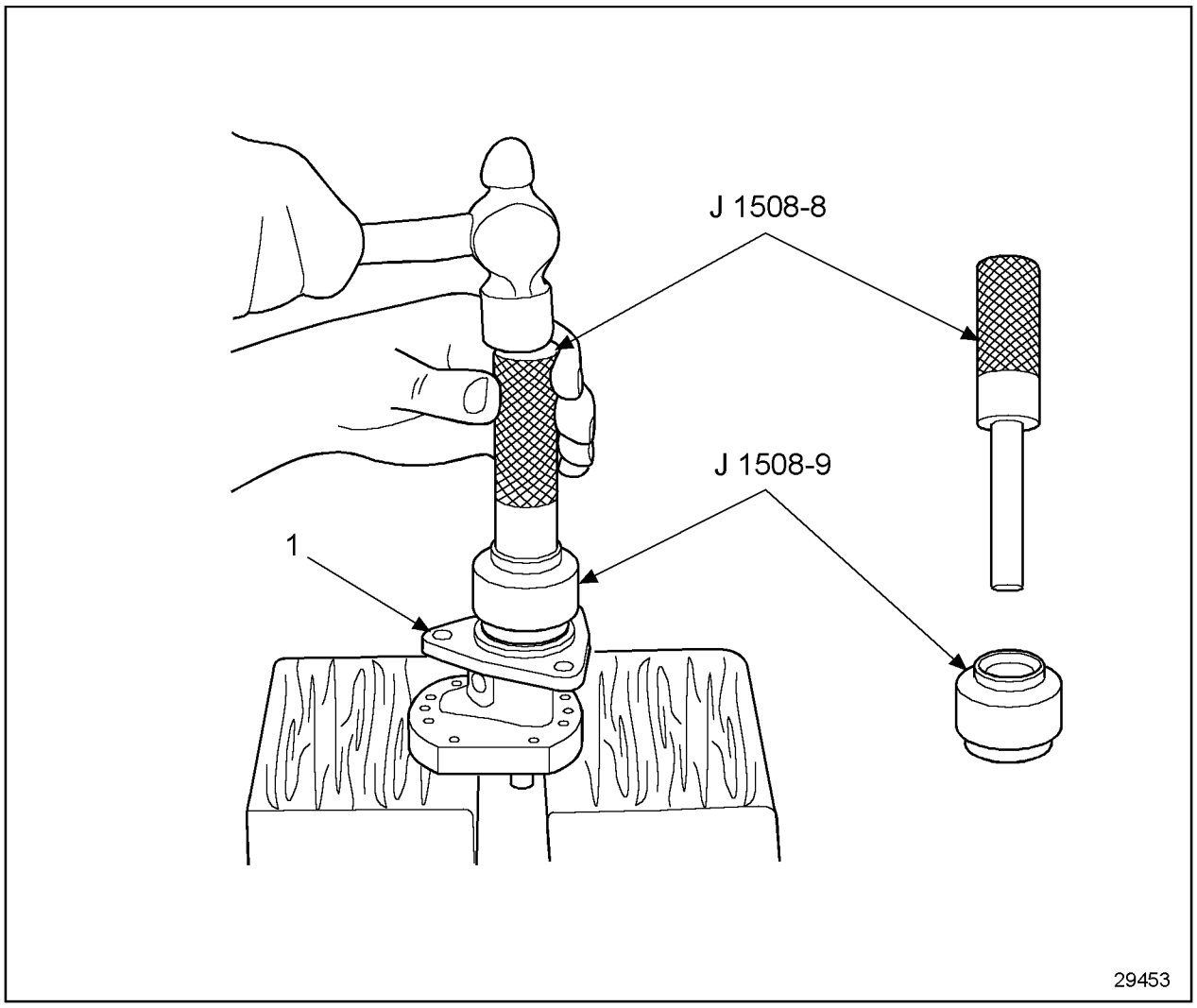
1. Fuel Pump Body

Figure 2-108 Installing Inner Oil Seal using Tool J 1508-8 (from Set J 1508-E)

4. Place the shorter end of the adaptor J 1508-9 (from Set J 1508-E) over the pilot and against the shoulder of the installer handle.
5. Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing away from the adaptor.

6. Insert the pilot of the installer handle into the pump body, and drive the seal in until the shoulder of the adaptor contacts the pump body. See Figure 2-109.

NOTE:
The oil seals will be positioned so the space between them will correspond with the drain holes located in the bottom of the pump body.



1. Fuel Pump Body

Figure 2-109 Installing Outer Oil Seal using Tools J 1508-8 and J 1508–9 (from Set J 1508-E)

7. Clamp the pump body in a soft jawed bench vise, with the valve cavity up.
8. Lubricate the outside diameter of the valve, and place it in the cavity with the hollow end up.
9. Insert the spring inside of the valve, and the pin inside of the spring.

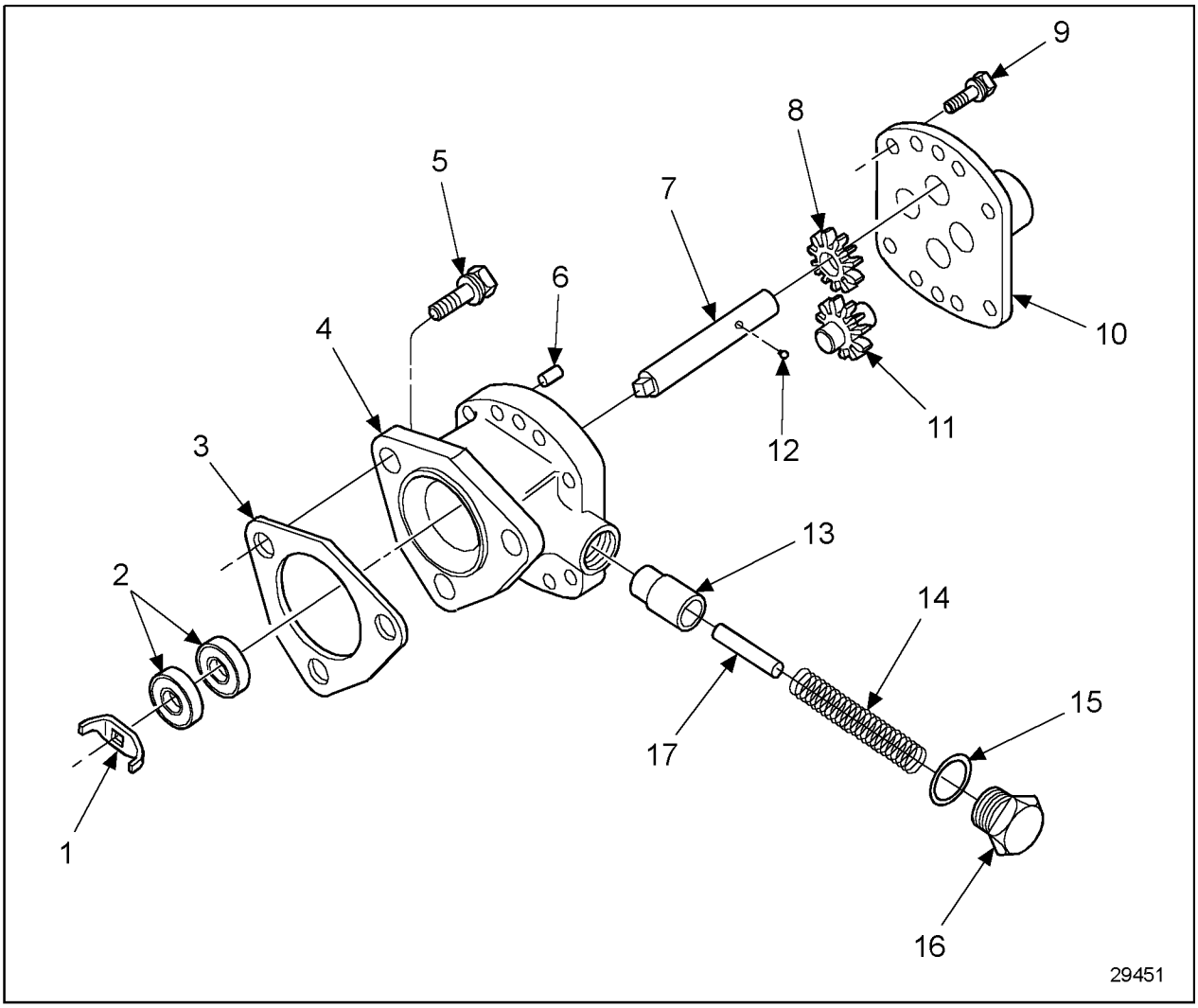
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10. With a new gasket in place next to the head of the valve plug, place the plug over the spring. Thread it into the pump body.
11. Tighten the 1/2 in.-20 plug to 24-30 N·m (18-22 lb·ft) torque.

NOTICE:
Pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals and fine score marks.

12. Install the fuel pump drive gear over the end of the drive shaft.
13. Press the gear beyond the gear retaining ball detent.
14. Place the ball in the detent, and press the gear back until the end of the slot contacts the ball.

15. Lubricate the pump shaft. Insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals. See Figure 2-110.



1. Drive Coupling
2. Oil Seals
3. Gaskets
4. Fuel Pump Body
5. Pump Body Mounting Bolts (3)
6. Dowel Pins (2)
7. Drive Shaft
8. Drive Gear
9. Cover Bolts
10. Pump Cover
11. Driven Gear and Shaft
12. Steel Ball
13. Relief Valve
14. Spring
15. Gasket Seal
16. Plug
17. Pin

Figure 2-110 Typical Fuel Pump

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16. Place the driven shaft and gear assembly in the pump body.

NOTE:
The driven gear must be centered on the shaft to give proper end clearance. The production gear's chamfered end must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

17. Lubricate the gears and shafts with clean engine oil.

NOTICE:

Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

18. Apply a thin coat of quality sealant on the pump cover face.

NOTE:
The sealant coating must be extremely thin since the pump clearances have been set up on a metal-to-metal contact basis. Too much sealant could increase the clearances and affect pump efficiency.

19. Place the cover against the pump body, with the two cover dowel pins entering the pump body holes.

NOTE:
The cover can be installed in only one position over the two shafts.

20. Secure the cover with eight bolts and lock washers. Tighten the bolts alternately and evenly.
21. After assembly, hand rotate the pump shaft to ensure that the parts rotate freely. If the shaft does not rotate freely, tap a corner to attempt to free it.

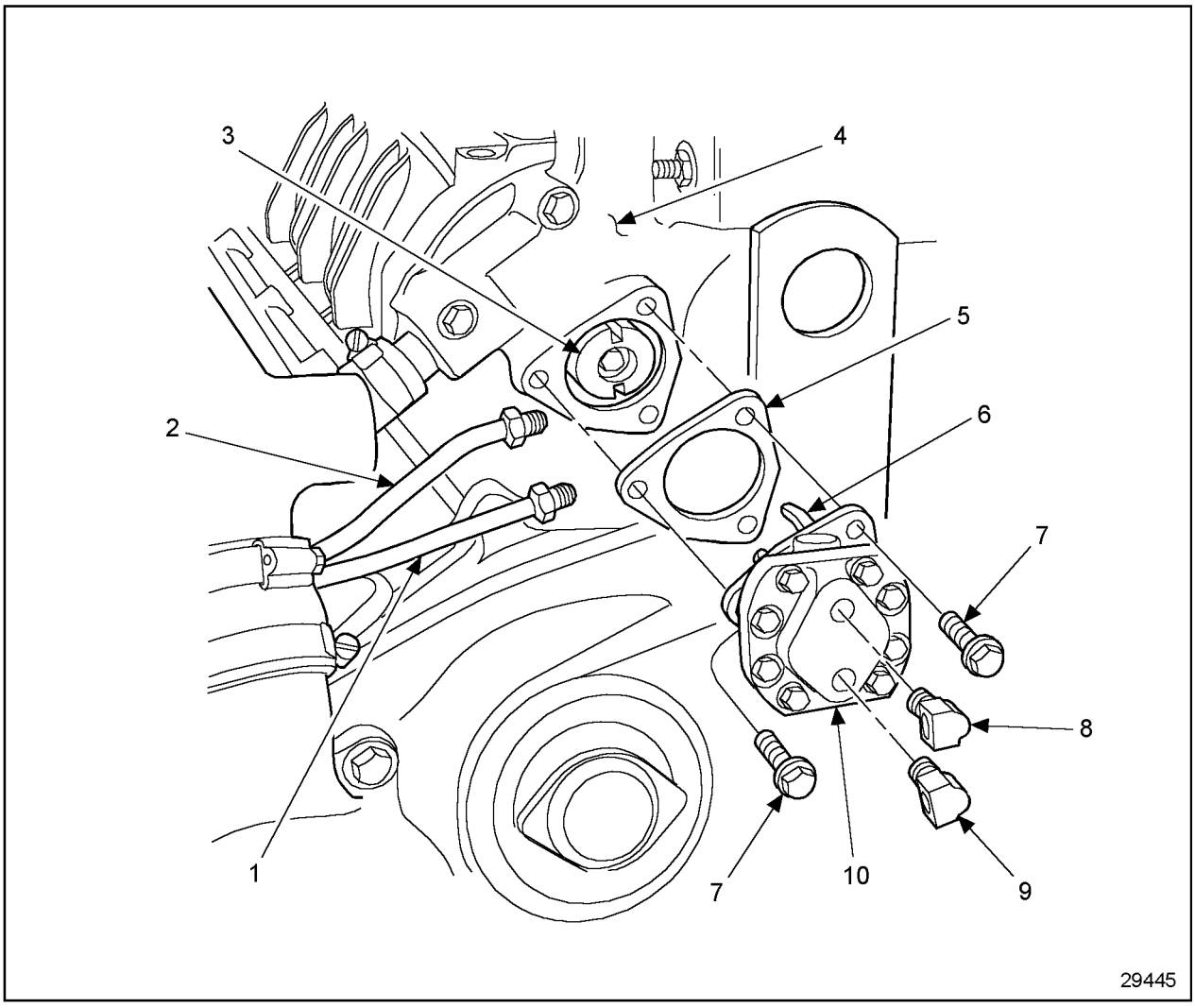
22. Install 1/8 in. pipe plugs in the upper unused drain holes.
23. If the pump will not be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

2.21.5 Installation of Fuel Pump

Install the fuel pump as follows:

NOTE:
The pump must always be installed with the pump cover inlet opening (marked "L.H. IN") next to the balance weight cover or blower housing on 6V and 8V engines. See Figure 2-111 and note that the fuel pump is bolted to the governor housing (on DDEC engines, verify that the drive coupling is the latest design) and is driven by the drive coupling fork and the drive disc which is attached to the blower rotor.

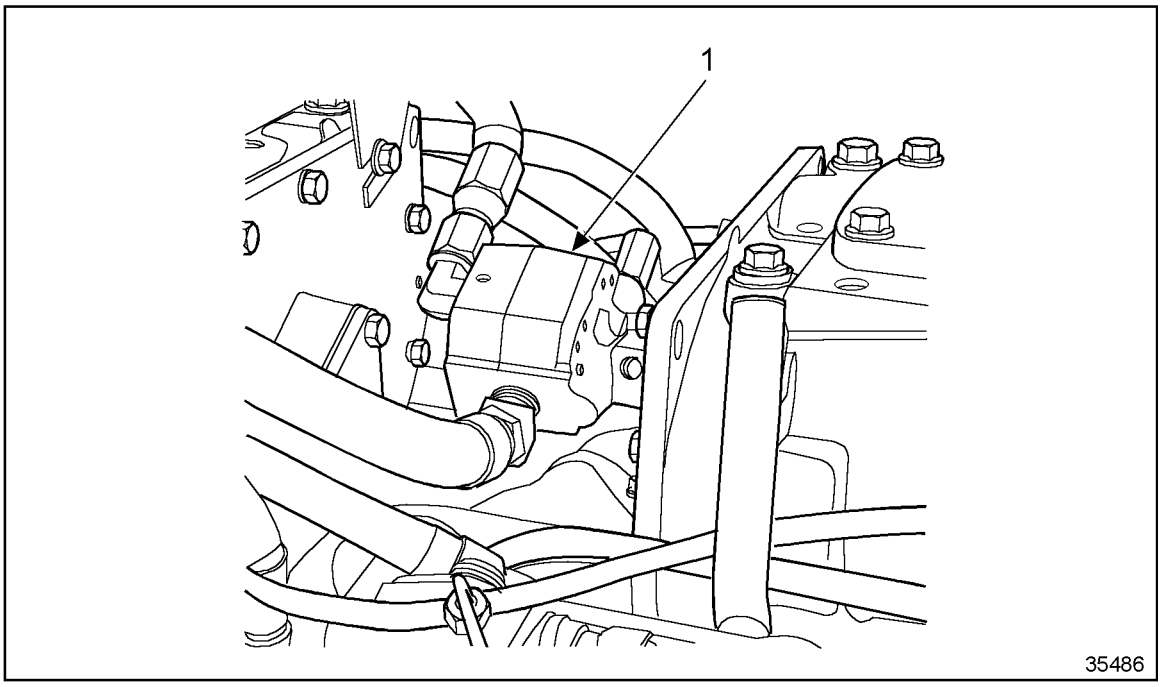
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1. Inlet Fuel Line
2. Outlet Fuel Line
3. Blower Drive Coupling
4. Governor Housing
5. Gasket
6. Bolt and Lock Washer Assembly
7. Outlet Fuel Fitting
8. Inlet Fuel Fitting
9. Fuel Pump Assembly
10. Drive Fork

Figure 2-111 Fuel Pump Assembly

NOTE:
See Figure 2-112 when installing the fuel pump on a 12V and 16V engine.



1. Fuel Pump

Figure 2-112 Installation of Fuel Pump (12V and 16V)

1. Affix a new gasket to the pump body mounting flange. Place the drive coupling fork on the square end of the drive shaft.
2. Place the fuel pump against the housing, making certain that the drive coupling fork registers with the drive disc slots.
3. Secure the pump to the housing with three nylon patch bolts.

NOTE:
To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

4. Install the inlet and outlet elbows in the pump cover.

NOTICE:
Do not use Teflon tape or paste on the fittings. This can cause the fuel pump cover to crack before the required torque is reached.

5. Before installing, coat the inlet and outlet elbow threads lightly with , Permatex 2, or an equivalent non-hardening sealant.

NOTE:
To prevent sealant from entering the fuel system, do not apply it to the first two threads of the fittings.

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6. Tighten fittings to the low end of the torque. If necessary, continue tightening until alignment is achieved, but do not exceed maximum torque. Tighten 1/4 in. fittings to 19-22 N·m (14-16 lb·ft), 3/8 in. fittings to 24-30 N·m (18-22 lb·ft), and 1/2 in. fittings to 27-34 N·m (20-25 lb·ft) torque.

NOTE:
Tighten fittings on the fuel filter-to-cooler plate and cooler plate-to-fuel pump hoses to 21.47-22.60 N·m (190-200 lb·in.) torque. **Hold connector block securely with a second wrench while tightening fittings.**

7. Connect the inlet and outlet fuel lines to the fuel pump elbows.
8. Connect the fuel pump drain tube, if used, to the pump body.
9. If the fuel pump is replaced or rebuilt, prime the fuel system with tool J 5956 before starting the engine. This will reduce the possibility of pump seizure when first starting.
10. Refer to section 2.21.5 for verification of proper fuel pump installation.

2.22 FUEL STRAINER AND FUEL FILTER

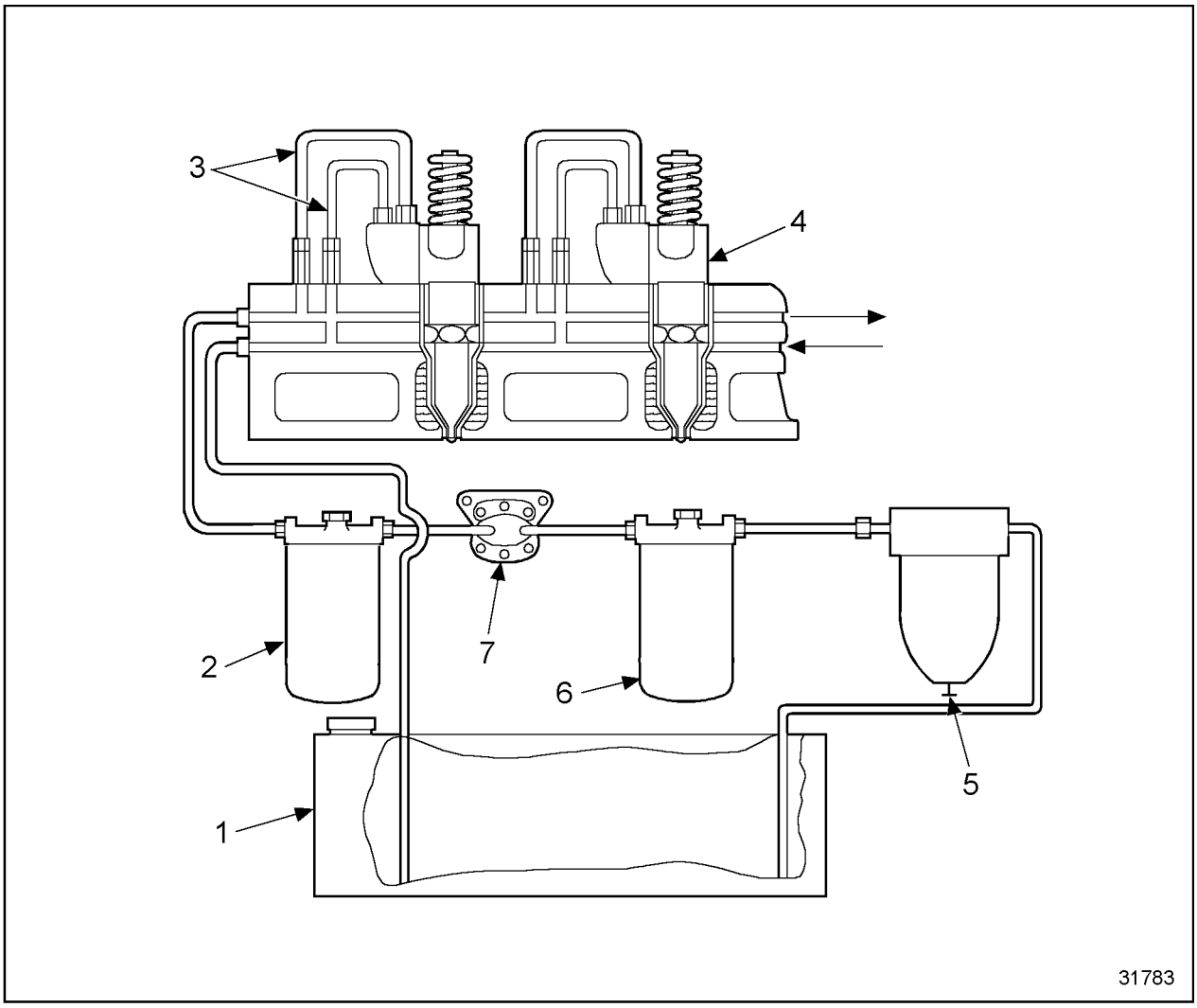
The fuel strainer (primary) and fuel filter (secondary) are used to remove impurities from the fuel. The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density-type element is capable of filtering out moisture, sludge, and other coarse debris. The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable cellulose element can remove particles as small as 10 microns. Fiberglass elements can remove particles as small as 5 microns.

A fuel/water separator must be located on the suction side of the fuel system (before the fuel pump).

NOTE:
Detroit Diesel does not approve the installation of a combination water separator, primary filter, and a standard primary filter on the same engine.

The installation can be a separate fuel/water separator plumbed in series with the normal DDC primary fuel filter or a combination water separator/primary fuel filter. See Figure 2-113. See Figure 2-114. If the latter is used, the original primary filter must be removed.

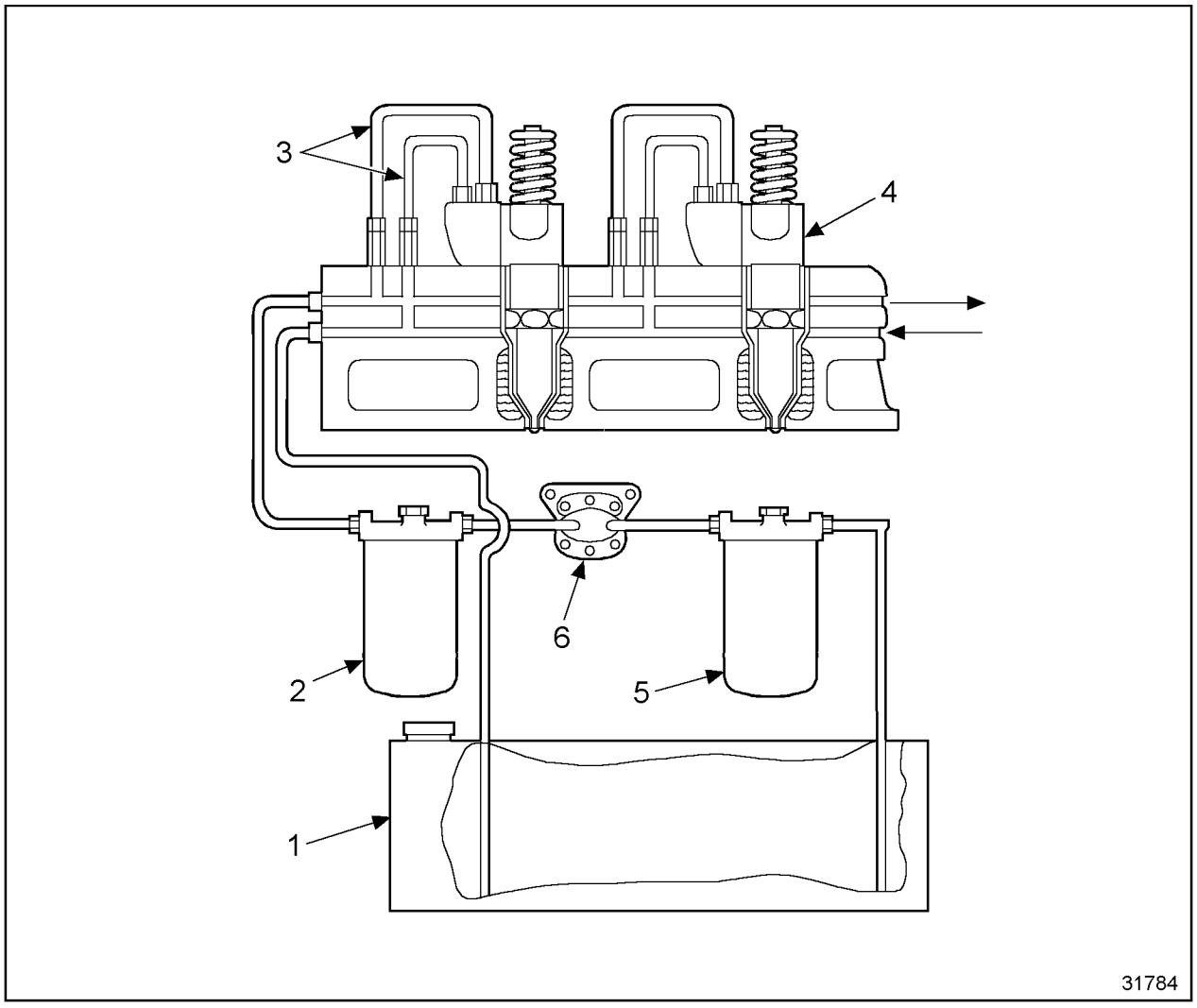
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1. Fuel Tank
2. Secondary Fuel Filter
3. Fuel Pipes
4. Injectors
5. Fuel/Water Separator
6. Fuel Filter (Strainer)
7. Fuel Pump

Figure 2-113 Fuel/Water Separator Installed

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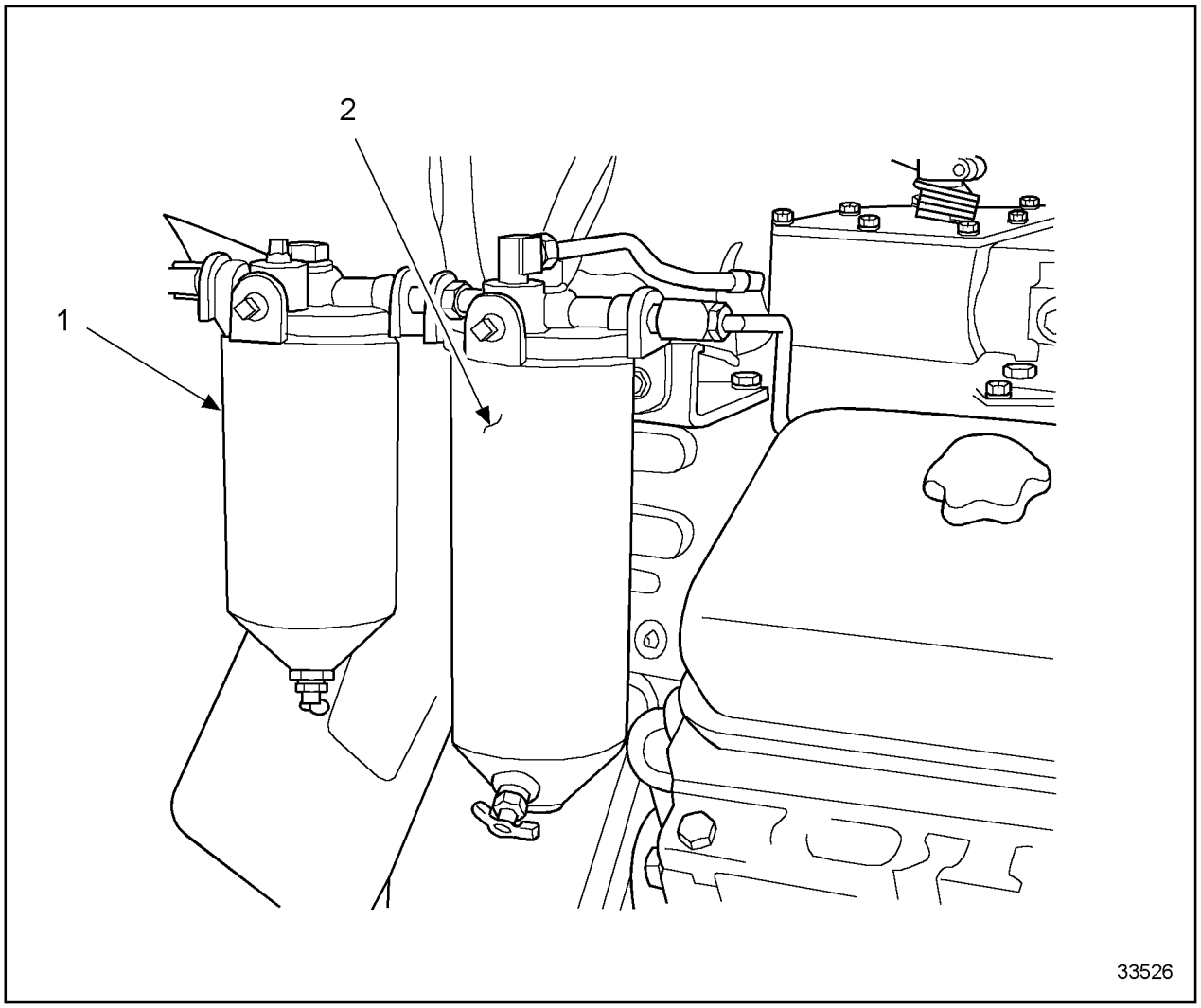
1. Fuel Tank
2. Secondary Fuel Filter
3. Fuel Pipes
4. Injector
5. Combination Fuel/Water Separator Primary Filter
6. Fuel Pump

Figure 2-114 Combination Fuel/Water Separator - Primary Filter Installed

A typical fuel/water separator has a drain for collected water removal. The fuel pump inlet restriction, must not raise above 6 in. Hg, for a clean strainer and 12 Hg for a dirty strainer, the same as any other primary filter.

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A spin-on type fuel strainer and fuel filter are used on certain engines. See Figure 2-115. The spin-on-filter cartridge consists of a canister, element, and gasket combined in a unitized replacement assembly. No separate springs or seats are required to support the filters. Detroit Diesel recommends replacing canister type fuel filter assemblies with the spin-on element assemblies where convenient.



1. Fuel Strainer
2. Fuel Filter

Figure 2-115 Fuel Strainer and Fuel Filter Elements

The filter covers incorporate a threaded stud to accept the spin-on-filter cartridges. The word "Primary" or "P" is cast on the fuel strainer cover, and the word "Secondary" or "S" is cast on the fuel filter cover for identification.

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No drain cocks are provided with spin-on-filters. In applications where water in the fuel is likely, DDC recommends a water separator or a combination fuel/water separator primary filter be installed.

NOTE:
Detroit Diesel does not approve the installation of a combination water separator, primary filter, and a standard primary filter on the same engine.

NOTE:
Removing and inverting the filter may drain the residue. Refill the filter with clean fuel oil before installing.

NOTICE:
A galvanized steel fuel tank should never be used for fuel storage. The fuel oil reacts chemically with the zinc coating to form powdery flakes that quickly clog the fuel filter and damage the fuel pump and fuel injectors, eventually damaging the engine.

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The fuel filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the filter base inlet passage and into the canister surrounding the filter element. Pump created, pressure or suction causes the fuel to flow through the filter element, where dirt particles are removed. Clean fuel flows to the interior of the filter element, up through the filter base central passage, and into the outlet passage. The fuel enters the fuel inlet manifold in the cylinder head.

NOTICE:
DDC has determined engines used in certain mining applications may experience high rates of fuel injector seizure and/or plunger and bushing scoring. To eliminate or greatly reduce the injector damage, DDC recommends installing a severe-duty secondary fuel filter assembly.

2.22.1 Repair or Replacement of Fuel Strainer or Fuel Filter

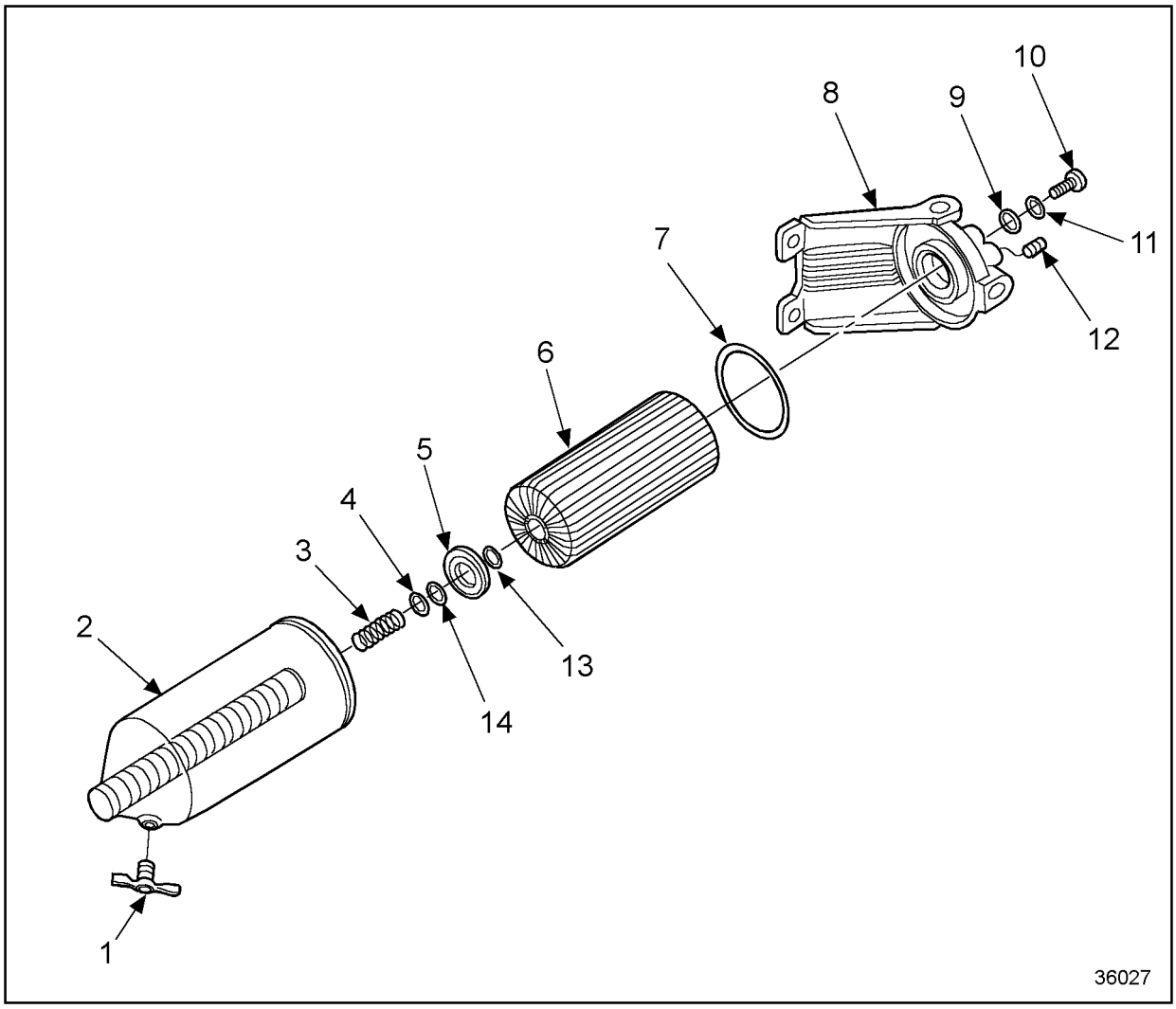
The fuel strainer or fuel filter is not a serviceable item. Refer to OEM guidelines or an authorized Detroit Diesel distributor for service recommendations.

2.22.2 Removal of Spin-On Type Fuel Strainer or Fuel Filter

Remove the spin-on type fuel strainer or fuel filter as follows:

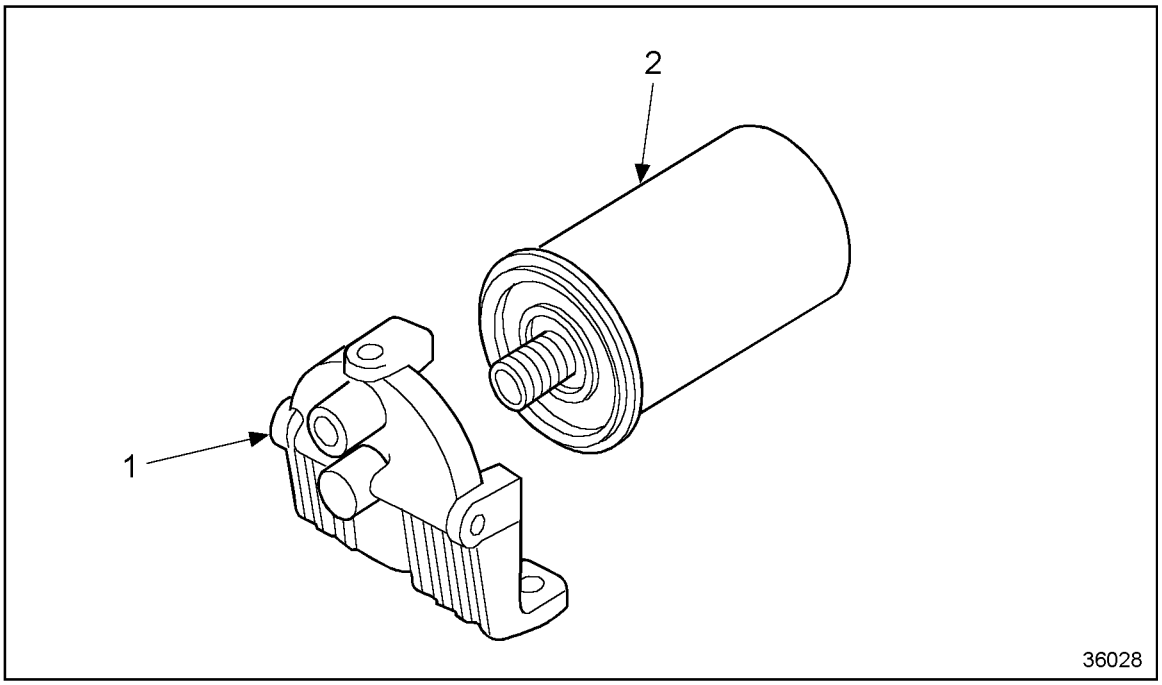
NOTE:
The procedure for removing an element is identical for both the fuel strainer and fuel filter. See Figure 2-116 and see Figure 2-117 for illustration.

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1. Draincock
2. Fuel Strainer Shell
3. Spring
4. Sprint Seat
5. Retainer
6. Fuel Strainer Element
7. Gasket
8. Fuel Strainer Cover
9. Washer
10. Screw
11. Gasket
12. Plug
13. Washer
14. Washer

Figure 2-116 Fuel Strainer Assembly



1. Fuel Strainer Cover
2. Fuel Filter

Figure 2-117 Fuel Filter

NOTE:
Only filter elements designed for fuel oil filtration should be used to filter the fuel.

NOTICE:
The wiring harness, starting motor, or other electrical equipment must be shielded during the filter change. Fuel oil can permanently damage the electrical insulation.

1. With the engine stopped, place a container under the strainer or filter.
2. Unscrew the filter or strainer, and discard it.

2.22.3 Installation of Spin-On Type Fuel Strainer or Fuel Filter

Install the spin-on type fuel strainer or fuel filter as follows:

NOTICE:
The wiring harness, starting motor, or other electrical equipment must be shielded during the filter change. Fuel oil can permanently damage the electrical insulation.

1. Fill the new filter replacement cartridge about two-thirds full with clean fuel oil.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

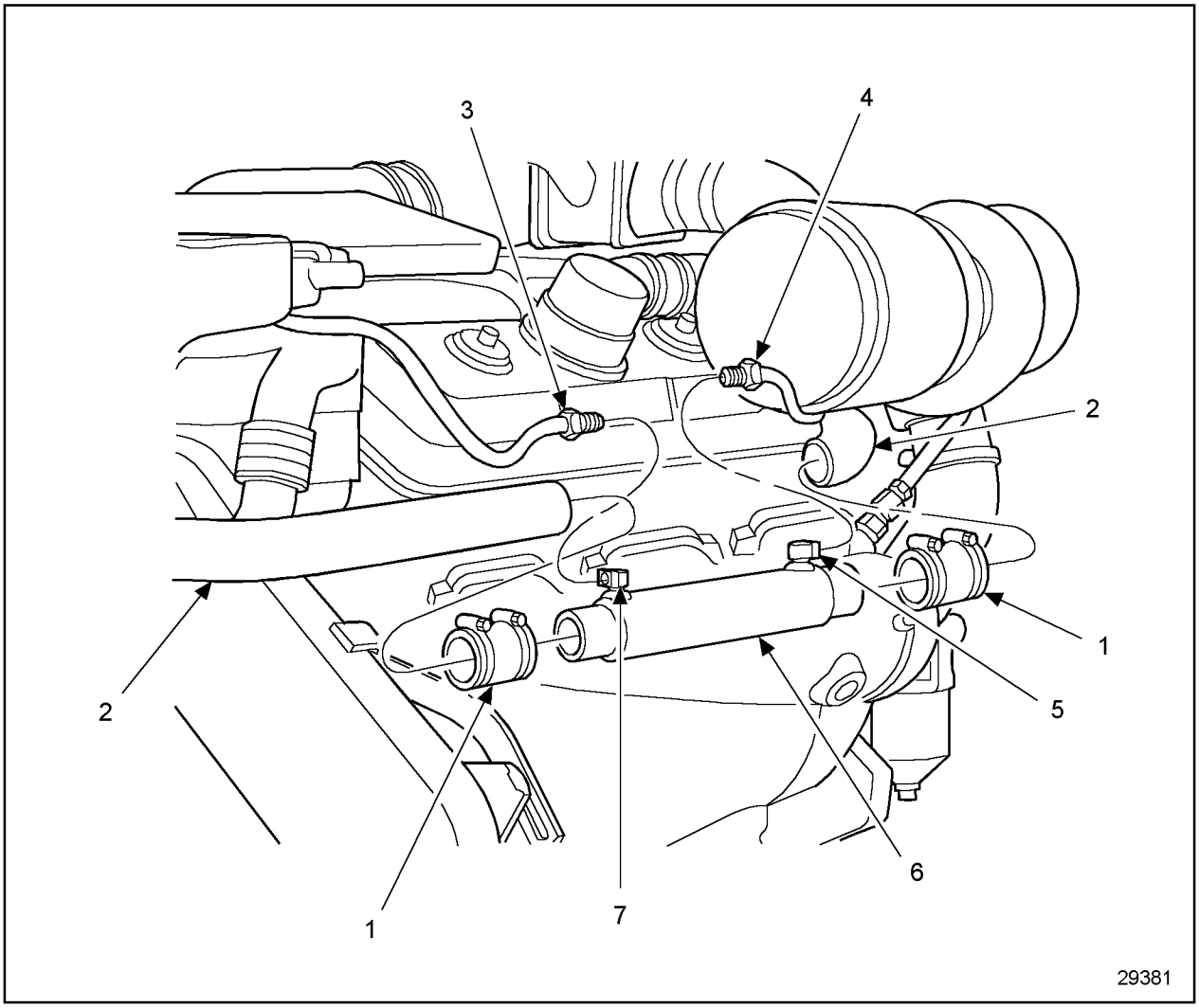
Diesel fuel is relatively harmless at ambient temperatures.

2. Coat the seal gasket lightly with clean fuel oil.
3. Install the new filter assembly.
4. Tighten it to one-half turn beyond the gasket contact.
5. Start the engine, and check the fuel system for leaks.

2.23 FUEL COOLER

A fuel cooler may be mounted in the raw water system between the heat exchanger and the raw water pump, so that the fuel leaving the engine is cooled before it returns to the fuel tank. See Figure 2-118.

Fuel cycling through an engine causes the fuel in the tank to become heated after extended operation. Excessive fuel temperatures can affect engine operation. An increase in the fuel inlet temperature above 32.2°C (90°F) will result in a brake horsepower loss of approximately 2% per 11°C (20°F).



1. Flexible Hose and Clamp Assemblies
2. Raw Water Pump Tubes
3. Fuel Inlet Line
4. Fuel Outlet Line
5. Outlet Fitting
6. Fuel Cooler
7. Inlet Fitting

Figure 2-118 Location of Fuel Cooler Parts

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2.23.1 Repair or Replacement of Fuel Cooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-119.

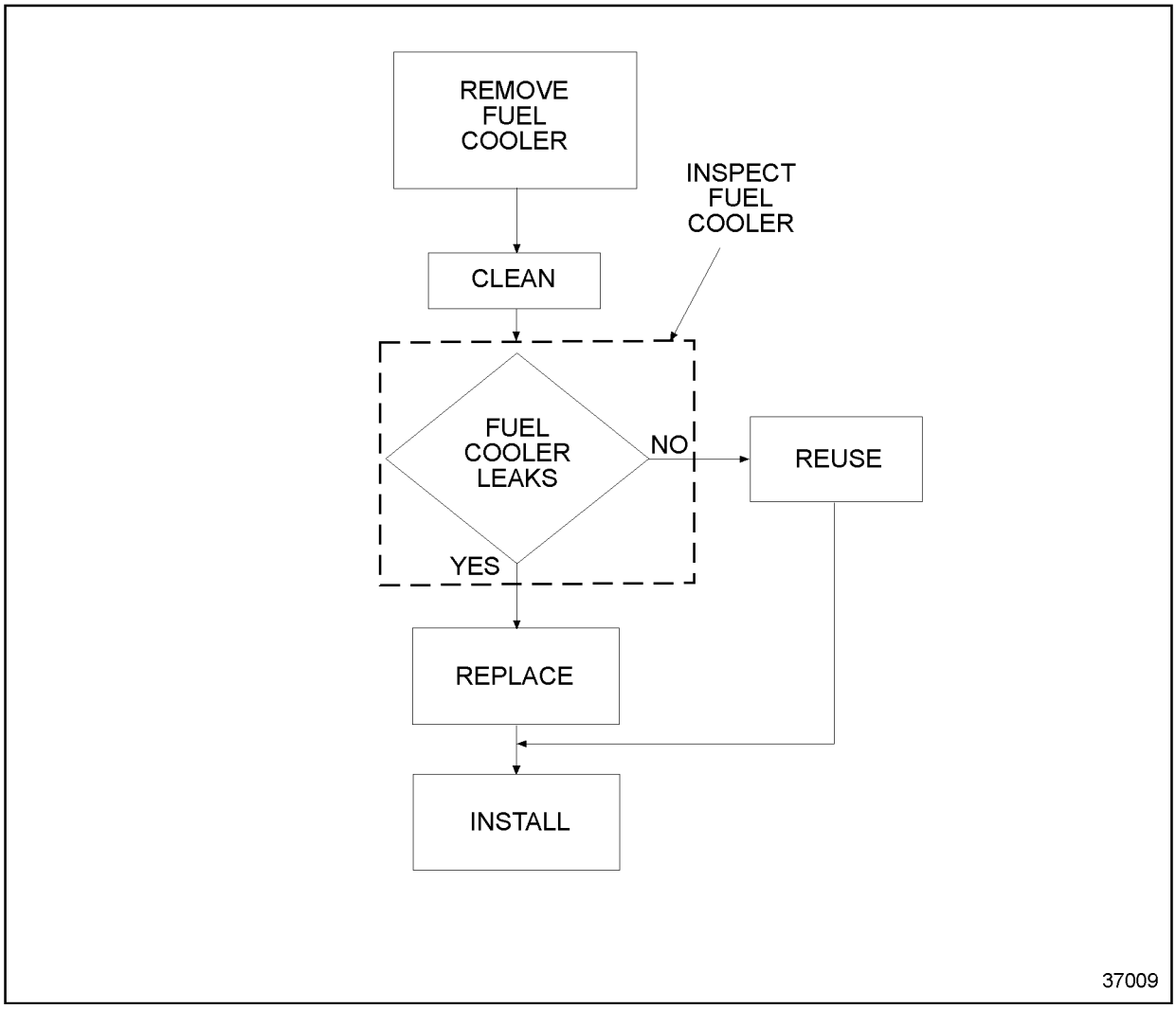


Figure 2-119 Flowchart for Repair or Replacement of Fuel Cooler

2.23.2 Removal of Fuel Cooler

Remove the fuel cooler as follows:

1. Disconnect the flexible hoses at the fuel cooler.
2. Loosen the hose clamps, and slide the hoses back on the raw water pump tubes.

2.23.2.1 Cleaning of Fuel Cooler

Follow OEM procedures for cleaning instructions.

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2.23.2.2 Inspection of Fuel Cooler

Inspect the fuel cooler as follows:

⚠ 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.

1. Plug one of the fuel openings with a 1/4 in. pipe plug, and attach an air hose to the other opening to check for leaks.
2. Apply approximately 256 kPa (40 lb/in.^{2}) air pressure, and submerge the cooler in a container of heated water (82°C or 180°F).

NOTE:
Air bubbles in the water indicate a leak.

[a] If leaks are indicated, replace the cooler. Refer to section 2.23.3.

[b] If not leaks are detected, reuse the fuel cooler.

2.23.3 Installation of Fuel Cooler

Install the fuel cooler as follows:

1. Slide the hoses onto the fuel cooler tubes.
2. Tighten the hose clamps.
3. Connect the flexible hoses at the fuel cooler.

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2.24 LIMITING SPEED MECHANICAL GOVERNOR

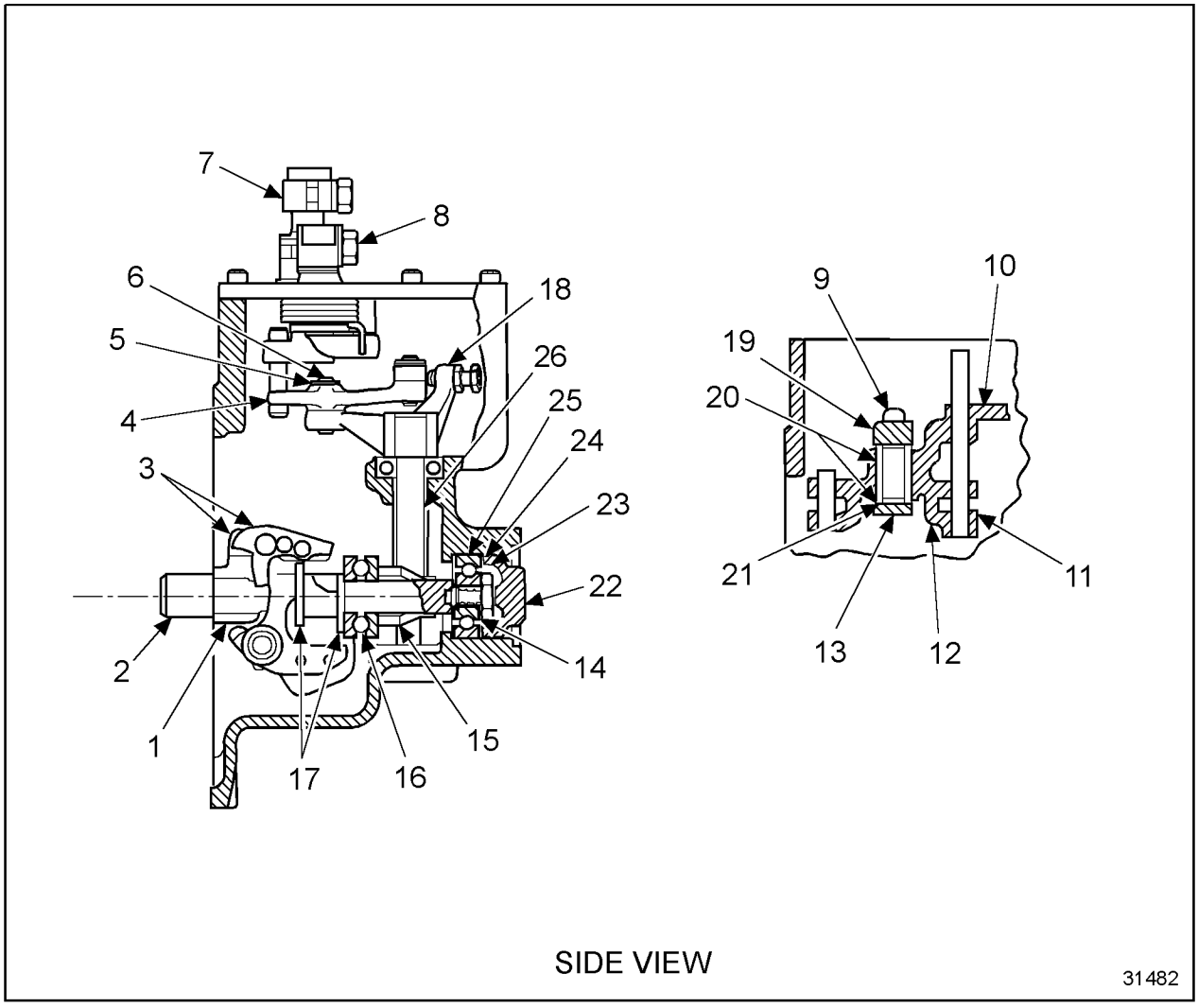
Fluctuating loads vary horsepower requirements. The governor is introduced in the linkage between the throttle control and the fuel injectors and is mounted to the front end of the blower. It controls the fuel amount required to hold the engine speed constant during load fluctuations.

Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with a limiting speed mechanical governor.

The limiting speed mechanical governors used on the V-92 engines perform the following two functions:

- Control the engine idling speed
- Limit the maximum operating engine speed

The double-weight limiting speed governor is used to improve the performance of some engines. See Figure 2-120. The double-weight limiting speed governor includes the lighter weight fuel squeezer engine weight system. When encountering performance problems, replace the former single weight governor with the current double-weight governor. See Figure 2-121.

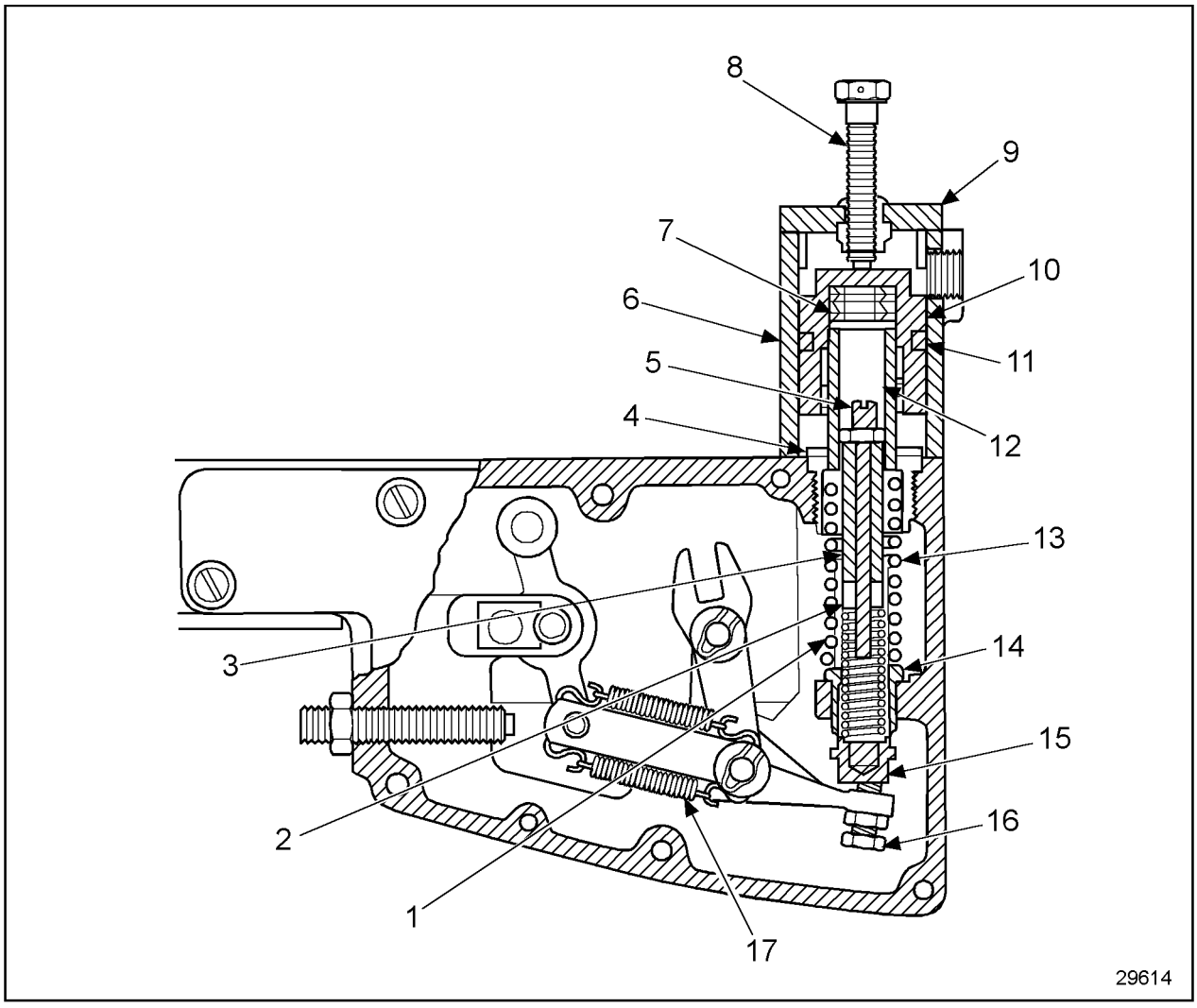


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1. Carrier and Weight Assembly (Turbocharged Engines)
2. Weight Shaft
3. Carrier and Weight Assembly (Non-Turbocharged Engines)
4. Differential Lever
5. Plain Washer
6. Spring Retainer
7. Speed Control Lever
8. Stop Lever
9. Flat Washer
10. Operating Lever Connecting Link
11. Connecting Pin
12. Control Link Operating Lever Assembly
13. Governor Housing
14. Lock Washer
15. Fork
16. Riser Thrust Bearing
17. Riser
18. Operating Shaft Lever
19. Flat Washer
20. Needle Bearings
21. Control Link Operating Shaft
22. Housing Plug
23. Bearing Retaining Bolt
24. Gasket
25. Weight Shaft Bearing
26. Operating Shaft

Figure 2-120 Cross Section of Double-Weight Limiting Speed Mechanical Governor

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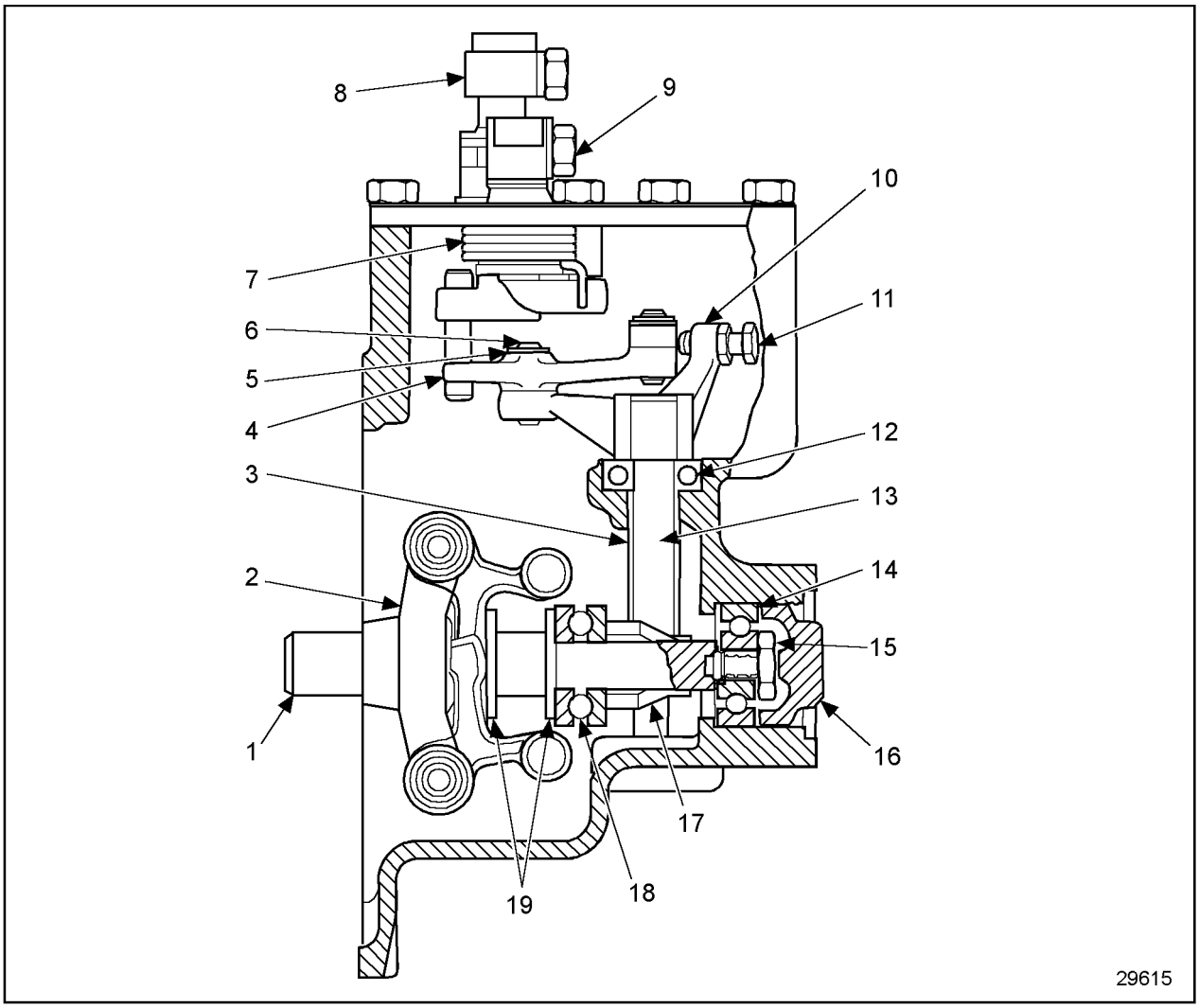
1. Low-Speed Spring
2. Low-Speed Spring Seat
3. High-Speed Spring Seat
4. High-Speed Spring Retainer
5. Idle-Speed Adjustment Screw
6. Spring Housing
7. Shims
8. Low Maximum Speed Adjusting Screw
9. Cover
10. Piston
11. Seal Ring
12. Sleeve
13. High-Speed Spring
14. High-Speed Spring Plunger
15. Low-Speed Spring Cap
16. Gap Adjusting Screw
18. Yield Link Assembly

Figure 2-121 Cross Section of Dual-Range Governor Spring Assembly

A tamper-resistant double weight limiting speed governor is provided for highway vehicle engines. Refer to section ADDITIONAL INFORMATION.

The single weight limiting speed governor is used on 6V and 8V engine applications, except fuel squeezer and coach engines that require low idle speed control (below 500 RPM). See Figure 2-122.

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1. Balance Weight Shaft
2. Balance Weight Assembly
3. Spacer
4. Differential Lever
5. Washer
6. Spring Retainer
7. Return Spring
8. Speed Control Lever
9. Stop Lever
10. Operating Shaft Lever
11. Gap Adjusting Screw
12. Upper Bearing
13. Operating Shaft
14. Weight Shaft Bearing
15. Bearing Retaining Bolt
16. Housing Plug
17. Fork
18. Riser Thrust Bearing
19. Riser

Figure 2-122 Cross Section of Single Weight Limiting Speed Mechanical Governor

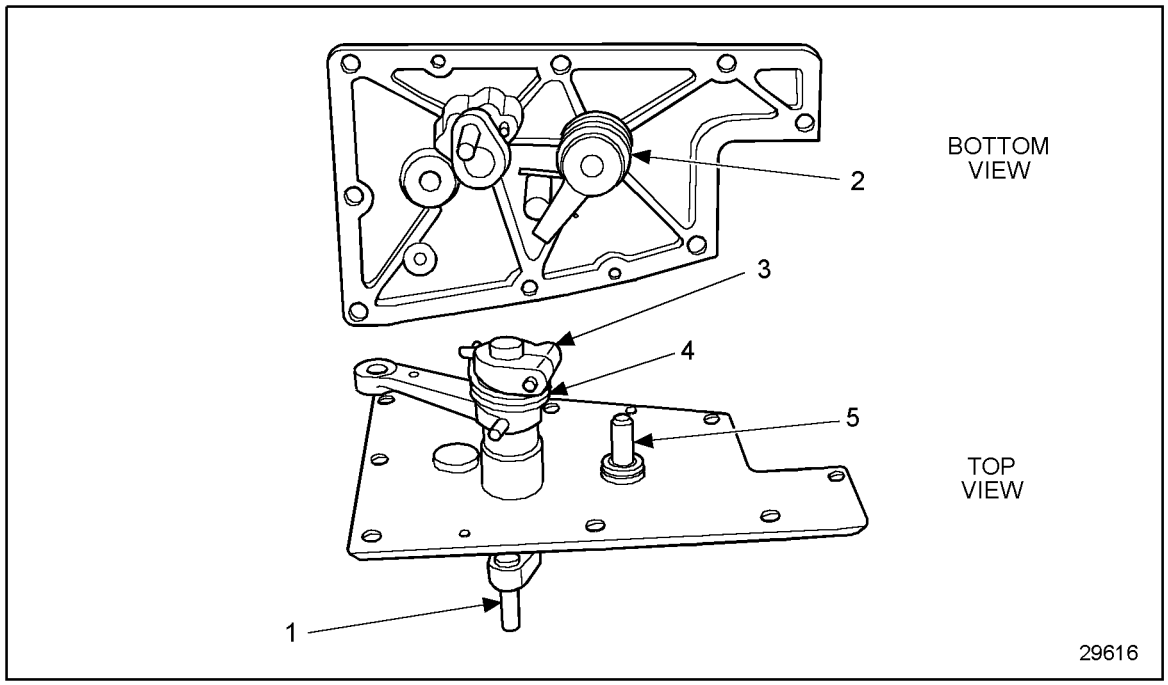
Each governor has an identification plate located on the governor housing. It contains the governor assembly number, type, idle range speed and manufacturing date.

On 6V and 8V engines, the governor is mounted on the front end of the blower. On 12V and 16V engines, the governor is mounted on the front end of the rear blower. The governor auxiliary drive housing is mounted on the rear end of the front blower. A blower rotor drives the governors.

The governor consists of the following two subassemblies:

- Control housing cover
- Control and weight housing

A die cast governor cover with serrated shafts and three bosses is used to provide additional design features. See Figure 2-123. Two bosses are drilled for the limiting speed governors, one for the throttle shaft, and one for the shutdown shaft.



1. Speed Control Lever Shaft
2. Return Spring
3. Yieldable Speed Control Lever
4. Spring Clamp
5. Stop Lever Shaft

Figure 2-123 Die Cast Governor Covers

NOTE:
If a customer furnished mounting bracket is attached to the new cover, rework the old bracket to clear the unused cast bosses (one for limiting speed governors).

The die cast governor cover assemblies include a 3/8 in. diameter serrated shutdown shaft for limiting speed governors. This assures positive clamping between the serrated levers and the shafts and prevents slippage. Four serrations are eliminated on the shutdown shafts to permit some customers to design a mating lever with missing serrations. This provides a fixed position for their particular requirements. DDC levers are not provided with missing serrations.

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To reduce governor speed control lever shaft assembly stop pin wear and prolong bushing and O-ring seal life, a yieldable speed control lever is available. This yieldable speed control lever cannot be used with the former stamped cover assemblies. However, a service yieldable speed control lever is available for use with the stamped cover.

A standard double-weight governor operates as follows:

The governor holds the injector racks in the advanced fuel position for starting when the speed control lever is in the idle position. Immediately after starting, the governor moves the injector racks to the idling position.

To limit fuel input during engine start-up when the speed control lever is in its idle position, turbocharged engines use a starting aid screw. The starting aid screw is externally mounted in the front of the governor housing, that has a domed end, and cannot be removed from the outside of the housing. When the screw is not required, back it out as far as possible to make it ineffective.

When the centrifugal force of the revolving governor weights balances out the tension on the high or low-speed spring (depending on the speed range), the governor stabilizes the engine speed for a given speed control lever setting.

In the low-speed range, the centrifugal force of the low and high-speed weights operate against the low-speed spring. As the engine speed increases, the centrifugal force of the low and high-speed weights compress the low-speed spring until the low-speed weights are against their stops, limiting their travel. The low-speed spring will be fully compressed and the low-speed spring cap is within 0.05 mm (0.002 in.) of the high-speed spring plunger.

Throughout the intermediate speed range, the operator has complete engine control because both the low-speed spring and the low-speed weights are against their stops, and the high-speed weights are not exerting enough force to overcome the high-speed spring.

As the speed increases, the centrifugal force of the high-speed weights increases until this force can overcome the high-speed spring. The governor takes control of the engine, limiting the maximum engine speed.

Fuel rods are connected to the differential lever and injector control tube levers through the control link operating lever and connecting link. This arrangement allows the governor to change the injector control rack fuel settings.

The governors' low-speed spring force determines the engine idle speed. When the governor speed control lever is placed in the idle position, the engine will operate at the speed where the force of the governor low-speed weights will equal the force of the governor low-speed spring.

Adjusting the idle adjusting screw changes the engine idle speed by changing the force on the low-speed spring. Refer to section 12.4.9 for 6V and 8V engine idle speed adjustment. Refer to section 12.5.5 for 12V and 16V engines idle speed adjustment.

The high-speed spring force determines the engine maximum no-load speed. When the governor speed control lever is placed in the maximum speed position, the engine will operate at a speed where the force of the governor high-speed weights equals the force of the governor high-speed spring.

Adjusting the high-speed spring retainer will increase or decrease the high-speed spring tension. Refer to section 12.4.16 for 6V and 8V engines maximum no-load speed adjustments. Refer to section 12.5.6 for 12V and 16V engines maximum no-load speed adjustments.

The double-weight dual high-speed range governor operates as follows:

The mechanical double-weight limiting speed dual-range governor has been designed for use in applications that require a high maximum speed occasionally and a low maximum speed the rest of the time.

In vehicle operation, this governor permits a high engine speed in the lower gear ratios for maximum vehicle acceleration, while providing a conservative vehicle speed in the higher gears. The valve for controlling the governor's high and low-speed ranges is usually connected to the transmission. The transmission shift from low gear to high gear will automatically shift the governor from its high maximum speed range to the low maximum speed range.

Air or oil pressure used behind a piston to increase the tension on the governor high-speed spring activates the two speed operation.

NOTE:
On current engines, the spring assembly has been revised to include a shorter sleeve and a longer idle speed adjustment set screw. The new sleeve (1.64 in.) and the new set screw (5/16 in.-24 x 2 in.) must be used together in the spring assembly. Do not mix with the former sleeve (1.84 in.) and set screw (5/16 in.-24 x 1 1/2 in.).

Removing air pressure from behind the piston permits the governor high-speed spring to force the piston against the low maximum speed adjusting screw, retaining enough tension in the governor high-speed spring to operate the engine at the desired lower speed.

A seal ring prevents air pressure from leaking past the piston assembly. The cylinder is lubricated at the time the piston assembly is installed.

The single-weight governor operates as follows:

When the centrifugal force of the revolving governor weights balances the tension on the high or low-speed spring (depending on the speed range), the governor stabilizes the engine speed for a given governor control lever setting.

In the low-speed range, the centrifugal force operates against the low-speed spring. As the engine speed increases, the centrifugal force compresses the low-speed spring until the spring cap is against the high-speed plunger. This removes the low-speed spring from operation. The governor is then in the intermediate speed range. In this range, the centrifugal force is operating against the high-speed spring. The engine speed is manually controlled.

As the engine speed increases to a point where the centrifugal force overcomes the high-speed spring preload, the governor moves the injector racks out to the required maximum no-load position.

A fuel rod, connected to the differential lever and the injector control tube lever, assists the governor in changing the injector control racks fuel settings.

The centrifugal force required to balance tension on the low-speed spring determines the engine idle speed.

Using the idle adjustment screw to change the low-speed spring tension adjusts the engine idle speed. Refer to section 12.4.18 for the idle speed adjustment.

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The centrifugal force required to balance the tension on the high-speed spring determines the maximum no-load speed.

The high-speed spring retainer adjusts the maximum no-load speed. The high-speed spring retainer nut movement will increase or decrease the tension on the high-speed spring. Refer to section 12.4.16 for the maximum no-load speed adjustment.

All governors are lubricated as described here:

A spray of lubricating oil from the blower end plate lubricates the governor. The governor weights distribute this oil to all governor assembly parts requiring lubrication. Oil returning from the governor is directed through passages in the blower end plate and cylinder block to the engine oil pan.

2.24.1 Repair or Replacement of Limiting Speed Mechanical Governor

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-124.

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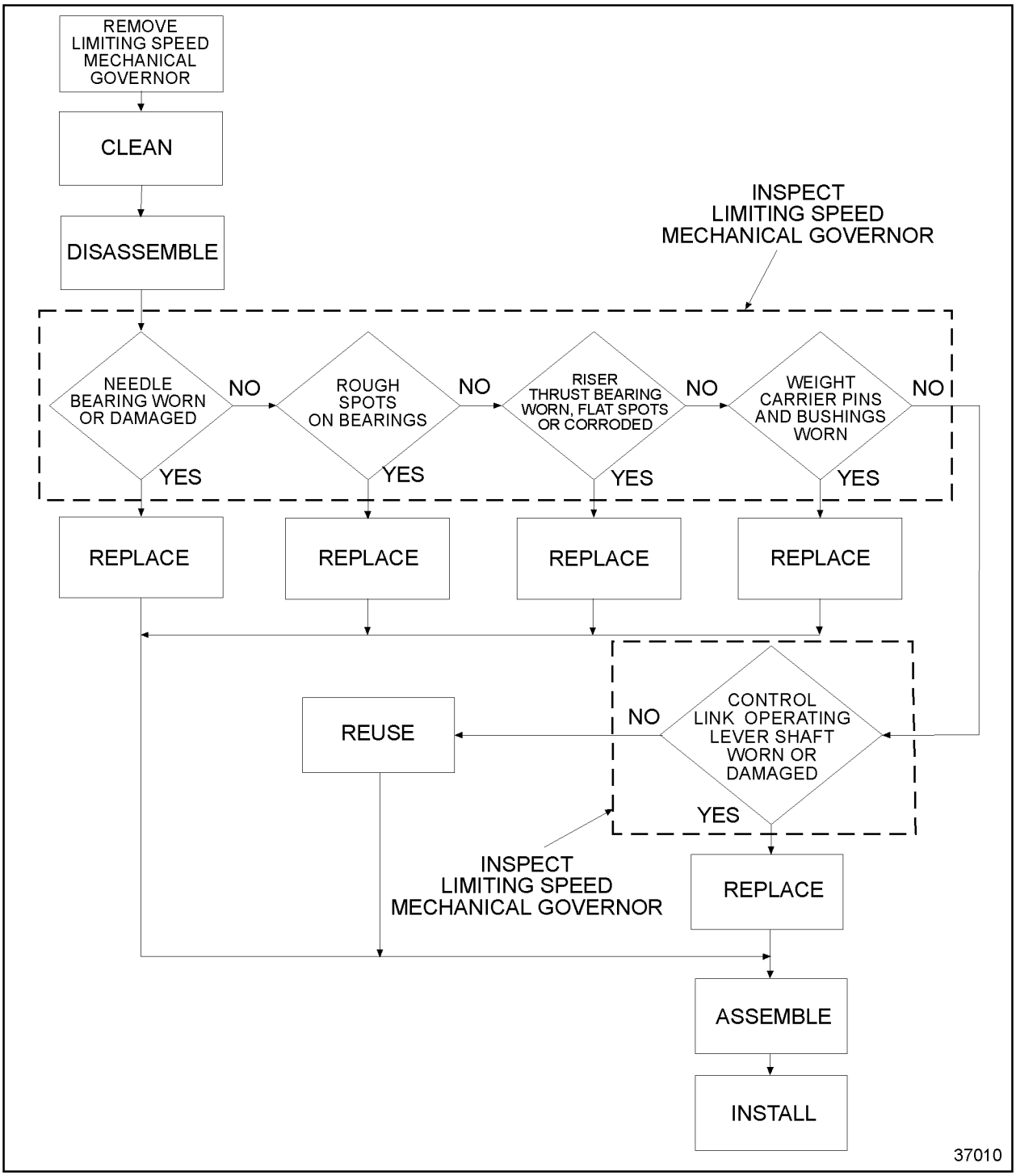


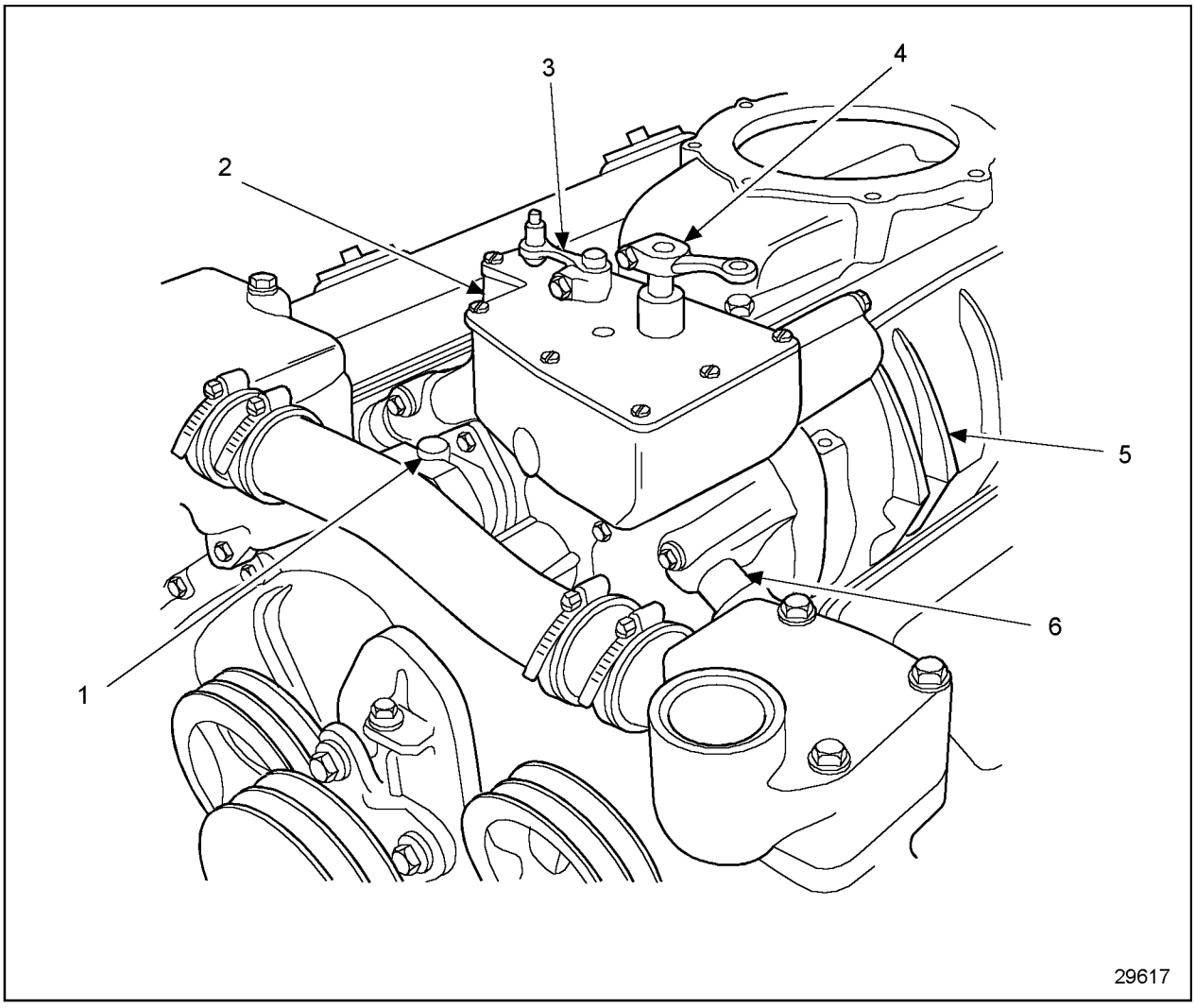
Figure 2-124 Flowchart for Repair or Replacement of Limiting Speed Mechanical Governor

2.24.2 Removal of Limiting Speed Mechanical Governor (6V and 8V Engines)

Remove the limiting speed mechanical governor on 6V and 8V engines as follows:

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1. Open the drain cocks, and drain the engine cooling system. Refer to section 13.12.3.
2. Remove any accessories attached to the cylinder head, governor, or engine front end that interfere with the governor assembly removal. On "TA" engines Refer to section 6.5.2 to remove the blower.
3. Disconnect the control linkage from the speed control and stop levers. See Figure 2-125.



1. Fuel Pump
2. Governor Assembly
3. Stop Lever
4. Speed Control Lever
5. Blower Assembly
6. Fuel Rod Cover

Figure 2-125 Limiting Speed Mechanical Governor Mounting (6V and 8V Engines)

4. Remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.
5. Remove the valve rocker covers from the cylinder heads. Discard the gaskets.

6. Remove the screw type pin in the control link operating lever and the clevis pin in the control tube lever. Withdraw the right-bank fuel rod from the governor.
7. Remove the clevis pin in the control tube lever, and lift the connecting pin out of the control link operating lever approximately three-quarters of an inch. Withdraw the fuel rod from the governor.
8. Loosen the hose clamps at each end of the water bypass tube. Slide the hoses and clamps onto the bypass tube, and remove the tube from the engine.
9. Disconnect and remove the fuel oil lines attached to the fuel pump and the crossover fuel oil line attached to each cylinder head.
10. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head. Slide each hose and clamp up on the tube in the governor housing.

NOTE:
Observe the location of the two copper lock washers and eight plain lock washers on the governor-to-blower bolts before removing them.

11. Remove the ten bolts and washers securing the governor and fuel pump assembly to the blower (two inside and eight outside).
12. Tap the sides of the governor housing lightly with a plastic hammer to loosen the governor from the blower.
13. Pull the governor and fuel pump assembly out from the dowels in the blower end plate.
14. Remove the governor-to-blower gasket.
15. Remove the drive coupling fork.

NOTE:
The fuel pump drive coupling fork may be on either the fuel pump or the blower rotor shaft.

16. Remove the three bolt and seal assemblies securing the fuel pump assembly to the governor housing.
17. Remove the fuel pump and gasket from the governor housing.

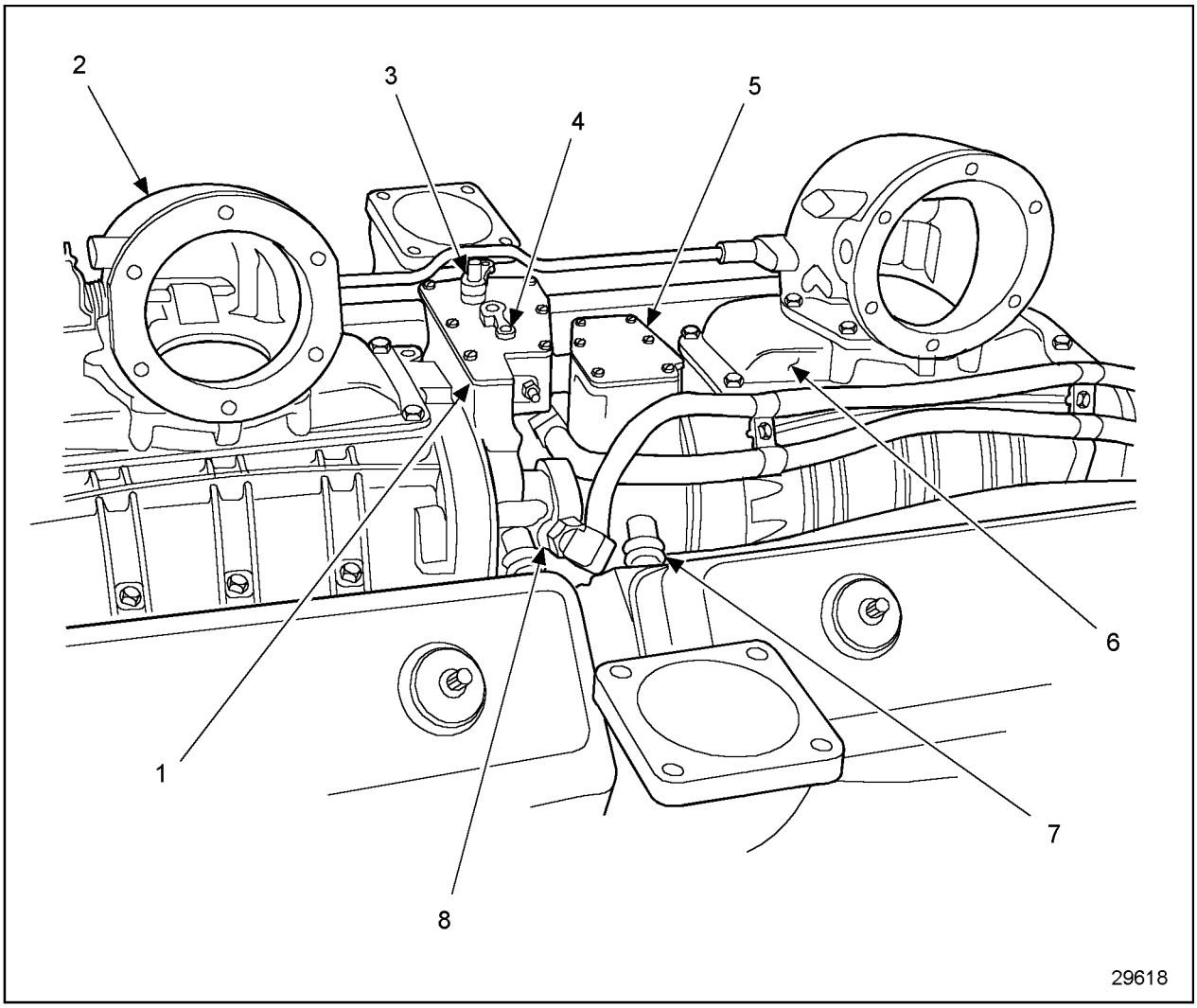
2.24.3 Removal of Limiting Speed Mechanical Governor (12V and 16V Engines)

Remove the limiting speed mechanical governor on 12V and 16V engines as follows:

1. Remove the blower assembly. Refer to section 1.30.4.

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2. Disconnect the linkage attached to the governor speed control and stop levers. See Figure 2-126.



1. Governor Assembly
2. Air Shutdown Housing Assembly
3. Speed Control Lever
4. Stop Lever
5. Auxiliary Control Link Housing
6. Air Shutdown Housing Adaptor
7. Fuel Rod Cover
8. Fuel Pump Assembly

Figure 2-126 Limiting Speed Governor Mounting (12V and 16V Engines)

3. On non-turbocharged engines, disconnect the air inlet tube attached to the air shutdown housing on each blower.
4. Disconnect the tube from the turbocharger and the air shutdown housing on the rear blower.
5. On marine engines, remove the air silencers from both air shutdown housings.

6. On non-turbocharged engines, remove the air shutdown housings and the air shutdown adaptor from the rear blower.
7. On marine engines, remove the air shutdown housings from the blowers. Remove the two air shutdown housings, with attaching rod, as a unit.
8. On turbocharged engines, disconnect the shutdown rod from the lever on the rear air shutdown housing. Remove the air shutdown housing and the air shutdown adaptor from the blower as an assembly.
9. Cover the top of the blower with masking tape to prevent the entry of foreign material.
10. Remove the rear cylinder head rocker covers. Discard the gaskets.
11. Remove the governor housing cover screws and lock washers. Remove the cover and gasket from the housing.
12. Remove the governor auxiliary control link housing cover screws and lock washers. Remove the cover and gasket from the housing.
13. Remove the screw type pin in the control link operating lever and the pin in the control tube lever to remove the right-bank fuel rod. Withdraw the fuel rod through the top of the governor housing.
14. Remove the connecting pin from the control link operating lever and the pin in the control tube lever to remove the left-bank fuel rod. Withdraw the fuel rod through the top of the governor housing.
15. Lift or pry each end of the connecting link from the ball joint studs. Remove the connecting link from the governor housing.
16. Loosen the fuel rod cover hose clamp at each side of the governor housing. Slide each hose against the governor housing. Tighten each clamp to retain it on the hose.
17. Loosen the hose clamp between the governor housing and the auxiliary control link housing. Slide the hose forward against the auxiliary control link housing. Tighten the clamp.
18. Disconnect the fuel pump inlet and outlet tubes or hoses from the fuel pump. If necessary, remove the fuel pump from the governor housing.
19. Disconnect the blower drive support oil tube from the blower drive support fitting.
20. Loosen the two bolts securing the oil tube seal ring retaining plate to the blower end plate. Push the oil tube into the end plate.
21. Remove the six bolts and lock washers securing the flywheel housing hole cover at the blower drive support. Remove the cover and gasket.
22. Remove the clevis pin and cotter pin from the fuel rod opposite injector control tube lever. Remove the fuel rod.
23. Remove the screw pin from the end of the fuel rod between the two bosses on the lever. Remove the fuel rod.
24. Install the short screw pin in the control link operating lever.
25. Remove the lower end of the right-bank fuel rod from the top of the governor housing.

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26. Remove the clevis pin and cotter pin, and remove the fuel rod from the injector control tube lever.
27. Remove the connecting pin from the fuel rod and lower boss, and remove the fuel rod from the two bosses on the lever.
28. Lower the connecting pin in the control link operating lever.
29. Remove the lower end of the left-bank fuel rod from the top of the governor housing.
30. If the engine is equipped with a rear mounted battery-charging alternator, refer to section 2.24.4.
31. If the engine is equipped with a hydraulic oil pump, refer to section 2.24.5.
32. Remove the blower drive shaft retaining snap ring from the blower drive flexible coupling.
33. Remove the blower drive shaft from the blower drive hub and the blower drive coupling.
34. Loosen the blower drive support-to-blower hose (seal) clamps. Push the hose (seal) back on the blower drive support.
35. Remove the bolt and washer securing the blower to the cylinder block from the top of each blower end plate.
36. Remove the bolts and retaining washers on each side of the blower that secure it to the cylinder block.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the lifting sling before removing from engine. Blower damage may result if the blower falls from the lifting device.

37. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.
38. Lift the blower assembly slightly, and move it forward to detach the blower from the hose (seal).
39. Lift the blower away from the engine and place it on a bench.
40. Remove the blower-to-cylinder block gasket.
41. With the blower and governor assembly removed from the engine, remove the ten bolts, lock washers, plain washer, and copper washers securing the governor assembly to the blower end plate.
42. Slide the governor assembly forward off of the dowel pins in the end plate. Remove the governor to blower end plate gasket.

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2.24.4 Removal of Limiting Speed Mechanical Governor (Engine Equipped with a Rear Mounted Battery-Charging Alternator)

On an engine equipped with a rear mounted battery-charging alternator, proceed as follows:

1. Loosen and remove the alternator drive belt.
2. Remove the alternator drive pulley nut and pulley from the alternator drive shaft.
3. Remove the bolts and lock washers securing the alternator drive assembly to the flywheel housing.
4. Remove the drive assembly, gasket, and drive coupling from the flywheel housing.
5. Refer to section 2.24.3, step 32 to continue removal.

2.24.5 Removal of Limiting Speed Mechanical Governor (Engine Equipped with a Hydraulic Oil Pump)

On an engine equipped with a hydraulic oil pump, proceed as follows:

1. Remove the six bolts and lock washers securing the oil pump to the flywheel housing and adaptor.
2. Remove the oil pump, adaptor, and gaskets from the flywheel housing.
3. Remove the drive coupling and the drive coupling hub from the blower drive shaft.
4. Refer to section 2.24.3, step 32 to continue removal.

2.24.5.1 Cleaning of Limiting Speed Mechanical Governor

Clean the limiting speed mechanical governor as follows:

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Thoroughly wash the cover assembly in clean fuel oil.
2. Thoroughly wash the control link operating lever containing the bearings in clean fuel oil.

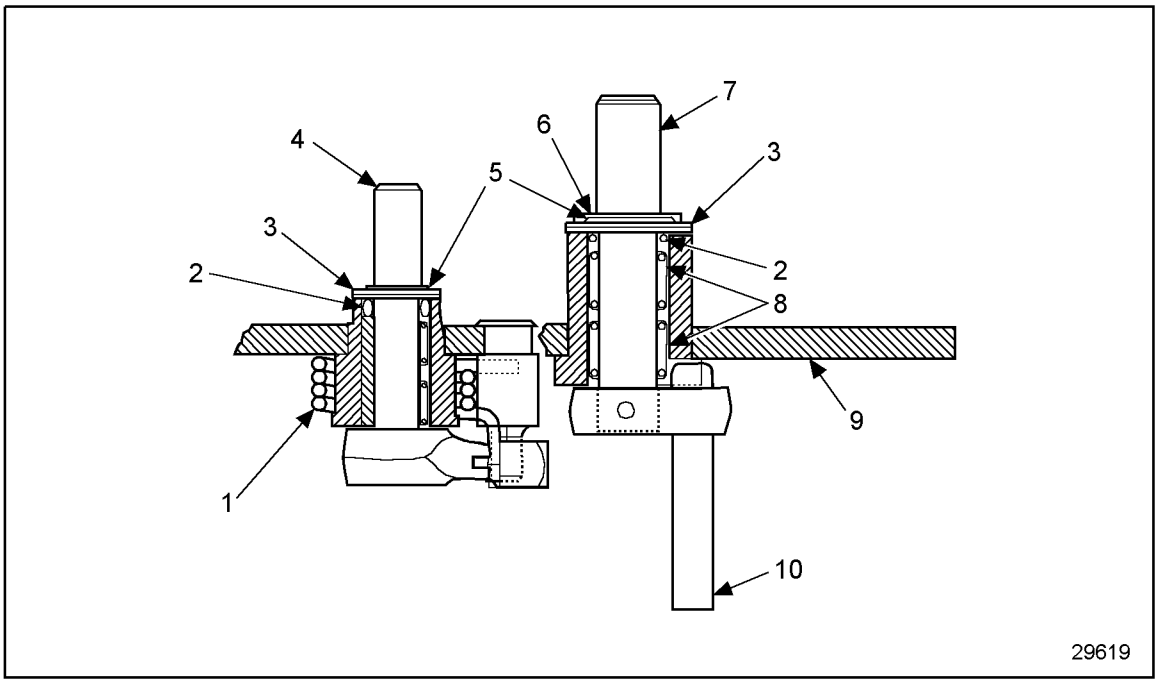
⚠ CAUTION:

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.

3. Dry components with compressed air.
4. Inspect for worn or damaged parts that may be repaired or replaced without complete disassembly.

2.24.6 Disassembly of Limiting Speed Mechanical Governor

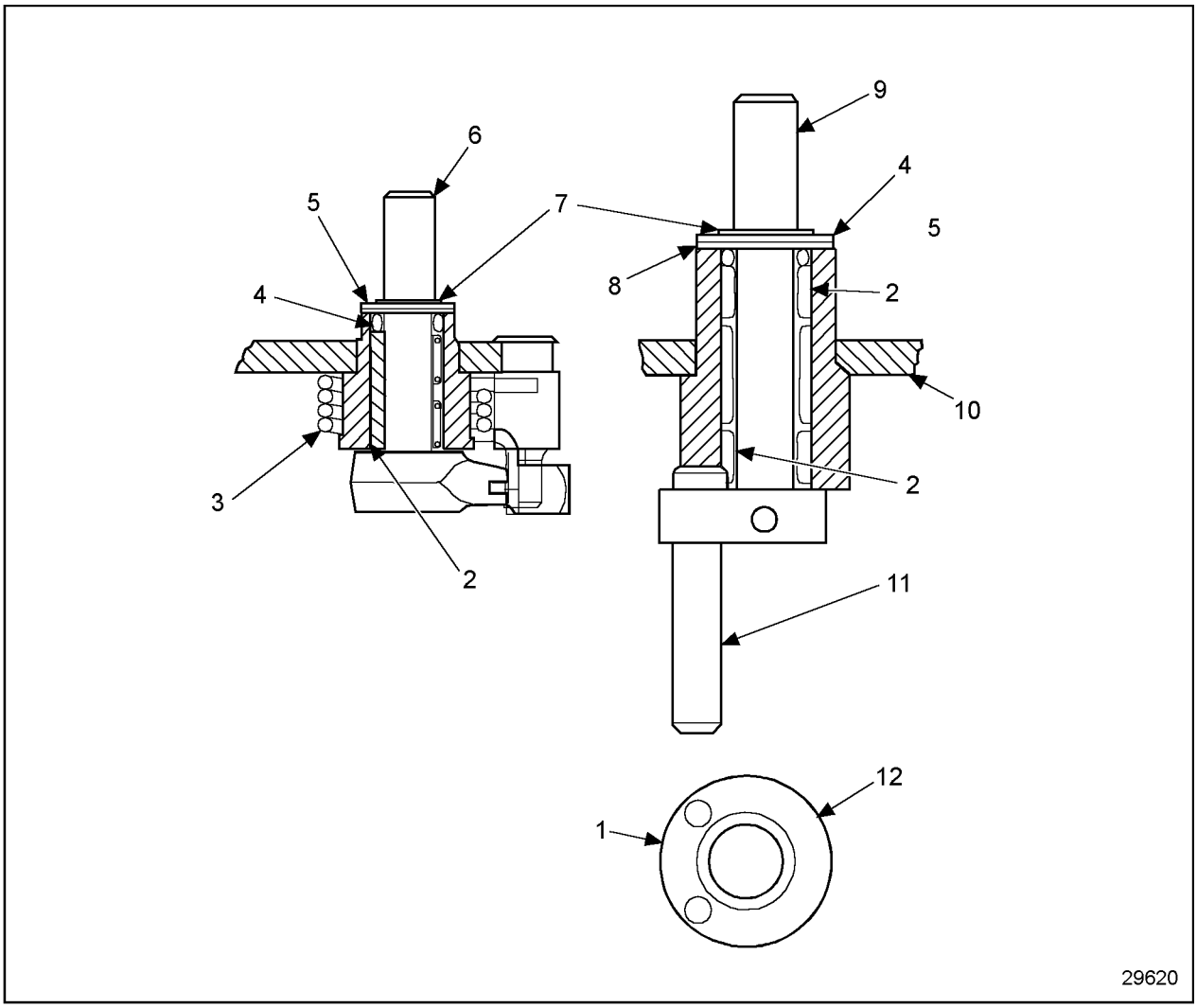
See Figure 2-127 and see Figure 2-128. Disassemble the limiting speed mechanical governor or the fuel squeezer engine cover as follows:



1. Return Spring
2. Seal Ring
3. Retaining Washers
4. Stop Lever Shaft
5. Snap Ring
6. Spacer
7. Speed Control Shaft
8. Bearings
9. Cover and Pin Assembly
10. Fulcrum Pin

Figure 2-127 Cross Section of Former Governor Cover

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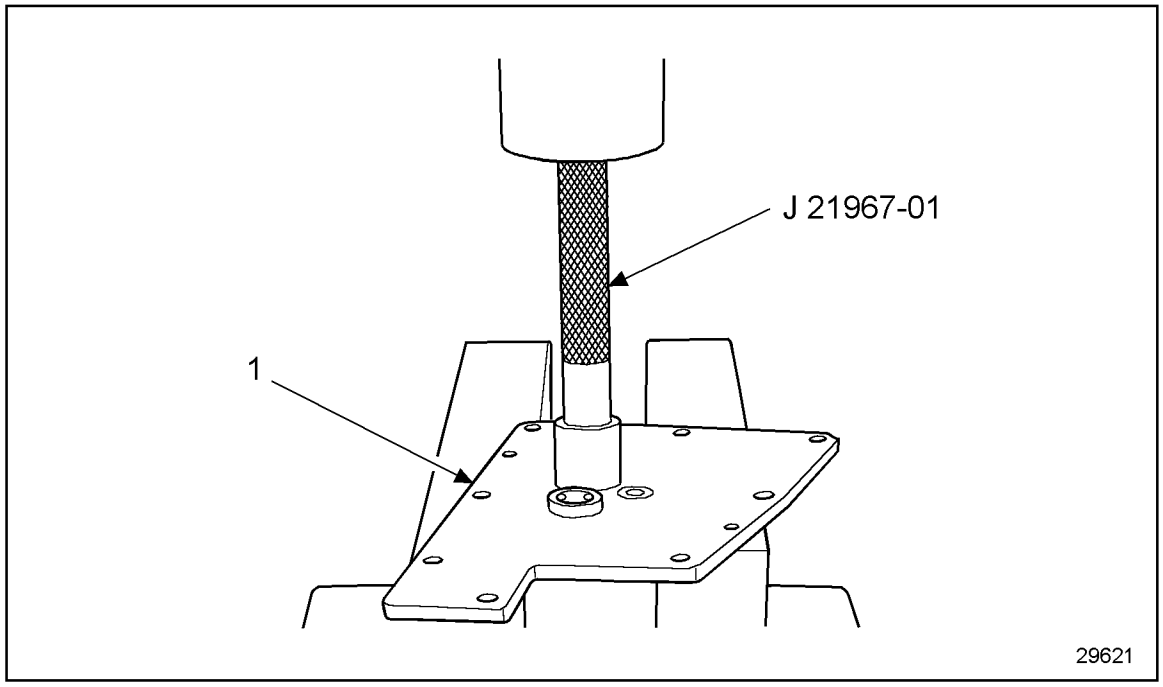
1. Stop Pins
2. Bushing
3. Return Spring
4. Seal Ring
5. Retaining Washers
6. Stop Lever Shaft
7. Snap Ring
8. Spacer
9. Speed Control Shaft
10. Cover and Pin Assembly
11. Fulcrum Pin
12. Hub

Figure 2-128 Cross Section of Current Governor Cover

NOTE:
All fuel squeezer engines have a governor cover with an extended hub and a longer speed control shaft (3.30 in. long). The cover also incorporates two hardened steel roll pins in the speed control shaft hub.

1. Remove the lubrication fitting from the speed control shaft.
2. Loosen the speed control lever retaining bolt, and lift the control lever from the speed control shaft.

3. Remove the spacer (if used), snap ring and two seal ring retaining washers, and seal ring from the speed control shaft.
4. Withdraw the shaft from the cover.
5. Loosen the bolt securing the stop lever to the stop lever shaft, and remove the stop lever.
6. Remove the snap ring, two seal ring retaining washers, and seal ring from the stop lever shaft. Withdraw the lever shaft and the lever shaft return spring from the cover.
7. If needle bearing removal is necessary, place the inner face of the cover over the opening on the arbor press bed.
8. Place remover J 21967-01 on the top of the bearing and under the press ram. Press both bearings out of the cover. See Figure 2-129.

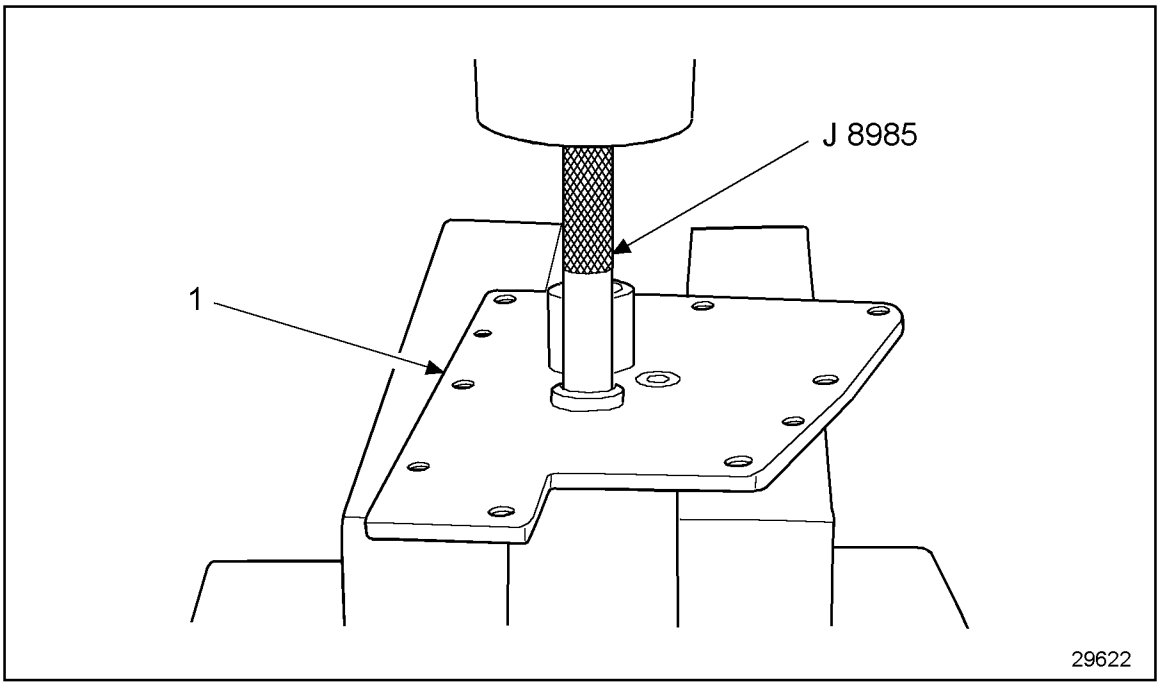


1. Governor Cover

Figure 2-129 Removing Speed Control Shaft Bearing from Governor Cover using Tool J 21967-01

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9. Remove the bushing or bearings from the stop lever shaft opening using remover J 8985. See Figure 2-130.



1. Governor Cover

Figure 2-130 Removing Stop Lever Shaft Bushings from Governor Cover using Tool J 8985

10. Disassemble the high and low-speed spring plunger, and adjusting screw (except on dual-range governor). Refer to section 2.24.7.
11. Disassemble the high and low-speed spring plunger, and adjusting screw (dual-range governor). Refer to section 2.24.8.
12. Disassemble the governor weights and shaft assembly (double and single-weight governor). Refer to section 2.24.9.
13. On non-turbocharged engines, remove the retaining rings from the weight pins. Tap the grooved end of the pins to drive them out of the carrier and the weights.
14. On turbocharged engines, refer to section 2.24.10 to disassemble governor weights and shaft assembly.
15. Remove the governor weights.
16. Remove the governor linkage. Refer to section 2.24.11.

2.24.7 Disassemble the High and Low-Speed Springs, Plunger, and Adjusting Screw (Except On Dual-Range Governors)

Disassemble the high and low-speed springs, plunger, and adjusting screw (except on dual-range governors) as follows:

1. Clamp the governor housing flange in a soft jawed vise.
2. Remove the two bolts and copper washers securing the high-speed spring retainer housing to the governor housing. Withdraw the retainer housing and gasket.
3. Loosen the high-speed spring retainer locknut with spanner wrench J 5345-12.
4. Remove the high-speed spring retainer, idle speed adjusting screw, high-speed spring, spring plunger, low-speed spring, spring seat, and spring cap as an assembly.
5. On fuel squeezer engines, loosen the set screw in the Belleville spring retainer nut.
6. Remove the retainer nut, two flat washers, and two Belleville washers from the high-speed spring plunger.
7. Remove the low-speed spring cap, spring, and spring seat from the high-speed spring plunger.
8. Depress the high-speed spring by hand, and remove the idle speed adjusting screw locknut.
9. Remove the high-speed spring seat, high-speed spring, and idle speed adjusting screw from the high-speed spring plunger.
10. Refer to section 2.24.6, step 13, to continue disassembly of governor.

2.24.8 Disassemble the High and Low-Speed Springs, Plunger, and Adjusting Screws (Dual-Range Governor)

Disassemble the high and low-speed springs, plunger, and adjusting screws of the dual-range governor as follows:

1. Clamp the flange of the governor housing in a soft jawed vise.
2. Remove the two bolts and lock washers securing the high-speed retainer housing and piston assembly to the governor housing.
3. Withdraw the retainer housing, piston, shims, and sleeve from the governor housing as an assembly.

NOTE:
Current governors have a blocking ring in the spring housing to prevent seal removal from the rear cover end of the spring housing. This prevents seal ring damage.

4. Remove the sleeve, shims, cover, cover gasket, and piston and seal ring assembly from the high-speed spring retainer housing. Remove the retainer housing gasket.
5. Remove the high-speed spring retainer with tool J 5345-12. Withdraw the retainer, idle speed adjusting screw, high-speed spring, spring plunger, low-speed spring, spring seat, and spring cap from the housing as an assembly.

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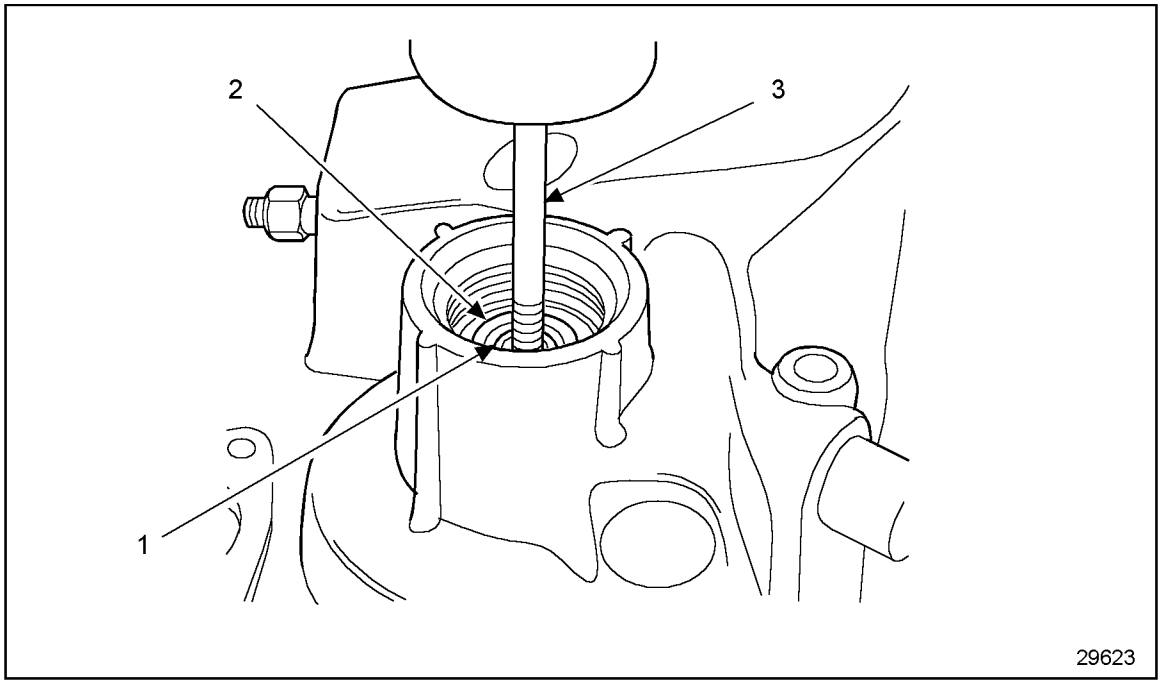
6. Remove the low-speed spring cap, spring, and spring seat from the high-speed spring plunger.
7. Depress the high-speed spring by hand, and remove the idle speed adjusting screw locknut.
8. Remove the high-speed spring seat, high-speed spring, and idle speed adjusting screw from the high-speed spring plunger.
9. Refer to section 2.24.6, step 13, to continue disassembly of governor.

2.24.9 Disassemble the Governor Weights and Shaft Assembly (Double and Single Weight Governors)

Remove the governor weights and shaft assembly (double and single weight governors) from the governor housing as follows:

1. Clamp the governor housing flange in a soft jawed vise.
2. Remove the governor weight housing plug and gasket.
3. Bend the tang on the lock washer away from the head of the bolt. While keeping the weight carrier from turning, remove the bearing retaining bolt, flat washer, and lock washer.

4. Thread a 5/16 in.-24 x 3 in. bolt into the bearing retaining bolt hole. Support the governor housing on the bed of an arbor press, and press the governor weight shaft from the bearing. See Figure 2-131.



1. Governor Weight Shaft
2. Bearing
3. Bolt 5/16 in.-24

Figure 2-131 Removing Governor Weight Shaft Assembly from Governor Housing

5. Slide the governor riser thrust bearing and riser from the weight shaft.

NOTE:
The thrust bearing is specially designed to absorb thrust load. Looseness between the mating parts does not indicate excessive wear.

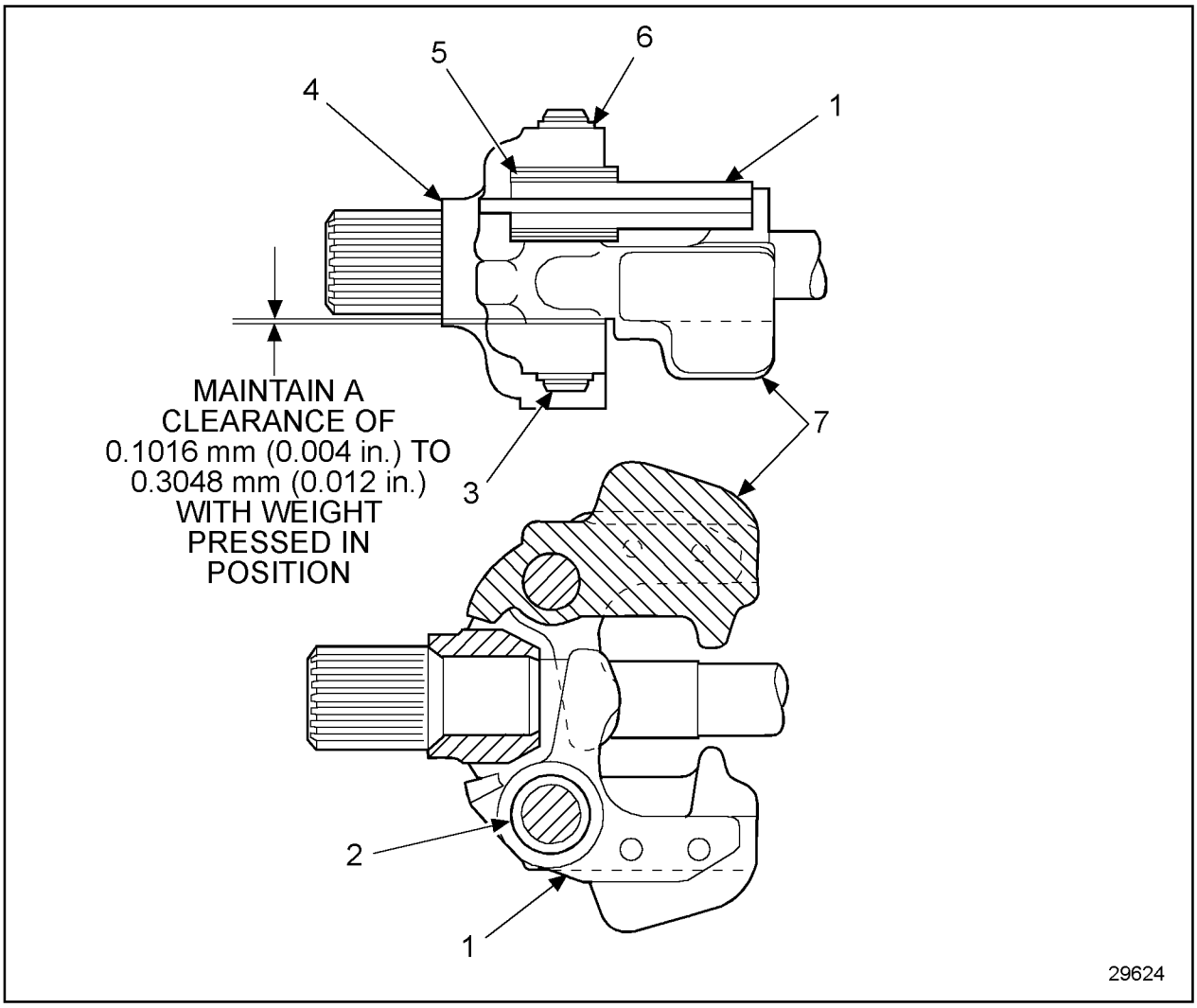
6. Remove the weight shaft bearing from the governor housing. If necessary, use a small brass rod and hammer to tap the bearing out of the housing.
7. Refer to section 2.24.6, step 13, to continue disassembly of governor.

2.24.10 Disassemble Governor Weights and Shaft Assembly on Turbocharged Engines

Disassemble the governor weights and shaft assembly on turbocharged engines as follows:

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1. If weight removal is necessary, remove the retainers, and press the weight pins from the low-speed weights. See Figure 2-132.

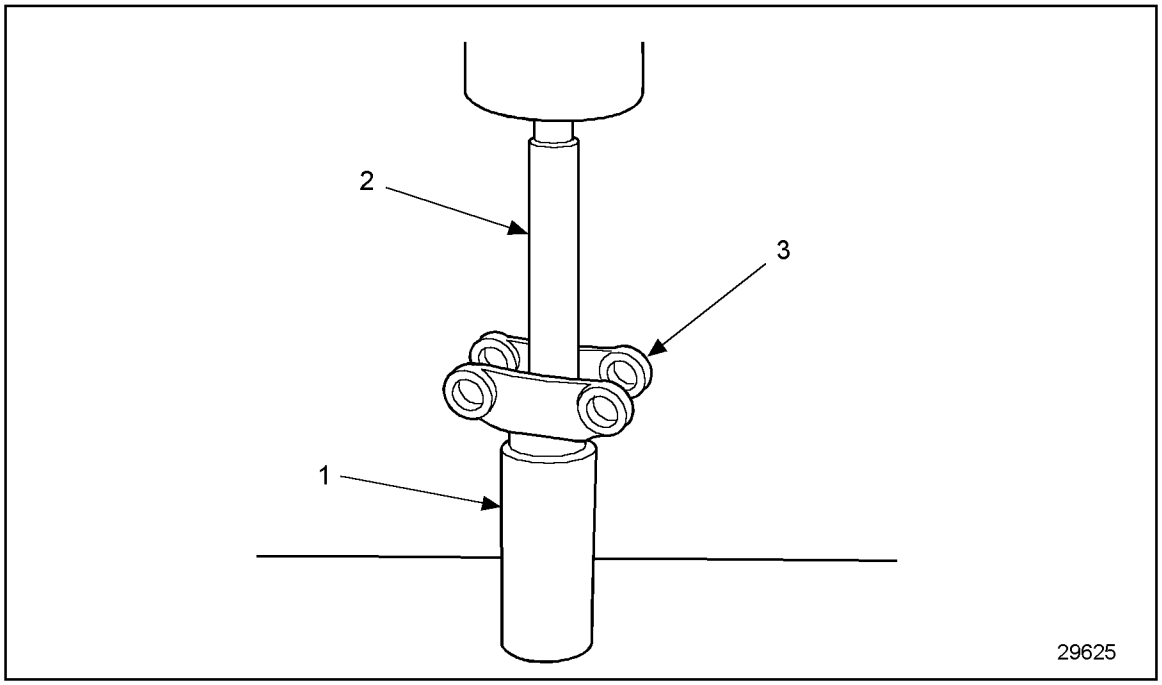


1. High-Speed Weight
2. Bushing
3. Weight Pin
4. Weight Carrier
5. Flat Washer
6. Retainer
7. Low-Speed Weight

Figure 2-132 Cross Section of Governor Weight Assemblies

NOTE:
The high-speed weights are not a press fit.

2. If weight carrier removal is necessary, support the shaft, weight carrier, and sleeve on arbor press bed. Press the shaft out of the weight carrier. See Figure 2-133.

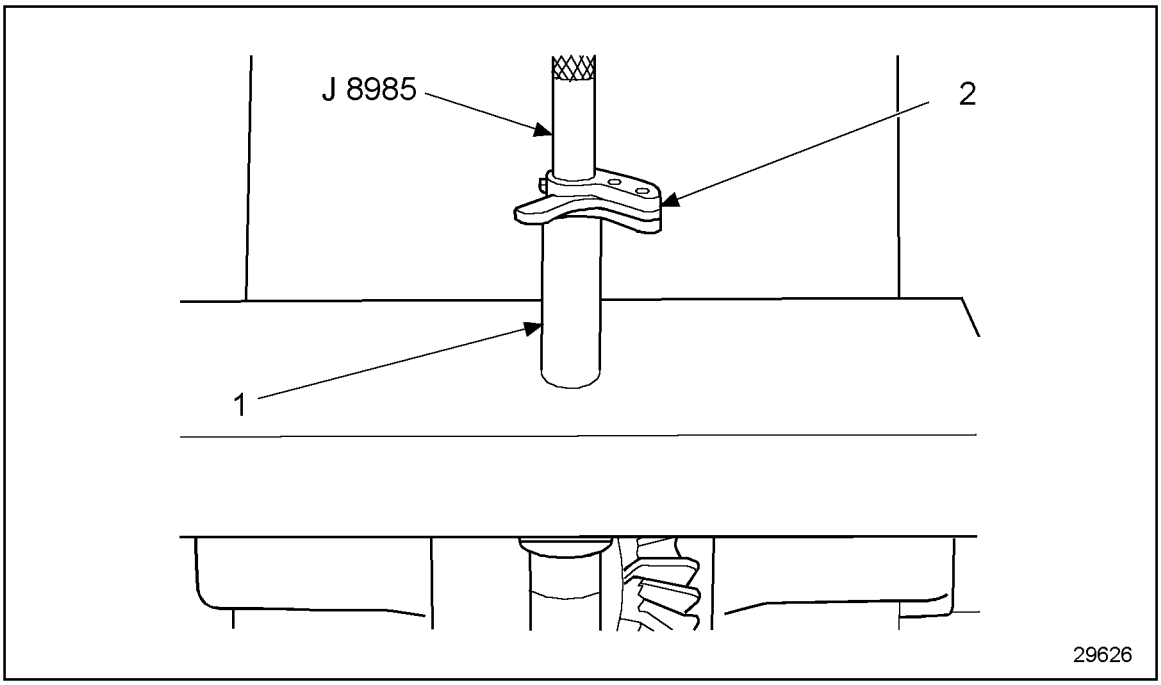


1. Sleeve
2. Weight Shaft
3. Weight Carrier

Figure 2-133 Removing Governor Weight Shaft from Weight

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3. Position the high-speed governor weight on a sleeve on an arbor press bed. Press the bearing from the weight using replacer J 8985. See Figure 2-134.



1. Sleeve
2. Weight

Figure 2-134 Removing Governor Weight Bearings using Tool J 8985

4. Remove the governor weights.
5. Remove the governor linkage. Refer to section 2.24.11.

2.24.11 Disassembly of Governor Linkage and Operating Shaft

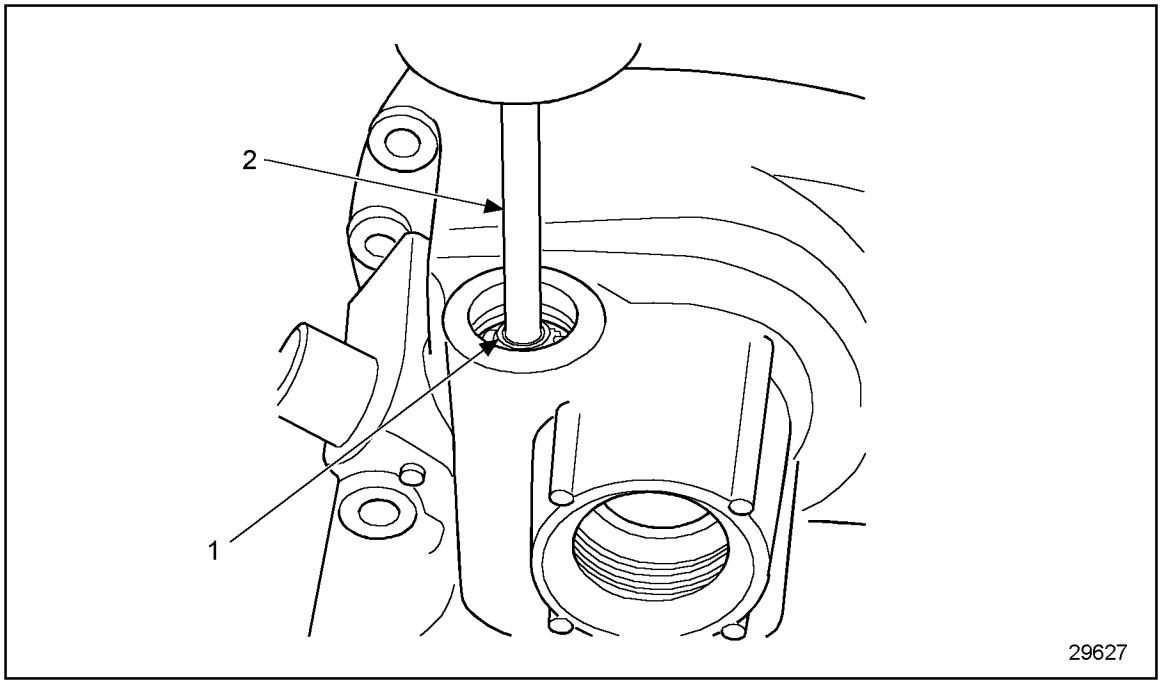
Disassemble the governor linkage and operating shaft from the governor housing as follows:

1. Remove the spring retainer and plain washer securing the connecting link to the differential lever. Remove the connecting link.
2. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever. Remove the differential lever.
3. Remove the low-speed gap adjusting screw from the operating shaft lever, if necessary.
4. Remove the screw, lock washer, and lock clip securing the control link operating lever shaft in the housing.

5. Lift the shaft out of the housing. Remove the operating lever and two flat washers at each side of the operating lever.

NOTE:
Do not lose the two flat washers located between the lever assembly and the governor housing.

6. Remove the expansion plug from the bottom of the governor housing.
7. Remove the operating shaft upper bearing retainer screw, lock washer, and flat washer securing the bearing in the governor housing.
8. With the two dowel pins in the top of the housing between the two steel supports, support the governor housing, bottom side up, on the bed of an arbor press.
9. Place a small brass rod on the end of the operating shaft. Press the shaft out of the bearing. See Figure 2-135.

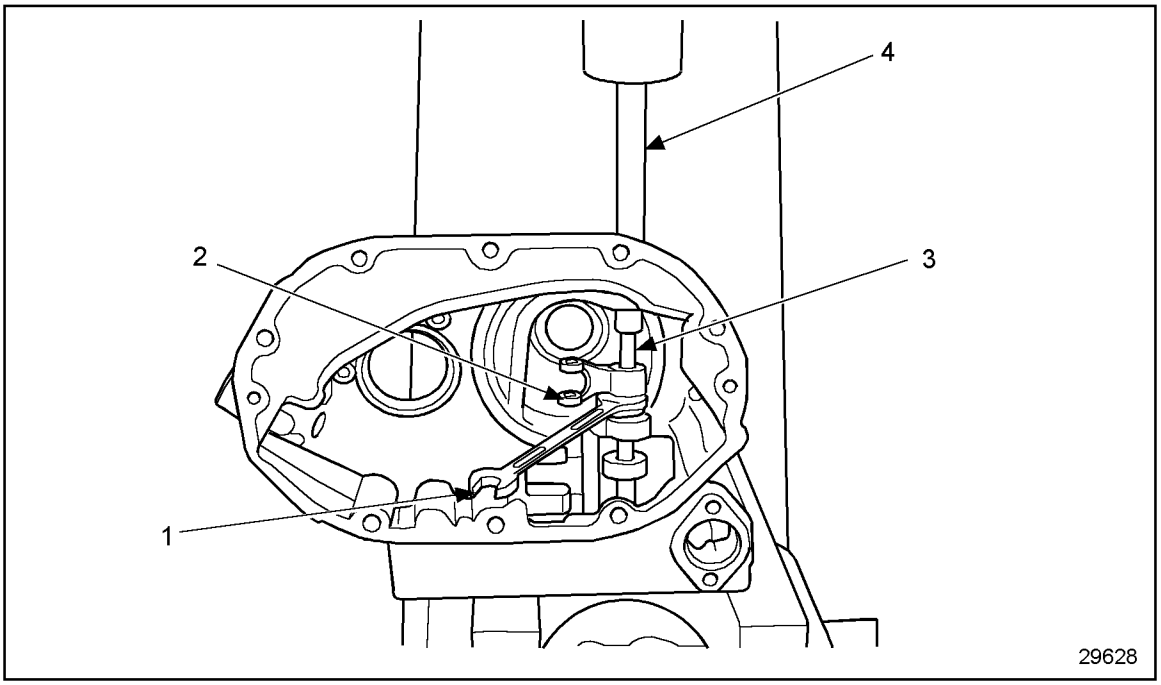


1. Lower Bearing
2. Brass Rod

Figure 2-135 Removing Operating Shaft from Operating Shaft Lower Bearing

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10. With the housing still supported on the press bed, place a 9/16 in. open end wrench under the operating fork. See Figure 2-136.



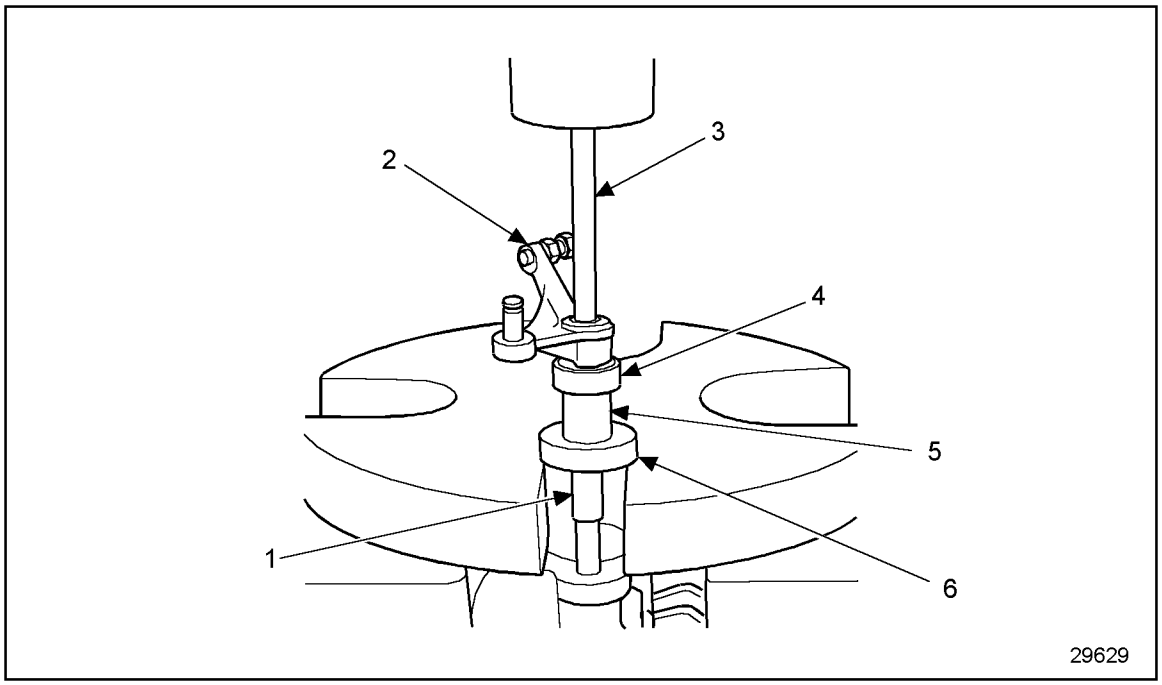
1. 9/16 in. Wrench
2. Operating Fork
3. Operating Shaft
4. Brass Rod

Figure 2-136 Removing Operating Fork Shaft and Lever Assembly from Governor Housing

11. Place a brass rod on the end of the shaft, and press the fork off of the operating shaft. Remove the shaft, operating lever, and bearing from the housing as an assembly.
12. Remove the operating shaft lower bearing from the bottom of the governor housing.
13. Slide the governor operating shaft spacer from the shaft.
14. Place a short 9/16 in. inside diameter sleeve over the end of the operating shaft. Rest it against the bearing inner race on the operating shaft.

NOTICE:
To prevent part damage, the bearing inner race must rest on the sleeve.

15. Support the operating shaft, lever, bearing, and sleeve on a large washer or plate with a 5/8 in. hole. Place them on an arbor press bed. See Figure 2-137.



1. Operating Shaft
2. Operating Lever
3. Brass Rod
4. Bearing
5. Sleeve
6. Washer

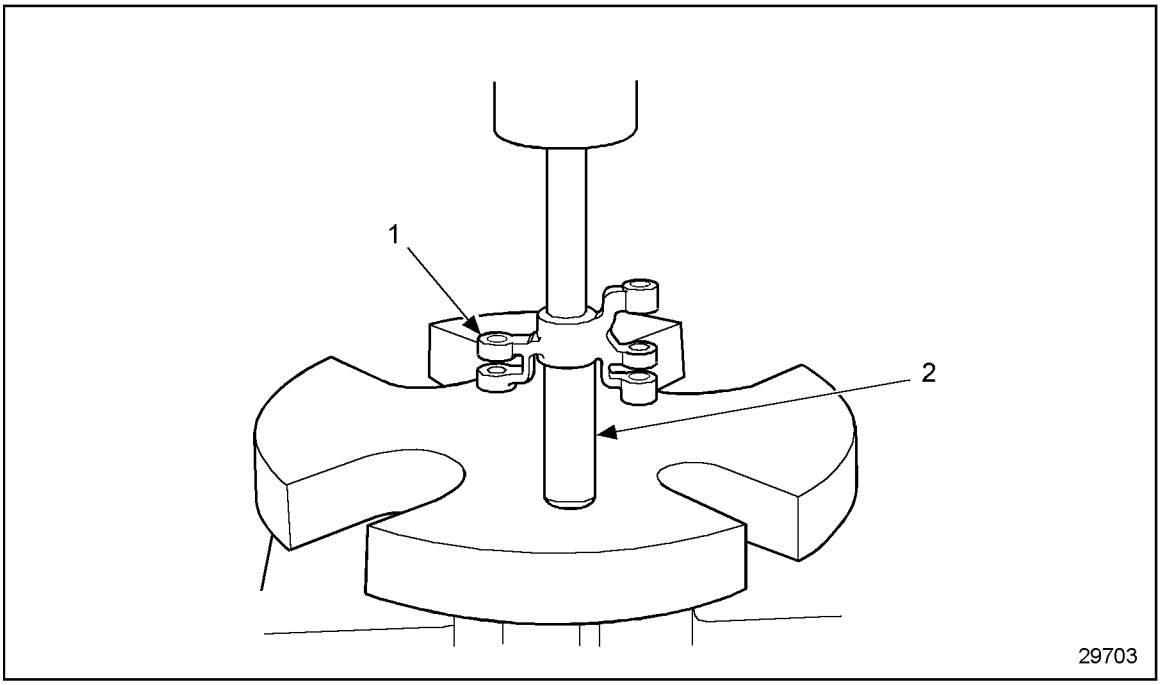
Figure 2-137 Removing Operating Lever and Upper Bearing from Operating Shaft

NOTICE:
To prevent part damage, catch the shaft by hand when pressing it from the lever and bearing.

16. Place a small brass rod on the shaft end. Press the operating shaft out of the operating lever and bearing.
17. If needle bearing removal is necessary, support the control link operating lever on a sleeve. Rest the sleeve on the arbor press bed.

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18. Place tool J 8985 on top of the bearing, and press both bearings out of the lever. See Figure 2-138.



1. Operating Lever
2. Sleeve

Figure 2-138 Removing Operating Lever Needle Bearings using Tool J 8985

19. Refer to section 2.24.12, to complete governor disassembly.

2.24.12 Disassembly of Limiting Speed Mechanical Governor (Continued)

Disassembly of Governor (Continued):

1. Remove the buffer screw from the governor housing.
2. Remove the external starting aid screw from the governor housing, if necessary.

2.24.12.1 Cleaning of Limiting Speed Mechanical Governor

Clean the limiting speed mechanical governor parts as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash 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 with compressed air.

2.24.12.2 Inspection of Limiting Speed Mechanical Governor

Inspect the limiting speed mechanical governor as follows:

1. Visually inspect the needle bearings for wear or damage.
   [a] If the bearings are worn or damaged, replace them. Refer to section 2.24.13.
   [b] If the bearings are not worn or damaged, continue inspection.
2. Visually inspect the needle bearings for corrosion or pitting.
   [a] If corroded or pitted, replace the bearings. Refer to section 2.24.13.
   [b] If not corroded or pitted, continue inspection.
3. While keeping the bearing inner race from turning, revolve the outer race slowly by hand, checking for rough spots.
   [a] If rough spots are evident, replace the bearings. Refer to section 2.24.13.
   [b] If no rough spots are detected, continue inspection.
4. Visually inspect the riser thrust bearing for excessive wear, flat spots, or corrosion.

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[a] If excessively worn, corroded, or flat spots are detected, replace the riser thrust bearing. Refer to section 2.24.13.

[b] If not excessively worn, corroded, or flat spots are not detected, continue inspection.

5. Visually inspect the weight carrier pins and bushings in the weights for wear.

   [a] If excessively worn, replace the weight carrier pins and bushings. Refer to section 2.24.13.

   [b] If not excessively worn, proceed with the inspection.

6. Visually inspect the control link operating lever shaft for wear or damage.

   [a] If the speed control and stop lever shaft has worn or damaged needle bearings or bushing, replace parts as necessary. Refer to section 2.24.13.

   [b] If not worn or damaged, continue inspection.

7. Visually inspect the spring seats, plunger, adjusting screws, locknuts, pins, seal rings, and any other parts in the governor housing for wear or defects that might affect governor operation.

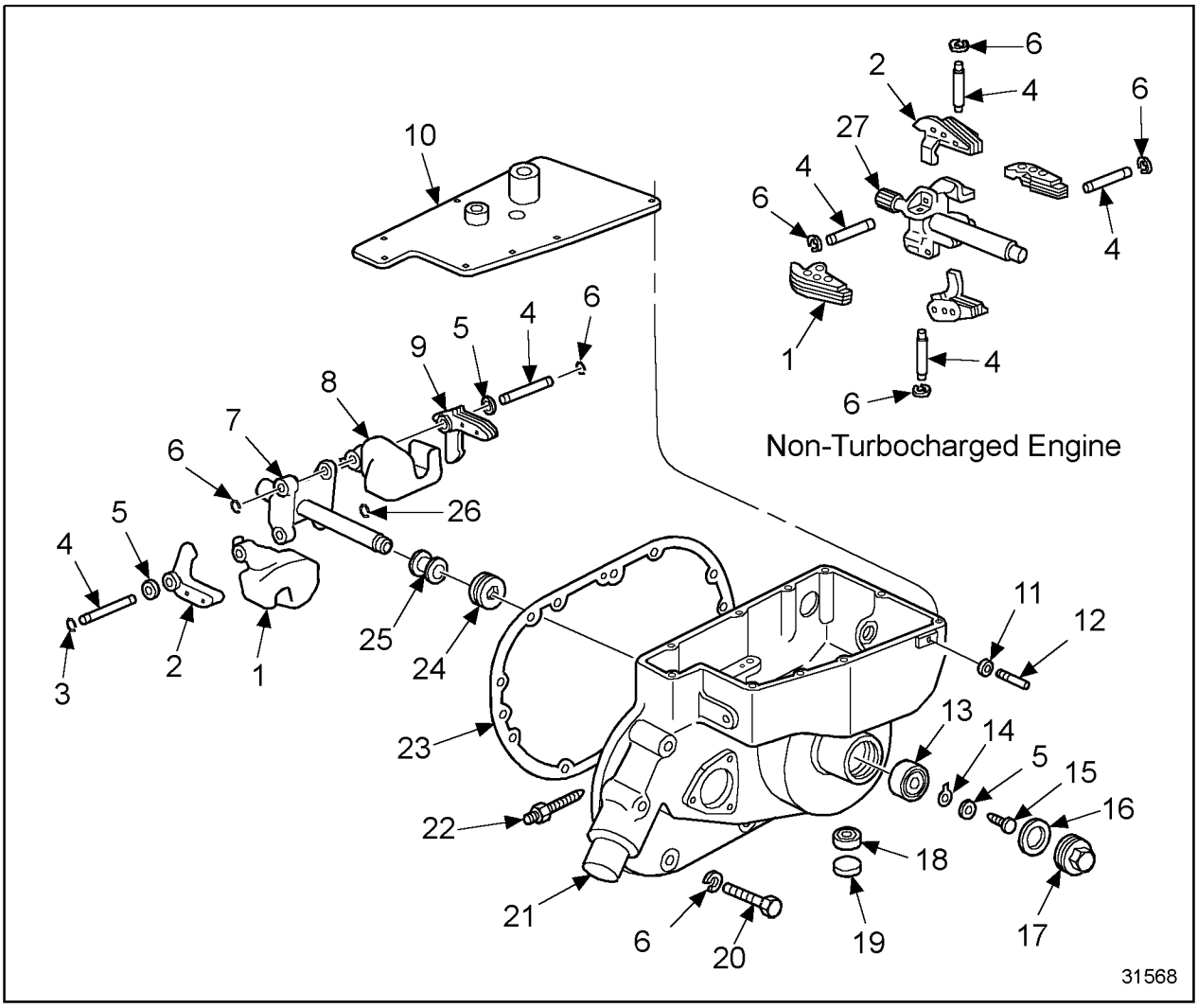
   [a] Replace all worn or damaged parts. Refer to section 2.24.13.

   [b] If not worn or damaged, reuse the limiting speed governor components.

NOTE:
The former and current cover and shaft assemblies are interchangeable on a governor. When replacing the former cover, replacement of both the cover and shaft assembly is needed. Current covers may be serviced separately.

2.24.13 Assembly of Limiting Speed Mechanical Governor

See Figure 2-139 and see Figure 2-140. Assemble the limiting speed mechanical governor as follows:

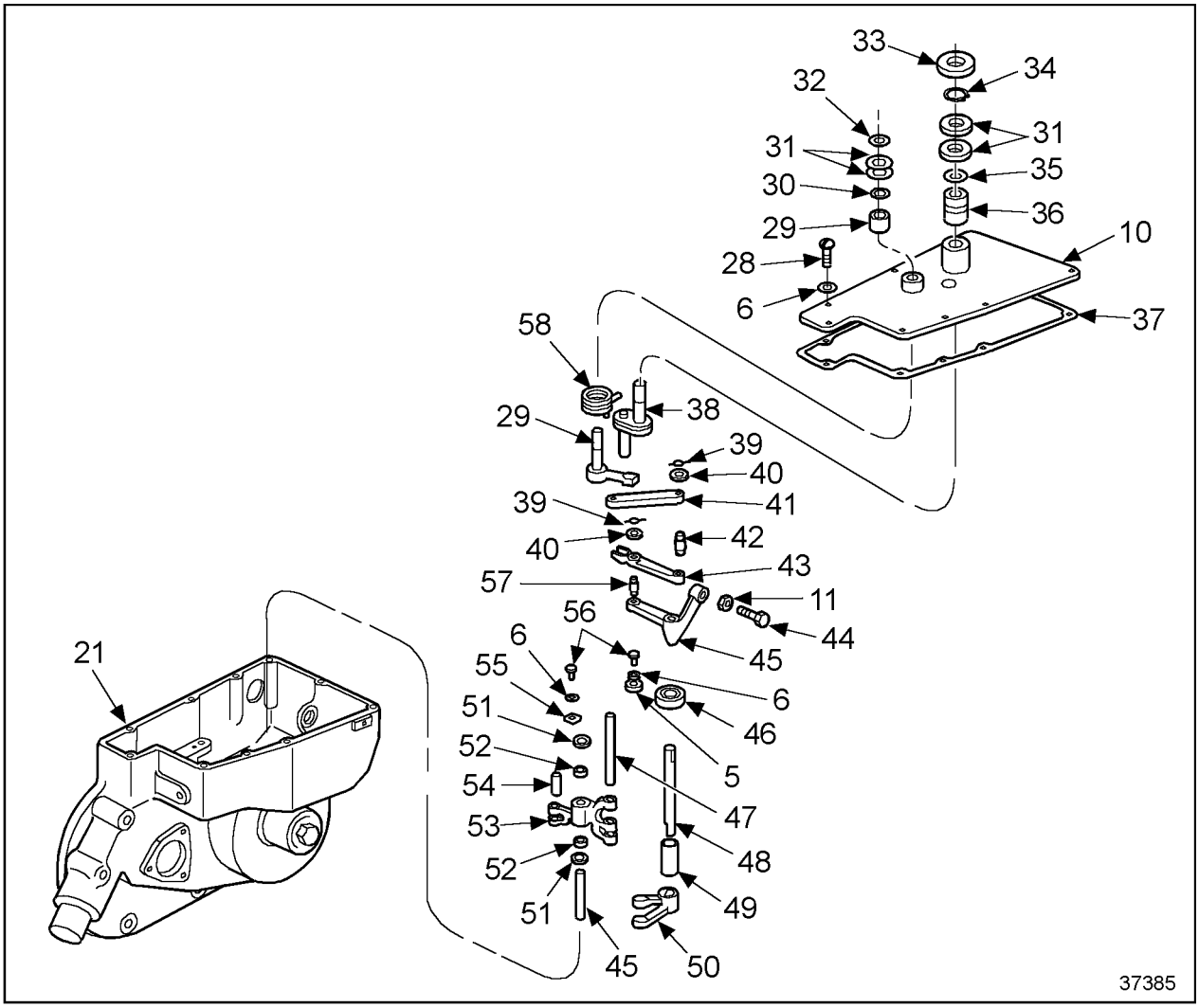


1. Low-Speed Weight (Left Side)
2. High-Speed Weight (Left Side)
3. Weight Pin Retainer Pin
4. Weight Pin
5. Flat Washer
6. Lock Washer
7. Governor Weight Carrier
8. Low-Speed Weight (Right Side)
9. High-Speed Weight (Right Side)
10. Governor Housing Cover
11. Locknut
12. Starting Aid Adjusting Screw (External)
15. Bearing Retainer Bolt
16. Housing Plug Gasket
17. Governor Housing Plug
18. Operating Shaft Bearing (Lower)
19. Expansion Plug
20. Housing to Blower Bolt
21. Governor Housing
22. Buffer Locknut and Screw
23. Housing-to-Blower Gasket
24. Riser Thrust Bearing
25. Governor Riser
26. Weight Pin Retainer Ring

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13. Weight Carrier Shaft End Bearing
14. Special Lock Washer
27. Weight Carrier Shaft

Figure 2-139 Limiting Speed Double-Weight Governor (1 of 2)



28. Housing Cover Screw
29. Stop Lever Shaft Bushing
30. Stop Shaft Seal Ring
31. Seal Ring Retainer Washer
32. Stop Shaft Snap Ring
33. Speed Control Shaft Spacer
34. Speed Control Shaft Snap Ring
35. Control Shaft Seal Ring
36. Speed Control Shaft Bearing
37. Governor Housing Cover Gasket
44. Gap Adjusting Screw (External)
45. Operating Shaft Lever
46. Operating Shaft Bearing (Upper)
47. Fuel Rod Connecting Pin (Long)
48. Governor Operating Shaft
49. Operating Shaft Spacer
50. Operating Shaft Fork
51. Operating Lever Bearing
52. Operator Lever Bearing
53. Control Link Operating Lever

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38. Speed Control Shaft Lever
39. Spring Retainer
40. Differential Lever and Connecting Link Flat Washer
41. Operating Connecting Link Lever
42. Differential Lever Pin
43. Governor Differential Lever
54. Fuel Rod Connecting Pin (Short)
55. Operating Lever Shaft Lock Clip
56. Screw
57. Shaft Lever Pin
58. Stop Lever Shaft Return Spring

Figure 2-140 Limiting Speed Double-Weight Governor (2 of 2)

NOTE:
If previously removed, install the external starting aid screw in the governor housing.

Assemble the operating shaft and governor linkage in the governor housing as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Lubricate the inside diameter of the governor operating shaft upper bearing with engine oil. Start the bearing, numbered side up, straight on the large end of the operating shaft.
2. Support the bearing and operating shaft on a 9/16 in. inside diameter sleeve, and place it on an arbor press bed with the inner race of the bearing resting on the sleeve.
3. Press the shaft into the bearing until 1/4 in. of the shaft protrudes through the bearing.
4. Install the bearing, numbered side up, on the shaft, and press it tight against the bearing washer.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

5. Lubricate the inside diameter of the governor operating shaft lever with engine oil.
6. Start the lever, operating lever pivot pin face up, straight on the operating shaft.

NOTE:
The flat on the shaft should register with the flat surface in the lever.

7. Support the operating lever, bearing, and shaft on an arbor press bed with a steel support directly under the center of the lever.
8. Press the operating shaft through the bearing and lever until the end of the shaft contacts the steel support.

NOTE:
The upper end of the shaft must be flush with the top surface of the lever.

9. Place the operating shaft spacer over the lower end of the shaft, and slide it against the upper bearing inner race.
10. Insert the end of the governor operating shaft, bearing, spacer, and lever assembly through the upper bearing bore in the governor housing.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

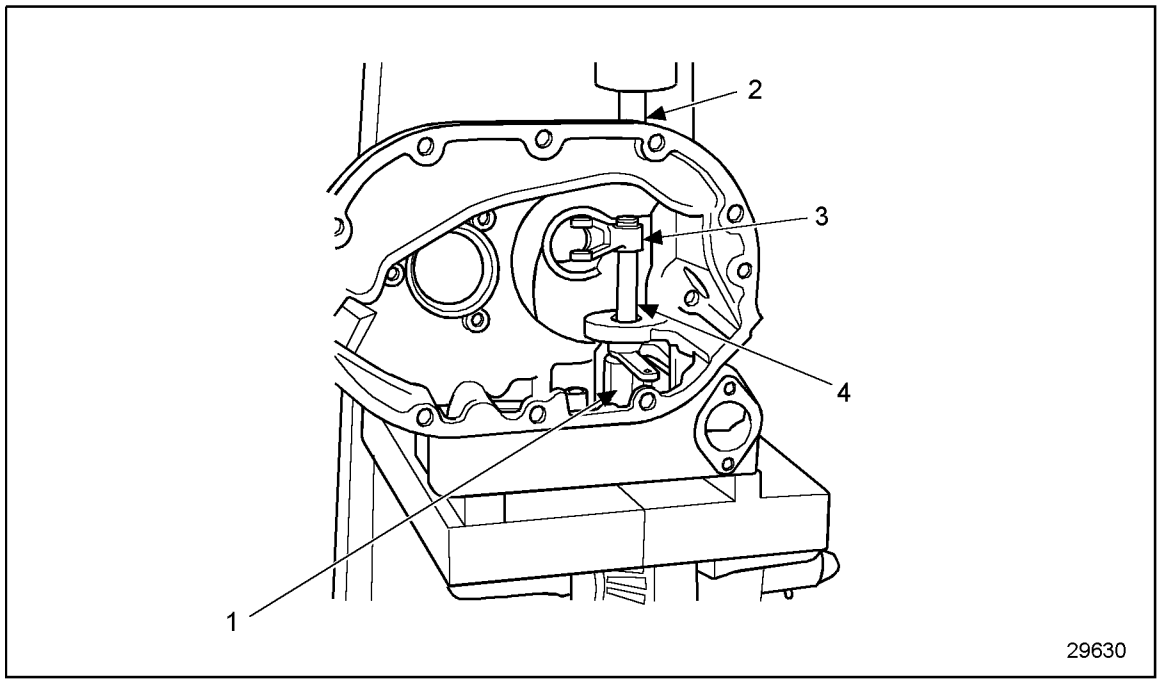
Diesel fuel is relatively harmless at ambient temperatures.

11. Lubricate the inside diameter of the governor operating shaft fork with engine oil.
12. Place the operating fork over the lower end of the shaft, with the finished cam surfaces on the fork fingers facing the rear of the governor housing.

NOTE:
The flat on the shaft should register with the flat surface in the fork.

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13. Support the governor housing and operating shaft assembly on an arbor press bed, with the upper end of the operating shaft resting on a steel support. See Figure 2-141.



1. Support
2. Sleeve
3. Fork
4. Shaft

Figure 2-141 Installing Governor Operating Shaft Fork on Shaft

14. Place a 7/16 in. inside diameter sleeve over the end of the shaft and against the fork. Press the fork tightly against the shaft spacer on the shaft

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

15. Lubricate the governor operating shaft lower bearing with engine oil. Start the bearing, numbered side up, straight in the governor housing and over the end of the operating shaft.
16. Support the governor housing and operating shaft assembly on the bed of an arbor press.

NOTE:
The upper end of the operating shaft should rest on a steel support.

17. Place a 7/16 in. inside diameter sleeve on the inner race of the bearing. Press the bearing on the shaft until it seats on the shoulder in the housing.
18. Install the governor operating shaft upper bearing retaining flat washer, lock washer, and screw in the governor housing.
19. Apply a thin coat of good quality sealant around the edge of a new expansion plug.
20. Place the plug, concave side up, in the opening in the housing next to the lower operating shaft bearing. Tap the center of the plug with a hammer to secure the plug in the housing.
21. Place the differential lever over the pivot pin in the operating lever, and secure it with a plain washer and spring retainer.
22. If removed, place the control link operating lever on the arbor press bed with steel support under the bearing bore.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

23. Lubricate the bearing with engine oil, and start the bearing, numbered end up, straight into the bore of the lever.
24. Insert the pilot end of installer J 8985 in the bearing. Press the bearing into the lever until it is flush with the top surface of the lever.
25. Reverse the lever on the press, and install the second bearing in the same manner.
26. Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent
27. Place the operating lever in position between the two bosses inside the governor housing. Insert a flat washer on each side of the lever.
28. Install the operating lever shaft with the slot up.
29. Align the slot in the operating lever shaft with the lock clip screw hole in the boss next to the shaft.
30. Install and tighten the lock clip, lock washer, and screw.
31. Place one end of the connecting link over the differential lever pin. Secure it with a washer and spring retainer.
32. Place the opposite end of the connecting link on top of the control link operating lever. Install the connecting pin.
33. If removed, thread the locknut on the buffer screw, and thread the buffer screw into the governor housing.
34. Refer to section 2.24.14 to assemble the governor double weights (non-turbocharged engines).
35. Refer to section 2.24.15 to assemble the governor double weights (turbocharged engines).
36. Refer to section 2.24.16 to assemble the governor single weights.

2.24.14 Assemble Governor Double Weights on Carrier and Shaft Assembly (Non-Turbocharged Engines)

Assemble the governor double weights on the carrier and shaft assembly on non-turbocharged engines as follows:

1. Position the low-speed weights, identified by the short cam arm, on opposite sides of the weight carrier.
2. Drive the weight pins in place, and install the retaining rings.
3. Install the high-speed weights on the carrier. Push the grooved end through the smaller hole in the carrier and through the weight. Drive the knurled end in so the retaining ring can be installed on the pin.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

4. Lubricate the weight shaft with clean engine oil.
5. Refer to section 2.24.17 for installation of the governor weights and shaft assembly in governor housing.

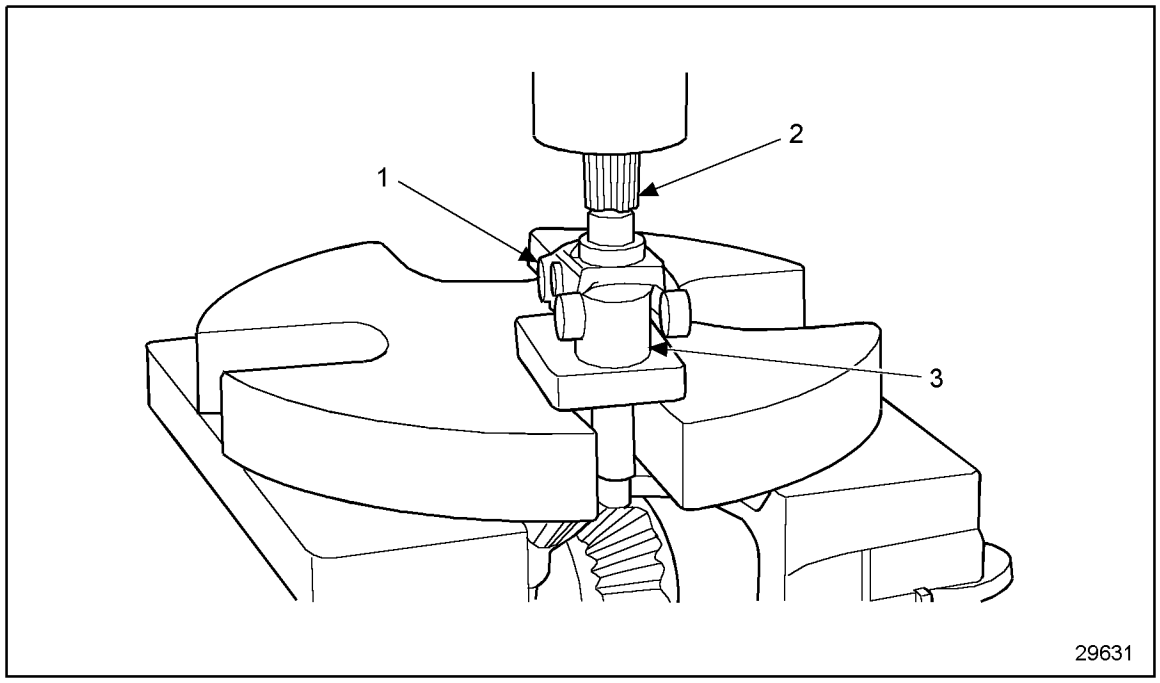
2.24.15 Assemble Governor Double Weights on Carrier and Shaft Assembly (Turbocharged Engines)

Assemble the governor double weight and shaft assembly on turbocharged engines as follows:

NOTE:
If the governor weight carrier assembly was removed from the weight shaft, the low and high-speed weights must be removed from the carrier before attempting to install the carrier on the shaft.

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1. Support the weight carrier, rear face up, on a sleeve and a steel support with a 1 in. hole over an opening in the arbor press bed. See Figure 2-142.



1. Weight Carrier
2. Shaft
3. Sleeve

Figure 2-142 Installing Governor Weight Shaft in Weight Carrier

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

2. Lubricate the weight shaft with engine oil. Insert the non-splined end of the shaft through the carrier, sleeve and hole in the steel support. Press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.
3. Install a retainer on either end of the weight pin.

NOTE:
Observe the matchmarks placed on the weight carrier and weights at the time of disassembly.

4. Slide the weight pin through the carrier, flat washer, and the high-speed weight and its bushing.
5. Place the low-speed weight in position. Press the weight pin through the low-speed weight and carrier until the retainer bottoms against the carrier.

NOTE:
Maintain a clearance of 0.102–0.305 mm (0.004–0.012 in.) with the weight pressed in position. To maintain this clearance, insert a 0.102–0.305 mm (0.004–0.012 in.) shim between the low-speed weight and carrier while pressing the pin into position.

6. Remove the shim, and install the second weight pin retainer.
7. Install the second pair of weights (three pairs of weights in the 12V and 16V turbocharged engine governor) in the carrier.
8. Refer to section 2.24.17 for installation of governor weights and shaft assembly.

2.24.16 Assemble Governor Single Weights

Assemble the governor single weights as follows:

1. Install the retainer in the weight pin groove. Place a flat washer over the pin and against the lock ring.

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2. Start the pin through the opening in the weight carrier. Place a second washer over the pin and against the projecting arm of the weight carrier.
3. Position the governor weight between the projecting arms of the weight carrier. Push the pin through the governor weight.
4. Place the third flat washer over the pin and against the weight.
5. Push the pin completely through the weight carrier, and place the fourth flat washer over the pin and against the projecting arm of the weight carrier.
6. Install a second lock ring in the groove of the weight carrier pin.
7. Install the second governor weight in a similar manner.
8. Refer to section 2.24.17 for installation of governor weights and shaft assembly.

2.24.17 Install Governor Weights and Shaft Assembly in Governor Housing

Install the governor weight and shaft assembly in the governor housing as follows:

1. Slide the governor riser on the weight shaft and against the fingers of the high-speed weight.
2. Place the governor riser thrust bearing over the weight shaft with the bearing race having the smaller inside diameter against the riser.

NOTE:
Ensure bearings are properly installed. Incorrect bearing installation will result in erratic governor operation.

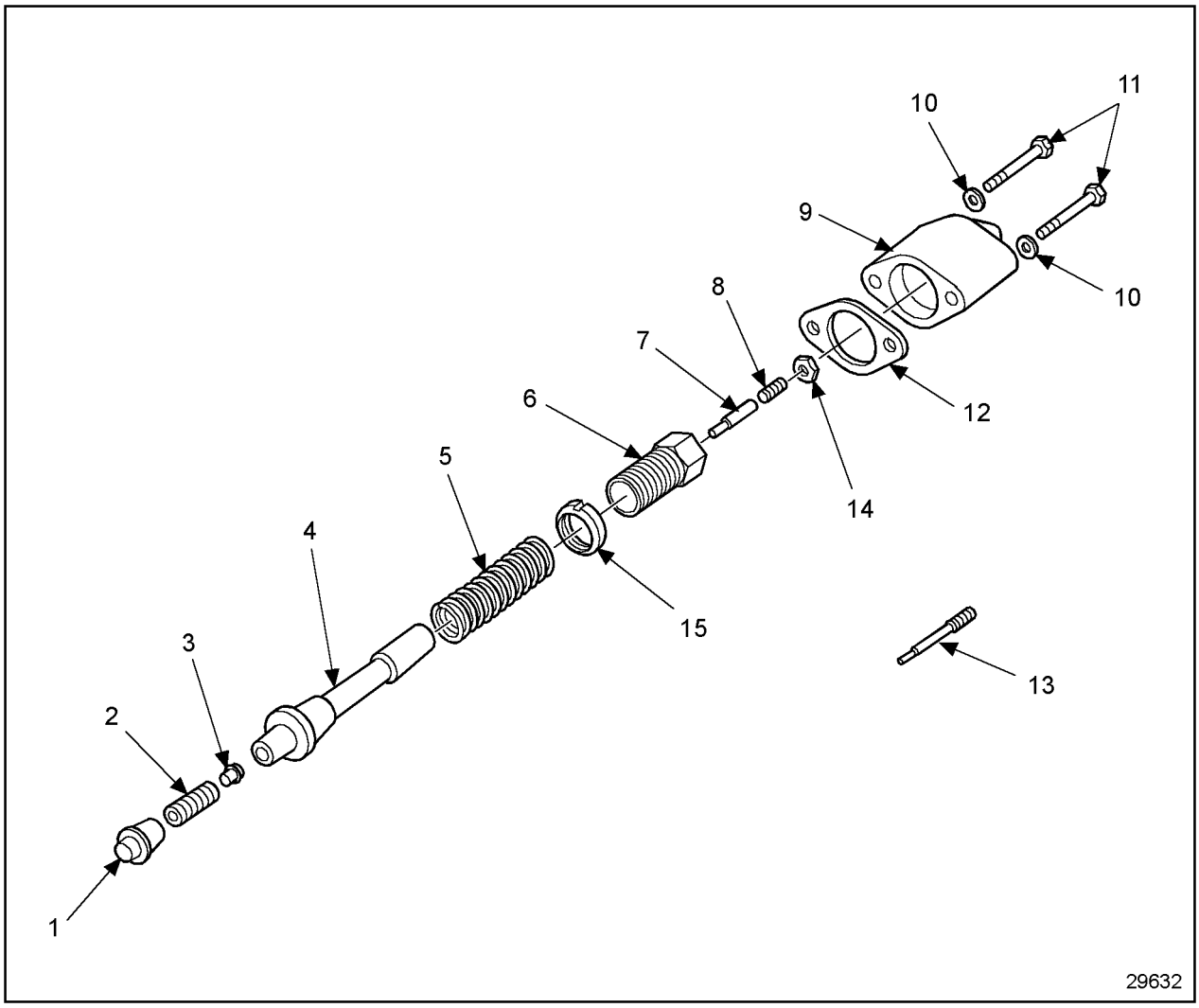
3. Insert the weight carrier and shaft assembly in the governor housing. Support the splined end of the shaft and the governor housing on the arbor press bed with the upper end of the shaft under the press ram.
4. Place the weight shaft bearing in the governor housing (numbered side up). Start it straight on the end of the weight carrier shaft.
5. Place a sleeve with a 1/2 in. inside diameter on top of the bearing inner race. Press the bearing into the housing and against the shoulder on the shaft.
6. Place the special lock washer on the end of the weight carrier shaft with the tang on the inner washer diameter in the notch in the shaft end.
7. Place the flat washer on the bearing retainer bolt and thread the bolt into the shaft.
8. Clamp the splined end of the weight carrier shaft in the soft jaws of a bench vise. Tighten the bearing retainer bolt to 20-26 N·m (15-19 lb·ft) torque. Bend the tang on the lock washer against the bolt head.
9. Place a gasket against the weight shaft bearing. Apply a sealant such as Loctite grade H, HV or HVW, or equivalent, on the threads of the governor housing and the plug.
10. Thread the plug into the housing. Tighten the plug to 61 N·m (45 lb·ft) torque.

11. Rotate the governor weight assembly. If it binds, remove the housing plug, and ensure the weight shaft bearing is fully seated in the governor housing.
12. Refer to section 2.24.18 to assemble the high and low-speed spring plunger and adjusting screw (except dual-range governors).
13. Refer to section 2.24.19 to assemble the high and low-speed spring plunger and adjusting screw (dual-range governors).

2.24.18 Assemble High and Low-Speed Spring Plunger and Adjusting Screw (Except Dual-Range Governors)

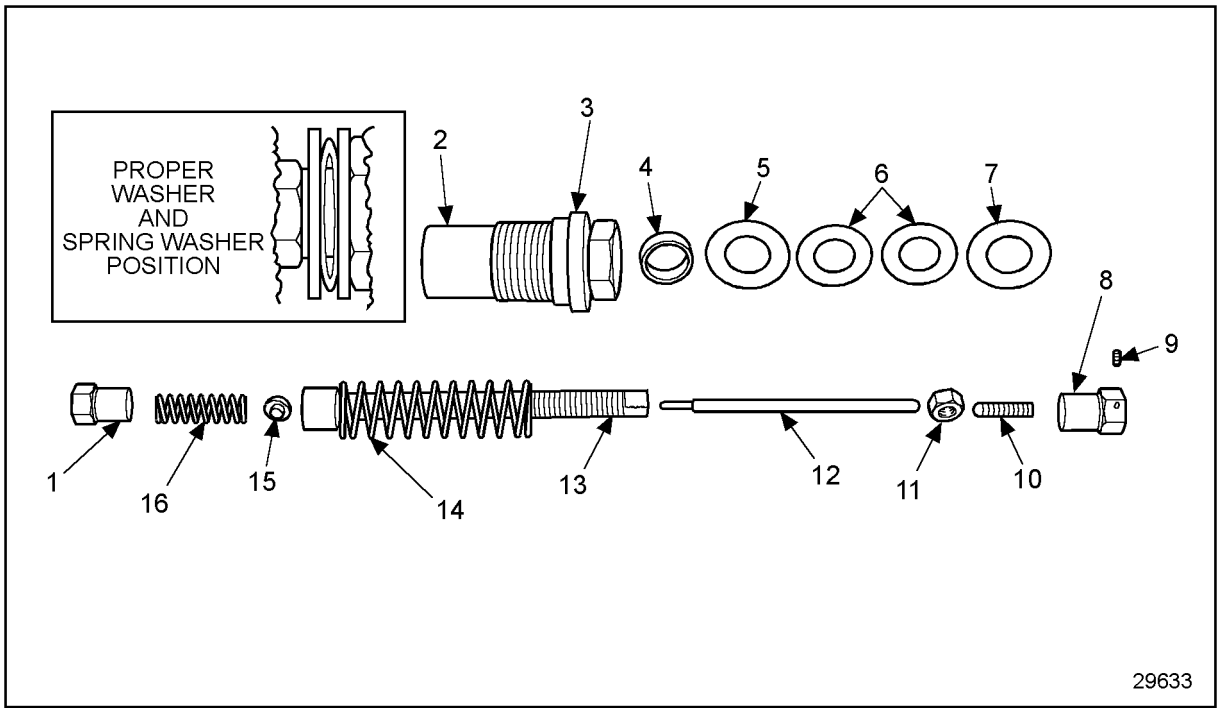
See Figure 2-143 and see Figure 2-144. Assemble the high and low-speed spring, plunger and adjusting screw (except dual-range governors) as follows:

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1. Cap
2. Low-Speed Spring
3. Spring Seat
4. Plunger
5. High-Speed Spring
6. Retainer
7. Adjusting Pin
8. Set Screw
9. Housing
10. Washer
11. Bolt
12. Gasket
13. Former Adjusting Screw
14. Small Locknut
15. Large Locknut

Figure 2-143 High and Low-Speed Springs and Plunger



1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Retainer Nut
9. Set Screw
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Pin
13. Plunger
14. High-Speed Spring
15. Low-Speed Spring Seat
16. Low-Speed Spring

Figure 2-144 High and Low-Speed Springs and Plunger Details Including Belleville Washers (Fuel Squeezer Engines)

1. If removed, thread the retainer locknut on the high-speed spring retainer approximately 1-1/2 in. Place the high-speed spring on the high-speed spring plunger with the close wound coils inside the spring retainer and the spring against the shoulder of the plunger.

NOTE:
Current TA engines operating at 1750 RPM full-load use a high-speed spring with one orange and one blue strip for identification. Engines operating at 1950-2100 RPM full-load use a high-speed spring with two pink stripes for identification.

2. Insert the high-speed spring and plunger assembly in the high-speed spring retainer. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2 in. Thread the locknut on the idle speed adjusting screw.

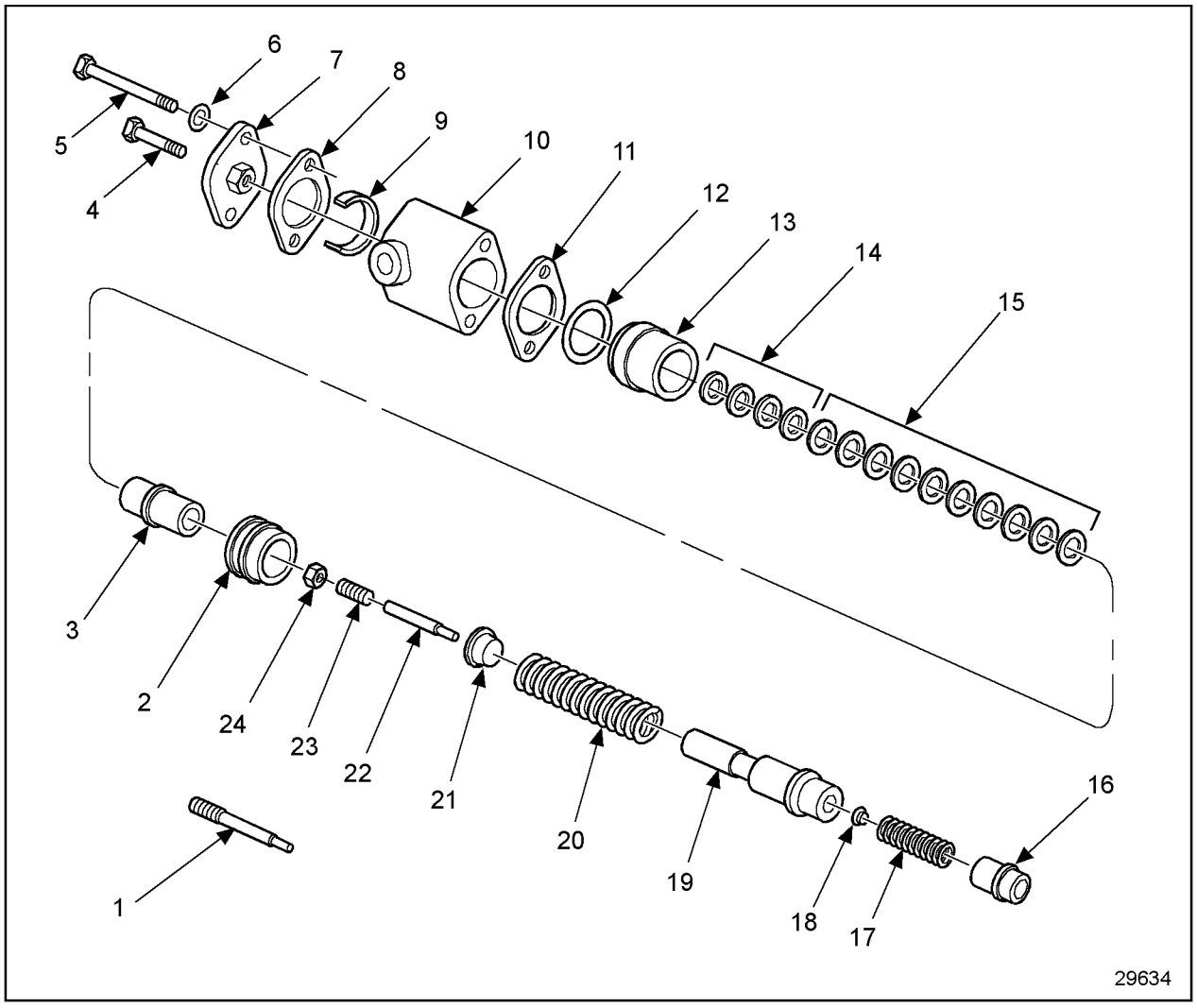
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3. Place the low-speed spring in the low-speed spring cap and the small end of the low-speed spring seat in the opposite end of the spring.
4. Insert the low-speed spring seat, spring, and cap assembly into the high-speed spring plunger and over the idle speed adjusting pin.
5. For fuel squeezer engines, install the bushing in the end of the high-speed spring retainer, if removed, and align the two flat washers and two Belleville spring washers.
6. Install the set screw in the Belleville spring retainer nut, and thread the retainer nut onto the high-speed plunger.
7. Affix a new high-speed spring retainer housing gasket to the governor housing.
8. Insert the spring, plunger, and retainer assembly into the opening in the governor housing, and thread the retainer into the housing approximately one inch.
9. Install the high-speed spring retainer housing after the governor assembly has been installed on the engine, and the governor adjustment procedures have been performed. Refer to section 12.4 and Refer to section 12.5.

2.24.19 Assemble High and Low-Speed Spring Plunger and Adjusting Screw (Dual-Range Governors)

See Figure 2-145. Assemble the high and low-speed springs, plunger, and adjusting screws (dual-range governor) as follows:

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1. Former Adjusting Screw
2. Retainer
3. Sleeve
4. Short Bolt
5. Long Bolt
6. Washer
7. Cover
8. Gasket
9. Ring
10. Housing
11. Gasket
12. Seal Ring
13. Piston
14. Shim (0.100 in.)
15. Shim (0.010 in.)
16. Cap
17. Low-Speed Spring
18. Seat
19. Plunger
20. High-Speed Spring
21. Guide
22. Adjusting Pin
23. Set Screw
24. Locknut

Figure 2-145 High and Low-Speed Springs, Plunger and Piston (Dual Range)

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1. Thread the idle speed adjusting screw into the threaded end of the high-speed spring plunger approximately 1/2 in.
2. Place the high-speed spring guide in the end of the high-speed spring. Place the high-speed spring and guide over the end of the idle speed adjusting screw and plunger.
3. Thread the locknut on the idle speed adjusting screw and against the spring guide.
4. Place the low-speed spring in the low-speed spring cap and the small end of the low-speed spring seat in the opposite end of the spring.
5. Insert the low-speed spring seat, spring, and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.
6. Place the high-speed spring retainer over the high-speed spring guide. Insert the springs, plunger, and retainer assembly into the opening in the governor housing.
7. Thread the retainer into the housing. Tighten the retainer in the housing with tool J 5345-12.
8. If removed, install the piston blocking ring in the outer end of the high-speed spring retainer housing with the ring gap straddling the threaded hole and flush with the outside face of the housing.
9. Place the piston seal ring in the groove in the speed adjusting piston.
10. Apply a thin coat of grease on the inside diameter of the retainer housing. Insert the solid end of the speed adjusting piston in the retainer housing.
11. Install the four thick and the ten thin high-speed spring shims inside the speed adjusting piston. Insert the small end of the piston sleeve inside the piston and against the shims.
12. Affix a new high-speed spring retainer housing gasket to the governor housing.
13. If removed, thread the low maximum speed adjusting screw into the high-speed spring retainer housing cover approximately one inch. Affix a new gasket to the inside face of the cover.
14. Attach the high-speed spring retainer housing with piston, shims, sleeve, and cover to the governor housing with two bolts and lock washers. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

2.24.20 Assemble Governor Cover or Fuel Squeezer Engine Cover

Assemble the governor cover or fuel squeezer engine cover as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

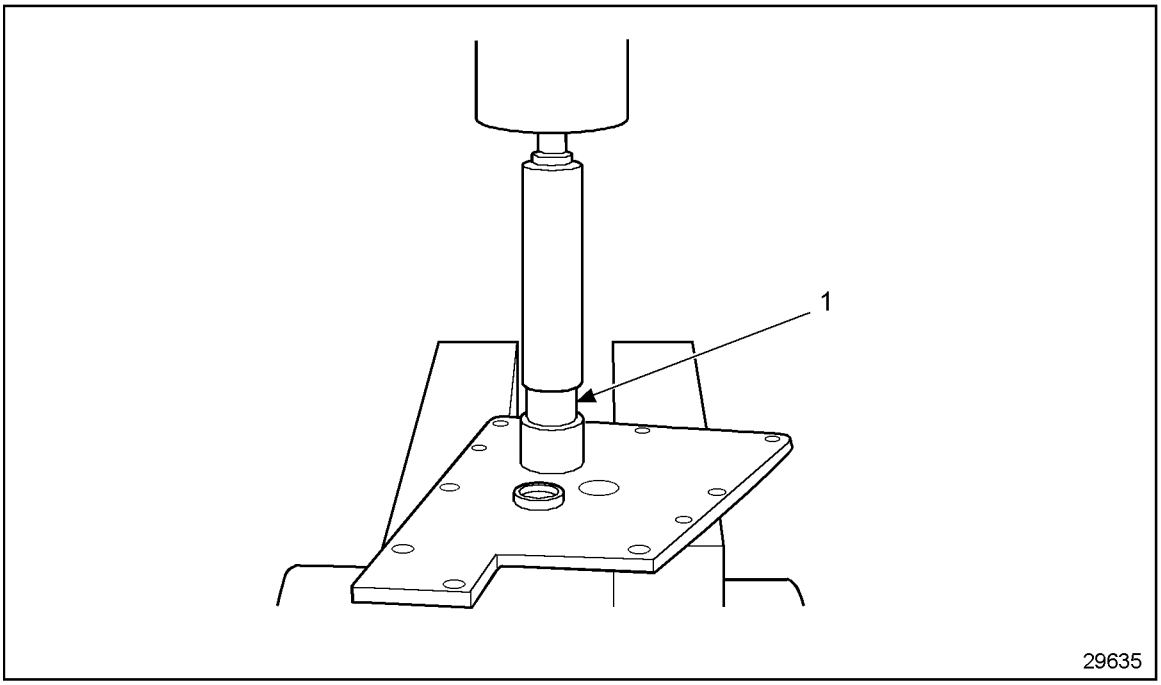
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. If the speed control lever shaft needle bearing was removed from the cover, place the cover, inner face down, on two steel supports on an arbor press bed. Lubricate the outside diameter of a bearing with engine oil, and start the bearing, numbered end up, straight in the cover boss bore.

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2. Place the correct end of the bearing installer J 21068 in the bearing. See Figure 2-146. Press the bearing into the bore until the stop on the installer contacts the cover boss.



1. Bearings

Figure 2-146 Installing Bearing in Governor Cover

NOTE:
Installer J 21068 has a pilot on each end. One end is for the speed control shaft upper bearing. The other is for the stop shaft bushing or upper bearing.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

3. Reverse the governor cover, inner face up, on the bed of the arbor press. Lubricate the outside diameter of the lower bearing with engine oil.
4. Start the bearing, numbered end up, straight in the bore in the cover boss.
5. Place the bearing installer J 21068 in the bearing, and press the bearing in the bore until it is flush with the face of the boss.
6. On a governor cover equipped with stop lever shaft needle bearing, install the needle bearings.

NOTE:
Use the small pilot end of installer J 21068 to install the bearings.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

7. Lubricate the outside diameter of a bearing with engine oil, and start the bearing, numbered end up, straight in the cover boss bore.
8. Place the correct end of the bearing installer J 21068 in the bearing. Press the bearing into the bore until the stop on the installer contacts the cover boss.

NOTE:
Installer J 21068 has a pilot on each end. One end is for the speed control shaft upper bearing. The other is for the stop shaft bushing or upper bearing.

⚠ CAUTION:

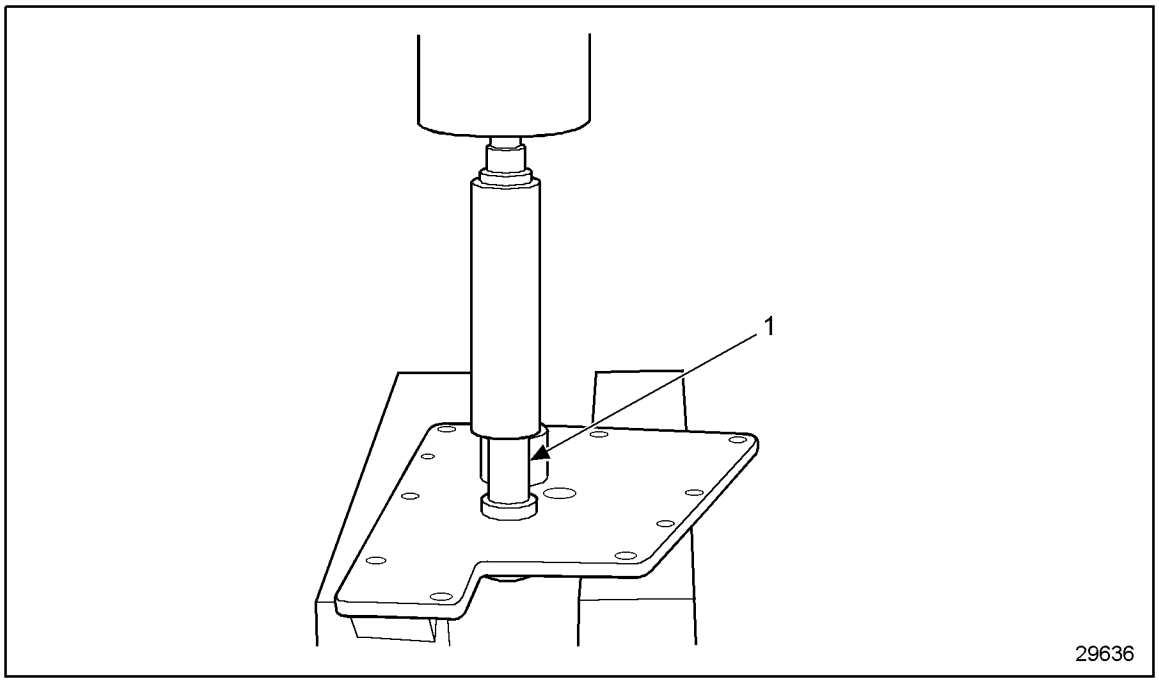
To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

9. Reverse the governor cover, inner face up, on an arbor press bed. Lubricate the outside diameter of the lower bearing with engine oil.

10. On a governor equipped with a stop lever shaft bushing, install the bushing in the cover. See Figure 2-147. Use the small pilot end of installer J 21068 to install the bushing.



1. Bushing

Figure 2-147 Installing Bushings Governor Case

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

11. Lubricate the outside diameter of a bearing with engine oil, and start the bearing, numbered end up, straight in the cover boss bore.

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12. Place the correct end of the bearing installer J 21068 in the bearing. Press the bearing into the bore until the stop on the installer contacts the cover boss.

NOTE:
Installer J 21068 has a pilot on each end. One end is for the speed control shaft upper bearing. The other is for the stop shaft bushing or upper bearing.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

13. Reverse the governor cover, inner face up, on the bed of the arbor press. Lubricate the outside diameter of the lower bearing with engine oil.
14. Lubricate the stop lever shaft needle bearings or bushing with Shell Alvania No. 2 grease, or equivalent.
15. Place the stop lever shaft return spring over the boss on the inner face of the cover. Insert the shaft part way through the bearings or bushing, and hook the return spring end over the lever end.
16. Push the shaft in the cover. Position the lever end on the right side of the stop pin.

NOTE:
Seal rings made of a Viton material are being used for the speed control lever shaft and for the stop lever shaft.

17. Place a new seal ring over the shaft, and push it into the bearing bore and against the bearing or bushing.
18. Place the two seal ring retainer washers on the shaft and against the cover boss. Install the snap ring in the groove in the shaft.
19. Install the stop lever on the shaft, and secure with the retaining bolt and lock washer.
20. Lubricate the speed control shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Insert the speed control shaft through the bearings.
21. Place the seal ring over the shaft, and push it into the bearing bore and against the bearing.

22. Place the two seal ring retainer washers on the shaft and against the cover boss. Install the snap ring in the groove in the shaft.
23. Install the spacer on the speed control shaft (slip fit) against the retaining washers and over the snap ring.
24. Install the speed control lever on the shaft. Secure it in place with the retaining bolt and lock washer.

NOTE:
Ensure that the lever contacts the spacer.

25. Install the lubrication fitting in the speed control shaft.

2.24.21 Installation of Limiting Speed Mechanical Governor (6V and 8V Engines)

Install the limiting speed mechanical governor on 6V and 8V engines as follows:

1. Affix a new gasket to the fuel pump bolting flange.
2. Place the fuel pump against the governor housing in its original position, and secure it with the three bolt and seal assemblies. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.
3. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing.
4. Affix a new gasket to the forward face of the blower end plate.
5. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower.
6. Rotate the fuel pump fork until the fork prongs align with the drive disc slots.
7. Rotate the weight shaft, and align the shaft splines with the blower rotor splines.
8. Push the governor straight over the dowels in the blower end plate and against the gasket.
9. See Figure 2-148 for torque sequence and bolt locations. Listed in Table 2-7 are the corresponding bolt locations and bolt sizes. Install the bolts, lock washers, copper

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washers, and plain washer securing the governor to the blower. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

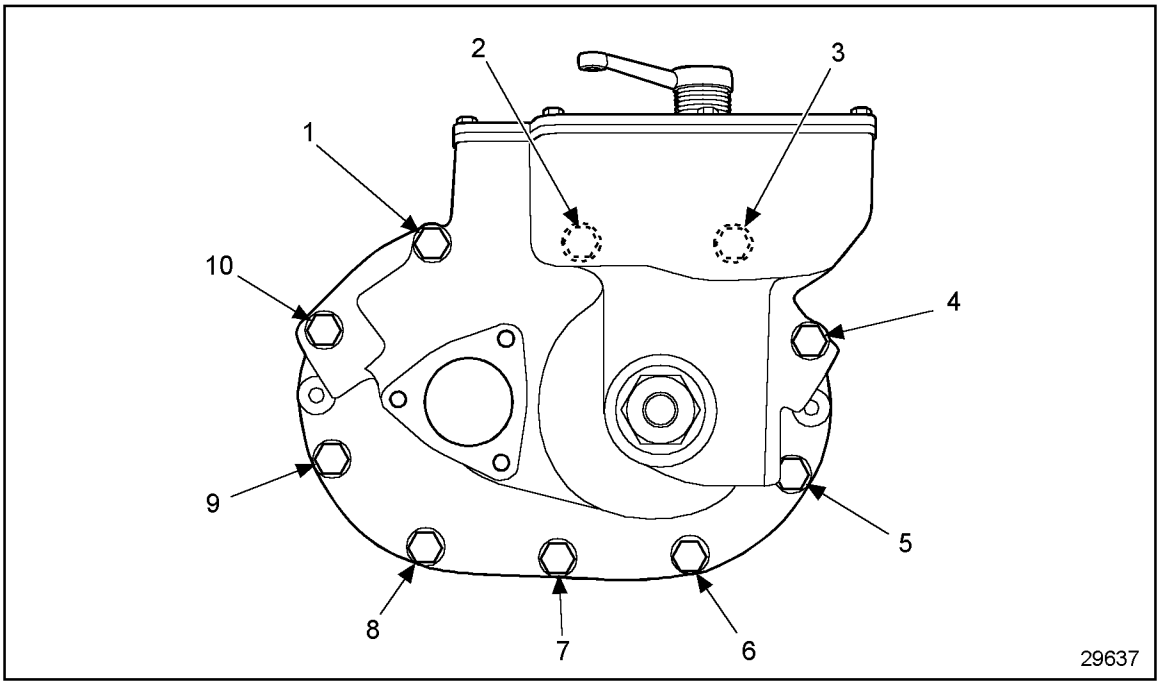


Figure 2-148 Torque Sequence and Location of Governor Mounting Bolts

Bolt Size	Washer	Position
5/16 in. 18 x 5-1/4 in.	Copper	4
5/16 in. 18 x 4	Copper	10
5/16 in. 18 x 3-3/4 in.	Lock and Plain	1
5/16 in. 18 x 2-1/4 in.	Lock and Plain	2, 3, 5, 6, 7, 8, 9

Table 2-7 Corresponding Location and Size of Governor Retaining Bolts

10. Slide each fuel rod cover tube hose on the cover tube attached to the cylinder heads. Tighten the hose clamps.
11. Install and connect the crossover fuel oil line to each cylinder head, and connect the fuel oil lines to the fuel pump.
12. Place the water bypass tube between the two thermostat housings, and slide the hoses part way on the thermostat housings.
13. Position the bypass tube so it clears the governor, fuel pump, and fuel oil lines. Tighten the hose clamps.
14. Insert the lower end of the left-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
15. Raise the connecting pin in the control link operating lever.

16. Insert the end of the fuel rod between the two bosses on the lever. Insert the connecting pin through the fuel rod and into the lower boss.
17. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
18. Insert the lower end of the right-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
19. Remove the short screw pin from the control link operating lever.
20. Insert the end of the fuel rod between the two bosses on the lever, and install the screw pin. Tighten the pin securely.
21. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
22. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the speed control shaft assembly pin in the differential lever slot and the housing dowel pins in the dowel pin holes in the cover.
23. Install the eight governor cover attaching screws and lock washers. Tighten the screws securely.

NOTE:
The short cover attaching screw, with the drilled head, goes in the corner hole next to the high-speed spring retainer housing.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

24. Using a new gasket, install the cylinder head rocker covers.
25. Install all accessories removed from the cylinder head, governor, or the front end of the engine.
26. Connect the control linkage to the speed control and stop levers.
27. Close the drain cocks, and fill the cooling system.
28. Perform the governor and injector rack control adjustment. Refer to section 12.4.

2.24.22 Installation of Limiting Speed Mechanical Governor (12V and 16V Engine)

Install the limiting speed mechanical governors on 12V and 16V engines as follows:

1. Affix a new governor housing gasket to the forward face of the blower end plate.

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2. Position the governor in front of the end plate. Align the weight shaft splines with the blower rotor splines.
3. Push the weight shaft in the rotor, and slide the governor housing over the dowel pins in the end plate and against the gasket.
4. See Figure 2-149 for torque sequence and bolt locations. Listed in Table 2-8 are the corresponding bolt locations and bolt sizes. Install the bolts, lock washers, plain washer, and copper washers that secure the governor to the blower. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

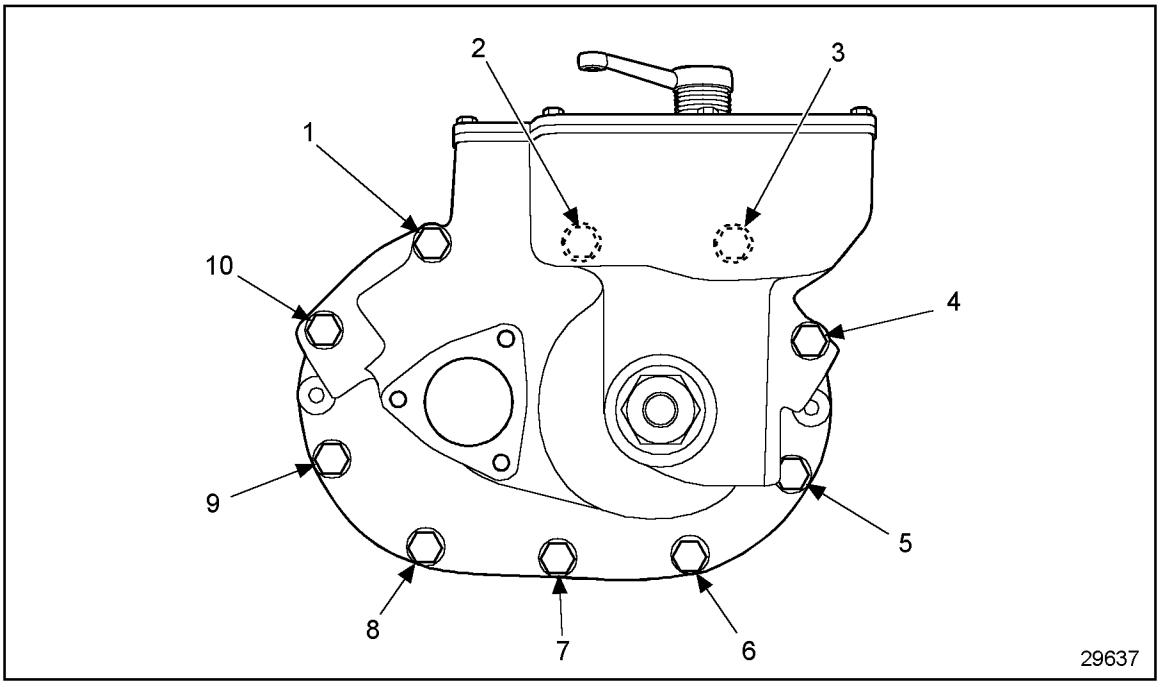


Figure 2-149 Torque Sequence and Location of Governor Mounting Bolts

Bolt Size	Washer	Position
5/16 in. 18 x 5-1/4 in.	Copper	4
5/16 in. 18 x 4	Copper	10
5/16 in. 18 x 3-3/4 in.	Lock and Plain	1
5/16 in. 18 x 2-1/4 in.	Lock and Plain	2, 3, 5, 6, 7, 8, 9

Table 2-8 Corresponding Location and Size of Governor Retaining Bolts

5. Affix a new blower housing gasket to the cylinder block with a good grade gasket cement to prevent the gasket from shifting when the blower is positioned.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the lifting sling before removing from engine. Blower damage may result if the blower falls from the lifting device.

6. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the engine before releasing the lifting sling. Blower damage may result if the blower falls from the engine.

7. Lift the blower and governor assembly, at a slight angle, and position it on top of the cylinder block, with the rear end plate cover flange inside the blower drive shaft cover hose.
8. Finger-tighten a 7/16 in.-14 x 8-1/4 in. bolt and special washer in each blower end plate center hole. Finger-tighten the 3/8 in.-16 x 5-1/2 in. bolts and retaining washers at each side of the blower housing.

NOTE:
The lip at the beveled end of the bolt retaining washer goes in the small recess in the housing just above the bolt slot.

9. Tighten the bolts as follows:
   [a] Tighten the blower-to-block end plate bolts to 54-81 N·m (40-60 lb·ft) torque.
   [b] Tighten the blower housing-to-block side angle bolts to 41-47 N·m (30-35 lb·ft) torque in 7 N·m (5 lb·ft) increments.
   [c] Recheck the torque on the blower-to-block end plate bolts.
10. Slide the blower drive support-to-blower hose (seal) and clamps into position, and tighten the clamps.

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11. Insert the blower drive shaft through the blower drive flexible coupling and into the blower drive coupling. Install the retaining snap ring in the coupling groove.
12. Affix a new gasket to the flywheel housing hole cover, and attach the cover to the flywheel housing with six bolts and lock washers.
13. Refer to section 2.24.23 for installation of the limiting speed mechanical governor (engines equipped with a hydraulic oil pump).
14. Refer to section 2.24.24 for installation of the limiting speed mechanical governor (engines equipped with a rear mounted battery charging alternator).
15. On an engine equipped with a hydraulic oil pump, refer to *M.MH. Marine Service Manual* - Form 00SA1984.
16. Connect the blower drive support oil tube to the fitting in the blower drive support. Tighten the two seal ring retaining plate bolts to 18-23 N·m (13-17 lb·ft) torque.
17. Affix a new gasket to the fuel pump flange.
18. Install the fuel pump drive fork and fuel pump on the governor housing.
19. Connect the fuel pump inlet and outlet tubes or hoses to the fuel pump.
20. Slide the governor housing to auxiliary control link housing hose, and clamp it into position between the two housings. Tighten the hose clamp.
21. Slide the fuel rod cover hose on the cover tube attached to the cylinder head at each side of the governor housing. Tighten the hose clamps.
22. Place the control link operating lever connecting link in position in the governor and auxiliary housings, and connect it to the ball joint studs in the control link operating levers.
23. Refer to section 2.24.25 for installation of the limiting speed mechanical governor (fuel rods between the cylinder head and governor).
24. Place a new auxiliary control link housing cover gasket on the housing. Install the cover, and secure it with screws and lock washers.
25. Place a new governor housing cover gasket on the housing. Install the cover, and secure it with screws and lock washers.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

26. Using new gaskets, install the cylinder head rocker covers.
27. On a non-turbocharged engine, proceed as follows:
    [a] Remove the cover from the top of the blower.
    [b] Place the blower screen, wire side down, on top of the blower, and install the air shutdown adaptor.

[c] Attach the air shutdown housings and gaskets to the adaptors.

28. On turbocharged engines, proceed as follows:

    [a] Remove the cover from the top of the blower.

    [b] Place the blower screen, wire side down, and install the air shutdown adaptor and air shutdown housing as an assembly on the blower.

    [c] Attach the shutdown rod to the lever on the shutdown housing.

29. On marine engines, proceed as follows:

    [a] Remove the cover from the top of the blowers.

    [b] Place the blower screen, wire side down, on top of the blower, and install the air shutdown housings.

30. On non-turbocharged engines, connect the air inlet tubes to the air shutdown housings.
31. On turbocharged engines, attach the air inlet tube to the rear air shutdown housing and the turbocharger.
32. On marine engines, install the air silencers on the air shutdown housings.
33. Connect the linkage that was removed to the governor speed control and stop levers.
34. Perform an engine tune-up. Refer to section 12.1.

2.24.23 Installation of Limiting Speed Mechanical Governor (Engines Equipped with a Hydraulic Oil Pump)

On engines equipped with a hydraulic oil pump, proceed as follows:

1. Install the drive coupling and the drive coupling hub.
2. Install the oil pump, adaptor, and gaskets from the flywheel housing.
3. Secure with six bolts and lock washers.
4. Refer to section 2.24.22, step 15, to continue installation of the limiting speed mechanical governor.

2.24.24 Installation of Limiting Speed Mechanical Governor (Engines Equipped with a Rear Mounted Battery-Charging Alternator)

On an engine equipped with a rear mounted battery-charging alternator, proceed as follows:

1. Affix a new gasket to the alternator drive assembly.
2. Place the alternator drive coupling on the drive hub.
3. Place the drive assembly into position, and align the slots in the drive coupling with the drive hub on the blower drive gear.
4. Place the drive assembly against the flywheel housing, and install the bolts, lock washers, and alternator adjusting strap.

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5. Install the alternator drive pulley and drive belt.
6. Refer to section 2.24.22, step 15, to continue installation of the limiting speed mechanical governor.

2.24.25 Installation of Limiting Speed Mechanical Governor (Fuel Rods Between Cylinder Heads and Governor)

Install the fuel rods between the cylinder heads and the governor as follows:

1. Insert the lower end of the left-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
2. Raise the connecting pin in the control link operating lever.
3. Insert the end of the fuel rod between the two bosses on the lever, and insert the connecting pin through the fuel rod and into the lower boss.
4. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
5. Insert the lower end of the right-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
6. Remove the short screw pin from the control link operating lever.
7. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.
8. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
9. Refer to section 2.24.22, step 24, to complete installation of the limiting speed mechanical governor.

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2.25 LIMITING SPEED MECHANICAL GOVERNOR (VARIABLE LOW-SPEED)

The variable low-speed limiting speed mechanical governor is used on highway vehicle engines where the same engine powers both the vehicle and auxiliary equipment used to unload bulk products (such as cement, grain, and liquids) and a high idle speed range is desired during auxiliary operation.

The governor is a single-weight type and provides an idle speed range of 500 to 1800 RPM. The governor is mounted on the front end of the blower and is driven by one of the blower rotors.

A nameplate attached to the governor housing identifies the governor. The letters V.L.S.L.S. stamped on the nameplate denote a variable low-speed limiting speed mechanical governor.

During highway operation, the governor functions as a limiting speed governor, controlling the engine idling speed and limiting the maximum operating speed. At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle, on the cable operated governor, is turned to the speed required within the above range to operate the auxiliary equipment. For the air operated governor, increasing or decreasing the air supply pressure to the governor changes the required engine speed. The governor functions as a variable speed governor, maintaining a constant speed when the load is constantly changing during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned back to the stop and turned ahead about one-quarter of a turn. The air operated governor air supply pressure must be vented before resuming highway operations.

2.25.1 Repair or Replacement of Limiting Speed Mechanical Governor (Variable Low-Speed)

To determine if repair or replacement is necessary, perform the following procedure. See Figure 2-150.

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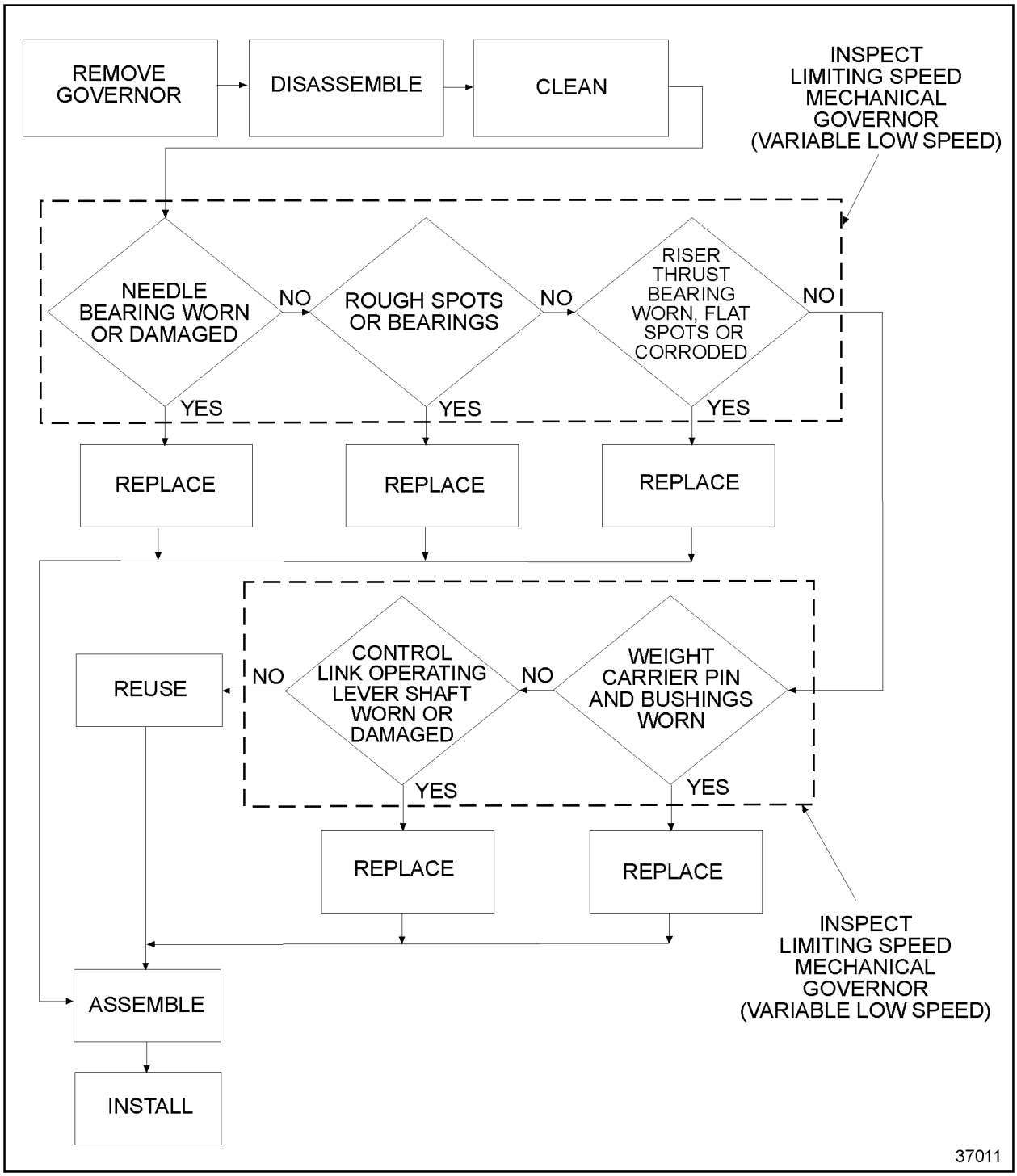


Figure 2-150 Flowchart for Repair or Replacement of Limiting Speed Mechanical Governor (Variable Low-Speed)

2.25.2 Removal of Cable Operated Governor

Remove the cable operated governor as follows:

1. Disconnect the manual control flexible shaft from the governor spring housing.
2. Remove the governor. Refer to section 2.24.3.

2.25.3 Removal of Air Operated Governor

Remove the air operated governor as follows:

1. Disconnect the air controls from the governor spring housing.
2. Remove the governor. Refer to section 2.24.3.

2.25.4 Disassembly of Cable Operated Governor

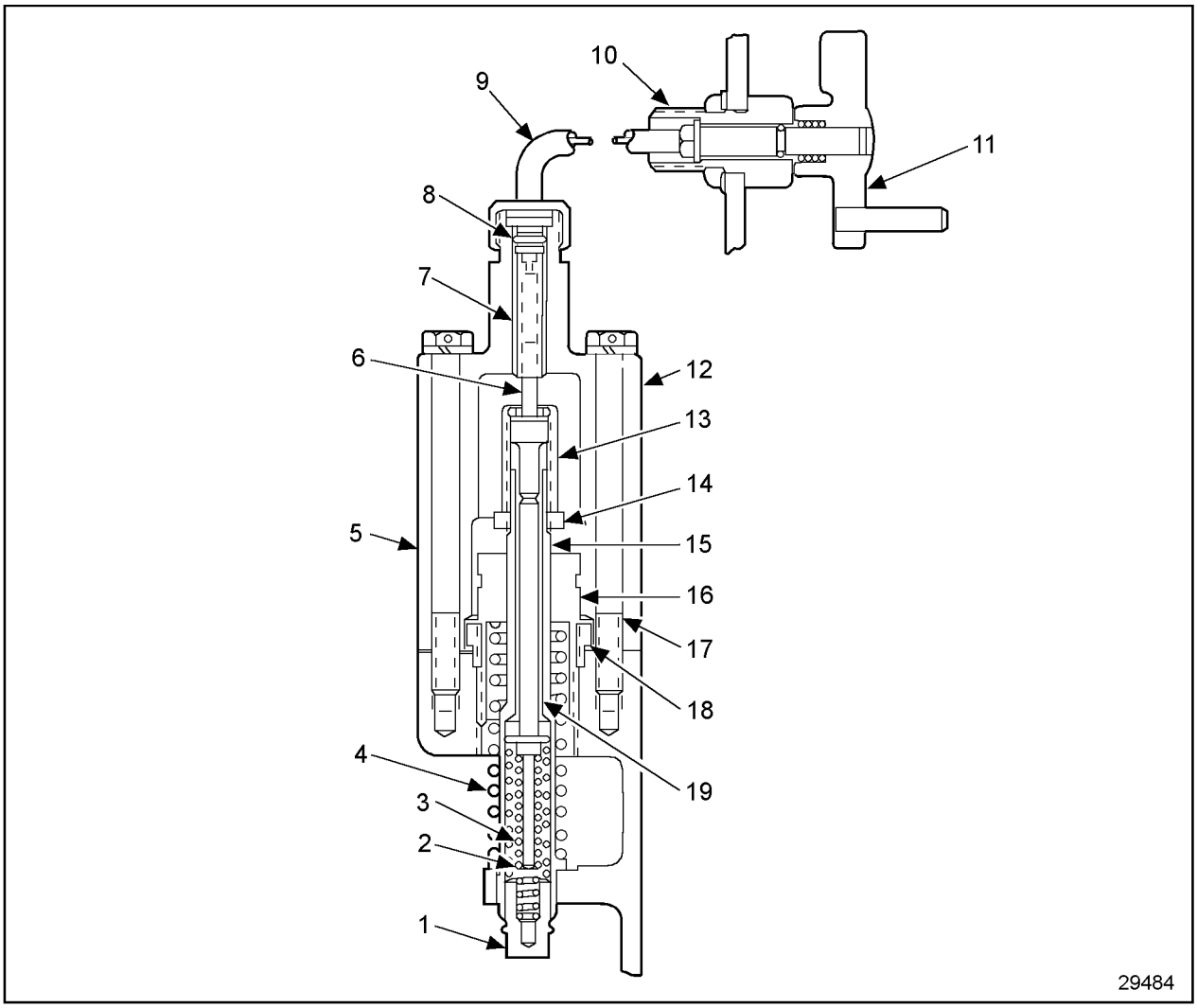
Disassemble the cable operated governor as follows:

NOTE:
The variable low-speed limiting speed governor is similar to the limiting speed governor, with the exception of the spring housing and its components. Therefore, only the disassembly procedure for the spring housing and its components is listed below. Refer to section 2.24.6 for general governor disassembly procedure.

1. Clamp the governor housing flange in a soft-jawed vise.

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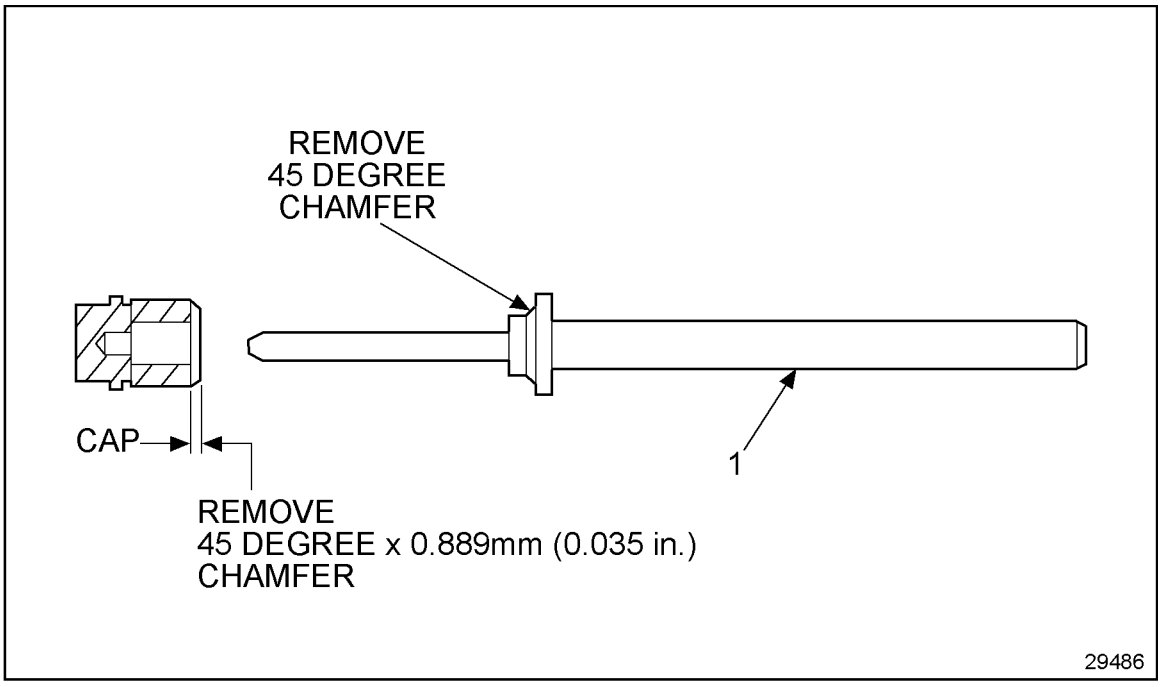
2. Remove the two bolts and copper washers securing the spring housing to the governor housing. Withdraw the spring housing and gasket. See Figure 2-151.



1. Low-Speed Spring Cap
2. Low-Speed Spring (Outer)
3. Low-Speed Spring (Inner)
4. High-Speed Spring
5. Governor Housing
6. Adjusting Shaft
7. Adjusting Coupling
8. Seal Ring
9. Flexible Shaft
10. Manual Control Assembly
11. Speed Adjusting Handle
12. Spring Housing
13. Adjusting Shaft Retainer
14. Adjusting Locknut
15. High-Speed Spring Plunger
16. High-Speed Spring Retainer
17. Gasket
18. Spring Retainer Locknut
19. Low-Speed Spring Plunger

Figure 2-151 Cable Operated Governor Spring Housing and Components

3. Remove the adjusting coupling from the adjusting shaft.
4. Hold the adjusting locknut with a wrench, and back off the retainer and adjusting shaft.
5. Unscrew the adjusting shaft from the retainer.
6. Unscrew the idle speed adjusting locknut from the end of the high-speed spring plunger.
7. Unscrew the high-speed spring retainer locknut. Remove the high-speed spring retainer, plunger and spring, low-speed spring plunger, inner and outer springs, and low-speed spring cap from the governor housing as an assembly.
8. Remove the high-speed spring retainer and spacer assembly and spring from the high-speed spring plunger.
9. Remove the low-speed spring cap from the opposite end of the high-speed spring plunger, and remove the low-speed spring plunger and the inner and outer low-speed springs. See Figure 2-152.



1. Plunger

Figure 2-152 Rework Former Plunger and Cap

2.25.5 Disassembly of Air Operated Governor

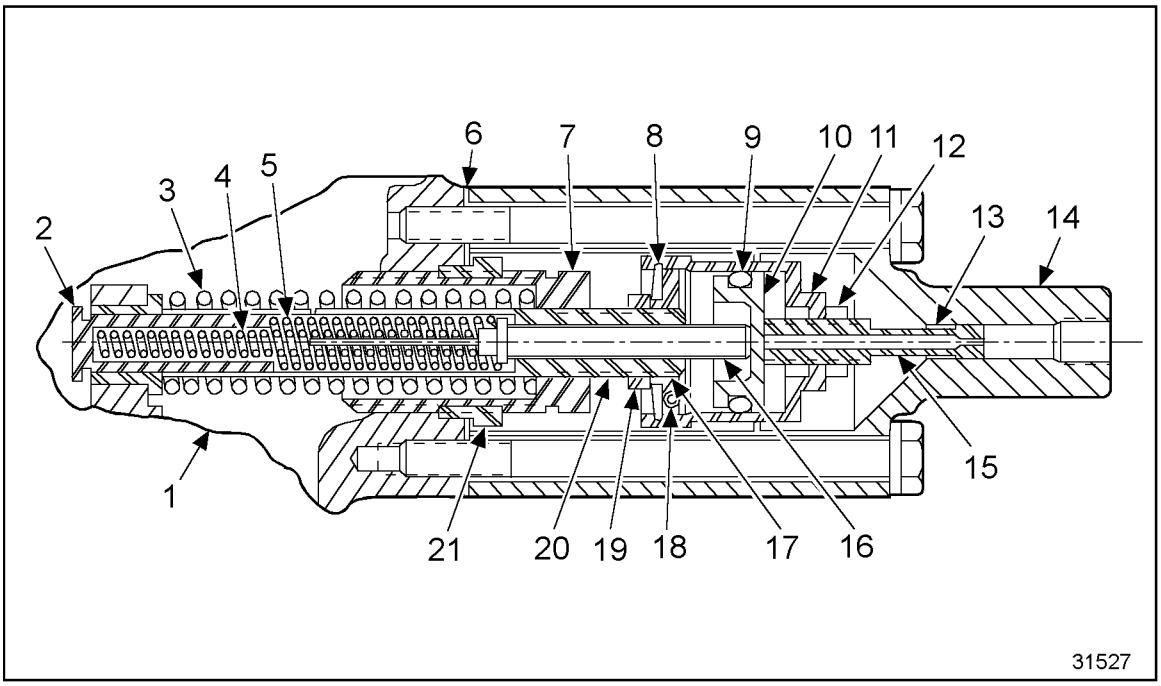
Disassemble the air operated governor as follows:

NOTE:
The variable low-speed limiting speed governor is similar to the limiting speed governor, with the exception of the spring housing and its components. Therefore, only the

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disassembly procedure for the spring housing and its components is listed below. Refer to section 2.24.6 for general governor disassembly procedure.

1. Clamp the governor housing flange in a soft jawed vise.
2. Remove the two bolts and lock washers securing the spring housing to the governor housing. Withdraw the spring housing and gasket. Discard the gasket. See Figure 2-153 and see Figure 2-154.



1. Governor Housing
2. Spring Cap
3. High-Speed Spring
4. Idle Spring (Inner)
5. Idle Spring (Outer)
6. Gasket
7. Spring Retainer
8. Retainer Ring
9. Seal Ring
10. Piston
11. Air Cylinder
12. Idle-Speed Jam Nut
13. Seal Ring
14. Spring Housing
15. Idle-Speed Adjusting Screw
16. Idle-Speed Plunger
17. Air Cap
18. Pin
19. High-Speed Jam Nut
20. High-Speed Plunger
21. Retainer Locknut

Figure 2-153 Air Operated Limiting Speed Governor (Variable Low Speed)

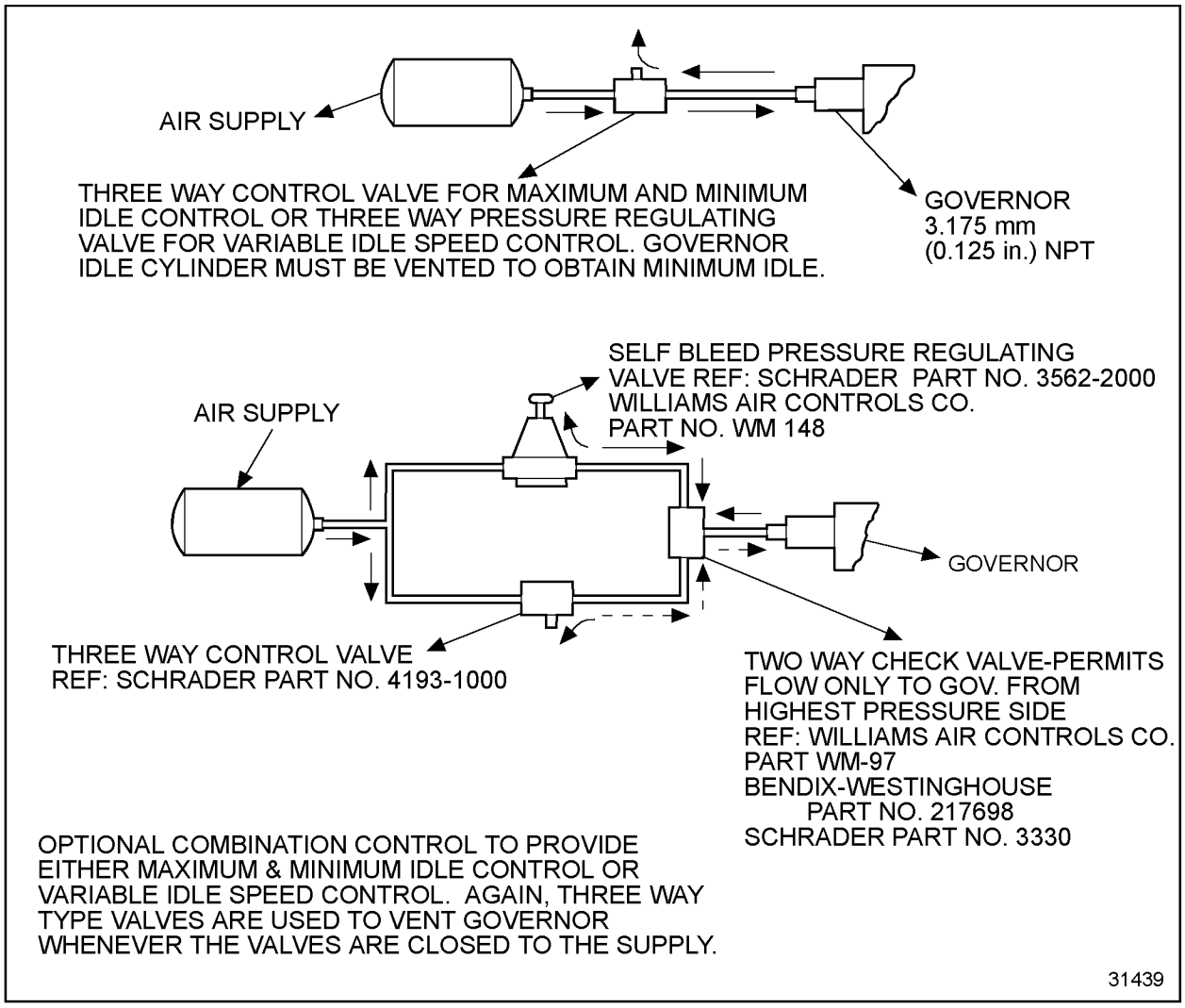


Figure 2-154 Limiting Speed Governor (Variable Low Speed) Optional Combination Air Controls

3. Loosen the 5/16 in.-24 idle speed jam nut, and remove the idle speed adjusting screw, seal ring, and nut as an assembly. Discard the seal ring.
4. Hold the 1/2 in.-20 jam nut on the high-speed spring plunger with a wrench, and unscrew the air cylinder cap, retainer ring, pin, piston, air cylinder, and seal ring as an assembly from the end of the high-speed spring plunger.
5. Disengage the retainer ring from the air cylinder, and remove the air cap and piston from the air cylinder.
6. Remove the seal ring from the piston. Discard the seal ring.
7. Unscrew the high-speed spring retainer locknut.
8. Remove the high-speed spring retainer, plunger, spring, and the low-speed spring plunger, inner and outer springs, and low-speed spring cap as an assembly from the governor housing. Discard the gasket.

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9. Remove the high-speed spring retainer and spacer assembly and spring from the high-speed spring plunger.
10. Remove the low-speed spring cap from the opposite end of the high-speed spring plunger.
11. Remove the low-speed spring plunger along with the inner and outer low-speed springs.

2.25.5.1 Cleaning of Variable-Speed Limiting Speed Mechanical Governor

Clean the governor as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash all 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 them with compressed air.

2.25.5.2 Inspection of Variable Speed Limiting Speed Mechanical Governor

General inspection procedures for mechanical governors are detailed elsewhere. Refer to section 2.24.12.2 for proper inspection procedures.

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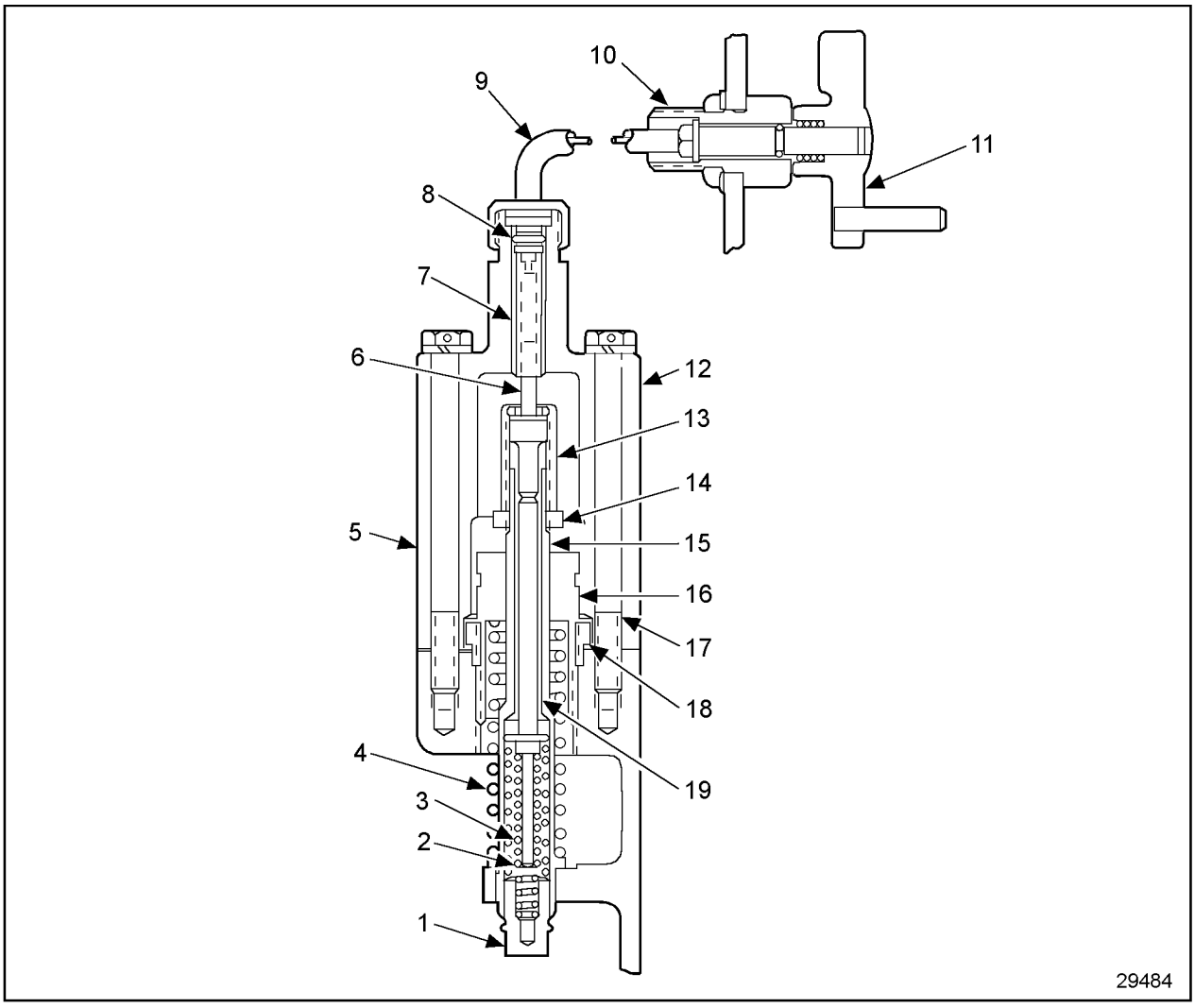
2.25.6 Assembly of Cable Operated Governor

Refer to section 2.24.13 for general governor assembly procedure. Assemble the cable operated governor as follows:

NOTE:
During assembly, lubricate all spring housing components and needle bearing assemblies with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

1. Thread the spring retainer locknut on the high-speed spring retainer approximately 1-1/2 in. See Figure 2-155.

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1. Low-Speed Spring Cap
2. Low-Speed Spring (Outer)
3. Low-Speed Spring (Inner)
4. High-Speed Spring
5. Governor Housing
6. Adjusting Shaft
7. Adjusting Coupling
8. Seal Ring
9. Flexible Shaft
10. Manual Control Assembly
11. Speed Adjusting Handle
12. Spring Housing
13. Adjusting Shaft Retainer
14. Adjusting Locknut
15. High-Speed Spring Plunger
16. High-Speed Spring Retainer
17. Gasket
18. Spring Retainer Locknut
19. Low-Speed Spring Plunger

Figure 2-155 Cable Operated Governor Spring Housing and Components

2. Place the high-speed spring on the high-speed spring plunger.
3. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.

4. Insert the low-speed spring plunger into the high-speed spring plunger.
5. Place the inner and outer springs in the lower end of the high-speed spring plunger, over the low-speed spring plunger.
6. Install the low-speed spring cap over the end of the inner low-speed spring and into the end of the high-speed spring plunger.
7. Install the assembly in the governor housing.

NOTE:
Place a new housing gasket in position before installing the assembly.

8. Thread the idle speed adjusting locknut on the threaded end of the high-speed spring plunger approximately 1/2 in.
9. Screw the adjusting shaft into the adjusting shaft retainer.
10. Install the adjusting retainer and shaft onto the high-speed spring plunger. Turn down the adjusting retainer against the idle speed adjusting locknut.
11. Install the adjusting coupling and spring housing after the governor adjustments have been performed. Refer to section 12.7.5.

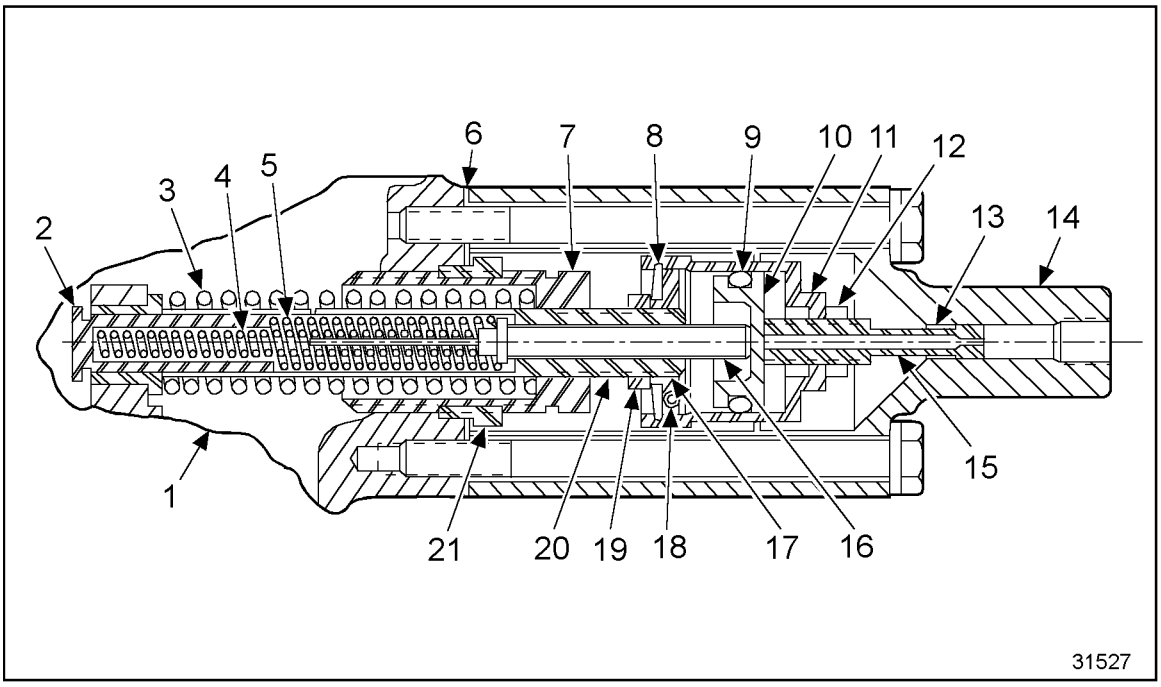
2.25.7 Assembly of Air Operated Governor

Refer to section 2.24.13 for general governor assembly procedure. Assemble the air operated governor as follows:

NOTE:
During assembly, lubricate all spring housing components and needle bearing assemblies with MIL. G3278A, Aero Shell 7A grease, or equivalent (special grease for high and low temperature operations).

1. Thread the spring retainer locknut on the high-speed spring retainer approximately 1-1/2 in. See Figure 2-156 and see Figure 2-157.

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1. Governor Housing
2. Spring Cap
3. High-Speed Spring
4. Idle Spring (Inner)
5. Idle Spring (Outer)
6. Gasket
7. Spring Retainer
8. Retainer Ring
9. Seal Ring
10. Piston
11. Air Cylinder
12. Idle Speed Jam Nut
13. Seal Ring
14. Spring Housing
15. Idle-Speed Adjusting Screw
16. Idle-Speed Plunger
17. Air Cap
18. Pin
19. High-Speed Jam Nut
20. High-Speed Plunger
21. Retainer Locknut

Figure 2-156 Air Operated Limiting Speed Governor (Variable Low Speed)

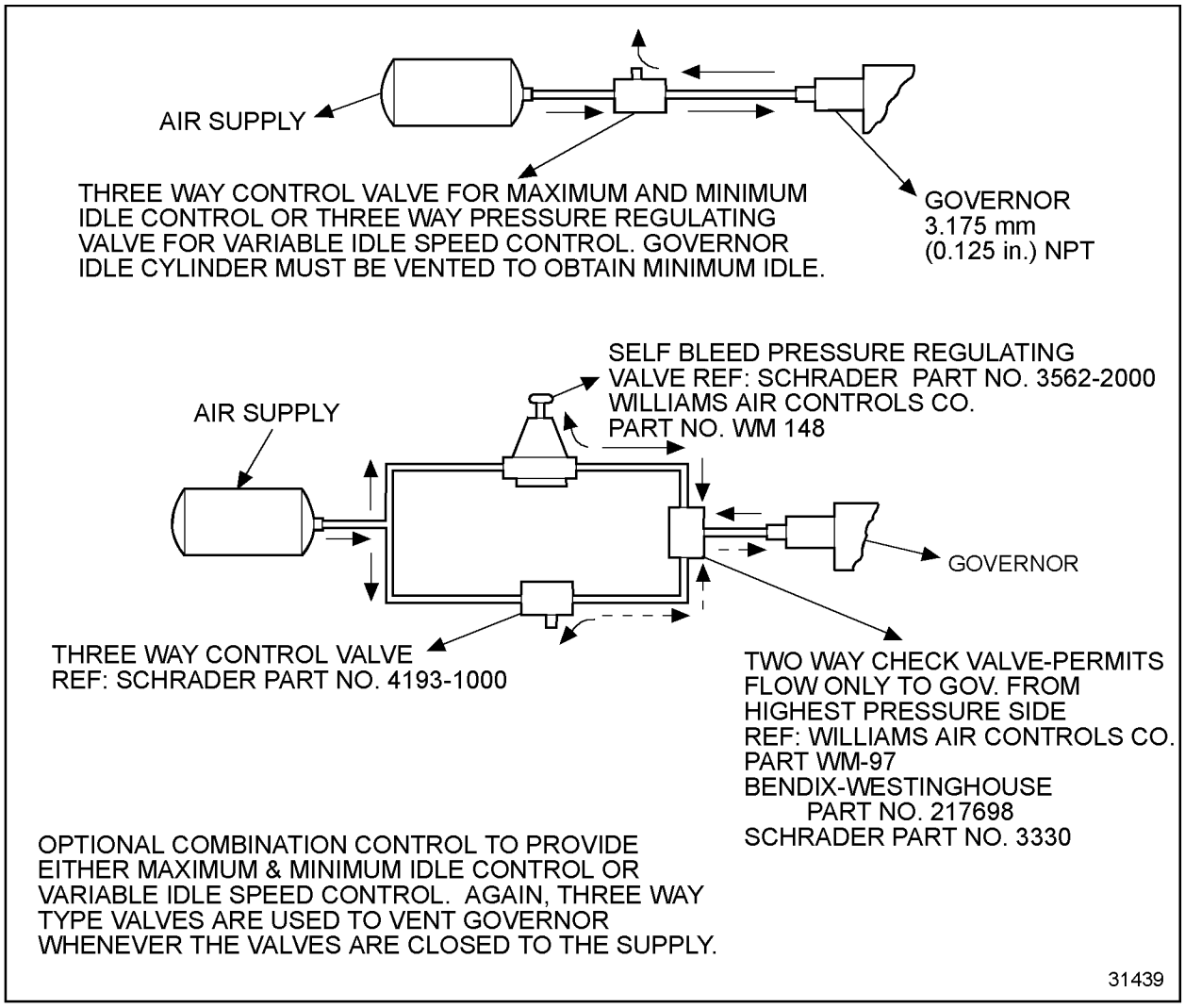


Figure 2-157 Limiting Speed Governor (Variable Low Speed) Optional Combination Air Controls

2. Place the high-speed spring on the high-speed spring plunger.
3. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.
4. Insert the low-speed spring plunger into the high-speed spring plunger.
5. Place the inner and outer springs in the lower end of the high-speed spring plunger over the low-speed spring plunger.
6. Install the low-speed spring cap over the end of the inner low-speed spring and into the end of the high-speed spring plunger.
7. Install the assembly in the governor housing.

NOTE:
Place the new spring housing gasket in position before installing the assembly.

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8. Thread the 1/2 in.-20 high-speed spring jam nut on the threaded end of the plunger approximately 1/2 in.
9. Place a new seal ring on the piston and assemble the piston and air cap in the air cylinder. Secure them in the air cylinder with the retainer ring.
10. Screw the air cylinder assembly on the high-speed spring plunger and against the high-speed spring plunger and jam nut.
11. Place a new seal ring on the idle speed adjusting screw. Install the adjusting screw and jam nut in the air cylinder.
12. Install the spring housing after the governor adjustments have been performed. Refer to section 2.25.6.

2.25.8 Installation of Cable Operated Governor

Install the cable operated governor as follows:

1. Refer to section 2.24.21 for general installation procedures.
2. Connect the manual control flexible shaft to the governor spring housing.
3. Adjust the governor. Refer to section 12.4.

2.25.9 Installation of Air Operated Governor

Install the air operated governor as follows:

1. Refer to section 2.24.21 for general installation procedures.
2. Connect the air controls to the governor spring housing.
3. Adjust the governor. Refer to section 12.4.

2.26 LIMITING SPEED MECHANICAL GOVERNOR (VARIABLE HIGH SPEED)

The air operated limiting speed mechanical governor (variable high speed) is used for highway vehicle applications where the same engine powers both the vehicle and auxiliary equipment, for unloading bulk products (such as cement, grain or liquids) and where a variable speed range is desired during auxiliary constant speed operation.

The idle speed range for these governors is the same as for the standard limiting speed governors. The normal no-load speed range is the same as for the standard limiting speed governor. A variable high-speed limiting speed governor will control engine RPM. from any normal no-load speed down to near idle speed. In addition to the high-speed control kit, a regulated air supply and an air cylinder to move the throttle to the wide open throttle position is required.

2.26.1 Repair or Replacement of Limiting Speed Mechanical Governor (Variable High-Speed)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-158.

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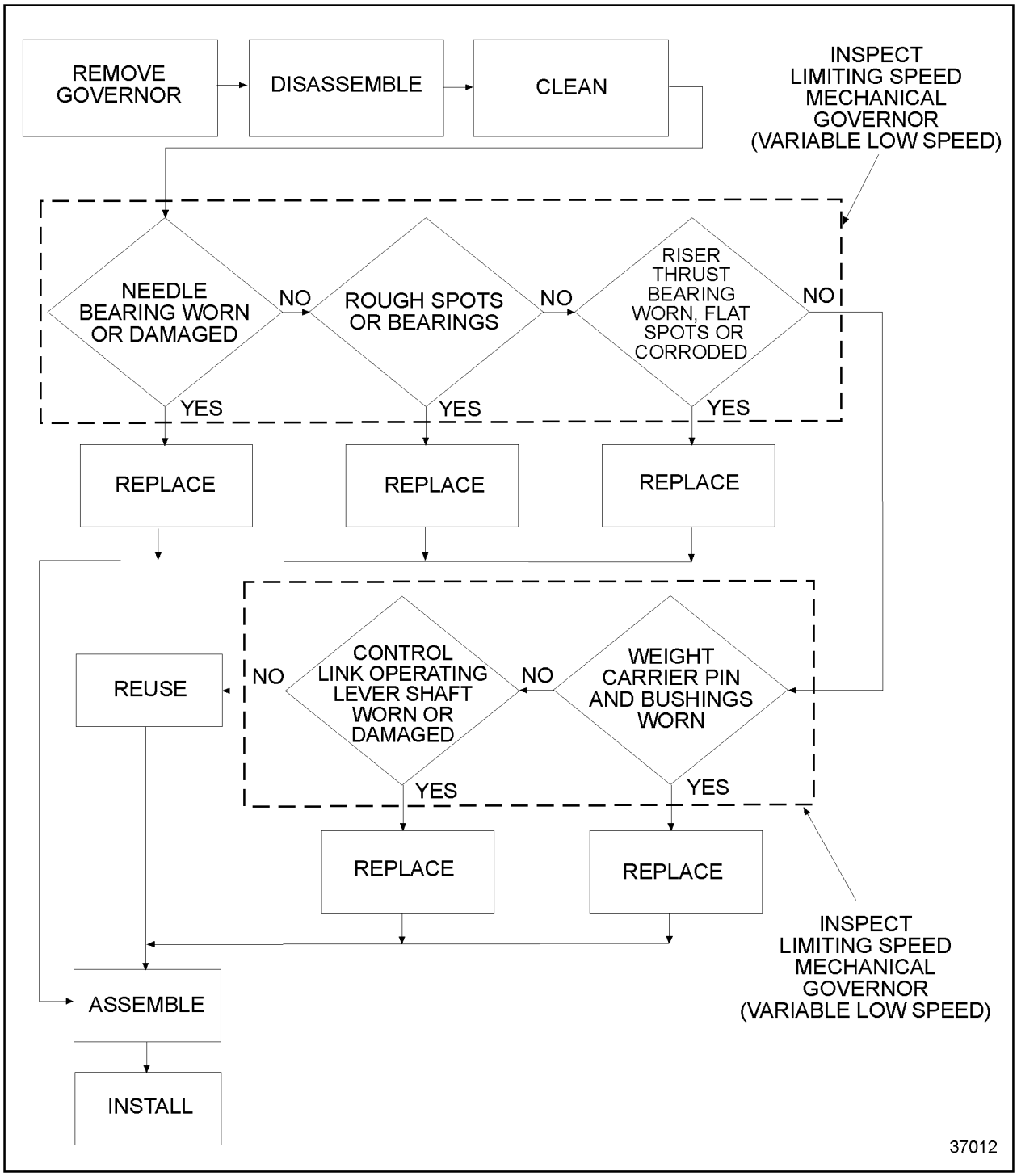


Figure 2-158 Flowchart for Repair or Replacement of Limiting Speed Mechanical Governor (Variable High-Speed)

2.26.2 Removal of Limiting Speed Mechanical Governor (Variable High-Speed)

To remove the governor, refer to section 2.24.2.

Remove the control housing as follows:

1. Remove the air cylinder on the governor cover.
2. Remove the two copper washers and two 5/16 in.-18 x 4 1/2 in. bolts. Remove the gaskets and flat or tamper-resistant cover.
3. Remove the idle screw self-locking nut.
4. Remove the housing and piston assembly from the spring retainer and idle speed screw.

2.26.3 Disassembly of Limiting Speed Mechanical Governor (Variable High-Speed)

Refer to section 2.24.6 for disassembly procedure.

Disassemble the high-speed control housing as follows:

1. Remove the piston from the housing.
2. Remove the small ring in the spring housing and the large seal ring on the piston.

2.26.3.1 Cleaning of Limiting Speed Mechanical Governor (Variable High-Speed)

Prior to inspection, clean the parts as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash the parts in clean fuel oil.

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⚠ 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.

2.26.3.2 Inspection of Limiting Speed Mechanical Governor (Variable High-Speed)

Inspect the governor as follows:

Refer to section 2.24.12.2 for inspection procedures.

2.26.4 Assembly of Limiting Speed Mechanical Governor (Variable High-Speed)

Refer to section 2.24.13 for assembly procedures.

Assemble the high-speed control housing as follows:

1. Install the small ring in the spring housing and the large seal ring on the piston.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

2. Lubricate the piston and inside of the housing with engine oil.
3. Install the piston in the housing.

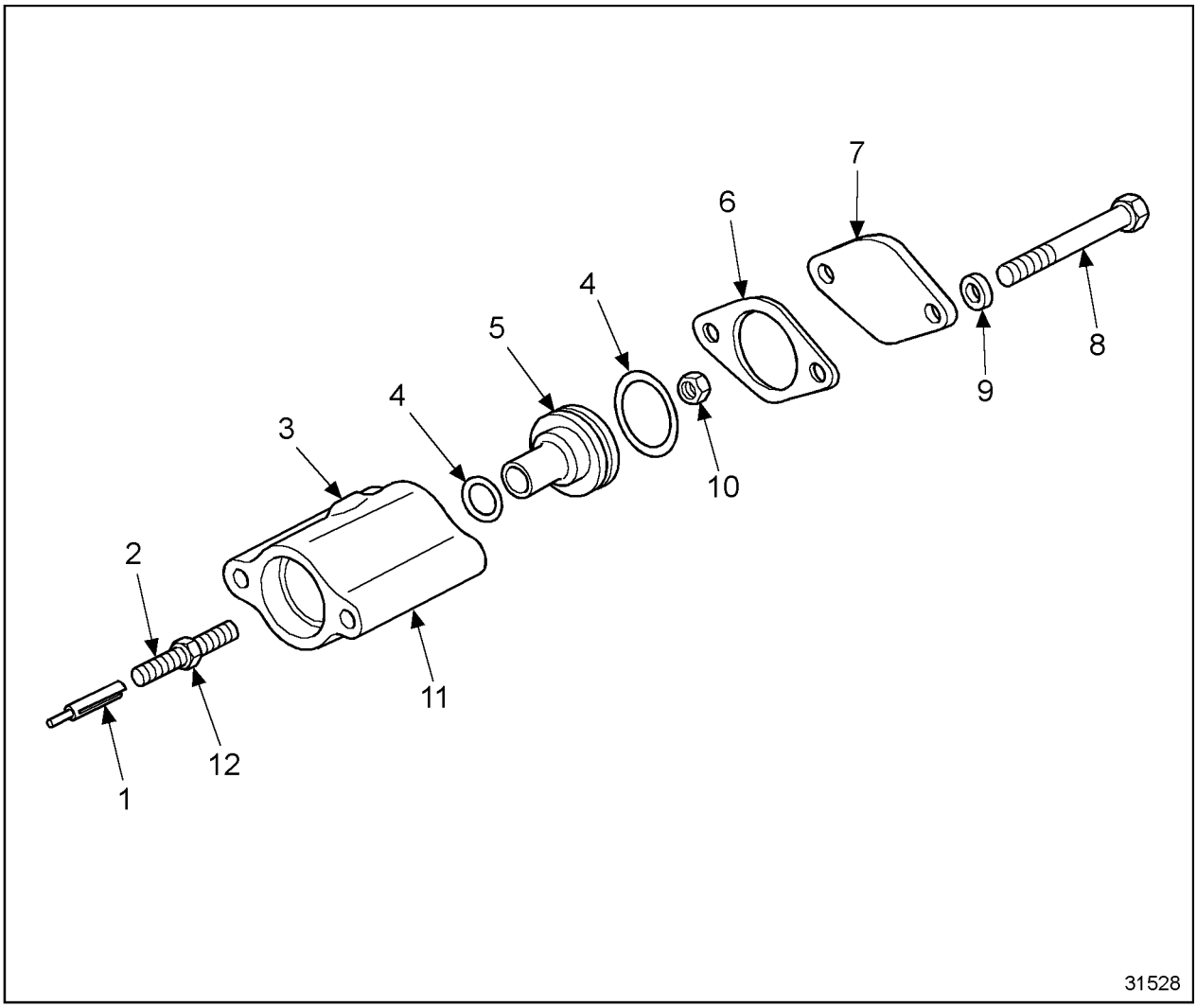
2.26.5 Installation of Limiting Speed Mechanical Governor (Variable High-Speed)

Install the governor as follows:

Refer to section 2.24.21 for governor installation instructions.

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See Figure 2-159. Without disturbing the engine tune-up, install a high-speed control housing assembly on a standard limiting speed governor having a long spring pack as follows:



1. Adjusting Pin
2. Idle Screw
3. Air Hole
4. Seal Ring
5. Piston
6. Gasket
7. Cover
8. Bolt
9. Copper Washer
10. Locknut
11. Spring Housing
12. Locknut

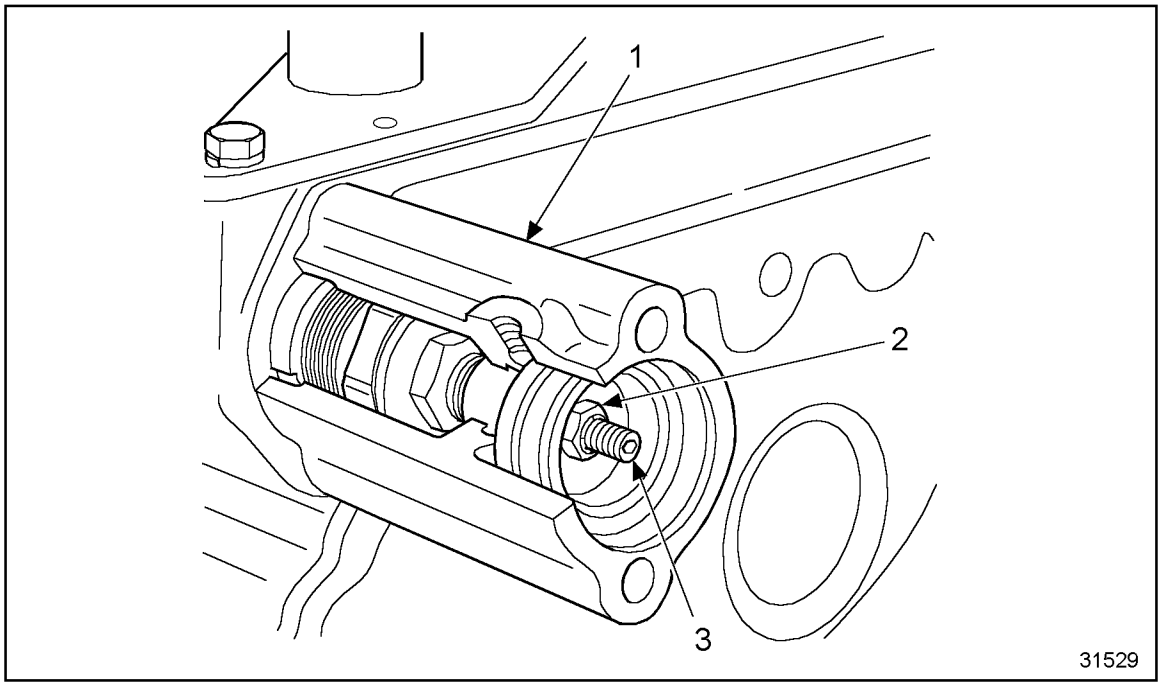
Figure 2-159 Limiting Speed Mechanical Governor Components (Air Operated Variable High Speed)

1. Loosen the two bolts and copper washers, and remove the spring retainer housing.

2. Remove the idle speed adjustment screw, and replace it with the longer high-speed control idle speed screw. Reset the idle speed RPM to the previous setting.

NOTE:
If the governor has the former one piece idle speed screw, replace it with the current idle speed pin and long screw.

3. Refer to section 12.1 for the engine tune-up procedure for the high-speed control governor. Use the longer idle speed screw to perform the adjustment.
4. Slide the housing and piston assembly over the spring retainer and idle speed screw.
5. Install the idle screw self-locking nut, and make the following adjustments:
   [a] Place a 0.010 in. feeler gage between the VHS housing gasket and the main governor housing.
   [b] Using tool J 28598-B, adjust the elastic stop nut, while holding the idle screw stationary, until a slight drag is felt on the shim. See Figure 2-160.



1. VHS Housing
2. Elastic Stop Nut
3. Idle Speed Screw

Figure 2-160 Adjust Elastic Stop Nut using Tool J 28598-B

   [c] Remove the shim.
6. Install the gasket and either flat or tamper-resistant cover with two copper washers and two 5/16 in.-18 x 4 1/2 in. bolts (flat cover). Tighten the bolts.

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⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

NOTICE:

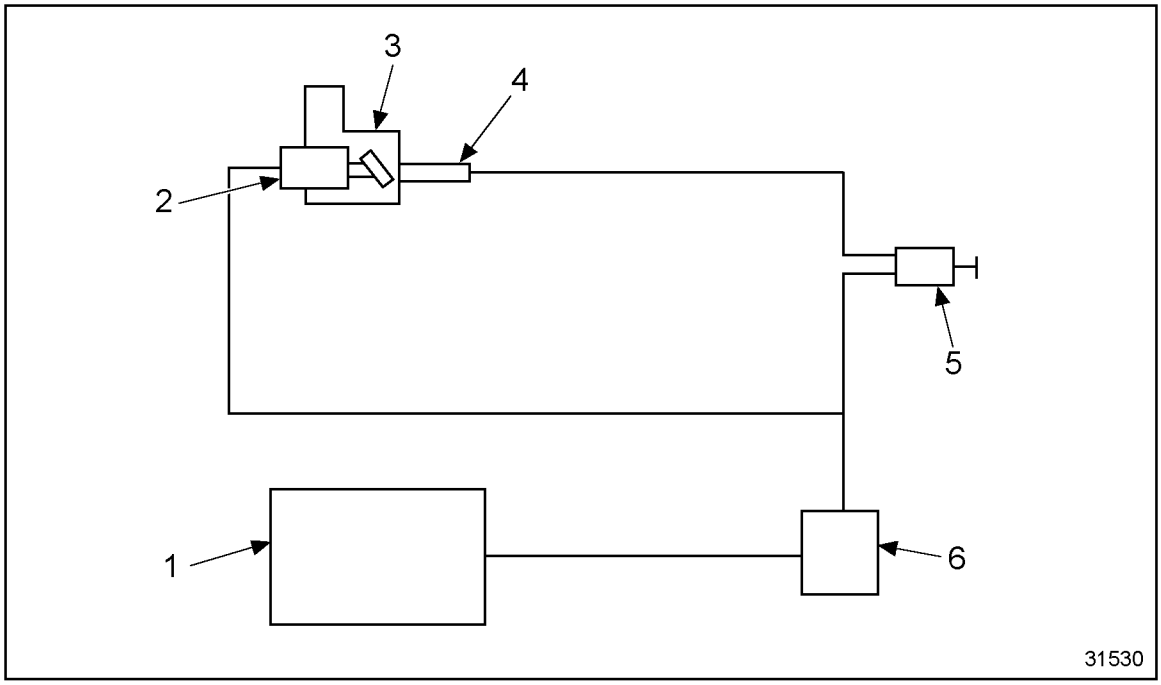
Before starting an engine after an engine speed control adjustment or after engine governor cover and lever assembly removal, determine if the injector racks move to the no fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

7. Install the air cylinder on the governor cover so that it does not interfere with the throttle linkage when no air pressure is applied. When full air pressure is applied, the speed control lever should be wide open. See Figure 2-161.

NOTE:
Supply air should only be taken from the accessory air supply. At no time should supply air be taken from the service brake system. All air supply components however, should

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be plumbed and mounted in compliance with the recommendations for the air brake system. Both air cylinders must be vented to ensure rapid disengagement.



1. Air Supply
2. Throttle Lock Air Cylinder
3. Governor
4. VHS Housing
5. Regulator
6. On/Off Valve

Figure 2-161 Schematic Drawing of Limiting Speed Mechanical Governor (Variable High Speed)

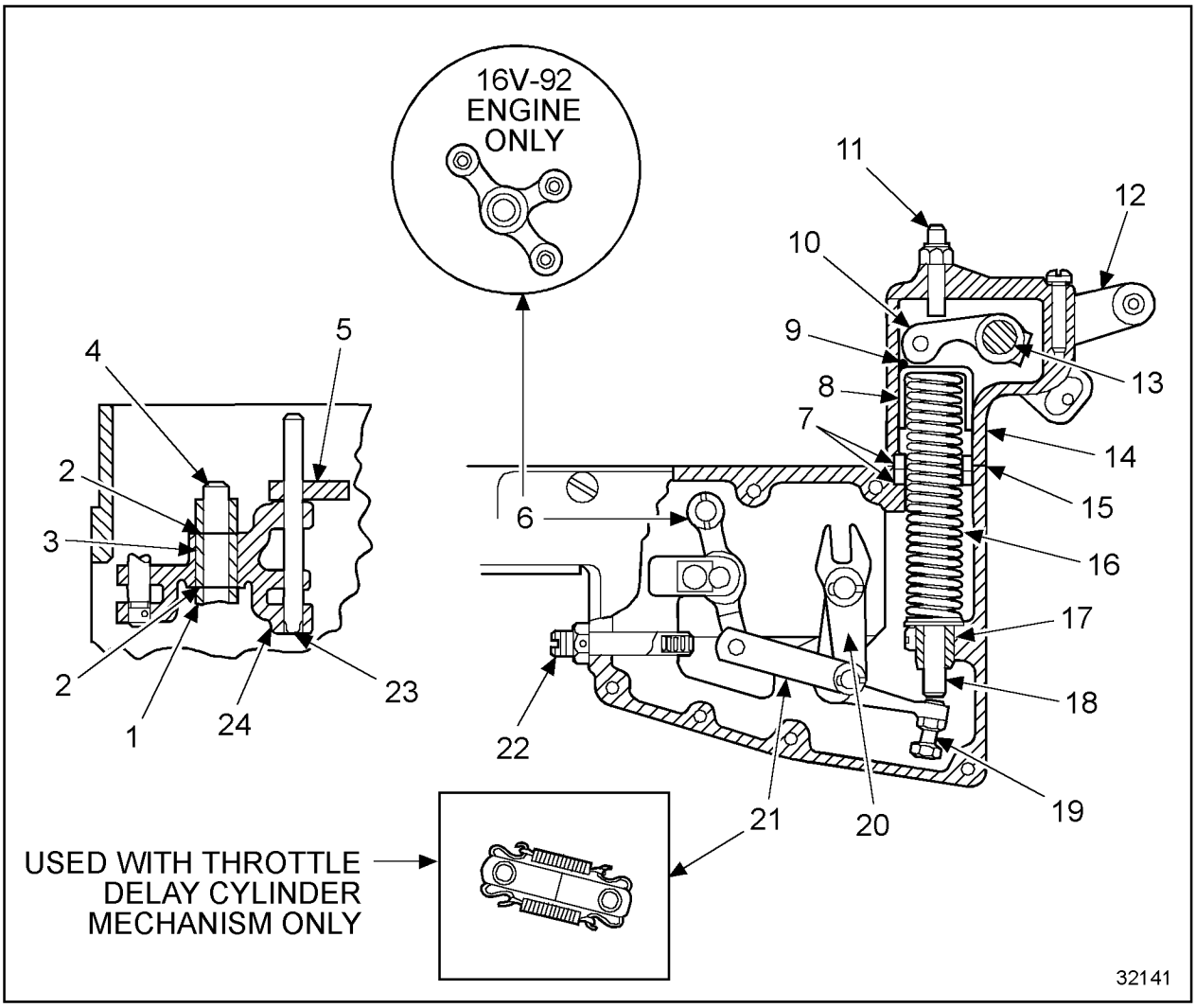
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2.27 VARIABLE SPEED MECHANICAL GOVERNOR

The variable speed mechanical governor performs the following three functions:

1. It controls the engine idle speed.
2. It limits the maximum no-load speed.
3. It holds the engine at any constant speed, between idle and maximum, desired by the operator. See Figure 2-162 and see Figure 2-163.

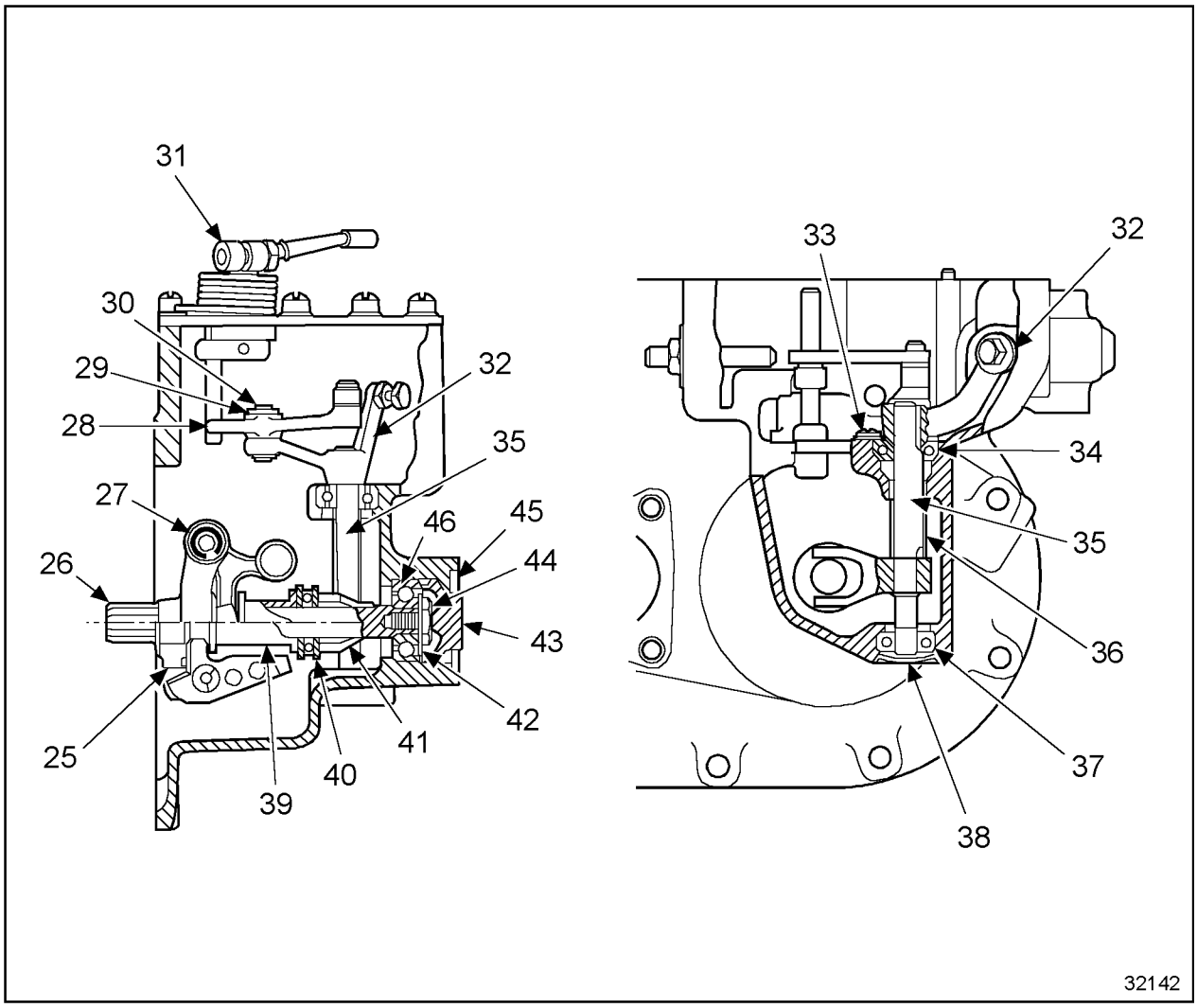
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1. Governor Housing
2. Flat Washers
3. Needle Bearings
4. Control Link Lever Shaft
5. Operating Lever Connecting Link
6. Control Link Operating Lever
7. Governor Stops
8. Spring Retainer
9. Governor Shims
10. Spring Lever
11. Idle Speed Adjusting Screw
12. Speed Control Lever
13. Speed Control Lever Shaft
14. Variable Speed Spring Housing
15. Gasket
16. Variable Speed Spring
17. Plunger Guide
18. Variable Speed Spring Plunger
19. Gap Adjusting Screw
20. Differential Lever
21. Connecting Link
22. Buffer Screw
23. Connecting Pin
24. Control Link Operating Lever Assembly

Figure 2-162 Cross Section of Variable Speed Mechanical Governor (1 of 2)

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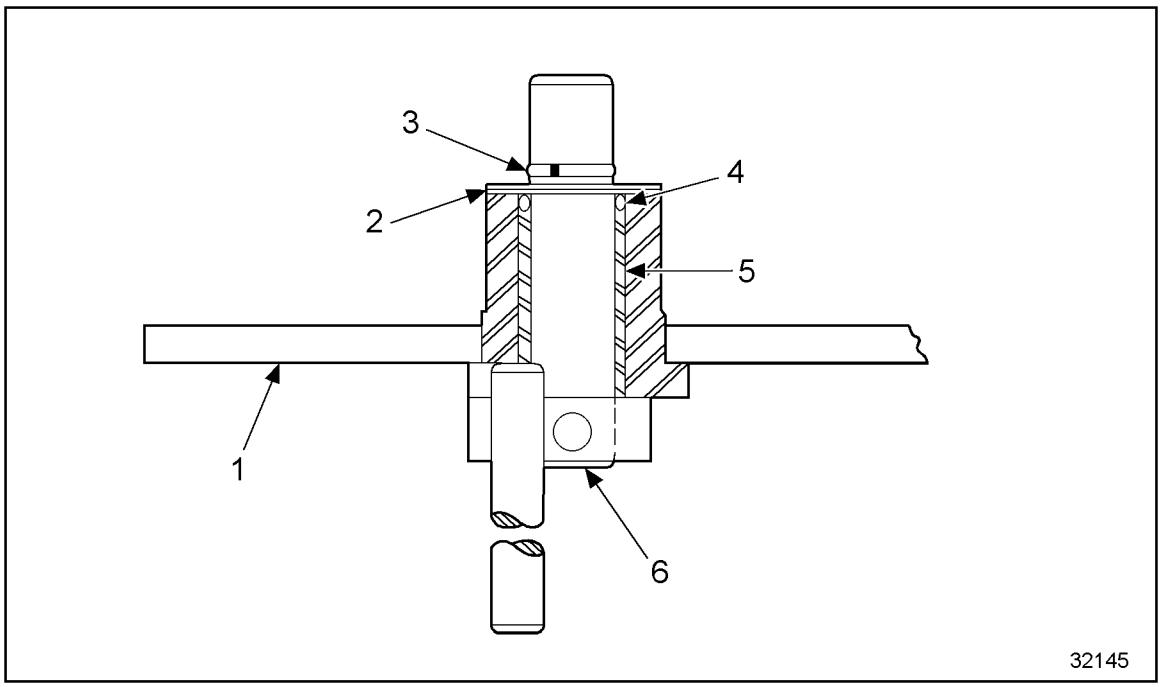
25. Carrier and Weight Assembly (Non-Turbocharged)
26. Weight
27. Carrier and Weight Assembly (Turbocharged)
28. Differential Lever
29. Plain Washer
30. Spring Retainer
31. Stop Lever
32. Operating Shaft Lever
33. Operating Shaft Retaining Screw
34. Operating Shaft Upper Bearing
35. Operating Shaft
36. Spacer
37. Operating Shaft Lower Bearing
38. Expansion Plug
39. Riser
40. Riser Thrust Bearing
41. Fork
42. Lock Washer
43. Housing Plug
44. Bearing Retaining Bolt
45. Gasket
46. Weight Shaft Bearing

Figure 2-163 Cross Section of Variable Speed Mechanical Governor (2 of 2)

The nameplate attached to the governor housing identifies the mechanical engine governor. The letters "S.W.-V.S." stamped on the nameplate denote a single-weight variable speed governor.

On 6V and 8V engines, the governor is mounted on the front end of the blower. On 12V and 16V engines, the governor is mounted on the front end of the rear blower and the governor auxiliary drive housing is mounted on the rear end of the front blower. The governors are driven by a blower rotor. The governor assembly consists of three subassemblies.

1. Control Housing Cover
2. Variable Speed Spring Housing and Shaft
3. Control and Weight HousingFor 12V and 16V turbocharged engines, the governor has three weights and a heavier variable speed spring. See Figure 2-164.



1. Cover Assembly
2. Retaining Washers
3. Snap Ring
4. Seal Ring
5. Bushing
6. Stop Lever Shaft Assembly

Figure 2-164 Cross Section of Governor Cover Assembly

To provide additional design features, a new die cast governor cover with serrated shafts and three bosses is now being used. One boss is drilled for the variable speed governor shutdown (run/stop) shaft.

NOTE:
If a customer furnished mounting bracket is attached to the new cover, it may be necessary to rework the old bracket to clear the unused cast bosses (two for variable speed governors).

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The die cast governor cover assemblies include a 1/2 in. diameter serrated shutdown shaft for variable speed governors. This assures positive clamping between the serrated levers and the shafts to prevent any slippage.

Four serrations are eliminated on the shutdown shafts to permit customers to design a mating lever with missing serrations, that will provide a fixed position for particular requirements. Levers are not provided with missing serrations.

To reduce governor speed control lever shaft assembly stop pin wear and prolong bushing and O-ring seal life, a yieldable speed control lever is available. This yieldable speed control lever cannot be used with the former stamped cover assemblies. A service yieldable speed control lever is available for use with the stamped cover.

The former and new cover and shaft assemblies are interchangeable on a governor.

NOTE:
When only a former cover needs replacing, replace the cover and shaft assembly. Only the new cover is serviced separately. The former control shafts and levers will continue to be serviced for the former governors.

Two manual controls are provided on the variable speed governor, a governor stop lever, and a speed control lever. For starting, the governor stop lever is moved to the RUN position. This moves the injector control racks to the FULL-FUEL position. Upon starting, the governor moves the injector racks out to the position required for idling. The manual speed control lever controls the engine speed.

The centrifugal force of the revolving governor weights is converted into linear motion, which is transmitted through the riser and operating shaft to the operating shaft lever. One end of the operating shaft lever bears against the variable speed spring plunger, while the other end provides a changing fulcrum on which the differential lever pivots.

The centrifugal force of the governor weights is opposed by the variable speed spring. Load changes or movement of the speed control lever create an unbalanced force between the revolving governor weights and tension on the variable speed spring. When the two forces are equal, the engine speed stabilizes for a setting of the speed control lever.

The differential lever through the operating lever connecting link operates the fuel rods connected to the injector control tube levers and the control link operating lever assembly. This arrangement provides a means for the governor to change the fuel settings of the injector rack control levers.

The centrifugal force required to balance out the tension on the variable speed spring in the low-speed range determines the engine idle speed.

Changing the tension on the variable speed spring by means of the idle speed adjusting screw adjusts the engine idle speed. Refer to section 12.4.18 6V and 8V, or refer to section 12.5.5 12V and 16V.

Installing or removing stops and shims to vary the tension on the variable speed spring adjusts the maximum no-load speed. Refer to section 12.4.16 for 6V and 8V or refer to section 12.5.6 12V and 16V for the maximum no-load speed adjustment.

A spray of lubricating oil from the blower end plate lubricates the governor. The governor weights distribute this oil to all parts of the governor assembly requiring lubrication.

Oil returning from the governor is directed through passages in the blower end plate and cylinder block to the engine oil pan.

2.27.1 Repair or Replacement of Variable Speed Mechanical Governor

To determine if repair or replacement is necessary, perform the following procedure. See Figure 2-165.

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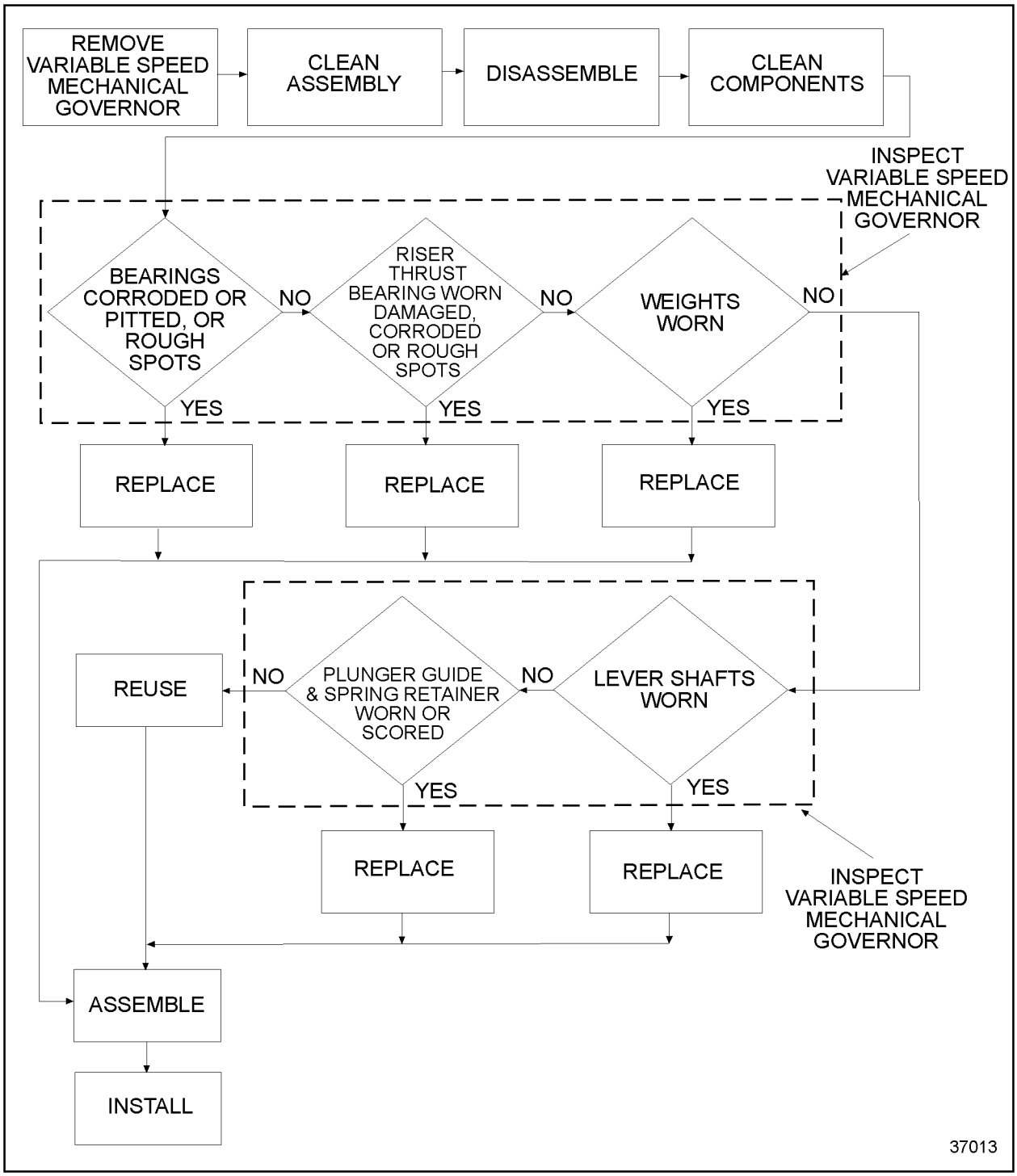
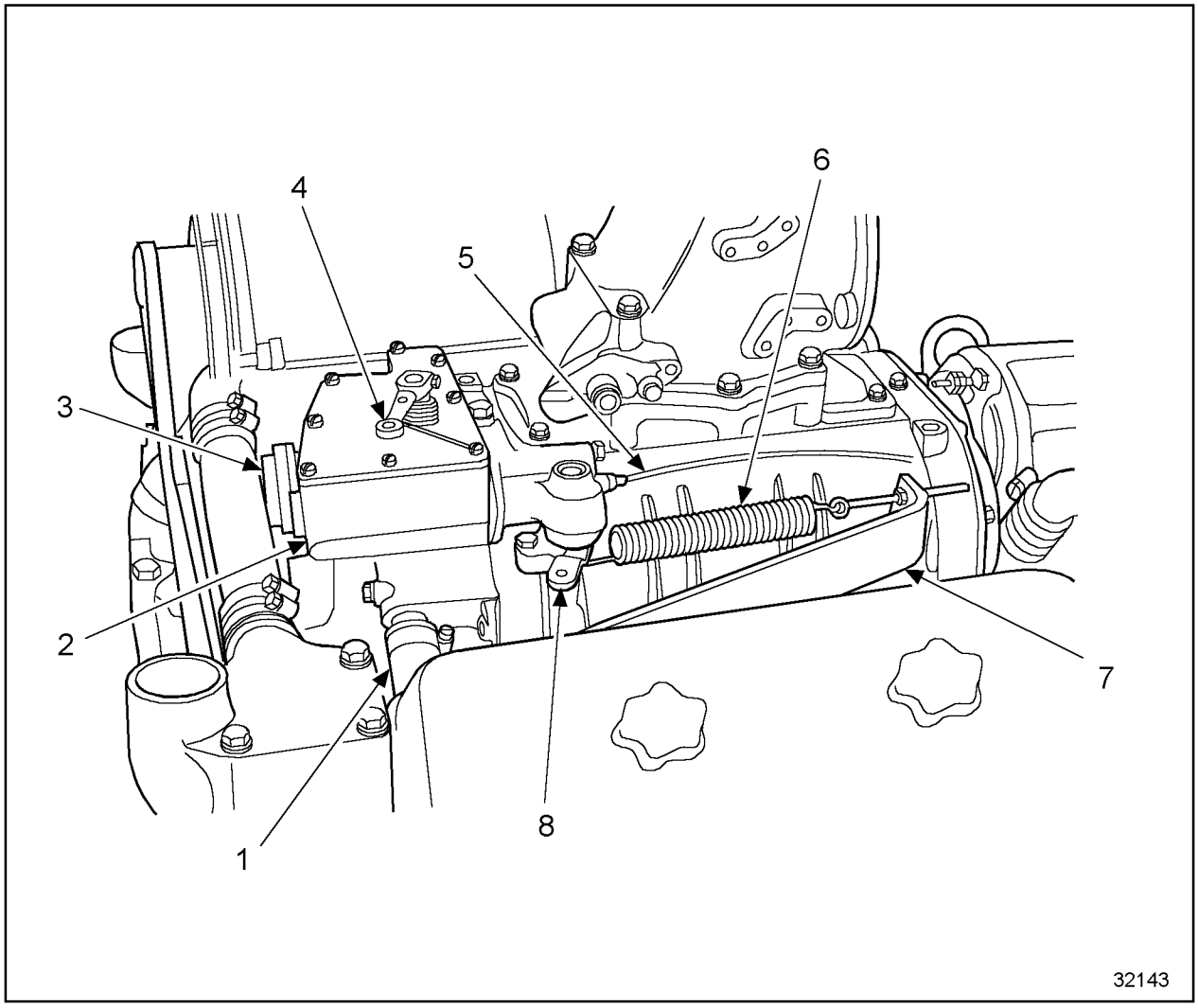


Figure 2-165 Flowchart for Repair or Replacement of Variable Speed Mechanical Governor

2.27.2 Removal of Variable Speed Mechanical Governor (6V and 8V Engines)

Remove the governor as follows:

1. Open the drain cocks, and drain the engine cooling system. Refer to section 13.12.3.
2. Remove any accessories attached to the cylinder head, governor, or front end of the engine that interfere with the removal of the governor assembly.
3. Disconnect the control linkage from the speed control and stop levers. See Figure 2-166.



1. Fuel Rod Cover
2. Governor
3. Fuel Pump
4. Stop Lever
5. Blower
6. Booster Spring
7. Booster Spring Bracket
8. Speed Control Lever

Figure 2-166 Variable Speed Governor Mounting (6V and 8V Engines)

4. Remove the end of the stop lever return spring from behind the head of the special governor cover attaching screw.

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5. Remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.

Remove the fuel rods from the control link operating lever assembly and the injector control tube levers as follows:

1. Remove the valve rocker covers from the cylinder heads.
2. Remove the screw type pin, in the control link operating lever, and the clevis pin in the control tube lever. Withdraw the fuel rod from the governor.
3. Remove the clevis pin in the control tube lever to remove the left-bank fuel rod.
4. Lift the connecting pin out of the control link operating lever approximately three-quarters of an inch.
5. Withdraw the fuel rod from the governor.

Continue governor removal as follows:

1. Loosen the hose clamps at each end of the water bypass tube. Slide the hoses and clamps onto the bypass tube, and remove the tube from the engine.
2. Disconnect and remove the fuel oil lines attached to the fuel pump and the crossover fuel oil line attached to each cylinder head.
3. Loosen the outer booster spring adjusting nut, and remove the booster spring from the speed control lever.
4. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head, and slide each hose and clamp up on the tube in the governor housing.
5. Note the location of the two copper, one plain, and eight lock washers on the governor to blower bolts before removing them. Remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.
6. Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower.
7. Pull the governor and fuel pump assembly straight out from the dowels in the blower end plate. Remove the governor to blower gasket.

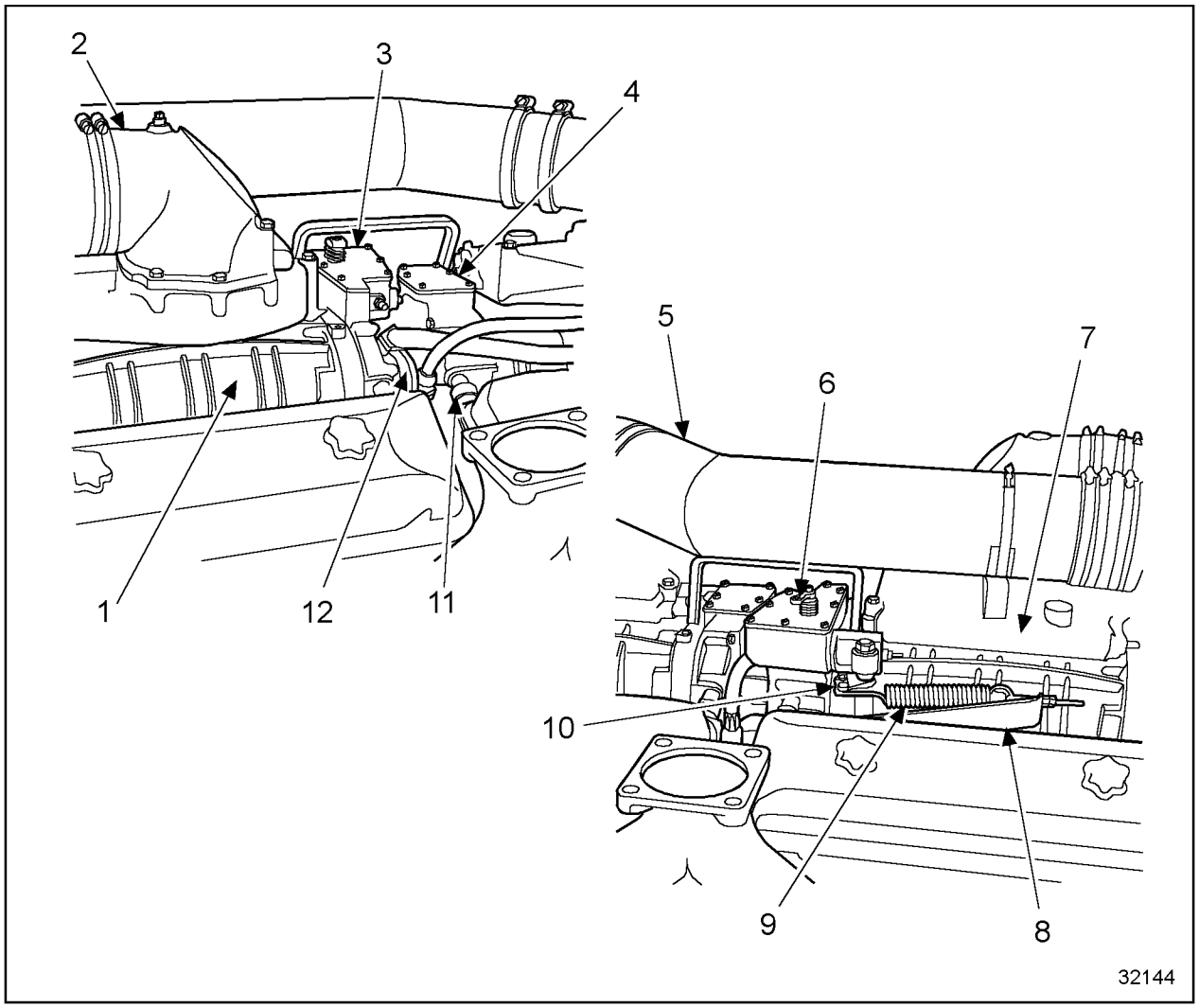
NOTE:
The fuel pump drive coupling fork may stay on either the fuel pump or the blower rotor shaft.

8. Remove the drive coupling fork.
9. Remove the three bolt and seal assemblies securing the fuel pump assembly to the governor housing. Remove the fuel pump and gasket from the governor housing.

2.27.3 Removal of Variable Speed Mechanical Governor (12V and 16V Engines)

Remove the governor as follows:

1. Disconnect the linkage attached to the governor speed control and stop levers. See Figure 2-167.



1. Blower Assembly
2. Air Shutdown Assembly
3. Governor Assembly
4. Auxiliary Control Line Housing
5. Air Inlet Housing
6. Stop Lever
7. Air Shutdown Housing Adaptor
8. Booster Spring Bracket
9. Booster Spring
10. Speed Control Lever
11. Fuel Rod Cover
12. Fuel Pump

Figure 2-167 Variable Speed Governor Mounting (12V and 16V Engines)

2. On non-turbocharged engines, disconnect the air inlet tube attached to the air shutdown housing on each blower.
3. On turbocharged engines, disconnect the tube from the turbocharger and the air shutdown housing on the rear blower.

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4. On marine engines, remove the air silencers from both air shutdown housings.
5. On non-turbocharged engines, remove the air shutdown housings and the air shutdown adaptor from the rear blower.
6. On turbocharged engines, disconnect the shutdown rod from the lever on the rear air shutdown housing. Remove the two air shutdown housings, with attaching rod, as a unit from the adaptors or the blowers.
7. Cover the top of the blower with masking tape to prevent the entry of foreign material.
8. Remove the rear cylinder head rocker covers.
9. Remove the end of the stop lever return spring from behind the head of the special governor cover attaching screw.
10. Remove the eight screws and lock washers securing the governor cover to the housing. Lift the cover and gasket from the housing.
11. Remove the governor auxiliary control link housing cover screws and lock washers. Remove the cover and gasket from the housing.

Disconnect the fuel rods from the control link operating lever and the injector control tube levers as follows:

1. Remove the screw type pin in the control link operating lever and the pin in the control tube lever. Withdraw the fuel rod through the top of the governor housing.
2. Remove the connecting pin from the control link operating lever and the pin in the control tube lever. Withdraw the fuel rod out through the top of the governor housing.

Continue governor removal as follows:

1. Lift or pry each end of the connecting link off of the ball joint studs. Remove the connecting link from the governor housing.
2. Loosen the fuel rod cover hose clamp at each side of the governor housing. Slide each hose against the governor housing. Tighten each clamp to retain it on the hose.
3. Loosen the hose clamp between the governor housing and the auxiliary control link housing. Slide the hose forward against the auxiliary control link housing. Tighten the clamp to retain it on the hose.
4. Disconnect the fuel pump inlet and outlet tubes or hoses from the fuel pump. Remove the fuel pump from the governor housing.
5. Loosen the outer booster spring adjusting nut, and remove the booster spring from the speed control lever. Remove the booster spring bracket from the cylinder head.
6. Disconnect the blower drive support oil tube from the fitting in the blower drive support.
7. Loosen the two bolts securing the oil tube seal ring retaining plate to the blower end plate, and push the oil tube into the end plate.
8. Remove the six bolts and lock washers securing the flywheel housing hole cover at the blower drive support, and remove the cover and gasket.

2.27.4 Removal of Variable Speed Mechanical Governor (Engine Equipped with a Rear Mounted Battery-Charging Alternator)

On an engine equipped with a rear mounted battery-charging alternator, loosen and remove the alternator drive belt.

1. Remove the alternator drive pulley nut and pulley from the alternator drive shaft.
2. Remove the bolts and lock washers securing the alternator drive assembly to the flywheel housing, and remove the drive assembly, gasket and drive coupling from the flywheel housing.

2.27.5 Removal of Variable Speed Mechanical Governor Continued (12V and 16V Engines)

Continue governor removal as follows:

1. On an engine equipped with a hydraulic oil pump, remove the six bolts and lock washers securing the oil pump to the flywheel housing and adaptor.
2. Remove the oil pump, adaptor and gaskets from the flywheel housing. Remove the drive coupling and the drive coupling hub from the blower drive shaft.
3. Remove the blower drive shaft retaining snap ring from the blower drive coupling, and remove the blower drive shaft from the blower drive hub and the blower drive support.
4. Loosen the blower drive support-to-blower hose (seal) clamps. Push the hose (seal) back on the blower drive support.
5. Remove the bolt and washer through the top of each blower end plate securing the blower to the cylinder block.
6. Remove the bolts and retaining washers on each side of the blower securing the blower to the cylinder block.
7. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.
8. Lift the blower assembly, and move it forward to detach the blower from the hose (seal).
9. Lift the blower away from the engine, and place it on a bench.
10. Remove the blower to cylinder block gasket.
11. Remove the ten bolts, lock washers, plain washer, and copper washers securing the governor assembly to the blower end plate.
12. Slide the governor assembly forward off of the dowel pins in the end plate, and remove the governor to blower end plate gasket.

2.27.5.1 Cleaning of Variable Speed Mechanical Governor

Wash and inspect the governor prior to disassembly as follows:

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Before removing any parts from the governor, wash the entire unit in clean fuel oil.

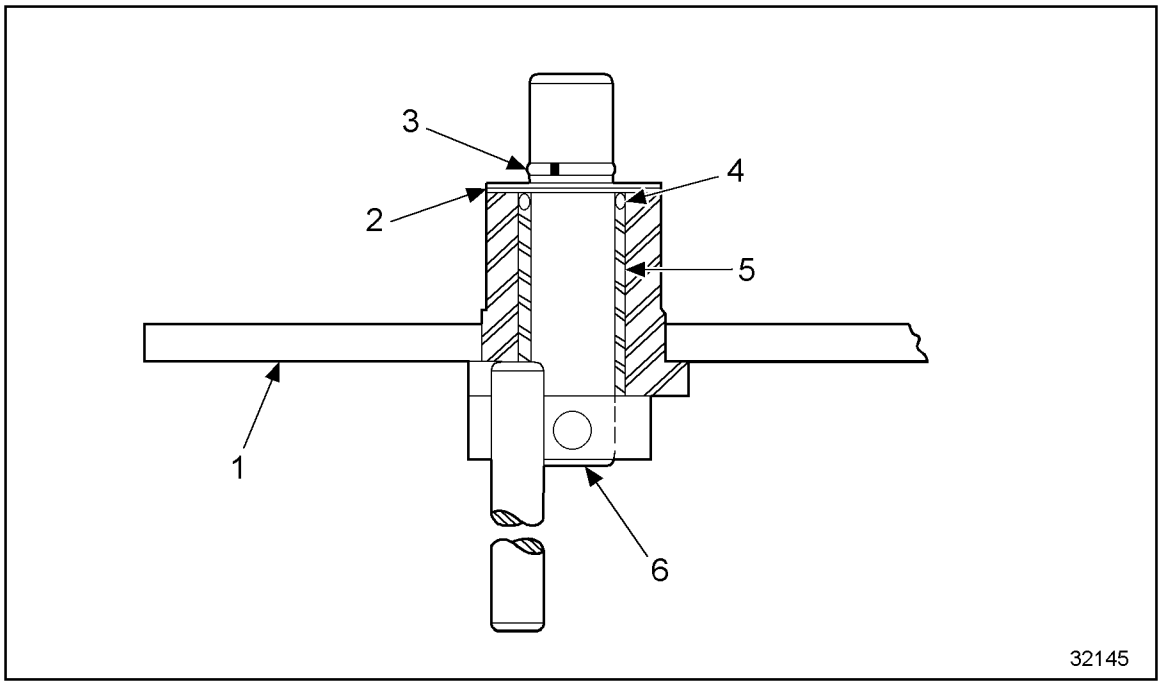
⚠ CAUTION:

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. Inspect for worn or damaged parts that may be repaired or replaced without complete disassembly.

2.27.6 Disassembly of Variable Speed Mechanical Governor

See Figure 2-168, and disassemble the governor cover as follows:



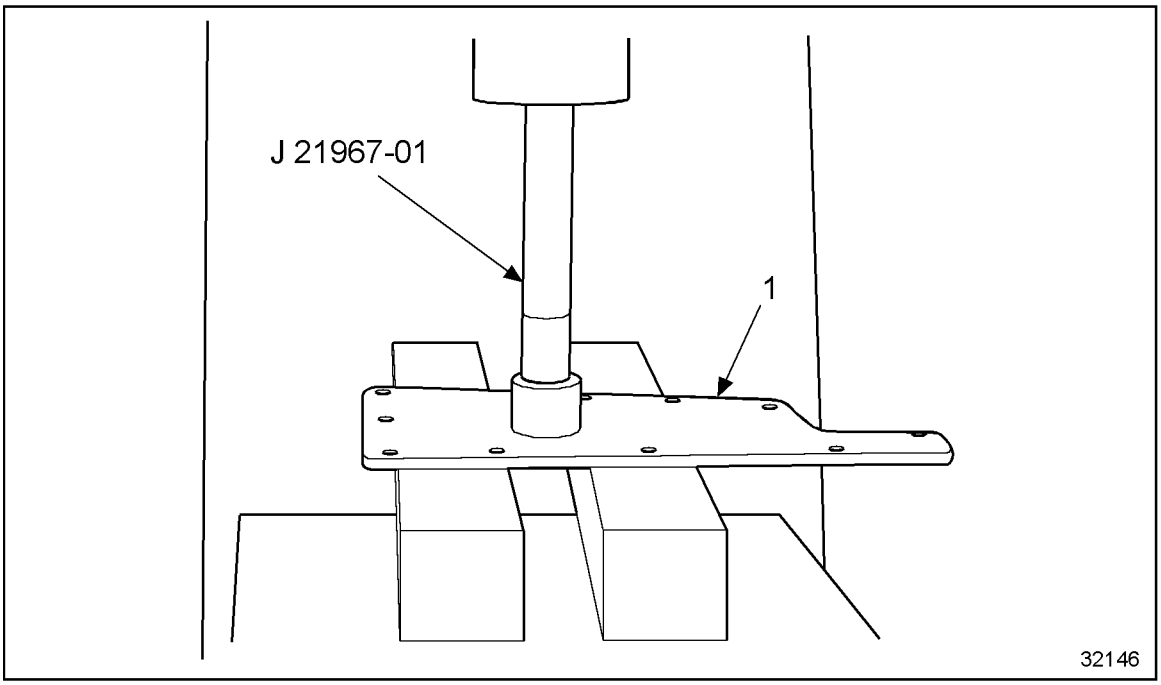
1. Cover Assembly
2. Retaining Washers
3. Snap Ring
4. Seal Ring
5. Bushing
6. Stop Lever Shaft Assembly

Figure 2-168 Cross Section of Governor Cover Assembly

1. Clamp the cover assembly in a soft-jawed vise.
2. Loosen the stop lever retaining bolt, and pull the lever from the shaft. Remove the return spring from the shaft.
3. Remove the snap ring from the groove in the stop lever shaft, and remove the two seal ring retaining washers.
4. Pull the stop lever shaft out of the cover, and remove the seal ring (on top of the bushing) from the cover.
5. At this stage of disassembly, wash the cover assembly (containing the bushing) thoroughly in clean fuel oil, and inspect the bushing for wear and damage.
6. If the bushing is satisfactory for further use, removal is unnecessary.
7. If bushing removal is necessary, support the inner face of the cover over the opening in the arbor press bed.

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8. Place the remover J 21967-01 on top of the stop shaft bushing, and press the bushing out of the cover. See Figure 2-169.



1. Governor Cover

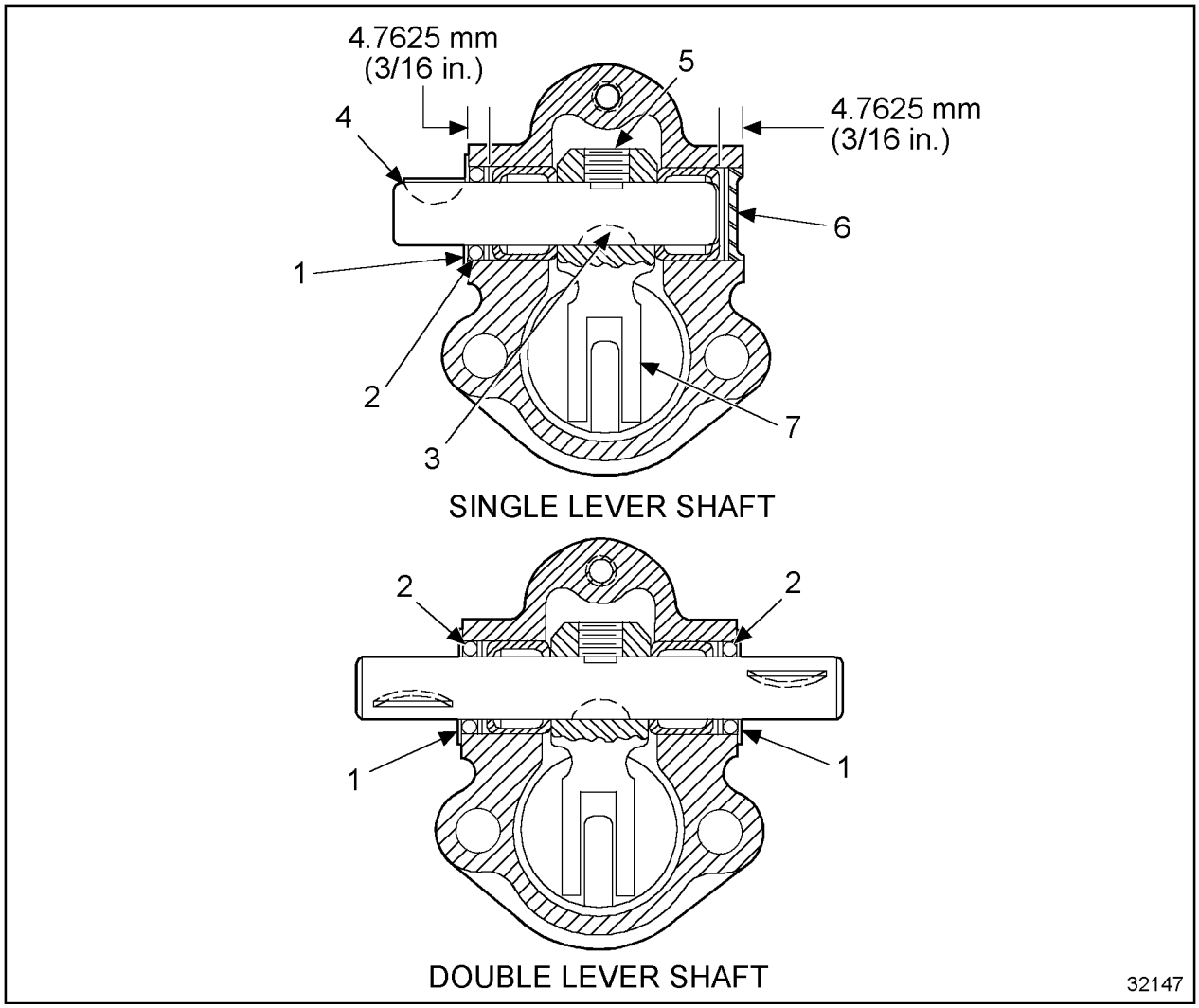
Figure 2-169 Removing Stop Lever Shaft Bushing From the Governor Cover using J 21967-01

Remove the variable speed spring, spring plunger, and spring housing assembly from the governor housing as follows:

1. Clamp the flange of the governor housing in a soft-jawed vise.
2. Remove the two bolts and lock washers securing the variable speed spring housing to the governor housing.
3. Withdraw the spring housing, spring retainer, shims, split stop and spring from the governor housing as an assembly.
4. Remove the spring housing gasket.
5. Remove the variable speed spring, split stop, shims, and spring retainer from the spring housing.
6. Remove the spring plunger from the plunger guide.
7. Remove the spring retainer solid stop from the governor housing.
8. If necessary, remove the variable speed spring plunger guide from the governor housing with a small brass rod and hammer.

Disassemble the variable speed spring housing as follows:

1. Loosen the bolt securing the speed control lever to the speed control shaft, and pull the lever from the shaft.
2. Remove the Woodruff key and flat washer from the speed control shaft.
3. Remove the pipe plug in the top of the variable speed spring housing. Remove the variable speed spring lever set screw from the speed control shaft and spring lever. See Figure 2-170.

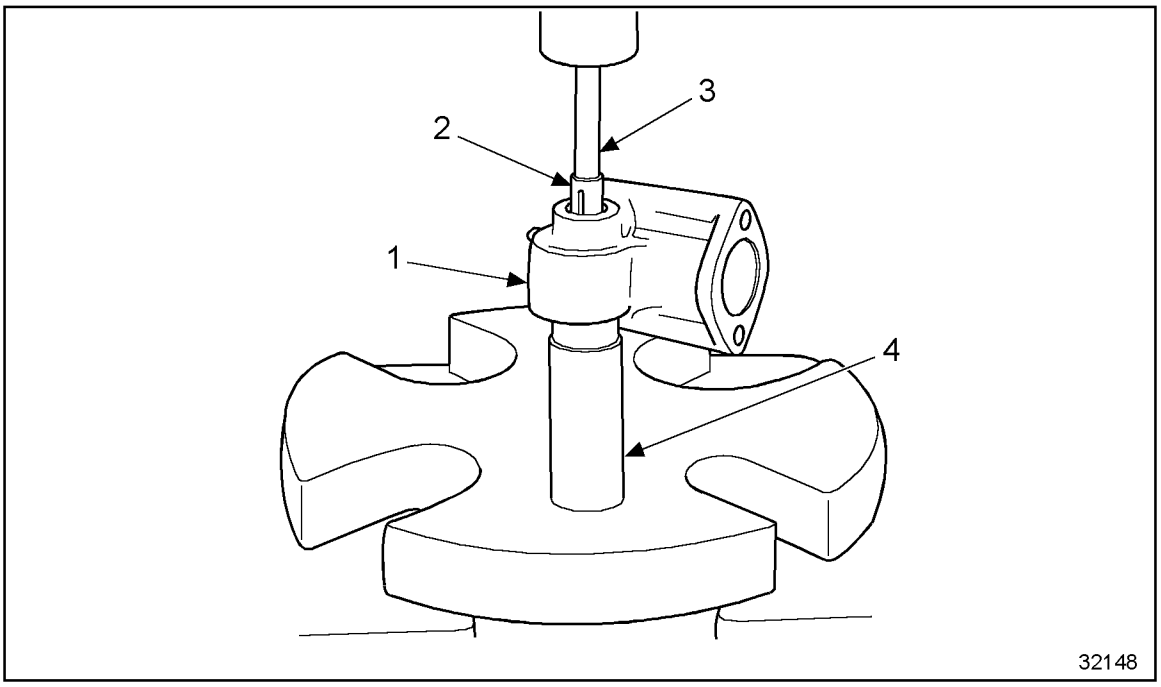


1. Plain Washer
2. Seal Ring
3. Key
4. Speed Control Shaft
5. Set Screw
6. Cup Plug
7. Spring Lever

Figure 2-170 Cross Section of Governor Variable Speed Spring Housing

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4. Place a 3/4 in. inside diameter sleeve approximately 1-1/2 in. long on the arbor press bed. Support the spring housing assembly on top of the sleeve with the cup plug, if used, in the side of the housing over the sleeve opening.
5. Place a small brass rod on the shaft end. See Figure 2-171. Press the plug, if used, and bearing out of the spring housing.



1. Spring Housing
2. Control Shaft
3. Brass Rod
4. Sleeve

Figure 2-171 Removing Speed Control Shaft, Bearing and Cup Plug from Variable Speed Spring Housing

6. Remove the spring lever from the spring housing and the bearing from the speed control shaft. Discard the bearing. If necessary, remove the Woodruff key from the shaft.

NOTICE:

Do not reuse the needle bearing. The inner end of the needle bearing is damaged when pressed out of the spring housing.

CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

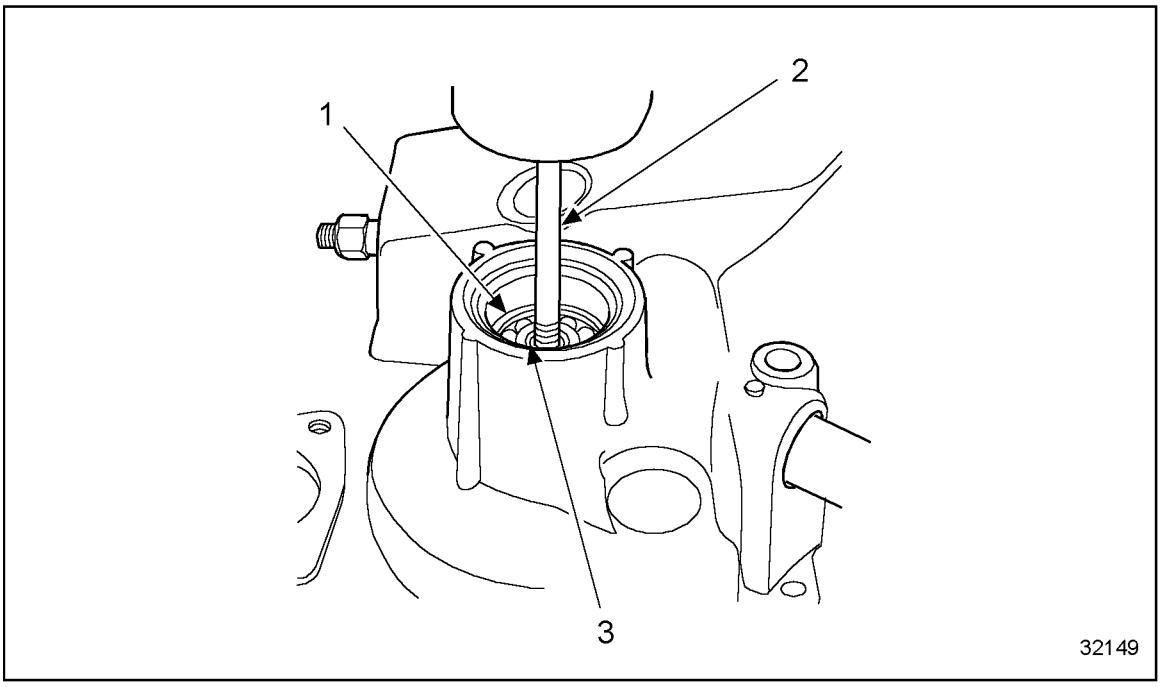
7. Wash the spring housing, containing the remaining bearing, thoroughly in clean fuel oil.
8. Inspect the needle bearing for wear and damage.
   [a] If worn or damaged, continue disassembly.
   [b] If the bearing is satisfactory for further use, bearing removal is unnecessary.
9. If needle bearing removal is necessary, support the spring housing, bearing side down, on top of the 3/4 in. inside diameter sleeve on the arbor press bed.
10. Insert the bearing remover J 21967-01 through the housing, and rest it on top of the bearing. Press the bearing out of the housing.

Remove the governor weight and shaft assembly from the governor housing as follows:

1. Clamp the governor housing flange in a soft-jawed vise.
2. Remove the governor weight housing plug and gasket.
3. Bend the tang on the lock washer away from the bolt head. While keeping the weight carrier from turning, remove the bearing retaining belt, flat washer, and lock washer.
4. Thread a 5/16 in.-24 x 3 in. bolt into the bearing retaining bolt hole.

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5. Support the governor housing on the arbor press bed, and press the governor weight shaft from the bearing. See Figure 2-172.



1. Bearing
2. Bolt 5/16 in.-24
3. Governor Weight Shaft

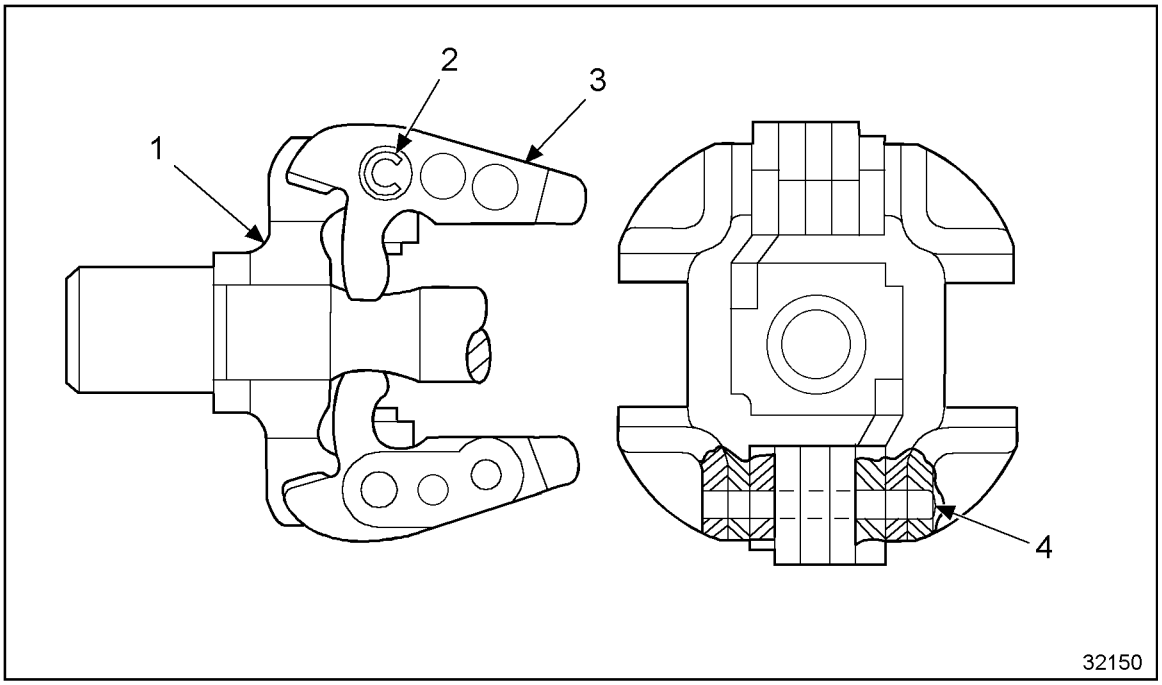
Figure 2-172 Removing Governor Weight Shaft Assembly from Governor Housing

6. Slide the governor riser thrust bearing and riser from the weight shaft.

NOTE:
The thrust bearing is specially designed to absorb thrust load. Looseness between the mating parts does not indicate excessive wear.

7. Remove the weight shaft bearing from the governor housing. If necessary, use a small brass rod and hammer and tap the bearing out of the housing.

See Figure 2-173. Remove the governor weights from the carrier and shaft assembly on non-turbocharged engines as follows:



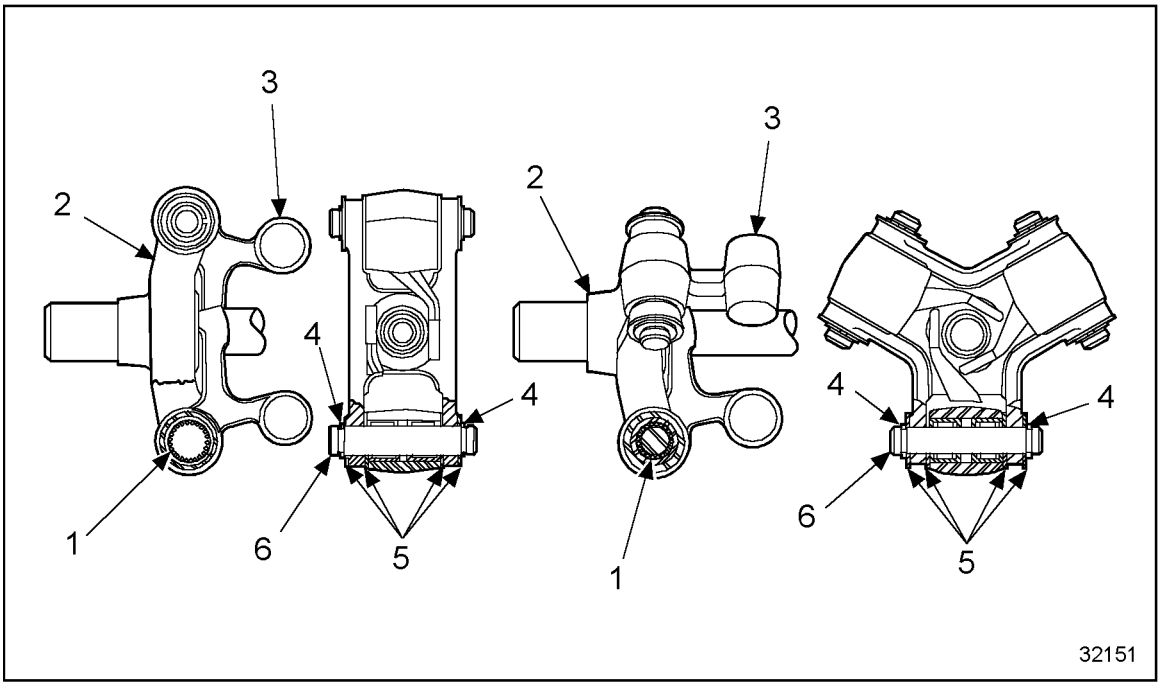
1. Weight Carrier
2. Weight Pin Snap Ring
3. Governor Weight
4. Weight Pin

Figure 2-173 Cross Section of Governor Weight Assembly (Non-Turbocharged Engines)

1. Matchmark the weights and carriers with paint or a center punch for identification.
2. Remove the retaining rings from the weight pins.
3. Drive the pins out of the carrier and the weights by tapping on the grooved end of the pins. Remove the governor weights.

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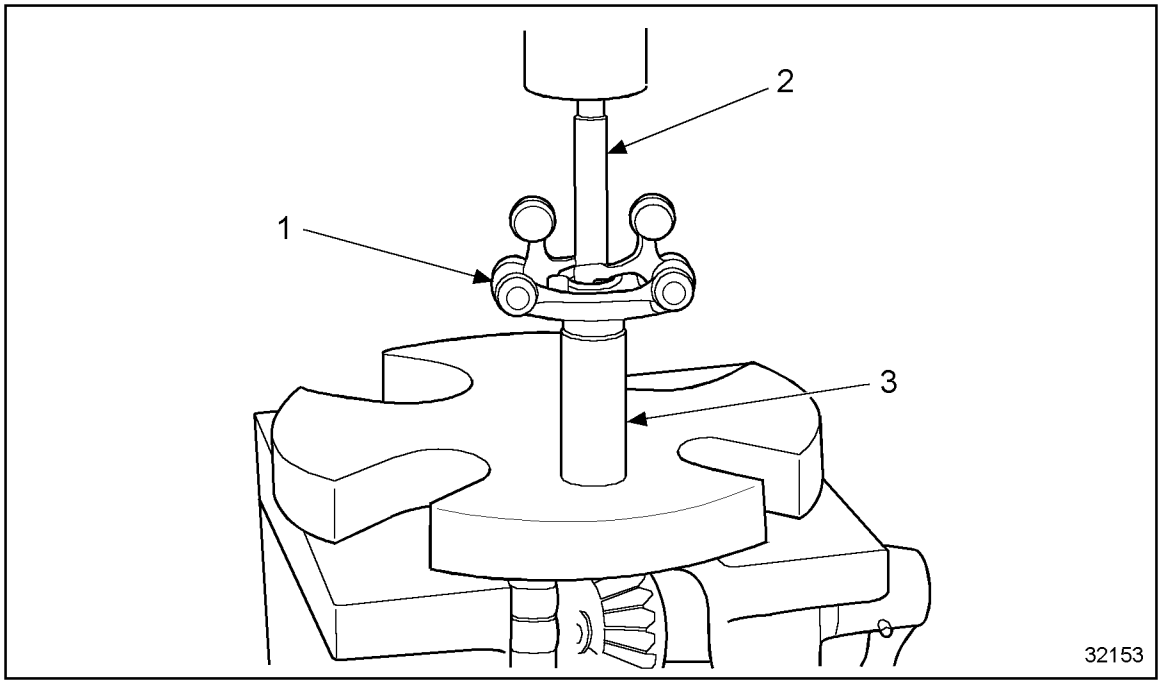
See Figure 2-174. Disassemble the governor weights and shaft assembly as follows:



1. Needle Bearings
2. Weight Carrier
3. Governor Weight
4. Lock Ring
5. Flat Washers
6. Weight Pin

Figure 2-174 Cross Section of Governor Weight Assemblies(Turbocharged Engines)

1. If weight carrier assembly removal from the shaft is necessary, support the shaft, weight carrier, and sleeve on the arbor press bed. See Figure 2-175. Press the shaft out of the weight carrier assembly.



1. Weight Carrier Assembly
2. Shaft
3. Sleeve

Figure 2-175 Removing Governor Weight Shaft from Weight Carrier Assembly

2. Remove the lock ring from the weight pin with a pair of snap ring pliers.
3. Remove the weight pin, flat washers, and weight assembly from the weight carrier.
4. Remove the second weight from the carrier.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

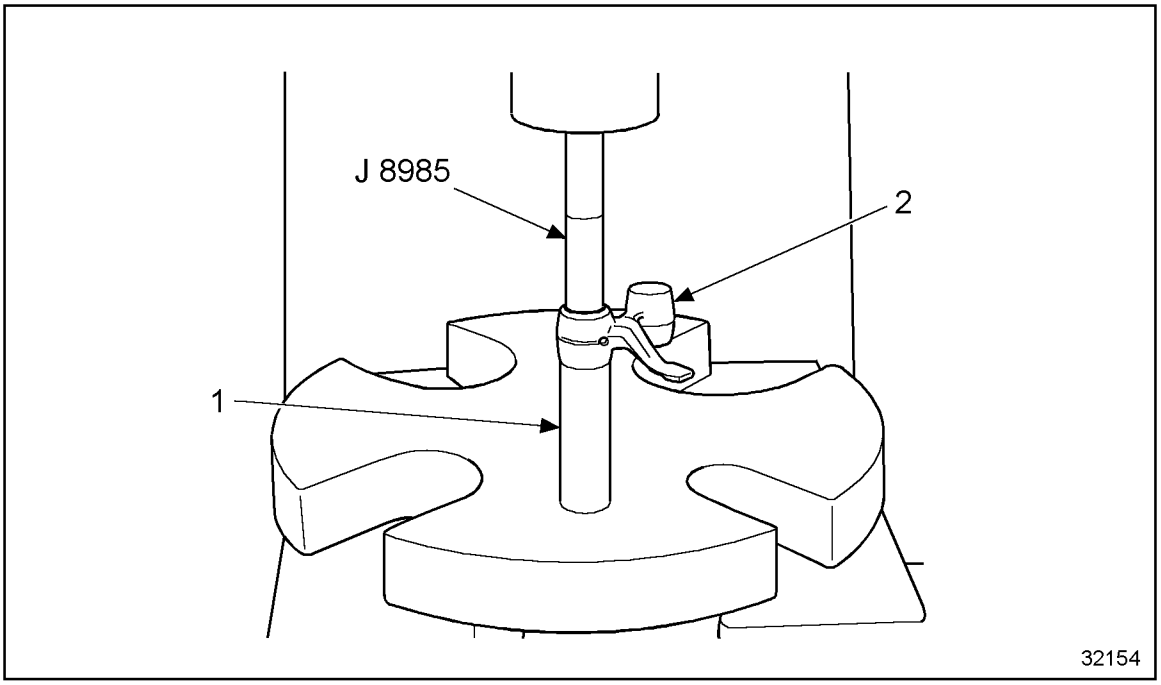
Diesel fuel is relatively harmless at ambient temperatures.

5. At this stage of disassembly, wash the weights (containing the needle bearing) thoroughly in clean fuel oil, and inspect the bearings for wear and damage.

   [a] If the bearings are worn or damaged, continue disassembly.

   [b] If the bearings are satisfactory for further use, bearing removal is unnecessary.

6. If needle bearing removal is necessary, support the weight on a 5/8 in. inside diameter sleeve on the arbor press bed. See Figure 2-176.



1. Sleeve
2. Weight

Figure 2-176 Removing Governor Weight Bearings using Tool J 8985

7. Place the bearing remover J 8985 on top of the bearing, and press both bearings out of the weight.
8. Remove the needle bearings from the second weight.

Remove the governor linkage and operating shaft from the governor housing as follows:

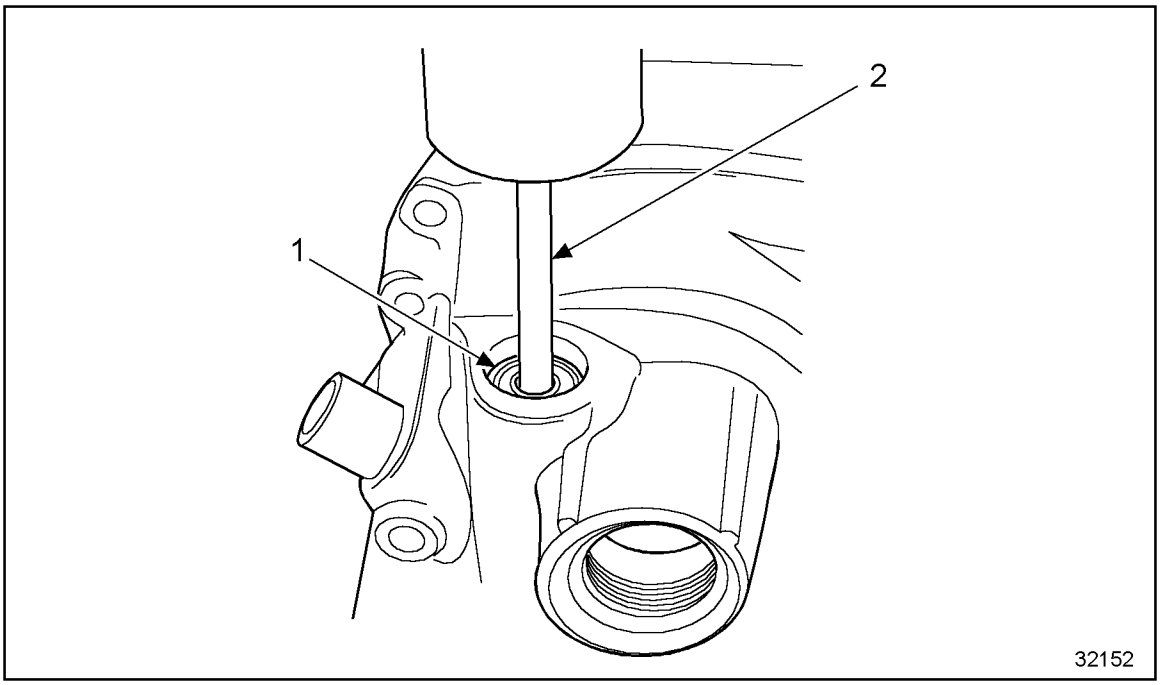
1. Remove the spring retainer and plain washer securing the connecting link to the differential lever. Remove the connecting link.
2. Remove the spring retainer and plain washer securing the differential lever to the operating shaft lever. Remove the differential lever.
3. Remove the screw, lock washer, and lock plate securing the control link operating lever shaft in the housing.

NOTE:
Do not lose the two flat washers located between the top and bottom of the lever assembly and the governor housing.

4. Lift the shaft out of the housing, and remove the operating lever and two flat washers at each side of the operating lever.
5. Remove the expansion plug from the bottom of the governor housing.
6. Remove the operating shaft upper bearing retaining screw, lock washer, and flat washer securing the bearing in the governor housing.

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7. Support the governor housing, bottom side up, on the arbor press bed with the two dowel pins in the top of the housing between the two steel supports. See Figure 2-177.



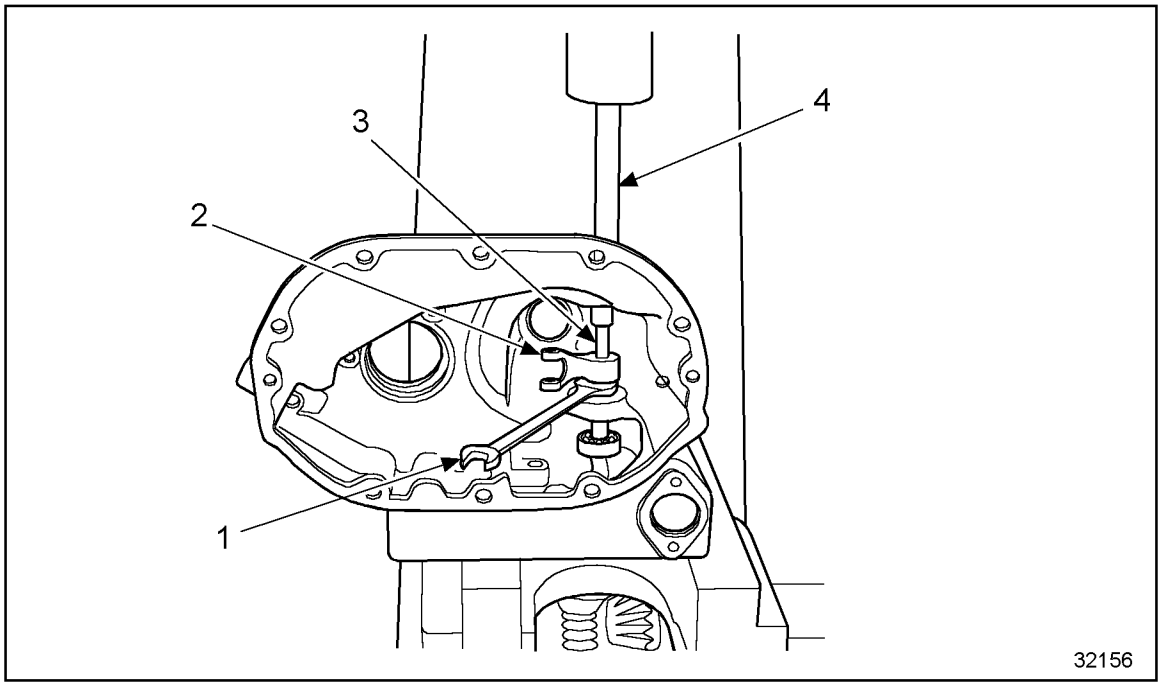
1. Lower Bearing
4. Arbor Press

Figure 2-177 Removing Operating Shaft from Operating Shaft Lower Bearing

8. Place a small brass rod on the end of the operating shaft. Press the shaft out of the bearing.

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9. Place a 9/16 in. open end wrench under the operating fork. See Figure 2-178.



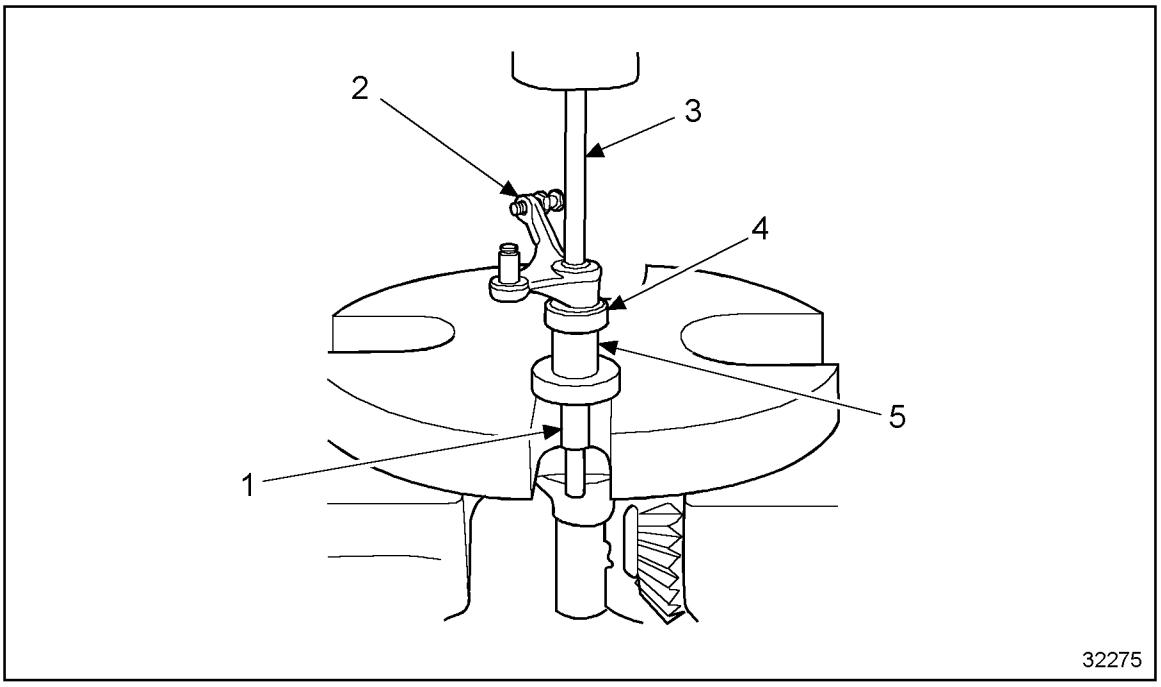
1. 9/16 in. Wrench
2. Operating Fork
3. Operating Shaft
4. Brass Rod

Figure 2-178 Removing Operating Fork, Operating Shaft and Lever Assembly from Governor Housing

10. Place a brass rod on the end of the shaft, and press the fork off the operating shaft. Remove the shaft, operating lever, and bearing from the housing as an assembly.
11. Remove the operating shaft lower bearing from the bottom of the governor housing.
12. Slide the governor operating shaft spacer from the shaft.
13. Place a short 9/16 in. inside diameter sleeve over the end of the operating shaft, and rest it against the bearing inner race on the current operating shaft, or the flat washer under the bearing on the former operating shaft.

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14. Support the operating shaft, lever, bearing, and sleeve on a large washer or plate with a 5/8 in. hole on the arbor press bed. See Figure 2-179.



1. Operating Shaft
2. Operating Lever
3. Brass Rod
4. Bearing
5. Sleeve

Figure 2-179 Removing Operating Lever and Upper Bearing from Operating Shaft

NOTICE:
Catch the shaft by hand when pressed from the lever and bearing to prevent part damage.

NOTICE:
Ensure bearing inner race is resting on the sleeve. If it is not, the bearing could be damaged.

15. Place a small brass rod on the end of the shaft, and press the operating shaft out of the operating lever and bearing.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

16. At this stage of disassembly, wash the control link operating lever (containing the bearings) thoroughly in clean fuel oil, and inspect the needle bearings for wear or damage.

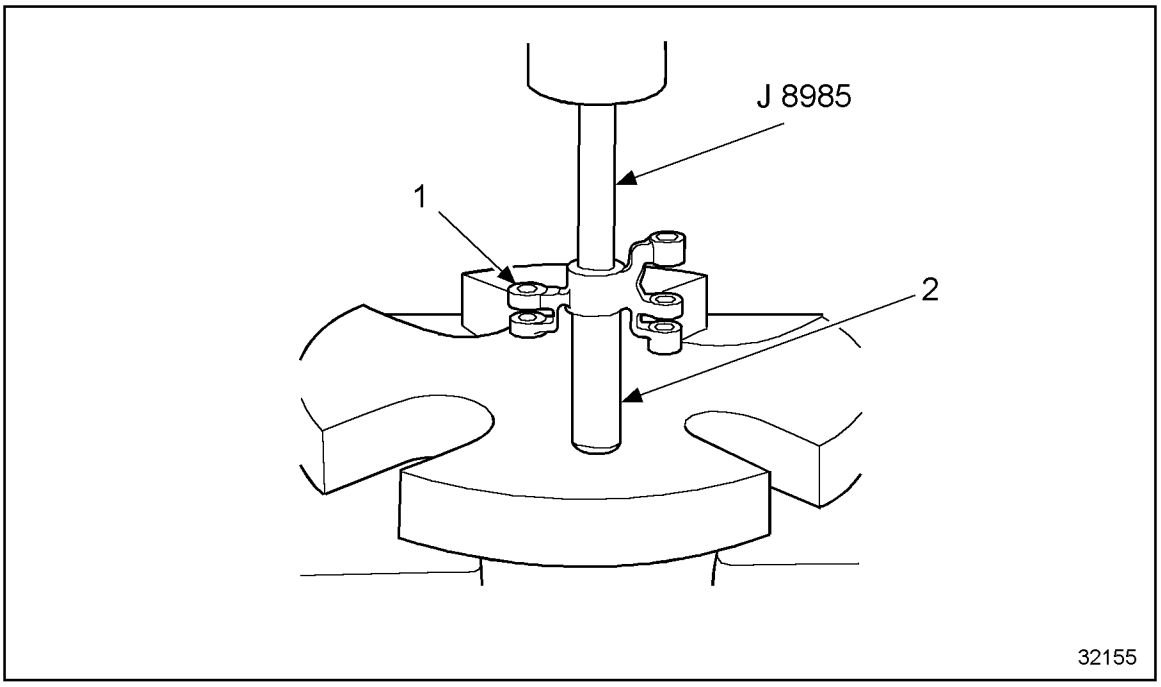
    [a] If worn or damaged, continue disassembly.

    [b] If the bearings are satisfactory for further use, bearing removal is unnecessary.

17. If needle bearing removal is necessary, support the control link operating lever on a sleeve, and rest the sleeve on the arbor press bed.

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18. Place tool J 8985 on top of the bearing, and press both bearings out of the lever. See Figure 2-180.



1. Operating Lever
2. Sleeve

Figure 2-180 Remove Operating Lever Needle Bearings using Tool J 8985

19. Remove the buffer screw from the governor housing.

2.27.6.1 Cleaning of Variable Speed Mechanical Governor

Prior to inspection, clean all parts as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash all 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 them with compressed air.

2.27.7 Inspection of Variable Speed Mechanical Governor

Inspect the variable speed mechanical governor as follows:

1. Visually inspect the bearings for corrosion or pitting.
   [a] If excessively corroded or pitted, replace the bearings. Refer to section 2.27.8.
   [b] If not corroded or pitted, continue inspection.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate each bearing with light engine oil. While keeping the bearing inner race from turning, revolve the outer race slowly by hand and check for rough spots.
   [a] If rough spots are evident, replace the bearings. Refer to section 2.27.8.
   [b] If no rough spots are detected, continue inspection.

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3. Visually inspect the riser thrust bearing for excessive wear, flat spots, damage, or corrosion.
   [a] If it is worn, damaged, corroded, or has flat spots, replace the riser thrust bearing. Refer to section 2.27.8.
   [b] If not worn, damaged, or corroded, continue inspection.
4. Visually inspect the weight carrier pins and needle bearings in the weights for wear.
   [a] If worn, replace the weight carrier pins and needle bearings. Refer to section 2.27.9.
   [b] If not worn, continue inspection.
5. Visually inspect the governor weight at the riser contact area for excessive wear.
   [a] If excessively worn, install a new governor weight. Refer to section 2.27.11.
   [b] If not excessively worn, proceed with the inspection.
6. Visually inspect the control link operating lever shaft and needle bearings for wear and damage.
   [a] If worn or damaged, replace the control link operating lever shaft and needle bearings. Refer to section 2.27.8.
   [b] If not worn or damaged, continue inspection.
7. Visually inspect the stop lever shaft and bushing in the governor cover for wear.

NOTE:
The stop lever shaft bushing is not serviced. When bushing replacement becomes necessary, it must be replaced with two needle bearings.

   [a] If worn, replace the stop lever shaft and bushing with two needle bearings. Refer to section 2.27.8.
   [b] If not worn, proceed with the inspection.
8. Visually inspect the speed control lever shaft and needle bearings in the variable speed spring housing for wear.
   [a] If worn, replace the speed control lever shaft and needle bearings. Refer to section 2.27.8.
   [b] If not worn, continue inspection.
9. Visually inspect the variable speed spring lever roller and pin for excessive wear.

NOTE:
The roller type bearing rides on a hardened bearing pin which is press fit in the spring lever and is staked at three places on both sides.

   [a] If worn, replace the variable speed spring lever roller and pin. Refer to section 2.27.8.
   [b] If not worn, continue inspection.

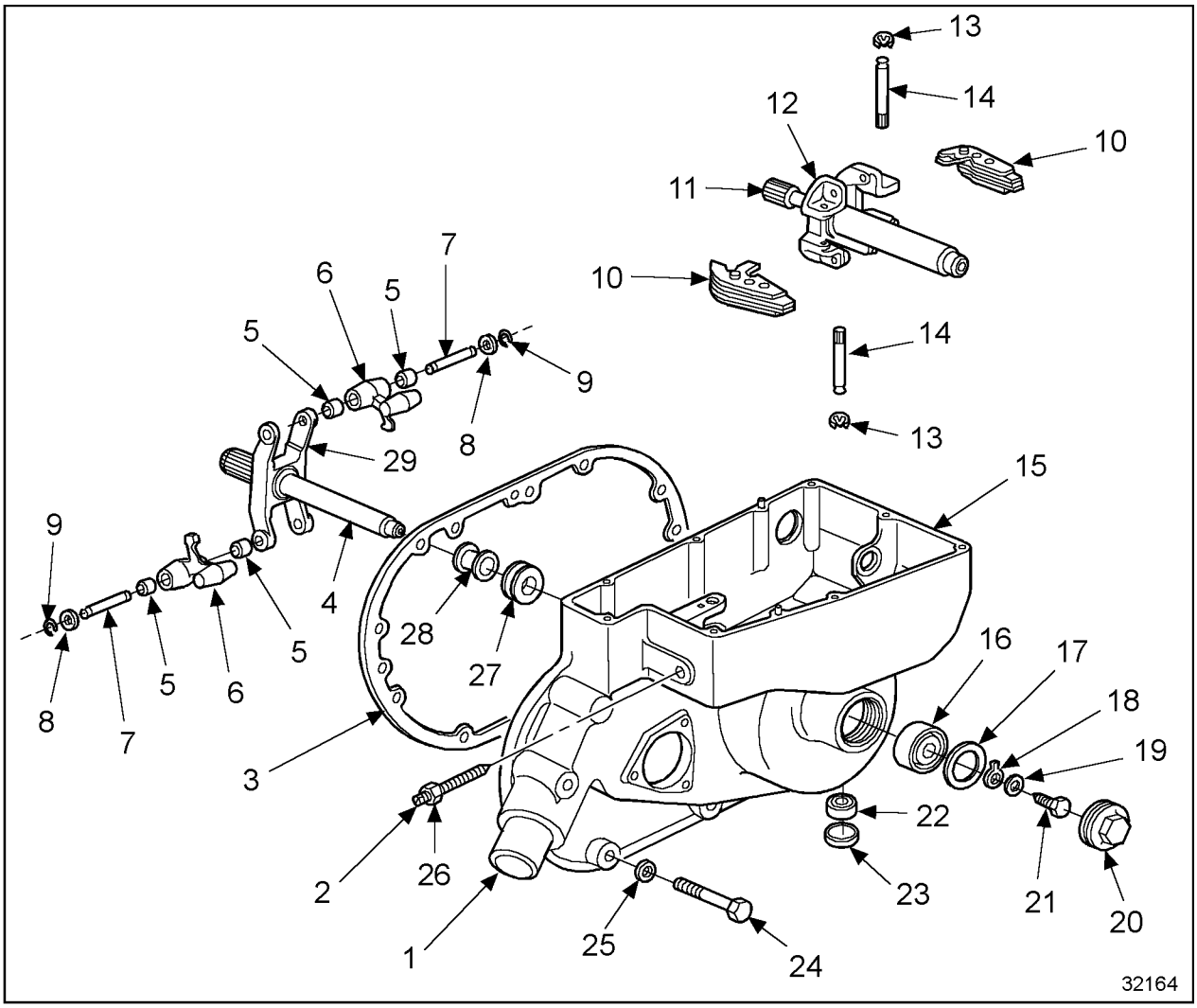
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10. Visually inspect the variable speed spring plunger, guide, and spring retainer for wear or score marks.
    [a] If the retainer or plunger is slightly scored or worn, clean them up with crocus cloth.
    [b] Replace the retainer, plunger and guide if excessively scored or worn. Refer to section 2.27.8.
    [c] If not worn or scored, continue inspection.
11. Visually inspect the adjusting screw, locknut, pins, seal rings and any other parts in the governor housing for wear or defects that might affect governor operation.
    [a] Replace all worn or damaged parts. Refer to section 2.27.8.
    [b] If not worn or damaged, reuse the parts.

2.27.8 Assembly of Variable Speed Mechanical Governor

See Figure 2-181 and see Figure 2-182 for the location of the various parts. Assemble the governor as follows:

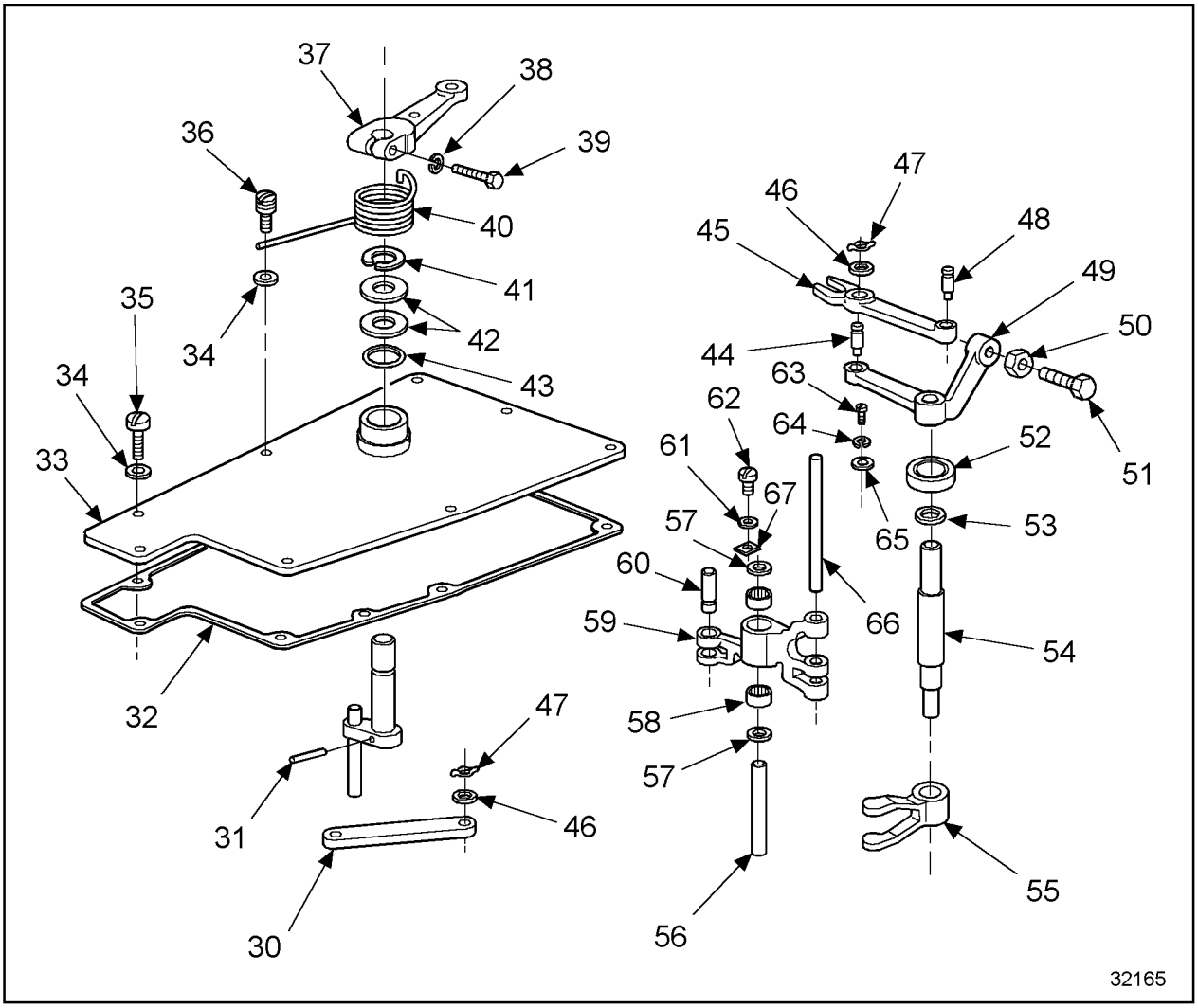
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1. Fuel Rack Linkage Outlet
2. Buffer Screw
3. Gasket
4. Carrier Weight Shaft
5. Weight Bearing
6. Governor Weight
7. Weight Pin
8. Flat Washer
9. Snap Ring
10. Governor Weight
11. Carrier Weight Shaft
12. Governor Weight Carrier
13. Weight Pin Retainer
16. Carrier Weight Bearing
17. Housing Plug Gasket
18. Special Lock Washer
19. Flat Washer
20. Plug
21. Bearing Retainer Bolt
22. Operating Shaft Bearing
23. Expansion Ring
24. Bolt
25. Lock Washer
26. Buffer Screw Locknut
27. Riser Thrust Bearing
28. Governor Riser

14. Weight Pin
15. Governor Housing
29. Governor Weight Carrier

Figure 2-181 Variable Speed Governor (1 of 2)



30. Operating Lever Connecting Link
31. Stop Lever Shaft Pin
32. Gasket
33. Governor Cover
34. Lock Washer
35. Cover Bolt
36. Housing Cover Special Screw
37. Governor Stop Lever
38. Lock Washer
39. Stop Lever Bolt
49. Operating Shaft Lever
50. Locknut
51. Gap Adjusting Screw
52. Operating Shaft Upper Bearing
53. Plain Washer
54. Governor Operating Shaft
55. Operating Shaft Fork
56. Control Link Lever Shaft
57. Plain Washer
58. Operating Lever Bearing

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40. Shaft Return Spring
41. Snap Ring
42. Seal Ring Retainer Washers
43. Shaft Seal Ring
44. Shaft Lever Pin
45. Differential Lever
46. Differential Washer
47. Spring Retainer
48. Differential Lever Pin
59. Control Link Operating Lever
60. Fuel Rod Connecting Pin
61. Plain Washer
62. Lock Clip Screw
63. Bearing Retainer Screw
64. Lock Washer
65. Flat Washer
66. Fuel Rod Connecting Pin (Short)
67. Operating Lever Shaft Lock Clip

Figure 2-182 Variable Speed Governor (2 of 2)

Install the operating shaft and governor linkage in the governor housing as follows:

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the inside diameter of the governor operating shaft upper bearing with engine oil.
2. Support the bearing and operating shaft on a 9/16 in. inside diameter sleeve on the arbor press bed, with the bearing inner race resting on the sleeve.
3. Start the bearing, numbered side up, straight on the large end of the operating shaft.
4. Press the shaft into the bearing until 1/4 in. of the shaft protrudes through it.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

5. Lubricate the inside diameter of the governor operating shaft lever with engine oil.
6. Start the lever, operating lever pivot pin face up, straight on the operating shaft with the flat of the shaft registering with the flat surface in the lever.

NOTE:
The upper end of the shaft must be flush with the top surface of the lever.

7. Support the operating lever, bearing and shaft on the arbor press bed with a steel support directly under the center of the lever.
8. Press the operating shaft through the bearing and lever until the end of the shaft contacts the steel support.

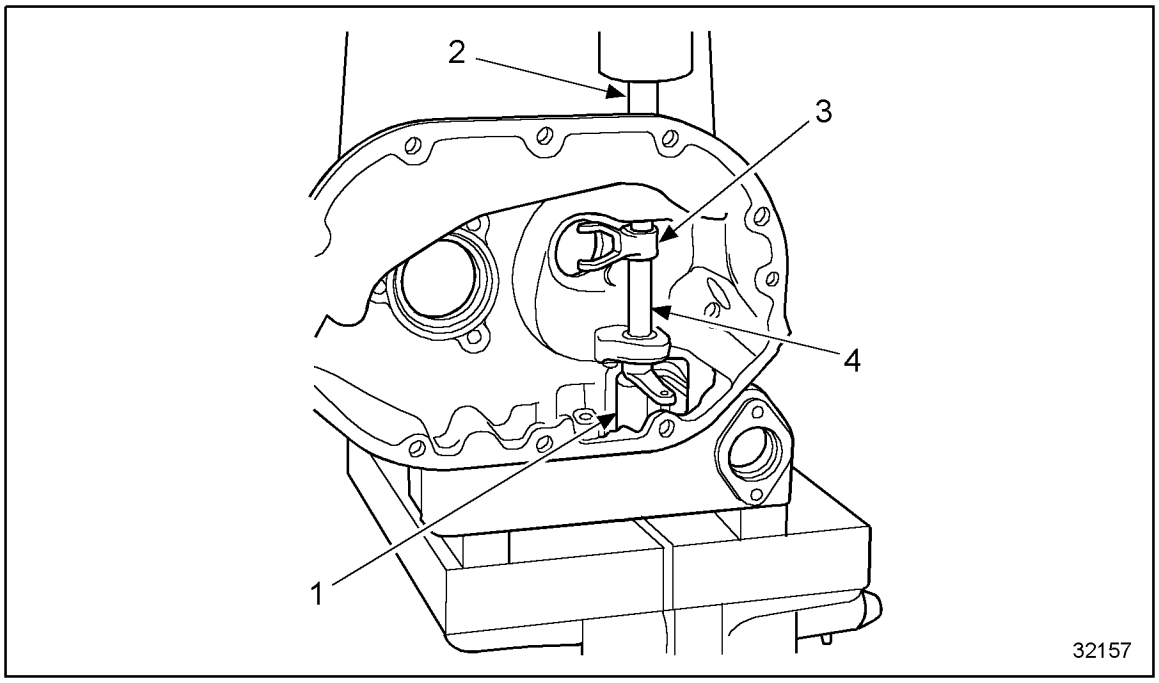
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9. Place the operating shaft spacer over the lower end of the shaft, and slide it against the upper bearing inner race.
10. Insert the end of the governor operating shaft, bearing, spacer, and lever assembly through the upper bearing bore in the governor housing.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

11. Lubricate the inside diameter of the governor operating shaft fork with engine oil.
12. Place the operating fork over the lower end of the shaft, with the finished cam surfaces on the fork fingers facing the rear of the governor housing and the flat of the shaft registering with the flat surface in the fork.
13. Support the governor housing and operating shaft assembly on the arbor press bed with the upper end of the operating shaft resting on a steel support. See Figure 2-183.



1. Support
2. Sleeve
3. Fork
4. Shaft

Figure 2-183 Installing Governor Operating Shaft Fork on Shaft

14. Place a 7/16 in. inside diameter sleeve over the end of the shaft and against the fork. Press the fork tight against the shaft spacer.

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

15. Lubricate the governor operating shaft lower bearing with engine oil.
16. Start the bearing, numbered side up, straight in the governor housing and over the end of the operating shaft.
17. Support the governor housing and operating shaft assembly on the arbor press bed with the upper end of the operating shaft resting on a steel support.
18. Place a 7/16 in. inside diameter sleeve on the inner race of the bearing, and press the bearing on the shaft until it seats on the housing shoulder.
19. Install the governor operating shaft upper bearing retaining flat washer, lock washer, and screw in the governor housing.
20. Apply a thin coat of good quality sealant around the edge of a new expansion plug.
21. Place the plug, concave side up, in the opening of the housing next to the lower operating shaft bearing. Tap the center of the plug with a hammer.
22. Place the differential lever over the pivot pin in the operating lever, with the pin in the lever up, and secure with a plain washer and spring retainer.
23. If previously removed, install the governor gap adjusting screw and locknut in the tapped hole in the operating shaft lever.
24. If removed, place the control link operating lever on the arbor press bed, with a steel support under the bearing bore.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

25. Lubricate the outer surface of the bearing with engine oil, and start the bearing, numbered end up, straight into the lever bore.
26. Insert the pilot end of installer J 8985 in the bearing, and press the bearing into the lever until it is flush with the top surface of the lever.
27. Reverse the lever on the press, and install the second bearing.
28. Lubricate the control link operating lever needle bearings with Shell Alvania No. 2 grease, or equivalent.
29. Place the lever in position between the two bosses inside the governor housing. Insert a flat washer on each side of the lever.
30. Install the control link operating lever shaft with the slot up.

31. Align the slot in the control link operating lever shaft with the lock clip screw hole in the boss next to the shaft.
32. Install the lock clip, lock washer, and screw. Securely tighten the screw.
33. Place one end of the connecting link over the differential lever pin, and secure it with a plain washer and spring retainer.
34. Place the opposite end of the connecting link on top of the control link operating lever, and install the connecting pin.
35. If removed, thread the locknut on the buffer screw, and thread the buffer screw into the governor housing.

2.27.9 Assembly of Governor Weights and Carrier and Shaft Assembly (Non-Turbocharged Engines)

Assemble the governor weights and carrier and shaft assembly on non-turbocharged engines as follows:

1. Position the weights on opposite sides of the weight carrier. Observe the matchmarks placed on the weight carrier and weights at the time of disassembly.
2. Drive the weight pins in place, and install the retaining rings.

NOTE:
To install a weight pin correctly, push the grooved end through the smaller hole in the carrier and through the weight. Drive the knurled end in just enough so the retaining ring can be installed on the pin.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

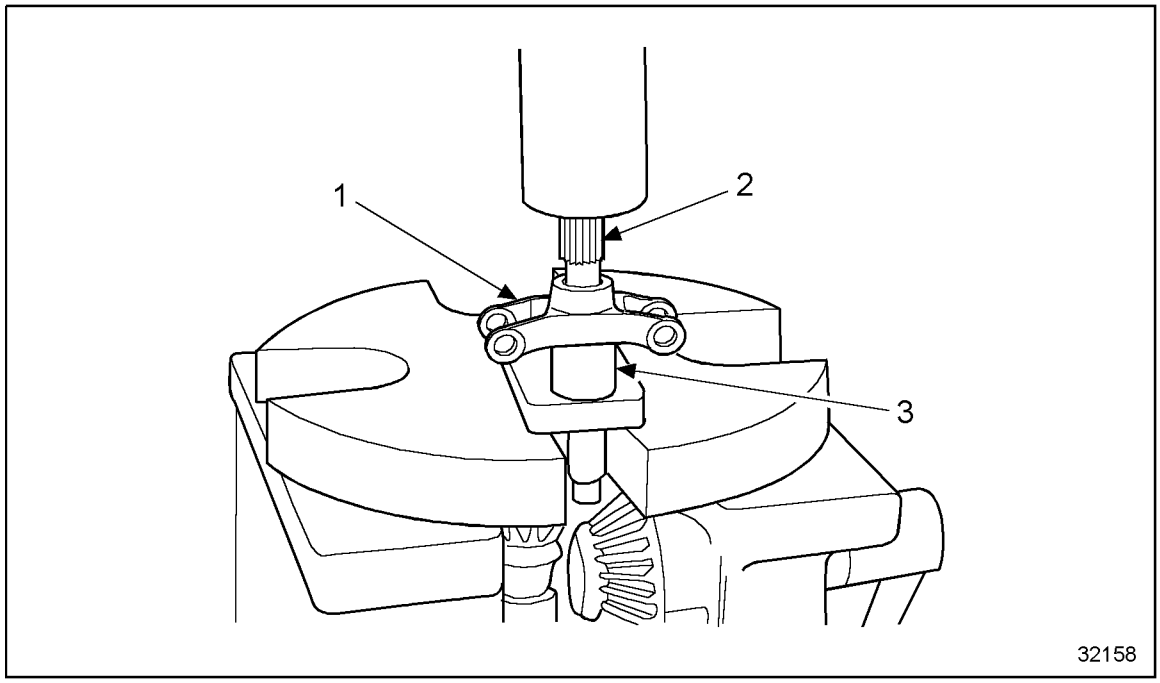
3. Lubricate the weight shaft with clean engine oil.

2.27.10 Assembly of Governor Weight and Shaft Assembly(Turbocharged Engines)

Assemble the governor weight and shaft assembly on engine as follows:

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1. Support the weight carrier, rear face up, on a sleeve and a steel support, with a 1 in. hole, over an opening in the arbor press bed. See Figure 2-184.



1. Weight Carrier
2. Shaft
3. Sleeve

Figure 2-184 Installing Governor Weight Shaft in Weight Carrier

CAUTION:

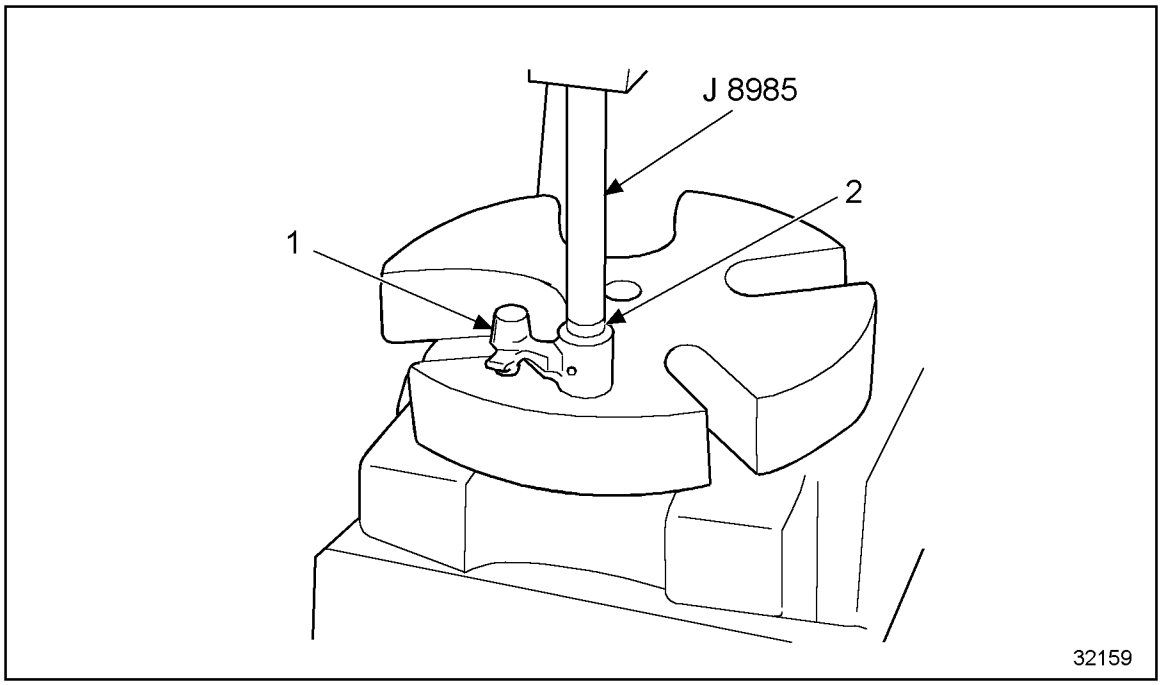
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the weight shaft with engine oil.
3. Insert the non-splined end of the shaft through the carrier, sleeve, and hole in the steel support. Press the shaft straight into the carrier until the shoulder on the shaft is tight against the carrier.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. If removed, place the governor weight, either end up, on the arbor press bed. Lubricate the outer surface of the bearing with engine oil, and start the bearing, numbered end up, straight into the weight bore.
5. Insert the pilot end of installer J 8985 in the bearing and under the press ram. See Figure 2-185.



1. Weight
2. Bearing

Figure 2-185 Installing Bearings in Governor Weight using Tool J 8985

6. Press the bearing straight in the weight until it is flush with the top of the weight. Reverse the weight on the press and install the second bearing.
7. Install the bearings in the second weight, if removed. Place the governor weight, either end up, on the arbor press bed.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

8. Lubricate the outer surface of the bearing with engine oil, and start the bearing, numbered end up, straight into the weight bore.
9. Insert the pilot end of installer J 8985 in the bearing and under the press ram.
10. Press the bearing straight in the weight until it is flush with the top of the weight. Reverse the weight on the press and install the second bearing.
11. Lubricate the needle bearings with Shell Alvania No. 2 grease, or equivalent.
12. Position the weight carrier and shaft assembly on a bench with one pair of the weight pin arms facing up.
13. Install a lock ring in the weight pin groove. Place a flat washer over the opposite end of the pin and against the lock ring.
14. Insert the pin through the bearing in the carrier arm, and place a second flat washer over the pin and against the carrier arm.
15. Position the governor weight and bearing assembly between the weight carrier arms. Push the weight pin through the weight.
16. Insert a third flat washer between the inner face of the carrier arm and the weight, and push the pin through the washer and the carrier arm.
17. Install the fourth flat washer over the pin and against the outside of the carrier arm. Install the second lock ring in the weight pin groove.
18. Install the second and third (12V and 16V turbocharged engines) governor weight and bearing assemblies in the carrier. Install a lock ring in the weight pin groove. Place a flat washer over the opposite end of the pin and against the lock ring.
19. Insert the pin through the bearing in the carrier arm, and place a second flat washer over the pin and against the carrier arm.
20. Position the governor weight and bearing assembly between the weight carrier arms. Push the weight pin through the weight.
21. Insert a third flat washer between the inner face of the carrier arm and the weight, and push the pin through the washer and the carrier arm.
22. Install the fourth flat washer over the pin and against the outside of the carrier arm. Install the second lock ring in the weight pin groove.

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2.27.11 Installation of the Governor Weight and Shaft Assembly (Non-Turbocharged)

Install the governor weight and shaft assembly in the governor housing on non-turbocharged engines as follows:

1. Slide the governor riser on the weight shaft and against the high-speed weight fingers.
2. Place the governor riser thrust bearing over the weight shaft with the bearing race having the smaller inside diameter against the riser.
3. Insert the weight carrier and shaft assembly in the governor housing. Support the splined end of the shaft and the governor housing on the arbor press bed, with the upper end of the shaft under the press ram.
4. Place the weight shaft bearing in the governor housing, numbered side up, and start it straight on the end of the weight carrier shaft.
5. Place a sleeve with a 1/2 in. inside diameter on top of the bearing inner race, and press the bearing into the housing and against the shaft shoulder.
6. Place the special lock washer on the end of the weight carrier shaft with the tang on the washer inner diameter in the notch in the shaft end.
7. Place the flat washer on the bearing retainer bolt, and thread the bolt into the shaft.
8. Clamp the splined end of the weight carrier shaft in the soft jawed bench vise, and tighten the bearing retainer bolt to 20-26 N·m (15-19 lb·ft) torque. Bend the lock washer tang against the bolt head.
9. Place a gasket in the housing and against the bearing. Apply a Loctite sealant grade HV, or equivalent, to the full plug circumference.

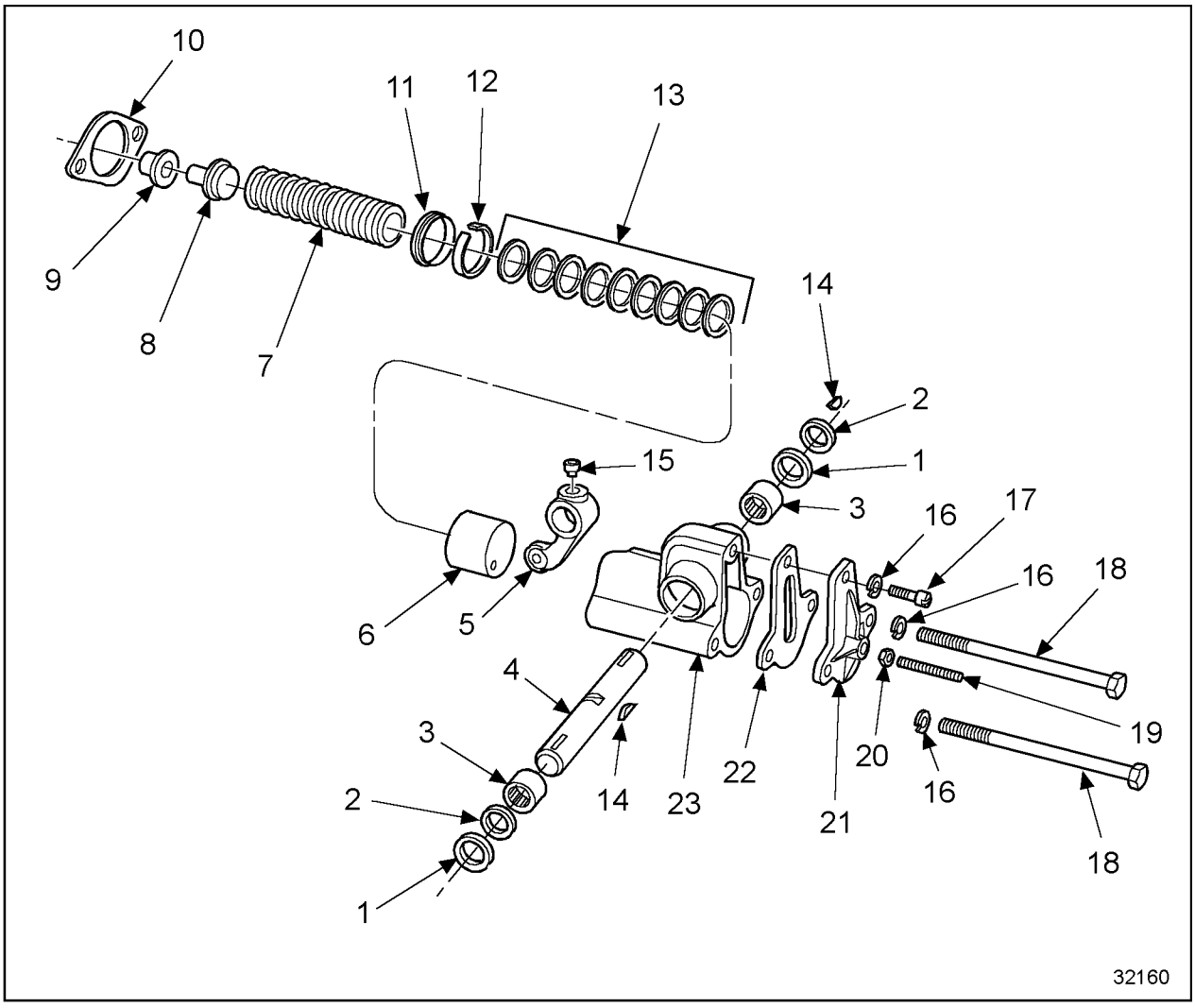
NOTE:
Rotate the governor weight assembly. If it binds, remove the housing plug and inspect the weight shaft bearing. It must be fully seated in the governor housing.

10. Thread the plug into the tapped end of the governor weight housing. Tighten the plug to 61 N·m (45 lb·ft) torque.

2.27.12 Assembly of Variable Speed Spring Housing

See Figure 2-186 for part locations. Assemble the variable speed spring housing as follows:

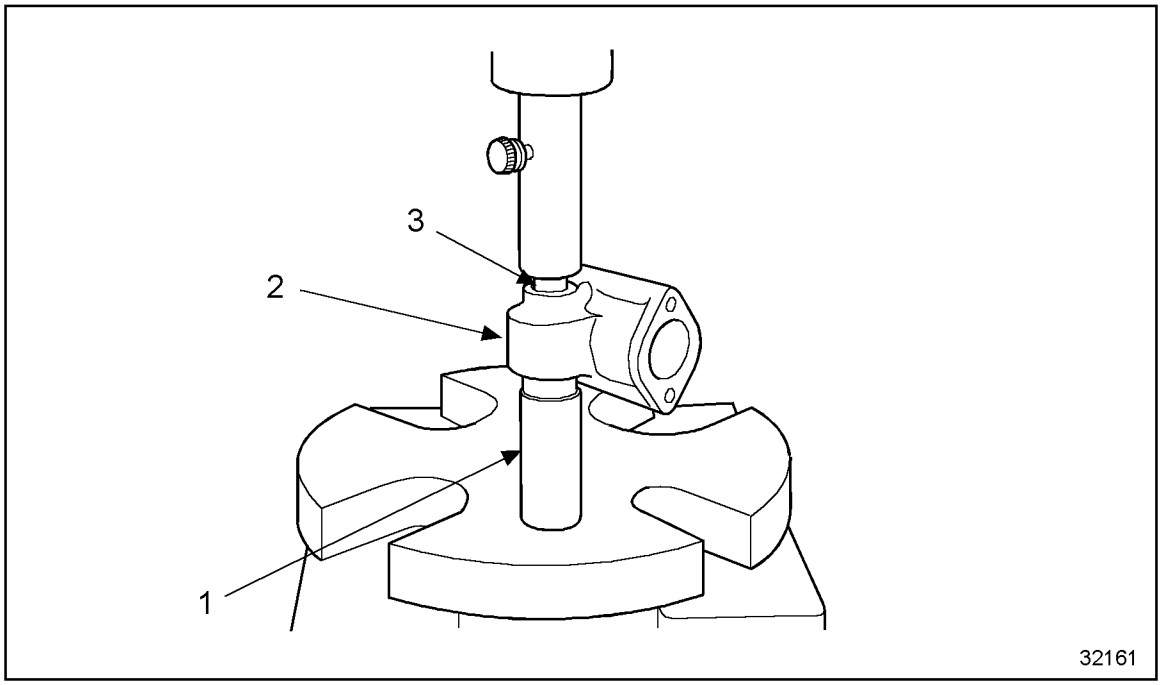
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1. Washer
2. Seal Ring
3. Bearing
4. Shaft
5. Lever
6. Spring Retainer
7. Spring
8. Plunger
9. Plunger Guide
10. Gasket
11. Solid Stop
12. Split Stop
13. Shims
14. Key
15. Set Screw
16. Lock Washer
17. Allen Screw
18. Bolt
19. Idle Screw
20. Locknut
21. Cover
22. Cover Gasket
23. Housing

Figure 2-186 Variable Speed Spring Housing

1. Lubricate the speed control lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent.
2. Start one of the bearings, numbered end up, straight in the bearing bore in the right hand side of the spring housing.
3. Install the needle bearing pilot rod in the installer body, and secure it in place with the retaining screw.
4. Place the bearing installer assembly pilot rod end in the bearing. Support the spring housing, bearing, and installer on a short sleeve on the arbor press bed. See Figure 2-187.



1. Sleeve
2. Spring Housing
3. Bearing

Figure 2-187 Installing Speed Control Shaft Bearing in Spring Housing

5. Press the bearing in the housing until the installer shoulder contacts the housing.

NOTE:
When the shoulder on the installer body contacts the housing, the bearing will be properly positioned in the housing.

6. Install the roller type bearing and pin in the spring lever. Press the pin below the surface of the lever, and stake at three places on both sides of the lever.
7. If removed, install the spring lever Woodruff key in the speed control lever shaft center keyway.
8. Place the spring lever assembly between the bearing bores inside the spring housing with the lever arm facing out.

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9. Insert the correct end of the speed control lever shaft, single or double lever type, through the bearing bore in the side of the spring housing, opposite the bearing previously installed.
10. Align the key in the shaft with the keyway in the spring lever, and push the shaft through the lever and in the bearing until the flat on the top of the shaft is centered under the lever set screw hole.
11. Thread the set screw into the spring lever, ensuring screw point is seated in the flat on the shaft.
12. Place the second speed control lever shaft needle bearing, numbered end up, over the protruding shaft end, and start it straight in the housing bore.
13. Remove the bearing pilot rod from the installer body, and place the installer body over the shaft end and against the bearing.
14. Support the spring housing, bearings, and installer on a short sleeve on the arbor press bed. Press the bearing in the housing until the installer shoulder contacts the housing.
15. If a single lever shaft was installed in the spring housing, apply a thin coat of sealing compound to the outside diameter of the cup plug.
16. Start the cup plug straight in the housing bearing bore. Support the spring housing, bearings, and shaft assembly on a sleeve on the arbor press bed, and press the cup plug in flush with the housing outside face.
17. Clamp the spring housing assembly in a soft-jawed bench vise. Tighten the spring lever retaining set screw to 7-10 N·m (5-7 lb·ft) torque.
18. Stake the edge of the spring lever set screw hole with a small center punch and hammer to retain the set screw in the lever. Install the plug in the spring housing.
19. On a single lever shaft, place a seal ring over the shaft end, and push it into the bearing bore and against the bearing.
20. Place the plain washer over the shaft and against the housing. Install the Woodruff key in the keyway in the shaft.
21. On a double lever shaft, place a seal ring over each shaft end, and push them into the bearing bores and against the bearings.
22. Place a plain washer over each shaft end and against the housing. Install a Woodruff key in the keyway at each shaft end.
23. Place the speed control lever(s) on the shaft in its original position. Align the keyway in the lever with the key in the shaft, and push the lever in against the plain washer. Secure it with the retaining bolt and lock washer.
24. If removed, thread the locknut on the idle speed adjusting screw. Thread the idle speed adjusting screw into the spring housing approximately 1 in.

Attach the variable speed spring plunger guide, plunger, retainer, shims, spring, stops, and spring housing assembly to the governor housing as follows:

1. Clamp the governor housing flange in a soft-jawed vise.

2. If removed, start the variable speed spring plunger guide straight in the boss inside the governor housing. Tap it into place with a small brass rod and hammer.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Lubricate the small end of the variable speed spring plunger with engine oil. Insert the plunger in the governor housing plunger guide.
4. Place the spring retainer solid stop in the governor housing counter bore.
5. Lubricate the outside diameter of the variable speed spring retainer with engine oil. Insert the spring retainer, solid end first, into the spring housing and against the spring lever.

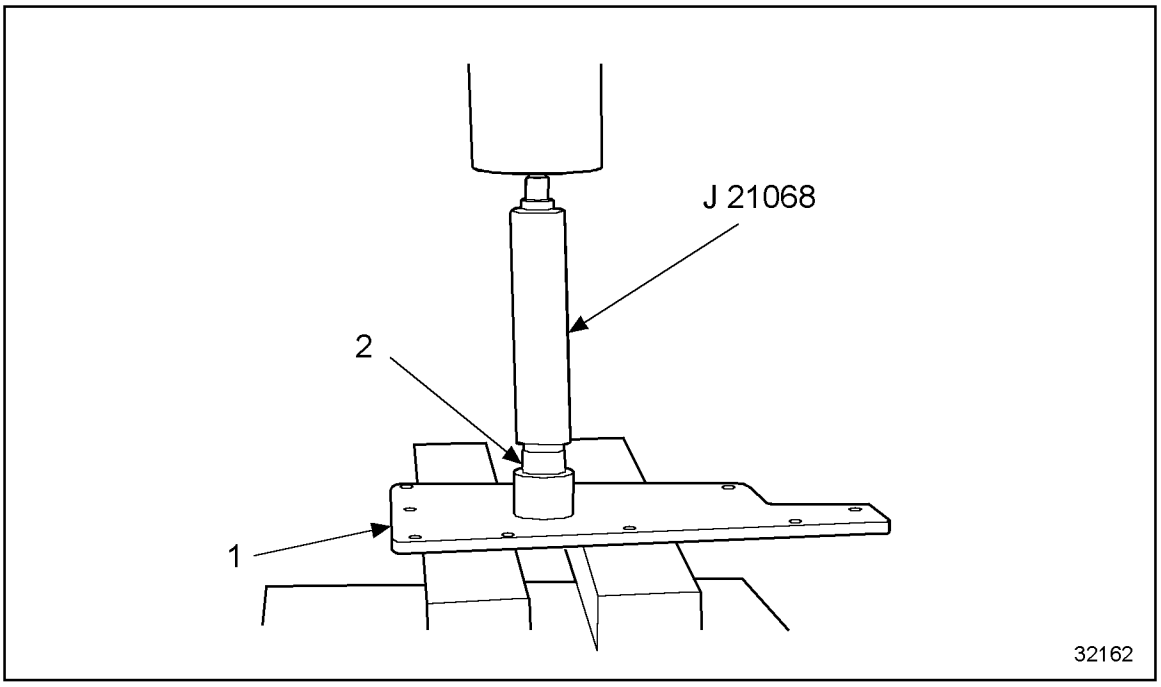
NOTE:
Use shims with an 11/32 in. inside diameter and a spring retainer with three bleed holes when a two-spring assembly is used. On the one-spring assembly, either spring retainer may be used with shims that have a 3/4 in. inner diameter. Do not use the 11/32 in. inner diameter shims with a spring retainer that has only one air bleed hole.

6. Replace as many shims in the spring retainer as were removed, thin shims first. Insert the spring retainer split stop in the spring housing approximately 1/16 in. from the finished face of the housing.
7. Affix a new gasket to the spring housing forward face. Insert the variable speed spring into the spring housing and spring retainer with the tightly wound end of the spring against the shims in the retainer. If a tow spring assembly is used, insert the inner spring inside the outer spring.
8. Place the variable speed spring housing into position against the governor housing with the speed control lever facing the bottom of the governor and the variable speed spring over the spring plunger end inside the governor housing.
9. Install the two spring housing retaining bolts and lock washers. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

Assemble the governor cover as follows:

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1. If the stop lever bushing was removed from the cover, place the cover, inner face down, on two steel supports on the arbor press bed. See Figure 2-188.



1. Governor Cover
2. Bearings

Figure 2-188 Installing Bearings in Governor Cover using Tool J 21068

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the new needle bearing with engine oil. Start the bearing, numbered end up, straight in the bearing bore in the cover boss.
3. Place the end of installer J 21068 in the bearing, and press the bearing into the cover until the stop on the installer contacts the cover boss.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Reverse the cover, inner face up, on the arbor press bed. Lubricate the second bearing with engine oil, and start the bearing, numbered end up, straight in the cover boss bore.
5. Place the bearing installer J 21068 in the bearing, and press the bearing in the bore until it is flush with the boss face.
6. Lubricate the stop lever shaft needle bearings with Shell Alvania No. 2 grease, or equivalent. Insert the stop shaft through the bearings in the cover.
7. Place the seal ring over the shaft, and push it into the bearing bore and against the bearing.
8. Place the two seal ring retainer washers on the shaft and against the cover boss. Install the snap ring in the shaft groove.
9. Place the stop shaft lever return spring over the stop shaft with the hooked end of the spring facing up. Install the stop lever on the shaft, and secure it with the retaining bolt and lock washer.

2.27.13 Installation of Variable Speed Mechanical Governor(6V and 8V Engines)

Install the governor on 6V and 8V engines as follows:

1. Affix a new gasket to the fuel pump bolting flange. Place the fuel pump against the governor housing in its original position, and secure it with the three bolt and seal assembly. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.
2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing.
3. Affix a new gasket to the forward face of the blower end plate.
4. Place the fuel pump drive fork on the fuel pump shaft. Position the governor and fuel pump assembly in front of the blower.
5. Rotate the fuel pump fork until the fork prongs align with the drive disc slots. Rotate the weight shaft, and align the shaft splines with the blower rotor splines.
6. Push the governor straight back over the dowels in the blower end plate and against the gasket.

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7. See Figure 2-189. Install the bolts, lock washers, copper washers, and plain washer that secure the governor to the blower. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

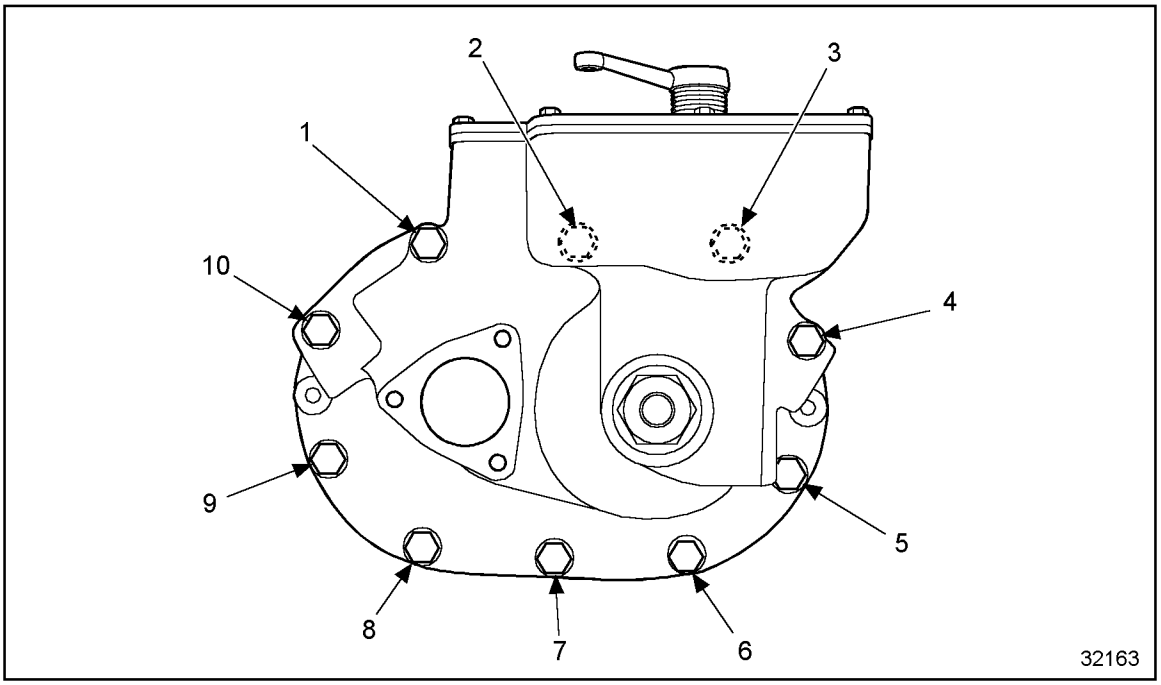


Figure 2-189 Torque Sequence

8. Slide each fuel rod cover tube hose on the cover tubes attached to the cylinder heads. Tighten the hose clamps.
9. Install and connect the crossover fuel oil line to each cylinder head, and connect the fuel oil lines to the fuel pump.
10. Place the water bypass tube between the two thermostat housings, and slide the hoses part way on the thermostat housings.
11. Position the bypass tube so it clears the governor, fuel pump, and fuel oil lines. Tighten the hose clamps.

Install the fuel rods between the cylinder heads and the governor as follows:

1. Insert the lower end of the left-bank fuel rod down through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
2. Raise the connecting pin up in the connecting link lever. Insert the fuel rod end between the two lever bosses, and insert the connecting pin through the fuel rod and into the lower boss.
3. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
4. Insert the lower end of the right-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.

5. Remove the short screw pin from the control link operating lever. Insert the end of the fuel rod between the two lever bosses, and install the screw pin. Tighten the pin.
6. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

Continue governor installation as follows:

1. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the stop control shaft assembly pin in the differential lever slot and the housing dowel pins in the cover dowel pin holes.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

2. Install the stop lever return spring special screw. Install the eight governor cover attaching screws and lock washers. Tighten the screws.

NOTE:
The short cover attaching screw with the drilled head goes in the corner hole next to the variable speed spring housing.

3. With the hooked end of the stop lever return spring in position on the lever, place the extending end of the spring behind the special cover attaching screw.
4. Attach the booster spring to the speed control lever, and tighten the outer booster spring adjusting nut on the eyebolt.
5. Install all of the accessories that were removed from the cylinder head, governor or the front end of the engine.
6. Connect the control linkage to the speed control and stop levers.
7. Close the drain cocks, and fill the cooling system. Refer to section 13.12.
8. Perform the governor and injector rack control adjustment. Refer to section 12.4.

2.27.14 Installation of Variable Speed Mechanical Governor(12V and 16V Engines)

Install the governor on 12V and 16V engines as follows:

1. Affix a new governor housing gasket to the forward face of the blower end plate.
2. Position the governor in front of the end plate. Align the weight shaft splines with the blower rotor splines.
3. Push the weight shaft in the rotor, and slide the governor housing over the end plate dowel pins and against the gasket.

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4. Install the bolts, lock washers, plain washer, and copper washers that secure the governor to the blower. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.
5. Affix a new blower housing gasket to the cylinder block with a good grade gasket cement to prevent the gasket from shifting when the blower is positioned.
6. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.
7. Lift the blower and governor assembly at a slight angle, and position it on top of the cylinder block with the rear end plate cover flange inside the blower drive shaft cover hose.
8. Finger-tighten a 7/16 in.-14 x 8-1/4 in. bolt and special washer in the center hole of each blower end plate.
9. Install and finger-tighten the 3/8 in.-16 x 5-1/2 in. bolts and retaining washers at each side of the blower housing.

NOTE:
The lip at the beveled end of the bolt retaining washer goes in the small recess in the housing just above the bolt slot.

10. Tighten the bolts as follows:
    [a] Tighten the blower-to-block end plate bolts to 54-81 N·m (40-60 lb·ft) torque.
    [b] Tighten the blower housing-to-block side angle bolts uniformly to 41-47 N·m (30-35 lb·ft) torque in 7 N·m (5 lb·ft) increments.
    [c] Recheck the blower-to-block end plate bolts.
11. Slide the blower drive support-to-blower hose (seal) and clamps into position. Tighten the clamps.
12. Insert the blower drive shaft through the blower drive coupling and into the blower drive hub. Install the retaining snap ring in the flexible coupling groove.
13. Affix a new gasket to the flywheel housing hole cover. Attach the cover to the flywheel housing with six bolts and lock washers.

2.27.15 Installation of Variable Speed Mechanical Governor (Engine Equipped with a Rear Mounted Battery-Charging Alternator)

On an engine equipped with a rear mounted battery-charging alternator, proceed as follows:

1. Affix a new gasket to the alternator drive assembly.
2. Place the alternator drive coupling on the drive hub.
3. Place the drive assembly into position, and align the slots in the drive coupling with the drive hub on the blower drive gear.
4. Place the drive assembly against the flywheel housing.
5. Install the bolts, lock washers, and alternator adjusting strap.

6. Install the alternator drive pulley and drive belt.

2.27.16 Installation of Variable Speed Mechanical Governor(12V and 16V Engines Continued)

Continue governor installation as follows:

1. On an engine equipped with a hydraulic oil pump, refer to the manufacturers' service manual for the marine gear, reduction gear, or transmission used on the engine.
2. Connect the blower drive support oil tube to the fitting in the blower drive support. Tighten the two seal ring retaining plate bolts to 18-23 N·m (13-17 lb·ft) torque.
3. Affix a new gasket to the fuel pump flange, and install the fuel pump drive fork and fuel pump on the governor housing.
4. Connect the fuel pump inlet and outlet tubes or hoses to the fuel pump.
5. Slide the governor housing-to-auxiliary control link housing hose, clamp it into position between the two housings, and tighten the hose clamp.
6. Slide the fuel rod cover hose down the cover tube attached to the cylinder head at each side of the governor housing. Tighten the hose clamps.
7. Position the control link operating lever connecting link in the governor and auxiliary housings. Connect it to the ball joint studs in the control link operating levers.

Install the fuel rods between the cylinder heads and the governor as follows:

1. Insert the lower end of the left-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
2. Raise the connecting pin up in the connecting link lever. Insert the end of the fuel rod between the two lever bosses. Insert the connecting pin through the fuel rod and into the lower boss.
3. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
4. Insert the lower end of the right-bank fuel rod through the top of the governor housing and through the fuel rod cover tubes to the injector control tube lever.
5. Remove the short screw pin from the control link operating lever. Insert the fuel rod end between the two lever bosses.
6. Install the screw pin, and tighten it securely.
7. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

Complete governor installation as follows:

1. Place a new auxiliary control link housing cover gasket on the housing. Install the cover, and secure it with screws and lock washers.
2. Place a new governor housing cover gasket on the housing. Install the cover, and secure it with screws and lock washers.

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3. If removed, attach the booster spring bracket to the cylinder head. Attach the booster spring to the speed control lever. Tighten the outer booster spring adjusting nut on the eyebolt.

> **⚠ CAUTION:**
>
> **To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.**

4. Install the cylinder head rocker covers. Refer to section 1.6.5.
5. On non-turbocharged engines, proceed as follows:
   [a] Remove the cover from the top of the blower.
   [b] Place the blower screen, wire side down, on top of the blower.
   [c] Install the air shutdown adaptor.
   [d] Attach the air shutdown housings and gaskets to the adaptors.
6. On turbocharged engines, proceed as follows:
   [a] Remove the cover from the top of the blower.
   [b] Place the blower screen, wire side down, and install the air shutdown adaptor and air shutdown housing on the blower as an assembly.
   [c] Attach the shutdown rod to the lever on the shutdown housing.
7. On non-turbocharged engines, connect the air inlet tubes to the air shutdown housings.
8. On turbocharged engines, attach the air inlet tube to the rear air shutdown housing and the turbocharger.
9. On marine engines, install the air silencers on the air shutdown housings.
10. Connect the linkage to the governor speed control and stop levers.
11. Perform an engine tune-up. Refer to section 12.1.

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2.28 SG HYDRAULIC GOVERNORS

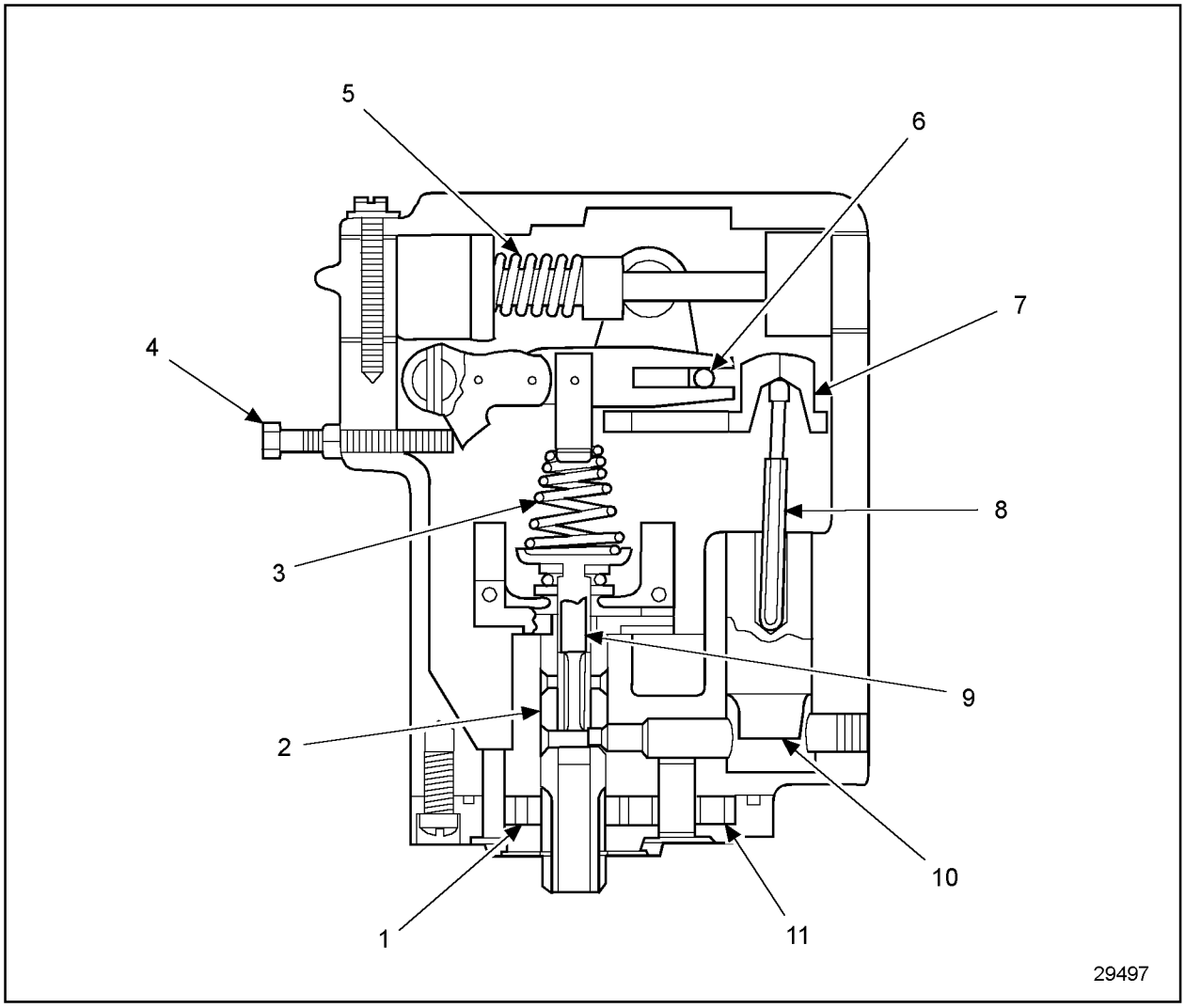
Fluctuating loads vary the engine horsepower requirements. The governor controls the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. A governor is introduced in the linkage between the throttle control and the fuel injectors.

Engines, subjected to varying load conditions that require an automatic fuel compensation to maintain a more constant engine speed with a minimum speed droop, are equipped with a hydraulic governor.

In the hydraulic governor, the governor throttle control terminal lever retracting spring decreases the fuel and the opposing action of the power piston increases it. A pilot valve controls the oil flow to the power piston. The governor flyweights control the pilot valve movement. The speeder spring compression opposes the centrifugal force of these flyweights, which may be varied, and accurately set and held at any speed between idle and maximum speed. The speed droop, the difference between no-load speed and full-load speed, is adjustable to within a very small percentage at maximum speed.

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The governor is a hydraulic type with a speed droop stabilization mechanism. See Figure 2-190. Oil admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor transmits the hydraulic action. The auxiliary pump develops the oil pressure necessary to actuate the governor mechanism.



1. Oil Pump Drive Gear
2. Ball Head and Weight Assembly
3. Speeder Spring
4. Maximum Speed Adjusting Screw
5. Fuel Rod Spring
6. Droop Adjusting Bracket
7. Terminal Lever
8. Floating Pin
9. Pilot Valve Plunger
10. Power Piston
11. Oil Pump Driven Gear

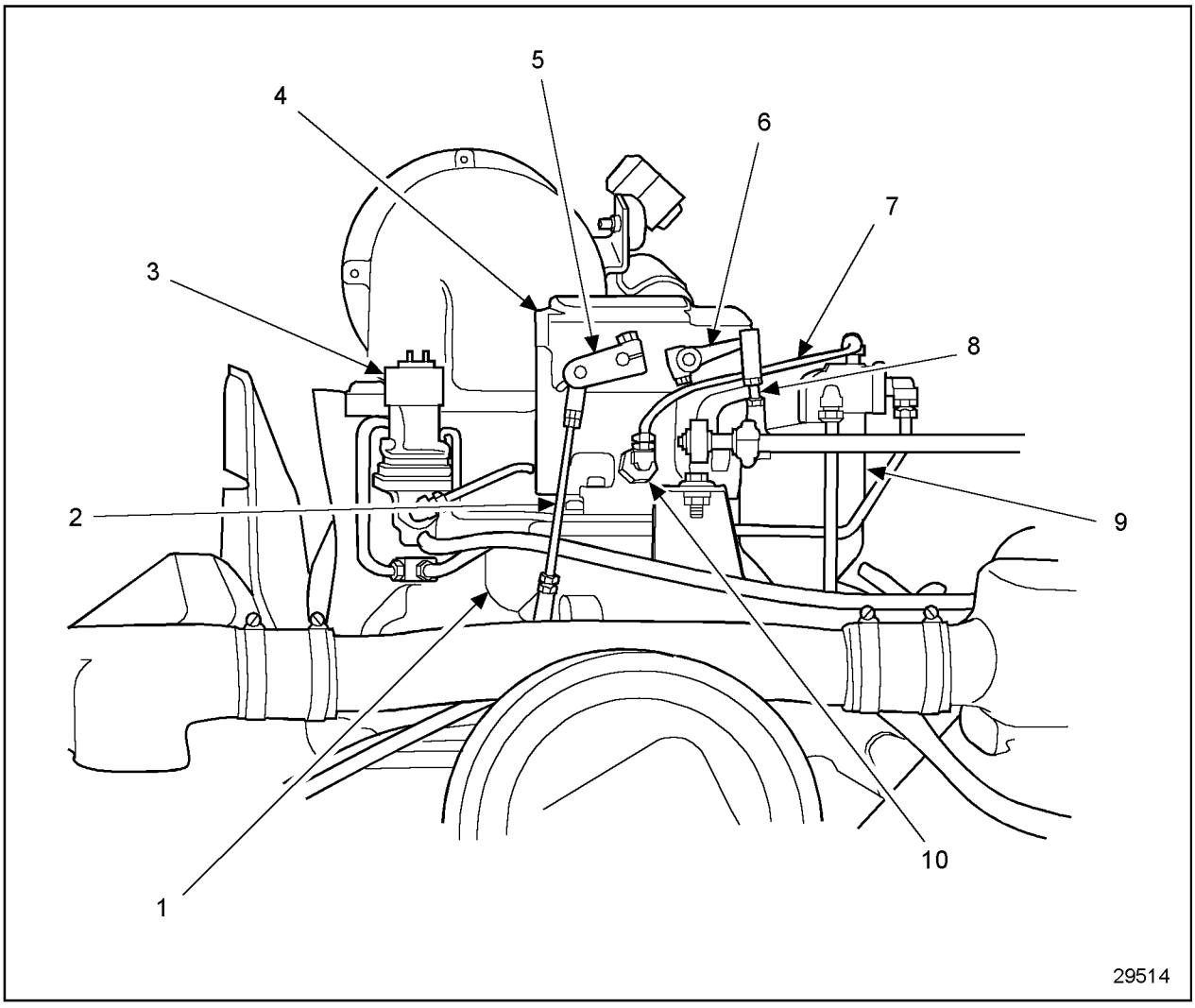
Figure 2-190 Hydraulic Governor Assembly

To stabilize the governor, a speed droop adjustment is incorporated in the governor mechanism. A droop adjusting bracket attached to the top of the terminal lever regulates the speed droop. To decrease the governor droop, move the droop adjusting bracket IN and move it in the opposite direction to increase the governor droop.

The hydraulically operated power piston increases the amount of fuel supplied to the injectors. The fuel rod spring decreases it.

The governor is located at the front of the 6V and 8V engines and at the center of the 12V and 16V engines. See Figure 2-191. It is mounted on the governor drive housing, which also serves as the blower front cover (rear blower on the 12V and 16V engine). See Figure 2-192.

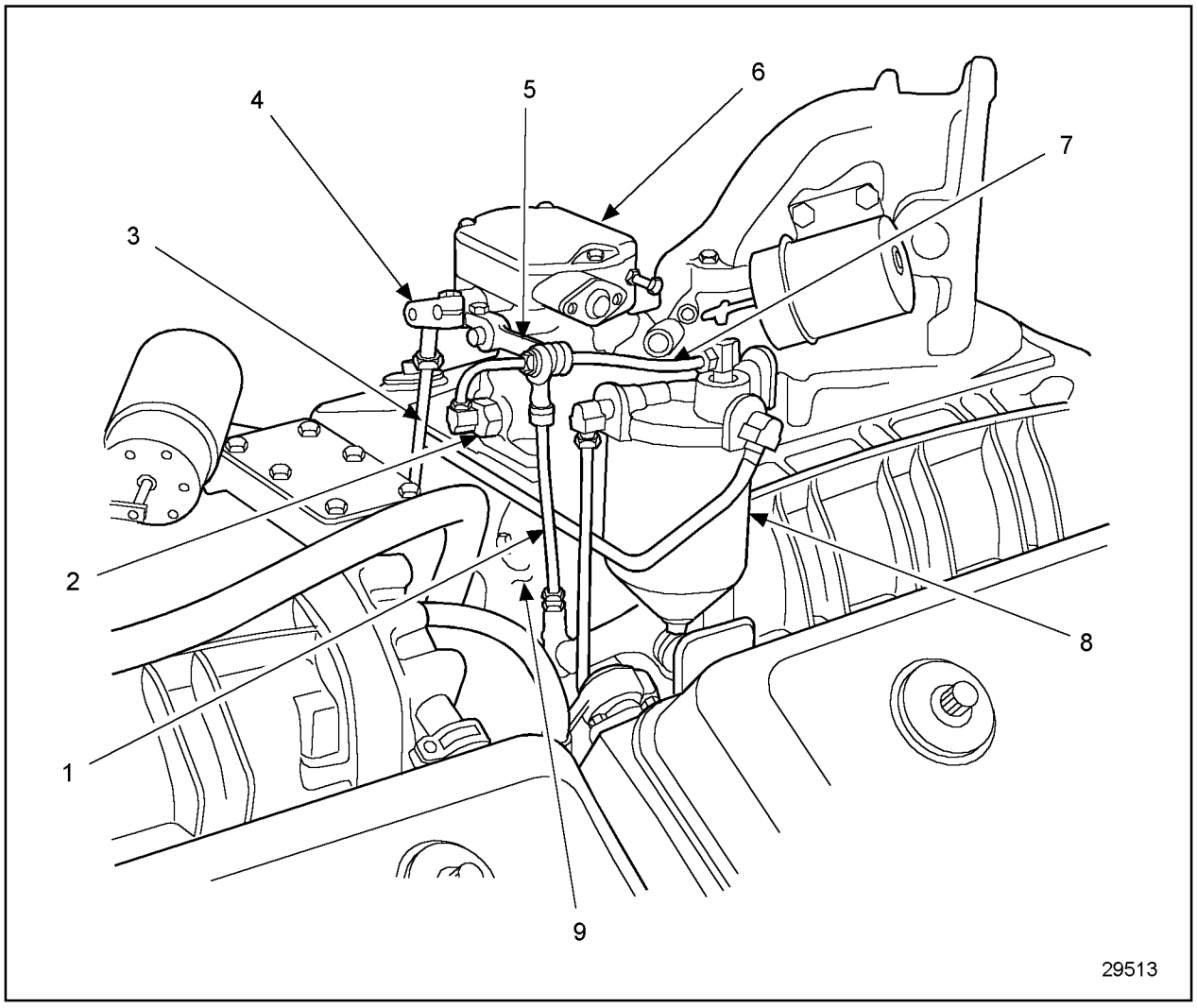
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1. Governor Drive Housing
2. Left Vertical Link Assembly
3. Governor Operating Solenoid Valve
4. Governor Assembly
5. Governor Operating Lever
6. Speed Control Lever
7. Oil Inlet Tube
8. Right Vertical Assembly
9. Governor Oil Reservoir
10. Oil Inlet Plug

Figure 2-191 Typical Hydraulic Governor Mounting

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1. Left Vertical Link Assembly
2. Oil Inlet Plug
3. Right Vertical Link Assembly
4. Governor Operating Lever
5. Speed Control Lever
6. Governor Assembly
7. Oil Inlet Tube
8. Governor Oil Reservoir
9. Governor Drive Housing

Figure 2-192 Hydraulic Governor Mounted on 12V and 16V Engine

The governor is driven by one of the blower rotors through a horizontal drive shaft and bevel gear and a vertical driven sleeve and bevel gear, both mounted on ball bearings and retained in the governor drive housing.

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The governor, through a linkage consisting of the fuel rods, vertical link, and levers, actuates the injector control tubes. Refer to section 2.30. See Figure 2-193.

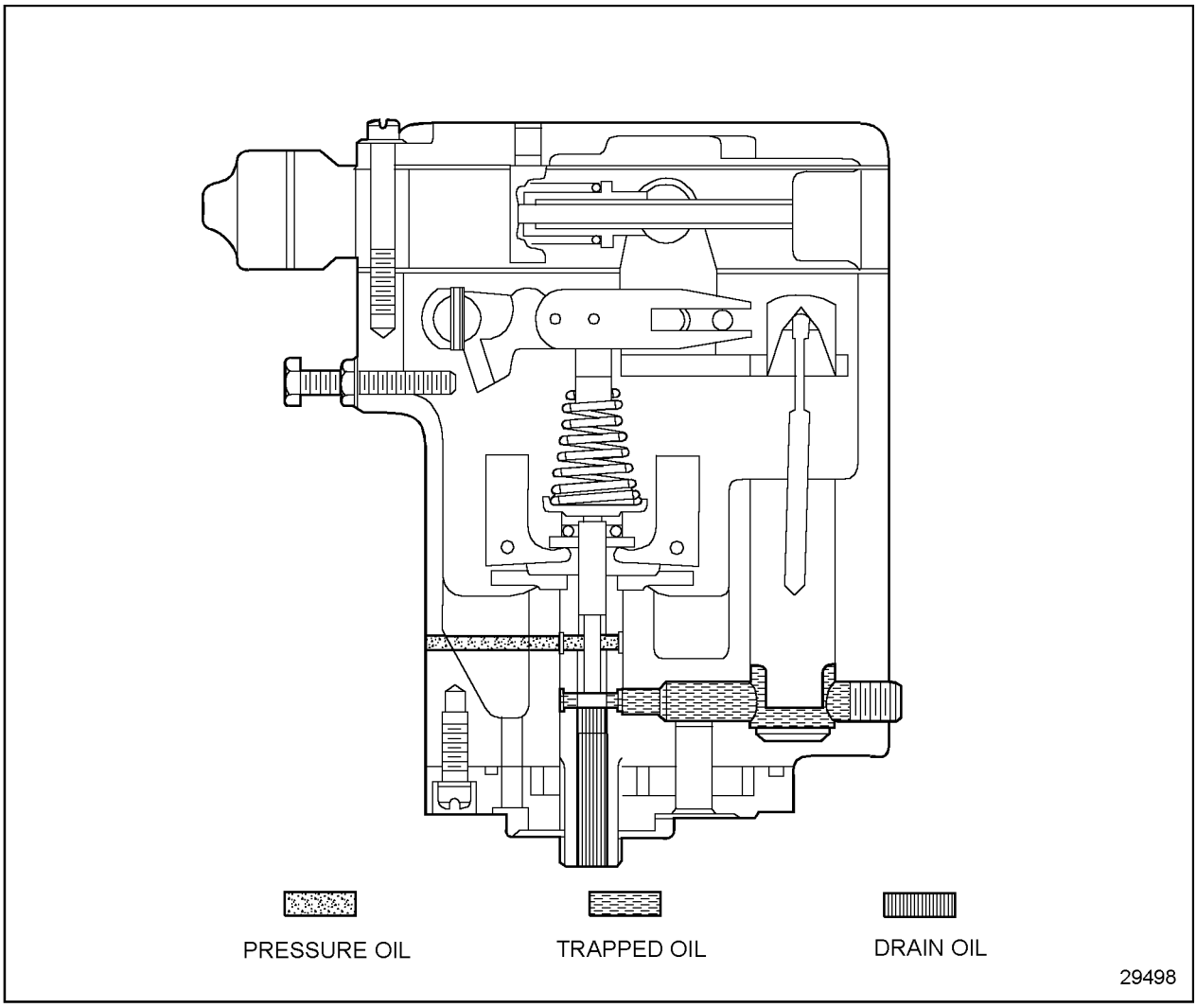


Figure 2-193 Position of Governor Mechanism When Load is Constant

Two pairs of fuel rods are used on the 12V and 16V engines. Each pair of rods is connected to a shaft and lever assembly. The two shaft and lever assemblies, mounted on self-aligning bearings, are connected to a common lever to which the vertical link is attached.

With a cold engine, time is required to develop sufficient oil pressure to operate the governor and move the injector control racks to the full-fuel position. Since this delay is undesirable, the starting time can be shortened by moving the governor operating lever to the full-fuel position, taking injector rack control away from the governor. On certain installations, an oil reservoir supplies the governor with sufficient oil to overcome this delay in governor operation.

NOTE:
Move the governor operating lever to the no fuel position to stop the engine, regardless of the governor.

The hydraulic governor acts as an automatic shutdown device if engine lubricating oil pressure is lost. Should the engine fail to supply oil to the governor, the power piston will drop, allowing the governor operating lever to return to the no-fuel position.

With the engine operating, oil from the engine lubrication system is admitted to the space around the oil pump gears. The gears raise the oil pressure to a value determined by the relief valve plunger spring, which opposes the relief valve plunger. Oil pressure is maintained in the annular space between the undercut portion of the pilot valve plunger and the ball head bore.

For any given throttle setting, the speeder spring has a definite compressional force. The centrifugal force of the revolving flyweights opposes the compressional force. When the two forces are equal, the pilot valve plunger land covers the lower opening in the ball head, maintaining a constant speed.

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When the load on an engine is increased, the engine speed will momentarily drop. The speeder spring will force the governor weights inward, permitting the pilot valve plunger to uncover the lower port in the ball head. Once this port is uncovered, oil, under governor pump pressure, will enter the cavity at the lower end of the power piston and force the piston and floating lever upward. See Figure 2-194. The upward piston motion is transmitted through the terminal lever and the fuel rod to the injector control tube, causing the engine fuel setting to increase.

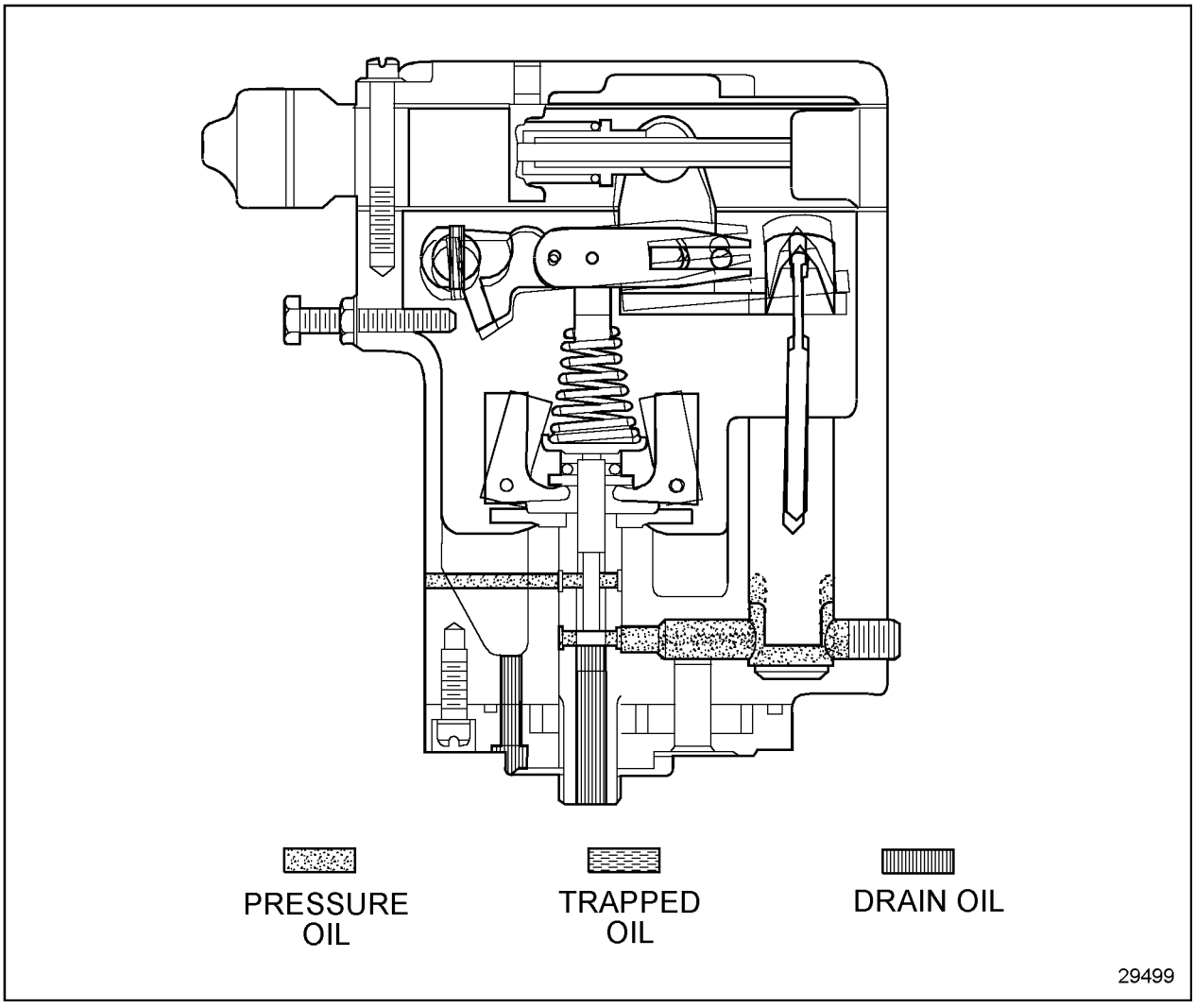


Figure 2-194 Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

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As the power piston and the floating lever rise, the compressional load on the speeder spring is reduced, allowing the flyweights to move out to their normal vertical position. With the governor weights in a vertical position, the land on the pilot valve plunger will cover the ball head ports, trapping the regulating oil under the power piston. The engine will carry the increased load at a slightly reduced speed. See Figure 2-195.

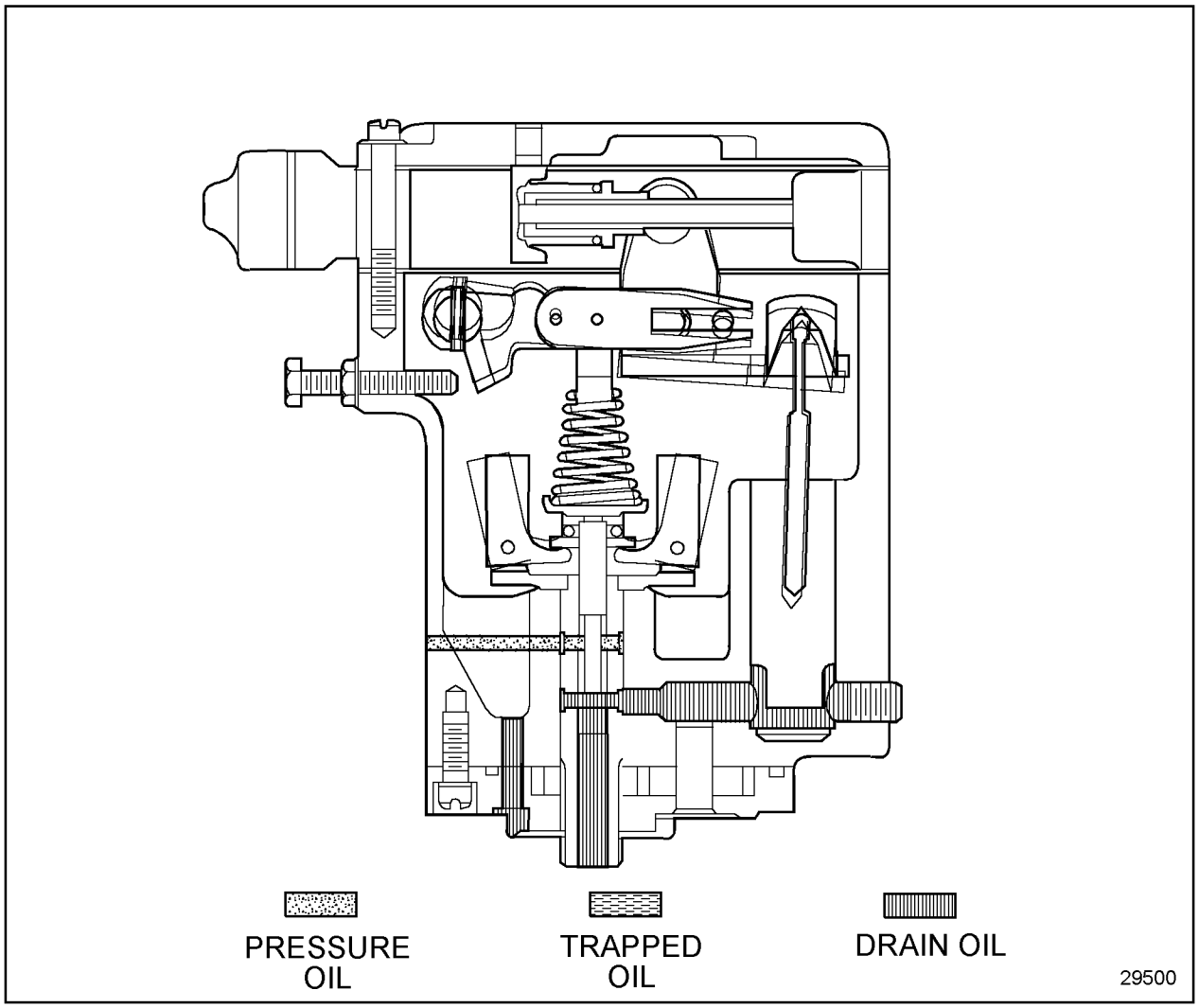


Figure 2-195 Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

The revolving governor flyweights vaporize the oil seeping past the power piston and pilot valve plunger, providing lubrication to the moving parts in the governor housing. The governor pump, pilot valve plunger, and power piston are exposed to pressurized oil. The pilot valve plunger has two oil holes to provide additional lubrication to the thrust bearing. Oil, that collects on the governor housing floor, passes through a passage into the governor drive housing and provides lubrication to the governor drive and driven shaft beveled gears and their bearings.

On rare occasions, the linkage of SG hydraulic governors will jam, but only when all of the following conditions occur:

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1. The SG governor output (terminal) shaft is rotated more than 39 degrees while the power piston is still at minimum position.
2. The SG governor has a horizontal return spring and no internal return spring.
3. The SG governor contains a 011649 power piston with a 0.380 in. diameter or larger hole for the 218259 strut (manufactured since mid-1983).
4. The SG governor is tilted off vertical in the right direction to allow the 218259 strut to fall into a jammed position.

For further information regarding this condition, Woodward® Governor Company should be contacted directly at:

Woodward Governor Company1000 East Drake RoadFort Collins, Co 80522-1519,Phone: (303) 482-5811

2.28.1 Repair or Replacement of SG Hydraulic Governor

To determine if repair or replacement is necessary, perform the following procedure. See Figure 2-196.

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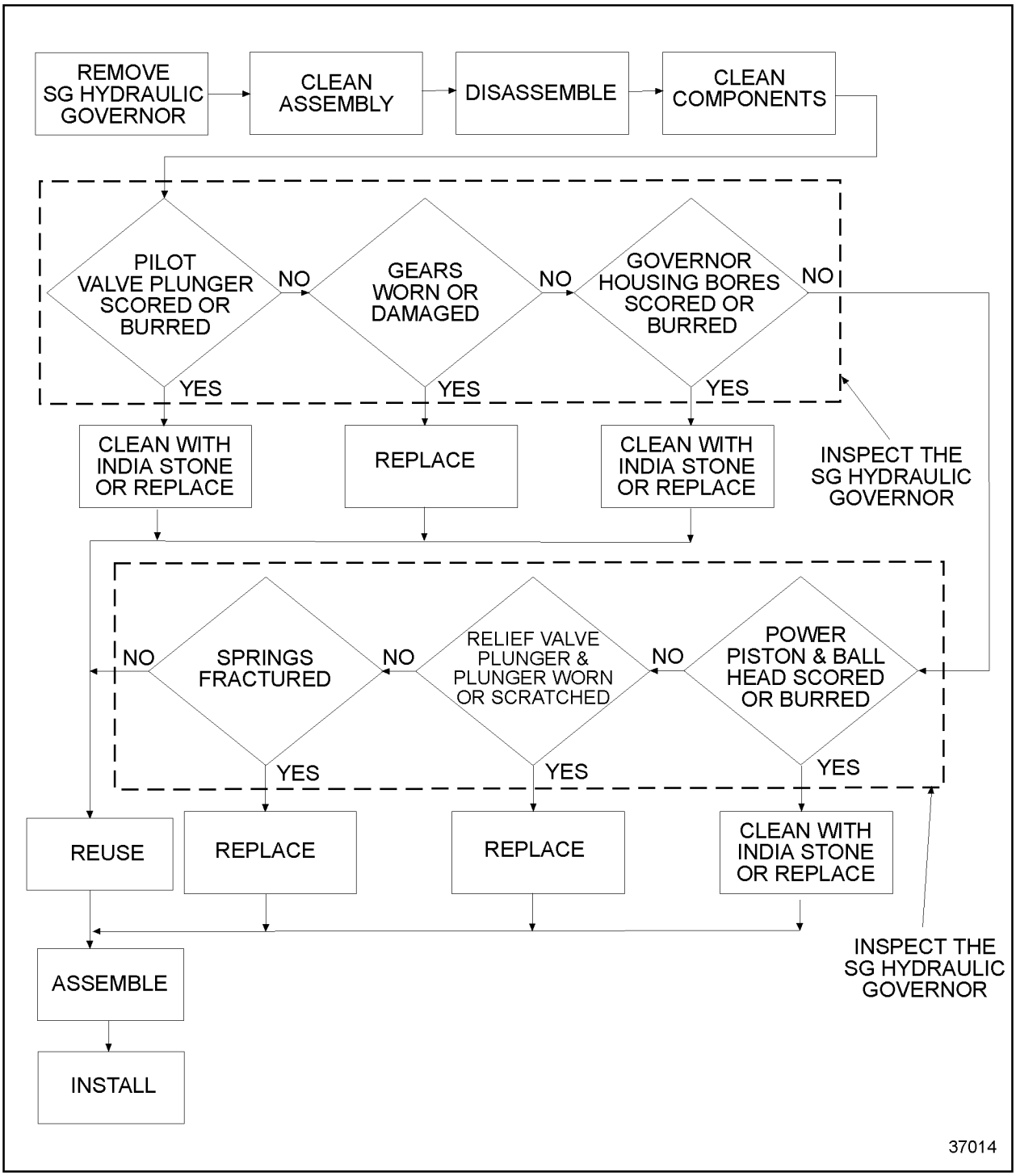


Figure 2-196 Flowchart for Repair or Replacement of SG Hydraulic Governor

2.28.2 Removal of SG Hydraulic Governor

Remove the governor as follows:

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1. Remove the nut, lock washer, and bolt securing the speed control lever to the speed adjusting shaft. Pull the lever with link assembly attached from the shaft.
2. Mark the governor operating lever position on the terminal lever shaft.
3. Loosen the bolt securing the lever to the shaft. Pull the lever, with link assembly attached, from the shaft.

NOTE:
The surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and cylinder block.

4. If the governor is equipped with a governor operating solenoid valve assembly, disconnect and remove the oil tube from the valve assembly and governor housing.
5. Disconnect and remove the oil inlet tube assembly from the governor oil inlet elbow and the governor oil reservoir, if used.
6. On a governor equipped with a synchronizing motor, tag and disconnect the wires from the motor.
7. Remove the four bolts and lock washers securing the governor assembly to the governor drive housing or housing cover.

NOTICE:
Do not remove only the vertical shaft and bearing. If the horizontal drive shaft and bearing assembly is left in the governor drive housing, the shaft will move freely back and forth during engine operation. This is due to the absence of load on the bevel gear which would normally keep the horizontal shaft in position. The rapid rotation and back-and-forth movement of the horizontal drive shaft can cause severe damage to the governor drive housing.

8. Lift the governor away from the drive housing or cover, and remove the gasket.

2.28.2.1 Cleaning of SG Hydraulic Governor

Clean the governor as follows:

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash the governor 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.

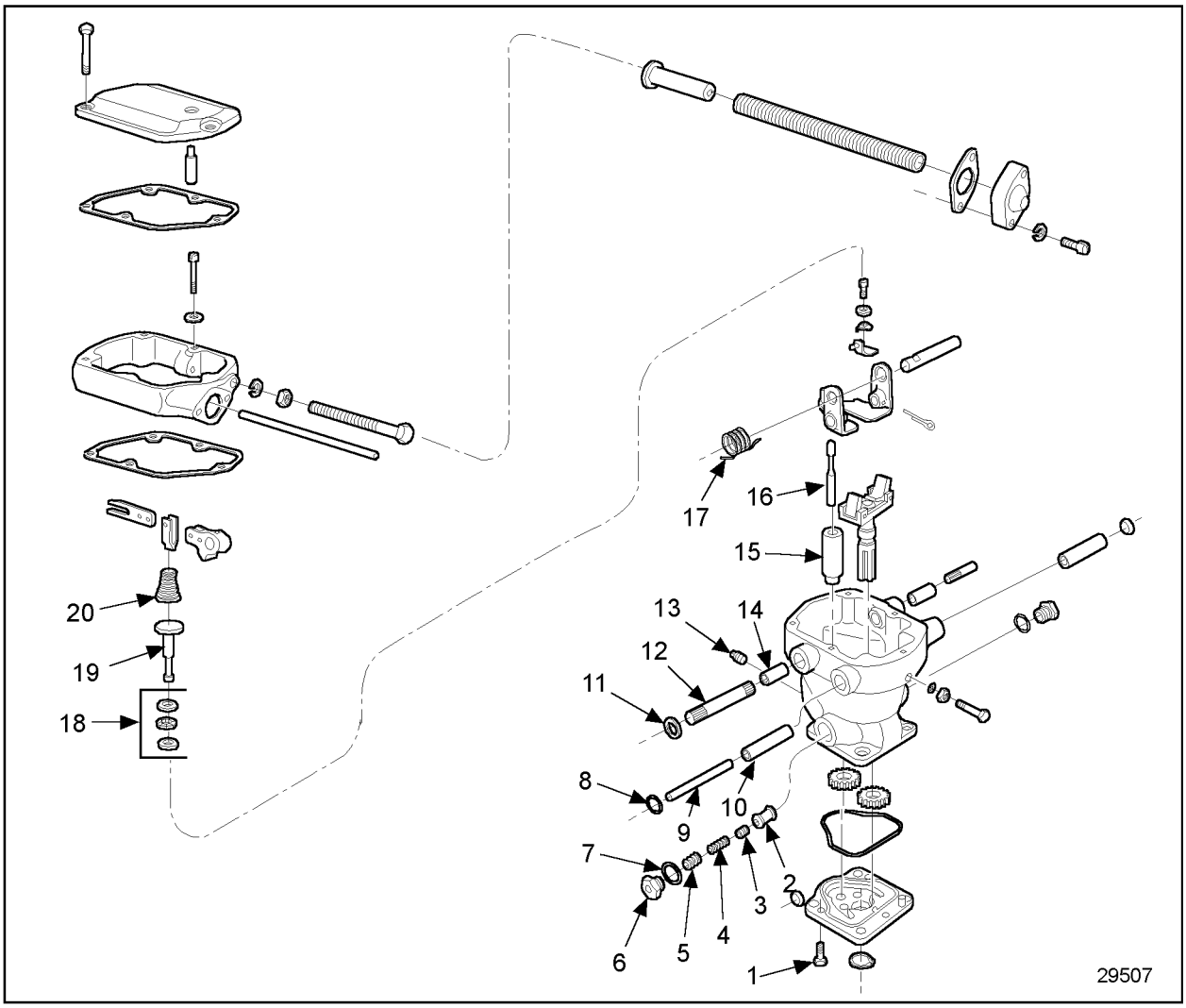
2. Dry it with compressed air.

NOTE:
Governor disassembly should to be carried out only as far as necessary to correct the difficulties that interfere with proper governor operation.

2.28.3 Disassembly of SG Hydraulic Governor

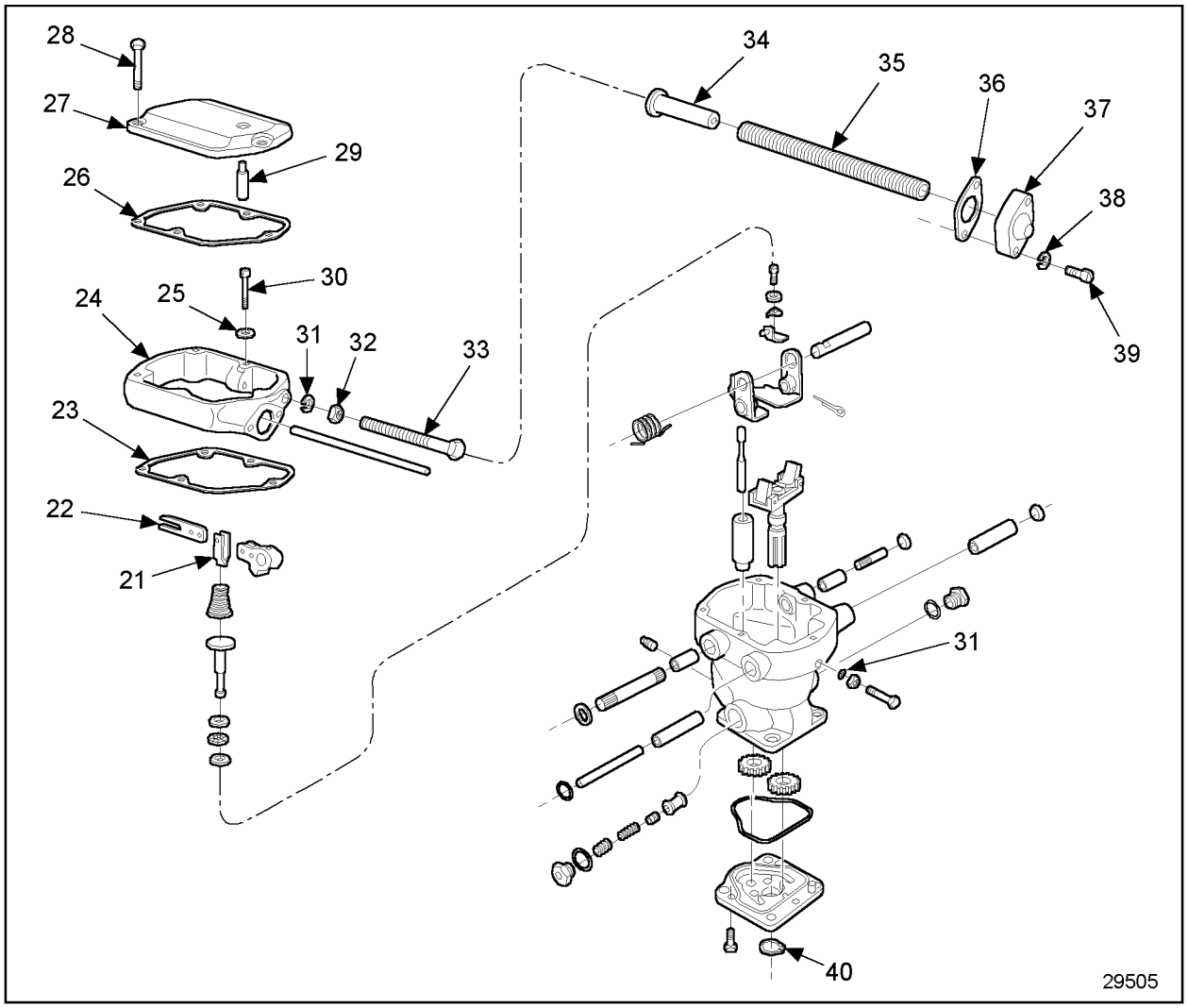
See Figure 2-197, see Figure 2-198, and see Figure 2-199 for component location. Disassemble the governor as follows:

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1. Governor Base Screw
2. Relief Valve Sleeve
3. Relief Valve
4. Relief Valve Spring
5. Retaining Sleeve Spring
6. Governor Oil Inlet Plug
7. Relief Valve Gasket
8. Relief Valve Oil Seal
9. Speed Adjusting Lever Shaft
10. Bushing
11. Terminal Lever Oil Seal
12. Front Terminal Lever Shaft
13. Housing Plug
14. Terminal Lever Bushing
15. Power Piston
16. Floating Pin
17. Torsion Spring
18. Thrust Plunger, Pilot Valve and Bearing
19. Pilot Valve Plunger
20. Speeder Spring

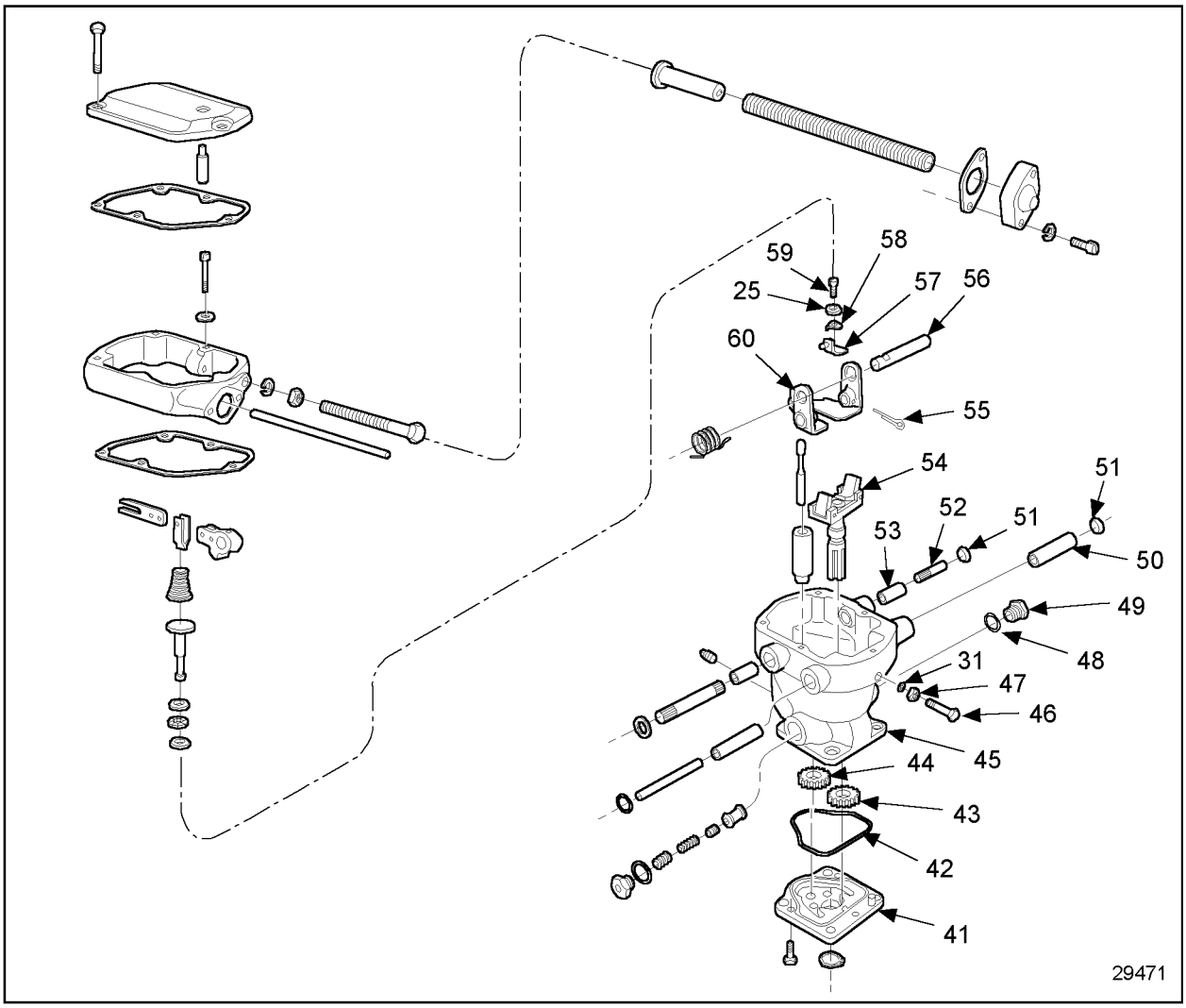
Figure 2-197 SG Hydraulic Governor (1 of 3)



21. Adjusting Fork
22. Floating Adjusting Speed Lever
23. Subcap Gasket
24. Subcap
25. Lock Washer
26. Governor Cover Gasket
27. Governor Cap
28. Bolt
29. Low-Speed Stop Screw
30. Subcap Housing Screw
31. Copper Washers
32. Locknut
33. Load-Limit Adjusting Screws
34. Guide Rod Spring Seat
55. Terminal Lever Return Spring
36. Gasket
37. Spring Pad Cover
38. Internal Lock Washer
39. Spring Pad Screw
40. Lock Ring

Figure 2-198 SG Hydraulic Governor (2 of 3)

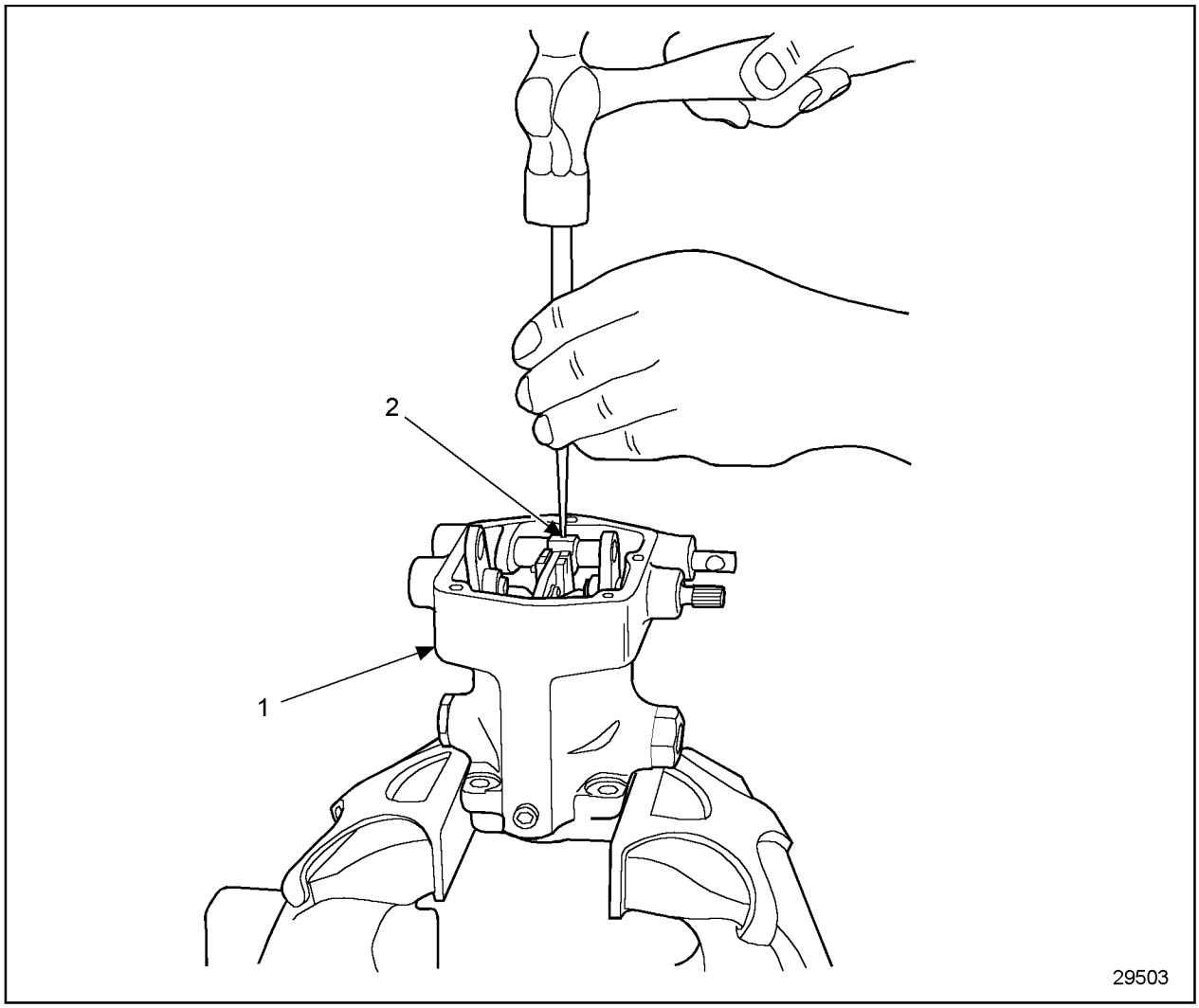
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41. Governor Base
42. Ring Seal
43. Oil Pump Drive Gear
44. Oil Pump Driven Gear
45. Governor Housing
46. Maximum Speed Adjusting Screw
47. Locknut
48. Spacer Cap Gasket
49. Dummy Hole Plug
50. Speed Adjusting Lever Shaft Bushing
51. Cap Plug
52. Rear Terminal Lever Shaft
53. Terminal Lever Bushing
54. Ball Head Assembly
55. Cotter Pin
56. Terminal Lever Cross Pin
57. Speed Droop Adjusting Bracket
58. Plain Washer
59. Droop Adjusting Bracket Screw
60. Terminal Lever

Figure 2-199 SG Hydraulic Governor (3 of 3)

1. Clamp the governor housing and base assembly in a soft-jawed bench vise. See Figure 2-200.



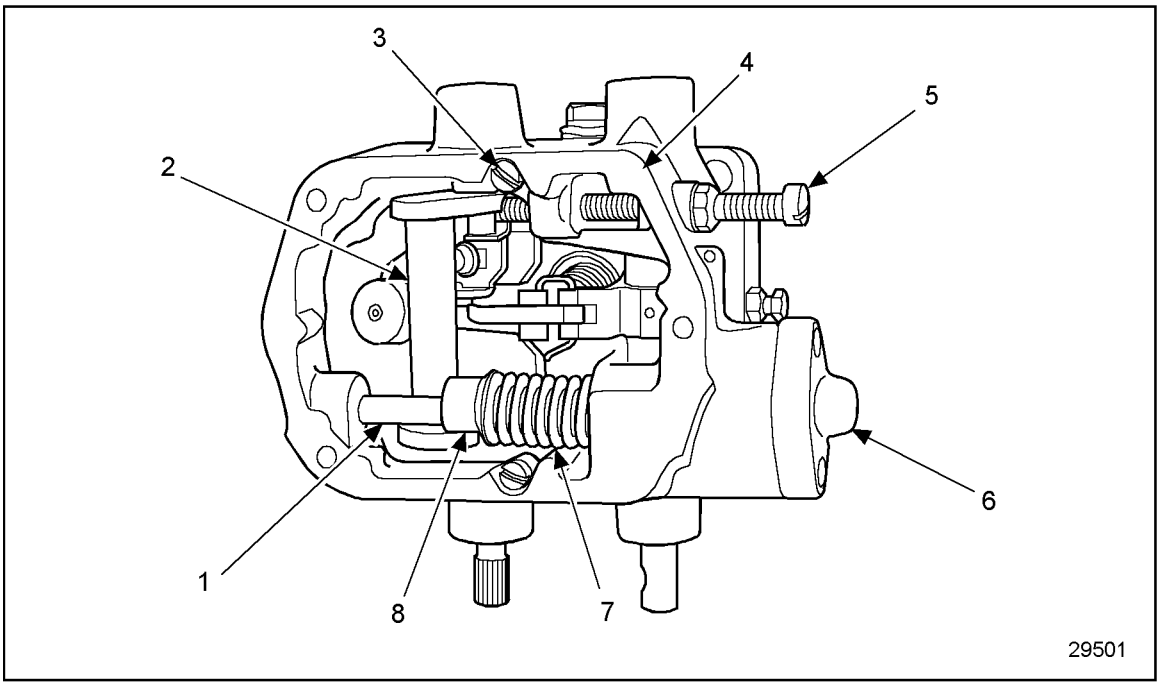
1. Governor Housing
2. Speed Adjusting Lever

Figure 2-200 Removing Speed Adjusting Lever Roll Pin

2. If necessary, remove the oil inlet elbow or fitting from the oil inlet plug.
3. Remove the three cover screws. Remove the cover and gasket from the housing.

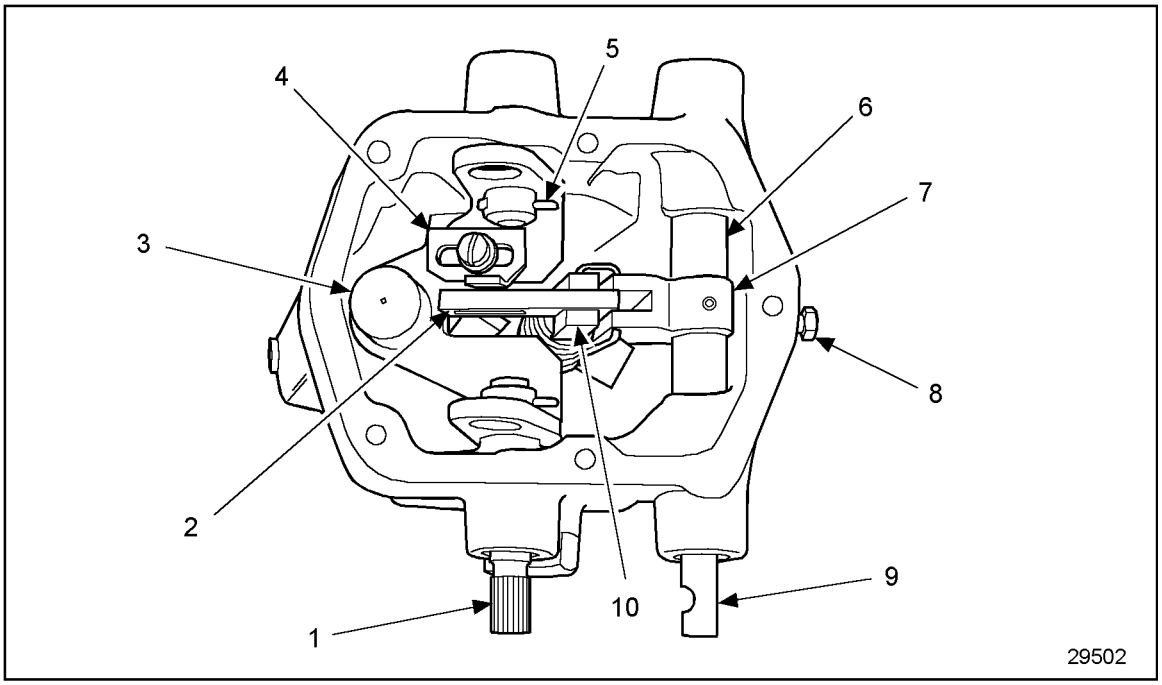
NOTE:
To facilitate governor subcap removal, disassemble the subcap before removing from the governor housing. See Figure 2-201 and see Figure 2-202.

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1. Spring Guide Rod
2. Terminal Lever Cross Pin
3. Subcap Screw
4. Subcap
5. Load Limit Adjusting Screw
6. Spring Pad Cover
7. Fuel Rod Spring
8. Spring Seat

Figure 2-201 Top View of Governor Assembly with Cover Removed



1. Terminal Lever Shaft
2. Floating Lever
3. Terminal Lever
4. Droop Adjusting Bracket
5. Cotter Pin
6. Bushing
7. Speed Adjusting Lever
8. Maximum Speed Adjusting Screw
9. Speed Adjusting Screw
10. Spring Fork

Figure 2-202 Top View of Governor with Subcap Removed

4. Remove the two screws and lock washers securing the spring pad cover to the subcap.
5. Remove the cover from the spring guide rod. Remove the cover gasket.
6. Remove the fuel rod spring and the spring guide rod seat from the spring guide rod and subcap. Pull the spring guide rod from the subcap with a pair of pliers.
7. Loosen the load limit adjusting screw locknut, and remove the screw, locknut and copper washer from the subcap.
8. Remove the two subcap screws and lock washers securing the subcap to the governor housing. Remove the subcap and gasket from the housing.
9. Remove the terminal lever cross pin from the terminal lever arms.
10. On a governor equipped with a synchronizing motor, remove the end of the speed adjusting lever retracting spring from the hole in the side of the speed adjusting lever with needle nose pliers.

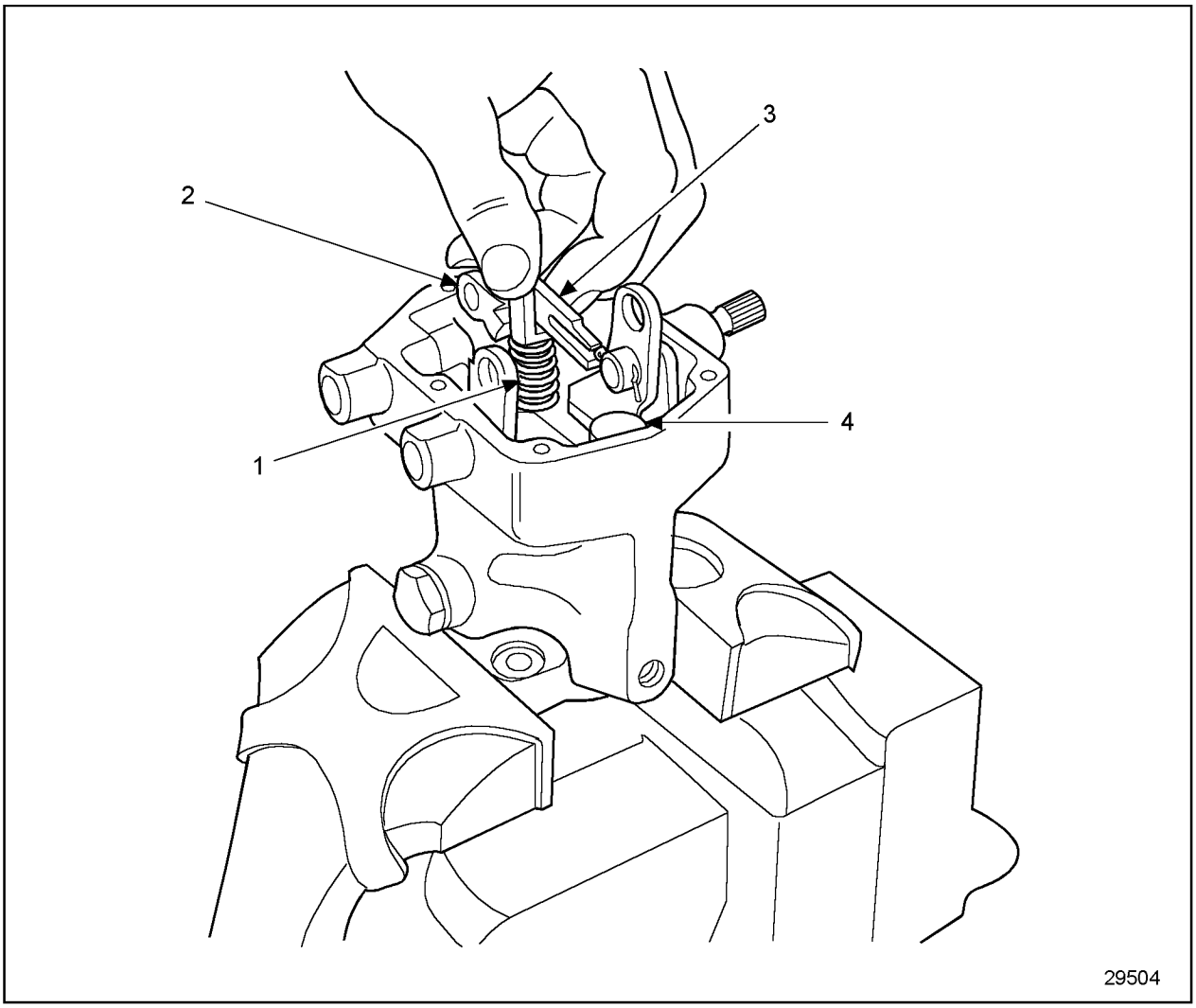
NOTE:
If the maximum speed adjusting screw is not removed, the speed adjusting lever roll (spring) pin will hit the screw when it is removed from the speed adjusting lever and shaft.

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11. Loosen the maximum speed adjusting screw locknut, and remove the adjusting screw, nut and copper washer from the governor housing.
12. Remove the speed droop adjusting bracket screw lock washer and plain washer from the terminal lever.
13. Remove the droop adjusting bracket from the floating lever and the terminal lever.
14. Remove the speed adjusting lever roll (spring) pin from the speed adjusting lever and the lever shaft with a small punch and hammer.
15. Record the position of the groove in the outside diameter of the speed adjusting lever shaft to ensure the groove will be installed in the same position at reassembly.
16. Pull the shaft out of the speed adjusting lever and governor housing.

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17. Lift the speed adjusting lever, floating lever, spring fork, speeder spring, and pilot valve plunger from the governor housing as an assembly. See Figure 2-203.



1. Speeder Spring
2. Speed Adjusting Lever
3. Floating Lever
4. Terminal Lever

Figure 2-203 Removing Speed Adjusting Lever, Spring Fork, Speeder Spring and Pilot Valve Plunger Assembly

18. Remove the pilot valve plunger thrust bearing and the roll (spring) pin from the governor housing.
19. On a governor equipped with a synchronizing motor, slide the speed adjusting lever retracting spring off the speed adjusting shaft bushing, and remove it from the housing.

If necessary, the speed adjusting lever, floating lever, spring fork, speeder spring, and pilot valve plunger and spring seat assembly may be disassembled as follows:

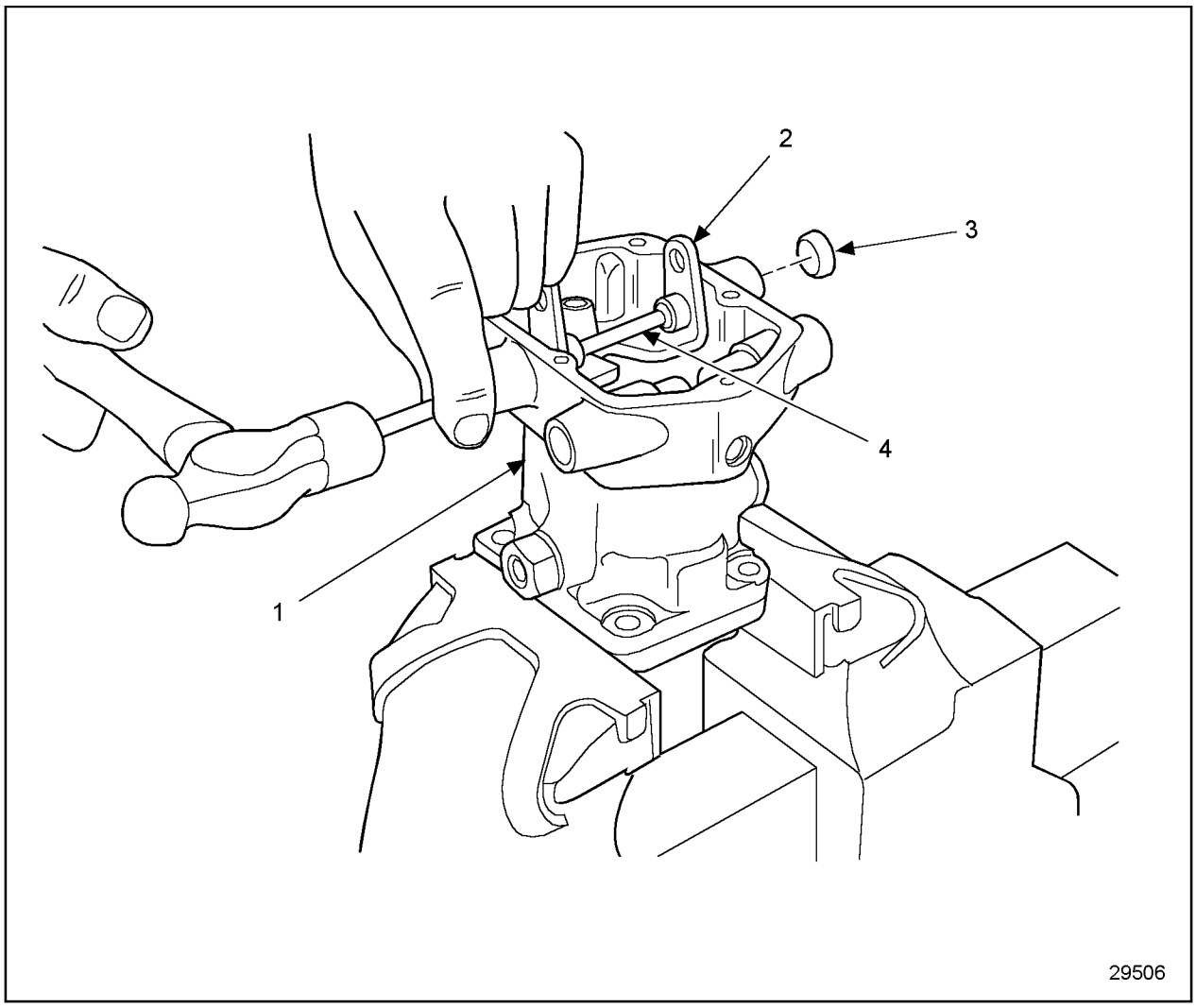
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1. Straighten the bent end of the wire pin securing the speed adjusting lever and spring fork to the speed adjusting floating lever.
2. Pull the pin out of the speed adjusting lever, floating lever and spring fork with a pair of pliers.
3. Insert a small screwdriver between the spring and fork, and pry the speeder spring from the spring fork.
4. Work a small screwdriver under the speeder spring, and remove the spring from the pilot valve plunger and spring seat assembly.

Continue governor removal as follows:

1. Remove the two cotter pins securing the terminal lever to the terminal lever shafts. Pull the long terminal lever shaft from the terminal lever and the governor housing.
2. Place a 1/4 in. brass rod approximately 5 in. long through the terminal lever shaft opening in the governor housing and terminal lever and against the inner end of the second terminal lever shaft.

3. Drive the governor housing cup plug out of the housing boss. See Figure 2-204.



1. Governor Housing Assembly
2. Terminal Lever
3. Cup Plug
4. Terminal Lever Shaft

Figure 2-204 Removing Cup Plug from Governor Housing

4. Push the terminal lever shaft out of the terminal lever and housing with the brass rod.
5. Remove the brass rod, and lift the terminal lever out of the housing.
6. Remove the terminal lever-to-power piston pin from the piston.
7. Remove the governor housing from the bench vise. Turn the governor upside down, and remove the power piston from the housing.

NOTE:
It may be necessary to tap the face of the governor housing lightly on a wood block to jar the piston out of the housing.

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8. Place the governor housing, bottom side up, on a bench.
9. Remove the lock ring from the groove in the ball head shaft with snap ring pliers. Remove the ball head and flyweight assembly from the housing.
10. Remove the three screws securing the governor base to the governor housing.
11. Tap the edge of the governor base lightly with a plastic hammer to loosen it. Remove the base and seal ring from the governor housing and dowel pins.
12. Remove the oil pump drive and driven gears from the governor base or housing.
13. Clamp the bottom (square portion) of the governor housing in a soft-jawed bench vise.
14. Remove the oil inlet plug, gasket, relief valve plunger sleeve retaining spring, and relief valve plunger spring from the governor housing.
15. Remove the dummy hole plug and gasket from the opposite side of the governor housing.
16. Insert a small brass rod through the dummy hole opening, and push the relief valve plunger and the relief valve plunger sleeve out of the governor housing. Catch the relief valve plunger and sleeve by hand when removing them.

NOTE:
The relief valve plunger incorporates a No. 8-32 thread to facilitate plunger removal from the housing, when required, without removing and disassembling the governor.

17. If necessary, remove the pipe plug in the forward face of the governor housing.
18. If necessary, insert a 1/4 in. brass rod through the shaft opening to remove the speed adjusting lever shaft hole plug in the governor housing. Tap the cup plug out of the housing boss with a hammer.

2.28.3.1 Cleaning of SG Hydraulic Governor

Clean the governor as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash all governor 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 with compressed air.

2.28.3.2 Inspection of SG Hydraulic Governor

Inspect the governor as follows:

1. Visually inspect the pilot valve plunger and its bore in the ball head for scoring and burrs.
   [a] If slightly scored, the area may be cleaned with a fine India stone.

NOTE:
Use care not to round off the plunger edges.

   [b] If excessively scored or burred, replace the plunger. Refer to section 2.28.4.
   [c] If not scored or burred, continue inspection.
2. Visually inspect the oil pump gears and the driven gear bushing for excessive wear and damage.
   [a] If excessively worn or damaged, replace the oil pump gears and driven gear bushing. Refer to section 2.28.4.
   [b] If not excessively worn or damaged, proceed with the inspection.
3. Visually inspect the power piston and its governor housing bore for scoring and burrs.
   [a] If slightly scored, the areas may be cleaned up with a fine India stone.

NOTE:
Use care to prevent stoning flat areas and rounding off the piston edges.

   [b] If excessively scored or burred, replace the power piston and governor housing. Refer to section 2.28.4.
   [c] If not scored or burred, continue inspection.
4. Visually inspect the outside diameter of the ball head and its bore in the governor housing for scoring and burrs.
   [a] If slightly scored, the areas may be cleaned up with a fine India stone.

NOTE:
Use care to prevent stoning flat areas and rounding off the edges of the ball head.

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[b] If excessively scored or burred, replace the ball head and the governor housing. Refer to section 2.28.4.

[c] If not scored or burred, continue inspection.

5. Visually inspect the pilot valve plunger thrust bearing for excessive wear and flat spots.

NOTE:
The pilot valve plunger power piston and ball head assembly must operate freely in their respective bores.

[a] If excessively worn and flat spots are detected, replace the pilot valve plunger thrust bearing. Refer to section 2.28.4.

[b] If not excessively worn and no flat spots are evident, proceed with the inspection.

6. Inspect the finished flyweight radius (thrust bearing contact surfaces) for excessive wear or flat spots.

[a] If excessively worn flat spots are detected, replace the flyweights. Refer to section 2.28.4.

[b] If not excessively worn and no flat spots are evident, proceed with the inspection.

7. Visually inspect the ends of the power piston-to-terminal lever pin for wear and scoring.

[a] If slightly scored, clean the ends with a fine India stone.

[b] If excessively scored or worn, replace the power piston-to-terminal lever pin. Refer to section 2.28.4.

[c] If not scored or worn, proceed with inspection.

8. Visually inspect the speed adjusting lever shaft and terminal lever shaft oil seals in the governor housing for excessive wear.

[a] If excessively worn, replace the speed adjusting lever shaft and terminal lever shaft oil seals. Refer to section 2.28.4.

[b] If not excessively worn, continue inspection.

9. Inspect the speed adjusting lever shaft and terminal lever shaft bushing in the governor housing for excessive wear.

[a] If excessively worn, replace the speed adjusting lever shaft and terminal lever shaft bushing. Refer to section 2.28.4.

[b] If not excessively worn, proceed with inspection.

10. Visually inspect the relief valve plunger and the inside diameter of the plunger sleeve for wear, scratches, and sludge in the grooves and holes in the plunger and sleeve.

NOTE:
The current plunger incorporates four relief holes and is slightly larger than the former plunger. The current sleeve assembly has the washer affixed to the sleeve. When it is necessary to replace either the former plunger or the sleeve and washer, a plunger kit must be used which includes the current plunger and a sleeve assembly.

[a] If worn, scratched, and sludge is present, replace with new plunger kit. Refer to section 2.28.4.

[b] If not worn, scratched, and sludge is not present, continue inspection.

11. Visually inspect the plunger and sleeve springs for fractured coils.

[a] If fractures are evident, replace with new plunger kit. Refer to section 2.28.4.

[b] If no fractures are evident, continue inspection.

12. Visually inspect the fuel rod spring for fractured coils.

[a] If fractured, replace the fuel rod spring. Refer to section 2.28.4.

[b] If not fractured, continue inspection.

13. Visually inspect the spring guide rod seat face where it contacts the terminal lever cross pin for scoring and wear.

[a] If scored or worn, replace the spring guide rod seat. Refer to section 2.28.4.

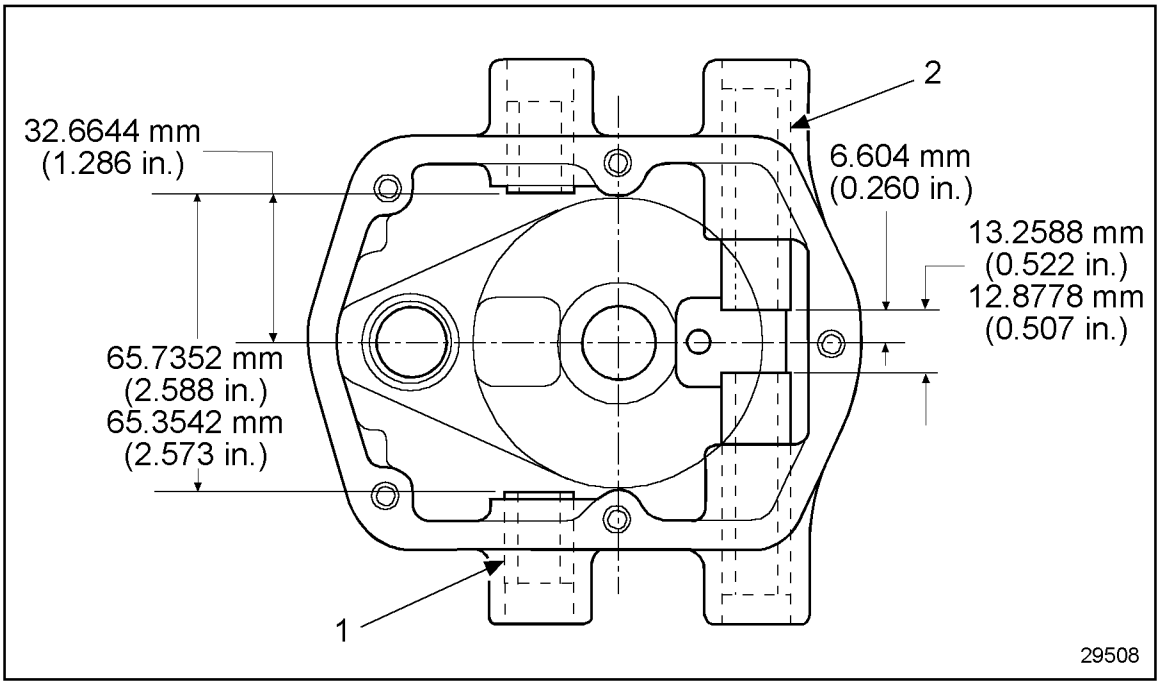
[b] If not scored or worn, reuse the parts.

2.28.4 Assembly of SG Hydraulic Governor

Assemble the governor as follows:

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1. If removed, install new speed adjusting lever and terminal lever shaft bushings in the governor housing to the specified dimensions. See Figure 2-205.



1. Terminal Lever Shaft
2. Speed Adjusting Lever Shaft

Figure 2-205 Location of Speed Adjusting Lever and Terminal Lever Shaft Bushings in Governor Housing

2. If removed, install the pipe plug in the governor housing.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Lubricate the two oil pump gears with engine oil, and place them in their respective positions in the governor base.
4. Place a new seal ring in the groove in the governor base, with the wide side of the seal down in the groove.
5. Set the governor housing on the has, aligning the base dowels with the housing holes and the housing idler gear stud with the idler gear hole.
6. Press the housing against the seal ring in the base.
7. Lubricate the outside diameter of the ball head and flyweight assembly with engine oil.
8. Insert the end of the ball head straight into and through the governor housing bore, drive gear and base.

9. Insert the three screws through the governor base, and thread them into the governor housing.
10. Turn the ball head assembly while tightening the three screws to ensure the ball head assembly rotates freely.
11. If it binds, loosen the three screws, tap the sides of the base lightly with a plastic hammer, and tighten the screws.
12. Revolve the ball head assembly, and check for bind. Repeat until all parts rotate freely.
13. Install the ball head lock ring in the groove in the ball head shaft with a pair of snap ring pliers.

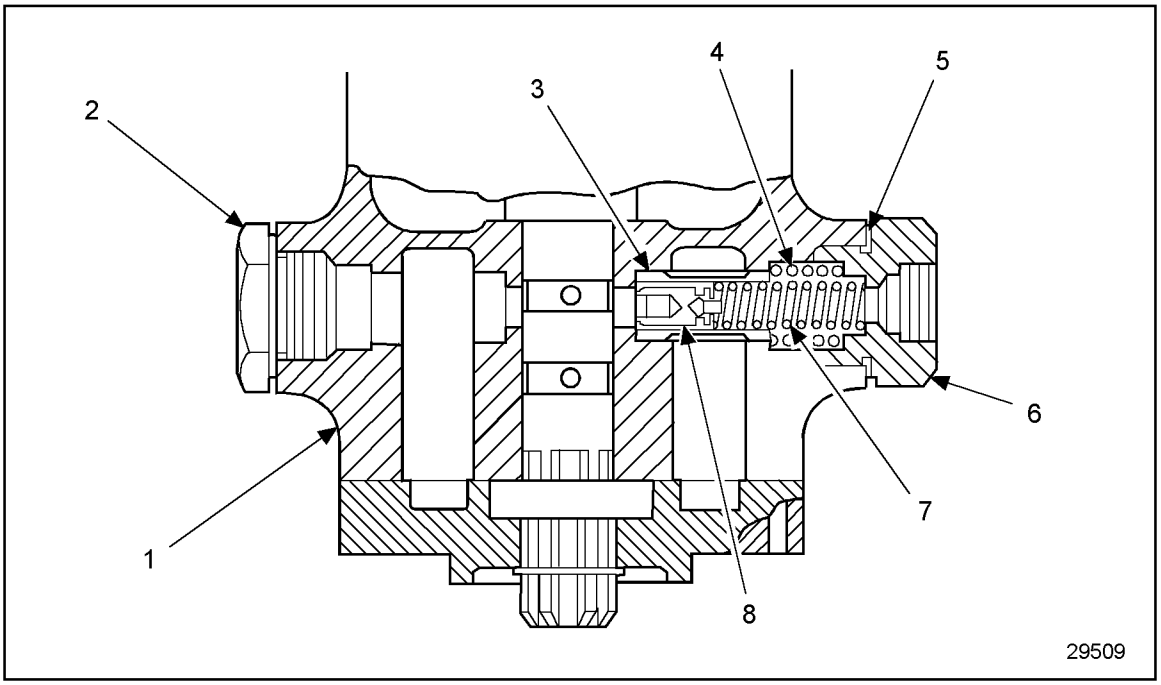
⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

14. Lubricate the outside diameter of the relief valve plunger and plunger sleeve with engine oil. Insert the relief valve plunger into the plunger sleeve.
15. Insert the relief valve plunger and sleeve assembly straight into the opening in the right-hand side of the governor housing (when viewed from the power piston side) with

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the tapped hole in the relief valve plunger facing out. Push it in against the shoulder in the housing. See Figure 2-206.



1. Governor Housing
2. Plug
3. Plunger Sleeve
4. Sleeve Spring
5. Gasket
6. Oil Inlet Plug
7. Plunger Spring
8. Relief Valve Plunger

Figure 2-206 Location of Oil Relief Valve Plunger, Plunger Sleeve, Springs, Oil Inlet Plug, and Dummy Plug

16. Place the relief valve plunger spring and the plunger sleeve retaining spring in the housing and against the plunger and sleeve.
17. Place a gasket on the oil inlet plug. Place the plug over the ends of the springs, and thread it into the governor housing.
18. Place a gasket on the dummy hole plug, and thread it into the opening in the opposite side of the governor housing.
19. Clamp the bottom (square portion) of the governor housing and base assembly in a soft-jawed bench vise.
20. Tighten the oil inlet plug and the dummy hole plug securely.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

21. Lubricate the power piston with engine oil. Insert the piston, small end down, straight into the governor housing piston bore, and push it in until it bottoms.
22. Apply a thin coat of sealing compound to the outside diameter of a new terminal lever shaft oil seal.
23. Start the seal, with the lip of the seal facing down, straight into the terminal lever shaft opening in the oil inlet plug side of the housing. Press the seal in flush with the outside face of the boss.
24. Clamp the bottom (square portion) of the governor housing and base assembly between the soft jaws of a bench vise.

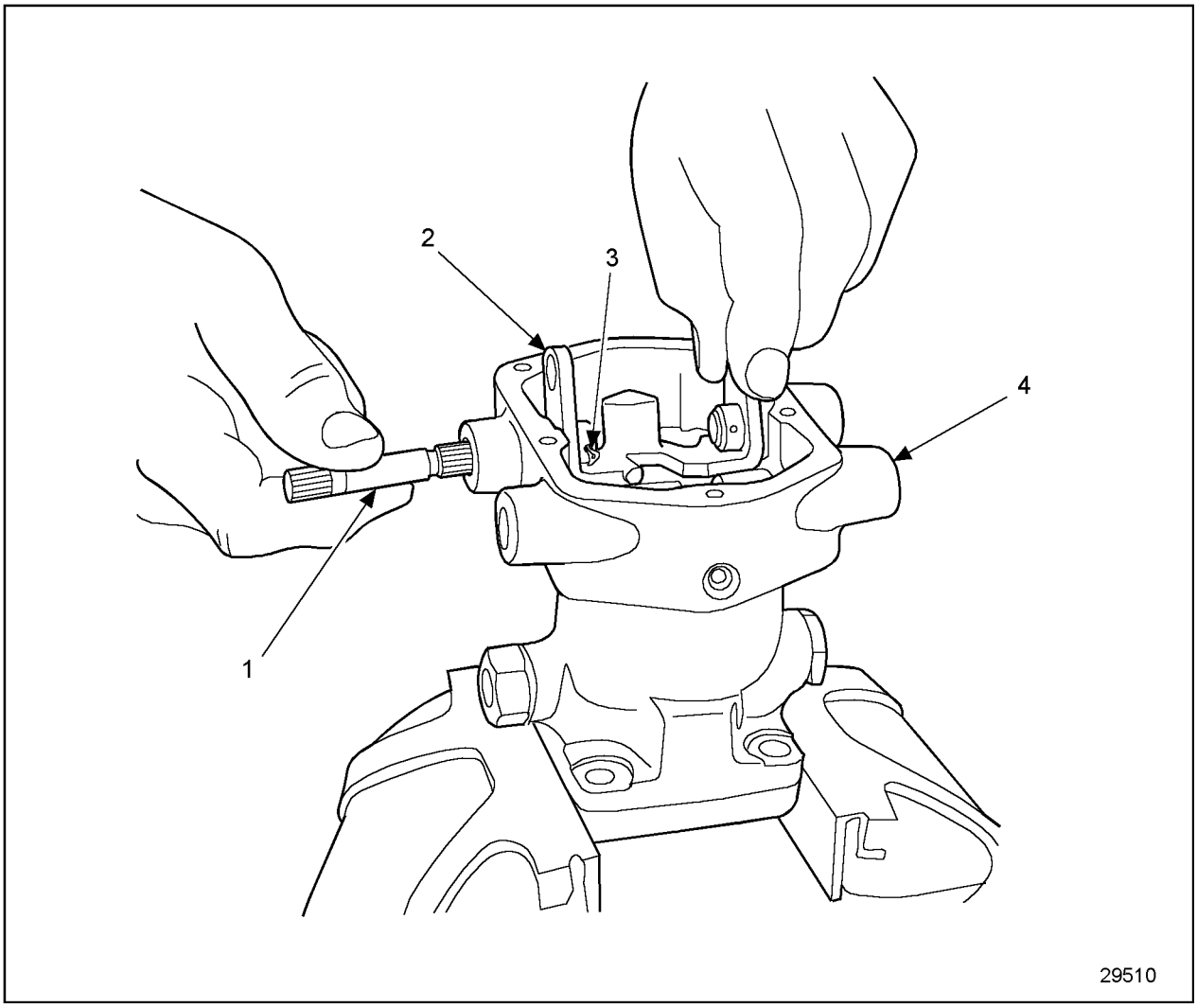
CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

25. Lubricate the long terminal lever shaft with engine oil.
26. Place the terminal lever between the ends of the two bushings inside the governor housing.

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27. Insert the serrated end (with the cotter pin hole) of the shaft through the oil seal and bushing in the housing, with the cotter pin holes in the shaft and terminal lever aligned. See Figure 2-207.



1. Terminal Lever Shaft
2. Terminal Lever
3. Cotter Pin
4. Governor Housing Assembly

Figure 2-207 Installing Terminal Lever Shaft in Governor Housing and Terminal Lever

28. Push the shaft into the lever until the two holes align.
29. Install a cotter pin through the terminal lever and shaft, and bend the ends over the side of the terminal lever.
30. Install the second terminal lever shaft in the housing and terminal lever at the opposite side of the governor housing.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

31. Lubricate the long terminal lever shaft with engine oil.
32. Place the terminal lever between the ends of the two bushings inside the governor housing.
33. With the cotter pin holes in the shaft and terminal lever aligned, insert the serrated end (with the cotter pin hole) of the shaft through the oil seal and bushing in the housing.
34. Push the shaft into the lever until the two holes align.
35. Install a cotter pin through the terminal lever and shaft, and bend the ends over the side of the terminal lever.
36. Apply a thin coat of sealing compound to the outside diameter of a new governor housing cup plug.
37. Start the plug, open end out, straight into the terminal lever shaft opening in the housing. Press the plug in flush with the outside face of the housing boss.
38. Apply a thin coat of sealing compound to the outside diameter of a new speed adjusting lever shaft oil seal.
39. Start the seal, with the seal lip facing down, straight into the speed adjusting lever shaft opening in the oil inlet plug side of the housing. Press the seal in flush with the outside face of the boss.
40. Apply a thin coat of sealing compound to the outside diameter of a new governor housing cup plug.
41. Start the plug, open end out, straight into the speed adjusting lever shaft opening in the housing. Press the plug in flush with the outside face of the housing boss.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

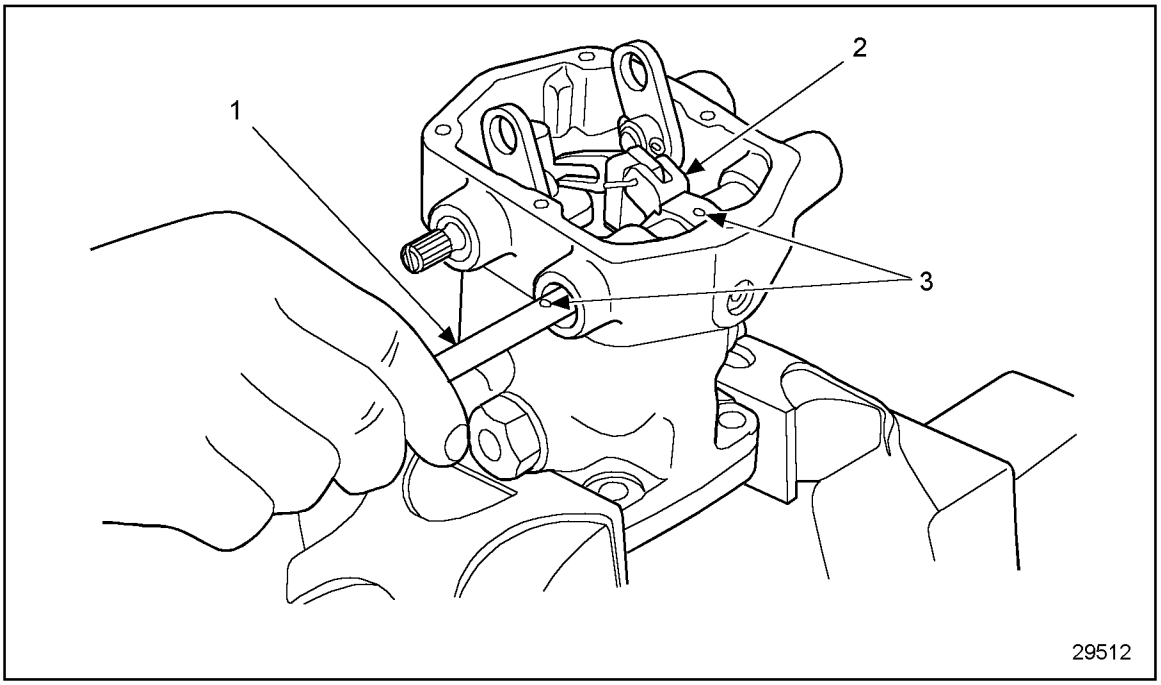
42. Lubricate the terminal lever-to-power piston pin with engine oil.
43. Raise the edge of the terminal lever, and insert the pin in the power piston hole. Lower the terminal lever onto the pin.

If disassembled, assemble the speed adjusting lever, floating lever, spring fork, speeder spring, and pilot valve plunger as follows:

1. Place the non-slotted end of the speed adjusting floating lever in the slot of the speed adjusting lever so the pin holes are aligned.

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2. Insert the long end of the speed adjusting lever-to-floating lever wire pin through the pin hole in the speed adjusting lever and floating lever. See Figure 2-208.



1. Speed Adjusting Lever Shaft
2. Speed Adjusting Lever
3. Roll Pin Holes

Figure 2-208 Installing Speed Adjusting Lever Shaft in Governor Housing and Adjusting Lever

3. Place the speed adjusting floating lever in the spring fork slot, with the pin holes aligned. Insert the short end of the wire pin through the hole in the spring fork and floating lever.
4. Push the wire pin against the speed adjusting lever and spring fork, and bend the protruding end of the wire pin toward the slotted end of the floating lever.
5. Press the lower end of the spring fork into the small end of the speeder spring. Insert the opposite end of the spring in the spring seat of the pilot valve plunger.

Continue governor assembly as follows:

1. On a governor equipped with a synchronizing motor, place the speed adjusting lever retracting spring over the speed adjusting lever shaft bushing in the governor housing, with the hooked end over the slot between the two bushings.
2. Place the governor housing on its side, oil inlet plug side up, on a bench, housing top facing out.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Lubricate the pilot valve plunger thrust bearing with engine oil.
4. Place it over the end of the pilot valve plunger with the smallest, outside diameter, bearing race next to the spring seat.

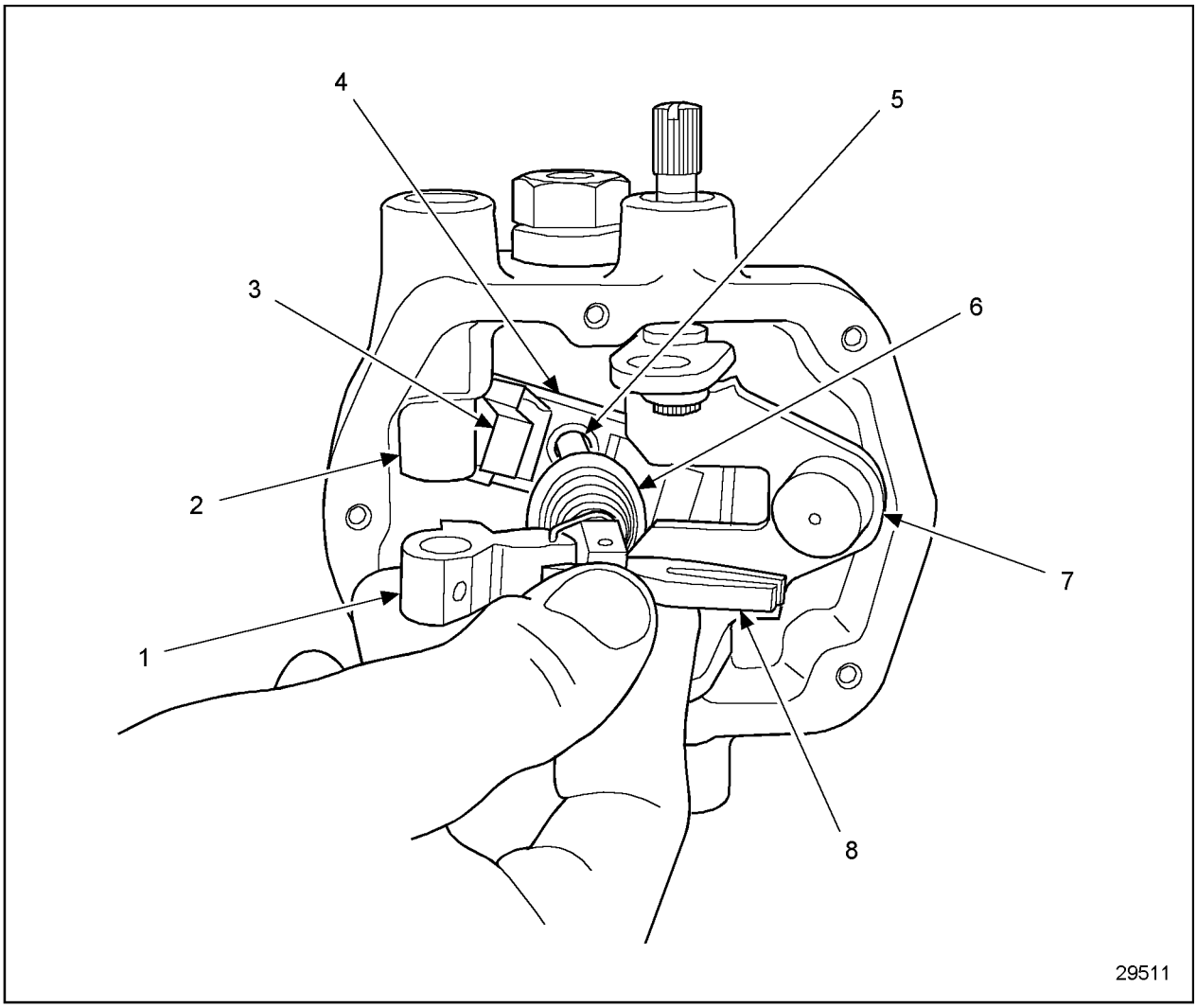
CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

5. Lubricate the pilot valve plunger with engine oil.

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6. Hold the thrust bearing against the spring seat, and insert the assembly in the governor housing with the speed adjusting lever facing the two housing bushings. See Figure 2-209.



1. Speed Adjusting Lever
2. Bushing
3. Flyweight
4. Ball Head Assembly
5. Pilot Valve Plunger
6. Speeder Spring
7. Terminal Lever
8. Floating Lever

Figure 2-209 Installing Speed Adjusting Lever, Floating Lever, Speeder Spring, and Pilot Valve Plunger Assembly

7. Start the pilot valve plunger straight into the ball head bore, and push the assembly in until the speed adjusting lever is in position between the two bushings and the thrust bearing is resting on the lip of the flyweights.
8. Clamp the governor housing and base assembly in a soft-jawed bench vise.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

9. Lubricate the speed adjusting lever shaft with engine oil.
10. Rotate the shaft so the slot in the outside diameter of the shaft is in the same position as at the time of removal.
11. Insert the shaft in the shaft bushing, from the oil inlet plug side, with the roll pin hole in the shaft and lever aligned.
12. While holding the speed adjusting lever, push the shaft through the bushing, and into the second shaft bushing until the pin holes are aligned.

NOTE:
On a governor equipped with a synchronizing motor, ensure hooked end of the speed adjusting lever retracting spring is on top of the speed adjusting lever before installing the shaft.

13. Start the speed adjusting lever roll (spring) pin straight in the pin hole in the lever. Tap the pin through the lever and shaft until it is flush with the top of the lever.
14. On a governor equipped with a synchronizing motor, rotate the speed adjusting lever retracting spring around the shaft bushing. Insert the hooked end of the spring in the small hole in the side of the speed adjusting lever with needle nose pliers.
15. Place the speed droop adjusting bracket against the top face of the terminal lever, with the pin in the bracket in the speed adjusting floating lever slot. Secure it to the lever with a flat washer, lock washer and screw.
16. If removed, thread the locknut on the maximum speed adjusting screw. Place the copper washer on the adjusting screw, and thread the screw approximately halfway in the governor housing.
17. Install the terminal lever cross pin through the pin holes in the terminal lever with the spring guide rod slot in the pin facing up.
18. Affix a new governor subcap gasket to the top of the governor housing.
19. Place the governor subcap on top of the gasket and housing with the fuel rod spring opening in the subcap facing the maximum speed adjusting screw side of the governor housing.
20. Install the two subcap screws and lock washers. Tighten them securely.

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

21. Lubricate the spring guide rod with engine oil. Insert the rod end through the opening in the subcap, through the slot in the terminal lever cross pin, and into the hole at the opposite end of the subcap.
22. Place the spring guide rod seat, large diameter end first, over the end of the spring guide rod. Push it forward over the rod and into the notch in the terminal lever cross pin with the flat on the side of the seat adjacent to the terminal lever cross pin support.
23. Insert the end of the fuel rod spring over the end of the spring guide rod, through the opening in the subcap and over the end of the spring guide rod seat.
24. Affix a new gasket to the flat face of the spring pad cover.
25. Place the spring pad cover against the end of the fuel rod spring.
26. Push in on the cover to compress the spring and, at the same time, pilot the end of the spring guide rod in the hole in the flat face of the cover.
27. Install the two screws and lock washers. Tighten them securely.
28. If removed, thread the locknut on the load limit adjusting screw. Place the copper washer over the end of the load limit adjusting screw.
29. Thread the screw into the subcap until the end protrudes approximately 1/8 in. through the second boss inside the subcap.
30. Affix a new gasket to the top face of the governor subcap. Place the governor cover on top of the gasket, and install the three screws with lock washers. Tighten the screws securely.
31. If removed, install the oil inlet elbow or fitting in the oil inlet plug.

2.28.5 Installation of SG Hydraulic Governor

Install the governor as follows:

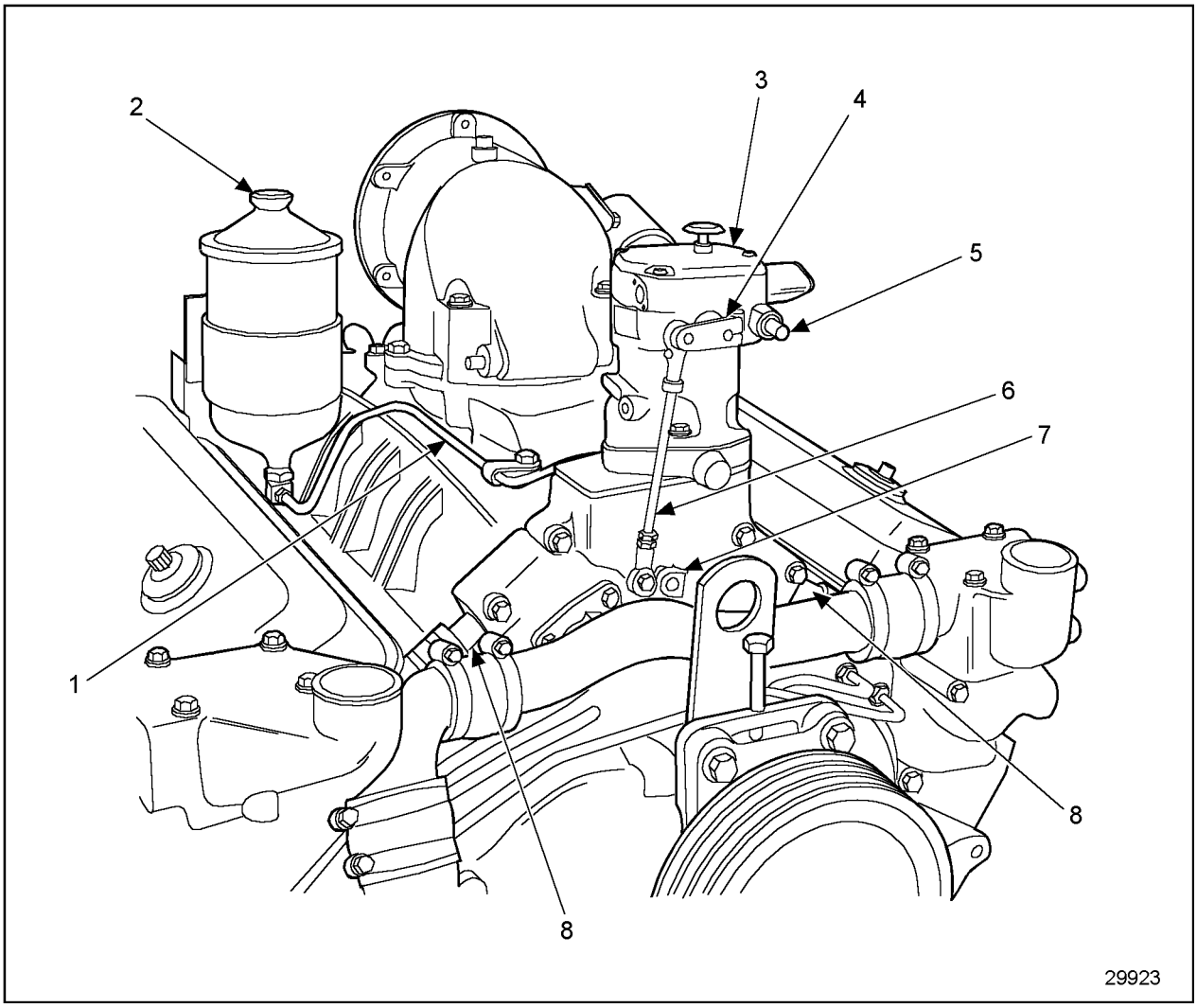
1. Affix a new gasket to the top of the governor drive housing or housing cover.
2. Position the governor over the governor drive housing or housing cover with the ends of the terminal lever and speed adjusting lever shafts facing the front end of the engine.
3. Turn the ball head assembly slightly to align the ball head shaft splines with the driven shaft sleeve splines. Enter the shaft straight in the sleeve, and set the governor on the gasket and drive housing or cover.
4. Install the four governor to drive housing bolts and lock washers. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.
5. Install and connect the oil inlet tube assembly to governor oil reservoir or oil supply valve (if used) and the oil inlet elbow or fitting.

6. If the governor is equipped with a governor operating solenoid valve assembly, install and connect the oil tube to the valve assembly and the governor housing.
7. On a governor equipped with a synchronizing motor, connect the wires to the motor.
8. Place the governor operating lever, with link assembly attached, on the terminal lever shaft in the same position as at the time of removal. Tighten the retaining bolt to 10-12 N·m (7-9 lb·ft) torque.
9. Place the speed control lever, with link assembly attached, on the speed adjusting lever shaft.
10. Install the bolt, lock washer, and nut. Tighten the bolt nut to 11-14 N·m (8-10 lb·ft) torque.
11. Position the injector control racks and make the final governor adjustments. Refer to section 12.4.

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2.29 PSG HYDRAULIC GOVERNOR

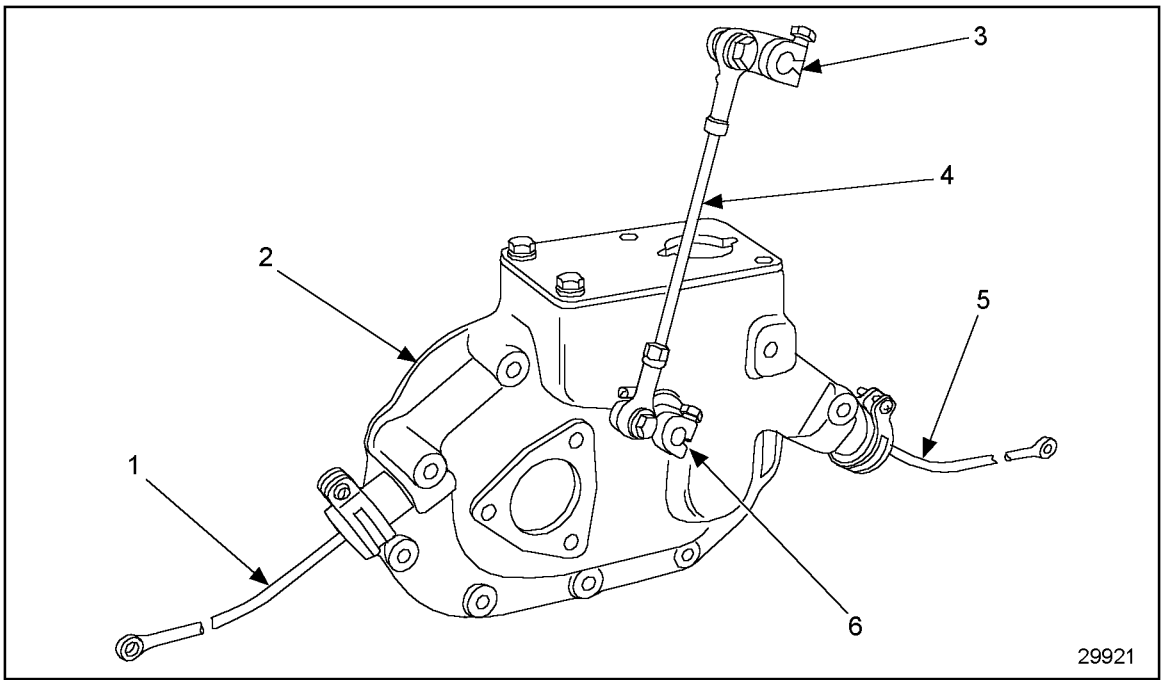
The governor is located at the front of the engine and is mounted on the governor drive housing, which serves as the blower front cover. See Figure 2-210.



1. Oil Supply Line
2. Oil Filter
3. Governor
4. Speed Control Shaft
5. Operating Lever
6. Vertical Link
7. Bell Crank Lever
8. Fuel Rod Cover

Figure 2-210 PSG Hydraulic Governor Mounting

A blower rotor drives the governor through a horizontal drive shaft and bevel gear and a vertical driven shaft. Both shafts are mounted on ball bearings and are retained in the governor drive housing. The governor, through a linkage consisting of the fuel rods, vertical link and levers, actuates the injector control tubes. See Figure 2-211.



1. Right-Bank Fuel Rod
2. Governor Drive Housing
3. Governor Operating Lever
4. Vertical Link
5. Left-Bank Fuel Rod
6. Control Link Lever

Figure 2-211 Enclosed Type Governor to Injector Rack Control Linkage

This isochronous hydraulic governor has a speed droop stabilization mechanism. Hydraulic action is transmitted by filtered oil under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The auxiliary pump develops the necessary oil pressure to actuate the governor mechanism.

The isochronous governor holds an engine at zero droop at a constant speed, regardless of the load, provided the load is within the unit capacity.

The hydraulically operated servomotor piston in the governor increases the fuel amount supplied to the injectors, and the terminal lever return spring decreases it.

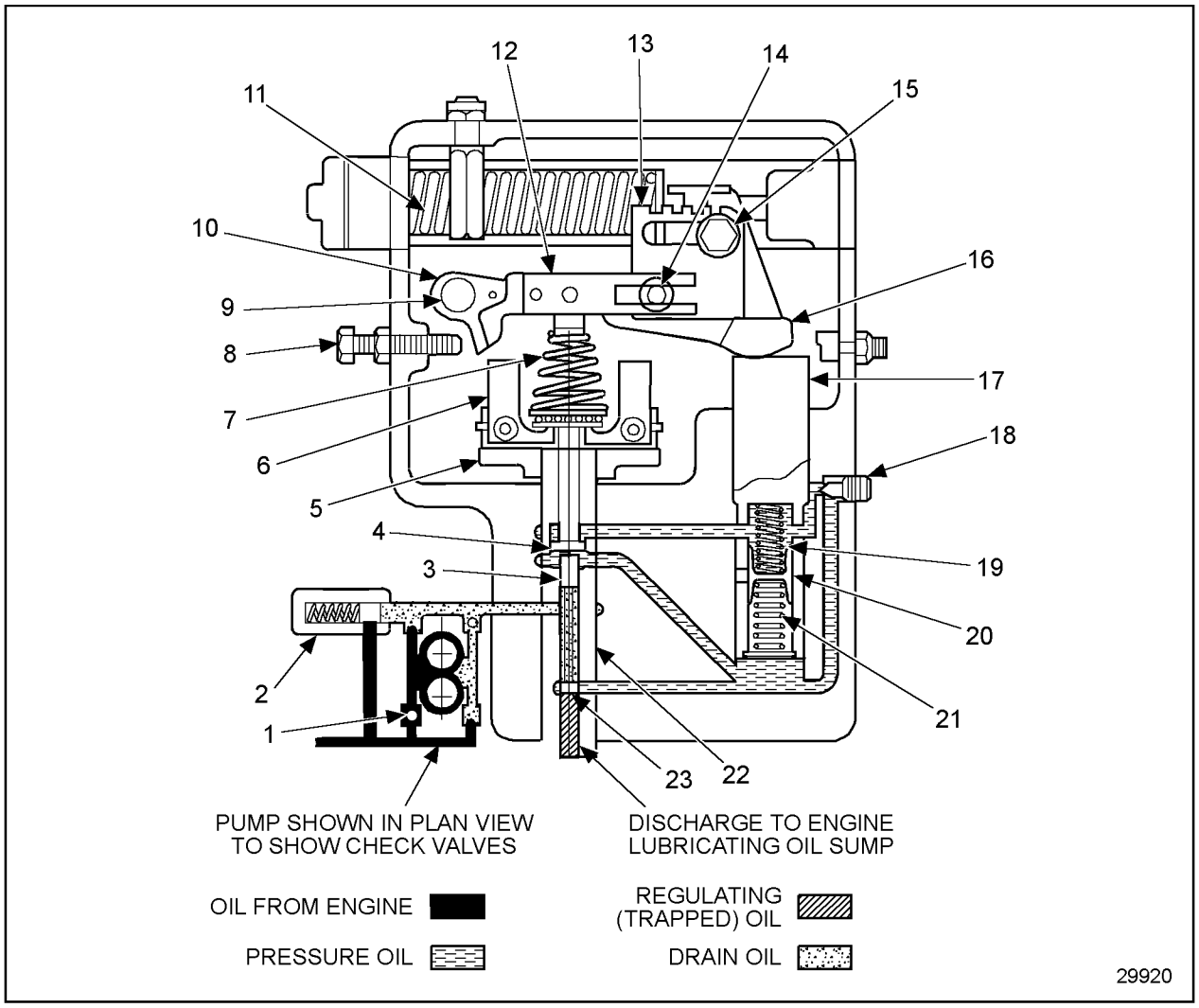
Cold engines require time to develop sufficient oil pressure to operate the governor and move the injector control racks to the full-fuel position. Move the governor operating lever to the full-fuel position to take injector rack control away from the governor and shorten the starting time. Move the governor operating lever to the no-fuel position to stop the governor.

The hydraulic governor acts as an automatic shutdown device in the event of engine lubricating oil pressure loss. Should the engine fail to supply oil to the governor, the servomotor piston will drop, allowing the governor operating lever to return to the no-fuel position.

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With the engine operating, oil from the engine lubricating system is admitted to the space around the governor pump gears. The pump gears raise the oil pressure. The oil pressure is maintained in the annular space between the undercut portion of the pilot valve plunger and the bore in the pilot valve bushing. See Figure 2-212.

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1. Check Valve
2. Relief Valve
3. Pilot Valve Plunger
4. Receiving Compensating Land
5. Ball Head Assembly
6. Flyweight
7. Speeder Spring
8. Maximum Speed Adjusting Screw
9. Speed Adjusting Shaft
10. Speed Adjusting Lever
11. Terminal Lever Return Spring
12. Floating Lever
13. Droop Adjusting Bracket
14. Terminal Shaft (Long)
15. Droop Adjusting Bolt
16. Terminal Lever
17. Servomotor Piston
18. Compensating Needle Valve
19. Buffer Spring (Upper)
20. Buffer Piston
21. Buffer Spring (Lower)
22. Pilot Valve Bushing
23. Pilot Valve Control Land

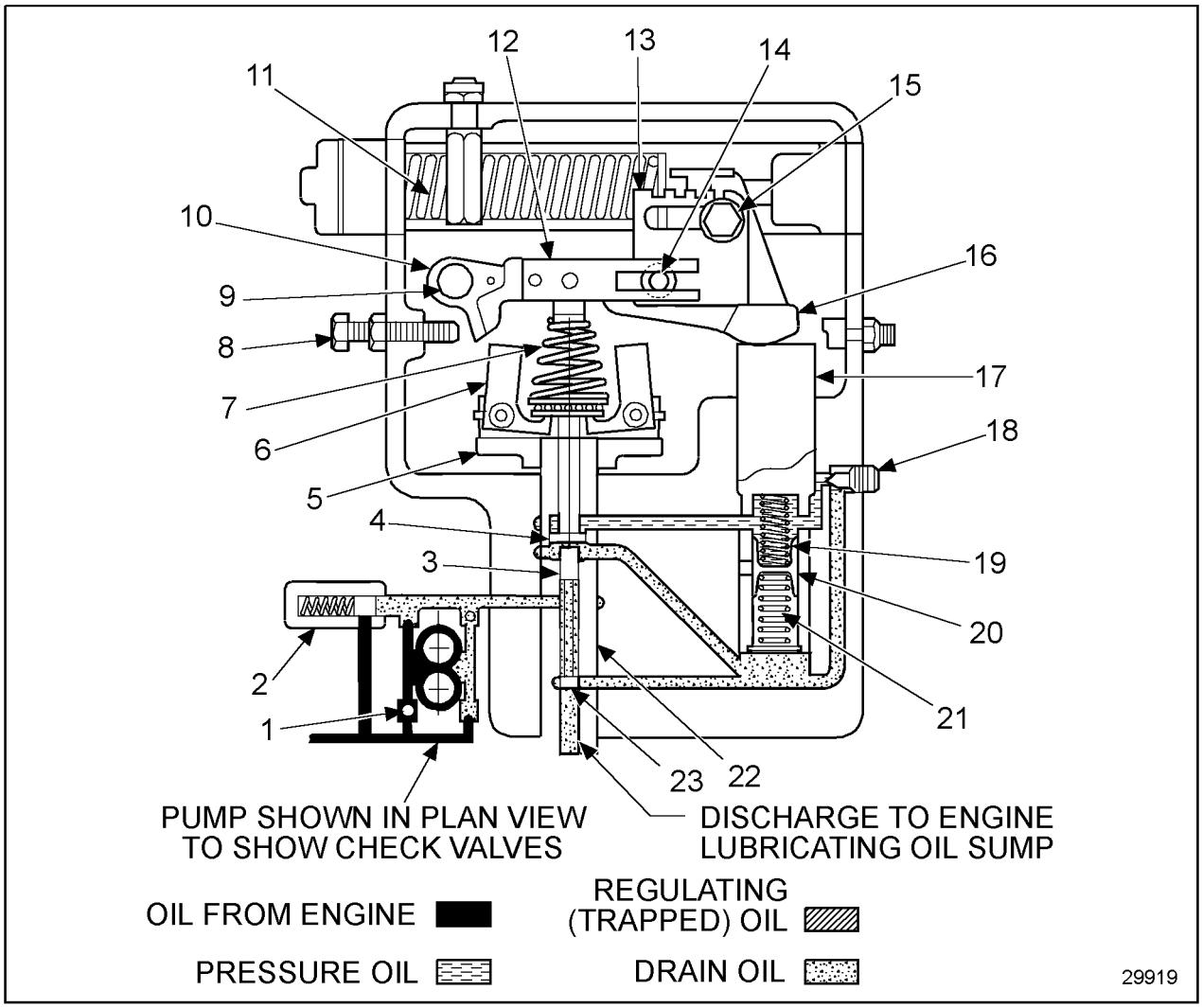
Figure 2-212 Stable Position of Governor When Load on Engine is Constant

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The centrifugal force of the revolving flyweights opposes the speeder spring force for any given throttle setting. When the two forces are equal, the control land on the pilot valve plunger covers the lower ports in the pilot valve bushing.

Under these conditions, equal oil pressure is maintained on both sides of the buffer piston and tension on the two buffer springs is equal. The oil pressure is equal on both sides of the receiving compensating pilot valve plunger land due to oil passing through the compensating needle valve. The hydraulic system is in balance and the engine speed remains constant.

Assuming a load increase is applied to the engine, the engine speed will momentarily drop, and the governor flyweights will be forced inward, lowering the pilot valve plunger. Oil under pressure will be admitted under the servomotor piston, causing it to rise. The servomotor piston's upward motion will cause the engine fuel setting to increase. See Figure 2-213.



1. Check Valve
2. Relief Valve
3. Pilot Valve Plunger
4. Receiving Compensating Land
13. Droop Adjusting Bracket
14. Terminal Shaft (Long)
15. Droop Adjusting Bolt
16. Terminal Lever

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5. Ball Head Assembly
6. Flyweight
7. Speeder Spring
8. Maximum Speed Adjusting Screw
9. Speed Adjusting Shaft
10. Speed Adjusting Lever
11. Terminal Lever Return Spring
12. Floating Lever
17. Servomotor Piston
18. Compensating Needle Valve
19. Buffer Spring (Upper)
20. Buffer Piston
21. Buffer Spring (Lower)
22. Pilot Valve Bushing
23. Pilot Valve Control Land

Figure 2-213 Position of Governor Mechanism as Load Increases and Engine Speed Tends to Decrease

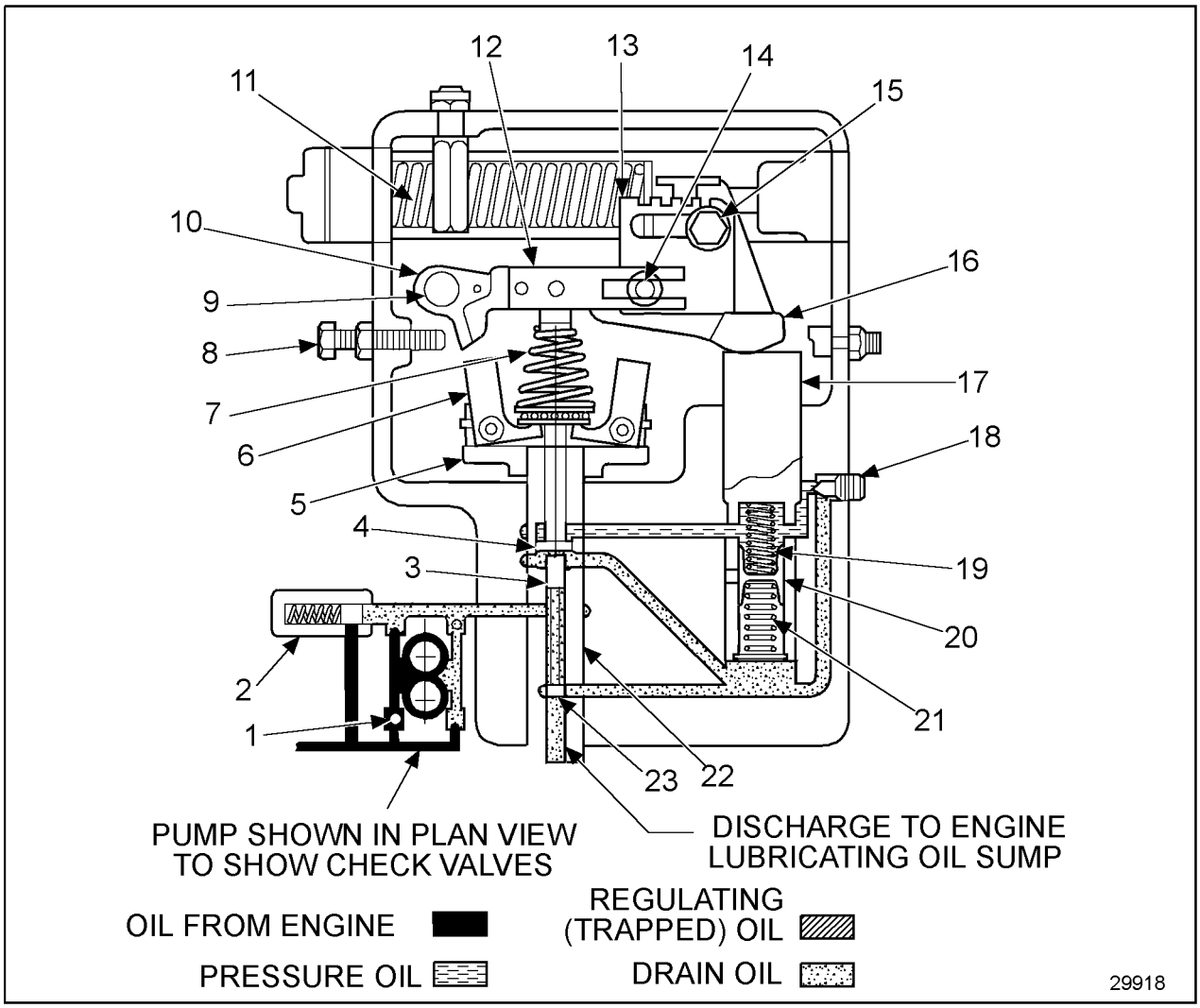
The unequal oil pressure forces the buffer piston upward. The upward piston motion compresses the upper buffer spring and relieves the pressure on the lower buffer spring.

The oil cavities above and below the buffer piston are common to the receiving compensating pilot valve plunger land. Since the higher pressure is below the compensating land, the pilot valve plunger is forced upward, re-centering the flyweights and causing the pilot valve control land to close the regulating port. The servomotor piston's upward movement stops when it has moved far enough to make the necessary fuel correction.

Oil passing through the compensating needle valve equalizes the pressure above and below the buffer piston, allowing the piston to return to its center position, which equalizes the pressure above and below the receiving compensating land. The pilot valve plunger moves to its central position, and the engine speed returns to its original setting.

With a decrease in the load, the engine speed will momentarily increase and the flyweights will move outward, raising the pilot valve plunger. This allows the oil below the buffer piston and below the receiving compensating land to flow to the drain passage, reducing the pressure on the lower side of the buffer piston and on the lower side of the receiving compensating land. This allows the servo-piston to move downward, which causes the engine fuel setting to decrease. See Figure 2-214.

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1. Check Valve
2. Relief Valve
3. Pilot Valve Plunger
4. Receiving Compensating Land
5. Ball Head Assembly
6. Flyweight
7. Speeder Spring
8. Maximum Speed Adjusting Screw
9. Speed Adjusting Shaft
10. Speed Adjusting Lever
11. Terminal Lever Return Spring
12. Floating Lever
13. Droop Adjusting Bracket
14. Terminal Shaft (Long)
15. Droop Adjusting Bolt
16. Terminal Lever
17. Servomotor Piston
18. Compensating Needle Valve
19. Buffer Spring (Upper)
20. Buffer Piston
21. Buffer Spring (Lower)
22. Pilot Valve Bushing
23. Pilot Valve Control Land

Figure 2-214 Position of Governor Mechanism as Load Decreases and Engine Speed Tends to Increase

The governor moves instantaneously in response to a load change and makes the necessary fuel adjustment to maintain the initial engine speed.

Governor movements occur through governor speed control lever movement and load changes. Speed control lever movement causes the pilot valve plunger to raise or lower.

Oil passes up through a drilled passage in the pilot valve plunger and is directed at the thrust bearing, from where the governor flyweights throw it onto the moving parts in the governor housing. The governor pump gears, pilot valve plunger, servomotor piston, and buffer piston are exposed to pressurized oil. Oil that collects on the governor housing floor passes through a drilled passage into the governor drive housing, lubricating the governor drive and driven gears and shafts and their bearings. Surplus oil returns to the engine crankcase through connecting drilled passages in the blower end plate and cylinder block.

2.29.1 Repair or Replacement of PSG Hydraulic Governor

The PSG hydraulic governor is not a serviceable item. Refer to OEM guidelines or an authorized Detroit Diesel distributor for service recommendations.

2.29.2 Removal of PSG Hydraulic Governor

Remove the governor as follows:

1. Disconnect any linkage that may be attached to the governor speed control lever.
2. Drain the governor oil filter.
3. Disconnect the oil supply tube between the governor and the filter.
4. Remove the oil filter element, and clean the filter housing. Install a new filter element.
5. Disconnect the vertical link assembly from the governor operating lever.
6. Disconnect the wires to the synchronizing motor, if used.

NOTE:
Tag the wires to facilitate reassembly.

7. Remove the four bolts and lock washers that attach the governor to the governor drive housing cover.
8. Lift the governor away from the drive housing. Remove the gasket.

2.29.3 Installation of PSG Hydraulic Governor

Install the governor as follows:

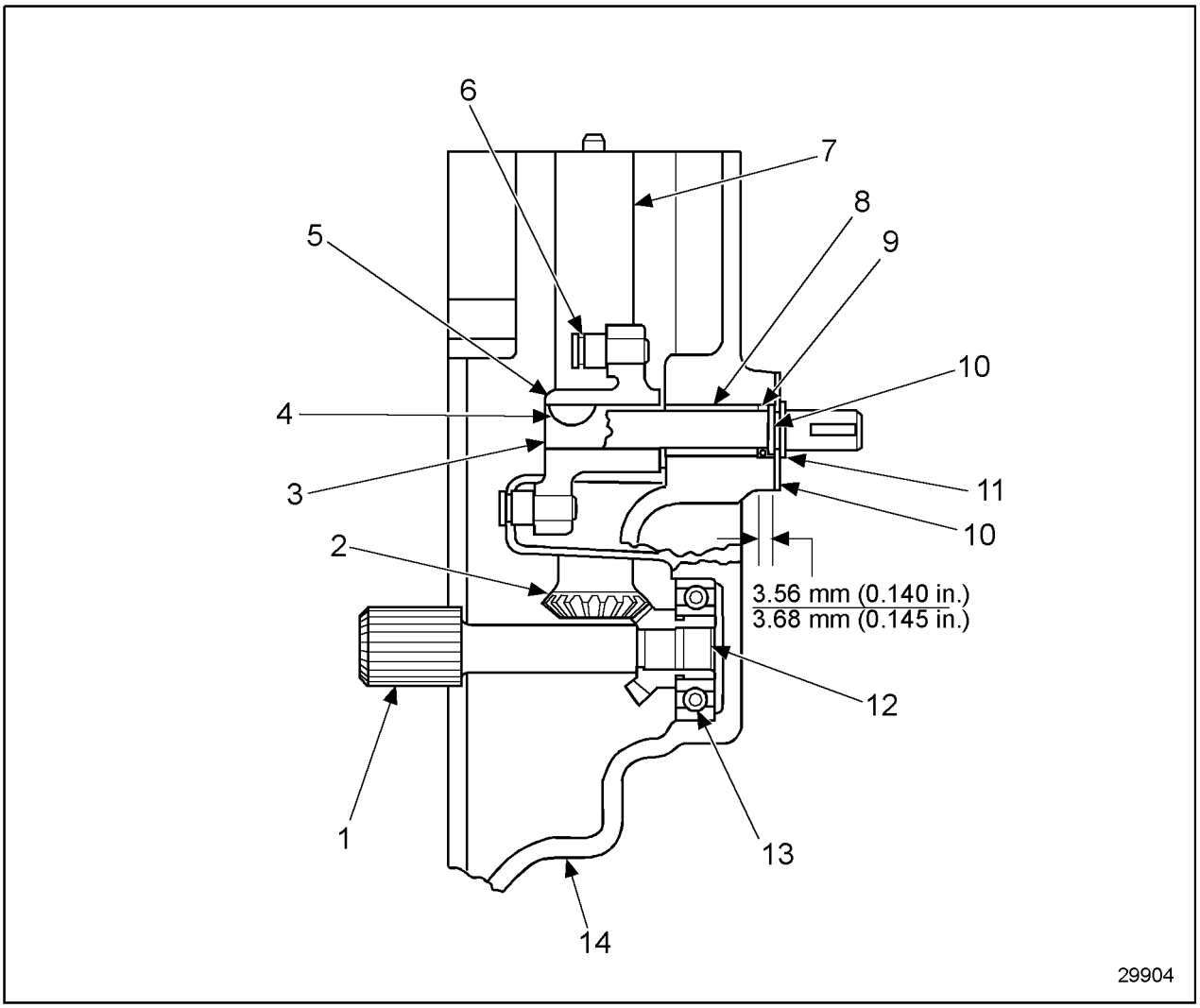
1. Place a new gasket on the governor drive housing.
2. Place the governor on the governor drive housing. Turn the ball head slightly, if necessary, to align the pilot valve bushing splines with the driven shaft sleeve splines.

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3. Secure the governor to the drive housing with four bolts and lock washers. Tighten the bolts uniformly.
4. Install the oil supply tube.
5. Pour approximately one pint of engine oil in the governor to provide initial lubrication.
6. Attach a new governor cover gasket to the subcap.
7. If previously removed, install the speed adjusting lever stop on the underside of the governor cover. Secure the lever stop to the cover with a locknut and copper washer.
8. Before installing the governor cover or connecting the governor linkage, perform a complete engine tune-up. Refer to section 12.1.

2.30 HYDRAULIC GOVERNOR DRIVE

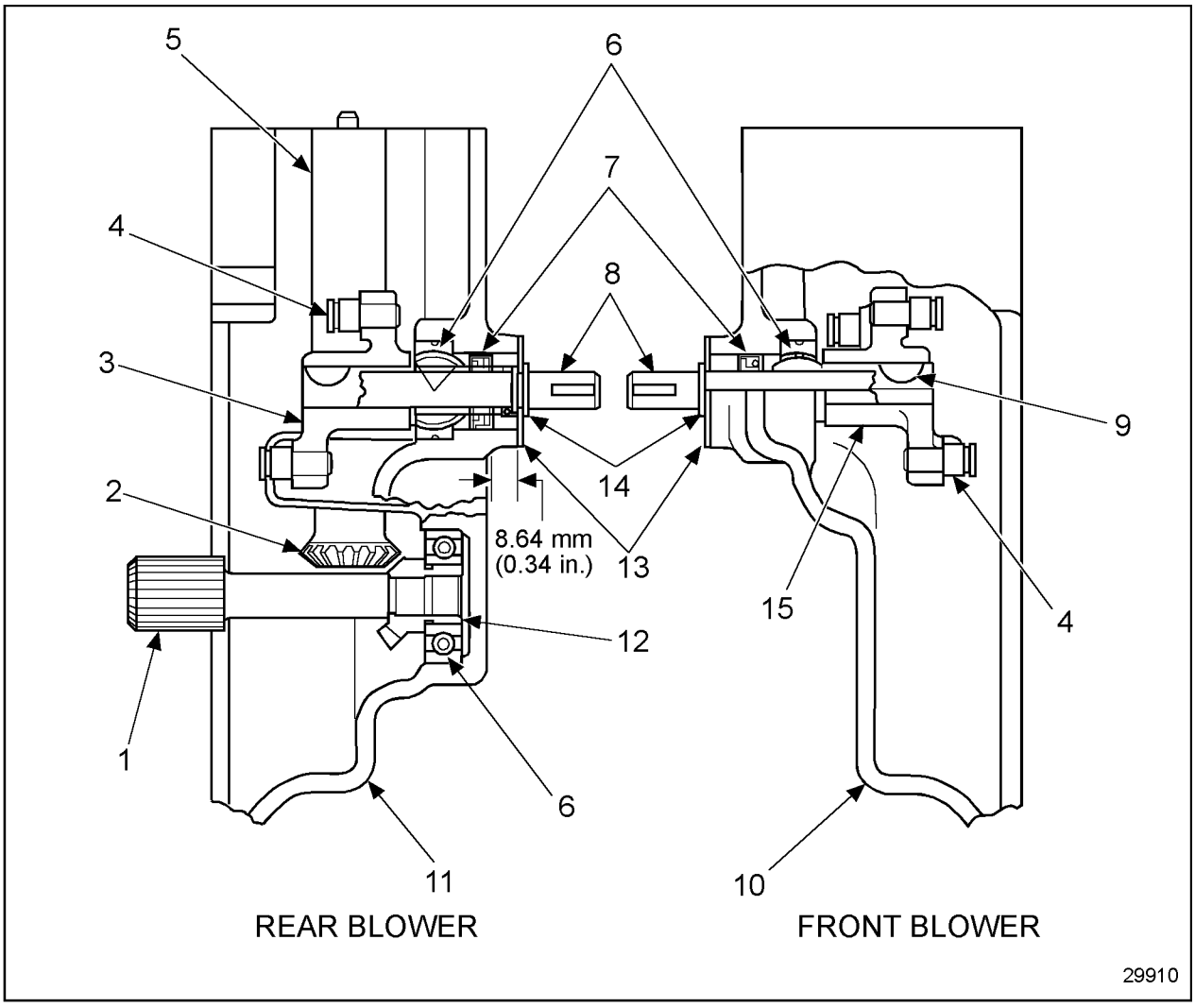
On 6V and 8V engines, a blower rotor, through a horizontal drive shaft and drive gear and an integral vertical driven gear, drives the governor. See Figure 2-215. Each gear is mounted on a ball bearing and is contained in a drive housing that also serves as the blower front cover. See Figure 2-216 for 12V and 16V engines.



1. Drive Shaft
2. Driven Gear
3. Shaft
4. Key
5. Control Link Lever
6. Lever Pin
7. Driven Gear Sleeve
8. Bushing
9. Seal Ring
10. Flat Washer
11. Snap Ring
12. Drive Gear
13. Bearing
14. Drive Housing

Figure 2-215 Governor Drive Assembly (6V and 8V Engines)

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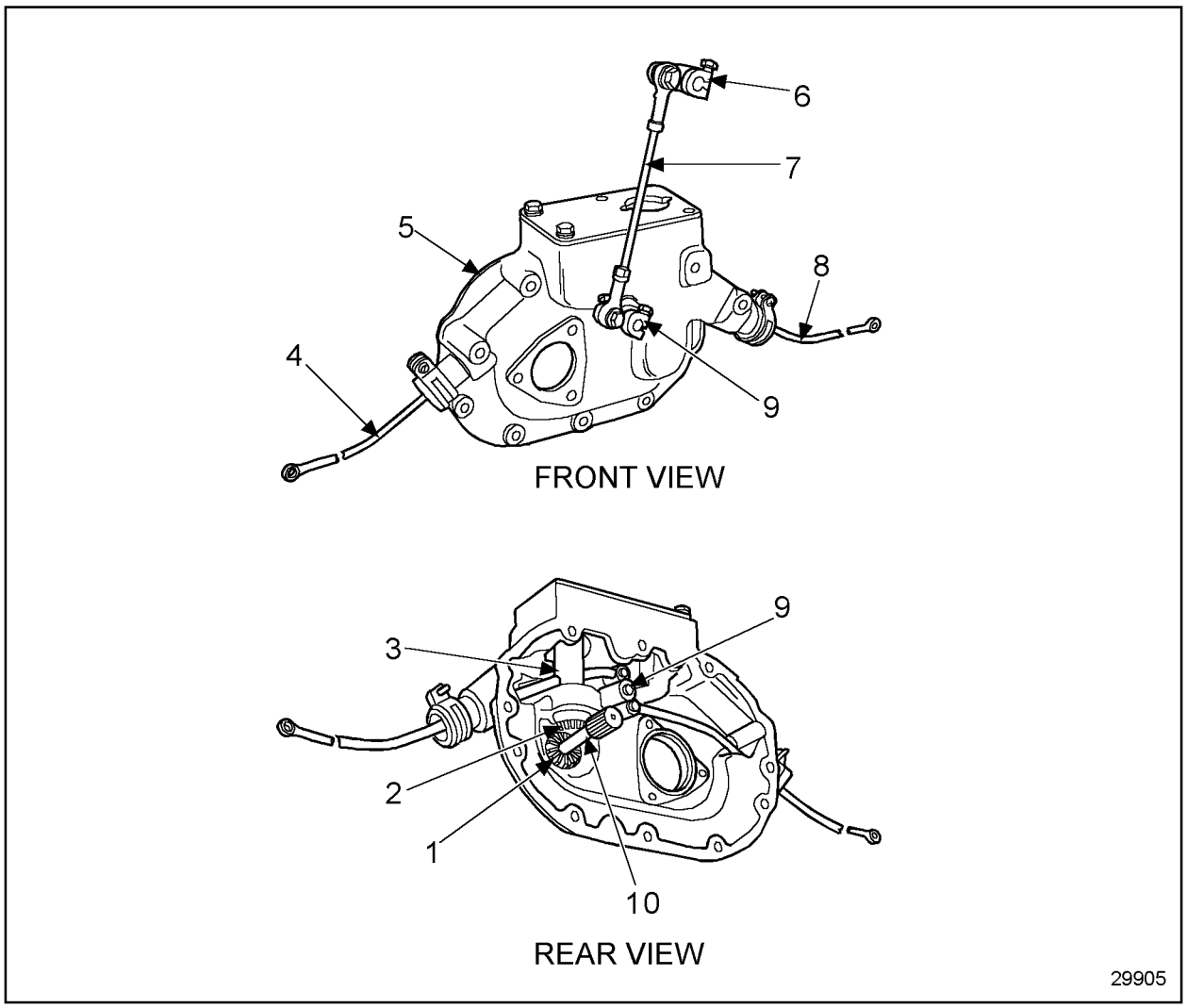
1. Drive Shaft
2. Driven Gear
3. Control Link Lever
4. Lever Pin
5. Driven Gear Sleeve
6. Bearings
7. Oil Seals
8. Shafts
9. Key
10. Lower Governor Control Housing
11. Governor Drive Housing
12. Drive Gear
13. Flat Washer
14. Snap Rings
15. Control Link Lever

Figure 2-216 Governor Drive and Control Housing Assembly(12V and 16V Engines)

The horizontal drive shaft splines engage the blower rotor shaft splines. The blower rotor shaft provides the drive. Splines on the lower end of the governor ball head mesh with the splines in the upper end of a vertical drive gear sleeve.

The fuel rod from each injector control tube is connected to a common control link lever, which is enclosed in the governor drive housing. On 12V and 16V engines, the second rod is enclosed in the governor control housing.

A vertical link attached to the control link lever and the governor operating lever connects the governor to the fuel rods. See Figure 2-217.



1. Drive Gear
2. Driven Gear
3. Driven Sleeve
4. Right-Bank Fuel Rod
5. Governor Drive Housing
6. Governor Operating Lever
7. Vertical Link
8. Left-Bank Fuel Rod
9. Control Link Lever
10. Drive Shaft

Figure 2-217 Hydraulic Governor Drive

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On 12V and 16V engines, a common lever and cap assembly connects the two control link lever shafts. A vertical link, attached to the common lever and cap assembly and the governor terminal operating lever, connects the variable speed hydraulic governor to the fuel rods.

Naturally aspirated engine drive assemblies include a reduction gear assembly.

Surplus oil from the governor, which spills over the moving parts, lubricates the governor drive assembly gears and bearings. The oil returns to the engine crankcase through drilled passages in the blower end plate and cylinder block.

The vertical link assembly rod end bearings are lubricated with grease through the fittings.

2.30.1 Repair or Replacement of Hydraulic Governor Drive

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-218.

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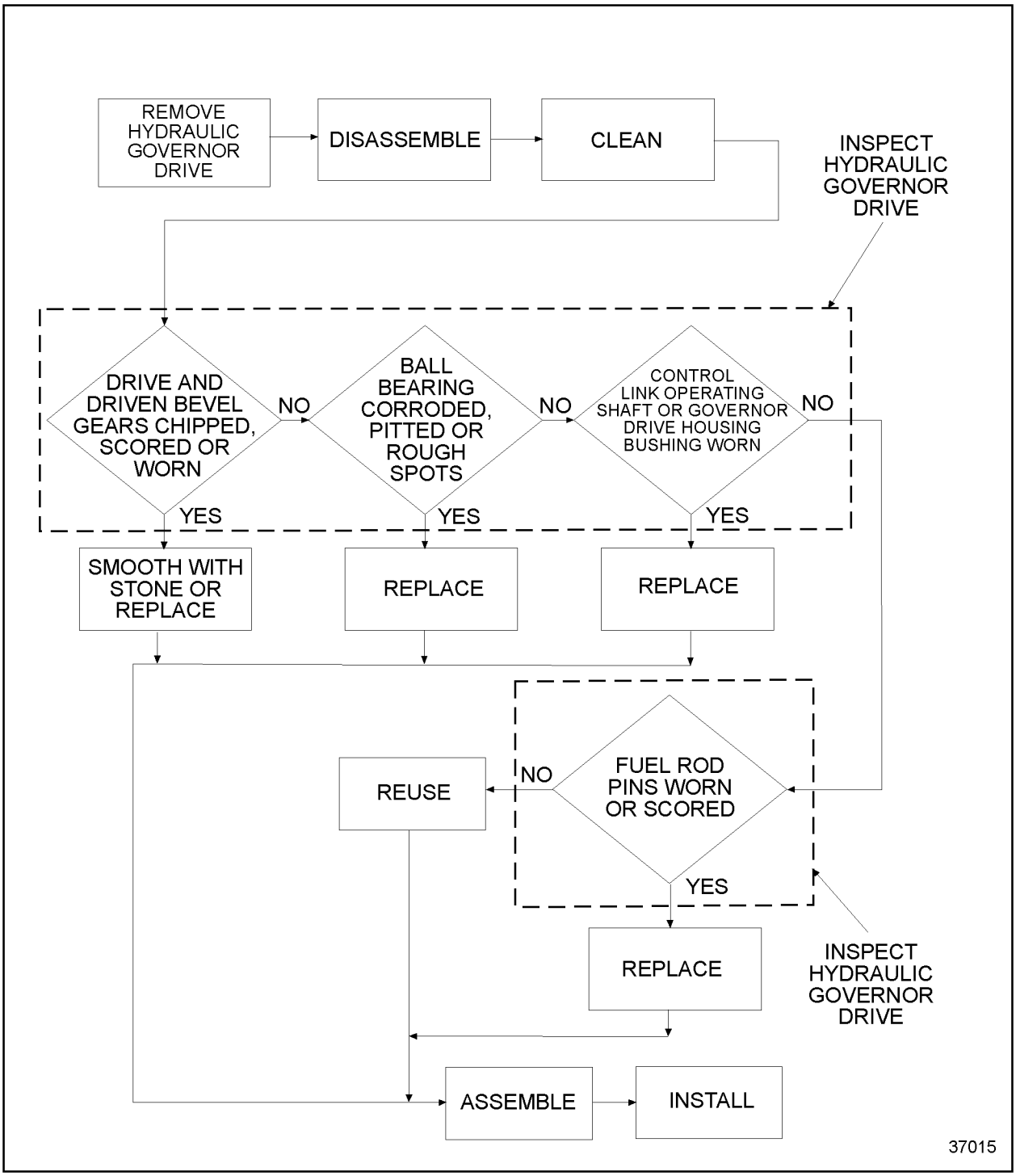


Figure 2-218 Flowchart for Repair or Replacement of Hydraulic Governor Drive

2.30.2 Removal of Hydraulic Governor Drive (6V and 8V Engines)

Remove the governor drive assembly on 6V and 8V engines as follows:

1. Disconnect the throttle control linkage to the governor speed control lever.

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2. Remove the bolts and lock washers that attach the vertical link assembly to the governor operating lever and the control link operating lever. Remove the link assembly.
3. If the engine is equipped with a governor oil reservoir, disconnect and remove the oil inlet, outlet, and return tubes from the reservoir, governor, and drive housing. Remove the oil reservoir from the drive housing.
4. If equipped with a governor operating solenoid, disconnect and remove the oil inlet and outlet tubes from the solenoid, governor, and drive housing.
5. Tag and remove the electrical wires from the top of the solenoid. Remove the solenoid from the drive housing.
6. If the governor is equipped with a synchronizing motor, tag and remove the electrical wires from the motor terminals.
7. Remove the four bolts and lock washers securing the governor to the governor drive housing.
8. Lift the governor from the drive housing cover, and remove the governor gasket.
9. Remove the housing cover and gasket.
10. Drain the cooling system. Refer to section 13.12.3.
11. Remove the water bypass tube between the two thermostat housings.
12. Disconnect and remove the fuel oil inlet and outlet pipes from the fuel pump.
13. Remove the fuel pump, gasket and drive coupling fork from the drive housing. Refer to section 2.21.2.
14. Remove the valve rocker covers. Refer to section 1.6.2.
15. Disconnect the fuel rods at the injector control tubes and the control link operating lever. Withdraw the fuel rods.
16. Loosen the clamps, and slide the hoses onto the fuel rod cover tubes.
17. Remove the ten bolts, seven lock washers, and three copper washers securing the governor drive housing to the blower end plate.

NOTICE:
Do not pry the housing off the dowels. This will damage the finished surfaces.

18. Tap the edge of the housing lightly with a plastic hammer to loosen it. Remove the housing from the dowels. Remove the housing gasket.

2.30.3 Removal of Hydraulic Governor Drive (12V and 16V Engines)

Remove the hydraulic governor drive on 12V and 16V engines as follows:

1. Disconnect the throttle control linkage to the governor speed control lever.

2. Remove the air inlet pipe between the air cleaner, or turbocharger, and the air shutdown housing on the rear blower.
3. Remove the air shutdown housing from the blower, and cover the top of the blower to prevent foreign materials from entering.
4. If a battery-charging alternator is attached to the top of the flywheel housing, tag and disconnect the electrical wires from the alternator. Remove the alternator.
5. Disconnect and remove the fuel oil inlet and outlet pipes from the fuel oil pump.
6. Disconnect and remove the oil inlet, outlet, and return tubes from the oil reservoir, governor, and drive housing. Remove the oil reservoir from the drive housing.
7. Disconnect and remove the oil inlet and outlet tubes from the governor operating solenoid. Remove the solenoid from the drive housing.
8. Disconnect and remove the vertical link assembly from the governor control link common lever and cap assembly and the governor operating lever.
9. Remove the four bolts and lock washers securing the governor to the governor drive housing. Lift the governor from the drive housing cover. Remove the governor gasket.
10. Remove the bolts and lock washers securing the governor control link common lever and cap assembly to the control link lever shafts between the drive housing and the lower governor control housing.
11. Remove the valve rocker covers from the rear of the engine.
12. Remove the governor drive housing cover and gasket from the top of the drive housing.
13. Disconnect the fuel rods at the injector control tube levers and the control link lever inside the governor drive housing. Withdraw the fuel rods.
14. Loosen the fuel rod hose clamps, and slide the hoses onto the fuel rod cover tubes in the drive housing.
15. Disconnect the blower oil pressure tube from the fitting in the blower drive support. Slide the tube into the blower end plate.
16. Loosen the hose clamp on the blower drive support to blower seal.
17. Remove the flywheel housing cover in back of the blower drive support.
18. Remove the snap ring from the blower drive flexible coupling, and pull the blower drive shaft from the blower drive coupling.
19. Disconnect the tachometer drive cable, if used, from the drive adaptor. Remove the drive adaptor.
20. Remove the bolt and washer through the top of each blower end plate.
21. Remove the six remaining bolts and lugs securing the blower housing to the cylinder block.

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⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the lifting sling before removing from engine. Blower damage may result if the blower falls from the lifting device.

22. Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts so the blower may be lifted at an angle.
23. Lift the blower assembly, front end first, at an angle to clear the front blower. Move the blower forward and away from the engine, and place it on a bench.
24. Remove the three bolt and seal assemblies securing the fuel pump to the governor drive housing.
25. Remove the fuel pump, gasket and drive coupling fork from the drive housing.
26. Remove the ten bolts, seven lock washers, and three copper washers securing the governor drive housing to the blower end plate.

NOTE:
Do not pry the housing off the dowels. This will damage the finished surfaces.

27. Tap the edge of the housing lightly with a plastic hammer to loosen it. Remove the housing from the dowels. Remove the housing gasket.

NOTE:
The cover must be removed from the governor control housing in order to disconnect the fuel rods from the control link lever in the housing.

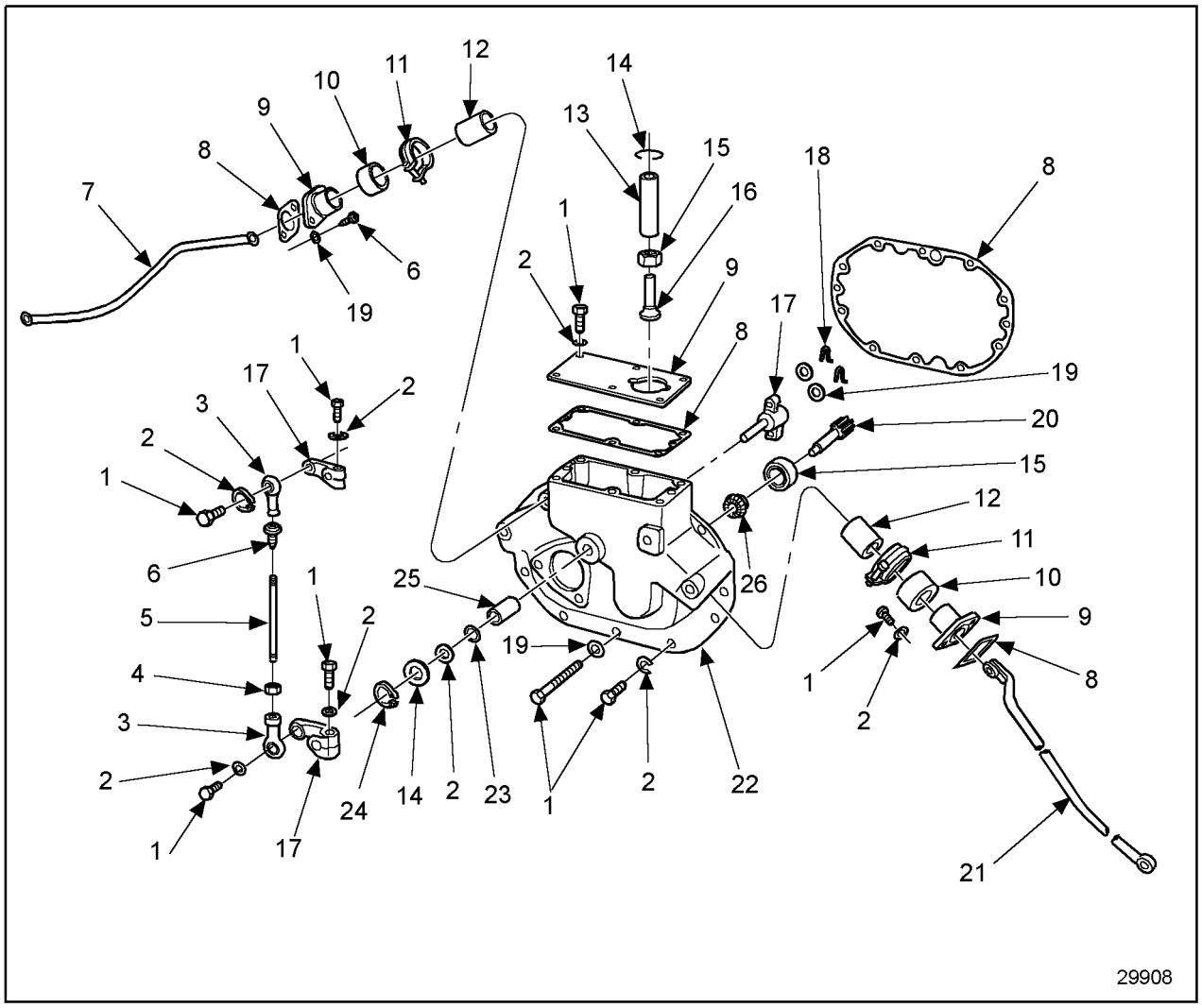
28. If necessary, the governor control housing may be removed from the engine front blower.

2.30.4 Disassembly of Hydraulic Governor Drive (6V and 8V Engines)

Disassemble the hydraulic governor drive as follows:

1. Loosen the bolt securing the control link shaft lever to the shaft.
2. Remove the lever and key from the shaft.
3. Remove the snap ring and flat washer that retains the control link lever and shaft assembly in the drive housing.
4. Pull the lever and shaft assembly from the housing.
5. Remove the small flat washer and seal ring from the bushing bore in the housing.

6. Remove the snap ring securing the governor driven gear bearing in the drive housing. See Figure 2-219. Pull the driven gear, bearing, and driven gear sleeve from the bore in the housing.



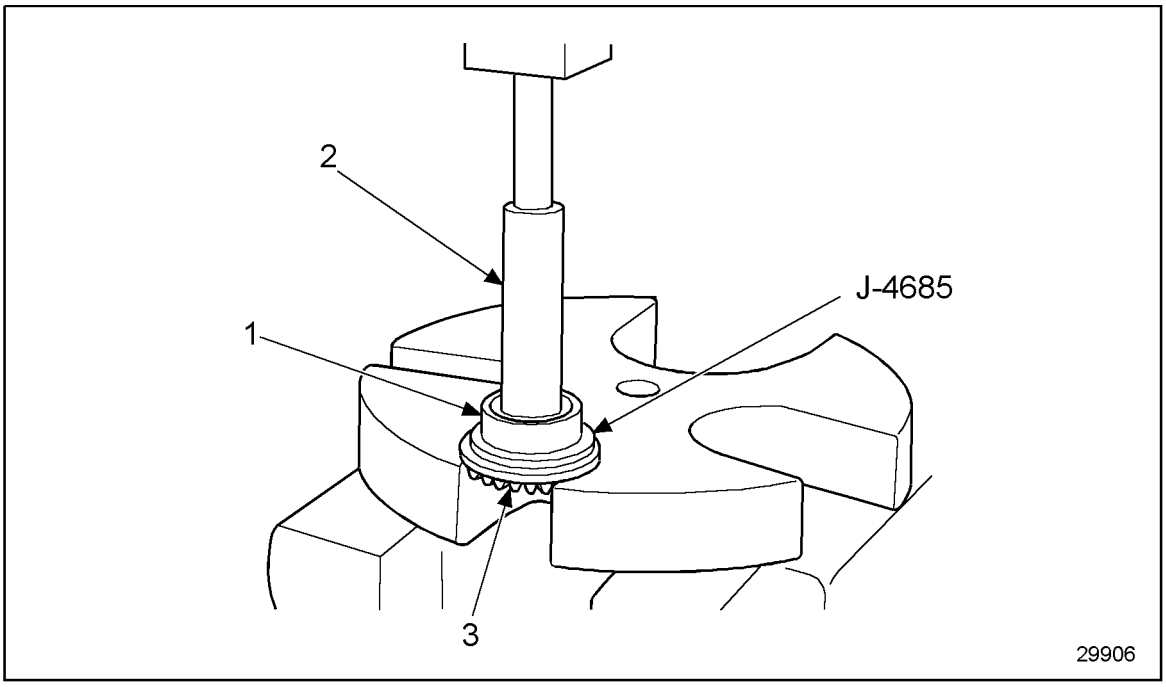
1. Bolt (6)
2. Lock Washer (8)
3. End Bearing (2)
4. Locknut
5. Link
6. Screw (2)
7. Right-Hand Fuel Rod
8. Gasket (4)
9. Cover (3)
10. Hose (2)
11. Clamp (2)
14. Snap Ring (2)
15. Bearing (2)
16. Driven Gear
17. Lever
18. Pins (2)
19. Washers (4)
20. Drive Shaft
21. Left-Hand Fuel Rod
22. Governor Housing
23. Seal Ring
24. Flat Washer

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12. Tube
13. Sleeve
25. Bushing
26. Drive Gear

Figure 2-219 Hydraulic Governor Drive (6V and 8V Engine)

7. Remove the governor driven gear sleeve and bearing from the driven gear as follows:
   [a] Place the drive ring remover J 4685 between the driven gear and the bearing, with the beveled side of the remover facing the gear.
   [b] Support the driven gear assembly and remover on an arbor press bed. See Figure 2-220.



1. Bearing
2. Driven Sleeve
3. Driven Gear

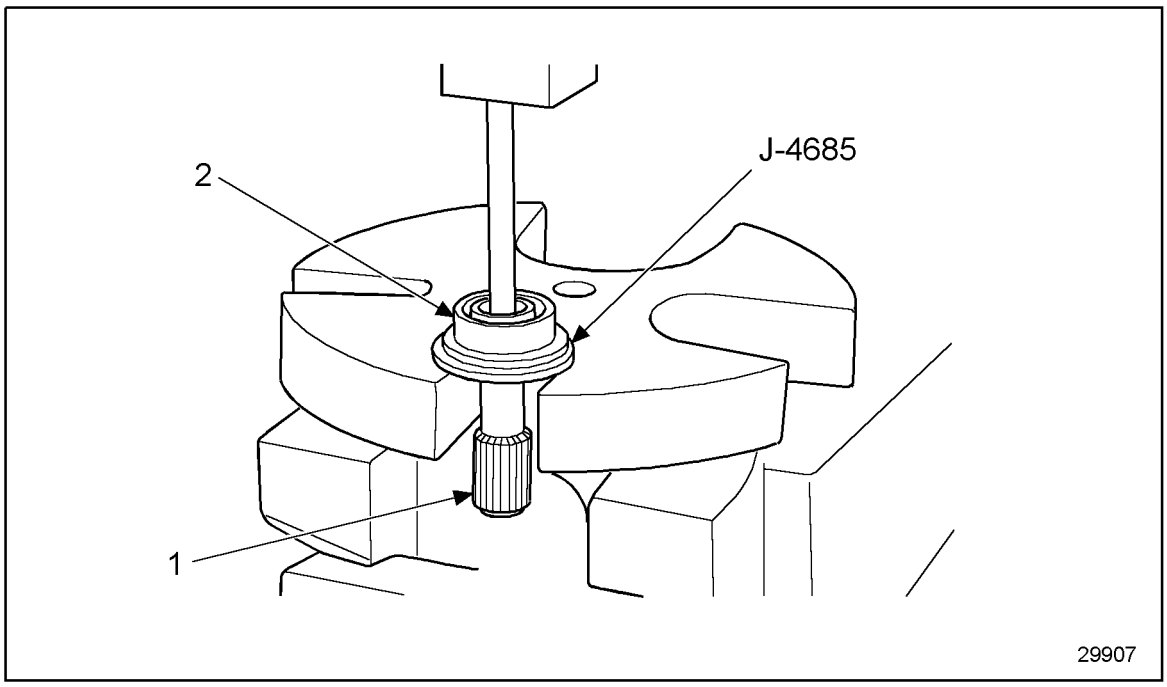
Figure 2-220 Removing Driven Sleeve and Bearing from Driven Gear

   [c] Place a brass rod inside the sleeve against the end of the driven gear. Press the driven gear from the sleeve and bearing. Catch the driven gear by hand when pressed from the bearing.
8. Pull the governor drive gear, drive shaft, and bearing assembly straight out of the housing bore.

Remove the governor drive gear shaft bearing and drive gear from the drive shaft as follows:

1. Place the split bearing remover J 4685 between the drive gear and the bearing, with the beveled side of the remover facing the gear.

2. Support the drive gear assembly and remover on an arbor press bed. See Figure 2-221.



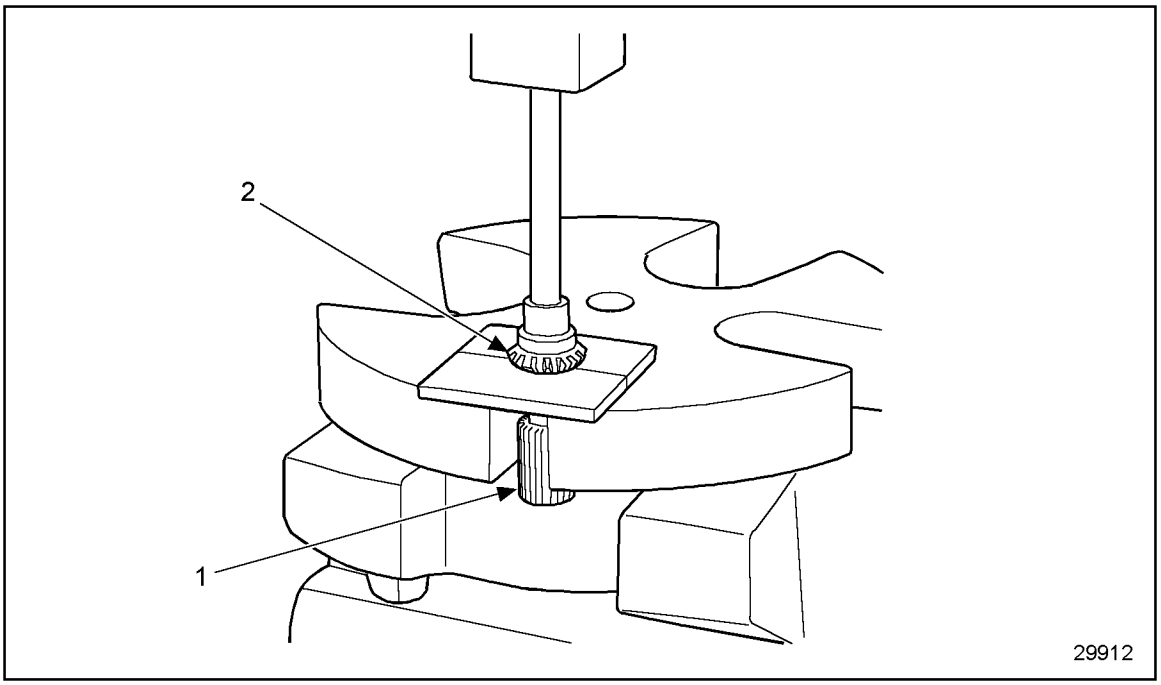
1. Drive Shaft
2. Bearing

Figure 2-221 Removing Bearing from Drive Gear

3. Place a brass rod on the end of the drive shaft. Press the drive gear and shaft assembly from the bearing. Catch the drive gear and shaft by hand when pressed from the bearing.

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4. Place two split brass plates beneath the drive gear teeth, and support the assembly on an arbor press bed. See Figure 2-222.



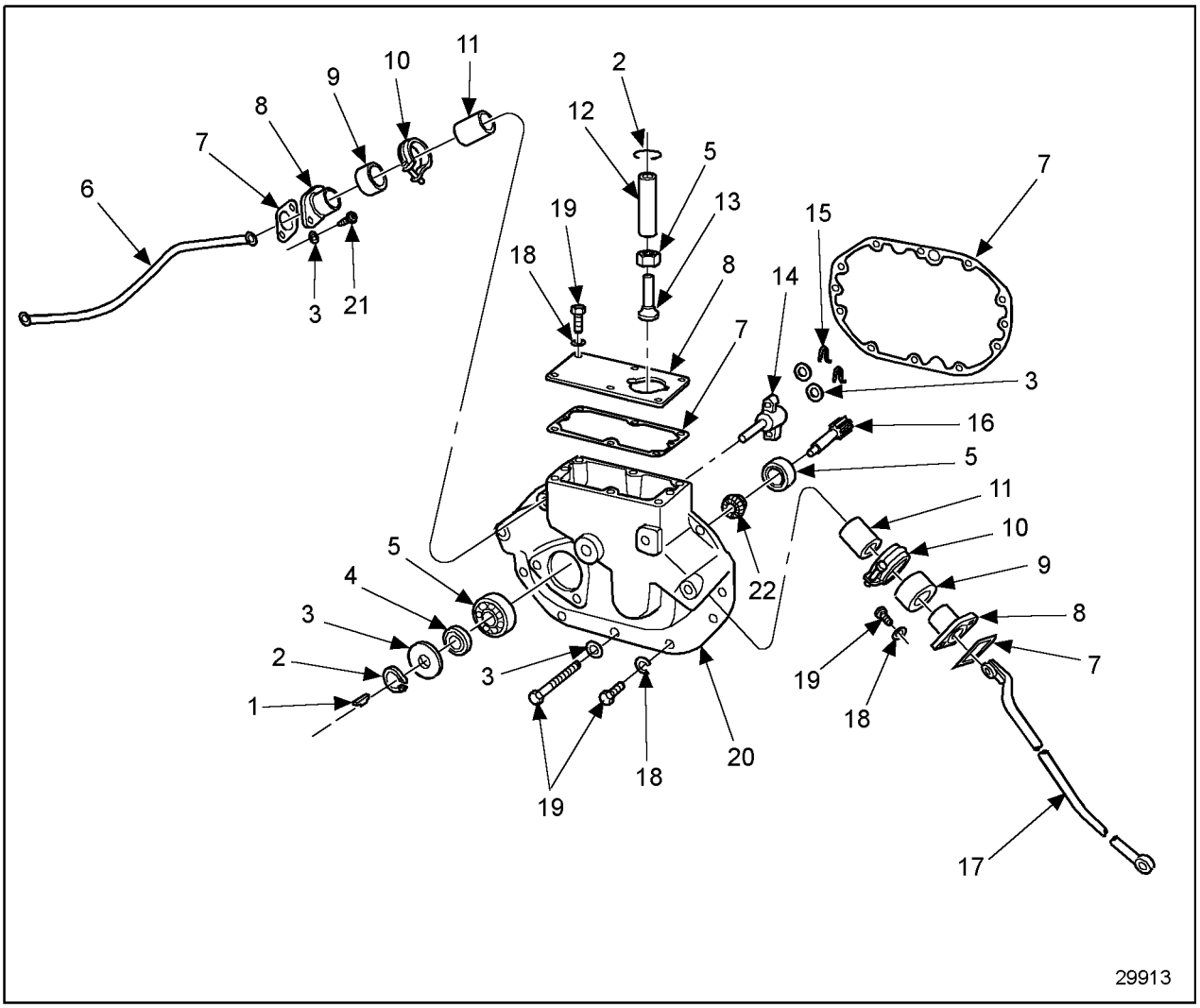
1. Drive Shaft
2. Drive Gear

Figure 2-222 Removing Drive Gear from Drive Shaft

5. Place a brass rod on the drive shaft end, and press the drive shaft from the drive gear.

2.30.5 Disassembly of Hydraulic Governor Drive (12V and 16V Engines)

See Figure 2-223, and disassemble the governor drive assembly as follows:



1. Key
2. Snap Ring
3. Washer
4. Oil Seal
5. Bearing
6. Right-Hand Fuel Rod
7. Gasket
8. Cover
9. Hose
10. Clamp
11. Tube
12. Sleeve
13. Driven Gear
14. Lever
15. Pin
16. Drive Shaft
17. Left-Hand Fuel Rod
18. Lock Washer
19. Bolt
20. Governor Housing
21. Screw
22. Drive Gear

Figure 2-223 Enclosed Linkage Type Hydraulic Governor Drive(12V and 16V Engines)

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1. Remove the Woodruff key from the governor control link lever shaft keyway.
2. Remove the snap ring and flat washer that retains the control link lever, shaft, and bearing assembly in the drive housing. Remove the lever, shaft, and bearing assembly from the housing.

NOTE:
The two governor control link lever, shaft, and bearing assemblies in the governor drive housing and governor control housing are identical, except for the location of the keyway in the outer end of the shaft. If both control link lever, shaft, and bearing assemblies are to be removed, tag one or both of the lever assemblies so they may be installed in their respective housings.

3. If necessary, remove the control link lever shaft bearing from the shaft as follows:
   [a] Support the inner end of the control link lever on a sleeve on an arbor press bed. Press the shaft approximately 1/4 in. out of the lower end of the lever.
   [b] Support the opposite end of the lever, next to the bearing, on an arbor press bed.

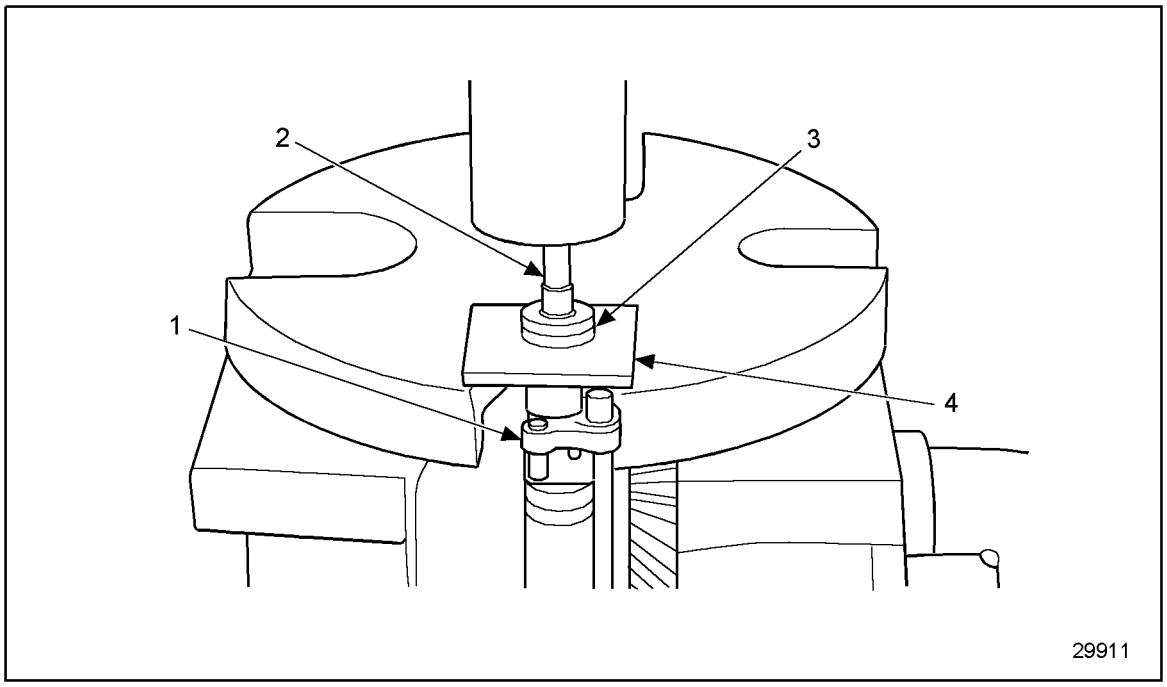
NOTE:
Do not put the support under the bearing.

   [c] Press the shaft in flush with the lever end.

NOTE:
This will leave approximately 1/4 in. space between the bearing and the lever.

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[d] Place two split plates between the bearing and the lever. Support the split plates, lever, shaft, and bearing assembly on an arbor press bed. See Figure 2-224.



1. Control Link Lever
2. Shaft
3. Bearing
4. Split Plates

Figure 2-224 Removing Bearing from Control Link Lever Shaft

[e] Press the shaft from the bearing.

NOTE:
The hole in the split plates should be the same diameter as the shaft so the inner race of the bearing will rest on the plates when in place.

[f] If necessary, the control link lever shaft may be pressed from the control link lever.

4. Inspect the control link lever shaft oil seal for wear and damage.

If necessary, the oil seal may be replaced in the governor drive housing without removing the drive and driven gear assemblies. Replace the oil seal as follows:

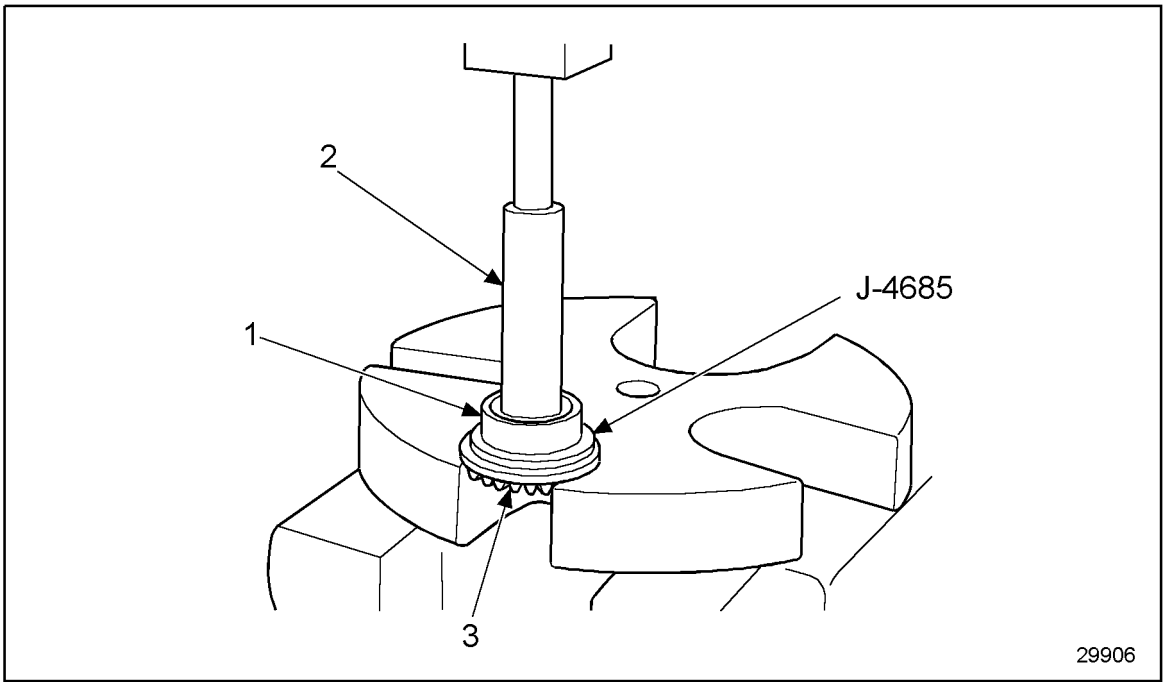
1. Support the inner face of the drive housing on two wood blocks approximately 2 in. thick. Place a short piece of 3/4 in. round bar stock on top of the oil seal, and tap it out of the housing with a hammer.
2. Apply a thin coat of sealing compound to the outside diameter of the new oil seal casing. Start the oil seal with the seal lip facing down, straight into the bore in the housing.
3. Support the drive housing inner face on two wood blocks on an arbor press bed.

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4. Place the 3/4 in. round bar stock on top of the oil seal and under the press ram. Press the oil seal into the housing until it is 8.64 mm (0.340 in.) below the outer face of the housing.

Continue disassembly as follows:

1. Remove the snap ring securing the governor driven gear bearing in the drive housing. Pull the driven gear, bearing, and driven gear sleeve from the bore in the housing.
2. Remove the governor driven gear sleeve and bearing from the driven gear as follows:
   [a] Place the split bearing remover J 4685 between the driven gear and the bearing, with the beveled side of the remover facing the gear.
   [b] Support the driven gear assembly and remover on the bed of an arbor press. See Figure 2-225.

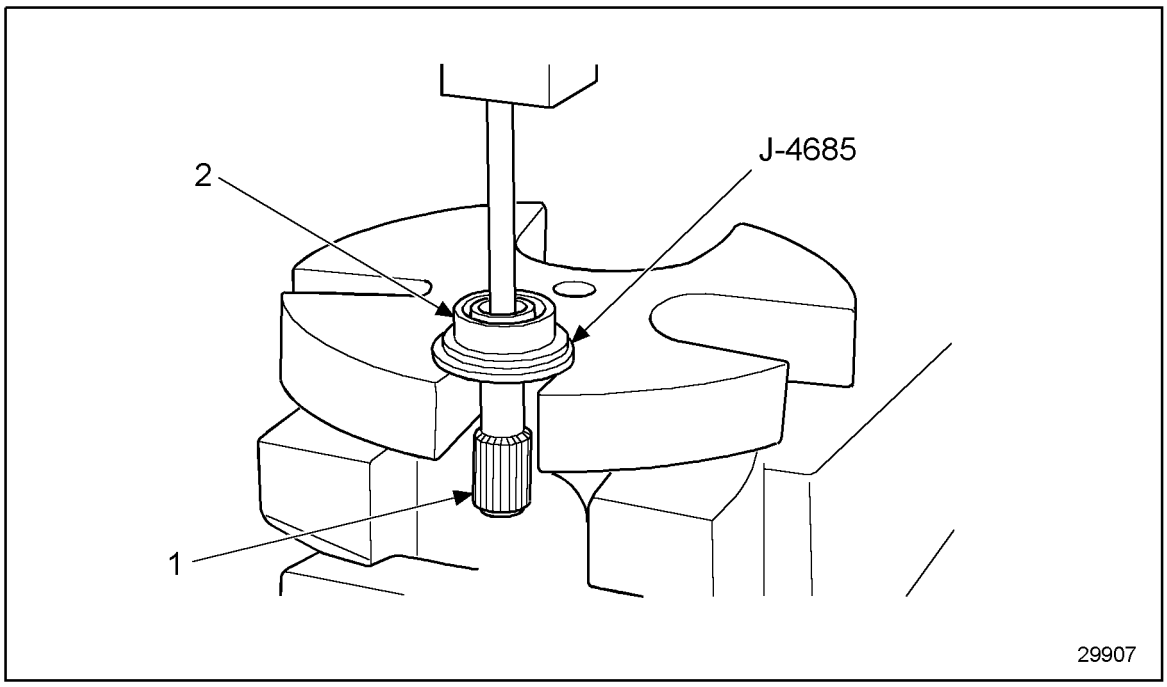


1. Bearing
2. Driven Sleeve
3. Driven Gear

Figure 2-225 Removing Driven Sleeve and Bearing from Driven Gear

   [c] Place a brass rod inside the sleeve, against the end of the driven gear, and press the driven gear from the sleeve and bearing. Catch the driven gear by hand when pressed from the bearing.
3. Pull the governor drive gear, drive shaft, and bearing assembly straight out of the housing bore.
4. Remove the governor drive shaft bearing and drive gear from the drive shaft as follows:
   [a] Place the split bearing remover J 4685 between the drive gear and the bearing, with the beveled side of the remover facing the gear.

[b] Support the drive gear assembly and remover on an arbor press bed. See Figure 2-226.



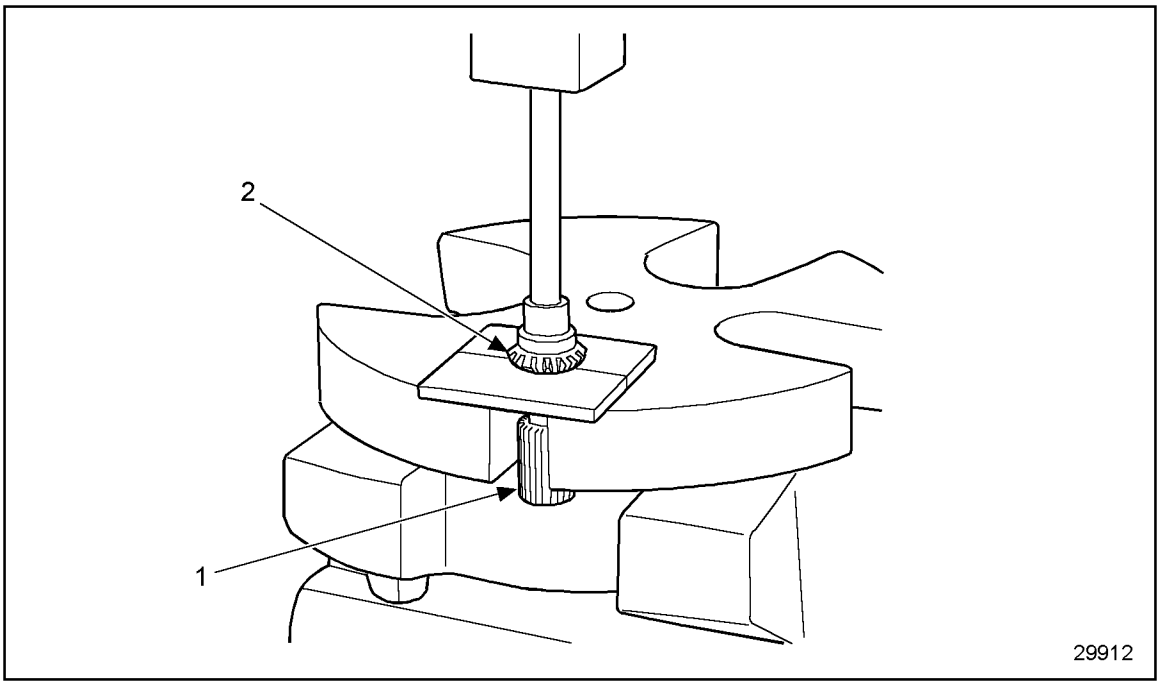
1. Drive Shaft
2. Bearing

Figure 2-226 Removing Bearing from Drive Gear

[c] Place a brass rod on the drive shaft end. Press the drive gear and shaft assembly from the bearing. Catch the drive gear and shaft by hand when pressed from the bearing.

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[d] Place two split brass plates beneath the drive gear teeth. Support the assembly on an arbor press bed. See Figure 2-227.



1. Drive Shaft
2. Drive Gear

Figure 2-227 Removing Drive Gear from Drive Shaft

[e] Place a brass rod on the end of the drive shaft. Press the drive shaft from the drive gear. Catch the drive shaft by hand when pressed from the drive gear.

If necessary, the governor control link lever assembly and oil seal may be removed from the governor control housing and the bearing removed from the control link lever shaft as follows:

1. Remove the Woodruff key from the governor control link lever shaft keyway.
2. Remove the snap ring and flat washer that retains the control link lever, shaft, and bearing assembly in the drive housing. Remove the lever, shaft, and bearing assembly from the housing.

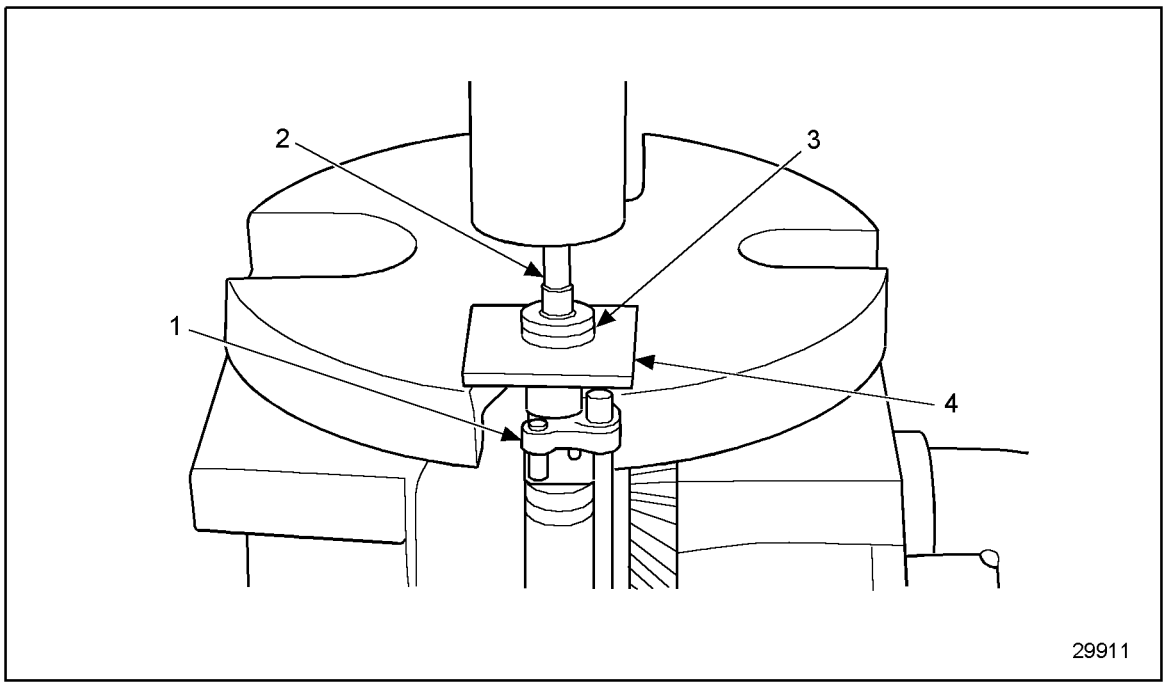
NOTE:
The two governor control link lever, shaft, and bearing assemblies in the governor drive housing and governor control housing are identical, except for the location of the keyway in the outer end of the shaft. If both control link lever, shaft, and bearing assemblies are to be removed, tag one or both of the lever assemblies so they may be installed in their respective housings.

3. If necessary, remove the control link lever shaft bearing from the shaft as follows:

[a] Support the inner end of the control link lever on a sleeve on an arbor press bed. Press the shaft approximately 1/4 in. out of the lower end of the lever.

[b] Support the opposite end of the lever, next to the bearing, on an arbor press bed. Do not put the support under the bearing. Press the shaft in flush with the lever end. This will leave approximately 1/4 in. space between the bearing and the lever.

[c] Place two split plates between the bearing and the lever. Support the split plates, lever, shaft, and bearing assembly on an arbor press bed. See Figure 2-228. Press the shaft from the bearing.



1. Control Link Lever
2. Shaft
3. Bearing
4. Split Plates

Figure 2-228 Removing Bearing from Control Link Lever Shaft

NOTE:
The hole in the split plates should be the same diameter as the shaft so the inner race of the bearing will rest on the plates when in place.

[d] If necessary, the control link lever shaft may be pressed from the control link lever.

4. Inspect the control link lever shaft oil seal for wear and damage.

If necessary, the oil seal may be replaced in the governor drive housing without removing the drive and driven gear assemblies. Replace the oil seal as follows:

1. Support the inner face of the drive housing on two wood blocks approximately 2 in. thick. Place a short piece of 3/4 in. round bar stock on top of the oil seal, and tap it out of the housing with a hammer.
2. Apply a thin coat of sealing compound to the outside diameter of the new oil seal casing. Start the oil seal with the seal lip facing down, straight into the bore in the housing.

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3. Support the drive housing inner face on two wood blocks on an arbor press bed.
4. Place the 3/4 in. round bar stock on top of the oil seal and under the press ram. Press the oil seal into the housing until it is 8.64 mm (0.340 in.) below the outer face of the housing.

2.30.5.1 Cleaning of Hydraulic Governor Drive

Clean the hydraulic governor drive as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash all 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 with compressed air.

2.30.5.2 Inspection of Hydraulic Governor Drive

Inspect the hydraulic governor drive as follows:

1. Inspect the teeth of the drive and driven bevel gears for chipping, scoring, or wear.

NOTE:
There must be approximately 0.025-0.076 mm. (0.001-0.003 in.) clearance between the governor drive and driven gears.

[a] Remove any slight score marks with a stone.

[b] If the teeth are severely scored, chipped, or worn, replace the gears. Refer to section 2.30.6.

[c] If not worn, scored, or chipped, continue inspection.

2. Visually inspect the drive shaft and the driven shaft sleeve for worn splines. Check the mating parts for wear.

NOTE:
When replacing the governor drive shaft sleeve on an engine with an EGB or LSG governor built prior to January 1971, the governor drive coupling must be removed. The

current governor drive shaft sleeve is 32.766 mm (1.290 in.) longer than the former sleeve to offset the drive coupling.

[a] If worn, replace the drive shaft and driven shaft sleeve. Refer to section 2.30.6.

[b] If not worn, continue inspection.

3. Visually inspect each ball bearing for corrosion or pitting.

   [a] If corroded or pitted, replace the bearing. Refer to section 2.30.6.

   [b] If not corroded or pitted, proceed with inspection.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the bearing with light engine oil. While holding the inner race, revolve the outer race slowly by hand, checking for rough spots.

   [a] If there are any rough spots, replace the bearing. Refer to section 2.30.6.

   [b] If no rough spots are detected, continue inspection.

5. Visually inspect the control link operating shaft and its governor drive housing bushing for wear.

   [a] If worn, replace the bushing or control link operating shaft. Refer to section 2.30.6.

NOTE:
If a new bushing is installed, press it in the drive housing to 3.556–3.683 mm (0.140–0.145 in.) below the outside face of the housing.

[b] If not worn, proceed with inspection.

6. Visually inspect the fuel rod cover hoses for damage.

   [a] If damaged, replace the fuel rod cover hoses. Refer to section 2.30.8.

   [b] If not damaged, proceed with inspection.

7. Visually inspect the fuel rod pins in the control link lever for wear and scoring.

   [a] If worn or scored, replace the fuel rod pins. Refer to section 2.30.8.

   [b] If not worn or scored, reuse the parts.

2.30.6 Assembly of Hydraulic Governor Drive (6V and 8V Engines)

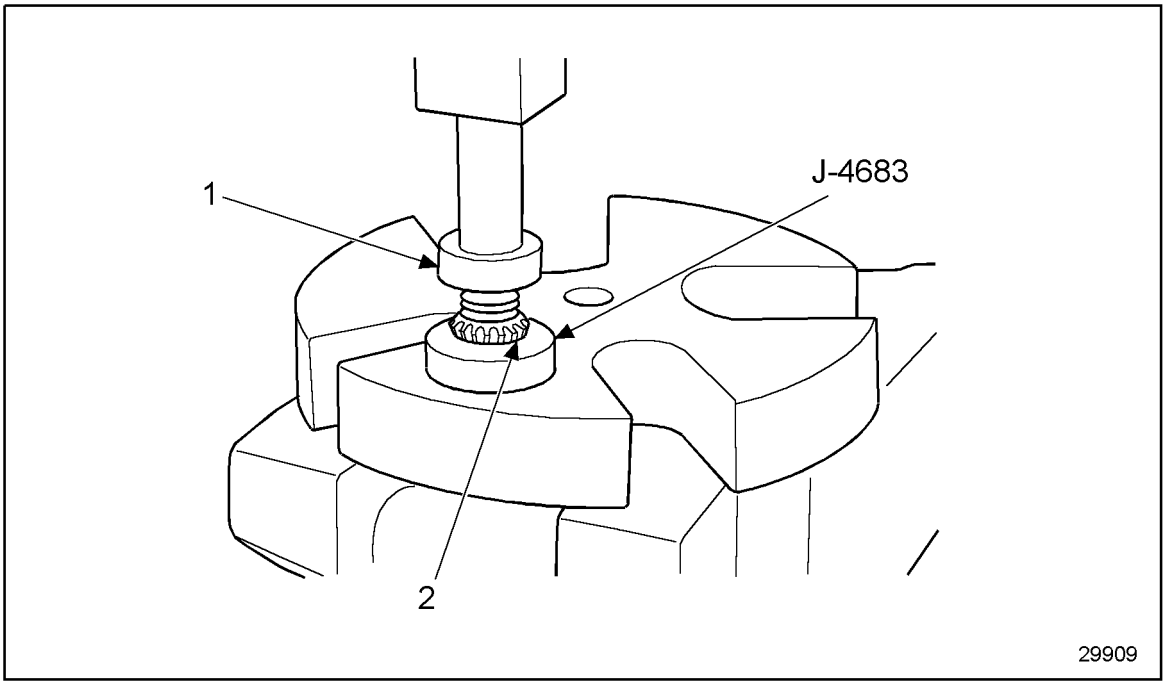
Install the governor drive shaft bearing and drive gear on the drive shaft as follows:

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the drive shaft bearing with engine oil, and start the bearing, numbered side up, straight on the end of the drive gear.
2. Place the beveled end of the drive gear on the bearing installer J 21068, and place the assembly on an arbor press bed. See Figure 2-229.



1. Bearing
2. Drive Gear

Figure 2-229 Installing Bearing on Drive Gear

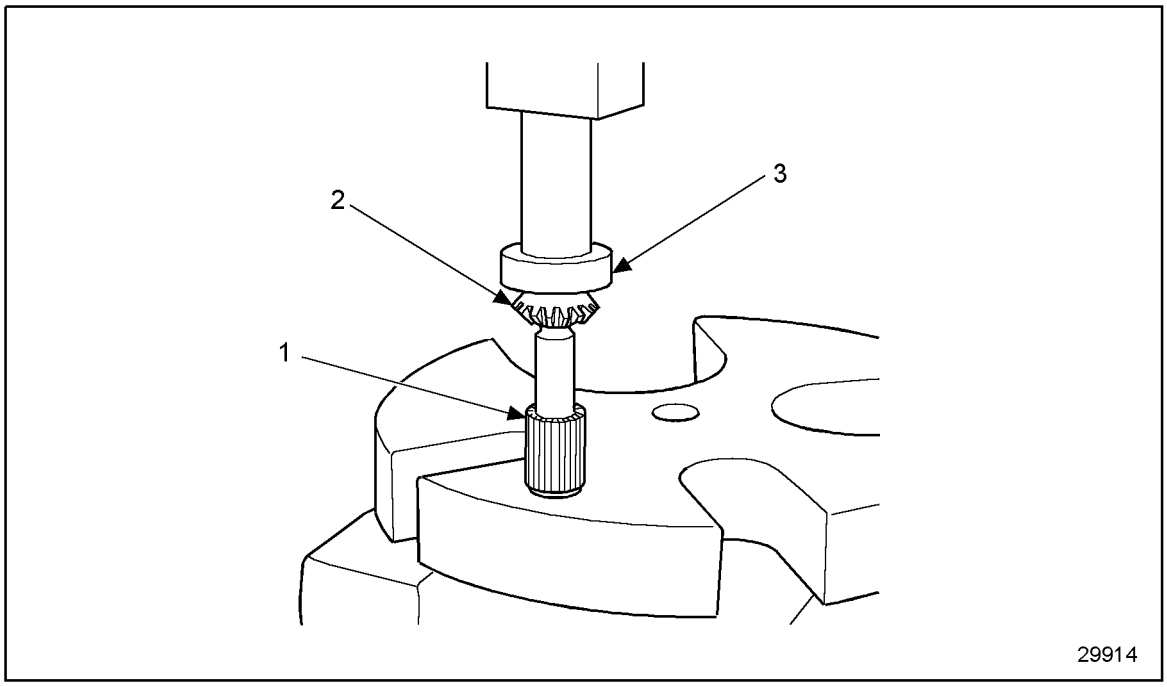
3. Place a sleeve on the bearing inner race, and press the bearing tightly against the drive gear shoulder.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the small end of the governor drive shaft with engine oil.
5. Start the drive gear straight on the shaft with the gear teeth facing the splined end of the shaft.

6. Place the drive shaft, gear and bearing assembly on an arbor press bed, bearing and gear end up. See Figure 2-230.



1. Drive Shaft
2. Drive Gear
3. Bearing

Figure 2-230 Installing Drive Gear and Bearing on Drive Shaft

7. Place a sleeve or a round brass bar on the bearing inner race.
8. Press the drive gear tightly against the shaft shoulder.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

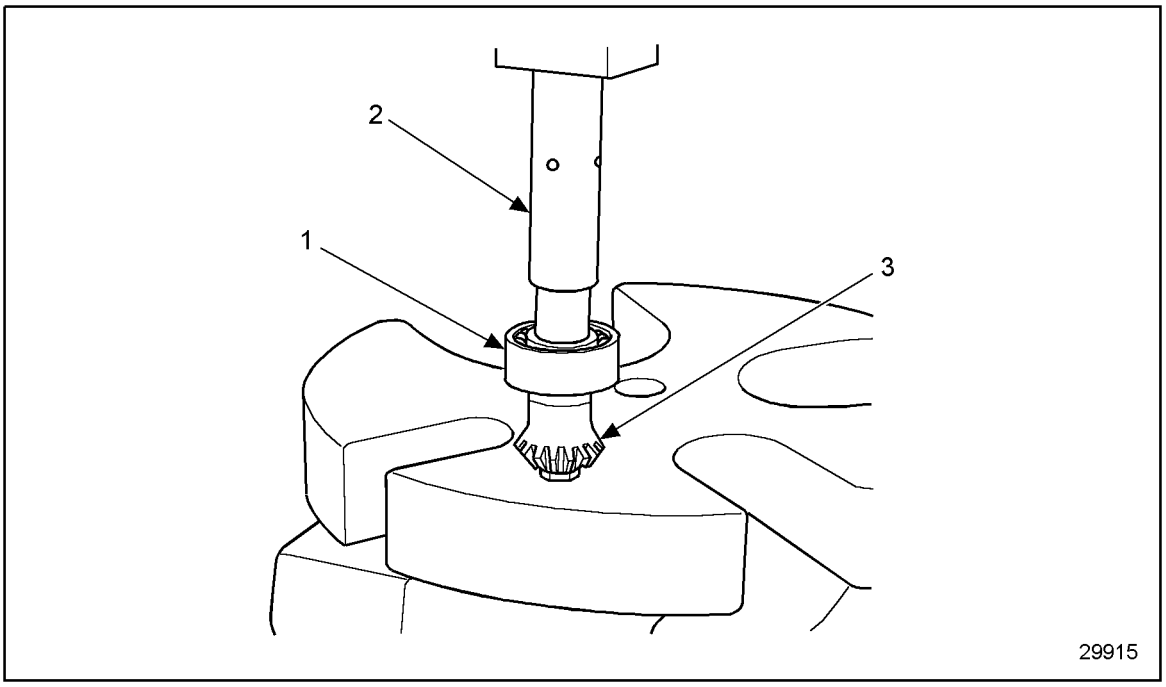
9. Lubricate the governor drive shaft bearing with engine oil. Insert the drive shaft, drive gear, and bearing assembly straight into the bearing bore in the drive housing.

Install the governor driven gear bearing and sleeve on the driven gear as follows:

1. Lubricate the driven gear bearing with engine oil. Start the bearing, numbered end up, straight on the driven gear.
2. Lubricate the inside diameter of the driven gear sleeve with engine oil. Start the sleeve, splined end up, straight on the end of the driven gear.

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3. Place the driven gear, bearing, and sleeve assembly on an arbor press bed, with a spacer under the gear to support the gear teeth above the press bed. See Figure 2-231.



1. Bearing
2. Driven Sleeve
3. Driven Gear

Figure 2-231 Installing Bearing and Driven Sleeve on Driven Gear

4. Press the sleeve and bearing tightly against the driven gear shoulder.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

Continue governor assembly as follows:

1. Lubricate the driven gear bearing with engine oil. Insert the driven gear, bearing, and sleeve assembly through the top of the drive housing.
2. Start the bearing straight into the bearing bore in the housing. Push the driven gear assembly into the housing until the driven gear teeth mesh with the drive gear and the bearing rests on the housing shoulder.

NOTE:
If necessary, rotate one of the gears slightly to align the gear teeth.

3. Install the snap ring in the housing groove next to the bearing.

4. Rotate the drive and driven gears, and check for freedom and clearance between the gear teeth. The clearance should be 0.0254-0.0762 mm (0.001-0.003 in.).

Install the governor control link lever and shaft assembly in the drive housing as follows:

CAUTION:

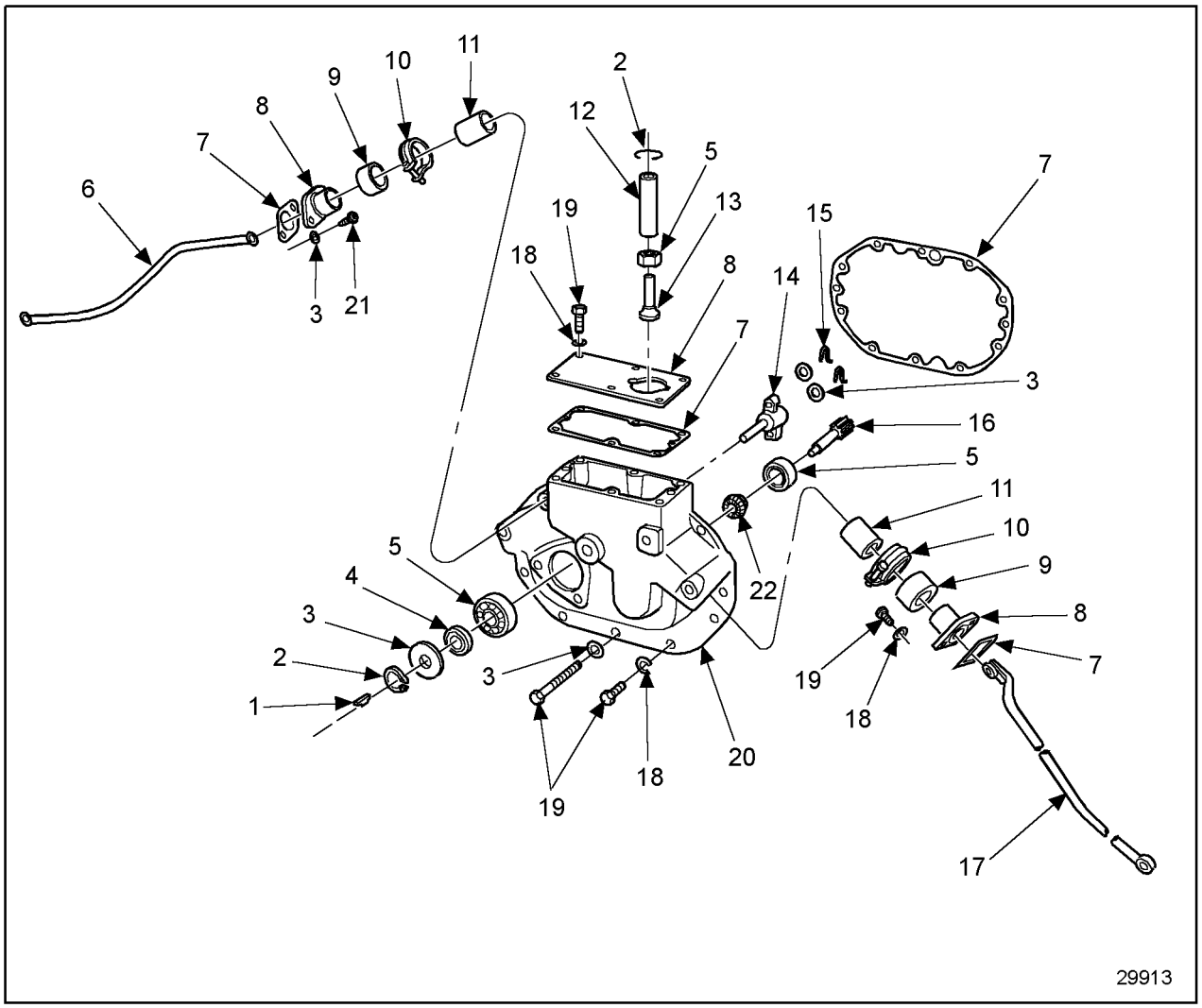
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the control link lever shaft with engine oil, and slide the shaft through the bushing from the inner side of the housing.
2. Place a new seal ring over the shaft, and slide it into the housing against the bushing.
3. Place the small flat washer over the shaft, and slide it against the seal ring.
4. Place the large flat washer over the shaft, and slide it against the housing. Install the snap ring in the groove in the shaft.
5. Install the Woodruff key in the shaft keyway.
6. Slide the control link shaft lever over the shaft and key. Secure it with a bolt and lock washer.

2.30.7 Assembly of Hydraulic Governor Drive (12V and 16V Engines)

See Figure 2-232. Assemble the hydraulic governor drive on 12V and 16V engines as follows:

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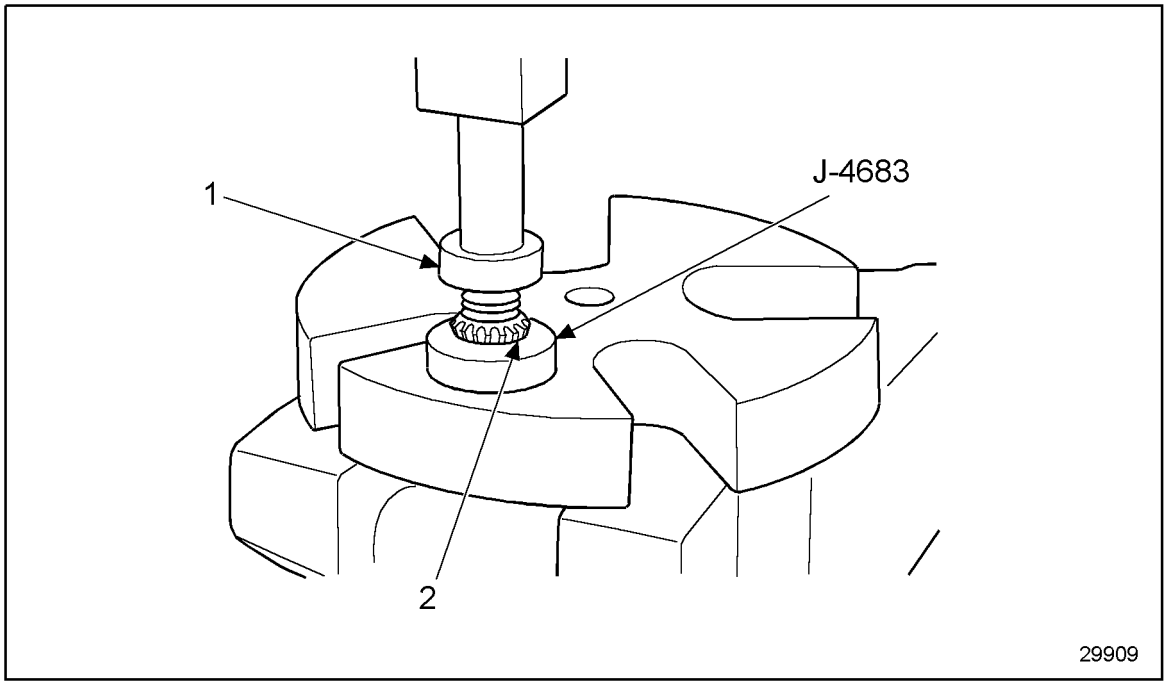
1. Key
2. Snap Ring
3. Washer
4. Oil Seal
5. Bearing
6. Right-Hand Fuel Rod
7. Gasket
8. Cover
9. Hose
10. Clamp
11. Tube
12. Sleeve
13. Driven Gear
14. Lever
15. Pin
16. Drive Shaft
17. Left-Hand Fuel Rod
18. Lock Washer
19. Bolt
20. Governor Housing
21. Screw
22. Drive Gear

Figure 2-232 Enclosed Linkage Type Hydraulic Governor Drive(12V and 16V Engines)

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the drive shaft bearing with engine oil. Start the bearing, numbered side up, straight on the end of the drive gear.
2. Place the beveled end of the drive gear on the bearing installer J 21068. Place the assembly on an arbor press bed. See Figure 2-233.



1. Bearing
2. Drive Gear

Figure 2-233 Installing Bearing on Drive Gear

3. Place a sleeve on the bearing inner race, and press the bearing tightly against the drive gear shoulder.

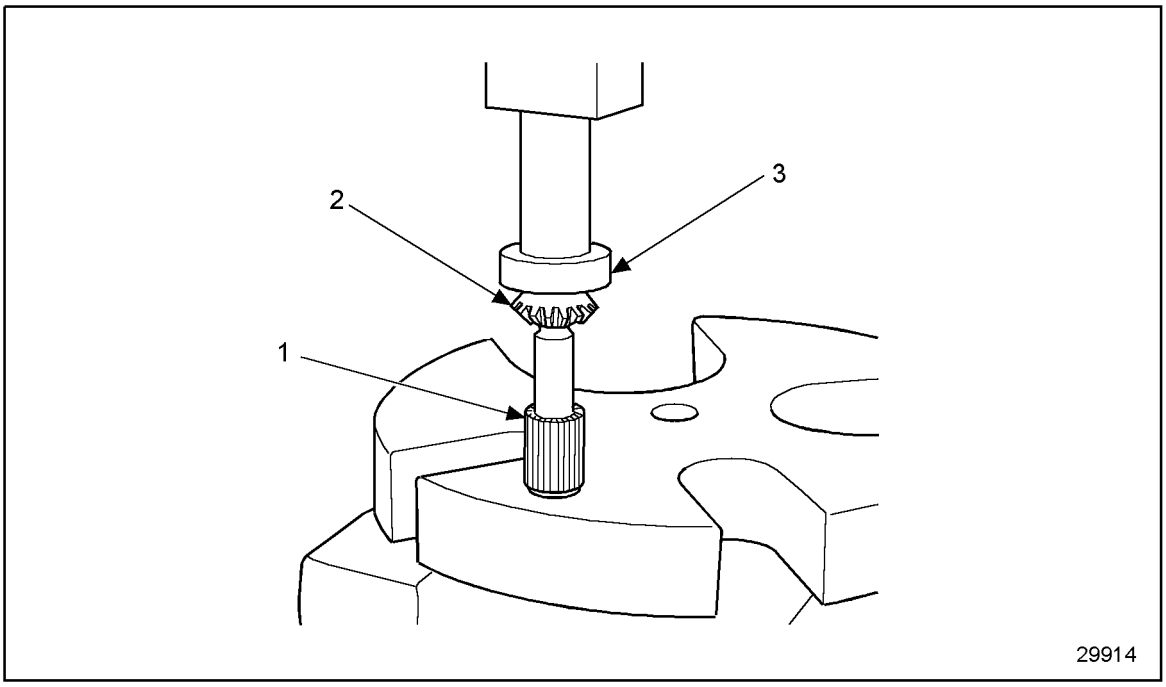
⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the small end of the governor drive shaft with engine oil.
5. Start the drive gear straight on the shaft, gear teeth facing the splined end of the shaft.

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6. Place the drive shaft, gear, and bearing assembly on an arbor press bed, bearing and gear end up. See Figure 2-234.



1. Drive Shaft
2. Drive Gear
3. Bearing

Figure 2-234 Installing Drive Gear and Bearing on Drive Shaft

7. Place a sleeve or a brass rod on the bearing inner race. Press the drive gear tightly against the shaft shoulder.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

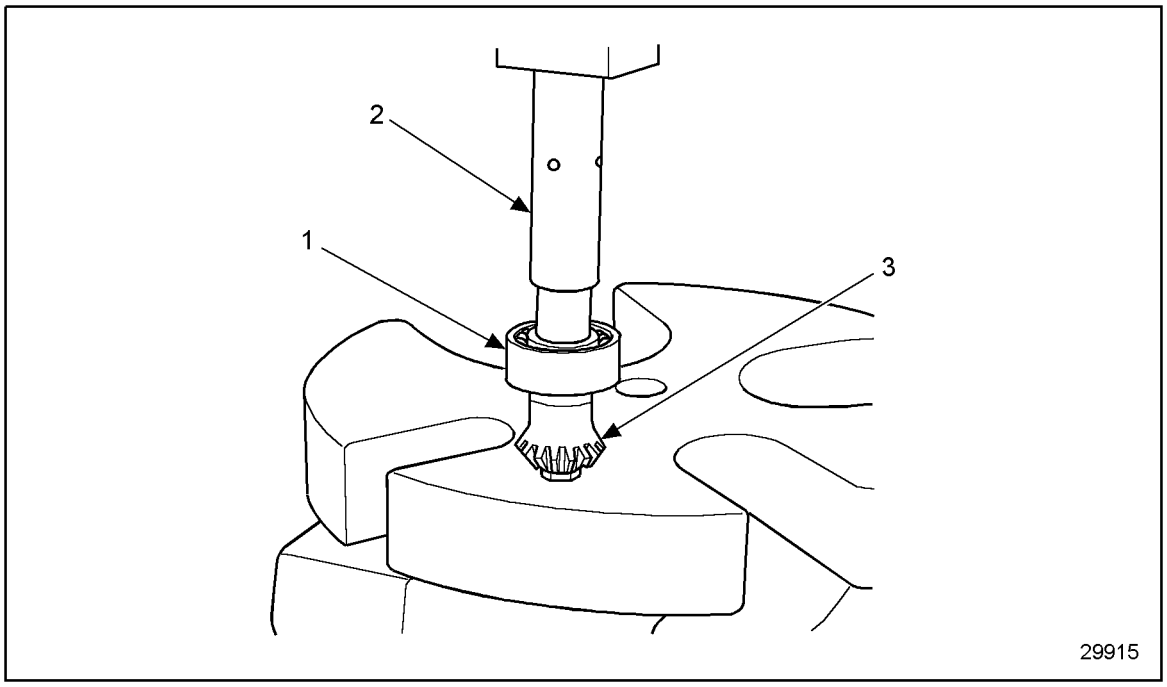
8. Lubricate the governor drive shaft bearing with engine oil. Insert the drive shaft, drive gear, and bearing assembly straight into the drive housing bearing bore.

Install the governor driven gear bearing and sleeve on the driven gear as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the driven gear bearing with engine oil, and start the bearing, numbered side up, straight on the driven gear.
2. Lubricate the inside diameter of the driven gear sleeve with engine oil. Start the sleeve, splined end up, straight on the end of the driven gear.
3. Place the driven gear, bearing, and sleeve assembly on an arbor press bed, with a spacer under the gear. See Figure 2-235. Press the sleeve and bearing tightly against the driven gear shoulder.



1. Bearing
2. Driven Sleeve
3. Driven Gear

Figure 2-235 Installing Bearing and Driven Sleeve on Driven Gear

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the driven gear bearing with engine oil, and insert the driven gear, bearing, and sleeve assembly through the top of the drive housing.
5. Start the bearing straight into the bearing bore in the housing. Push the driven gear assembly down in the housing until the driven gear teeth mesh with the drive gear and the bearing rests on the housing shoulder.

NOTE:
If necessary, rotate one of the gears slightly to align the gear teeth.

6. Install the snap ring in the housing groove next to the bearing.
7. Rotate the drive and driven gears, and check for freedom and clearance between the gear teeth.

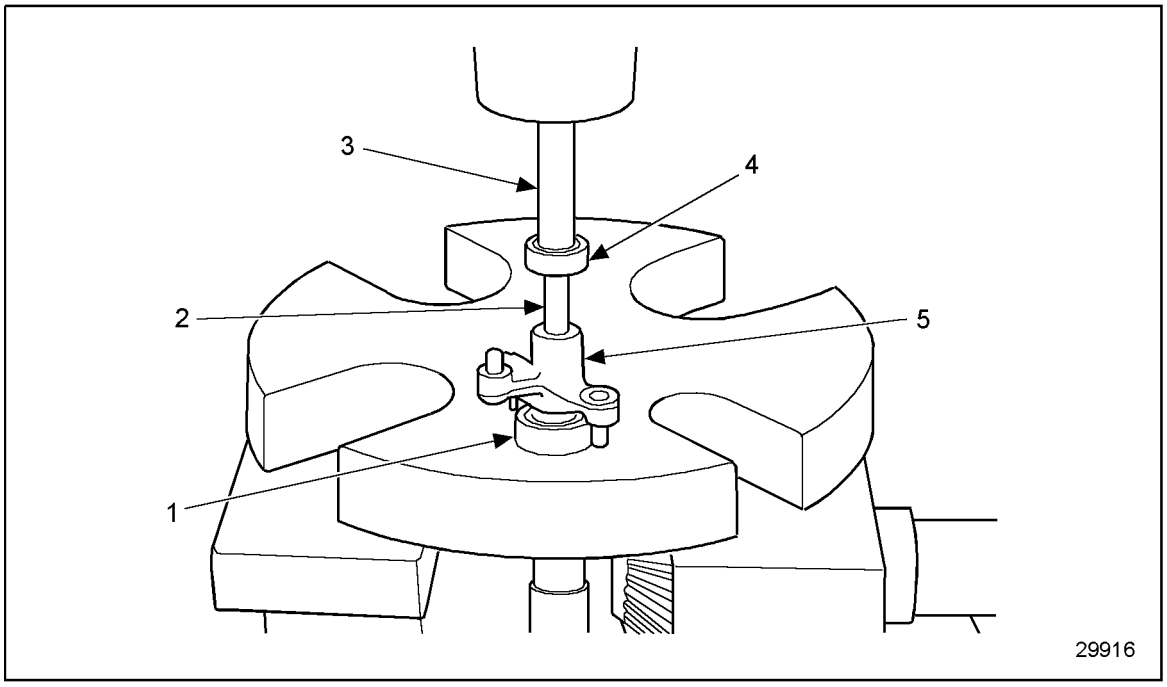
NOTE:
The clearance should be 0.025-0.076 mm (0.001-0.003 in.).

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

8. If removed, install the governor control link lever shaft spherical bearing on the shaft as follows:
   [a] Lubricate the control link lever shaft bearing with engine oil. Start the bearing straight on the control link lever shaft.

[b] Support the control link lever, shaft, and bearing assembly on an arbor press bed, with a spacer under the control link lever and shaft. See Figure 2-236.



1. Support
2. Shaft
3. Sleeve
4. Bearing
5. Control Link Lever

Figure 2-236 Installing Bearing on Governor Control Link Lever Shaft

[c] Place a sleeve on top of the bearing inner race, and press the bearing tightly against the control link lever.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

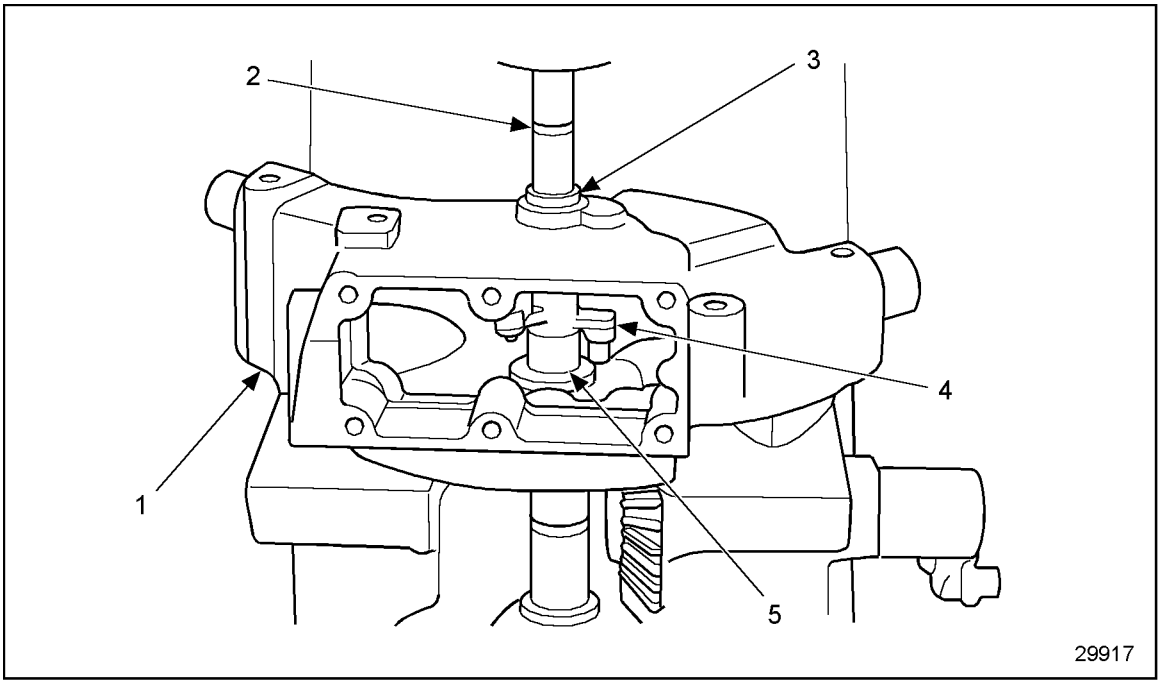
9. Lubricate the control link lever shaft bearing with engine oil. Start the control link lever, shaft and bearing assembly straight into the bore in the drive housing. Push the assembly in until the bearing is tight against the housing shoulder.

NOTE:
Ensure proper control link lever, shaft, and bearing assembly in the governor drive housing is installed. When the control link lever, shaft, and bearing assemblies are correctly installed, the keyway in the outer end of each shaft will face the right-hand side of the engine, as viewed from the rear, when the blower assemblies are attached to the cylinder block.

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Install the governor control link lever shaft oil seal in the governor drive housing as follows:

1. Wrap a thin layer of cellulose tape over the snap ring groove and keyway in the outer end of the control link lever shaft to protect the oil seal lip.
2. Support the governor drive housing on an arbor press bed, with a spacer under the end of the control link lever to prevent the bearing from slipping out of the housing. See Figure 2-237.



1. Housing
2. Sleeve
3. Oil Seal
4. Control Link Lever
5. Support

Figure 2-237 Installing Control Link Lever Shaft Oil Seal in Governor Drive

3. Apply a thin coat of sealing compound on the outside diameter of the new oil seal casing. Place the oil seal, with the seal lip facing down, over the end of the shaft. Start it straight into the bore in the housing. Be careful not to damage the oil seal lip.
4. Place a 23/32 in. outside diameter sleeve over the shaft end and rest it on top of the seal. Press the oil seal into the housing until it is 8.636 mm (0.340 in.) below the outer face of the housing.
5. Remove the tape from the shaft, and place the flat washer over the shaft against the housing.
6. Install the snap ring in the shaft groove. Install the Woodruff key in the keyway in the shaft.

2.30.8 Installation of Hydraulic Governor Drive (6V and 8V Engine)

Install the governor drive on 6V and 8V engines as follows:

1. Attach the governor drive to the blower.
2. Place a fuel rod cover hose and clamp on each fuel rod tube in the drive housing. Tighten the hose clamps.
3. Affix a new gasket to the blower end plate.
4. Align the governor drive shaft splines with the blower rotor shaft.
5. Insert the drive shaft into the rotor shaft. Slide the drive housing on the dowels and against the gasket.
6. Install the ten bolts, seven lock washers, and three copper washers that secure the drive housing to the blower end plates. Tighten the bolts to 18-33 N·m (13-17 lb·ft) torque.

NOTE:
The three copper washers are used on the three long bolts that are exposed to the oil inside the drive housing.

7. Insert the fuel rods through the opening in the top of the drive housing. Connect them to the injector control tube levers and to the control link lever inside the housing.
8. Loosen the fuel rod cover hose clamps, and slide the hoses on the covers and tubes. Tighten the hose clamps.

Attach the fuel pump assembly to the governor drive housing as follows:

1. Affix a new gasket to the fuel pump body bolting flange.
2. Place the fuel pump drive coupling fork over the square on the pump drive shaft end.
3. Align the drive coupling fork ends with the drive coupling disc slots.
4. Place the fuel pump against the governor drive housing.

NOTE:
Ensure drive coupling fork prongs are in the drive disc slots before installing and tightening the attaching bolts.

5. Install the three bolt and seal assemblies, and tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

Continue governor installation as follows:

1. Connect the fuel oil inlet and outlet pipes to the fuel pump.
2. Affix a new gasket to the top face of the governor drive housing.
3. Place the housing cover on top of the gasket with the governor opening in the cover over the governor driven gear sleeve.
4. Install two bolts and lock washers in the end holes. Do not tighten the bolts.

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Attach the governor assembly to the drive housing as follows:

1. Affix a new governor gasket to the top face of the housing cover.
2. Position the governor assembly over the governor drive housing, with the governor operating lever side of the governor facing the front end of the engine.
3. Align the ball head shaft splines with the driven gear sleeve splines.
4. Start the ball head shaft straight into the sleeve, and lower it against the gasket on the cover.
5. Install the four bolts and lock washers securing the governor to the drive housing. Tighten the four governor bolts and the two housing cover bolts to 18-23 N·m (13-17 lb·ft) torque.
6. Connect the vertical link assembly to the governor operating lever and the control link lever.

Continue governor assembly as follows:

1. If the governor is equipped with a synchronizing motor, connect the electrical wires to the motor terminals.
2. If a governor operating solenoid is used, attach the solenoid to the drive housing.
3. Connect the oil inlet and outlet tubes to the solenoid, governor, and drive housing.
4. Connect the electrical wires to the solenoid terminals.
5. If an oil reservoir is used, attach the reservoir to the drive housing. Connect the oil inlet, outlet, and return tubes to the oil reservoir, governor, and drive housing.
6. Connect the throttle control linkage to the speed control lever.
7. Lubricate the governor control linkage end bearings with grease through the fittings.
8. If drained, refill the cooling system. Refer to section 13.12.
9. Perform an engine tune-up. Refer to section 12.1.

2.30.9 Installation of Hydraulic Governor Drive (12V and 16V Engines)

Install the hydraulic governor drive on 12V and 16V engines as follows:

1. Affix a new gasket to the rear blower front end plate.
2. Align the governor drive shaft splines with the blower rotor shaft, and insert the drive shaft into the rotor shaft. Slide the drive housing on the dowels.
3. Install the ten bolts, seven lock washers, and three copper washers that secure the drive housing to the blower end plate. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

NOTE:
The three copper washers are used on the three long bolts which are exposed to the oil inside the drive housing.

4. Perform the following s to attach the fuel pump assembly to the governor drive housing.
   [a] Affix a new gasket to the fuel pump body bolting flange.

[b] Place the fuel pump drive coupling fork over the square on the pump drive shaft end.

[c] Align the drive coupling fork ends with the drive coupling disc slots. Place the fuel pump against the governor drive housing with the openings in the fuel pump inlet and outlet elbows facing up.

NOTE:
Ensure drive coupling fork prongs are in the drive disc slots before installing and tightening the attached bolts.

[d] Install the three bolt and seal assemblies. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

5. Place a hose and clamp on each of the fuel rod tubes in the governor drive housing. Tighten the clamp screws.
6. Affix a new blower housing gasket to the top of the cylinder block. Use a good grade, non-hardening cement to prevent the gasket from shifting when the blower is installed.
7. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the lifting sling before removing from engine. Blower damage may result if the blower falls from the lifting device.

8. Lift the blower assembly, front end first, at an angle, and position it over the top of the cylinder block.
9. Lower the blower, and start the blower seal on the rear blower end plate cover over the blower drive support. Move the blower back, and lower it against the gasket on the cylinder block.

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⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the engine before releasing the lifting sling. Blower damage may result if the blower falls from the engine.

10. Secure the blower to the cylinder block with bolts, retaining lugs, and flat washers. Uniformly tighten the blower side angle bolts to 41-47 N·m (30-35 lb·ft) torque in 7 N·m (5 lb·ft) increments. Tighten the blower-to-block end plate bolts to 54-61 N·m (40-45 lb·ft) torque.
11. Attach the tachometer drive adaptor, if used, to the blower. Connect the tachometer drive cable to the drive adaptor.
12. Insert the blower drive shaft through the blower drive flexible coupling and into the blower drive coupling. Install the snap ring in blower drive flexible coupling.
13. Affix a new gasket to the flywheel housing cover. Attach the cover to the flywheel housing with bolts and lock washers.
14. Place the lower seal clamp in position on the seal. Tighten the clamp screw.
15. Slide the blower oil pressure tube out of the blower, and connect it to the fitting in the blower drive support.
16. Insert the fuel rods through the opening in the top of the drive housing. Connect them to their injector control tube levers and to the drive housing control link lever.
17. Loosen the fuel rod cover hose clamps. Slide the hoses onto the covers and tubes, and tighten the hose clamps.
18. Place the governor control link lever and cap assembly over the governor control link lever shaft and key. Secure it with bolts and lock washers.
19. Affix a new gasket to the top of the governor drive housing. Place the housing cover on top of the gasket with the governor opening in the driven gear sleeve cover.
20. Install two bolts and lock washers in the end holes, opposite the governor opening. Do not tighten the bolts.
21. Affix a new governor gasket to the top face of the drive housing cover.
22. Position the governor assembly over the governor drive housing with the terminal lever shaft side of the governor facing the engine front blower.
23. Align the ball head shaft splines straight into the sleeve, and lower it against the gasket on the cover.

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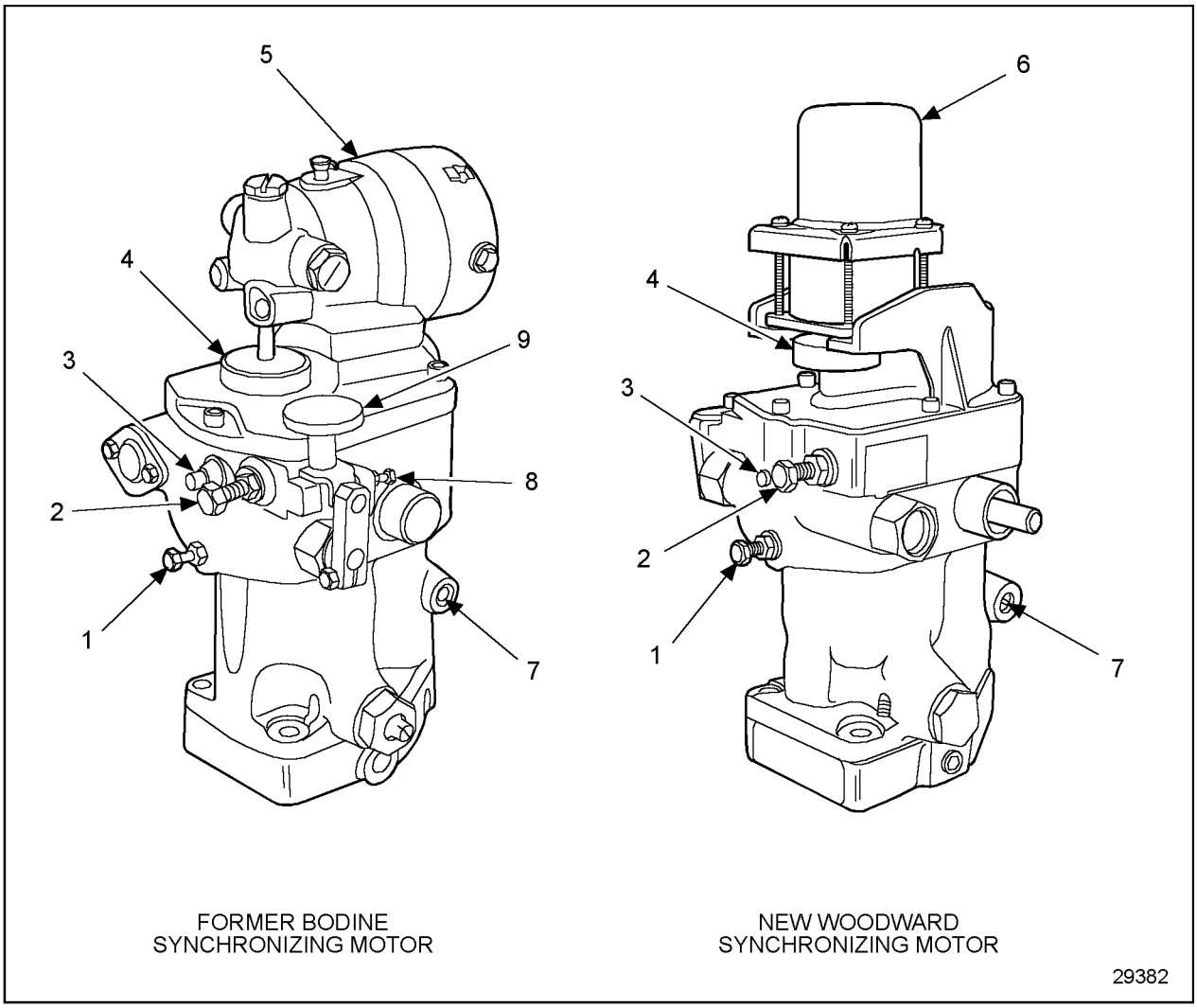
24. Install the four bolts and lock washers that secure the governor assembly to the drive housing cover. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.
25. If removed, install the governor operating lever on the terminal lever shaft. Connect the vertical control link assembly to the operating lever and the governor control link common lever and cap assembly.
26. Attach the governor operating solenoid to the governor drive housing, and connect the electrical wires to the solenoid terminals.
27. Connect the oil inlet and outlet tubes to the governor operating solenoid, governor, and drive housing.
28. Attach the governor oil reservoir to the governor drive housing. Connect the oil inlet, outlet, and return tubes to the oil reservoir, governor, and drive housing.
29. Connect the fuel oil inlet and outlet pipes to the fuel oil pump.
30. Attach the battery charging alternator to the engine flywheel housing. Connect the electrical wires to the alternator.
31. Attach the air shutdown housing to the top of the blower.
32. On industrial units, install the air inlet pipe between the air cleaner, or turbocharger, and the air shutdown housing on the rear blower.
33. On marine units, install the air inlet pipe between the air cleaner and the air shutdown housing on the rear blower.
34. Connect the throttle control linkage to the governor speed control lever.
35. Perform an engine tune-up. Refer to section 12.1.

NOTE:
Refer to section ADDITIONAL INFORMATION before installing a Barber-Coleman electronic governor on an engine previously equipped with a hydraulic governor.

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2.31 HYDRAULIC GOVERNOR SYNCHRONIZING MOTOR

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover. See Figure 2-238. This motor, used in place of a vernier control knob, permits close engine speed adjustment from a remote control point. This feature is especially valuable when synchronizing two generators from a central control panel.



1. Max. Speed Adjustment Screw
2. Load Limit Adjustment Screw
3. Min. Droop Setting Screw
4. Friction Drive
5. Former Bodine Motor
6. New Woodward Motor
7. Compensation Needle Valve
8. Max. Droop Setting Screw
9. Droop Adjustment Knob

Figure 2-238 Former and Current Synchronizing Motors on Woodward Hydraulic Governors

The motor is connected to the source of electrical supply through a two-way switch. See Figure 2-239.

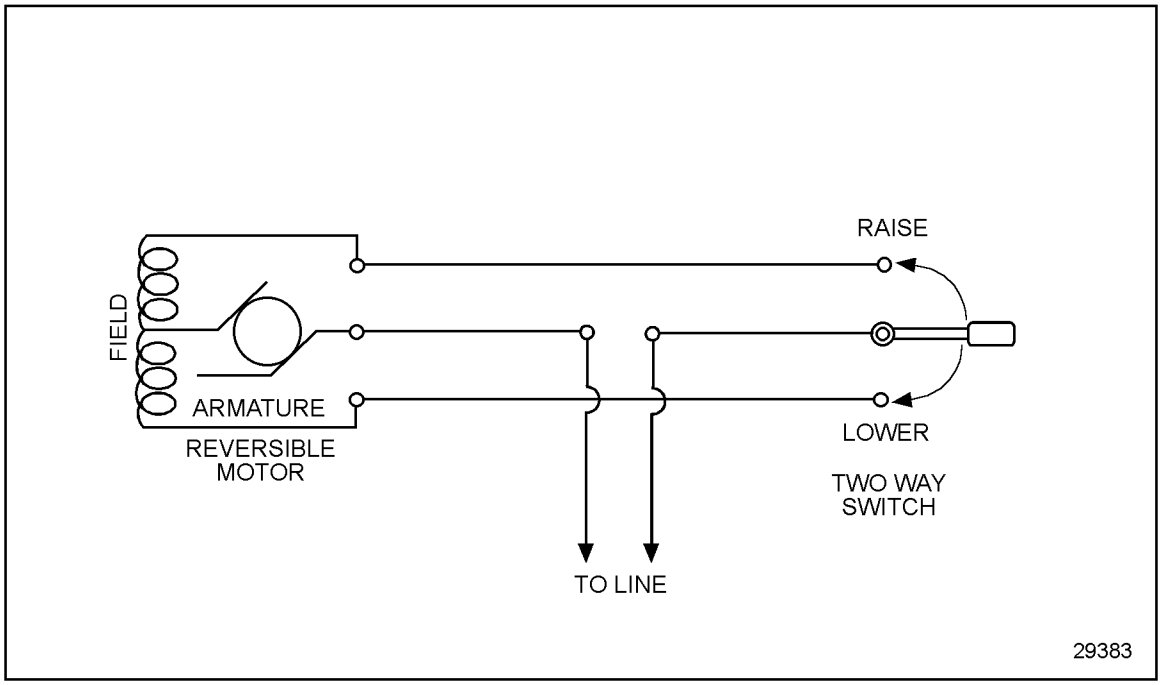


Figure 2-239 Synchronizing Motor Wiring Schematic

The motor drive shaft and the governor speed adjusting lever are mechanically connected through a reduction gear on the motor and a friction drive.

The synchronizing motor is used to change the engine speed when the unit is running alone or to adjust the load when the unit is operating in tandem with other units.

When the two-way control switch on the control panel is closed, the reduction gear and friction drive enables the motor shaft to turn the governor speed adjusting shaft. The rotational direction depends on the switch position. When the desired engine speed is indicated on a tachometer or frequency meter, the operator returns the switch to the off position.

If the switch is held in the lower speed position too long, the synchronizing motor will continue to lower the engine speed until it shuts the engine down. If the switch is held too long in the raise speed position, the motor will turn the governor speed adjusting shaft until it strikes the maximum speed adjusting screw. The friction drive will slip and the motor will continue to run at a slightly reduced speed without further effect.

If the motor is damaged or fails to operate, the entire motor should be replaced.

The friction drive spring washer must be strong enough to permit the motor to carry the speed adjusting lever up against the maximum speed adjusting screw without slipping, and it must be loose enough to slip after the lever contacts the screw.

Conversion kits with new extended life Woodward synchronizing motors have been released to replace the Bodine motors formerly used on Woodward SG and PSG hydraulic governors.

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The new motors differ from the former in that they are permanent magnet speed setting motors. The former Bodines were field wound motors. The new motors are mounted vertically on the governor covers and connected to the governor speed adjusting shafts through a short gear train. The Bodine motors were mounted horizontally on the governor covers and used a 90 degree offset drive connected to the speed adjusting shaft.

The current Woodward motors and kits completely replace the former Bodine motors, and only the new parts will be serviced.

2.31.1 Repair or Replacement of Hydraulic Governor Synchronizing Motor

For motor or converter replacement, contact an authorized Detroit Diesel parts distributor. For motor components or repair, contact an authorized Woodward Governor sales or service outlet or the Woodward Company at the address below.

Contact: Woodward Governor Company 1000 East Drake Road P.O. Box 1519, Fort Collins, CO 80522-9990

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2.32 ELECTRONIC GOVERNOR

Barber-Colman® Dyna 8000 and 8400 electronic governors are available on certain Detroit Diesel engines.

These 24-volt, all electric, constant speed governors have high reliability due to their few moving parts. This makes them suitable for applications such as power generator sets, where only minimal engine RPM. fluctuation can be tolerated. The governors are factory lubricated and sealed and require no special maintenance.

The new governors and their model applications are listed in Table 2-9.

Governor Number	Model Usage	Model Usage
23502462	1033-7005	1043-7000
Dyna 8000	1043-7005 1063-7005	1043-7305 1063-7305
23502463 (Dyna 8000)	7083-7005 7123-7005 7123-7400 7163-7305 8063-7400 8063-7416 8083-7305 8083-7405	7083-7305 7123-7305 7123-7405 8063-7305 8063-7405 8083-7000 8083-7400 8083-7416
23502464 (Dyna 8400)	7163-7305 8123-7405 8163-7305 8163-7416	8123-7305 8123-7416 8163-7405

Table 2-9 Governor Model Parts List

For proper set up and adjustment, refer to the Barber-Colman Dyna 8000 and 8400 manual.

2.32.1 Repair or Replacement of Electronic Governor

Refer to the Original Equipment Manufacturer for service procedure.

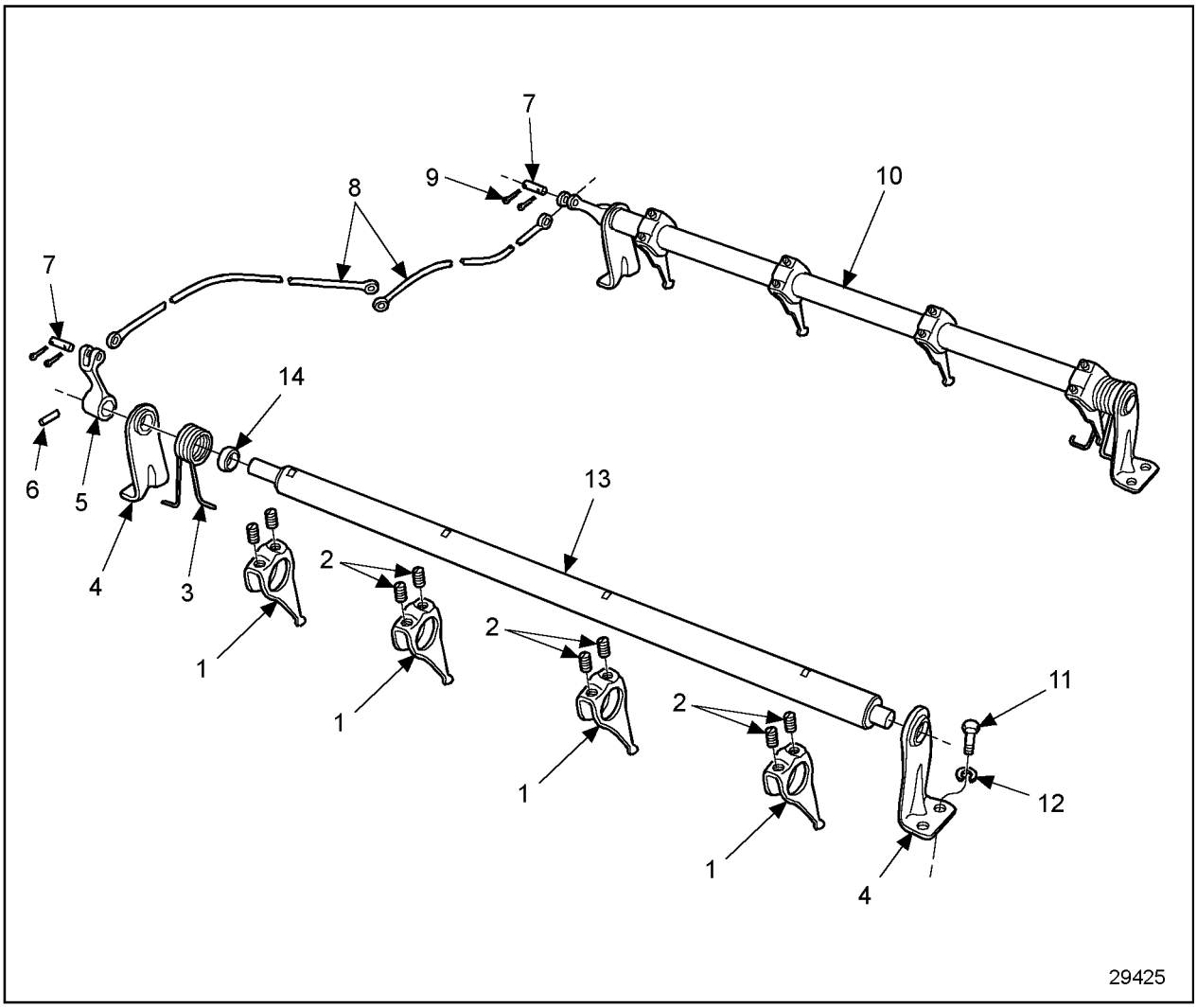
Barber-Colman electronic governors are sold only as assemblies. For component parts or service, contact an authorized Barber-Colman service outlet or the manufacturer:

Barber-Colman Company Precision Dynamics Division 1354 Clifford Avenue Loves Park, IL 61132-2940, Phone: (815) 877-0241

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2.33 FUEL INJECTOR CONTROL TUBE (NON-DDEC ENGINES)

The fuel injector control tube assemblies are mounted on the left and right-bank cylinder heads of an engine. They consist of a control tube, injector rack control levers, a return spring, and an injector control tube lever mounted in two bracket and bearing assemblies attached to each cylinder head. See Figure 2-240.



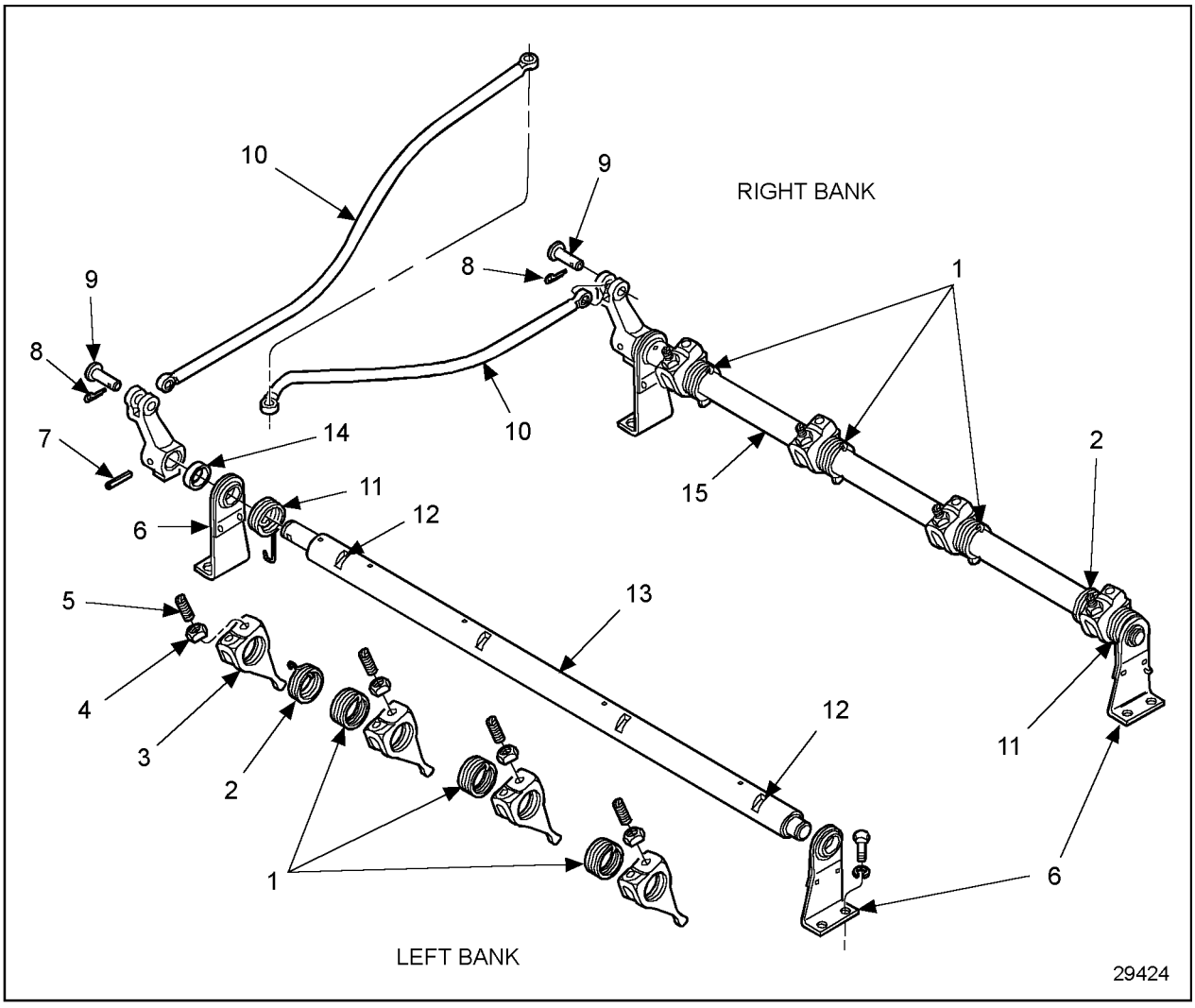
1. Rack Levers
2. Adjusting Screws
3. Return Spring
4. Bracket
5. Control Lever
6. Pin
7. Fuel Rod Pin
8. Fuel Rods
9. Cotter Pins
10. Control Tube Assembly
11. Bolt
12. Lock Washer
13. Control Tube
14. Spacer

Figure 2-240 Injector Control Tube Assemblies (Non-Spring Loaded)

The injector rack control levers connect to the fuel injector control racks. They are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. The injector control tube lever is pinned to the end of the control tube and connects to the fuel rod. Refer to section 12.4 for the injector rack control lever positions.

Certain engines use similar spring-loaded injector control tube assemblies similar to the above, except for a yield spring at each injector rack control lever and only one screw and locknut to keep each injector rack properly positioned. See Figure 2-241. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector rack. This could not be accomplished with the non-spring loaded two screw injector control tube. It also permits the use of an air inlet housing with no emergency air shutoff-valve.

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1. Spring (RH Helix)
2. Spring (LH Helix)
3. Rack Lever
4. Locknut
5. Adjusting Screw
6. Brackets
7. Pin
8. Cotter Pin
9. Clevis Pin
10. Fuel Rods
11. Return Spring
12. Slot
13. Control Tube
14. Spacer
15. Injector Control Tube Assembly

Figure 2-241 Injector Control Tube Assemblies (Spring Loaded)

NOTE:
Do not replace the spring-loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shutoff-valve. When the spring-loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown

mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to 15.9766 mm (0.6290 in.), and install a 5/8 in. cup plug at each end of the housing.

Pull the governor shutdown lever to the no fuel position to perform normal or emergency engine shutdown on the spring-loaded, one screw design fuel injector control tube. Trip the air shutoff-valve in the air inlet housing to perform an emergency shutdown on the two screw design injector control tube and lever assembly. Pulling the governor shutdown lever to the no-fuel position accomplishes normal shutdown. The single screw and locknut adjustment on each injector rack control lever can be performed the same as the two screw design rack control lever. Refer to section 12.4.8 and refer to section 12.4.12.

2.33.1 Repair or Replacement of Fuel Injector Control Tube

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 2-242.

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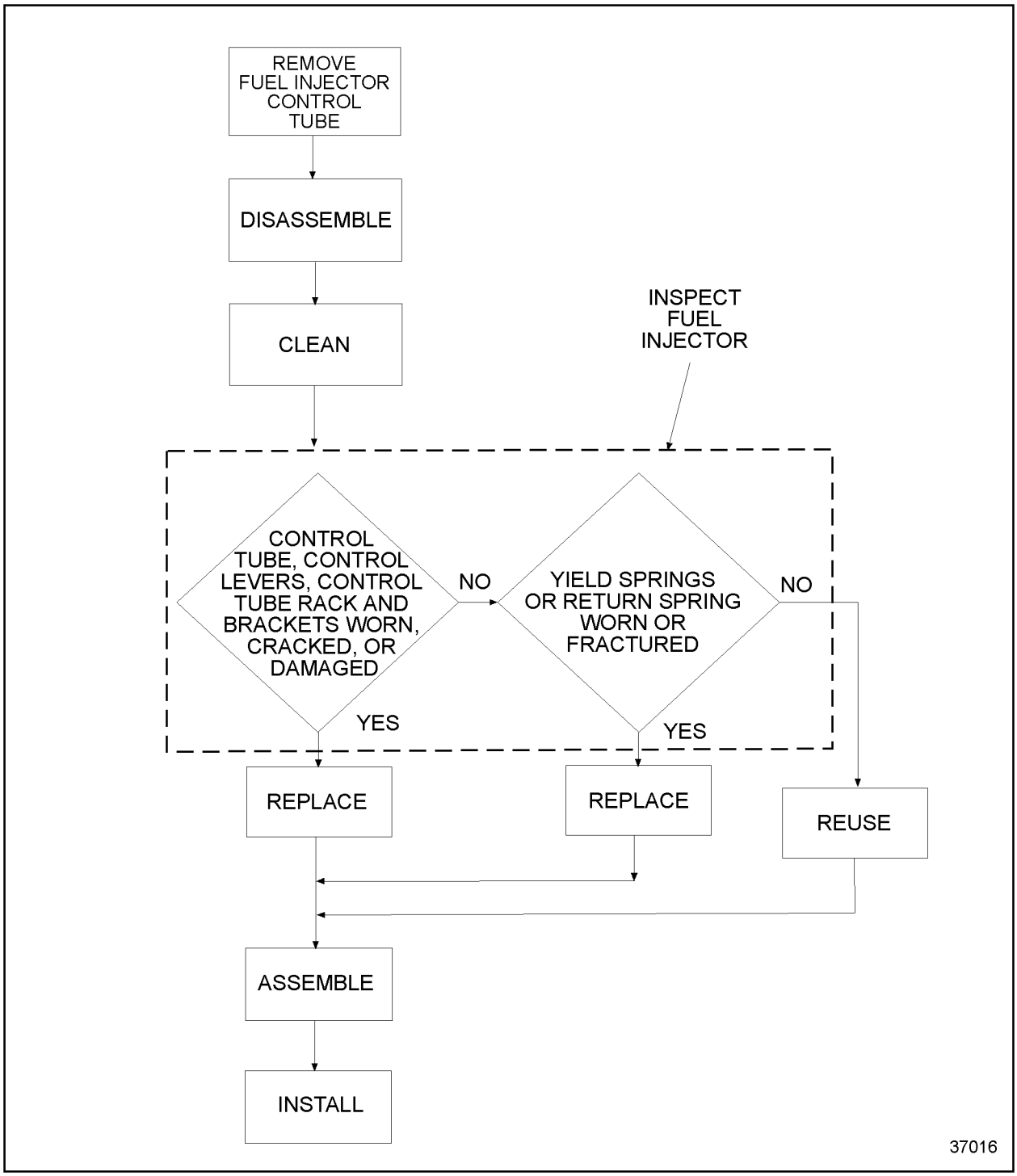


Figure 2-242 Flowchart for Repair or Replacement of Fuel Injector Control Tube

2.33.2 Removal of Fuel Injector Control Tube

Remove the fuel injector control tube as follows:

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube control lever.
2. Remove the two attaching bolts and lock washers at each bracket.
3. Remove the two 1/4 in.-20 x 5/8 in. bolts and lock washers at each bracket.
4. Disengage the rack levers from the injector control racks, and lift the control tube assembly from the cylinder head.

2.33.3 Disassembly of Fuel Injector Control Tube

Disassemble the fuel injector control tube as follows:

NOTE:
The injector control tube, one mounting bracket, a spacer, and injector control tube lever are available as a service assembly. When any part of this assembly needs replacing, DDC recommends replacing the complete service assembly. Therefore, complete disassembly procedures are not included.

1. Remove the bracket from the injector control tube.
2. Loosen the adjusting screws or adjusting screw and locknut at each injector rack control lever.
3. With the spring-loaded injector control tube, disconnect the yield springs at each rack lever. Roll the yield springs out of the slots and notch of the control tube.
4. Disconnect the return springs and/or return spring and rack levers from the control tube.

2.33.3.1 Cleaning of Fuel Injector Control Tube

Clean the fuel injector control tube as follows:

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash all injector control tube parts in clean fuel oil.

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⚠ 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.

2.33.3.2 Inspection of Fuel Injector Control Tube

Inspect the fuel injector control tube as follows:

1. Visually inspect the control tube, control lever, control tube rack, control levers, and brackets for excessive wear, cracks or damage.
   [a] If worn, cracked, or damaged, replace them.

NOTE:
The bearing in the bracket is not serviced separately.

   [b] If not worn, cracked, or damaged, continue inspection.
2. Visually inspect the yield springs and/or return spring for wear or fractures.
   [a] If worn or fractured, replace the springs.
   [b] If not worn or fractured, the components may be reused.
   [c] Refer to section 2.33.4 for assembly of the left-bank fuel injector, or refer to section 2.33.5 for assembly of the right-bank injector.

2.33.4 Assembly of Fuel Injector Control Tube (Left-Bank Cylinder Head)

Assemble the fuel injector control tube as follows:

1. Install the return spring on the control tube and against the front bracket.

On a two screw design injector control tube, proceed as follows:

1. Install the rack control levers on the control tube, with the levers facing the rear bracket position.
2. Turn the adjusting screws in far enough to position the levers on the control tube.

On a one screw and locknut design injector control tube, proceed as follows:

1. Install a rack control lever, with the lever facing the rear bracket position.
2. Install the odd (L. H. helix) yield spring.
3. Install the R. H. helix yield springs and rack control levers with the levers facing the rear bracket.
4. Attach the curled end of the yield springs to the rack control levers.

5. Roll the yield springs into the notch (odd spring) and slots (R. H. helix springs) in the control tube.
6. Turn the adjusting screws and locknuts into the slots far enough to position the levers on the control tube.
7. On both designs, attach the curled end of the control tube return spring to the rack control lever and the extended end of the spring behind the front bracket.
8. On both designs, install the rear bracket on the end of the injector control tube.
9. Refer to section 2.33.6 for installation of fuel injector control tube.

2.33.5 Assembly of Fuel Injector Control Tube (Right-Bank Cylinder Head)

Assemble the fuel injector control tube as follows:

On two screw design injector control tube proceed as follows:

1. Install the rack control levers on the control tube, with the levers facing the front bracket position.
2. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

On the one screw and locknut design injector control tube, proceed as follows:

1. Install the rack control levers, with the levers facing the front bracket position and the R. H. helix yield springs.
2. Install the odd (L. H. helix) yield spring and rack control lever, with the lever facing the front bracket position.
3. Attach the curled end of the yield springs to the rack control levers and roll the springs into the notch (odd yield spring) and the slots (R. H. helix yield springs) in the control tube.
4. Turn the adjusting screws and locknuts into the notch and slots far enough to position the levers on the control tube.

On both designs, proceed as follows:

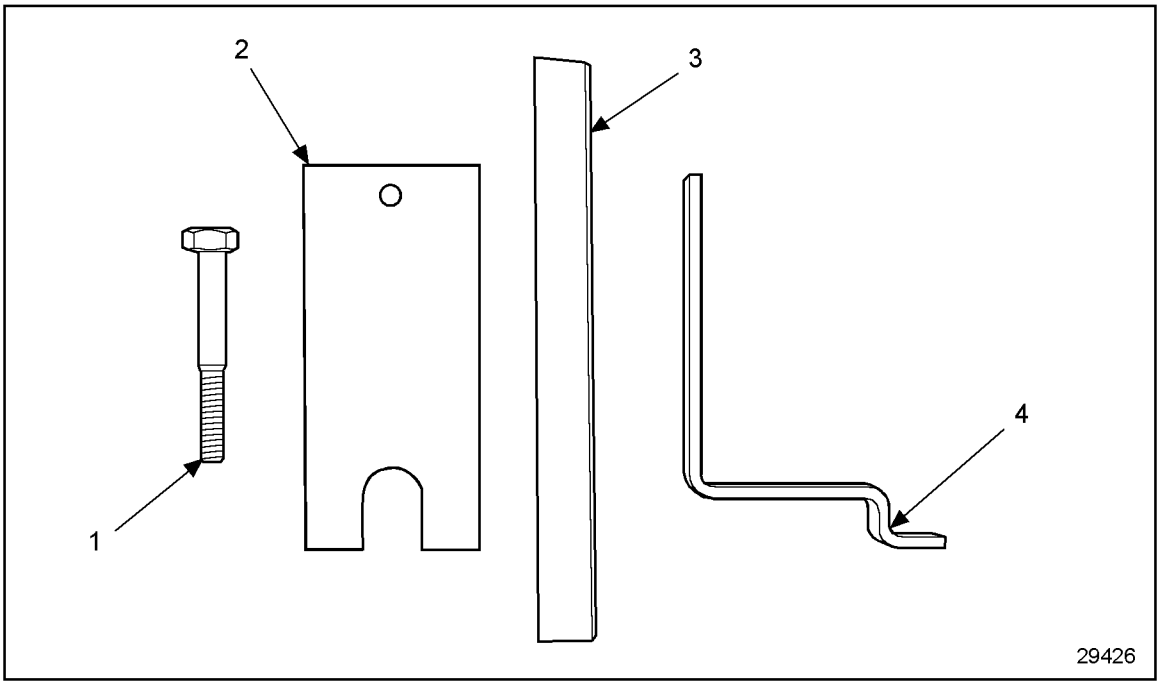
1. Install the control tube return spring and rear bracket on the control tube.
2. Attach the curled end of the return spring to the rack control lever and the extended end of the spring behind the rear bracket.

Index the control lever onto the injector control tube as follows:

1. Loosen the adjusting screw for the rack lever closest to the control lever.
2. Slide the return spring and rack lever back 3 to 4 inches.

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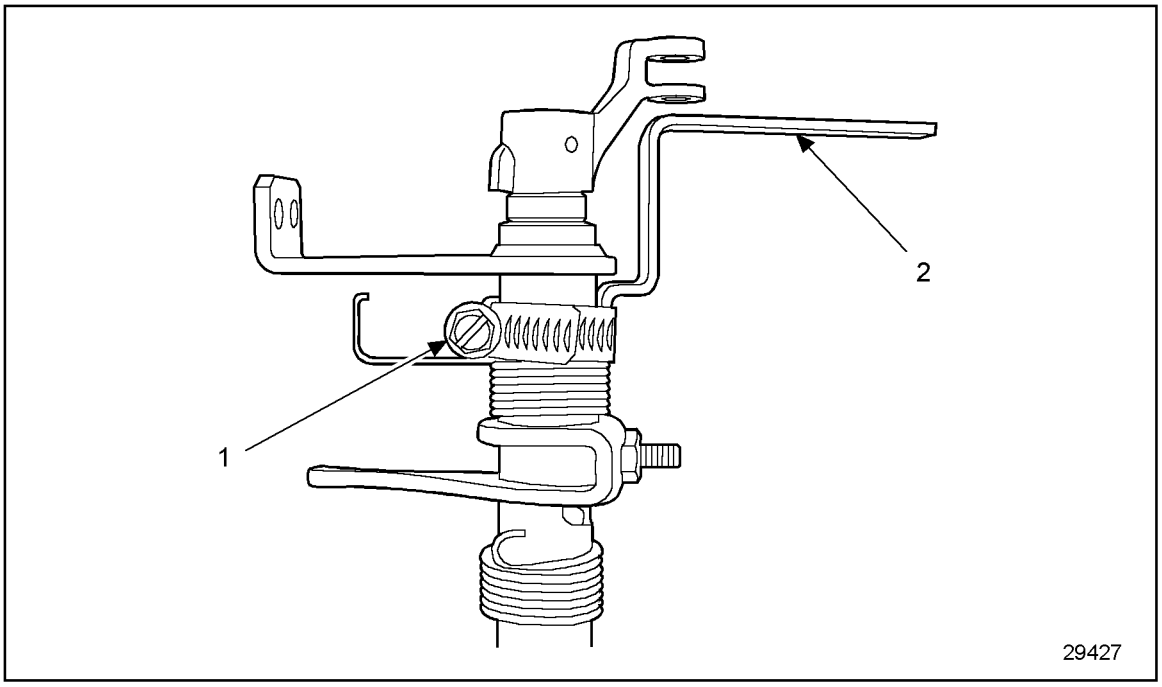
3. Fabricate an indexing bracket from a 5 in. long piece of 1/2 in. wide, 1/8 in. thick bar stock. See Figure 2-243.



1. Bolt 1/4 in. x 1 3/4 in.
2. Feeler Gage 0.011 in.
3. Flat Bar Stock 1/8 in. (1/2 in. Wide)
4. Bracket Made from Bar Stock

Figure 2-243 Fabricate Indexing Bracket

4. Secure the indexing bracket to the control tube with a hose clamp. See Figure 2-244.



1. Clamp
2. Bracket Made from Bar Stock

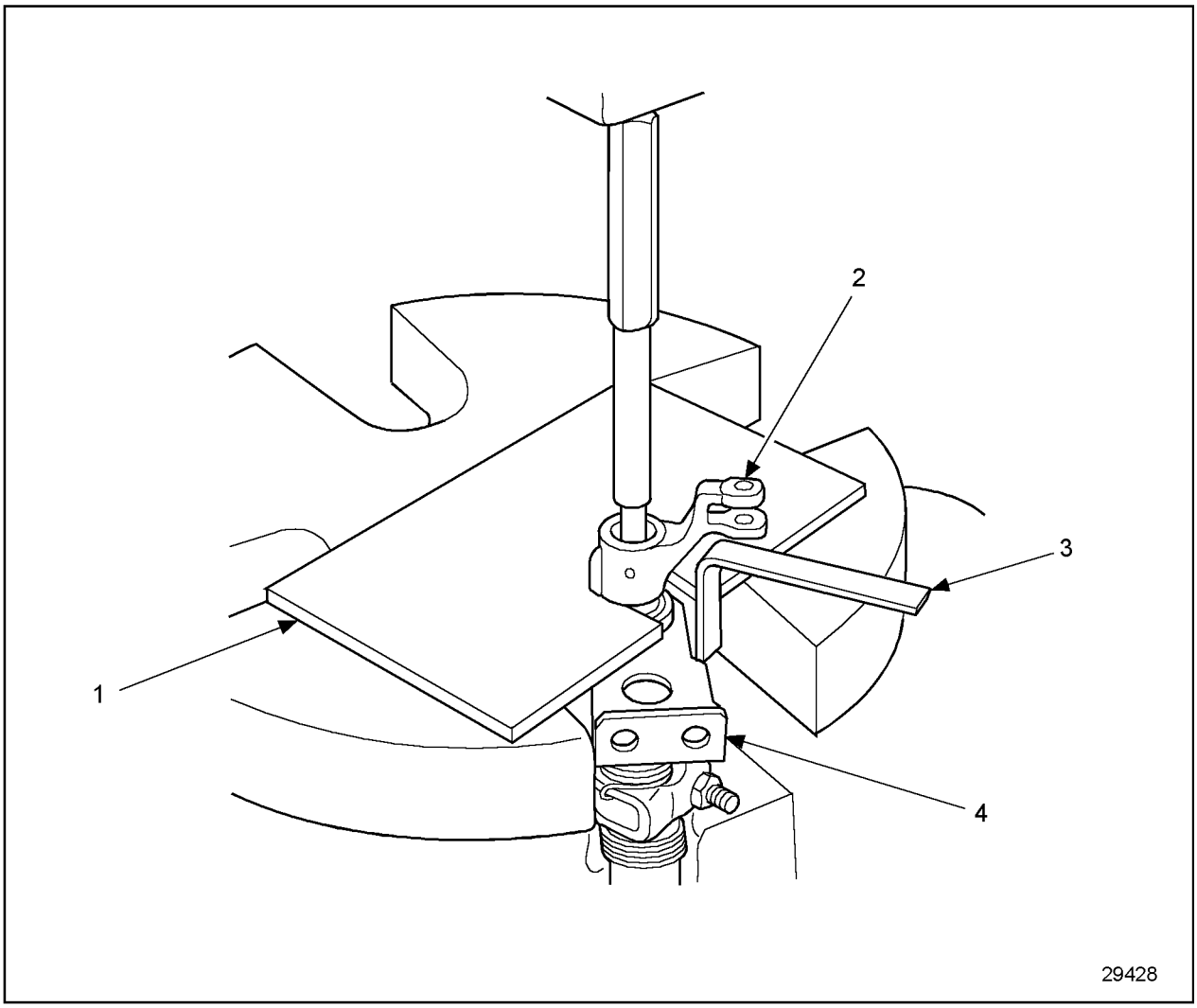
Figure 2-244 Secure Indexing Bracket to Control Tube

5. Insert a 1/4 in. x 1-3/4 in. bolt through the end of the control lever.
6. Rotate the bracket and clamp until the bracket is resting against the bolt.
7. Tighten the clamp to hold the bracket securely against the bolt.

NOTE:
Ensure that the indexing bracket cannot be moved.

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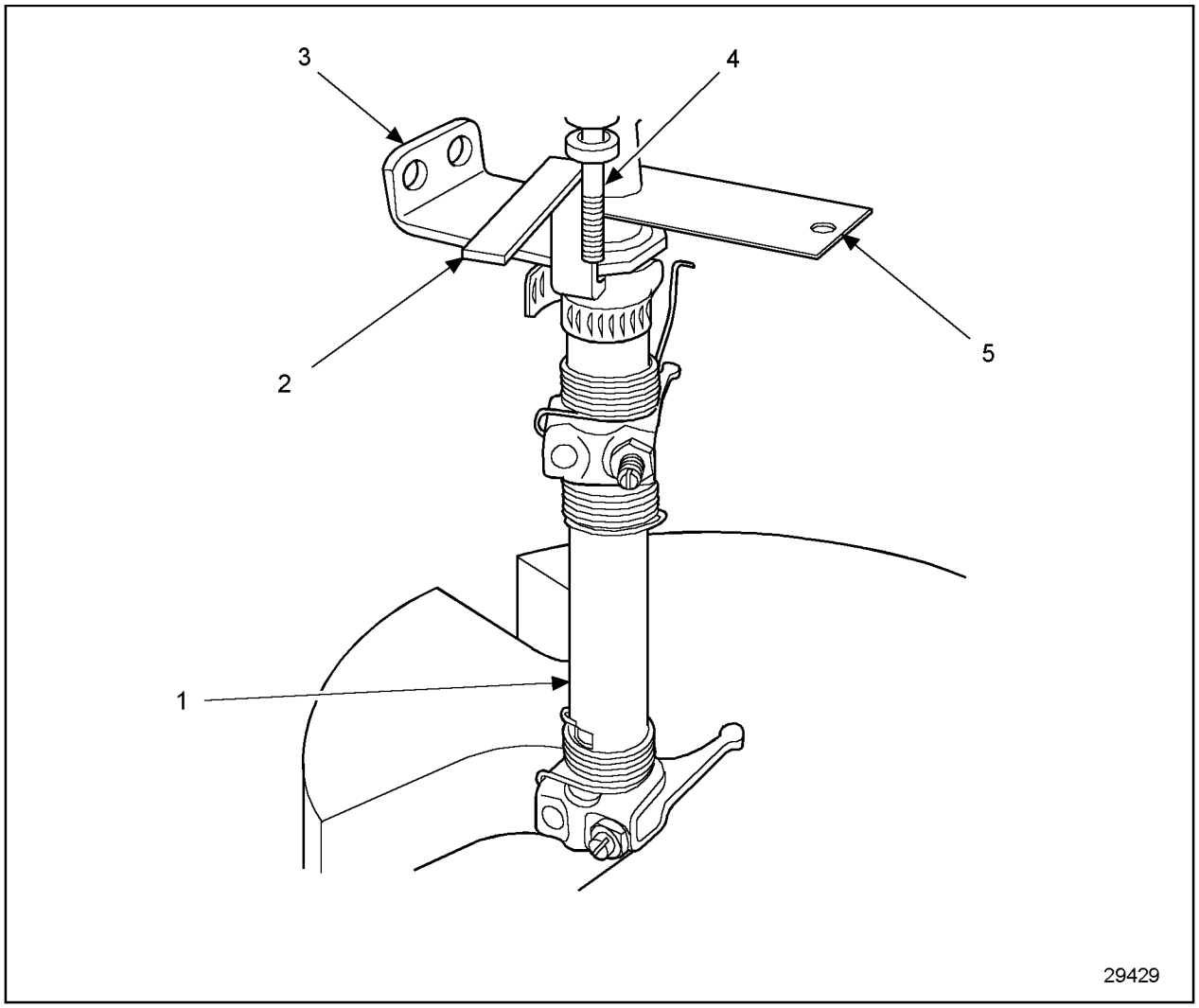
8. Remove the pin from the control lever, and press the old lever off the control tube. See Figure 2-245.



1. Fabricated Flat Stock
2. Lever
3. Bracket Made from Bar Stock
4. Control Tube Assembly

Figure 2-245 Pressing Old Lever Off Control Tube Assembly

9. Insert the 1/4 in. x 1-3/4 in. bolt through the end of a new lever. Press the lever onto the control tube with the bolt resting against the indexing bracket. See Figure 2-246.



1. Control Tube Assembly
2. Bracket Made from Bar Stock
3. Control Tube Bracket
4. Bolt
5. Feeler Gage

Figure 2-246 Installing New Lever on Control Tube Assembly

10. Place a 0.2794 mm (0.011 in.) feeler gage under the lever to get proper clearance between the lever and the spacer on the control tube.
11. Before pressing on the lever, make sure the opposite end of the control tube is supported.
12. Position the control tube on the table of a drill press.
13. Drill a 1/8 in. hole through the control lever approximately 45 degrees from the location of the former hole. (Use the replaced lever for reference).

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14. After drilling, install a new pin.

2.33.6 Installation of Fuel Injector Control Tube

Install the fuel injector control tube as follows:

1. Engage the injector rack control levers with the injector control racks. Place the brackets over the mounting holes on the cylinder head.
2. Install the two 1/4 in.-20 x 5/8 in. bolts and lock washers at each bracket to attach the injector control tube assembly to the cylinder head. Tighten the bolts to 14-16 N·m (10-12 lb·ft) torque.
3. Check the control tube to be sure it moves freely in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.
4. Connect the fuel rod to the injector tube control lever with a clevis pin and a new cotter pin.
5. Clean the control tube thoroughly.
6. Install in the engine.
7. Position the injector rack control levers. Refer to section 12.4.7.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

8. The injector rack control levers must be able to move to a no fuel position before restarting the engine.

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SHOP NOTES

Shop notes for the Series 92:

INSTALLATION OF 6V-92 EUI 0.10 g/bhp-hr PM US EPA-APPROVED EMISSION UPGRADE

The following is a *brief summery* of the 6V-92 EUI 0.10 g/bhp-hr PM US EPA-approved emission upgrade kit. *For specific installation procedures and engine model requirements, refer to 18SP479 provided with upgrade kit.*

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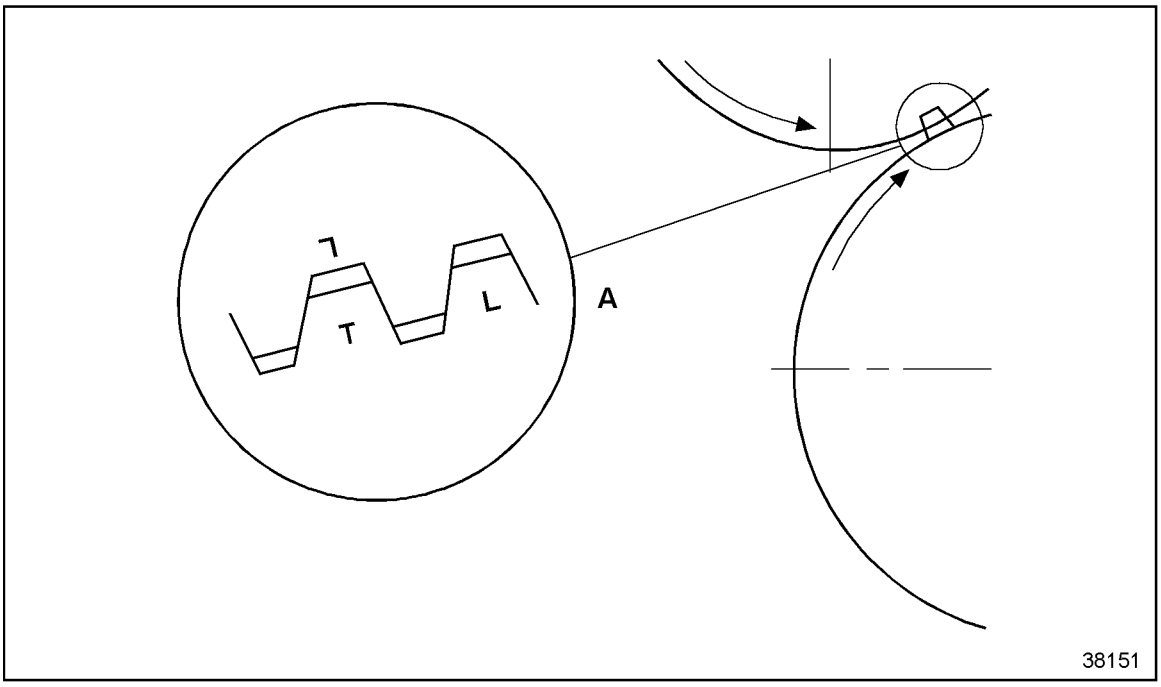
Before installing kit components, the engine camshaft and injector timing must be set. Refer to section 1.25.1 and refer to section 12.3.

After camshaft and injector timing has been set, the former pulse wheel, ECM, and SRS must be removed and replaced with the items from the kit. A new ECM heat shield and cold plate must also be installed. The fuel and lubrication systems require minor modifications, and new sensors must be installed. Following this, the ECM digital outputs may need configuring to ensure proper engine operation.

Camshaft Timing

Refer to section 1.29 and set crankshaft gear-to-idler gear timing as follows:

- ☐ Set gear-to-idler gear timing to 1 tooth retarded from the STANDARD R to R (or L to L) position. Note that the crankshaft gear has an "A" marking for the advanced position. See Figure 2-247.



Note that the “T” position is not currently on the crankshaft gear. This “retarded” position is to be used when setting all gear train timing to standard “V to V” positions. This is only an aide to show the gear teeth mesh should be in the opposite direction of the “A” (advanced) markings on the current gear.

Figure 2-247 Gear Train Setting for DDEC IV Required Retarded Timing on 6V-92 Engine

- ☐ Time the gears 1 tooth retarded from the STANDARD position in the opposite direction of this advanced setting. In the future, a "T" will be stamped on the crankshaft gear to indicate the retarded position.

Idler gear-to-camshaft gear timing remains unchanged as standard VR to R (or VL to L), and camshaft gear-to-camshaft gear position remains unchanged as standard V to V.

Injector Timing (DDEC IV Modification)

Set injector height as follows:

NOTICE:
Failure to set injector timing at the correct height can result in push rod bending and/or other serious damage to the overhead when the engine is cranked.

Using Kent-Moore tool J 44191, set the injector height to 1.540 in.

Installation of DDEC IV Components

Refer to section 2.8.3 for installation of DDEC IV components.

DDEC II Upgrade Procedure

The following is a brief summery of the 6V-92 EUI 0.10 g/bhp-hr PM US EPA-approved emission upgrade kit. For specific installation procedures and engine model requirements, refer to 18SP479 provided with upgrade kit.

1. A power harness adaptor is provided so that the DDEC II power supply harness does not need to be modified. Plug the adaptor into the current power harness.
2. This kit includes an additional oil temperature sensor, required for the DDEC IV upgrade. Install the sensor into the tee in the right front face of the block. Install the turbo oil supply line into the other end of the tee. Connect the pigtail on the engine sensor harness to the new oil temperature sensor.

NOTE:
All of the other sensors included in the kit are similar to those used in the DDEC II installation, so the former sensors should be replaced with the fresh sensors when the engine is converted to DDEC IV.

3. Modify the fuel system by installing an R70 elbow into the front of the RB cylinder head in the top hole. Install the 1/ 4 in. to 1/4 in. adaptor into the elbow, then install the 3/8 in. to 1/4 in. connector into this adaptor. Various other 3/8 in. to 1/4 in. bushings and elbows have also been included for adaptation to the fuel hoses provided.
4. Install the exhaust temperature sensor into the M14 X 1.5 mm boss located on the end plate of the catalytic converter. Connect the exhaust sensor harness to the long pigtail on the DDEC sensor harness (wires 132 and 452) Take care to route this harness away from the exhaust system.
5. Install the new coolant level sensor as follows:
   - Remove the DDEC II style coolant level sensor (CLS).
   - If the vehicle is equipped with the newer style integral connector type sensor, install either the 1/4 in. NPT coolant level sensor or the 3/8 in. NPT coolant level sensor. Attach the connector.

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- If an older style screw terminal sensor was removed, cut the signal wire screwed to the end of the sensor, and splice to the yellow wire in cavity “A” of the two-pin connector adaptor included in the kit. Splice the ground wire screwed to the side of the sensor to the black wire in cavity “B” of the adaptor. Solder and insulate using shrink tubing. Do not use crimp type connectors. Install the new sensor, and attach the connector adaptor.
- Locate the existing DDEC II coolant level module and remove. Install the DDEC II-IV coolant level module in its place.

6. Fill out the programming update request sheet (provided in kit). Once the mainframe is updated with the information provided, program the ECM.
7. Install injector calibration codes.

NOTE:
Some ECM digital inputs may need to be configured to ensure proper engine operation. These inputs should be set in the program as the engine is received from the factory; but in case of an error, they may be reset with a distributor reprogramming station. Required digital inputs are Listed in Table 2-10.

Pin	Wire	Digital Input - Function
E1	451	16 - Alt. Min. VSG (Necesssary for High Idle
F1	542	09 - Throttle Inhibit, Door Switch
G1	528	25 - SEO, Shutdown Engine Override, Diagnostic Request
H2	524	Park Brake Interlock (Necessary for Idle Shutdown)

Table 2-10 Required Digital Inputs

8. Refer to section 2.15.3.1 for adjustment of SRS and TRS sensor.
9. Install drive belts and adjust tension.
10. Check fluid levels and replenish, if required.

NOTICE:
The required injector calibration codes must be properly installed in the ECM before operating the engine. Failure to install required injector calibration codes may result in degraded engine performance and/or place the engine in violation of EPA (Environmental Protection Agency) certification.

11. Start the engine and check for proper operation.

REPAIRING ELECTRONIC CONTROL MODULE (ECM) COVER AND FASTENER

In February of 1993 Detroit Diesel released new EPROM kits for installation in ECMS.

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During installation of new EPROMs (refer to instructions contained in the EPROM kit), the ECM cover gasket and/or fastener(s) are sometimes damaged. A new non-corrosive gasket material, **Heavy Body Ultra No. 59876 RTV,** is now available from the Loctite Corporation to repair damaged ECM cover gaskets.

In addition, Detroit Diesel has developed a recommended repair procedure for damaged (broken off) cover-to-body fasteners.

The required tools needed are as follows:

- ☐ 1/4 in. Nut Driver
- ☐ Thin head standard screwdriver
- ☐ Antistatic wrist strap J 8639-01 (for electrostatic discharge prevention)
- ☐ Drill Press
- ☐ 5/32 in. carbide end mill (4 flute)
- ☐ 10-24 self-tapping screws (local purchase, quantity as required).
- ☐ Loctite 290 Threadlock (23509539)
- ☐ Loctite 59876 HB Ultra Block RTV (local purchase)

Repair Fastener

Use the 1/4 in. nut driver to remove the 16 screw fasteners which hold the ECM cover to the case. If any fasteners should break off, repair as follows:

1. With unbroken screws loosened, remove all but one screw from each side of the cover and tighten the remaining screws.

NOTICE:
The cover should remain in the case during this repair to prevent dirt and machining chips from entering the inside of the ECM case.

2. Clamp down the ECM case on the bed plate of the drill press. Ensure bed plate and case are square to the drill chuck centerline.
3. Install the 5/32 in. carbide end mill in the drill chuck and center and mill on the broken screw. Machine out the broken screw.

NOTICE:
When removing broken screws at the receptacle end of the case, care should be taken not to machine beyond the bottom of the screw hole into the plastic receptacle below.

4. Following removal of the broken screws, blow off all dirt and machining chips from the ECM case and cover.
5. Use number 10-24 self-tapping screws at repaired screw hole position(s). At final assembly place a drop of Loctite 290 Threadlock (23509539) on new screw and in screw hole.

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Repair Cover Gasket

Careful removal of the ECM cover will prevent gasket damage. If the cover gasket is damaged during removal it may be repaired using the following procedure:

1. Inspect the cover gasket for any damage or areas where a leak could possibly occur.
2. If gasket is damaged, repair using Loctite Heavy Body Ultra 59876 RTV silicone adhesive sealant. This is the only sealant recommended by Detroit Diesel. Other sealants emit corrosive gas during curing which harms electronic components and/or connections within the ECM.
3. Cut or damaged section(s) of the gasket may be repaired by placing a bead of sealant on and along the side of the damaged area. Missing pieces of gasket may be replaced with a similar size bead of sealant.
4. After applying sealant, the cover and case should be assembled within 15 minutes as sealant will become tack-free on an exposed surface in less than 20 minutes after application. Install fasteners and tighten to 2.0-2.2 N·m (17.7-19.5 lb·in.) torque.

Clean Cover and Case

Clean up cover and case as follows:

⚠ CAUTION:

To avoid injury to eyes and skin from uncured sealant, wear a face shield or goggles and protective gloves. In case of eye contact, immediately flush eyes with water for at least 15 minutes: call a physician. Avoid prolonged contact with skin.

Uncured sealant should be cleaned up immediately with Loctite cleaning solvent 755 or mineral spirits. Cured silicone rubber can be cut away with appropriate scrapers.

IMPROVED EPROM STABILIZER KIT FOR DDEC II ENGINES

In August of 1995 the Electronic Programmable Read Only Memory (EPROM) stabilizer kit 16171618 used on Series 92 DDEC II engines has been improved. The 141 software EPROM formerly included in this kit has been replaced by the improved 154 software EPROM. The improved software provides increased fuel combustion efficiency for all DDEC engines.

The improved EPROM is serviced only in improved EPROM stabilizer kit 16171618. Former and improved EPROM stabilizer kits are similar, except for EPROM assemblies, and are completely interchangeable. Only the improved kit will be serviced. Parts in the kit are listed in Table 2-11.

Part Number	Quantity	Description
16167640	1	Plate, Stabilizer
16190605*	1	EPROM Assembly (154 Software)
16167642	1	Spacer, EPROM
16167643	2	Spacer, EPROM
16167444	3	Screw
-	1	Installation Instructions

* Was EPROM Assembly 16168498

Table 2-11 Parts List of Improved EPROM Stabilizer Kit 16171618

The following tools are required to replace the former EPROM with the improved EPROM stabilizer kit:

- ☐ 1/4 in. Nut Driver
- ☐ Thin Head Standard Screwdriver
- ☐ Anti-Static Wrist Strap (for electrostatic discharge

Removal of EPROM Stabilizer Kit

Perform the following s to remove the former EPROM:

1. Using a Diagnostic Data Reader (DDR), J 38500-H, check for codes in the electronic control module (ECM). Note the codes. Erase the codes.
2. Remove the ECM from the engine and take to a clean environment.

NOTICE:
Failure to properly ground your hand while handling the ECM may result in damage to the EPROM, the ECM or both.

3. Fasten the wrist strap of tool J 8639-01. securely around your wrist and attach the test clip to a good ground.
4. Using the 1/4 in. nut driver, remove the 16 screws which fasten the ECM cover to the case.

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NOTICE:
Use care to avoid damaging the cover gasket on the ECM. A damaged cover gasket could allow contaminants to enter the ECM, which may cause damage.

5. Using the thin head standard screwdriver, carefully pry the cover loose from the case.

NOTE:
Early EPROM assemblies may have been installed in a blue 28-pin socket at the end of the ECM and under the stabilizer plate. To remove the EPROM assembly from its socket, push down (unlatch) the blue and white locking tabs and move them to the side.

6. Remove the EPROM. Then, using a suitable narrow diameter tool, remove the locking tabs by carefully pressing out the pins holding the tabs to the socket. Discard the tabs and pins.

Installation of Improved EPROM Stabilizer Kit

Install the improved EPROM stabilizer Kit as follows:

1. Using the 1/4 in. nut driver, remove the three mounting screws adjacent to the blue 28-pin socket. Discard the screws.
2. The EPROM assembly and socket are keyed, so the assembly can be installed only one way. Observe the keying and install the EPROM assembly by pushing it firmly down into the socket.
3. See Figure 2-248 and place the shorter spacer with two bands over the holes at locations 2 and 3. Lay the stabilizer plate over the EPROM so that the bolt holes line up with the

spacers and the holes in the circuit board. Fasten the stabilizer plate to the case with three 8-32 1 3/4 in. screws. Tighten screws to 3.0-3.7 N·m (26.6-32.7 lb·in) torque.

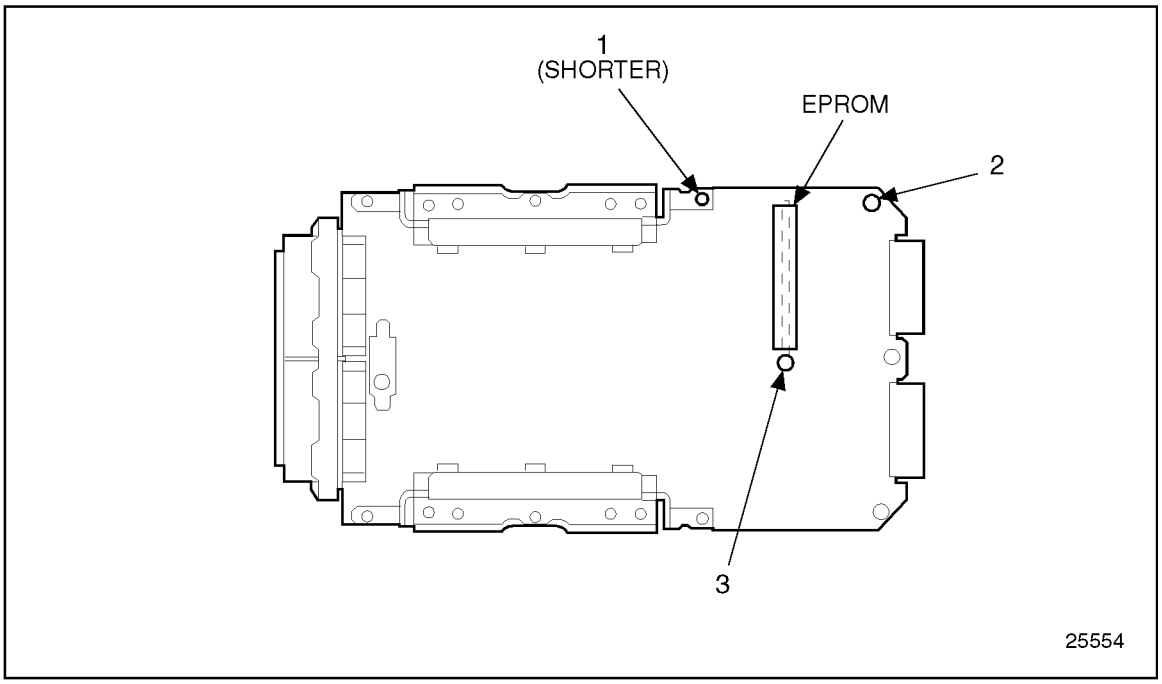


Figure 2-248 EPROM and Spacer Locations

NOTICE:
Use care to avoid damaging the cover gasket on the ECM. A damaged cover gasket could allow contaminants to enter the ECM, which may cause damage.

4. Carefully inspect the cover gasket for any damage or areas where a dust leak could possibly occur.

NOTE:
If gasket is damaged, it must be replaced with a new gasket.

5. Fasten the cover to the case with the 16 previously removed 8-32 x 1/2 in. screws. Tighten screws to 2.0-2.2 N·m (17.7-19.5 lb·in) torque.
6. Remove the wrist strap and ground clip.

To complete the EPROM upgrade perform the following:

1. Mount the ECM to the engine, ensuring rubber isolation mounts are properly seated. Replace isolation mounts if they are worn, brittle, or damaged.
2. Check the resistance of the EPROM assembly. With the 6-pin connector unplugged, the resistance from the ECM case to the engine should be greater than 100 kohms.
3. Return the EPROM assembly that was removed to:

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Detroit Diesel Corporation

13400 Outer Drive, West

Detroit, MI 48239-4001

Attn.: Technical Service Group

Speed Code: A07

CHECKING INJECTOR TESTER J 34760-B

The injector tester J 34760-B should be checked monthly to be sure that it is operating properly. Use the following procedure to check injector tester:

1. Fill the supply tank in the injector tester with clean injector test oil J 26400-5B.
2. Open the valve in the fuel supply line.
3. Place the test block on the injector locating plate, and secure the block with the fuel inlet connector clamp.
4. Operate the pump handle until all of the air is out of the test block, and clamp the fuel outlet connector onto the test block.
5. Break the connection at the gage, and operate the pump handle until all air bubbles in the fuel system disappear.
6. Tighten the connection at the gage.
7. Operate the pump handle to pressurize the tester fuel system to 16 536-17 225 kPa (2400-2500 lb/in.^{2}).
8. Close the valve on the fuel supply line.

NOTE:
After a slight initial drop, the pressure should remain steady. This indicates that the injector tester is operating properly.

9. Open the fuel valve, and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected, and the tester checked before checking an injector.

Occasionally, dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When pump valve leakage occurs, loosen the fuel inlet connector clamp, and operate the tester pump handle to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually eliminate dirt. If not, the pump check valve must be removed, lapped and cleaned. The pump check valve in J 34760-150A (from set J 34760-B) must be replaced.

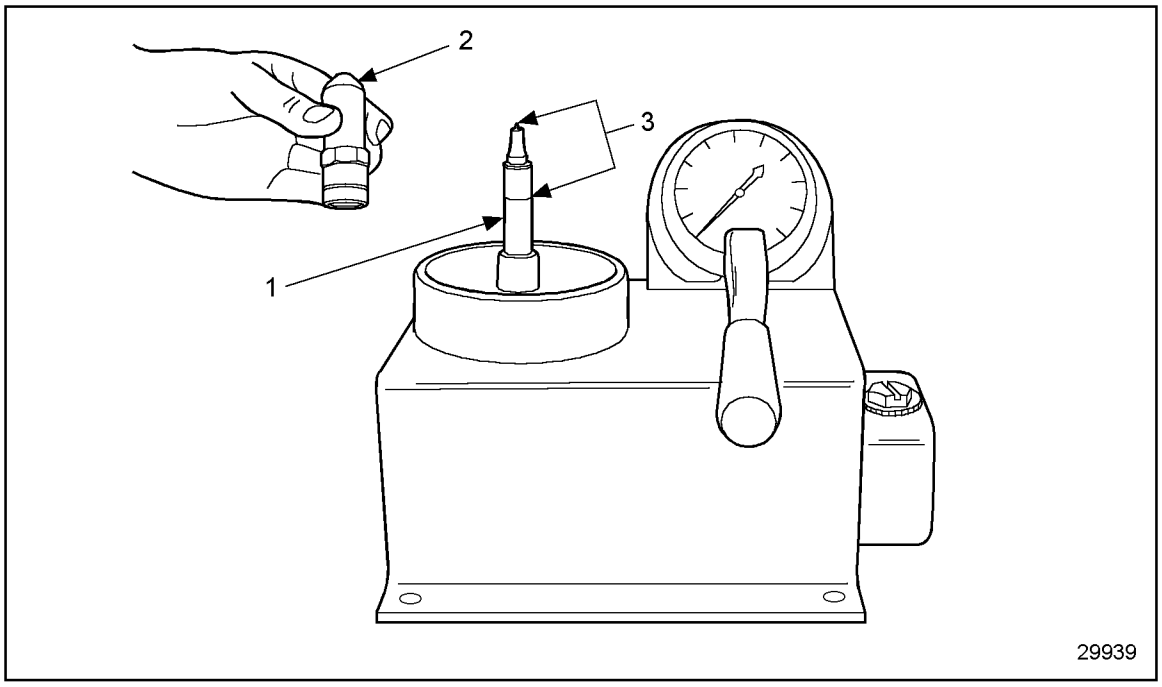
If an injector tester supply or gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines, since the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If you suspect that the lines have been shortened or replaced with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

CHECKING INJECTOR SPRAY TIP TESTER (J 22640-A)

Check injector spray tip tester J 22640-A as follows:

1. Operate the pump handle until a clear flow of test oil is obtained at the tip mounting pedestal.
2. Place the tip assembly, valve spring with cage and check valve cage on top of the pedestal. Tighten the injector nut. See Figure 2-249.

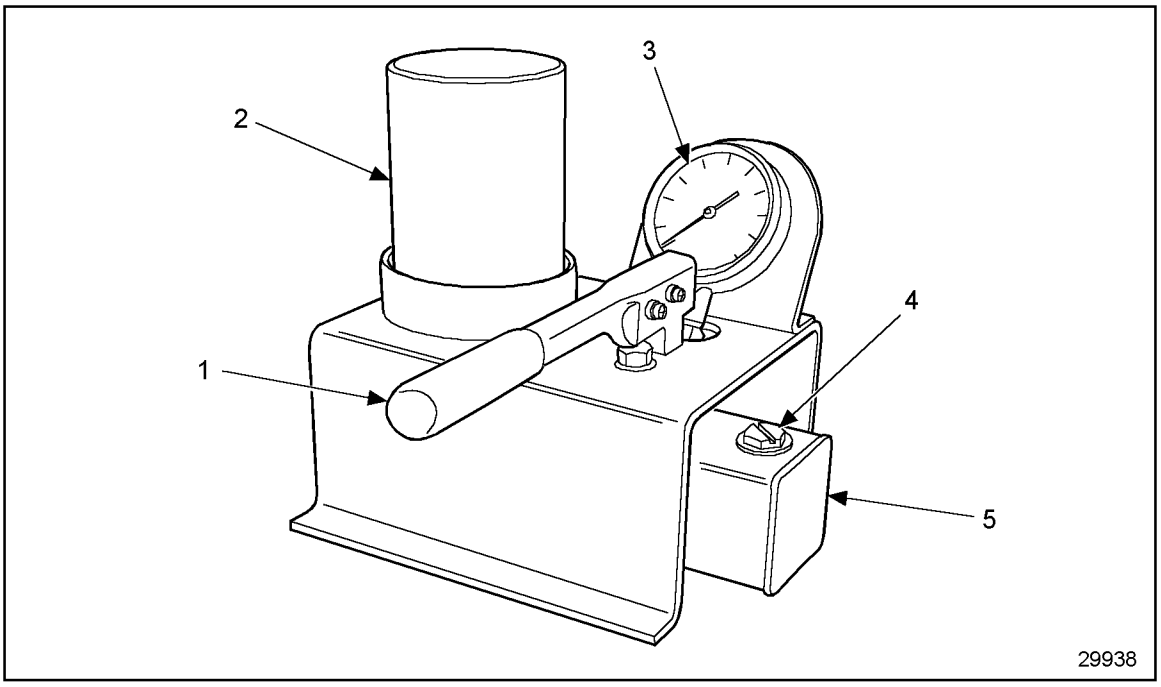


1. Tip Mounting Pedestal
2. Injector Nut
3. Injector Tip and Check Valve Components

Figure 2-249 Installing Injector Nut

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3. Place the shield on the tester and operate the pump handle until the needle valve has opened several times to purge air from the system. See Figure 2-250.



1. Pump Handle
2. Spray Shield
3. Pressure Gage
4. Filler Plug
5. Tank

Figure 2-250 Tester J 22640-A with Shield Installed

⚠ 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.

4. Operate the pump lever rapidly with smooth, even strokes (40 strokes per minute) simulating the tip functioning in the engine. Note the pressure at which the test oil delivery occurs.

NOTE:
Test oil delivery should occur between 15,158 and 22,737 kPa (2200 and 3300 lb/in.^{2}) except for the L-40 injector needle valve and spring which should open between 11,713 and 15,847 kPa (1700 and 2300 lb/in.^{2}). When using the high VOP spring, the oil delivery

will occur at 19,981-26,871 kPa (2900-3900 lb/in.^{2}). The beginning and ending of delivery should be sharp and the test oil should be a finely atomized spray.

NOTE:
If the valve opening pressure is below the minimum specified limits, or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within specified limits, check for spray tip leakage as follows:

NOTE:
When testing for spray tip leakage, use the proper spring for the valve tip being tested.

1. Actuate the pump lever several times and hold the pressure at 10,335 kPa (1500 lb/in.^{2}) for 15 seconds.
2. Inspect the spray tip for leakage. There should be no fuel droplets, although a slight wetting at the spray tip is permissible.

INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

Flow gage J 25600-B may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

Cleaning Injector Spray Tips

Clean the fuel injector as follows:

1. Clean the spray tip in sonic cleaner.
2. Hone the wire end until it is smooth and free of burrs. Taper the end to a distance of 1.588 mm (0.0625 in.) with stone J 8170.

NOTE:
Allow the wire to extend 3.18 mm (0.125 in.) from tool J 4298-1, (tool set J 8169-03).

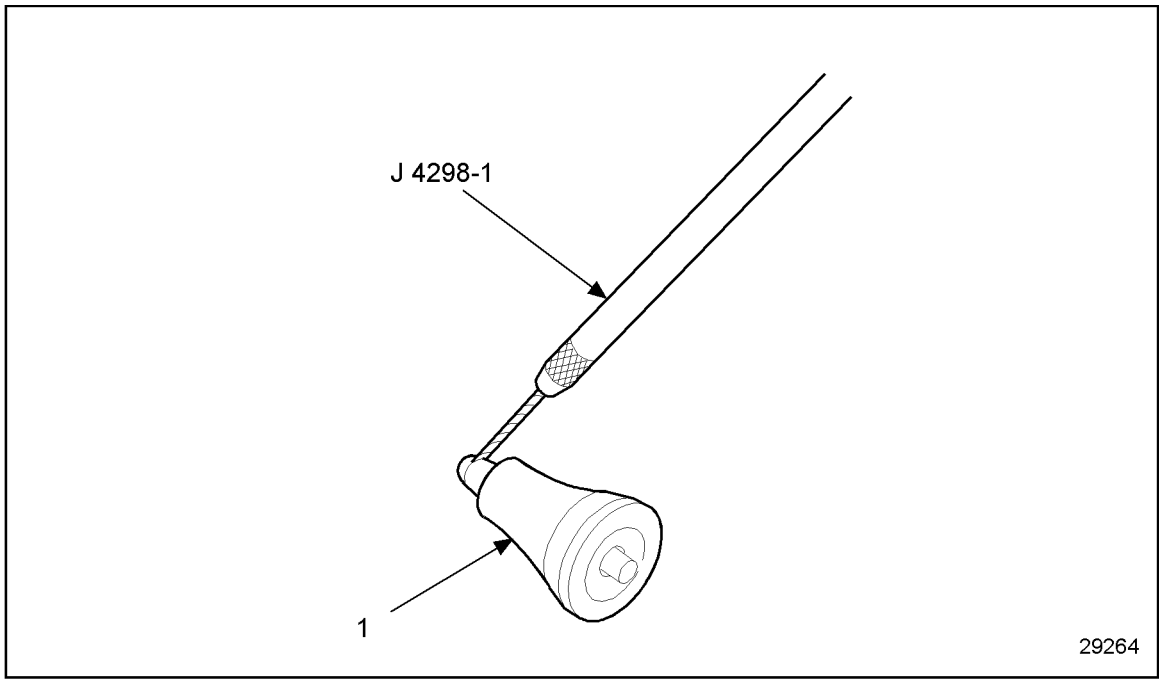
⚠ CAUTION:

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. Wash the tip in solvent, and dry with compressed air.
4. Clean the spray tip orifices with pin vise J 4298-1 (from tool set J 8169-03) and the proper size spray tip cleaning wire. Use wire J 21460-01 to clean 0.140 mm (0.0055 in.)

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diameter holes and wire J 21461-01 (from set J 8169-03 to clean 0.1524 mm (0.006 in.) diameter holes. See Figure 2-251.



1. Spray Tip

Figure 2-251 Cleaning Spray Tip Orifices with J 4298-1 from Set J 8169-03

NOTE:
Ultrasonic cleaning is also an acceptable way to clean the injectors.

NOTICE:
Do not buff the spray tip area excessively, and do not use a steel wire buffing wheel. The spray tip holes may be distorted.

CAUTION:
To avoid injury, wear a face shield or goggles.

5. The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel J 7944.

NOTE:
To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 RPM. Place the tip over the drill end of the spray tip cleaner tool J 24838, and hold the tip body against the buffing wheel. Rotate the spray tip while it is being buffed.

6. When the spray tip body is clean, lightly buff the end of the tip to clean the spray tip orifice 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.

7. Wash the spray tip in clean solvent, and dry it with 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.

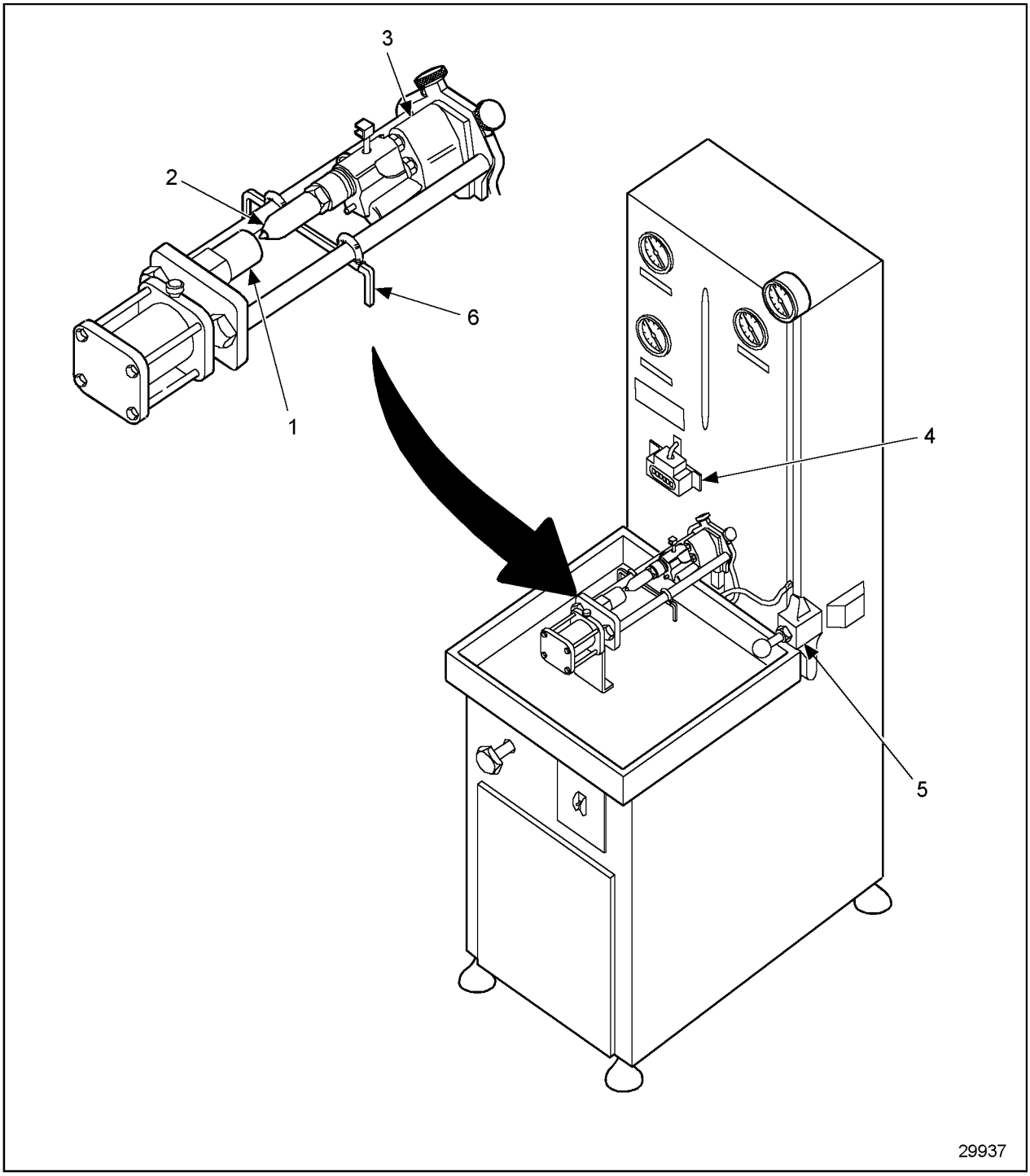
8. Using compressed air clean and blow out all injector body passages.

CHECK INJECTOR FUEL OUTPUT

Perform the injector fuel output test in calibrator. See Figure 2-252.

NOTE:
If calibrator J 22410 is not available use updated calibrator J 39300. Tools used on these machines ***are not interchangeable***. Refer to OEM.

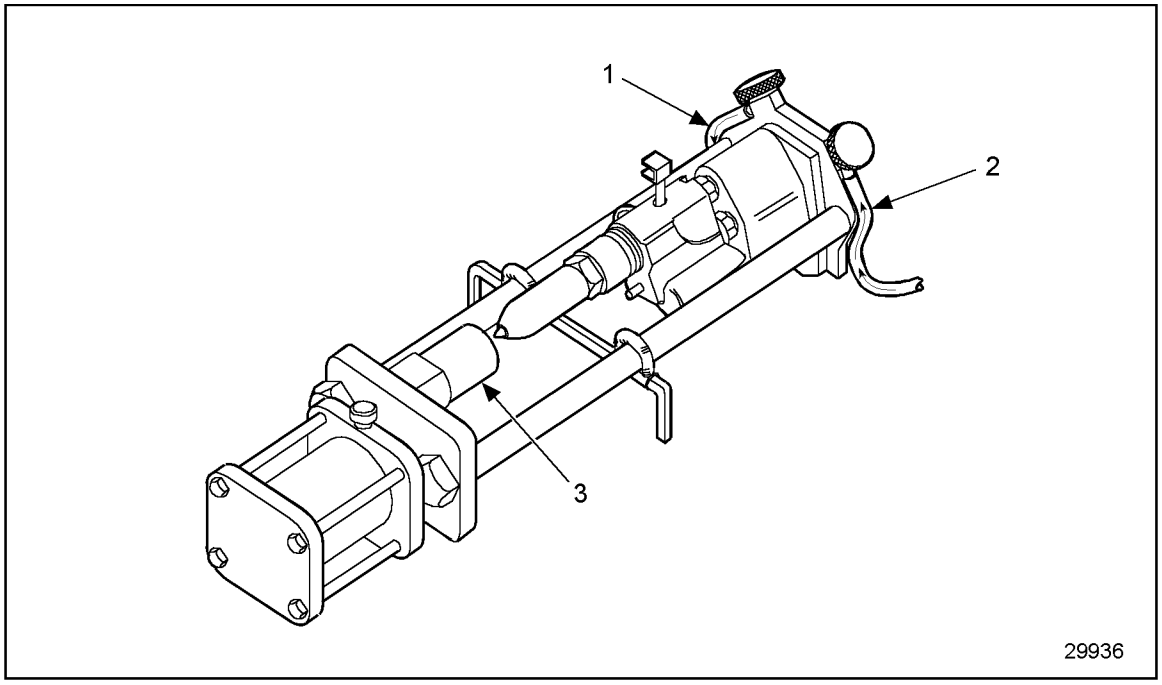
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1. Seat
2. Injector
3. Adaptor
4. Counter
5. Injector Clamp-up Valve
6. Cradle Handle

Figure 2-252 Injector in Calibrator

1. Before testing injector output, ensure calibrator test oil is supplied to the injector fitting located over the rack. To change the flow from the calibrator, exchange the positions of the braided and the clear fuel lines. See Figure 2-253.



1. Fuel Outlet
2. Fuel Inlet
3. Fuel Injector

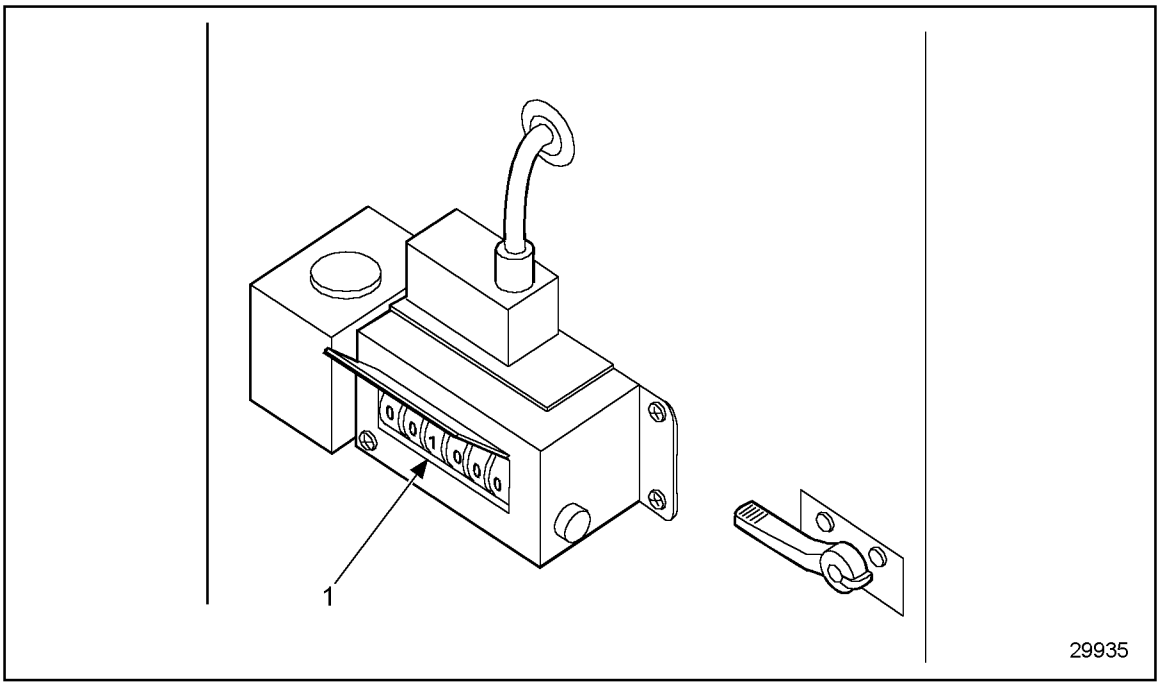
Figure 2-253 Position of Calibrator Fuel Flow Pipes

2. Place the cam shaft index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch to preheat the test oil to 35-40°C (95-105°F).
3. Place the proper injector adaptor between the tie rods, and engage it with the fuel block locating pin. Slide the adaptor forward and up against the fuel block face.
4. Place the injector seat J 22410-226 (from set J 22410) into the permanent seat (cradle handle in the vertical position). Clamp the injector into position by operating the injector clamp-up valve.

NOTE:
If calibrator J 22410 is not available use updated calibrator J 39300. Tools used on these machines ***are not interchangeable***. Refer to OEM

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5. Set the counter at the appropriate number of strokes, 500 or 1,000. See Figure 2-254. If for any reason this setting has been altered, reset the counter for the correct number of strokes.



1. Calibrator Stroke Counter

Figure 2-254 Setting Calibrator Stroke Counter

NOTE:
Calibrators with Serial No. 1175 or lower were manufactured as 1,000 stroke machines, but may have been converted to 500 stroke machines with a conversion kit. Refer to the calibrator instruction manual for information on setting the counter and any additional information required.

6. Pull the injector rack out to the no-fuel position.
7. Turn on the main power control circuit (vial light) switch. Start the calibrator by turning on the motor starter switch. The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.
8. After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge air that may be in the system.
9. After the air is purged, press the red button on the test switch. This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after the correct number of preset strokes are counted.
10. Shut the calibrator off when two consecutive tests show the same output. Usually, 3 tests are sufficient.

11. Observe the vial readings, and determine whether the injector fuel output falls within the specified limits listed in Table 2-12.

Injector	Minimum	Maximum	Injector	Minimum	Maximum
9270	65	75	9B90	85	91
9275	70	76	9C70	65	71
9280	75	81	9C75	70	76
9285	80	86	9C80	75	81
9290	85	91	9C90	85	91
9295	90	96	9E65	70	75
9200	95	101	9E70	75	80
9215	110	116	-	-	-
9225	118	126	-	-	-
9A80	75	81	9F90	85	91
9A85	80	86	7G65	67	72
9A90	85	91	7G70	72	77
9B70	65	71	7G75	77	82
9B75	70	76	-	-	-
9B80	75	81	-	-	-
9B85	80	86	-	-	-

Table 2-12 Injector Fuel Output Specifications

The calibrator may be used to check and select a set of injectors that will inject the same amount of fuel in each cylinder at a given throttle setting, thus resulting in a smooth running, well balanced engine.

An injector which passes all the above tests may be put back into service. An injector that fails to pass one or more of the tests, however, must be replaced.

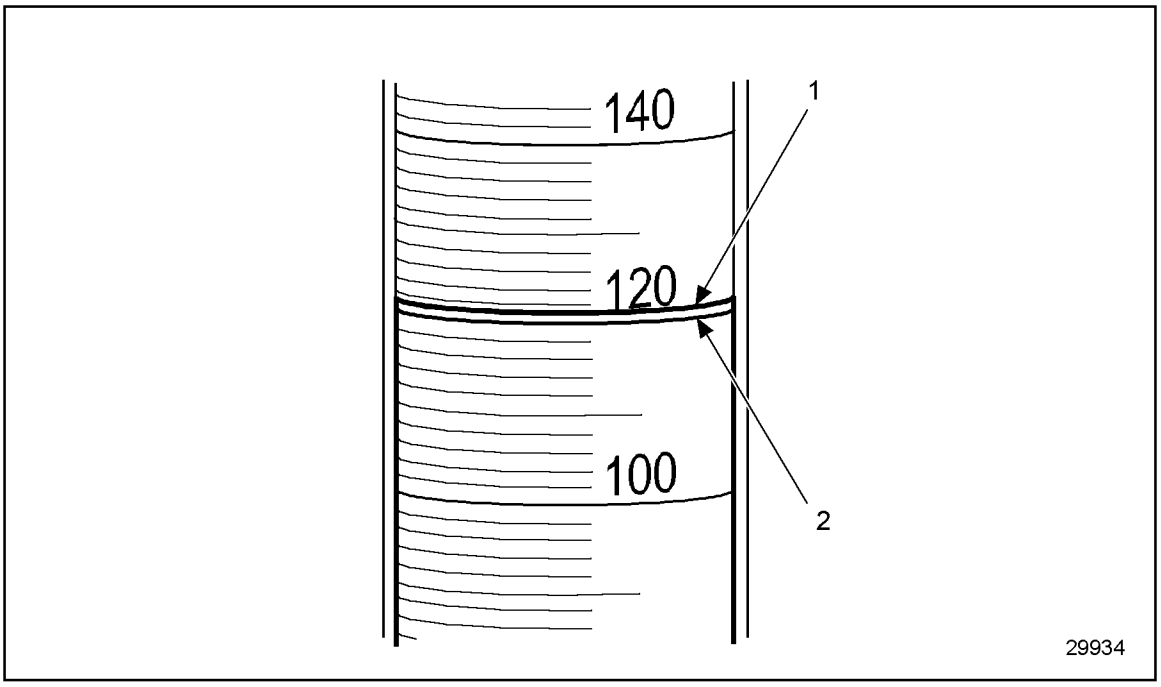
Any injector that is disassembled must be tested again before placing in service.

INJECTOR CALIBRATOR READINGS

Several factors affect the injector calibrator output readings. The four major factors are:

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1. Operator Errors: If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. See Figure 2-255.



1. Top of Meniscus
4. Bottom of Meniscus

Figure 2-255 Checking Fuel Output

2. Air in Lines: This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.
3. Counter Improperly Set: The counter should be set to divert the injector output at 1,000 strokes, but must be reset for 1,200 strokes to check 35 and 40 cu. mm injectors. An error may have been made while returning to the 1,000 stroke setting.

NOTE:
This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1,000 strokes (if properly set) although the counter may overrun several digits.

4. Test Oil: A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

The fuel oil introduced into the test oil during calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner, if required.

In addition, other malfunctions, such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these tell-tale conditions. Calibrator accuracy can only be verified using master injectors J 35369.

INJECTOR PLUNGERS

The fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. See Figure 2-256. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled. If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment it powers.

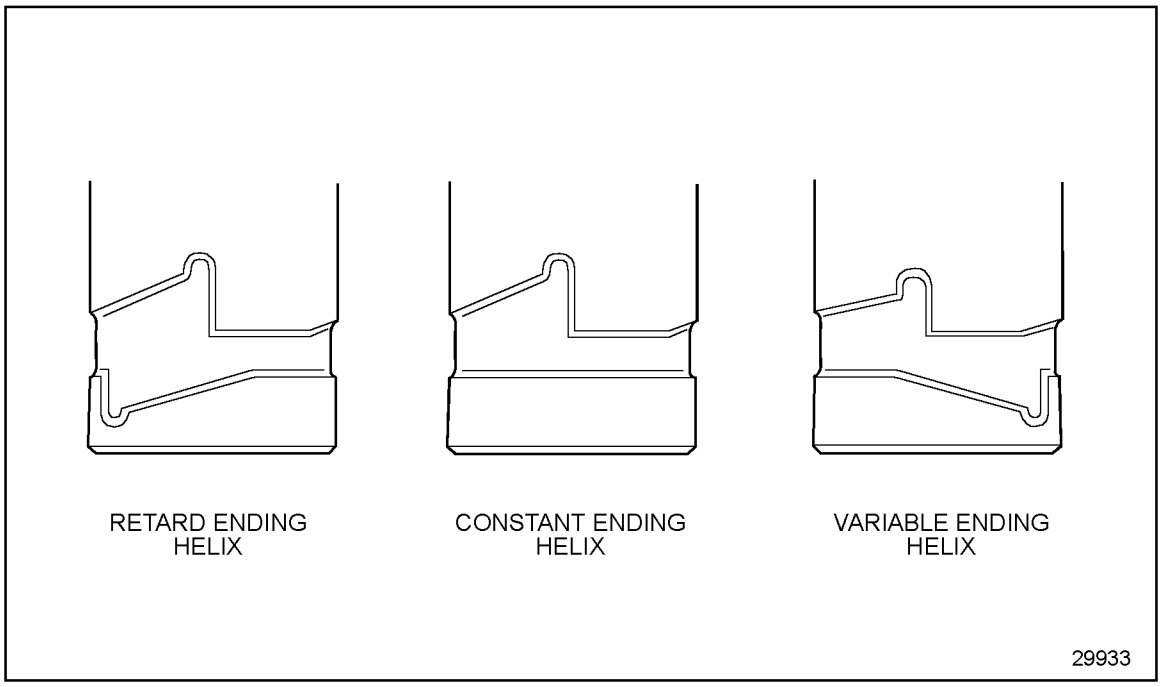


Figure 2-256 Types of Injector Plungers

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping of the helices and seizure or scoring of the plunger.

MASTER INJECTOR CALIBRATING KIT

Use master injector calibrating kit J 35369 to determine the accuracy of the injector calibrator.

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With the test fluid temperature at 38°C ± 1° (100°F ± 1°), and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2% of the values assigned to the calibrated masters, the calibrator can be considered accurate. Injector testing can be carried out now without any adjustment of figures. When testing new injectors for output, however, any difference between the calibrator and the masters should be used to compute new injector calibration. If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

PLUNGER/BUSHING AND TIP FLOW GAGE

The injector fuel output is largely dependent upon the combined output of its plunger/bushing and spray tip assemblies. To assist in the rebuilding of fuel injectors that will calibrate within specified limits, preselect and match plunger/bushings and tips according to their output prior to assembly into the injector.

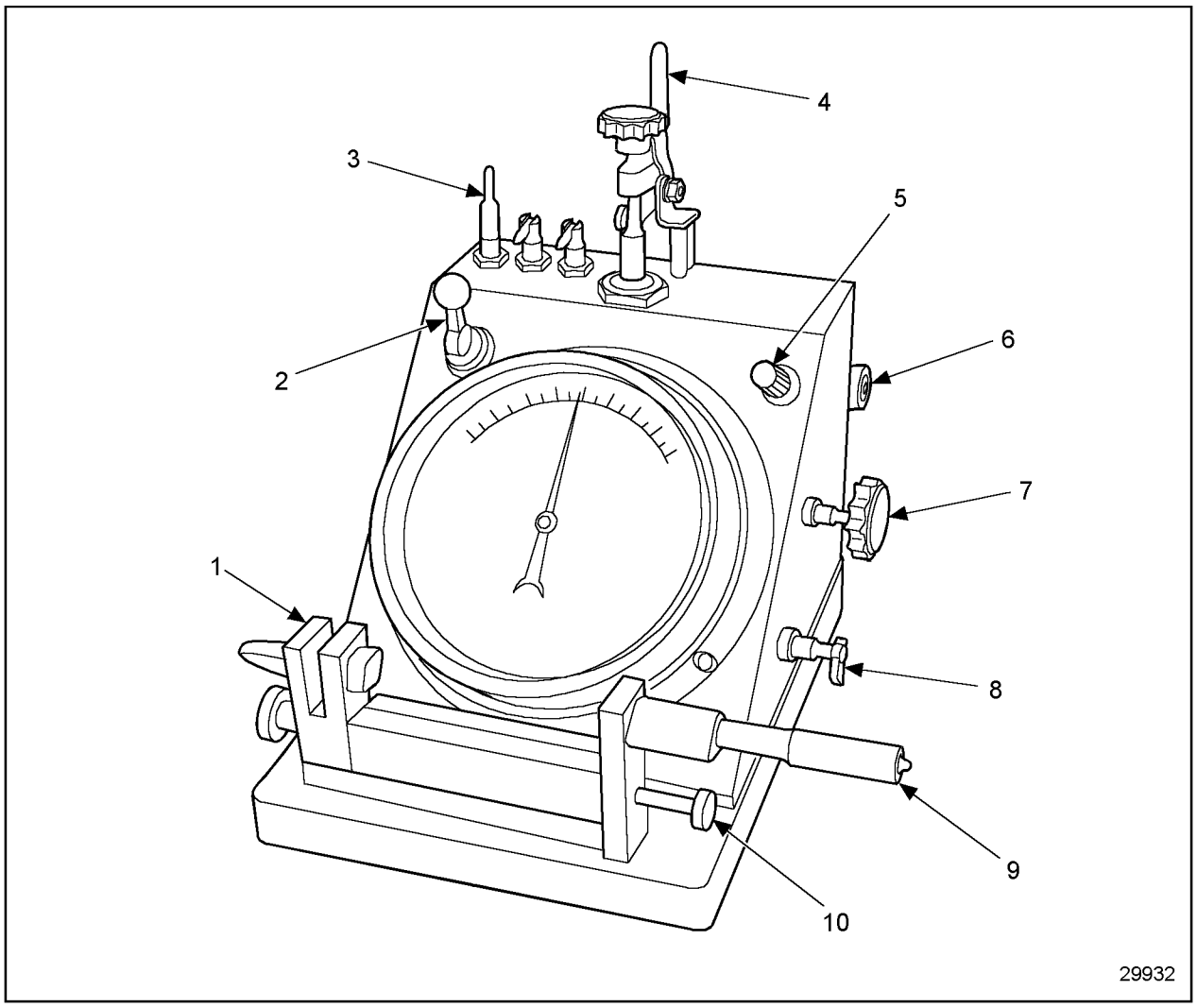
The J 25600-B plunger/bushing and tip flow tester, using low pressure air, measures the output of plunger/bushing and spray tip assemblies. The flow (output) of the spray tip can be correlated to high pressure fuel flow during calibration. Used spray tips, however, because of their worn spray holes, will often flow higher than indicated on a low pressure air tester.

Maintain records that indicate the output values of both plunger/bushing and spray tip assemblies being matched with resultant calibration in order to develop a useful matching chart.

Install the plunger/bushing and tip flow gage as follows:

1. Place the flow gage unit in a clean, well lighted area that has an air supply of 276 kPa (40 lb/in.^{2}), but not more than 1034 kPa (150 lb/in.^{2}).
2. Turn off the air supply valve (on the rear of the flow gage), and connect your air line.

3. Familiarize yourself with the various components on the unit. See Figure 2-257.



1. Clamping Head
2. Tip Toggle Valve
3. Master Orifice Toggle Valve
4. Spray Tip Clamp
5. Calibrating Valve
6. Air Supply Valve
7. Pressure Regulator Valve
8. Plunger and Bushing Toggle Valve
9. Micrometer Head
10. Carriage Adjustment Screw

Figure 2-257 Plunger/Bushing and Tip Flow Gage J 25600-B

REGULATED PRESSURE ADJUSTMENT

Perform the regulated pressure adjustment as follows:

1. Set all toggle valves in the closed position.
2. Open the calibrating valve approximately 4 turns.

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NOTICE:
DO NOT use this valve as an air shutoff-valve. Tight closing of this valve may result in valve seat damage.

3. Turn the pressure regulator knob in a counterclockwise direction until it spins freely.
4. Open the air supply valve approximately 3 turns. The pressure regulator is a constant bleed type (0.04 cubic feet per minute). The air supply valve is provided as a convenient shutoff to avoid compressed air waste when the flow gage is not in use.
5. Adjust the pressure regulator by rotating the knob in a clockwise direction until the gage needle is aligned exactly on the regulated pressure mark.

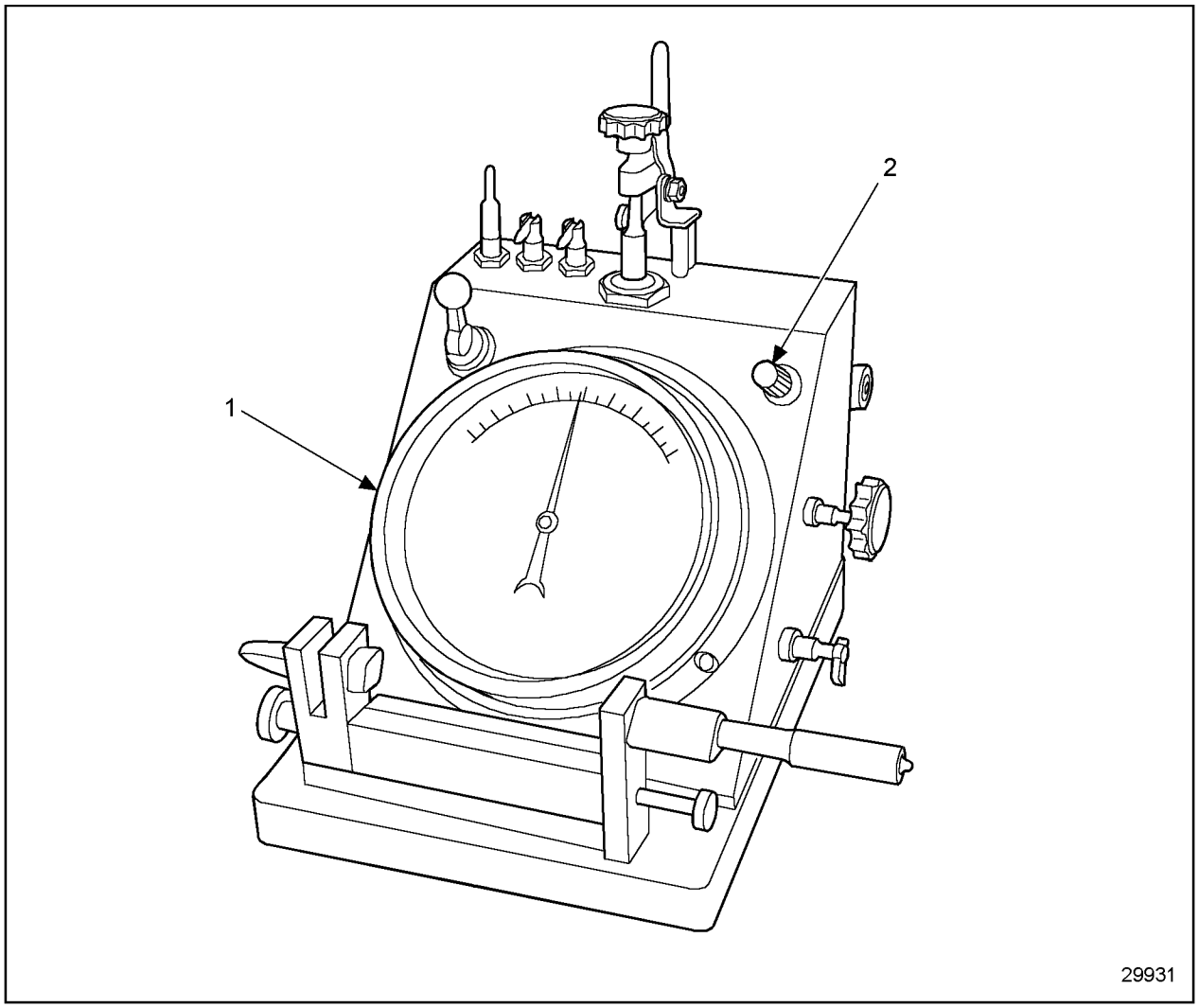
CALIBRATION TO MASTER ORIFICE

When no air is leaking through a master orifice, injector tip or plunger/bushing, the gage needle will go to the regulated pressure mark. The master orifices (A, B and C) are provided as controlled air leak passages. Flow tests are conducted comparing an injector tip or a plunger/bushing, to an air leak through a master orifice.

1. Ensure all toggle valves are in the off position. The gage needle will be at the regulated pressure mark.
2. Open master orifice valve A. The gage needle will move away from the regulated pressure mark.

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3. Adjust the calibrating valve, so that the gage needle is exactly at the "set line". See Figure 2-258.



1. Flow Gage Unit
2. Calibration Valve

Figure 2-258 Adjusting the Calibrating Valve

4. Close the master orifice toggle valve (needle will return to the regulated pressure mark).

MEASURE SPRAY TIP FLOW

Measure spray tip flow as follows:

1. Clean all spray tips thoroughly (correct flow rate is dependent on a clean spray tip).

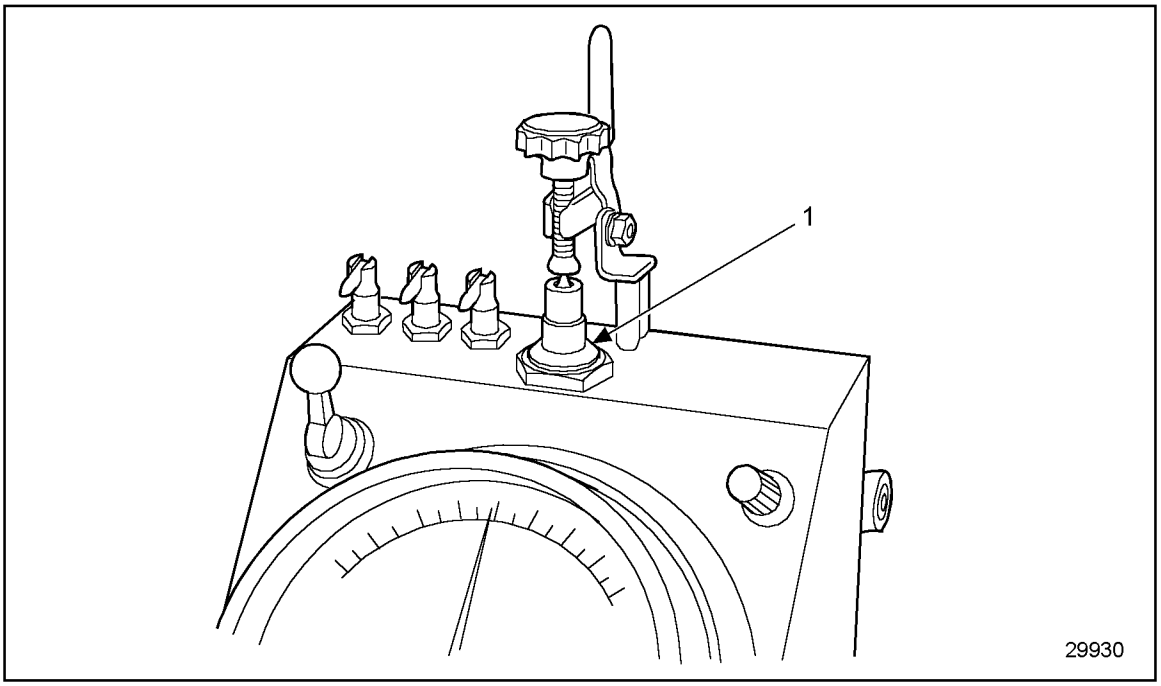
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2. Observe the number and size of the spray tip holes marked on the narrow end of the spray tip and calibrate to orifice A. Listed in Table 2-13 are flow values

Tip Stamp	Nominal Flow Value	Master Orifice Calibration
6-0.006	22	A
7-0.006	69	A
8-0.0055	26	A
8-0.006	48	A
9-0.0055	48	A
9.-0.0058	69	A

Table 2-13 Spray Tip Flow Values

3. Remove the needle valve, if installed, and clamp the spray tip on the unit. See Figure 2-259.



1. Injector Spray Tip

Figure 2-259 Spray Tip Installed in Tester

4. Open the tip toggle valve, and observe the gage reading.
5. The tip can now be compared to the specification sheet and sorted into groups, high, low, mean, etc.

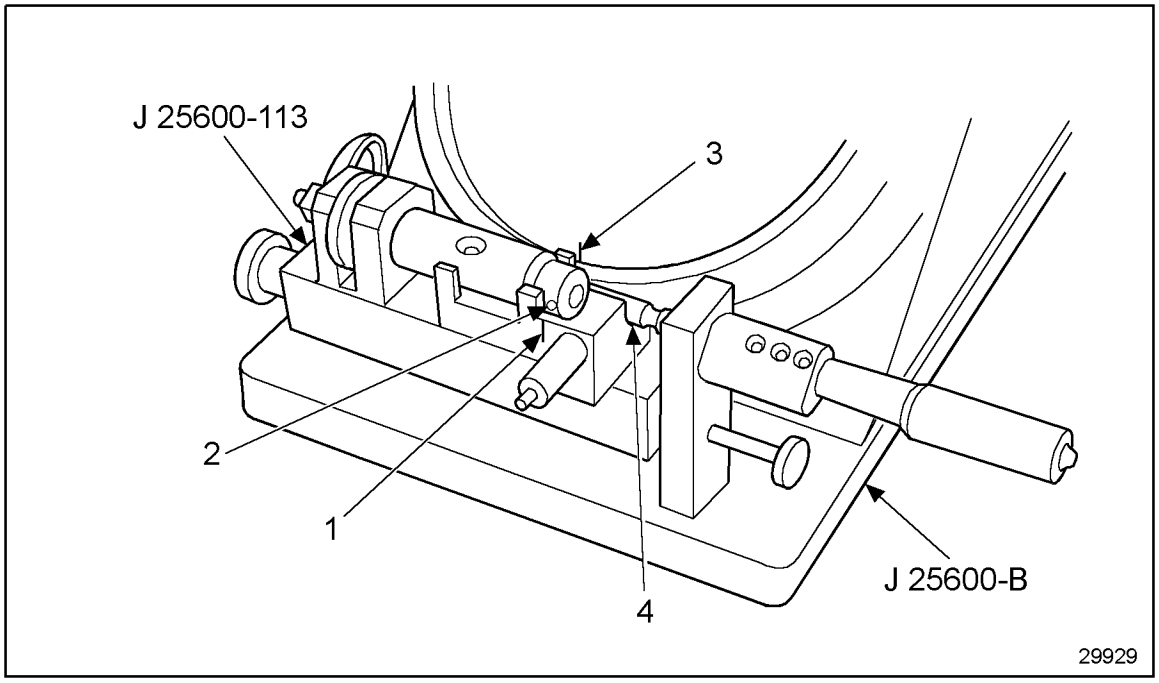
PLUNGER/BUSHING EFFECTIVE STROKE MEASUREMENT

The reason for measuring the flow through the plunger/bushing assemblies is to measure the effective stroke (port closing to opening), in thousandths of an inch. To find the closing and opening points, a controlled air leak is used ("A" master orifice is used as reference). When the plunger is moved close to the port closed position, the gage needle will be at the set line. At this position, the air leaking out the bushing port matches the air that would leak out the "A" orifice.

As the plunger is moved inward, the leak stops and the gage needle goes to the regulated pressure mark. When the plunger is moved further, air begins to leak again. The gage needle moves away from the regulated pressure mark and moves toward the set line. When the plunger is moved far enough to read the effective stroke, the gage needle will be at the set line again. The distance the plunger has moved as indicated on the micrometer, is the effective stroke. This stroke is measured while the plunger/bushing is held in the full-fuel position.

Measure plunger/bushing effective stroke as follows:

1. Select the proper cradle for the plunger/bushing to be tested, and mount on the fixture. See Figure 2-260.



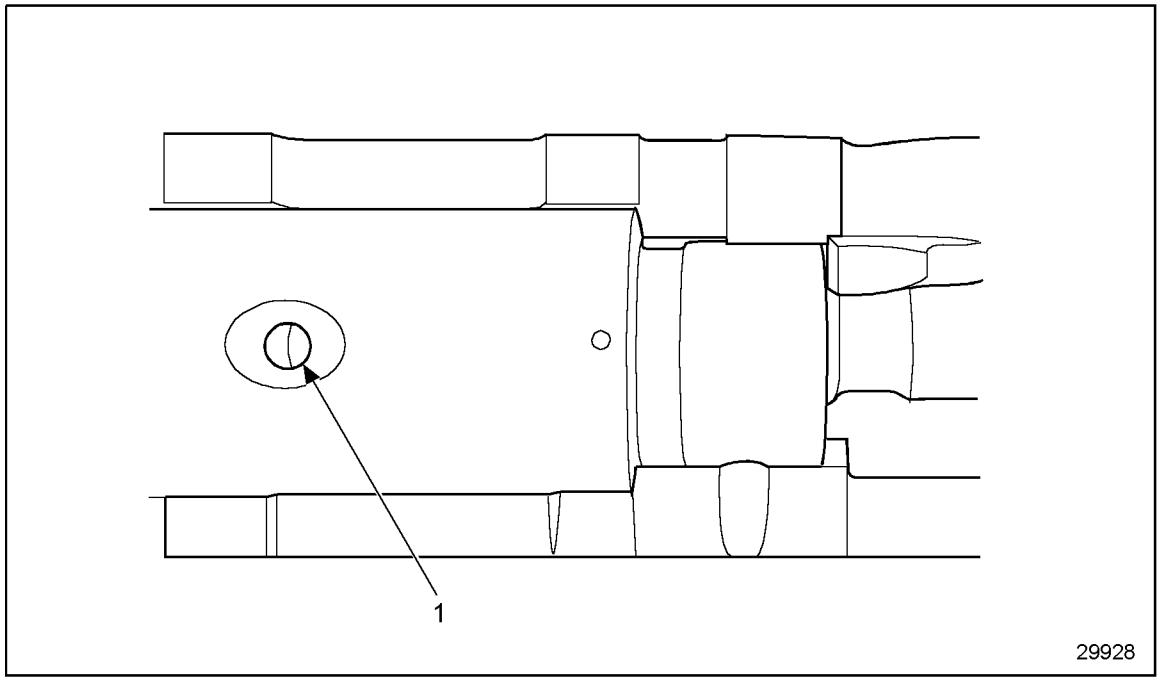
1. Locating Surface (Idle)
2. Bushing Pin
3. Locating Surface (Full)
4. Plunger Flat Position (Front)

Figure 2-260 Cradle Mounted on Fixture

2. Calibrate to the "A" orifice. Refer to *"Calibration to Master Orifice".* All plunger/bushing tests use the "A" orifice as reference.
3. Close all toggle valves. Gage needle will be at the regulated pressure mark.

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4. Adjust the micrometer to zero reading (all zeros).
5. Place the plunger/bushing in the cradle. Ensure plunger flat and locating pin or slot is properly positioned. To check in full-fuel position, rotate bushing until the bushing pin contacts the rear locating surface.
6. Adjust spring loaded button until enough force is exerted on the plunger flat to hold the plunger steady, but not enough to restrict sliding movement when air pressure is applied.
7. Hold the plunger against the micrometer, and rotate the carriage adjustment screw until the plunger almost closes the port. See Figure 2-261.



1. End of Plunger

Figure 2-261 End of Plunger Shown in Port

8. Open the plunger and bushing toggle valve.

NOTE:
If the plunger has not closed the port far enough, an air leak will be heard and the gage needle will be left of the set line. If it has closed the port too far, it will be to the right of the set line, toward or at the regulated pressure mark.

9. Turn the carriage adjustment screw until the gage needle is approximately at 20.
10. Turn the carriage adjustment screw clockwise very slowly until the gage needle is exactly at the set line. Always adjust in this manner, with the needle moving from approximately 20 to the set line.
11. Turn the micrometer thimble clockwise. The gage needle will move to the regulated pressure mark. Very little air will be heard leaking.

12. Continue turning clockwise until the gage needle begins to move away from the regulated pressure mark (air from the bushing will again be heard leaking). Turn very slowly until the gage needle reaches the set line.
13. Observe and record the micrometer reading. The number shown is the effective stroke in thousandths of an inch.
14. Turn the micrometer back to zero. Gage needle should return to or very near the set line.
15. Turn off the plunger/bushing test toggle valve.
16. Loosen the clamping knob, and remove the plunger/bushing.

NOTE:
Only minor carriage adjustment will be required for other plunger/bushing of the same type.

17. Chart the stroke readings and compare to the specifications. Sort into groups, high strokes, low strokes and mean strokes.

INJECTOR PART LAPPING

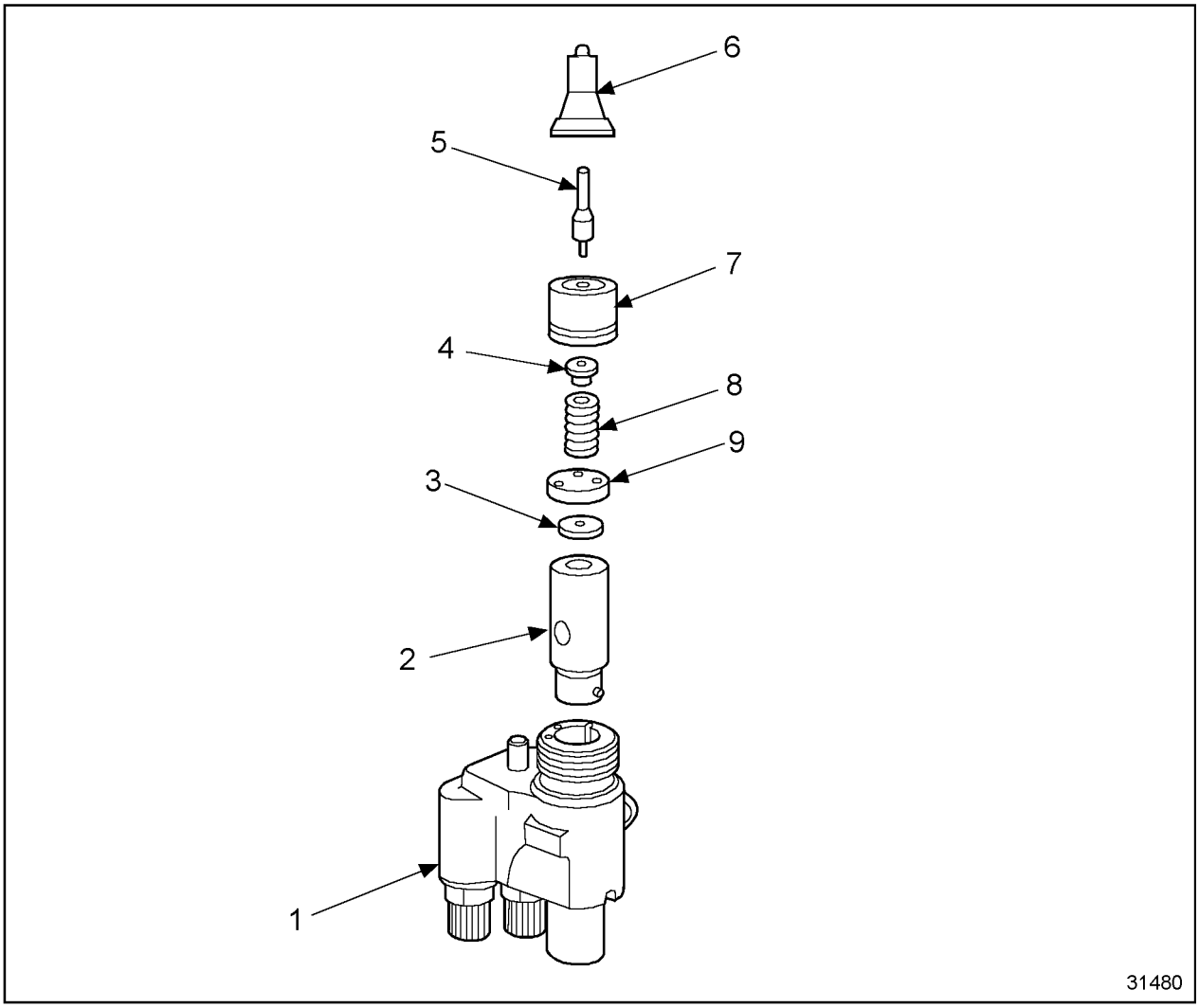
Lap the parts as follows:

NOTE:
New parts do not require lapping prior to use. Wash parts in clean solvent to remove the solidified preservative. If new parts become nicked or burred during handling, lapping will be necessary to provide adequate sealing between the flat parts.

NOTE:
The sealing surface of current spray tips is precision lapped by a process which gives the surface a dull, satin-like finish. The lapped surface on former spray tips was bright

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and shiny. DDC does not recommend lapping the surface of a new current spray tip. See Figure 2-262.



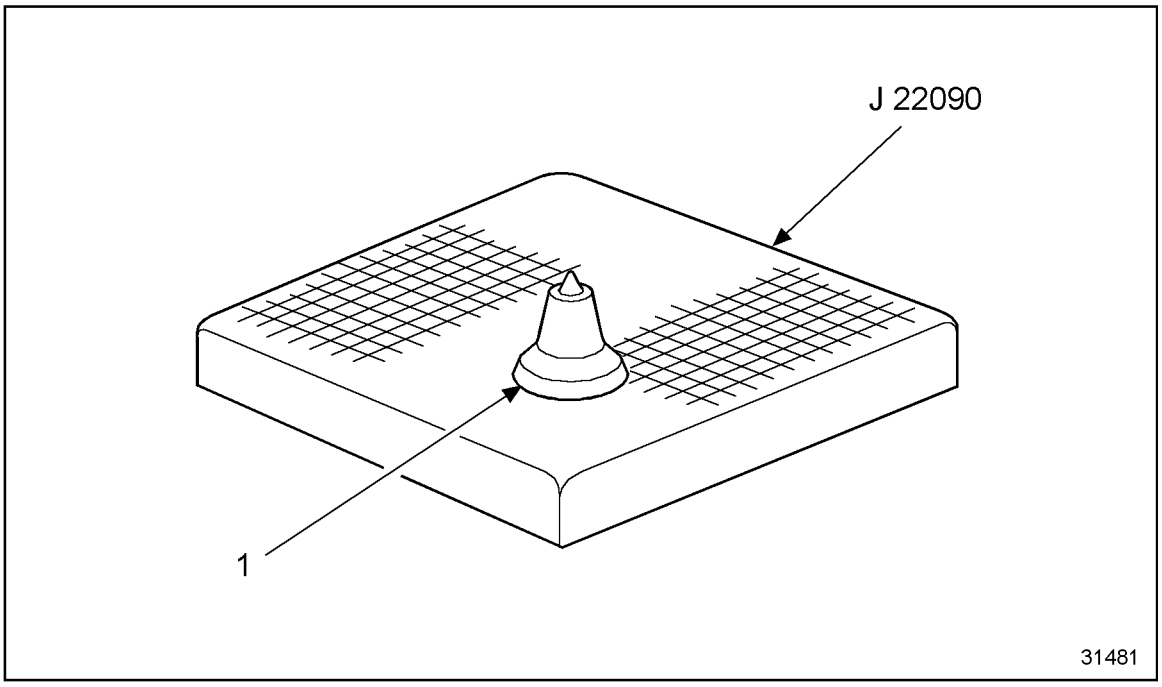
1. Injector Body Assembly
2. Bushing
3. Check Valve
4. Spring Seat
5. Needle Valve
6. Spray Tip Assembly
7. Spring Cage
8. Check Valve Cage
9. Valve Spring

Figure 2-262 Sealing Surfaces Which May Require Lapping

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 lapping blocks (J 22090-A) with compressed air. Do not use a cloth or any other material.
2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
3. Place the part flat on the block and move it back and forth across the block in a figure eight motion. See Figure 2-263. Do not press on the part. Use enough pressure to keep the part constantly flat on the block.



1. Injector Tip Nozzle

Figure 2-263 Cleaning Injector Tip Nozzle

4. After every four or five passes, draw the part across a clean piece of tissue placed on a flat surface to clean the lapping powder from it. Inspect the part. Do not lap excessively.

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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. When the part is flat, wash it in cleaning solvent, and dry it with compressed air.
6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. Do not lap excessively.

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.

7. Wash the part once more in cleaning solvent, and dry it with compressed air.
8. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat, and move it in a figure eight motion across the block several times. Lapping the dry part gives it the "mirror" finish required for perfect sealing.

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.

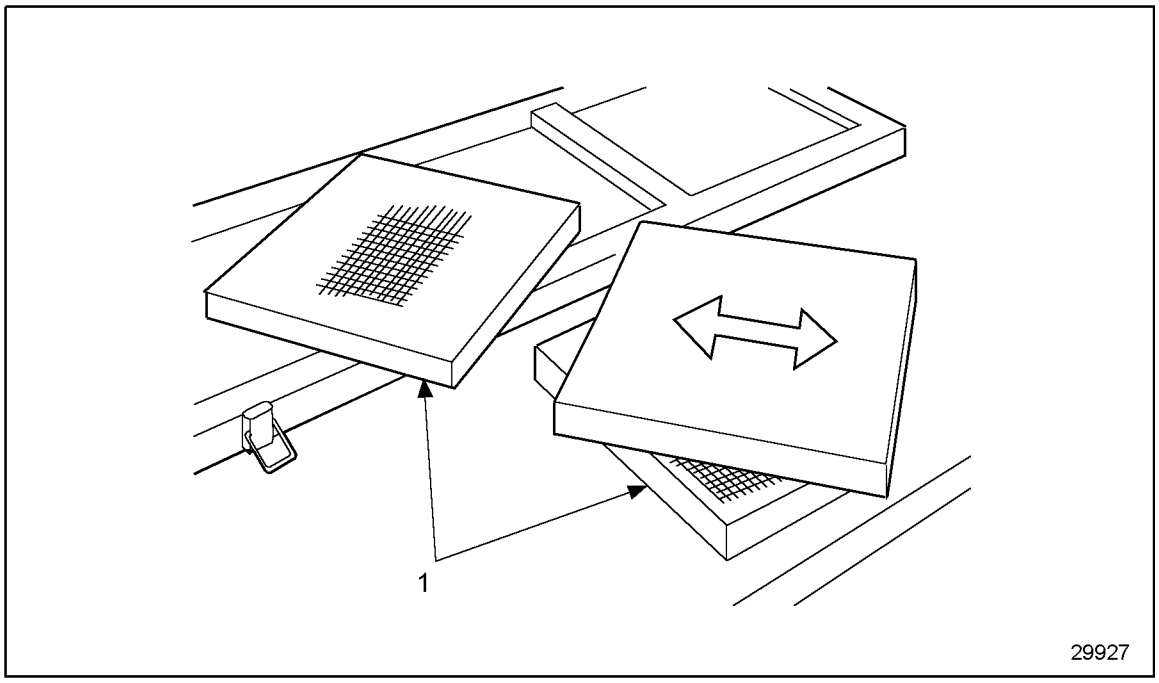
9. Wash all lapped parts in clean solvent, and dry them with compressed air.

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To finish the blocks, spread some 600 grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together. See Figure 2-264. Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2, and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections.



1. Lapping Blocks

Figure 2-264 Refinishing Lapping Blocks

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark gray. Bright or exceptionally dark spots indicate defects. Additional lapping is required.

After the surface has been finished, remove the powder by rinsing the lapping blocks in Tech Solv 340 and scrubbing with a bristle brush.

When not in use, store the lapping blocks in a close fitting wooden container to protect them from damage and dust.

EFFECT OF PRE-IGNITION ON FUEL INJECTOR

Pre-ignition occurs when fuel or lubricating oil ignites in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures, eventually causing injector spray tip burning and leading to injector failure in other cylinders.

When pre-ignition occurs, remove all injectors and check for burned spray tips or enlarged spray tip orifices.

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Before replacing the injectors, check the engine for the cause of pre-ignition to avoid a recurrent problem. Check for oil pull-over from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR TIMING

If you suspect that a fuel injector is "out of time", the injector rack-to-gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing. See Figure 2-265.

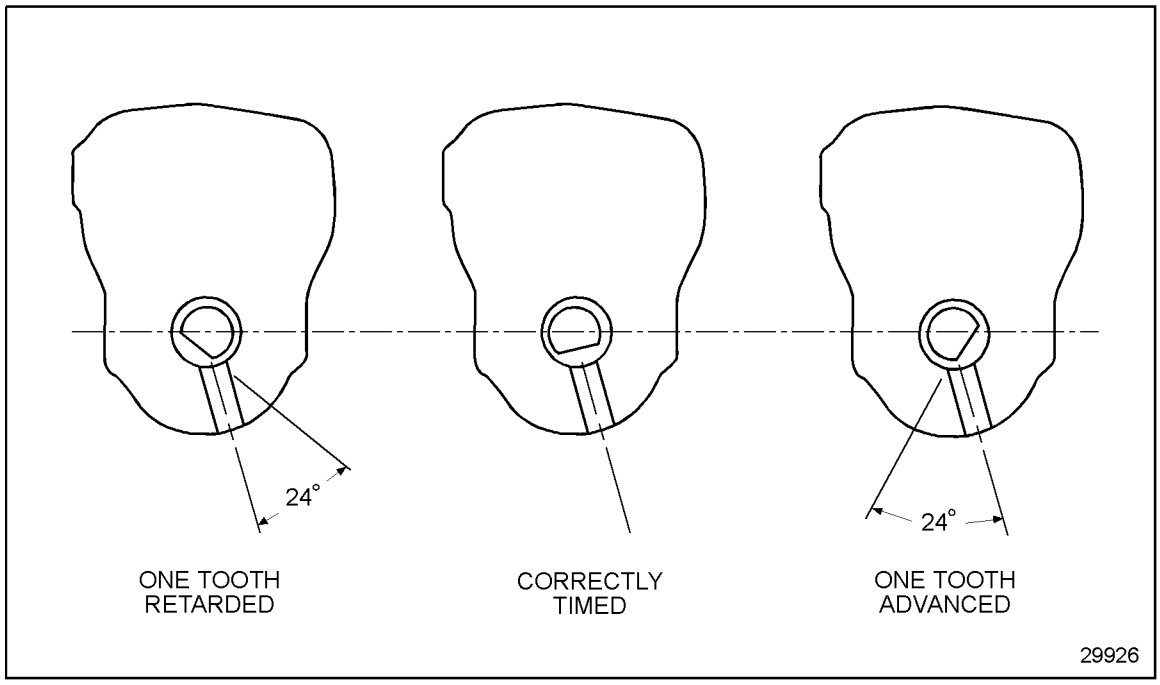


Figure 2-265 Injector Rack to Gear Timing

FUEL LINES

Flexible fuel lines are used to facilitate line connection leading to and from the fuel tank, and to minimize the effects of vibration.

Ensure a restricted fitting (*in head*) of the proper size is used to connect the fuel return to the fuel return manifold.

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When installing fuel lines, DDC recommends that connections be tightened only enough to prevent fuel leakage. Flared fuel line ends will become twisted or fractured by excessive tightening. After all fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If leaks occur, tighten the connections only enough to stop the leak. Check the filter cover bolts for tightness.

Locating Air Leaks in Fuel Lines

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or power loss. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter.

Check for loose or faulty connections. Also check for improper fuel line connections, such as a fuel pump suction line connected to the short fuel return line in the fuel tank. This will cause the pump to draw air.

An air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for fifteen to twenty minutes at a fairly high speed. If the filter canister is full when loosened from its cover, there is no leak. If the filter canister is only partly full, this indicates an air leak.

Pressurize Fuel System - Check for Leaks

Always check the fuel system for leaks after injector or fuel pipe replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a serious fuel leak in this area can lead to lube oil dilution and bearing and/or cylinder kit damage.

Prime and/or purge the engine fuel system before starting the fuel leak check. Prime the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (413-552 kPa or 60-80 lb/in.^{2}) to the secondary filter inlet. If the system is to be purged of air as well, allow the fuel to flow freely from the fuel return line until a solid stream without air bubbles is observed.

Use one of the following methods to check for leaks.

Method 1.

Use when the engine has been operating 20-30 minutes.

1. After operating the engine, shut it off and remove the rocker covers.
2. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

NOTE:
If there are any leaks at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking.

3. If leaks are detected, disassemble, inspect and correct or replace the suspected part (connector washer, connector, injector or jumper line). Test and re-inspect.

Method 2.

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Use when the engine is not operating, such as during or after repairs.

1. Remove the rocker covers.
2. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as discussed in Method 1.
3. Block off the fuel return line, and disconnect the fuel pump supply line at the secondary filter.
4. Install a pressure gage in the filter adaptor, then apply 413-552 kPa (60-80 lb/in.^{2}) fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear.
5. After maintaining 276-552 kPa (40-80 lb/in.^{2}) for 20 to 30 minutes, carefully inspect the puddles to reveal any suspected connectors.
6. Inspect and repair or replace connectors as necessary.
7. Test and inspect once more.

Method 3.

Use while the engine is operating at 400-600 RPM.

1. Apply an outside fuel source capable of 413-552 kPa (60-80 lb/in.^{2}) to the outlet side of the secondary filter.
2. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet.
3. Install a valve and a pressure gage in the fuel return line.
4. With the engine idling, close the valve enough to raise the engine fuel pressure to 483 kPa (70 lb/in.^{2}).
5. After ten to twenty minutes, inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on.
6. Repair and retest.

NOTE:
With the engine at rest, as in Method 2, all injectors will leak to some extent when pressurized. Leaks occur because there is no place else for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity, forming fuel droplets at the rack and dripping off.

Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exist.

If injectors are suspected of leaking and contributing to lube oil dilution, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure-holding capability. Refer to section ADDITIONAL INFORMATION.

Points to Remember:

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. Weak or missing puddles reveal the location of the leak.

All fuel leaks or spills during leak detection testing further dilute the lube oil, so the final in maintenance of this type should include lube oil and lube oil filter changes.

Detecting Internal Fuel Leaks

Used lube oil analysis often identifies a potential source of engine trouble before it occurs. 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 this test can uncover is the presence of excessive fuel in the lubricating oil. Inadequate bearing surface lubrication caused by lube oil dilution is a potential cause of engine malfunction and damage. Fuel should not exceed 2.5% maximum of oil volume. Refer to section 5.2 or refer to Detroit Diesel publication 7SE270, *"Engine Requirements - Lubricating Oil, Fuel, and Filters*" or refer to section 5.

While used lube oil analysis can indicate the presence of fuel in engine lubricating oil, other methods must be used to determine its source. Two particularly effective methods involve the use of dye additives.

NOTE:
Red LTO 1140 dye is a product of Chemserve Corp., 9505 Copland Ave., Detroit, MI 48209. Fluorescent dye J 28431-6, hand held black (ultraviolet) light J 28428-E, Injector "Pop" Tester J 37050-A and Injector "Pop-N-Fixture" J 34760-150A (from set J 34760-B are available from the Kent-Moore Corp., Service Tool Division, and can be ordered through an authorized Detroit Diesel service outlet.

Detroit Diesel believes these to be a reliable source of tools. Additional tool manufacturers may exist, but Detroit Diesel does not endorse, indicate any preference for, or assume any responsibility for the products or tools from these other firms or for any such items that may be available from other sources.

Fuel Leak Tests (Injectors Installed/Engine Off)

To locate a leaking injector, complete the following tests in the sequence shown and stop as soon as the leaking injector is diagnosed. If a leaking injector is found, do not arbitrarily replace more than that injector. Multiple injector malfunctions are rare on the same engine. Multiple injector returns under WARRANTY will require service outlet verification using the J 34760-B Pop-N-Fixture.

NOTE:
Fluorescent dye J 28431-6 is effective in fuel leak detection and should be the first choice when preparing a test fuel mixture. However, if this fluorescent dye and a "Black Light" are not available, Red LTO 1140 dye may be substituted.

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Fuel Leak Tester

Since there is no known fuel leak tester available in the commercial market today, one must be fabricated. Use the following guidelines to help create a fuel leak tester:

NOTE:
During fuel pressure testing (engine off, five minutes at 345 kPa or 50 lb/in.^{2}), fuel leaks will be evident at the injector body/plunger spring seat area. Factory tests have shown that fuel accumulation at each injector, approximately a tablespoon, may be evident during these tests. Evidence of fuel in this area is expected. When the injector cavities are pressurized, fuel is forced between the injector body and plunger.

If an injector is removed and installed in the head, the injector nut O-ring seals should be replaced with new parts.

1. Although test fuel can be pressurized by a variety of methods, Detroit Diesel recommends an air/fuel accumulator design capable of safely withstanding a minimum pressure of 345 kPa (50 lb/in.^{2}).
2. The tester should have a capacity of 2.5 gallons of test fuel and provide for contamination-free test fuel storage when not in use.
3. Regulated shop air should be used to charge the accumulator tank and maintain a constant test fuel pressure.
4. A shutoff-valve should be installed at the accumulator outlet line to start and stop pressurization during the testing sequence.

NOTE:
The use of Red LTO 1140 dye is effective when bench pressure-testing complete cylinder head assemblies or when pressure testing head assemblies on new or newly overhauled operating engines that have new, clean lubricating oil. The red dye is most visible when clean lubricating oil is used.

Prepare the Red LTO 1140 dye mixture as follows:

Mix 59 ml (two ounces) of Red LTO 1140 dye with 18.93 liters (five gallons) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent accidental use and be resealable to prevent contamination when not in use.

NOTE:
The use of J 28431-6 fluorescent dye and a "black light" (ultraviolet light) is preferable when testing an engine that has been in service and has dark lubricating oil (from engine operation). Use the following procedure:

Prepare the fluorescent dye mixture as follows:

Mix 118 ml (four ounces) of fluorescent dye additive J 28431-6 with 15.14 liters (four gallons) of clean No. 1 or No. 2 diesel fuel in a clean container. The container should be marked "Test Fuel" to prevent its accidental usage and be resealable to prevent contamination when not in use.

1. Fill the fuel system tester with the fluorescent or red dye fuel mixture (approximately 2.5 gallons).

CAUTION:
To avoid injury, wear a face shield or goggles.

2. Charge the tester (outlet valve closed) with shop air regulated at 345 kPa (50 lb/in.^{2}).

Connect the tester to the fuel system using either of the following **two options** based on ease of access:

Option 1 - Remove the fuel line from the outlet side of the fuel pump, and connect the fuel system tester line into this fuel hose fitting. This hook-up location will require that the fuel system shutoff-valve remain in the open position during testing. About one gallon of test fuel will be needed to charge the engine fuel system. Test fuel will not harm the fuel filters and may be left in the fuel system at the conclusion of testing.

Option 2 - Remove the fuel line from the outlet side of the fuel bypass filter adaptor and connect the fuel system tester line to this fuel hose fitting. About one-half gallon of test fuel will be required to charge the engine fuel system from this hook-up location.

NOTE:
Place the fuel shutoff-valve (if installed) in the closed position before removing the fuel line and leave closed until line is installed.

Continue testing as follows:

1. Remove the rocker cover, and disconnect the fuel outlet line at a convenient location between the cylinder head and the fuel tank.
2. Install an appropriate size plug (loose) in the fuel outlet line end, and place it in a container to catch the fuel while priming the cylinder head.
3. If equipped, Jake Brakes should be removed to allow visual injector examination during fuel leak testing and, if necessary, during the on-engine injector "pop" test.
4. Slowly open the fuel tester shutoff-valve, and charge the cylinder head fuel galley.
5. 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.
6. With the fuel tester shutoff-valve completely open and the cylinder head fuel galley pressurized to 345 kPa (50 lb/in.^{2}), visually monitor the overhead using a black light for five minutes.

NOTE:
If the test time goes beyond five minutes, the expected leaks at the injector plunger/body will make it difficult to determine the faulty injector.

7. Pay special attention to any leaks at the injector body, stop valve cover, and injector nut-to-body O-ring seals and fuel manifold plug.

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8. Correct the cause of any abnormal fuel leaks.

NOTE:
Some fuel leakage may normally be encountered from the follower and/or rack on DDC injectors while performing this test. It should not exceed the DDC guidelines for pressure holding test and the specification for lube oil dilution (2.5%). Refer to section 2.2.4.3.

NOTE:
Injector plunger/body leaks at the follower spring area are normal and expected during this test.

9. Bleed the pressure from the accumulator tank, and remove the pipe plug from the fuel outlet line.
10. Install the fuel outlet line in the engine fuel system.
11. Disconnect the fuel tester, and install the fuel inlet line in the engine fuel system.
12. Completely open the engine fuel shutoff-valve, and ensure all fuel connections are tight.
13. Install the rocker cover, and start the engine to purge air from the fuel system.
14. If the engine fails to start, it may be necessary to prime the fuel system with a commercially available fuel primer.
15. Since all fuel leaks or spills during leak detection testing dilute the lube oil, the final in maintenance of this type should include lube oil and lube oil filter changes. Refer to section 13.7.

Test Injector "Pop" (on Engine) with Tool J 37050-A

Perform this test if injector leaks cannot be identified after pressure testing the cylinder head.

NOTE:
Energizing and stroking the suspected injector(s) will produce the internal fuel pressures created during engine operation, increasing any abnormal fuel leaks. Refer to the manufacturer's instructions supplied with the J 37050-A tester for set-up procedure.

Perform the test as follows:

1. Wipe down the overhead to remove any fuel left over from previous testing.
2. Using the fuel leak tester, repressurize the cylinder head. Energize each injector using the J 37050-A tester.
3. Visually observe each injector for abnormal fuel leaks using a "black light" or look for evidence of red dye if fuel is used.
4. Correct the cause of any abnormal fuel leaks.

Test Injector Pop-N-Fixture with J 34760-B

If multiple injectors are removed for fuel leaks, each should be bench tested using tool J 34760-B Pop-N-Fixture. Fuel leaks may be easily observed while performing this bench test. Refer to the manufacturers' instructions supplied with the J 34760-B Pop-N-Fixture for set-up and test procedures.

Wash, wipe down, and allow injector to dry before mounting in test fixture. To aid fuel leak detection, add fluorescent dye to the fixture's fuel reservoir and use a "black light" to examine the injector during testing.

Since all fuel leaks or spills during leak detection testing dilute the lube oil, the final in maintenance of this type should include lube oil and lube oil filter changes.

FUEL JUMPER LINE MAINTENANCE AND REUSE

Maintain fuel jumper lines as follows:

NOTICE:

To avoid severe engine damage resulting from fuel oil leaking into the lubricating oil, follow proper procedures when removing, handling, and installing fuel jumper lines (fuel pipes).

NOTICE:

The fuel jumper lines that carry fuel to and from the fuel injectors must be handled and installed very carefully to prevent line damage that can result in severe engine damage.

CAUTION:

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

The following are some of the conditions that can result in fuel jumper line leaks:

1. Improper handling and storage of jumper lines when servicing the engine can result in physical damage and contamination.
2. Careless use of socket J 8932-B during removal or installation can cause a jumper line to bend and permanently distort.
3. Reuse of a bent or distorted jumper line can result in excessive stress and cause the line to crack or fracture at or above the flared ends of the jumper line, resulting in a fuel leak.
4. Excessive tightening of the jumper line nut will distort and fracture the flared end of the jumper line, resulting in a fuel leak.

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NOTICE:
DDC recommends NOT reusing the original fuel pipes. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932-B and "clicker" type torque wrench J 24405 (calibrated in inch-pounds) to apply proper torque and avoid damaging the fuel pipes. For torque specifications, refer to *General Information*. Fuel leaks from damaged or improperly installed fuel pipes can cause lube oil dilution, that may result in serious engine damage.

NOTE:
To help ensure more consistent fastening, tighten fuel pipe nuts on jumper lines to the single torque values. Refer to *General Information*. Use fuel line nut wrench J 8932-B and "clicker" type torque wrench J 24405 (calibrated in inch-pounds).

NOTE:
Because of their low friction surface, Endurion-coated nuts on fuel jumper lines must be tightened from 14.69-18.1 N·m (130-160 lb·in) torque, instead of the 18.3 N·m (160 lb·in) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion-coated nuts on the same cylinder head.

NOTE:
Jacobs Brake jumper lines and jumper lines used with load-limiting devices do not have coated nuts. Tighten these to specifications listed in Table 2-14.

Jumper Line Usage	Torque
Endurion-coated	14.69-18.1 N·m (130-160 lb·in.)
Uncoated	18.3 N·m (160 lb·in.)
*Jacobs Brakes	13.6 N·m (120 lb·in.)
Load Limiting Devices	18.3 N·m (160 lb·in.)
DDEC Engines	16.16 N·m (143 lb·in.)

* Not serviced. Available from Jacobs Manufacturing Company.

Table 2-14 Jumper Line Nut Torque

NOTICE:
When installing fuel jumper lines, do not overtighten. Damage to the jumper line flares and connector seats can result from excessive tightening, causing fuel to leak into the lubricating oil.

5. Damaged threads and flare seats on the injector and cylinder head jumper line connectors can also result in fuel leaks.
6. Leaks can also occur at injector filter nut gaskets and/or cylinder head connector washers due to distortion, damage or incorrect torque.

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Checking for Fuel Leaks

The following procedure is recommended after fuel jumper line installation to determine if fuel is leaking.

Always check the fuel system for leaks after injector or fuel jumper line replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a fuel leak in this area can lead to lube oil dilution. Use one of the following methods to check for leaks.

Method A

Use when the engine has been operating 20-30 minutes.

1. After operating the engine, shut it off and remove the rocker cover(s).
2. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel jumper lines join the fuel line nuts. If there are any leaks at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking.
3. Disassemble, inspect, and correct or replace the suspected part (connector washer, connector, injector or jumper line).
4. Test and inspect.

Method B

Use when the engine is not operating, such as during or after repairs.

1. Remove the rocker cover(s).
2. Pour clean lube oil over the fuel jumper lines and connectors that would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method A.
3. Plug the fuel return line at a convenient location (cylinder head or fuel tank, for example).
4. Disconnect the fuel pump supply line at the inlet of the secondary filter.
5. Connect an external source of pressurized fuel (414-552 kPa or 60-80 lb/in.^{2}) to the inlet of the secondary filter cover.
6. Install a pressure gage (0-689 kPa or 0-100 lb/in.^{2}) at the outlet of the filter cover. Gage installation can be accomplished by installing a "T" fitting between the filter cover and outlet line or by removing the pipe plug at the outlet in the cover.

NOTE:
Using a gage will allow ready reference to the fuel pressure being maintained for this test. Severe leaks are immediately visible and minor leaks take longer to appear. It may be necessary to maintain fuel pressure for a period of 20 to 30 minutes in order to find minor leaks.

7. Leaks may be repaired by replacing damaged parts or determining if the part is loose and below torque specifications.

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8. Test and inspect.

NOTE:
If injectors are suspected of leaking and contributing to lube oil dilution, do not pressurize the fuel system as in Method B. Injectors should be removed from the engine and high pressure tested. Refer to section 2.2.4.3.

METHOD C

Use while the engine is operating at 400-600 RPM.

1. Apply an outside fuel source capable of 414-552 kPa (60-80 lb/in.^{2}) to the outlet side of the secondary filter.
2. Pour lube oil over the fuel jumper lines and connectors so that oil puddles form where jumper lines and connectors meet.
3. Install a valve and a pressure gage in the fuel return line.
4. With the engine idling, close the valve enough to raise the engine fuel pressure to 414-552 kPa (60-80 lb/in.^{2}).
5. After 10-20 minutes, inspect the oil puddles to see if any have become smaller or run off completely.

NOTE:
The undiluted oil will hang the same as when the oil was poured on.

6. Repair and test.

NOTE:
Slightly worn injector plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exist.

METHOD D

When testing an engine that has been in service, use the fluorescent dye and "black light" method test. Proceed as follows:

1. Mix 4 oz. of fluorescent additive J 28431-6 with 15 liters (4 gallons) of clean diesel fuel (No. 1 or No. 2) in a clean container.

NOTE:
The container should be marked "Test Fuel" and be resealable so it will not become contaminated when not in use.

2. Isolate the engine fuel system so that the supply and return fuel lines are connected only to the test fuel container. It will be necessary to intermittently check the fuel level to maintain an adequate supply.
3. Warm up the engine by operating it at maximum no-load speed for approximately 15 minutes.

4. With the engine idling and the rocker cover removed, shine the black light over the head assembly. The lube oil will show a dull blue. If a fuel leak is present, the fuel with the fluorescent dye will glow a bright yellow.
5. After the cause of the fuel leak has been determined and corrected, wipe the area and fuel connections clean. Check again with the black light.
6. When no leaks are present, assemble the unit with the original fuel lines and normal fuel source. It is not necessary to change the fuel filters.
7. Run the engine to purge the air from the fuel system.

NOTE:
With the engine at rest, all injectors will leak to some extent when pressurized. The leakage occurs because there is no other place for the pressurized fuel to go. When the low and high pressure cavities in the injector are subjected to the high test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off. Special consideration must be given to this leakage. If it is excessive, the injector should be removed and tested for pressure holding capabilities.

8. Use new gasket(s), and install the valve rocker cover.

NOTE:
Since all fuel leaks or spills during leak detection testing dilute the lube oil, the final maintenance of this type should include lube oil and lube oil filter changes.

Points to Remember

1. Lube oil puddle inspection is one method of testing the fuel system for internal leaks. The missing puddles show where the leaks are. This test can be performed any time the rocker covers are removed, after the fuel jumper lines and connectors have been splashed with clean lube oil and there is normal fuel pressure in the system.
2. All fuel leaks or spills during leak detection testing further dilute the lube oil.
3. The final maintenance step should include lube oil filter changes if a fuel leak is detected.
4. An oil level above the dipstick "full" mark or a decrease in lube oil consumption may indicate internal fuel leaks.
5. Improper storage, handling or installation of jumper lines can cause fuel leaks, resulting in lube oil dilution and severe engine damage.

Fuel Injector Tube Leak Sealing

Repair the fuel injector tube as follows:

1. Use a new injector tube swagging tool J 28611-A to repair a leaking fuel injector tube.

NOTE:
A fuel injector tube can be repaired at the seal ring without removing the cylinder head from the cylinder block.

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2. Before removing the fuel injector, pressurize the cooling system at the radiator to verify the injector tube seal ring leak.
3. With the fuel injector removed, insert the swagging tool into the fuel injector hole tube.

NOTE:
The tool is tapered and flanged to prevent damage to the cylinder head of injector tube.

4. Hit the top of the tool moderately with a one pound hammer two or three times to seat the tool.

NOTE:
This will cause the top edge of the injector hole tube to expand, increasing the crush on the injector tube seal ring and seal the leak.

5. Install the fuel injector, and pressurize the cooling system to verify the leak has been stopped.
6. Use the swagging tool, as stated above, to restore tension to the seal ring.

REMOVAL OF BOLT-ON TYPE FUEL STRAINER OR FUEL FILTER

Remove the bolt-on type fuel strainer or fuel filter as follows:

1. With the engine stopped, place a container under the strainer or filter. Open the drain cock.
2. After the fuel has drained, close the drain cock.
3. While supporting the canister, unscrew the filter base nut or bolt.
4. Remove the canister and element.
5. Remove and discard the filter base nut retaining ring, if used.
6. Remove and discard the filter element and canister gasket, the filter base nut or bolt gasket, and, if used, the filter base bolt snap ring.

Cleaning of Bolt-On Type Fuel Strainer or Fuel Filter

Clean the fuel filter or fuel strainer as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Wash the canister 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.

2. Dry with compressed air.

Inspection of Bolt-On Type Fuel Strainer or Fuel Filter

Inspect the bolt-on fuel filter or fuel strainer as follows:

1. Visually inspect the element seat and the retaining ring to ensure they have not slipped out of place.
   [a] If out of place, move the retaining ring to its proper position.
   [b] If not out of place, continue inspection.
2. Press on the element seat to check the spring.
   [a] If when released the seat does not return against the retaining ring, replace the filter or strainer. Refer to section 2.22.3.
   [b] If the spring returns, continue inspection.

NOTE:
The filter element, seat spring, and washer cannot be removed from the strainer canister. If necessary, the canister assembly must be replaced. The filter canister components are serviced.

3. Visually inspect the filter retainer seal for cracks or hardening.
   [a] If cracked or hardened, replace the seal. Refer to section 2.22.3.
   [b] If not cracked or hardened, reuse the seal or strainer.

Installation of Bolt-On Type Fuel Strainer or Fuel Filter

Install the bolt-on type fuel strainer or fuel filter as follows:

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

NOTE:
Thoroughly soak the density-type strainer element in clean fuel oil before installing. This will expel any air trapped in the element and lead to a faster initial start.

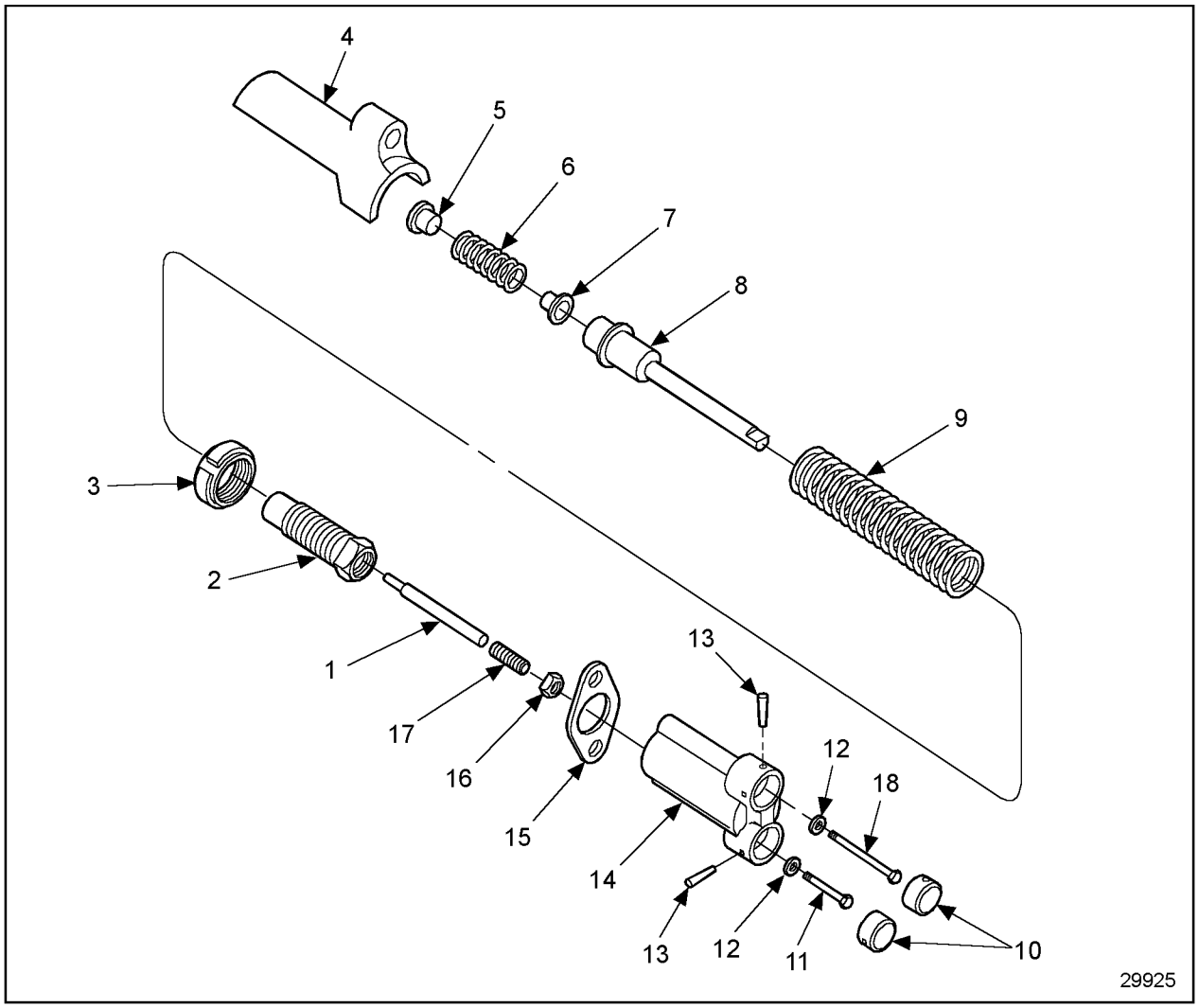
1. Place a new element over the center stud, and push it against the element seat. Make sure the drain cock is closed.
2. Fill the canister about two-thirds full with clean fuel oil.
3. Place a new canister gasket in the canister recess.
4. Place a new gasket on the filter base nut or bolt.
5. Place the canister and element in position under the filter base. Thread the cover bolt (or nut) in the center stud.
6. With the canister and gasket properly positioned, tighten the filter base bolt or nut enough to prevent fuel leakage.
7. Remove the pipe plug at the top of the cover, and finish filling the canister with fuel.
8. Fuel system primer J 5956 may be used to prime the entire fuel system.
9. Start the engine, and check the fuel system for leaks.

TAMPER-RESISTANT GOVERNOR FOR HIGHWAY VEHICLE ENGINES

A tamper-resistant double-weight limiting speed governor is provided for highway vehicle engines.

This governor incorporates an adaptable high-speed spring housing to make unauthorized speed setting changes extremely difficult.

The new governor spring housing has one inch of additional metal resembling two bosses cast on the bolt head of the housing. See Figure 2-266.

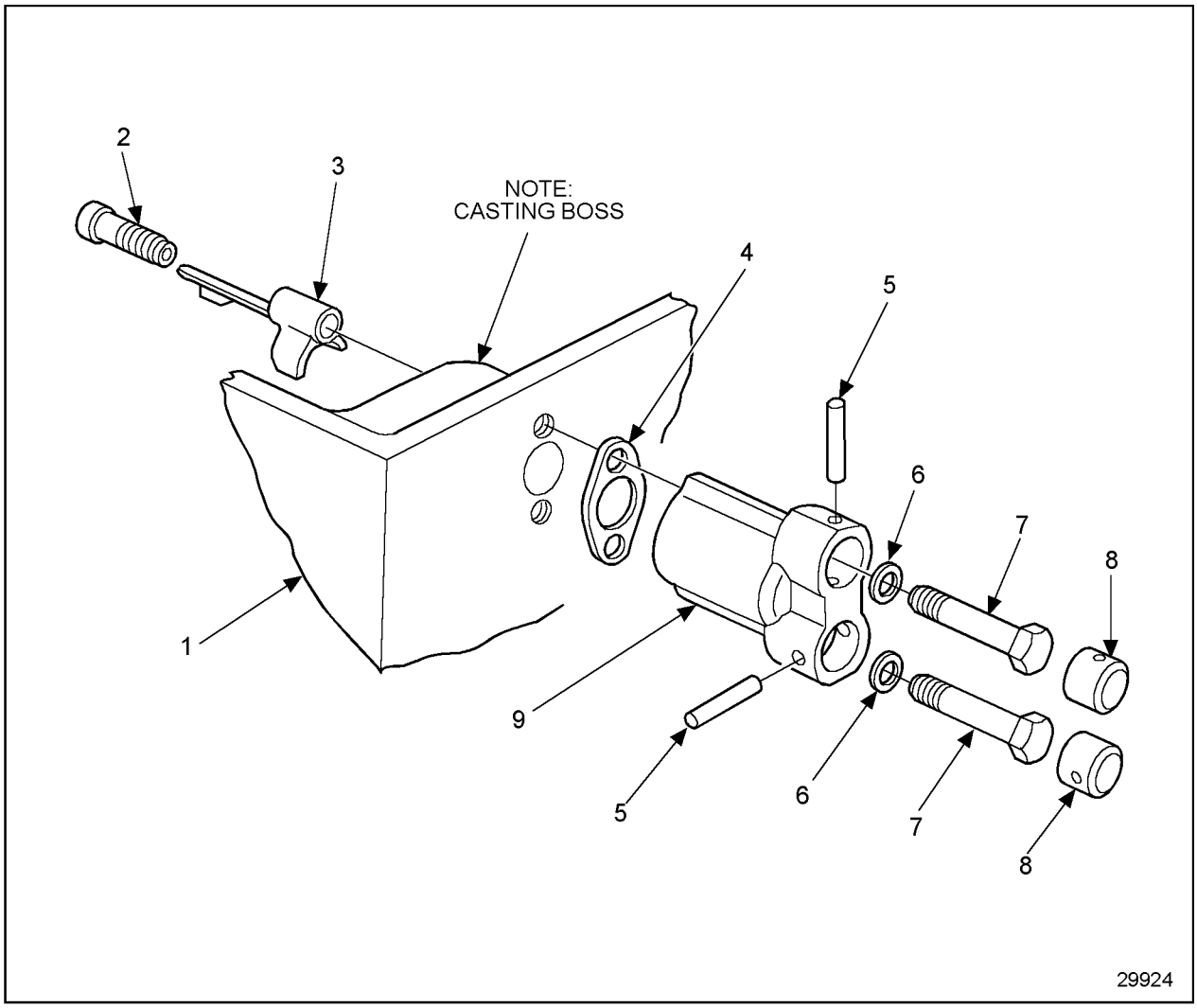


1. Adjusting Pin
2. Spring Retainer
3. Locknut
4. Gap Adjusting Screw and Spring Cover
5. Cap
6. Low-Speed Spring
7. Seat
8. Plunger
9. High-Speed Spring
10. Plugs (2)
11. Bolt 3-1/4 in.
12. Copper Washers (2)
13. Tapered Pins (2)
14. Spring Housing
15. Gasket
16. Nut
17. Set Screw
18. Bolt 4-3/4 in.

Figure 2-266 Tamper Resistant Governor Components (Former)

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These bosses are counterbored to accept the two bolts that hold the spring housing on the governor housing and to allow for the installation of plugs over the bolt heads. See Figure 2-267. The plugs are secured in the counterbores by tapered pins that, when driven in place, cannot be removed when the governor is mounted on the blower. In order to remove the pins to get to the spring housing retainer bolts, the complete governor must be removed from the blower.



1. Governor Housing
2. Allen Head Screw 1-1/4 in.
3. Gap Adjusting Screw and Spring Cover
4. Gasket
5. Pin (2)
6. Copper Washer (2)
7. Bolt 3-1/4 in.
8. Plug
9. Spring Housing

Figure 2-267 Tamper Resistant Governor Components (Current)

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The governor is not tamper-resistant as furnished on an engine by the factory. The spring housing retainer bolts are removable to permit governor adjustments that may be necessary before the engine is placed in service following delivery. To make the governor tamper-resistant after initial engine start-up, two plugs, two tapered pins and the gap adjusting screw and spring cover must be added to the governor.

Disassemble the governor spring housing and spring assemblies as follows:

1. Remove the two bolts and washers securing the high-speed spring housing to the governor housing. Withdraw the housing.
2. Loosen the high-speed spring retainer locknut with a spanner wrench.
3. Remove the high-speed spring retainer, idle speed adjusting pin and set screw, high-speed spring, spring plunger, low-speed spring, spring seat and spring cap as an assembly.
4. Remove the gasket.
5. Remove the governor housing cover and lever assembly. Remove and discard the spring housing bolt retainer. It should be lying loose in the governor housing.

Install the gap adjusting pin and set screw, spring cover, and spring assemblies in the governor housing as follows:

1. On the current tamper-resistant governor, insert the 1-1/4 in. allen head retaining screw through the unthreaded clearance hole in the gap adjusting screw and spring cover.
2. Secure the cover to the inside of the governor housing. The retaining screw sets into a counterbore in the current cover.
3. Turn the retaining screw into the housing until the cover is secure.
4. On the former tamper-resistant governor, place the gap adjusting screw and spring cover in the governor housing with the threaded bolt hole up and in position to receive the spring and plunger assembly.
5. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.
6. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2 in. Thread the locknut on the idle speed adjusting screw.
7. Insert the low-speed spring seat, spring, and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.
8. Affix a new spring housing gasket to the governor housing.
9. Insert the springs, plunger, and retainer into the governor opening as an assembly and through the center of the gap adjusting screw and spring cover. The inner diameter of the cover should pilot on the outer diameter of the retainer.
10. Thread the retainer into the housing approximately one inch.

Perform the governor adjustments. Refer to section 12.4. Install the governor spring housing as follows:

1. Position the spring housing on the governor housing. On vehicles using a frontal air system, remove material from the air cleaner adaptor boss to provide clearance for the governor spring housing.

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2. On the current tamper-resistant governor, insert one of the 3-1/4 in. attaching bolts with copper washer through the top bolt hole in the spring housing. Thread it into the top hole on the outside of the governor housing. Tighten the bolt.
3. On the former tamper-resistant governor, insert the 4-3/4 in. attaching bolt with copper washer through the top bolt hole in the spring housing. Thread it into the threaded hole in the former gap adjusting screw and spring cover. Tighten the bolt.
4. Thread the 3-1/4 in. attaching bolt with lock washer (current and former governors) into the bottom hole in the spring and governor housings.
5. Coat the threads of the attaching bolts and the retaining screw with a Loctite sealant, or equivalent, to prevent loosening. Tighten each bolt to 18-24 N·m (13-17 lb·ft) torque.

Install the tamper-resistant plugs and pins in the counterbores of the spring housing as follows:

1. Install the top plug with the drilled passage in the vertical position and the larger opening up.
2. Install the bottom plug with the drilled passage horizontal and the larger opening away from the blower.
3. Drive the tapered pins, small end first, into the drilled passages in the top and side of the spring housing until the pin is below flush and firmly in place.

Most limiting speed governors on engines already in service can be converted to the tamper-resistant setup as follows:

1. Remove the two bolts and washers securing the high-speed spring housing to the governor housing. Withdraw the housing.
2. Loosen the high-speed spring retainer locknut with a spanner wrench.
3. Remove the high-speed spring retainer, idle speed adjusting pin and set screw, high-speed spring, spring plunger, low-speed spring, spring seat and spring cap as an assembly.
4. Remove the gasket.
5. Remove the governor housing cover and lever assembly.
6. Drill out the 5/16 in.-18 tapped hole in the governor housing at the spring housing top retaining bolt position to 11/32 in. diameter.
7. Remove all drilled particles from the inside of the governor housing.

Install the current gap adjusting screw and spring cover and the high and low-speed spring assemblies, replacing the original retainer with the new longer retainer in the governor housing as follows:

1. On the current tamper-resistant governor, insert the 1-1/4 in. allen head retaining screw through the unthreaded clearance hole in the gap adjusting screw and spring cover.
2. Secure the cover to the inside of the governor housing. The retaining screw sets into a counterbore in the current cover.
3. Turn the retaining screw into the housing until the cover is secure.

4. On the former tamper-resistant governor, place the gap adjusting screw and spring cover in the governor housing with the threaded bolt hole up and in position to receive the spring and plunger assembly.
5. Insert the high-speed spring and plunger assembly in the high-speed spring retainer.
6. Thread the idle speed adjusting screw into the threaded end of the plunger approximately 1/2 in. Thread the locknut on the idle speed adjusting screw.
7. Insert the low-speed spring seat, spring, and cap assembly into the high-speed spring plunger and over the idle speed adjusting screw.
8. Affix a new spring housing gasket to the governor housing.
9. Insert the springs, plunger, and retainer into the governor opening as an assembly and through the center of the gap adjusting screw and spring cover.

NOTE:
The inner diameter of the cover should pilot on the outer diameter of the retainer.

10. Thread the retainer into the housing approximately one inch.
11. Perform the governor adjustments. Refer to section 12.4.
12. Replace the original spring housing with the new spring housing.
13. Install the new housing and governor housing cover on the governor housing.
14. Install the tamper-resistant plugs and pins in the counterbores of the spring housing.

NOTE:
If the spring housing of a former tamper-resistant governor is removed for any reason, the gap adjusting screw and spring cover will fall into the governor housing. Remove the governor cover and lever assembly and ensure gap adjusting screw and spring cover is secured by the 5/16 in.-18 x 4-3/4 in. bolt after the spring housing is installed.

MODIFICATION OF GOVERNOR HOUSING TO ACCEPT CURRENT TAMPER-RESISTANT GAP ADJUSTING SCREW AND SPRING COVER

A former governor housing can be reworked to accept the new tamper-resistant gap adjusting screw and spring cover. Kent-Moore master thread repair kit J 26520 can be used.

With this procedure, two threaded inserts are installed in the governor housing, one from the inside and one from the outside. This will allow the new retaining screw to be installed on the inside of the governor housing and the new spring housing upper 3-1/4 in. bolt to be installed from the outside.

1. Remove the governor cover, high-speed spring housing and spring pack.
2. Apply a thick coat of grease to the inside of the housing. Fit an oil soaked rag through the spring pack hole, using the grease as a seal between the housing and the rag.
3. Drill the upper high-speed spring housing bolt hole to 13/32 in. Tap the hole with a 7/16 in.-14 tap.

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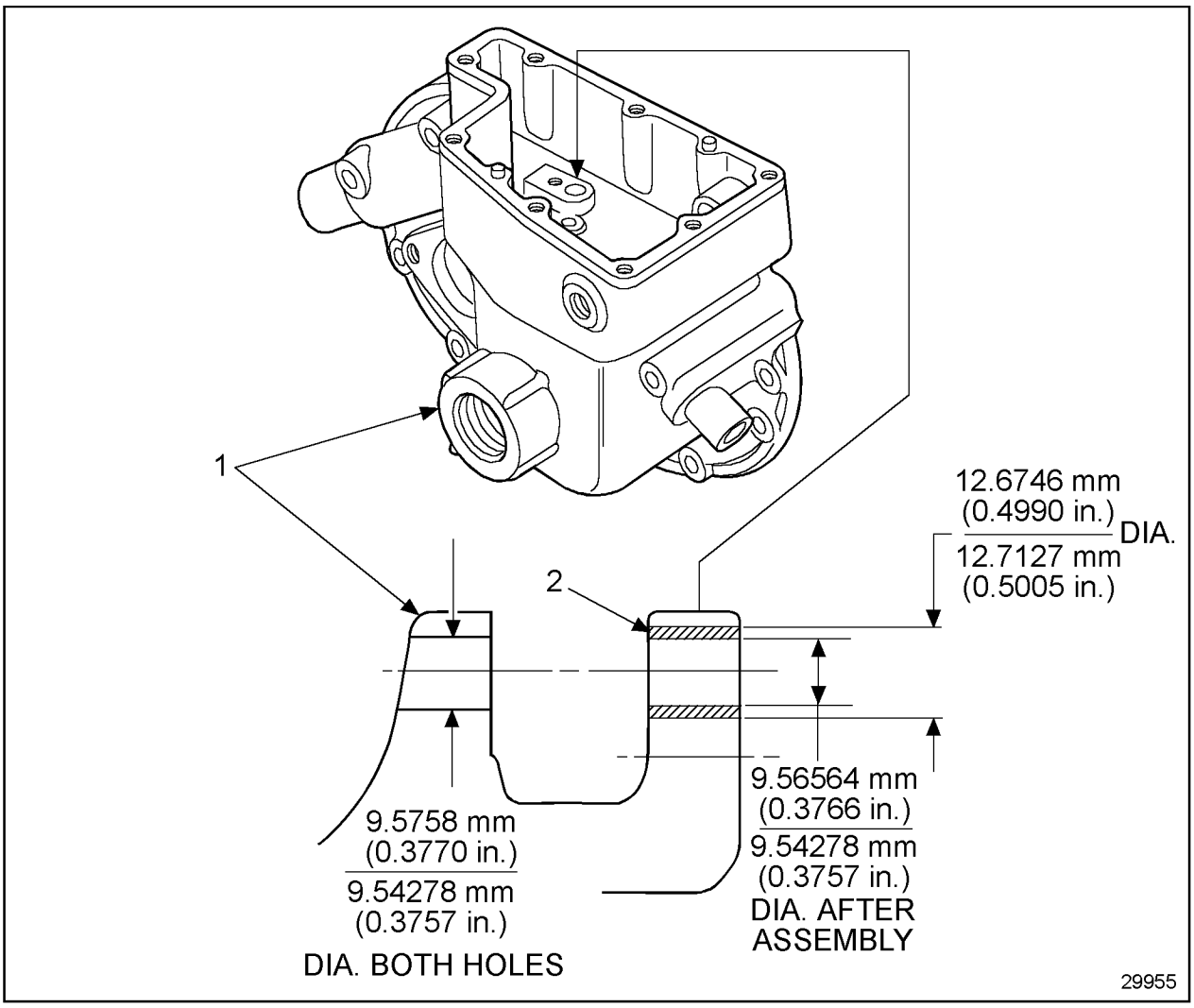
4. Remove the rag, making sure all of the chips are out of the housing. Wipe the grease from the housing.
5. Thread a 5/16 in.-18 insert by hand from each side until the lock tabs bottom.

NOTE:
The inside of the governor housing cast boss, where the drill breaks through, may need to be filed flat. This is to prevent the gap adjusting screw and spring cover from tilting out of position when the retaining screw is tightened.

REWORK GOVERNOR HOUSING

The engine mechanical governor housing can be reworked when wear occurs at the boss that holds either the upper or lower end of the operating lever shaft.

See Figure 2-268. Repair can be made by adding a bushing to the worn boss as follows:



1. Governor Housing
2. Bushing

Figure 2-268 Reworking Governor Housing

1. See Figure 2-268, and bore out the hole so that the repair bushing fits tightly (12.6746–12.7127 mm or 0.4990–0.5005 in. diameter).
2. Shorten the bushing to a length of 9.652 mm (0.380 in.).
3. Press the bushing in the hole flush to 0.25 mm (0.010 in.) below the surface of the housing boss.
4. Ream the bushing to 9.543–9.566 mm (0.3757 in.-0.3766 in.) diameter, using a 3/8 in. reamer.

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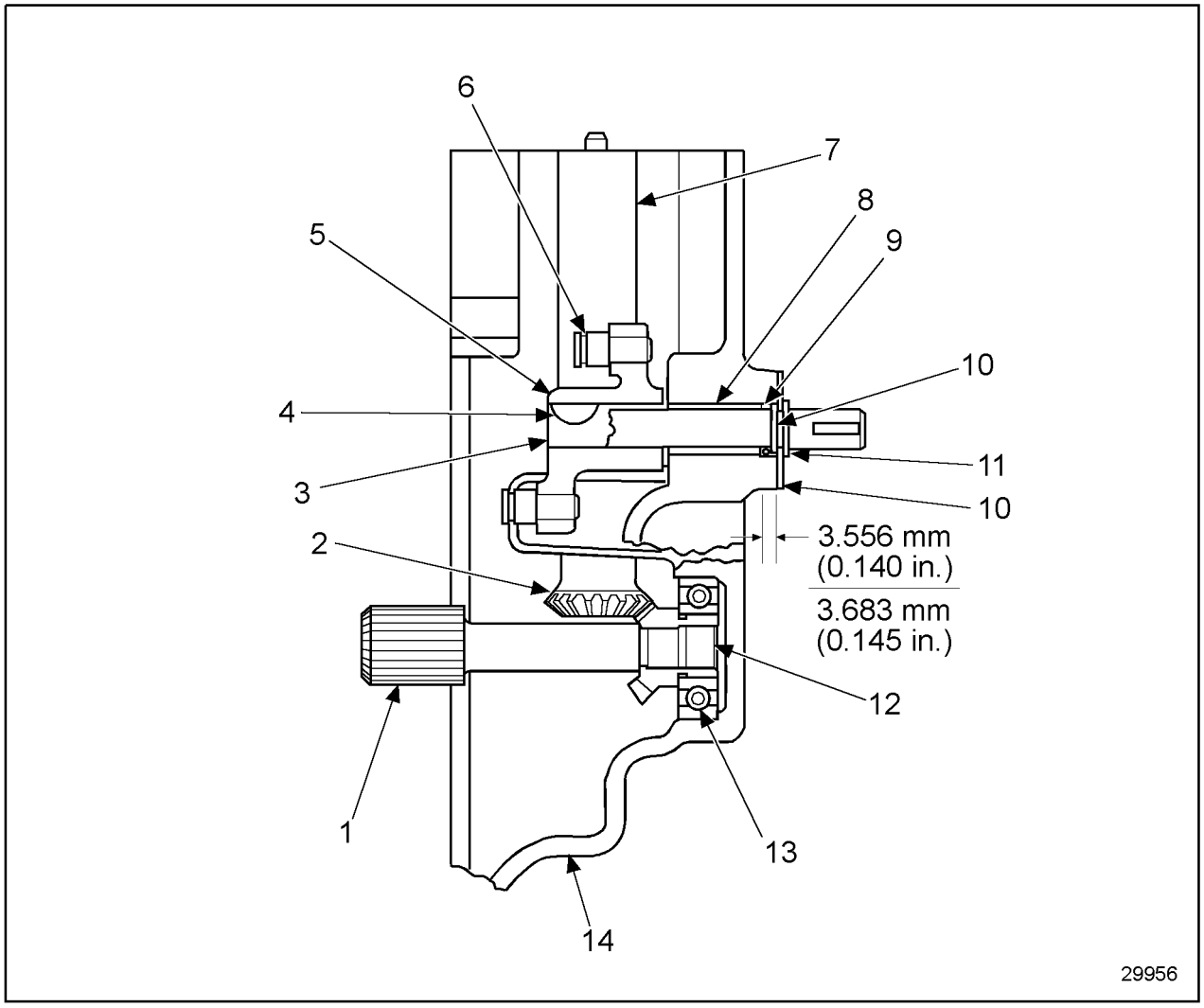
5. After assembling the governor, check for shaft freeness.

NOTE:
Careful workmanship is necessary to maintain proper geometry and fit within the governor.

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PRE-INSTALLATION OF A BARBER-COLEMAN ELECTRONIC GOVERNOR

Before a Barber-Coleman electronic governor is installed on an engine previously equipped with a hydraulic governor, the vertical driven gear, bearing, and gear sleeve and the horizontal drive gear, shaft and bearing must be removed from the governor drive housing. See Figure 2-269.



1. Drive Shaft
2. Driven Gear
3. Shaft
4. Key
5. Control Link Lever
6. Lever Pin
7. Driven Gear Sleeve
8. Bushing
9. Seal Ring
10. Flat Washer
11. Snap Ring
12. Drive Gear
13. Bearing
14. Drive Housing

Figure 2-269 Governor Drive Assembly (6V and 8V Engines)

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These components serve no useful purpose when the hydraulic governor is replaced with the electronic governor and will cause severe engine damage if not removed. Because the horizontal drive shaft is splined to the blower rotor shaft, both governor shafts will continue to rotate when the engine is operated. With the hydraulic governor removed, however, the horizontal and vertical shafts and bearings will no longer receive adequate support or lubrication and will quickly wear out.

NOTICE:
Do not remove only the vertical shaft and bearing. If the horizontal drive shaft and bearing assembly is left in the governor drive housing, the shaft will move freely back and forth during engine operation. This is due to the absence of load on the bevel gear that would normally keep the horizontal shaft in position. The rapid rotation and back-and-forth movement of the horizontal drive shaft can cause severe damage to the governor drive housing.

Follow this procedure before installing a Barber-Coleman electronic governor:

1. Remove the hydraulic governor drive. Refer to section 2.30.2 for 6V and 8V engines or refer to section 2.30.3 for 12V and 16V engines.
2. Remove the driven gear, bearing and gear sleeve, and the drive gear, shaft and bearing from the drive housing.
3. Install the governor drive housing and all parts previously removed, except the drive and driven gears and related components. Refer to section 2.30.8 on 6V and 8V engines or refer to section 2.30.9 for 12V and 16V engines.
4. Install the Barber-Coleman electronic governor per the manufacturers' instructions, and perform the engine tune-up. Refer to section 12.1.

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

The exceptions to the standard torque specifications are listed in Table 2-15.

Application	Thread	lb·ft	lb·in	N·m
Control Tube Bracket Bolts	1/4-20	10-12	-	14-16
Governor Weight Shaft Bearing Retaining Bolt	5/16-24	15-19	-	20-26
Variable Speed Spring Lever Set Screw	5/16-24	12-15	-	16-20
Air Inlet Housing Adaptor-to-Blower Housing Bolt	3/8-16	16-20	-	22-27
Air Inlet Housing-to-Adaptor Bolt	3/8-16	16-20	-	22-27
Injector Clamp Bolt	3/8-16	20-25	-	27-34
Fuel Pipe Nut (Endurion Coated)	3/8-24	-	130	14.69
Fuel Pipe Nut (Uncoated)	3/8-24	-	160	18.3
Fuel Pipe Nut (Load Limiting Device)	3/8-24	-	160	18.3
Fuel Pipe Nut (Jacobs Brake)	3/8-24	-	120	13.6
Blower End Plate-to-Cylinder Block Bolts	7/16-24	40-45	-	54-61
*Rocker Arm Bracket Bolts	1/2-13	90-100	-	122-136
Injector Filter Caps	5/8-24	65-75	-	88-102
Injector Nut	15/16-24	75-85	-	102-115

*102-115 N·m (75-85 lb·ft) torque on the two bolts attaching a load limit or power control screw bracket (if used) to the rocker arm shaft brackets.

Table 2-15 Exception to Standard Bolt and Nut Torque Specifications

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3 LUBRICATING SYSTEM

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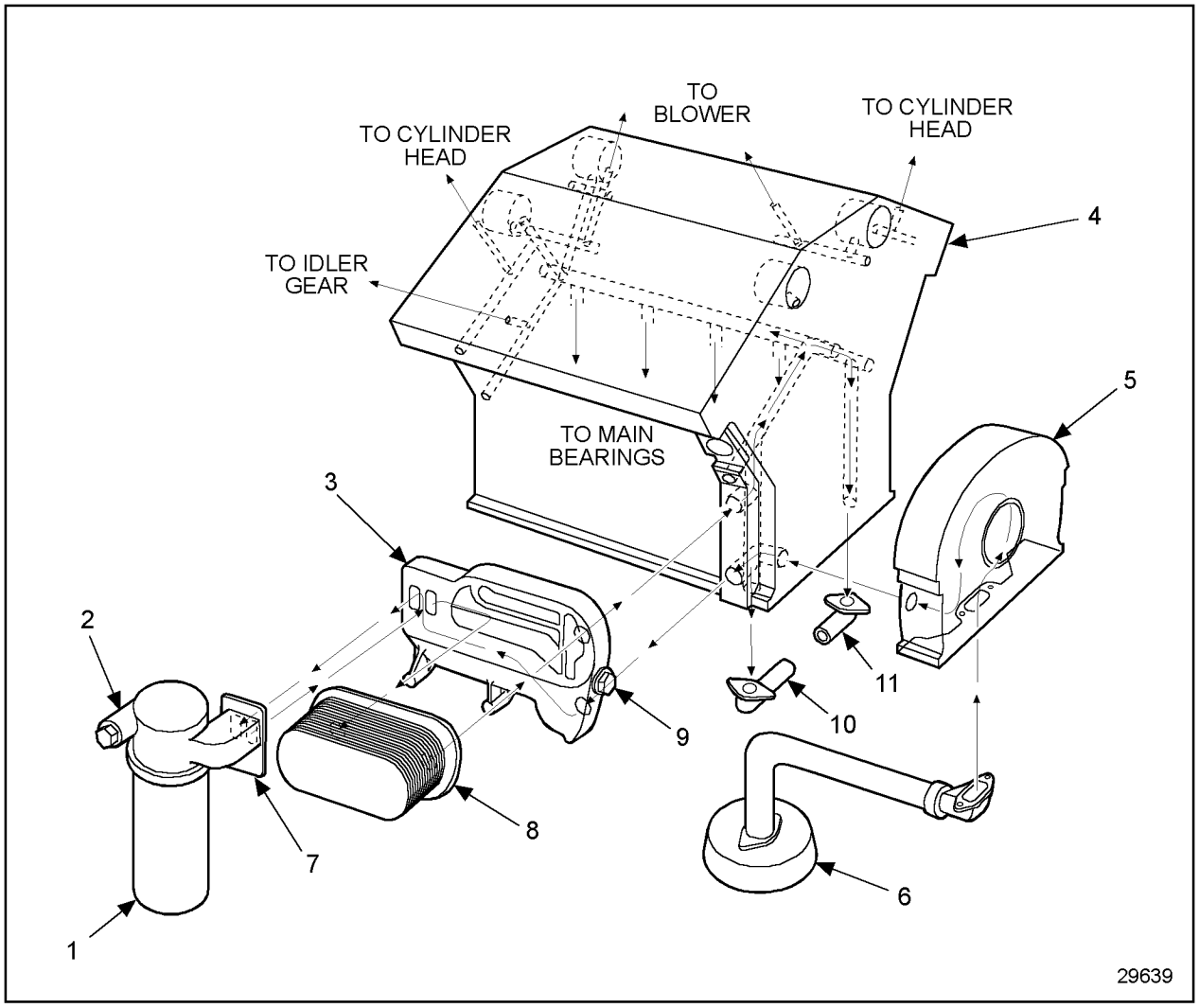
3.1 LUBRICATION SYSTEM

The lubricating system consists of the following:

- Oil Pump
- Full-flow Oil Filter
- Oil Cooler
- Oil Pressure Regulator Valve
- Oil Pressure Relief Valve
- Oil Cooler Bypass Valve

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The following schematic illustrates the flow of oil through a typical 6V or 8V-92 engine lubrication system, including the various components such as the oil pump, full-flow oil filter, oil cooler, pressure regulator and bypass valve. See Figure 3-1.

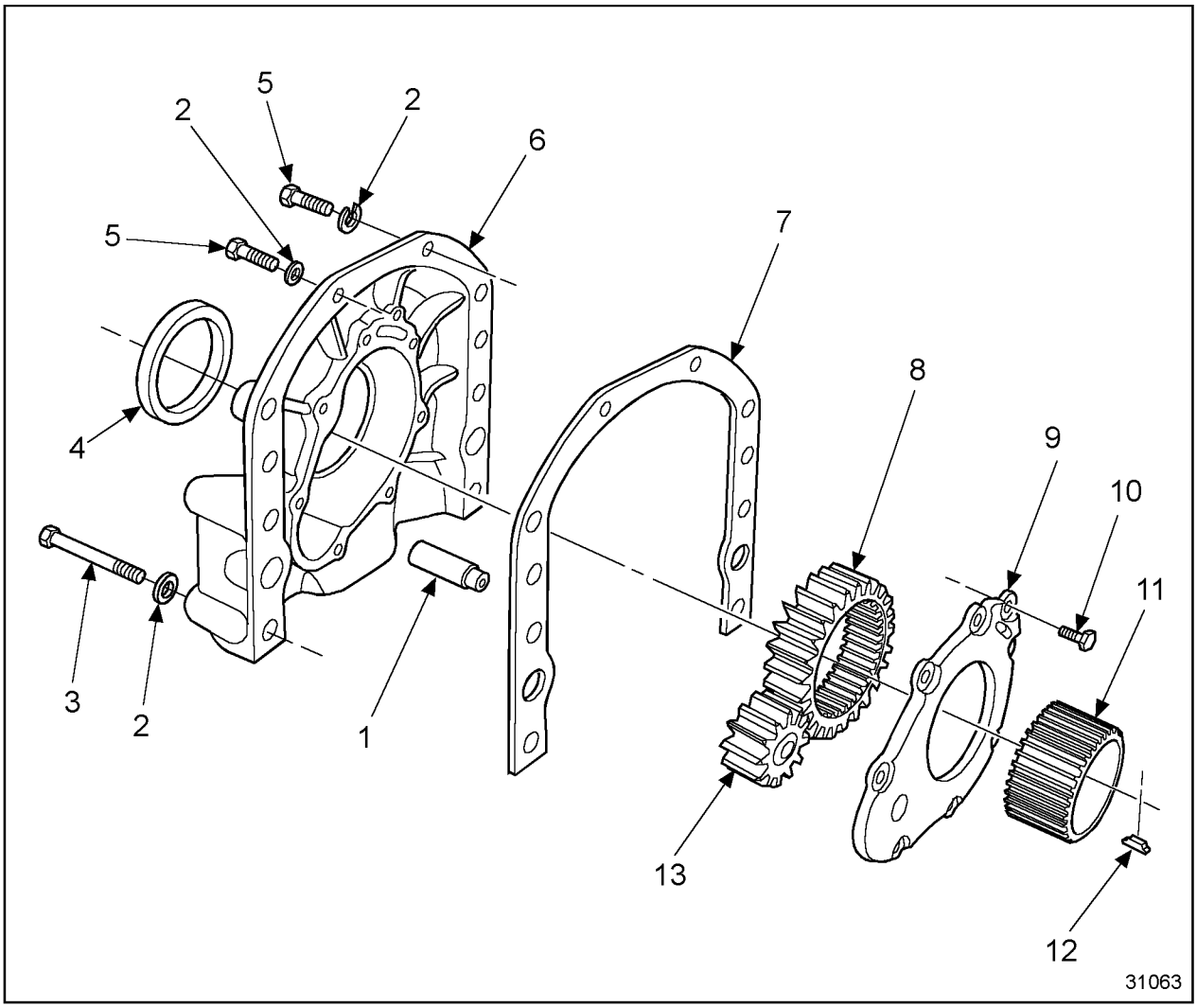


1. Oil Filter
2. Oil Filter Bypass Valve
3. Oil Cooler Adaptor
4. Cylinder Block
5. Front Cover and Oil Pump Assembly
6. Oil Pump Inlet Screen
7. Oil Filter Adaptor
8. Oil Cooler Core
9. Oil Cooler Bypass Valve
10. Pressure Relief Valve
11. Pressure Regulator Valve

Figure 3-1 Schematic Diagram of Typical 6V and 8V Lubrication Systems

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On 6V and 8V engines, the oil pump is placed in the crankshaft front cover and consists of a pair of spur gears, one large and one small, which mesh together and ride in a cavity inside the crankshaft front cover. The large gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump driven gear is much smaller and runs on a bushing and hardened steel shaft pressed into the crankshaft cover. See Figure 3-2.



1. Driven Gear Shaft
2. Washer
3. Long Bolt
4. Oil Seal
5. Short Bolt
6. Crankshaft Front Cover
7. Gasket
8. Drive Gear
9. Retaining Plate
10. Retaining Plate Bolt
11. Drive Hub
12. Key
13. Driven Gear

Detroit Diesel has two-cycle, left and right hand turning oil pumps.

Figure 3-2 Front Mounted Lubricating Oil Pump (6V and 8V Engines)

As the gears revolve, a vacuum is created on the inlet side of the pump and draws the oil from the oil pan, through the intake screen and pipe, to the oil pump, where it is pressurized. The oil passes from the pump under pressure, into a short gallery in the cylinder block, and to the oil cooler adaptor plate. At the same time, oil from the pump is directed to a spring-loaded pressure relief valve mounted on the cylinder block. This valve discharges excess oil directly to the oil sump when the pump pressure exceeds 724 kPa (105 lb/in.^{2}).

From the oil cooler adaptor plate, the oil passes into the full-flow filter, through the oil cooler, and back into the cylinder block. A short vertical oil gallery and a short diagonal oil gallery carry the oil to the main longitudinal oil gallery through the middle of the block. Valves are also provided to bypass the oil filter and oil cooler should either one become plugged.

Stabilized lubricating oil pressure is maintained in the engine at all speeds, regardless of the oil temperature, by means of a pressure regulator valve, located at the end of a vertical oil gallery and connected to the main oil gallery. The vertical gallery is located at the front of the cylinder block on the side opposite the cooler. When the oil pressure at the valve exceeds 345 kPa (50 lb/in.^{2}), the regulator valve opens, discharging oil into the sump.

From the main oil gallery, the pressurized oil flows through drilled passages to each main bearing, and passes to an adjacent pair of connecting rods through grooves in the unloaded halves of the main and connecting rod bearings and drilled passages in the crankshaft. The rifle-drilled connecting rods carry oil from the rod bearings to the piston pin bushing.

At the rear of the block, two diagonally drilled oil passages, which intersect the main oil gallery, carry oil to the two rear camshaft end bearings. Oil is conducted through the rifle-drilled camshaft to the intermediate and front end bearings. Oil from the camshaft intermediate bearings is directed against the camshaft lobes and cam rollers, which run in an oil bath. Oil from the intermediate bearings provides lubrication to the cam lobes immediately after starting the engine, when the oil is cold and before camshaft bearing oil flow and oil drainage from the cylinder head have had time to build up.

The diagonally drilled oil passage on the right side at the rear of the block intersects with a vertical passage to carry oil to the right bank cylinder head. A short gallery intersects with this diagonal passage to lubricate the idler gear bearing. Another gallery, intersecting the diagonal passage from the camshaft at the front of the block, supplies oil to the left bank cylinder head.

NOTICE:

Do not use the oil gallery on the upper front left cylinder block bank for an oil supply or pressure take-off. This gallery intersects the cylinder head oil supply gallery. If used, it will reduce oil pressure to the rocker arm assemblies and eventually cause engine damage.

Drilled passages, intersecting longitudinal galleries parallel to the camshafts, lead to the blower and supply oil for the blower drive gears and bearings.

Oil from the right-bank camshaft front end bearing lubricates the water pump drive gear and bearings and the front camshaft gear.

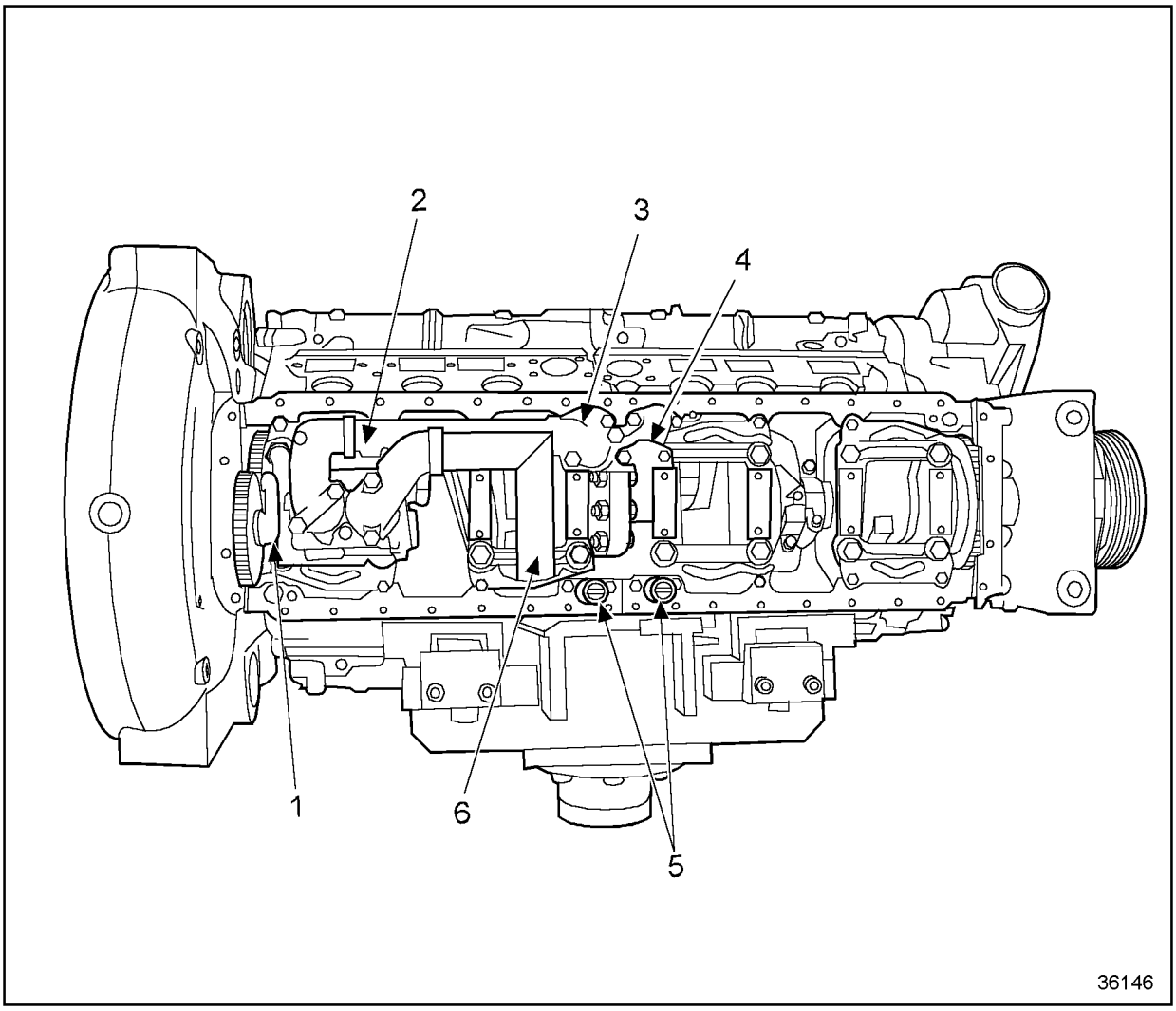
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The oil overflow from the camshaft pocket spilling into the gear train compartment and splash from the oil pan lubricate the gear train. Some oil spills into the gear train compartment from the camshaft rear end bearings, the blower drive gear bearing, and the idler gear bearing. The blower drive gear bearing is lubricated through an external pipe from the blower rear end plate to the blower drive support.

A longitudinal oil passage on the camshaft side of each cylinder head, which connects to the main oil gallery in the cylinder block, lubricates the valve and injector operating mechanism. Oil from this passage enters the drilled rocker arm shafts through the lower end of the rocker shaft bolts and rocker shaft brackets. Excess oil from the rocker arms lubricates the exhaust valves and cam followers.

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A gear-type pressure pump, mounted to the number seven and eight bearing caps (12V engine) or number nine and ten main bearing (16V engine) are gear-driven from the rear end of the crankshaft that circulates the lubricating oil. See Figure 3-3. On some engines, the oil pump is mounted to the front on the number one and two main bearing caps and gear-driven by an oil pump drive gear bolted to the front crankshaft gear.



1. Oil Pump
2. Oil Pump Outlet Tube
3. Junction Block
4. Oil Pressure Relief Valve
5. Oil Pressure Regulator Valves
6. Oil Pump Inlet

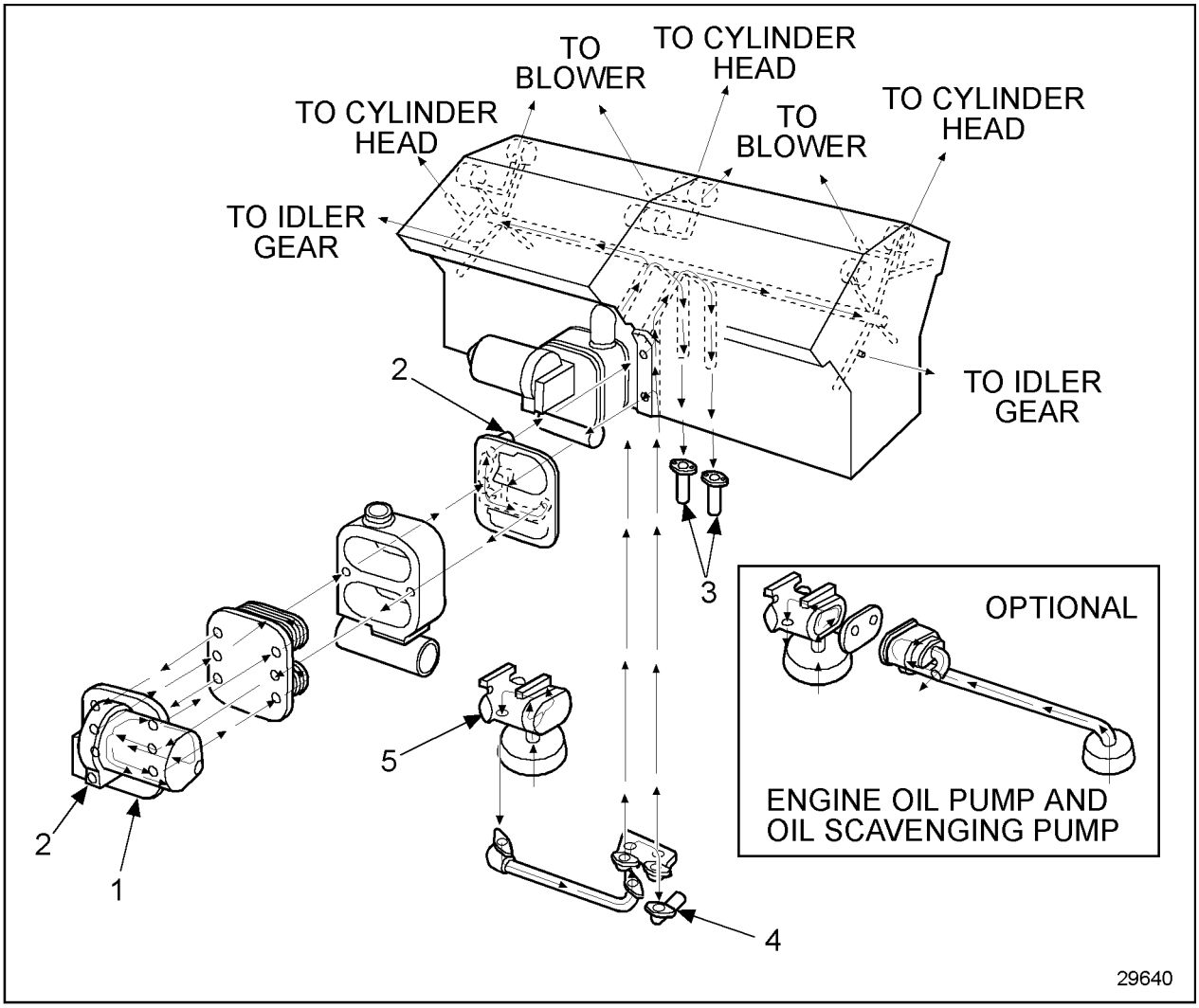
Figure 3-3 Typical Lubricating Oil Pump Rear Mounted (12V Engines)

An oil pressure relief valve, mounted on the junction block, bypasses excess oil directly into the oil sump when the pressure on the outlet side of the pump exceeds approximately 827 kPa (120 lb/in.^{2}).

Since bypass valves are provided in the oil coolers and the oil filters, the oil will bypass the coolers or filters if they become plugged.

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Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by two pressure regulator valves located at the end of the vertical oil galleries. See Figure 3-4. When the oil pressure at the regulator valves exceeds 345 kPa (50 lb/in.^{2}), the valves open, discharging excess oil back into the oil pump.



1. Oil Filter Bypass Assembly
2. Oil Cooler Bypass Valve
3. Oil Pressure Regulator Valve
4. Oil Pressure Relief Valve
5. Engine Oil Pump

Figure 3-4 Schematic Diagram of Typical 16V Lubrication System

Use the correct lubricating engine oil. Refer to section 5.2 and refer to section 13.5.1. Change the oil, and replace the oil filter elements at recommended intervals to ensure trouble-free lubrication and longer engine life. Refer to section ADDITIONAL INFORMATION for oil leak inspection procedures.

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The oil level should never be allowed to drop below the low mark on the dipstick. Overfilling the crankcase may contribute to abnormal oil consumption, high oil temperature, and result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time allowed for the oil to drain back from the various engine parts. If more oil is required, add enough to bring the level to the full mark on the dipstick.

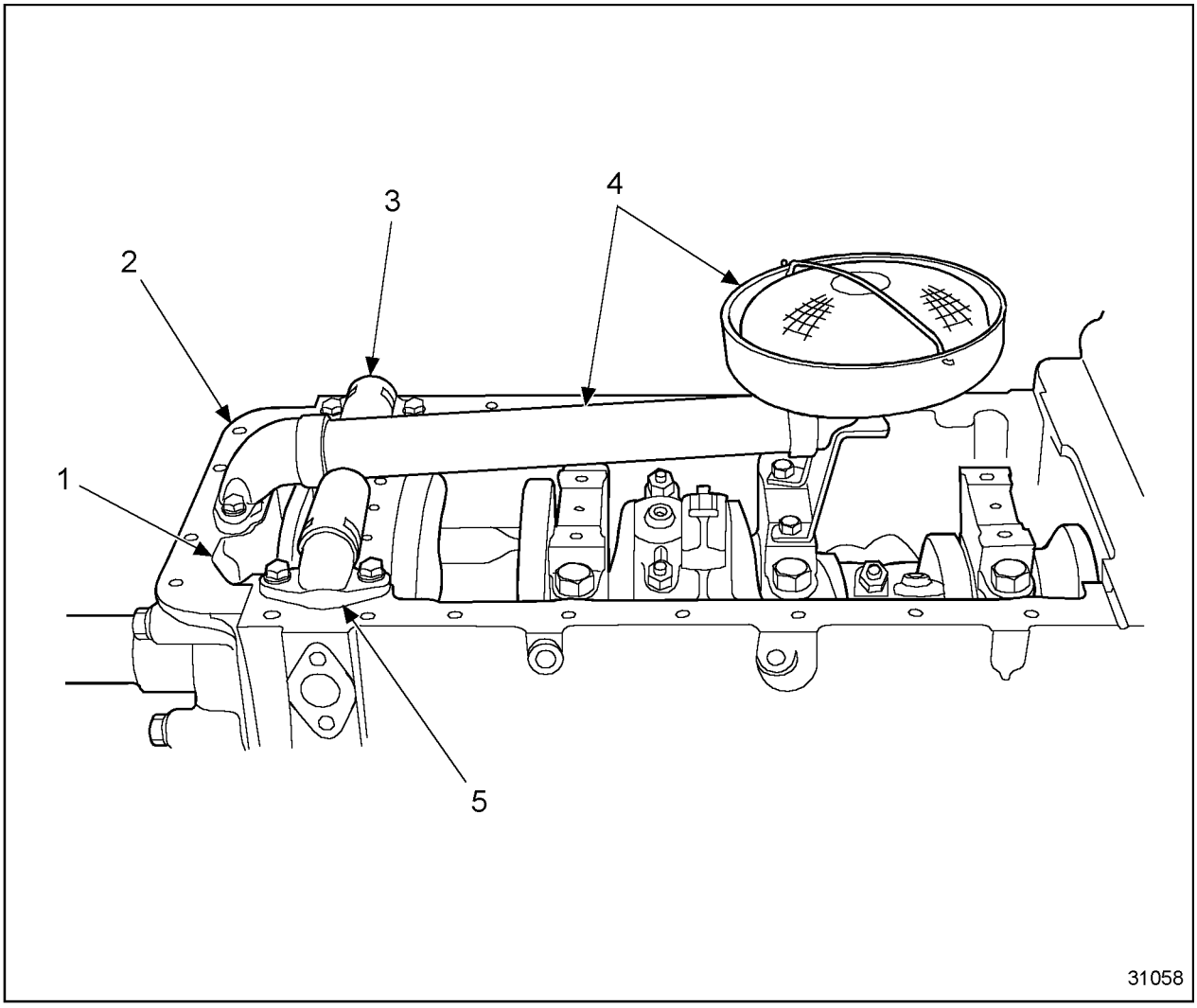
Thorough lubrication system flushing is required at times. Should the engine lubrication system become contaminated with an ethylene glycol base antifreeze solution or other soluble material,refer to section 13.12.4 for the recommended cleaning procedures.

NOTE:
DDC uses red dye to detect lube oil system leaks during engine testing. There may be some residual dye remaining in new engine lube oil systems. This dye should quickly disperse after the first few hours of engine operation.

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3.2 LUBRICATING OIL PUMP (6V AND 8V ENGINES)

On 6V and 8V engines, the gear type lubricating oil pump is mounted in the crankshaft front cover, which also functions as the oil pump body. See Figure 3-5. The pump consists of two spur gears, which mesh and rotate in a cavity inside the crankshaft cover. The pump drive gear is concentric with and splined to a pump drive hub on the front end of the crankshaft. The pump driven gear and bushing assembly rotates on a hardened steel shaft. One end of the driven gear shaft is pressed into the crankshaft front cover and the other end is supported in the oil pump gear retaining plate.

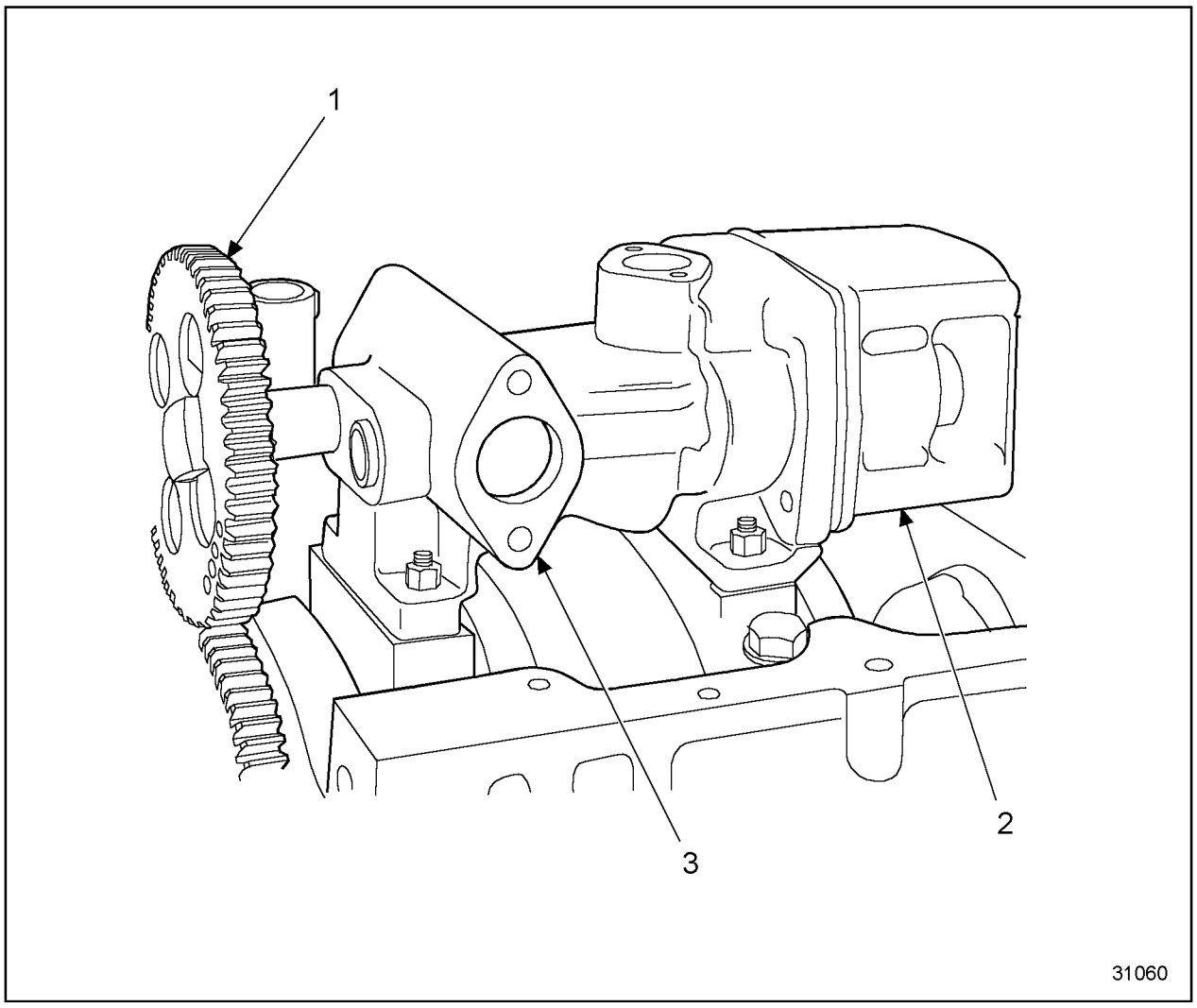


1. Oil Pump
2. Crankshaft Cover
3. Oil Pressure Regulator
4. Oil Pump Inlet Pipe and Screen
5. Oil Pressure Relief Valve

Figure 3-5 Typical Lubricating Oil Pump Mounting (6V or 8V Engines)

To standardize and provide more oil pressure at lower engine speeds, the 8V oil pump is used on 6V engines (effective with 6VF-51331). The 6V and 8V oil pumps are interchangeable, and only the 8V pump is serviced. Only the component parts of the 6V oil pump are serviced.

On a main bearing cap mounted pump, the gear-type scavenging oil pump used on the 6V and 8V engines is mounted on the No. 1 and 2 main bearing caps. An oil pump drive gear, mounted on the crankshaft, drives the oil pump. See Figure 3-6.



1. Oil Pump Driven Gear
2. Scavenging Pump
3. Oil Pump

Figure 3-6 Oil Pump Mounting (6V and 8V Engines)

An opening is provided on the oil pump body for mounting an oil pump inlet pipe and screen assembly. A scavenging oil pump inlet pipe and screen is mounted on the oil pump scavenging body and is supported with brackets to a main bearing cap.

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Oil is drawn by suction from the oil pan through the oil pump inlet screen and pipe into the oil pump, where it is pressurized.

NOTE:
The greatest amount of wear in the oil pump is imposed on the internal drive and driven gears. Keep the lubricating oil clean and acid-free to minimize wear. If dirt and sludge accumulate in the lubricating system, rapid gear wear will occur. Properly service the oil filters to increase the gear life.

3.2.1 Repair or Replacement of Lubricating Oil Pump (6V and 8V Engines)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-7.

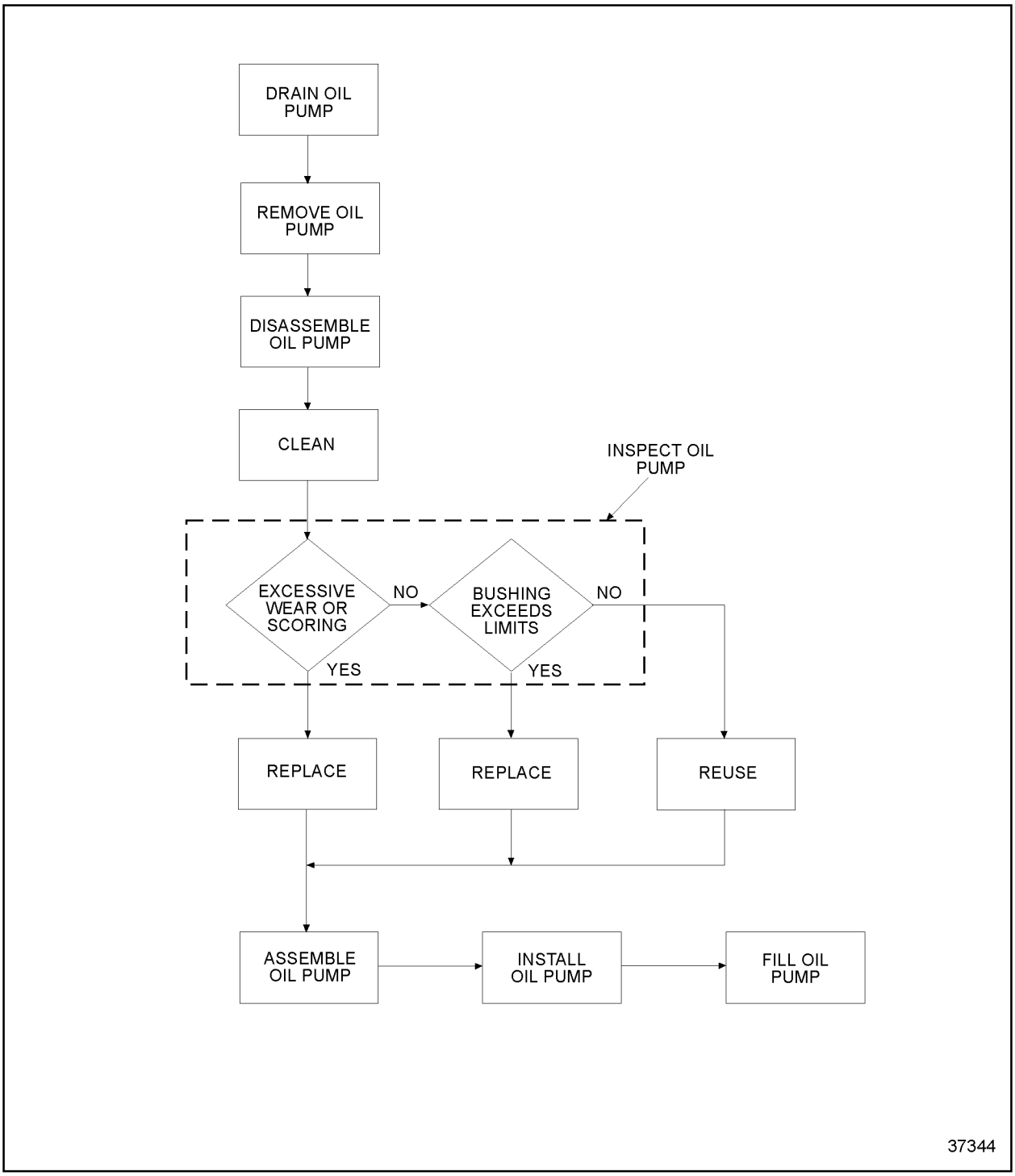


Figure 3-7 Flowchart for Repair or Replacement of Lubricating Oil Pump (6V and 8V)

3.2.2 Removal of Front Mounted Oil Pump (6V and 8V Engines)

Remove the front mounted oil pump as follows:

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1. Drain the oil. Refer to section 13.5.2.
2. Remove the oil pan. Refer to section 3.11.2.
3. Remove the oil pan gasket, and gasket material from the oil pan and the cylinder block.
4. Remove the bolts and lock washers securing the oil inlet pipe and screen support to the crankshaft front cover and the main bearing cap.
5. Remove the oil inlet pipe and screen support as an assembly.
6. Remove the crankshaft front cover from the engine. Refer to section 1.14.2.
7. Remove the oil pump drive hub and key from the crankshaft.

3.2.3 Removal of Main Bearing Cap Mounted Oil Pump(6V and 8V Engines)

Remove the main bearing cap mounted oil pump as follows:

1. Remove the drain plug from the oil pan, and drain the oil. Refer to section 13.5.2.
2. Remove the oil pan bolts, and remove the oil pan. Refer to section 3.11.2.
3. Remove the gasket from the oil pan and the cylinder block.
4. Remove the two mounting bolts and lock washers, and remove the oil pressure regulator valve from the cylinder block.
5. Remove the four bolts and lock washers that attach the oil pressure relief valve to the oil pump body and cylinder block.
6. Remove the two self-locking bolts, and lift the screen off the inlet pipe.
7. Remove the two bolts, and remove the oil pump inlet pipe.
8. Remove the bolts and lock washers that attach the support brackets to the oil pump scavenging inlet pipe and the main bearing cap.
9. Remove the two bolts and lock washers that attach the oil pump scavenging inlet pipe and baffle plate to the scavenging pump body. Remove the scavenging inlet pipe and baffle plate.
10. Remove the nuts and lock washers that attach the oil pump to the main bearing caps.
11. Remove the oil pump assembly.

3.2.4 Removal of the Oil Pump Drive Gear (6V and 8V Engines)

With the oil pan and lubricating oil pump removed, remove the oil pump drive gear from the crankshaft as follows:

1. Remove the crankshaft front cover. Slide the oil slinger off the crankshaft.
2. If required, use a suitable puller to pull the oil pump drive gear off the front end of the crankshaft.
3. Remove the Woodruff key from the crankshaft.

4. Slide the oil pump drive gear spacer off the end of the crankshaft.

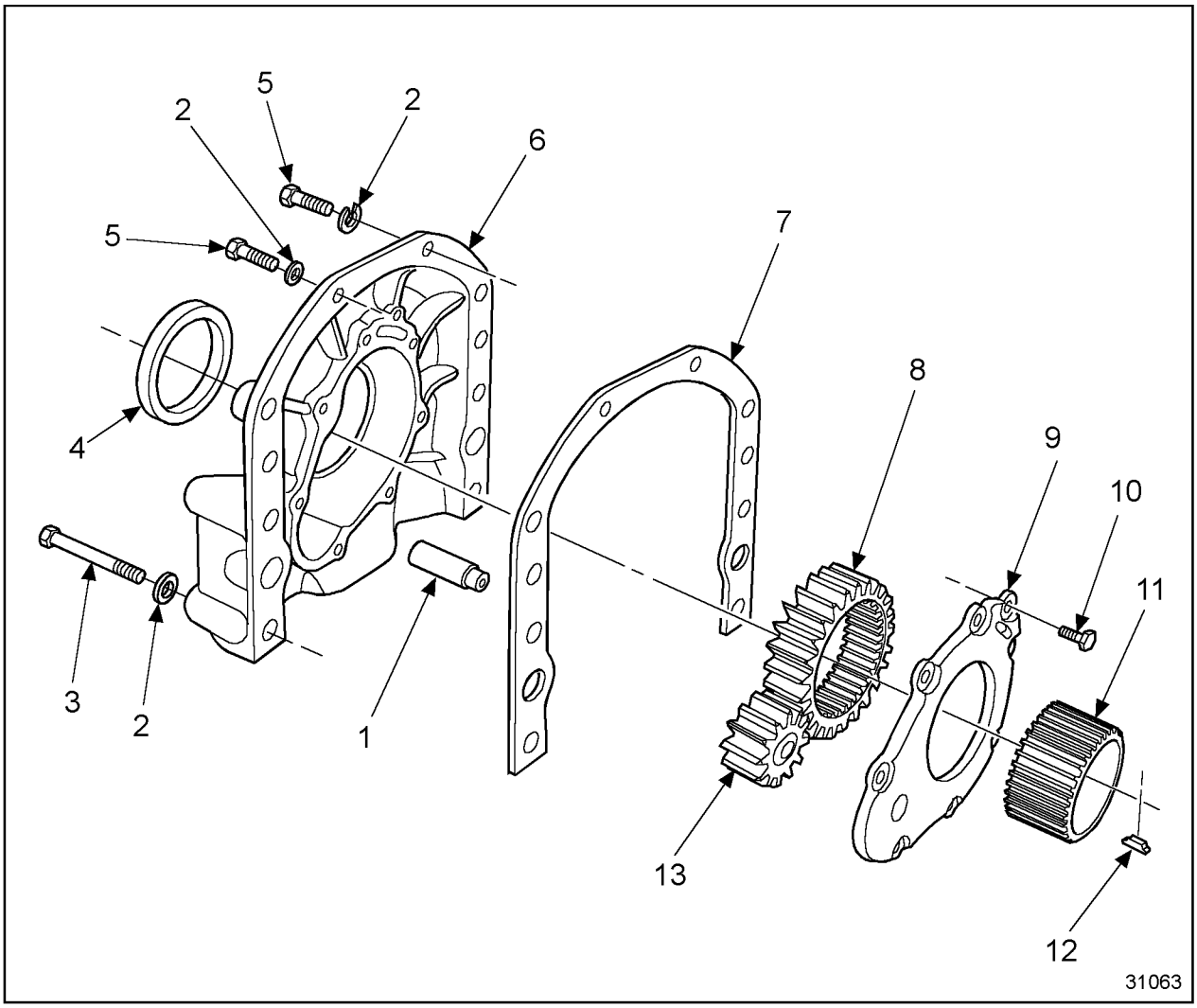
3.2.5 Disassembly of Front Mounted Oil Pump (6V and 8V Engines)

Disassemble the front mounted oil pump as follows:

1. Remove the self-locking bolts securing the oil pump gear retaining plate to the crankshaft front cover. Remove the retaining plate.

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2. Remove the oil pump drive and driven gears from the crankshaft front cover. See Figure 3-8.

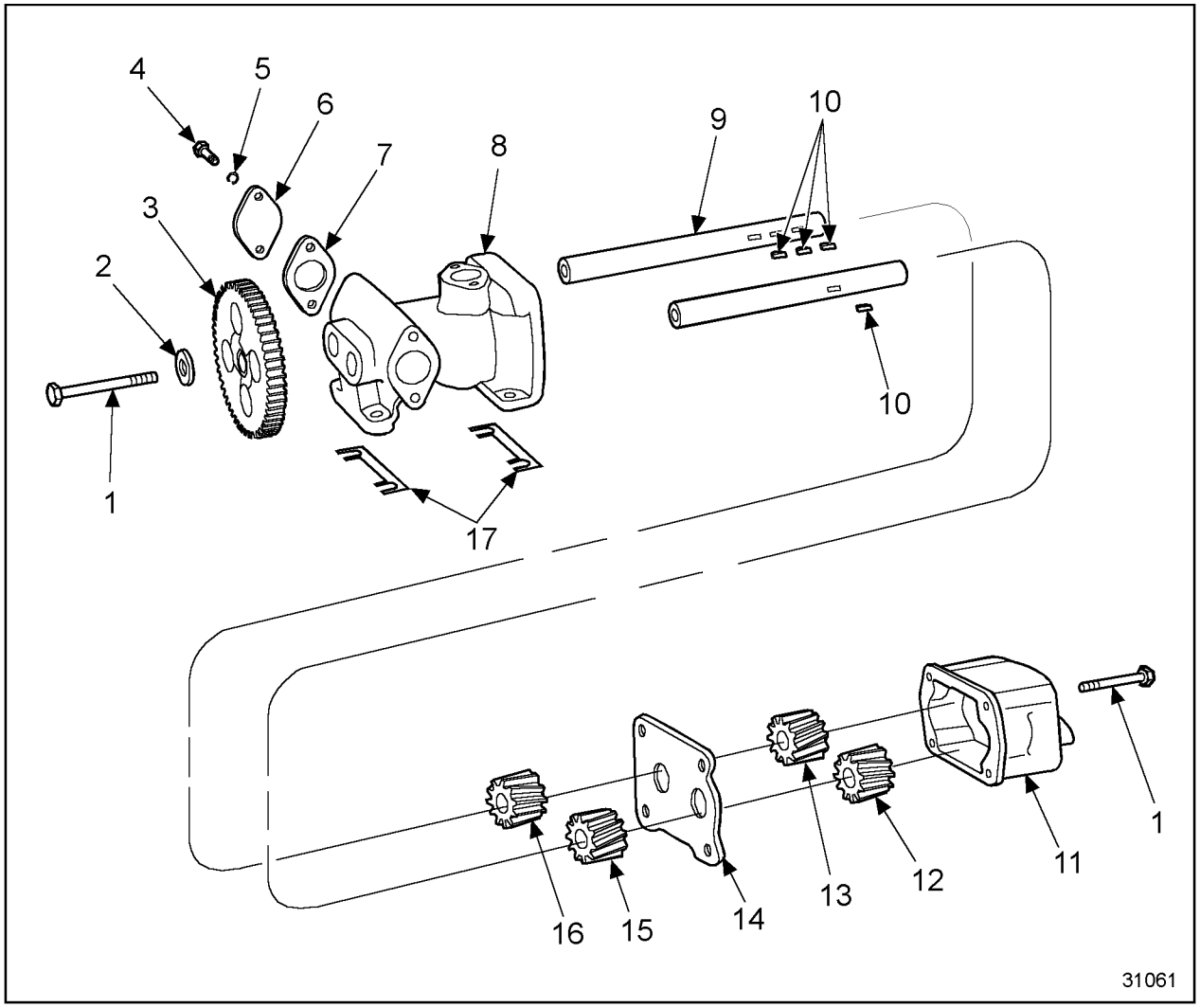


1. Driven Shaft
2. Washer
3. Long Bolt
4. Oil Seal
5. Short Bolt
6. Crankshaft Front Cover
7. Gasket
8. Drive Gear
9. Retaining Plate
10. Retaining Plate Bolt
11. Drive Hub
12. Key
13. Driven Gear

Figure 3-8 Front Mounted Lubricating Oil Pump (6V and 8V Engines)

3.2.6 Disassembly of Main Bearing Cap Mounted Oil Pump(6V and 8V Engines)

Disassemble the main bearing cap mounted oil pump as follows: See Figure 3-9.



1. Long Bolt (2)
2. Washer
3. Pump Drive-Driven Gear
4. Short Bolt
5. Lock Washer
6. Cover
7. Gasket
8. Pump Body
9. Drive Shaft
10. Keys (4)
11. Scavenging Pump Body
12. Driven Gear (Scavenging)
13. Drive Gear (Scavenging)
14. Spacer
15. Driven Gear
16. Drive Gear
17. Shims (2)

Figure 3-9 Main Bearing Cap Mounted Oil Pump (6V and 8V Engines)

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NOTE:
Carefully observe the position of all parts, including the oil pump inlet pipe and the scavenging oil pump inlet pipe during disassembly to facilitate oil pump assembly.

1. Remove the four self-locking bolts that attach the scavenging pump body to the oil pump body. Remove the scavenging pump body.
2. Remove the scavenging pump drive and driven gears from the oil pump drive and driven shafts.
3. Remove the Woodruff key from the drive shaft, and slide the spacer off the shaft end.
4. Withdraw the driven shaft and driven gear as an assembly from the oil pump body.
5. Remove the bolt and special washer securing the oil pump driven gear to the drive shaft. Remove the gear.
6. Withdraw the drive shaft and gear as an assembly from the oil pump body.
7. Press the oil pump drive shaft out of the oil pump gear. Remove the Woodruff key from the shaft.
8. Press the driven shaft out of the driven gear. Remove the Woodruff key from the shaft.
9. Remove the cover and gasket from the oil pump body.

3.2.6.1 Cleaning of Oil Pump (6V and 8V Engines)

Clean the oil pump as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean the 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. Remove the screen and cover from the oil inlet pipe assembly.

CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

4. Clean the 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.

5. Dry them with compressed air.
6. Assemble the screen, cover, and oil intake pipe.

3.2.6.2 Inspection of Front Mounted Oil Pump (6V and 8V Engines)

Inspect the front mounted oil pump as follows:

1. Visually inspect the oil pump gear cavity for wear or scoring.
   [a] If worn or scored, replace the cover. If necessary, replace the front oil seal. Refer to section 1.8.6.
   [b] If not worn or scored, proceed with inspection.

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2. Inspect the driven gear shaft for wear or scoring.

   [a] If excessively worn or scored, replace the driven gear shaft. Refer to section 3.2.7.

NOTE:
When a new shaft is pressed in place, the shaft shoulder must be flush to 0.51 mm (0.020 in.) below the finished face of the crankshaft front cover.

   [b] If not worn or scored, continue inspection.

3. Inspect the oil pump gear teeth and the pump drive hub for wear or scoring.

   [a] If worn or scored, replace the gear and hub. Refer to section 3.2.7.

   [b] If not worn or scored, continue inspection.

4. Inspect the drive and driven gear bushing for wear.

   [a] If worn, replace both the drive and driven gears. They are only serviced as a set. Refer to section 3.2.8.

NOTE:
The clearance between the driven gear bushing and the shaft should be 0.025-0.0635 mm (0.001-0.0025 in.) with new parts. With used parts, the maximum clearance allowed is 0.089 mm (0.0035 in.).

   [b] If not worn, proceed with inspection.

5. Inspect the oil pump gear retaining plate inner face for scoring and wear.

   [a] If scored or worn, replace the retaining plate. Refer to section 3.2.10.

NOTE:
Whenever the oil pump is removed for service, remove and inspect the oil pressure regulator and oil pressure relief valves. Refer to section 3.4.2 and refer to section 3.5.2.

   [b] If not scored or worn, reuse the parts.

3.2.6.3 Inspection of Main Bearing Cap Mounted Oil Pump(6V and 8V Engines)

Inspect the main bearing cap mounted oil pump as follows:

1. Visually inspect the internal gear cavity of the pump body and scavenger pump (if used) for wear or scoring.

   [a] If the pump body is excessively worn or scored, it must be replaced. Refer to section 3.2.11.

   [b] If not excessively worn or scored, continue inspection.

2. Inspect the pump cover or spacer between the pump and scavenger pump bodies for wear.

   [a] If worn, replace the pump cover and spacer. Refer to section 3.2.11.

[b] If not worn, reuse the parts.

3. Inspect the bushings in the pump body (or scavenging body) and cover.

[a] If bushings are excessively worn, replace the pump body (or scavenging body) and cover. Refer to section 3.2.11.

NOTE:
Bushings must be properly located and positioned. See Figure 3-10. The gear and bushing bores must be concentric within 0.05 mm (0.002 in.) total indicator reading. The shaft-to-bushing clearance with new parts is 0.0381-0.0813 mm (0.0015–0.0032 in.).

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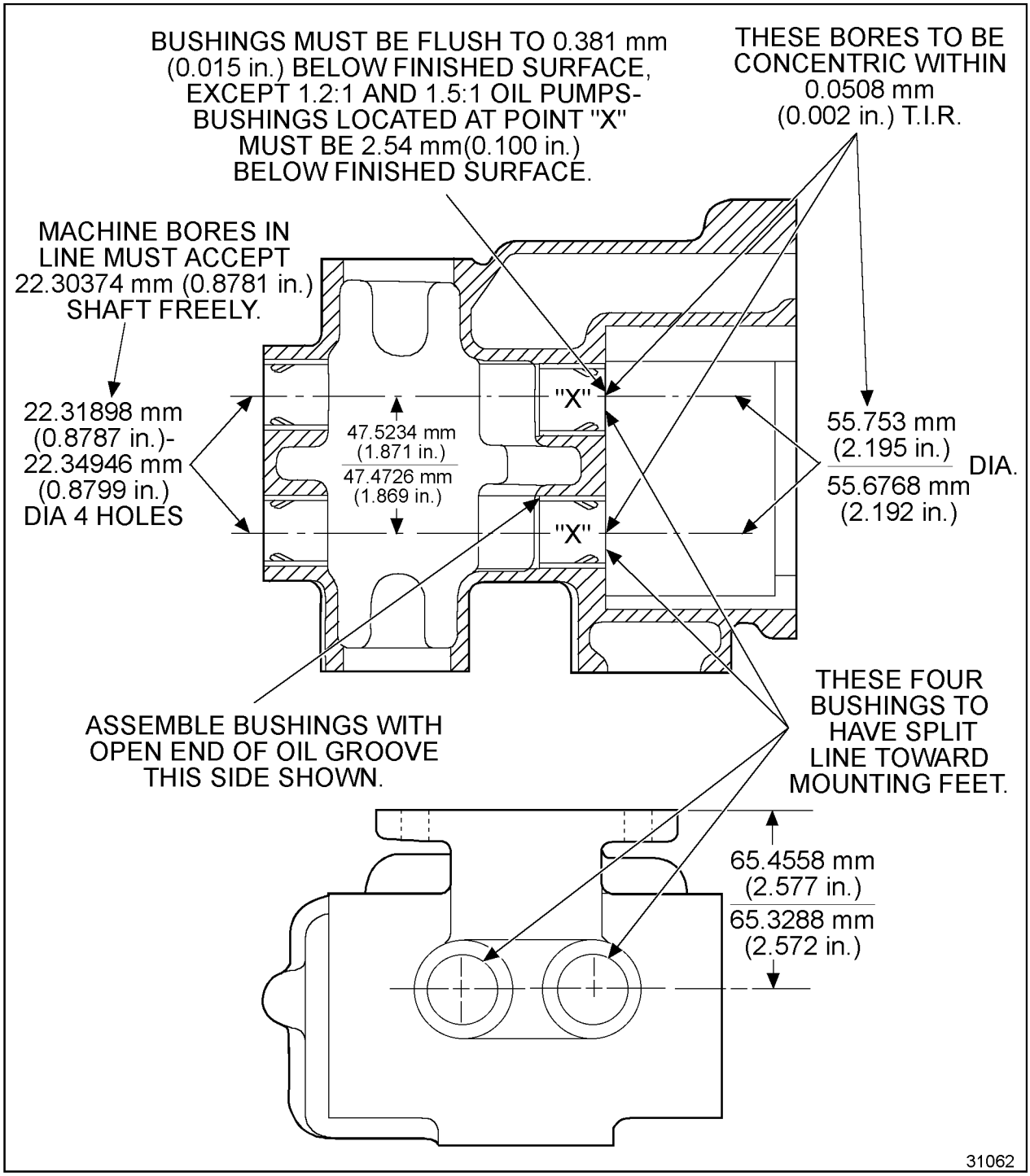


Figure 3-10 Diameter and Location of Bushing in Oil Pump(6V and 8V Engines)

[b] If bushings are within specifications, reuse the parts.

4. Inspect the gear teeth for scoring or wear.

NOTICE:
The use of excessively worn gears will result in low engine oil pressure. This, in turn, may lead to serious engine damage.

[a] If gear teeth are excessively scored or worn, they must be replaced. Refer to section 1.29.8.

[b] If gear teeth are not scored or worn, they may be reused.

5. Inspect the pump shafts and keyways for wear.

[a] If worn, replace the shafts. Refer to section 3.2.8.

[b] If not worn, the shafts may be reused.

6. Inspect the external pump drive-driven gear for wear.

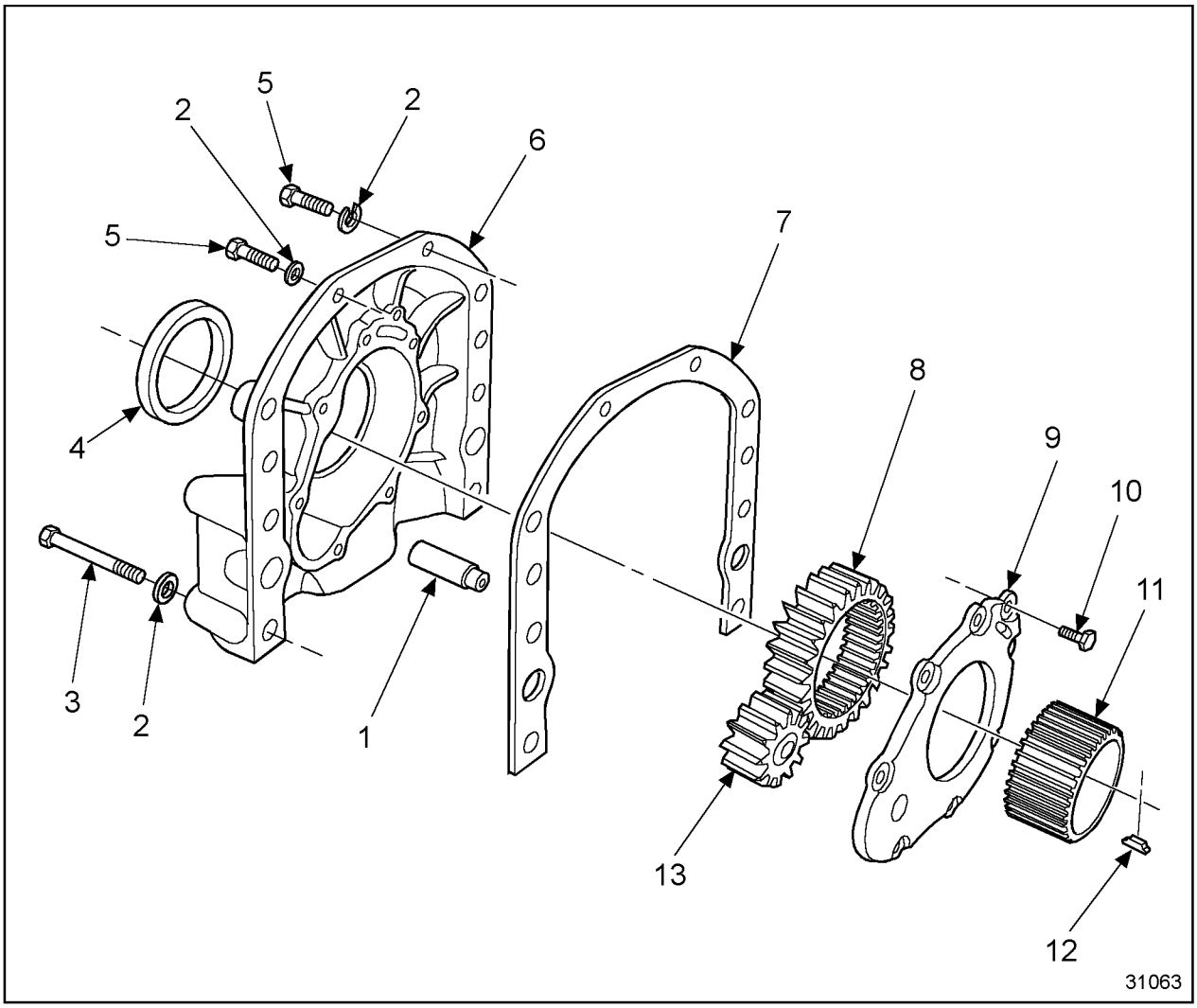
[a] If worn, the gear must be replaced. Refer to section 1.29.8.

[b] If not worn, the gear may be reused.

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3.2.7 Assembly of Front Mounted Oil Pump (6V and 8V Engines)

Assemble the front mounted oil pump as follows: See Figure 3-11.



1. Driven Shaft
2. Washer
3. Long Bolt (2)
4. Oil Seal
5. Short Bolt (2)
6. Crankshaft Front Cover
7. Gasket
8. Drive Gear
9. Retaining Plate
10. Retaining Plate Bolt
11. Drive Hub
12. Key
13. Driven Gear

Figure 3-11 Front Mounted Lubricating Oil Pump (6V and 8V Engines)

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the oil pump gears and the driven gear shaft with engine oil.
2. Install the gears in the crankshaft front cover.
3. Install the gear retaining plate, and secure it to the crankshaft front cover with eight 5/16 in.-18 x 3/4 in. self-locking bolts. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

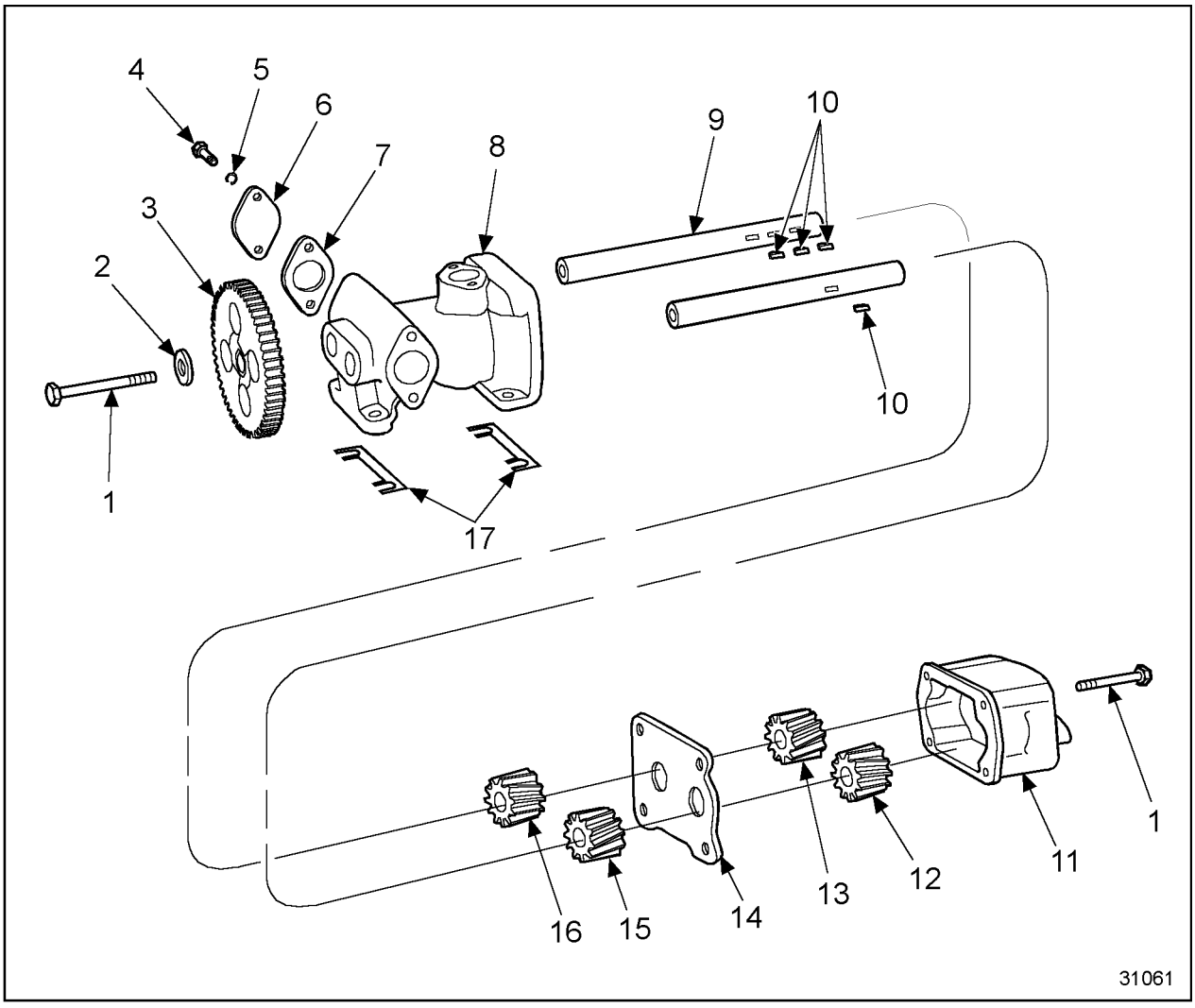
NOTE:
Due to the close clearance between the oil pump and the crankshaft, use self-locking bolts.

4. Install the key in the crankshaft, and slide the oil pump drive hub in place.

3.2.8 Assembly of Main Bearing Cap Mounted Oil Pump(6V and 8V Engines)

Assemble the main bearing cap mounted oil pump as follows: See Figure 3-12.

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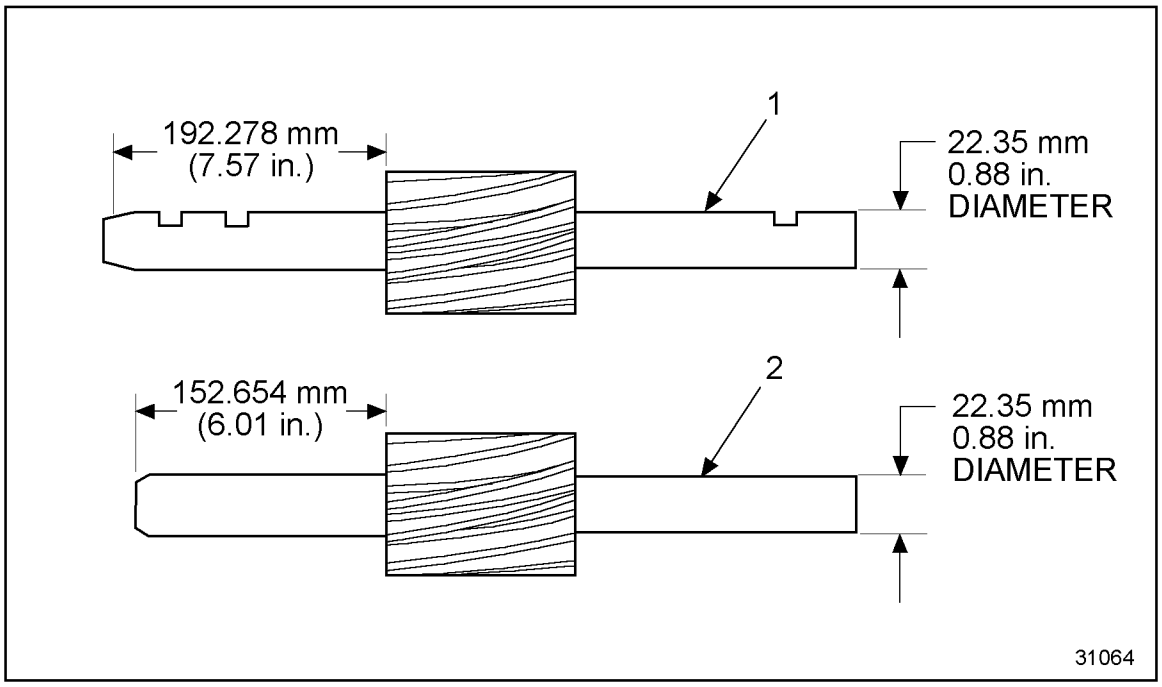
1. Long Bolt (2)
2. Washer
3. Pump Drive-Driven Gear
4. Short Bolt
5. Lock Washer
6. Cover
7. Gasket
8. Pump Body
9. Drive Shaft
10. Keys (4)
11. Scavenging Pump Body
12. Driven Gear (Scavenging)
13. Drive Gear (Scavenging)
14. Spacer
15. Driven Gear
16. Drive Gear
17. Shims (2)

Figure 3-12 Main Bearing Cap Mounted Oil Pump (6V and 8V Engines)

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Insert the Woodruff key in the oil pump drive shaft keyway, and apply a light coat of engine oil to the shaft.
2. Press the drive shaft into the oil pump drive gear. Position the gear 192.278 mm (7.570 in.) from the end of the drive shaft, using tool J 22398. See Figure 3-13.



1. Drive Shaft
2. Driven Shaft

Figure 3-13 Location of Oil Pump Gear on Shaft

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Insert the Woodruff key in the keyway of the driven shaft. Apply a light coat of engine oil to the shaft.
4. Press the shaft in the driven gear. Position the gear 152.654 mm (6.010 in.) from the end of the shaft using tool J 22398.
5. Install the drive shaft and gear assembly in the oil pump body.

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6. Install the oil pump driven gear on the drive shaft.
7. Place the special washer on the bolt with the crown side toward the bolt head, and tighten the bolt to 81-85 N·m (60-65 lb·ft) torque.
8. Install the driven shaft and gear assembly in the pump body.
9. Slide the spacer on the shafts. Insert the two remaining Woodruff keys in the drive shaft.
10. Slide the scavenging pump gears on the shafts.

NOTE:
The scavenging pump drive and driven gears must be in the same relative position as the oil pump drive and driven gears.

11. Secure the scavenging pump body to the oil pump body with four self-locking bolts.
12. Place a new gasket on the oil pump body side cover, and fasten it to the pump body with two bolts and lock washers.

NOTE:
The oil pump gears must turn freely after assembly. Any bind in the pump must be eliminated before it is installed on the engine.

3.2.9 Installation of Front Mounted Oil Pump (6V and 8V Engines)

Install the front mounted oil pump as follows:

1. Install the crankshaft front cover on the engine. Refer to section 1.14.4.
2. Install the oil inlet pipe and screen assembly. Use a new gasket between the oil inlet pipe and the crankshaft front cover.
3. Install the oil pan, using the new gasket. Refer to section 3.11.3.
4. Starting with the center bolt on each side and working toward each end of the oil pan, tighten the 3/8 in.-16 bolts to 14-27 N·m (10-20 lb·ft) torque.
5. Fill the oil pan to the proper level on the dipstick with the recommended lubricating oil. Refer to section 13.5.1 and refer to section 5.2.

3.2.10 Installation of Oil Pump Driving Gear on the Crankshaft(6V and 8V Engines)

Install the oil pump driving gear on the crankshaft as follows:

NOTE:
Whenever a 6V or 8V engine crankshaft-mounted oil pump drive gear requires replacement. Loctite RC/620 retaining compound, or equivalent, must be used to ensure proper gear retention.

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1. Measure the crankshaft diameter and gear bore.

NOTE:
Both parts must be within the specified limits. Replace, if necessary. C/S dia. - 63.449 mm (2.498 in.) / 63.5 mm (2.5 in.) Gear Bore - 63.5127 mm (2.5005 in.) / 63.5254 mm (2.5010 in.)

2. Clean the crankshaft, spacer, gear and key with a chlorinated solvent, such as that used with a dye penetrant kit. Ensure parts are dry before proceeding.
3. Install the spacer and key, but do not apply primer or retaining compound to either part.
4. Apply Loctite Primer "T" to the crankshaft and the gear bore. Allow to dry a minimum of 5 minutes before continuing. Follow the manufacturer instructions on the container.
5. Shake well before using, and apply a small amount of Loctite RC/620 to the gear bore. See Figure 3-14.

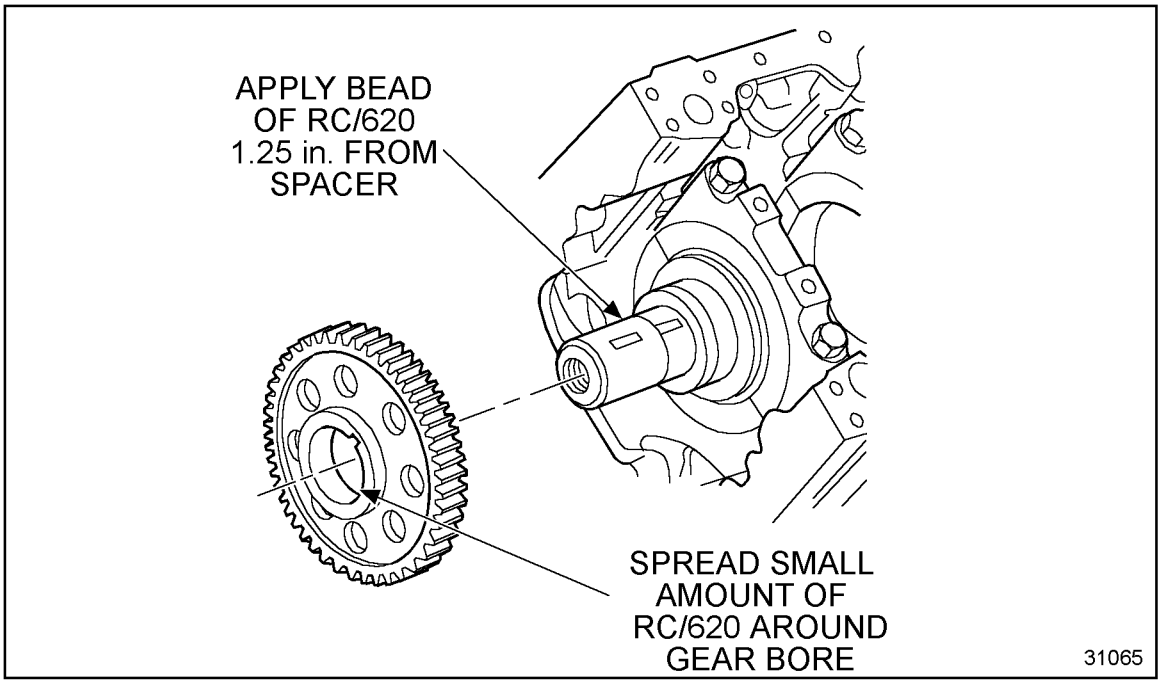


Figure 3-14 Location of Loctite RC/620

6. Spread the compound to ensure entire bore is covered. Remove excess compound from the chamfer area of the gear, but do not wipe dry.
7. Apply a thin bead of RC/620 around the crankshaft outer diameter, approximately 31.75 mm (1.25 in.) in front of the installed spacer. Do not spread the bead or wipe dry.
8. Slide the gear straight up to the spacer.

NOTE:
Ensure gear is in its final position with the key in place, since the Loctite will start to harden almost immediately. It will be impossible to move the gear later.

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9. Wipe the crankshaft clean.
10. Press the gear on the crankshaft. Drive the gear tightly against the spacer on the crankshaft.
11. Install the oil slinger with the dished side away from the gear.
12. Install the engine front cover. Refer to section 1.11.3.
13. Allow the Loctite to cure for four hours minimum before starting the engine.

NOTE:
Chemicals such as Loctite RC/620 have a shelf life of one year which should not be exceeded. Check with a Loctite supplier for product use beyond its recommended life.

3.2.11 Installation of the Main Bearing Cap Mounted Oil Pump(6V and 8V Engines)

Install the main bearing cap mounted oil pump as follows:

1. Position the oil pump over the studs on the No. 1 and 2 main bearing caps so that the gear teeth mesh with the crankshaft oil pump drive gear teeth.
2. Fasten the oil pump to the main bearing caps with four nuts and lock washers.

NOTE:
Place the same number of shims between the oil pump feet and the main bearing caps as were removed. Removing or installing shims controls the gear tooth adjustment. The addition or removal of one set of 0.13 mm (0.005 in.) shims will change the gear tooth clearance by 0.089 mm (0.0035 in.).

3. With the engine in the running position, check the tooth clearance between the oil pump gear and the crankshaft gear.

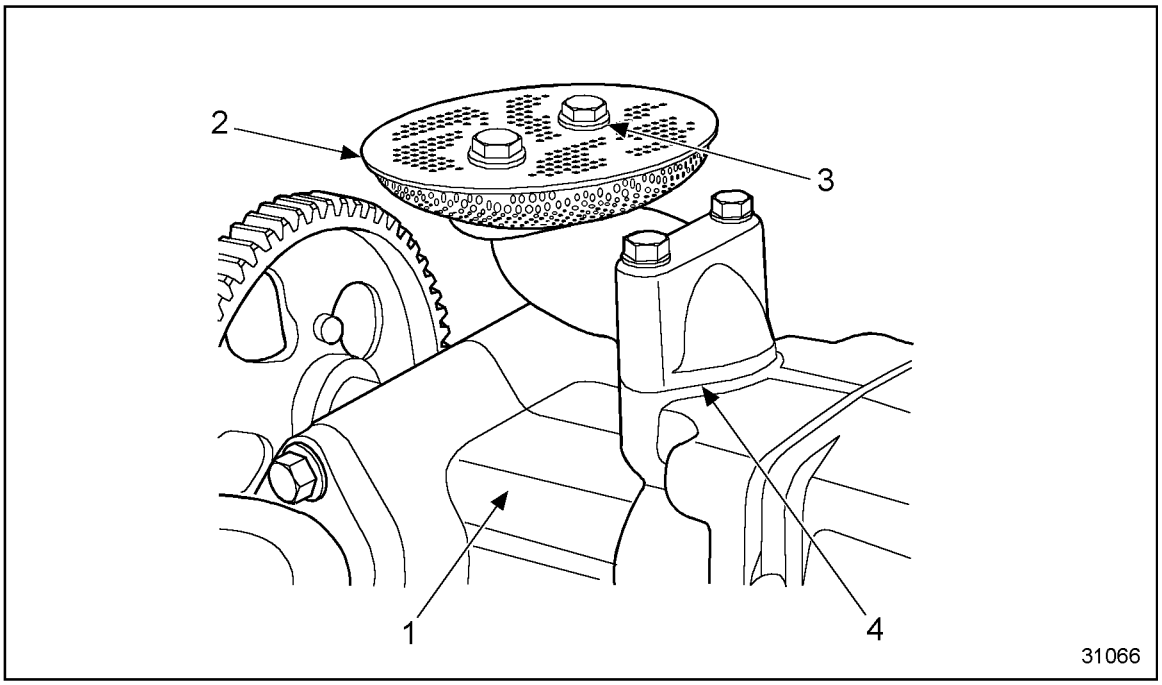
NOTE:
Shims are used between the oil pump mounting feet and the main bearing caps. Whenever the original pump is installed, the same shims or an equal number of new (identical) shims must be placed under the front and rear mounting feet. Adjust to obtain the proper clearance between the gears.

NOTE:
Use a feeler gage or a suitable indicator. The clearance should be 0.1524-0.3048 mm (0.006-0.012 in.).

4. Use two new gaskets and position the oil pressure relief valve on the cylinder block and against the oil pump body. Secure the oil pressure relief valve with four bolts and lock washers.
5. Use a new gasket, and position the oil pump inlet pipe on the oil pump body. Secure the inlet pipe with two bolts and lock washers.

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6. Place the screen on the inlet pipe, and fasten it with two self-locking bolts and two spacers. See Figure 3-15.

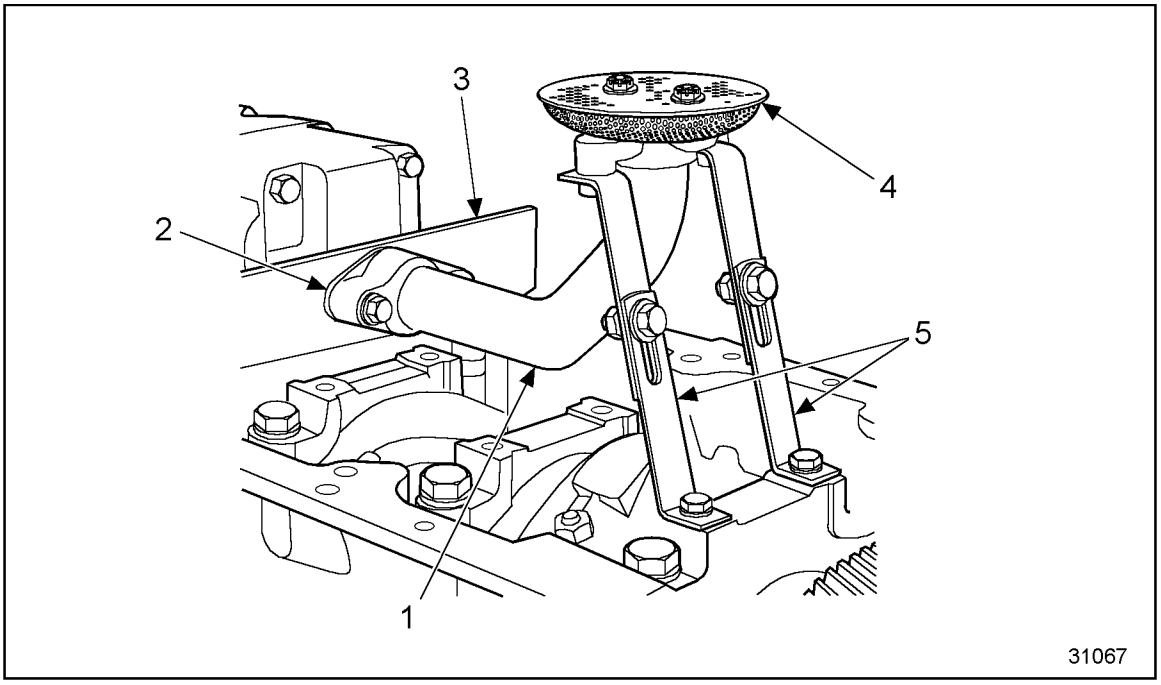


1. Oil Pump
2. Inlet Screen
3. Spacer
4. Gasket

Figure 3-15 Inlet Pipe and Screen Mounting

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7. Place a new gasket between the scavenging pump body and baffle plate and between the baffle plate and the scavenging oil pump inlet pipe. Secure the pipe and baffle with two bolts and lock washers. See Figure 3-16.



1. Scavenging Inlet Pipe
2. Gasket
3. Baffle
4. Inlet Screen
5. Support Bracket

Figure 3-16 Scavenging Inlet Pipe and Screen Mounting

8. Attach the two support brackets to the scavenging inlet pipe. Secure the brackets to the main bearing cap with bolts and lock washers.
9. Place the screen on the scavenging inlet pipe, and fasten it with two self-locking bolts and two plain washers.
10. Check all bolts.

NOTE:
Bolts should be tight to ensure that there will be no leaks in the oil pump and pipe connections.

11. Use a new gasket, and secure the oil pump pressure regulator valve to the cylinder block with two bolts and lock washers.

12. Place a new gasket on the oil pan, and install the pan on the cylinder block. Start all oil pan bolts before tightening them.

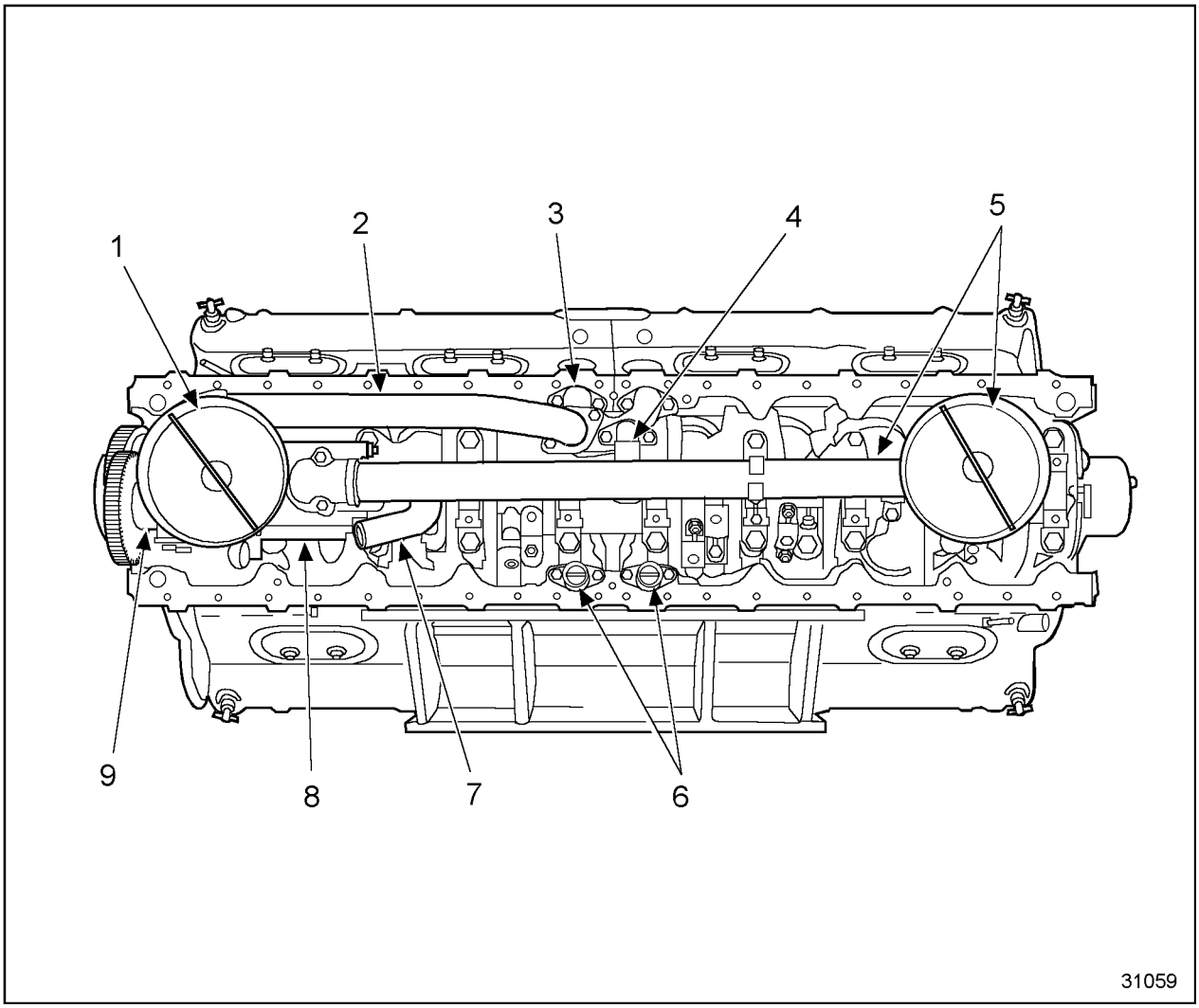
NOTE:
Excessive bolt tightening will crush the oil pan gasket.

13. Tighten the bolts snugly but not excessively, starting with the center bolts and working toward each end of the oil pan.
14. Fill the oil pan to the proper level with the recommended oil. Refer to section 13.5.1 and refer to section 5.2.

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3.3 LUBRICATING OIL PUMP (12V AND 16V ENGINES)

The gear-type scavenging lubricating oil pump is mounted on number seven and eight main bearing caps (12V engines) and number nine and ten main bearing caps (16V-92 engines). It is gear driven from the rear end of the crankshaft. See Figure 3-17. On some engines, the oil pump is mounted at the front on the number one and two main bearings caps and is gear-driven by an oil pump drive gear bolted to the front of the crankshaft gear.



1. Oil Pump Inlet
2. Oil Pump Outlet Tube
3. Junction Block
4. Oil Pressure Relief Valve
5. Scavenging Pump Inlet Pipe and Screen
6. Oil Pressure Regulator Valves
7. Scavenging Pump Outlet Pipe
8. Scavenging Pump
9. Oil Pump

Figure 3-17 Typical Lubricating Oil Pump Rear Mounted(12V and 16V Engines)

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NOTE:
The greatest amount of wear in the oil pump occurs on the internal drive and driven gears. Keep the lubricating oil clean and acid-free to minimize wear. If dirt and sludge accumulate in the lubricating system, rapid gear wear will occur. Properly service the oil filters to increase the gear life.

3.3.1 Repair or Replacement of Oil Pump (12V and 16V Engines)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-18.

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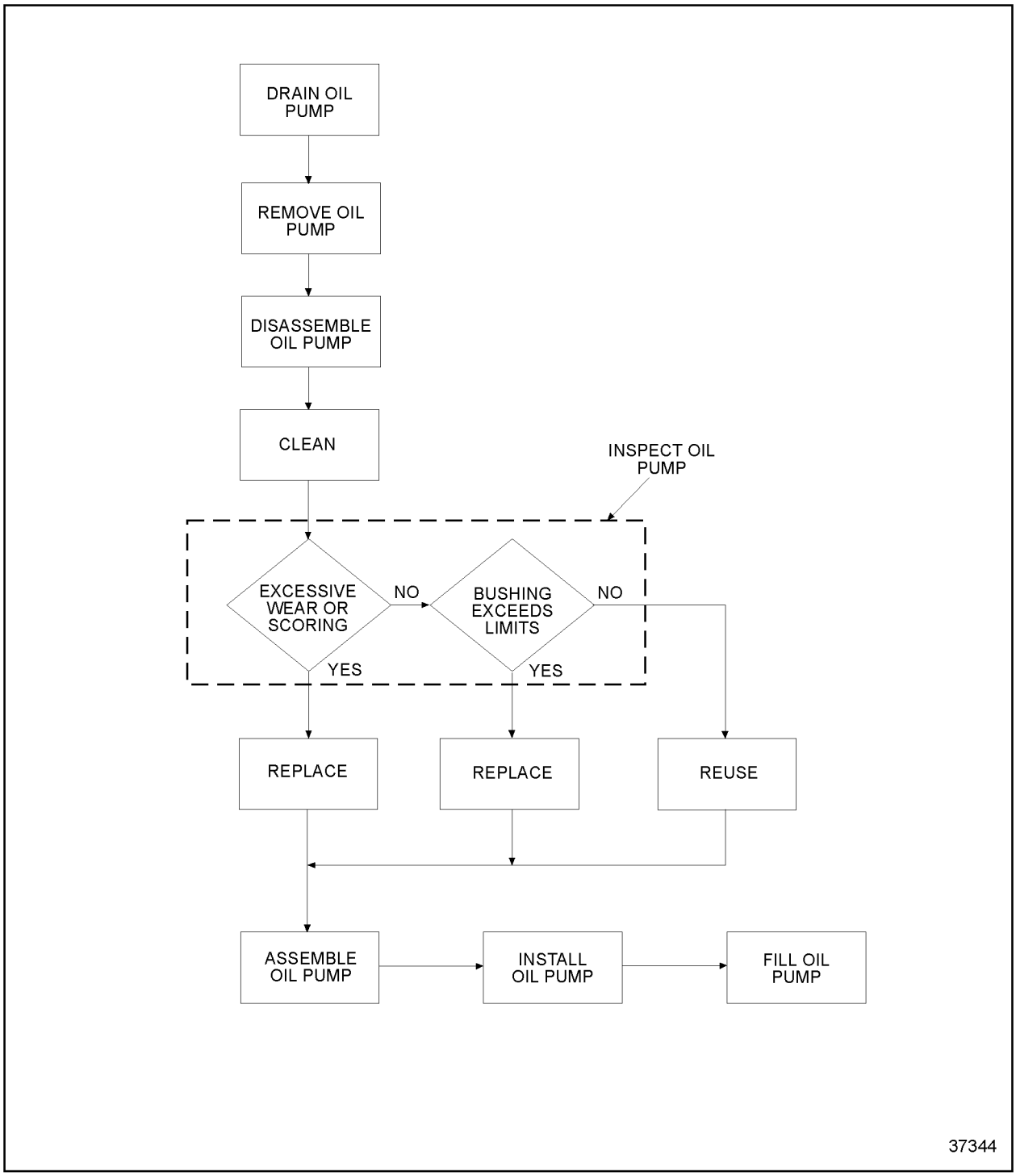


Figure 3-18 Flowchart for Repair or Replacement of Oil Pump(12V and 16V Engines)

3.3.2 Removal of Oil Pump (12V and 16V Engines)

Remove the oil pump as follows:

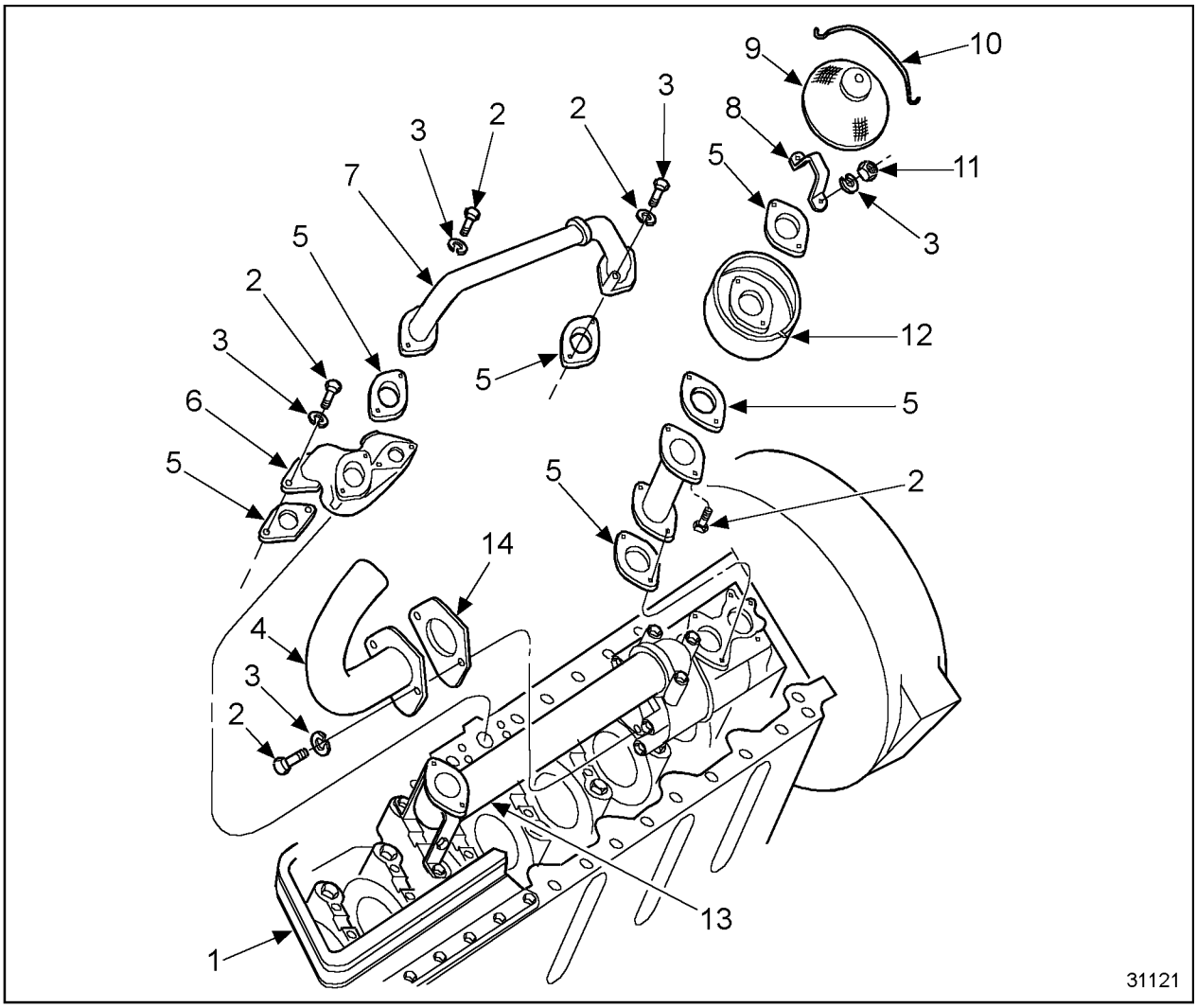
1. Drain the oil. Refer to section 13.5.2.
2. Remove the oil pan(s). Refer to section 3.11.2.
3. Remove and discard the oil pan gasket.
4. Remove the inlet and outlet tube assemblies from the oil pump and the scavenging pump.
5. Remove the nuts and lock washers that attach the oil pump to the main bearing caps.
6. Remove the oil pump.
7. Refer to section 1.29.2 for gear removal.

3.3.3 Disassembly of Oil Pump (12V and 16V Engines)

Disassemble the oil pump as follows:

NOTE:
Observe the relative position of the parts during disassembly to facilitate reassembly of the pump. See Figure 3-19.

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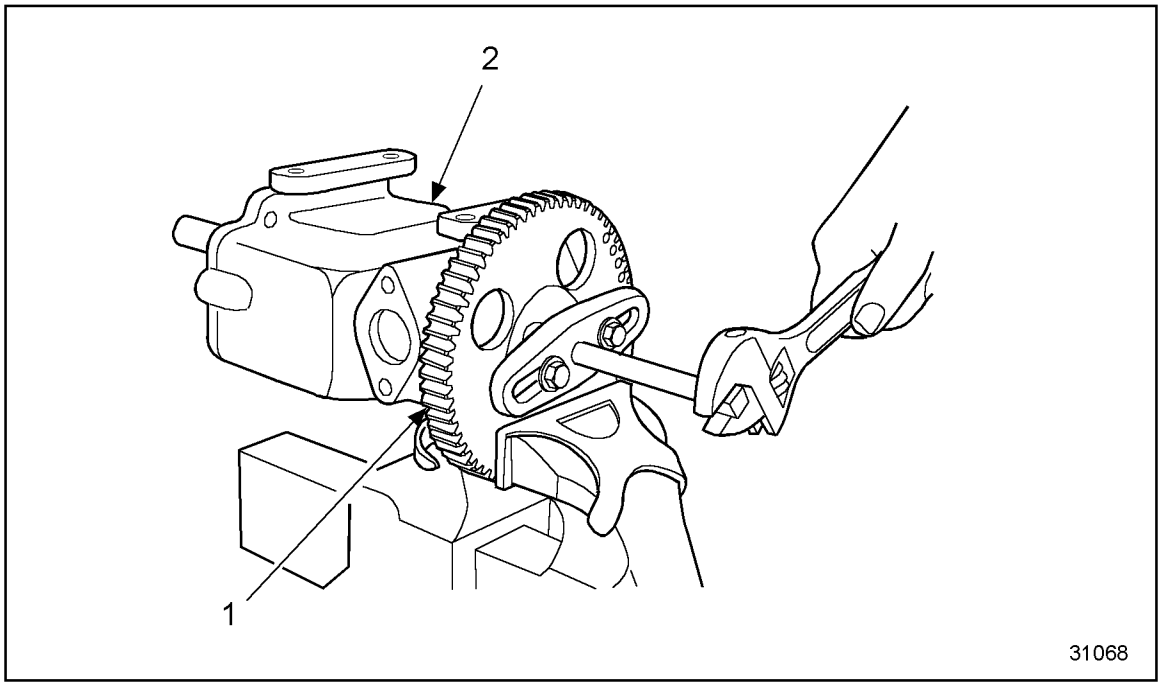


1. Cylinder Block
2. Bolt
3. Lock Washer
4. Scavenging Outlet Pipe
5. Gasket
6. Junction Block
7. Oil Pump Outlet Tube Assembly
8. Oil Pump Screen Support
9. Screen
10. Oil Pump Inlet Retainer
11. Nut
12. Screen Housing
13. Scavenging Inlet Tube
14. Outlet Gasket

Figure 3-19 Disassembly of Oil Pump for 12V and 16V Engines

1. Remove the five bolts, and lift the scavenging pump body from the pump body.
2. Withdraw the scavenging pump drive and driven gears from the pump shafts.
3. Remove the Woodruff keys from the drive shaft.
4. Remove the spacer.
5. Withdraw the driven shaft and gear as an assembly from the pump body.

6. Attach puller J 24420-C to the pump driven gear.
7. Place a couple of washers or a nut between the end of the pump shaft and the puller screw to protect the end of the pump shaft.
8. Turn the puller screw clockwise to remove the gear. See Figure 3-20.



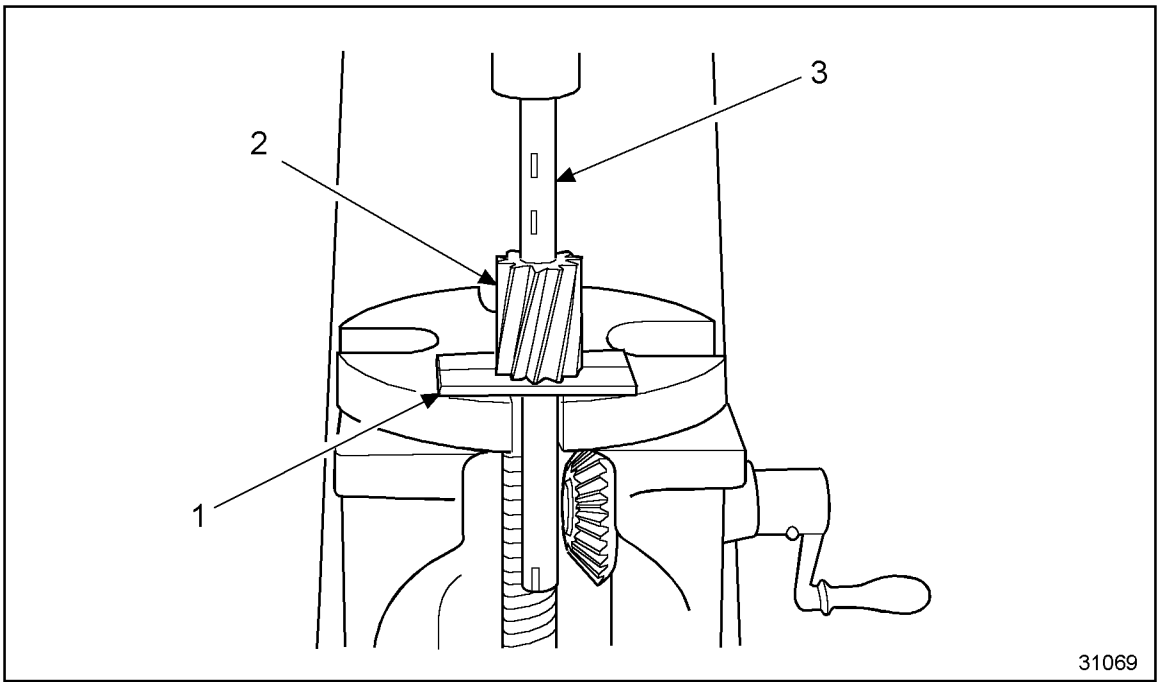
1. Oil Pump Drive Gear
2. Oil Pump Assembly

Figure 3-20 Removing Oil Pump Driven Gear

9. Remove the key from the shaft.
10. Withdraw the drive shaft and gear as an assembly from the pump body.

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11. Press the oil pump drive shaft out of the oil pump gear. See Figure 3-21.



1. Split Plates
2. Oil Pump Gear
3. Oil Pump Shaft

Figure 3-21 Pressing Oil Pump Gear From Shaft

12. Remove the key from the shaft.

3.3.3.1 Cleaning of Oil Pump (12V and 16V Engines)

Clean the oil pump as follows:

CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean the 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 with compressed air.
3. Remove the screen and cover from the oil inlet pipe assembly.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

4. Clean the 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.

5. Dry them with compressed air.
6. Reassemble the screen, cover, and oil intake pipe.

3.3.3.2 Inspection of Oil Pump (12V and 16V Engines)

Inspect the oil pump as follows:

1. Visually inspect the internal gear cavity of the pump body and scavenger pump (if used) for wear or scoring.
   [a] If the pump body is excessively worn or scored, it must be replaced.
   [b] If not excessively worn or scored, continue inspection.
2. Inspect the pump cover and spacer between the pump and scavenger pump bodies for wear.
   [a] If worn, replace the pump cover and spacer. Refer to section 3.3.5.
   [b] If not worn, reuse the parts.
3. Inspect the bushings in the pump body (or scavenging body) and cover.

[a] If bushings are excessively worn, replace the pump body (or scavenging body) and cover. Refer to section 3.3.4.

NOTE:
Bushings must be properly located and positioned. See Figure 3-22. The gear and bushing bores must be concentric within 0.05 mm (0.002 in.) total indicator reading. The shaft-to-bushing clearance with new parts is 0.0381-0.0813 mm (0.0015–0.0032 in.).

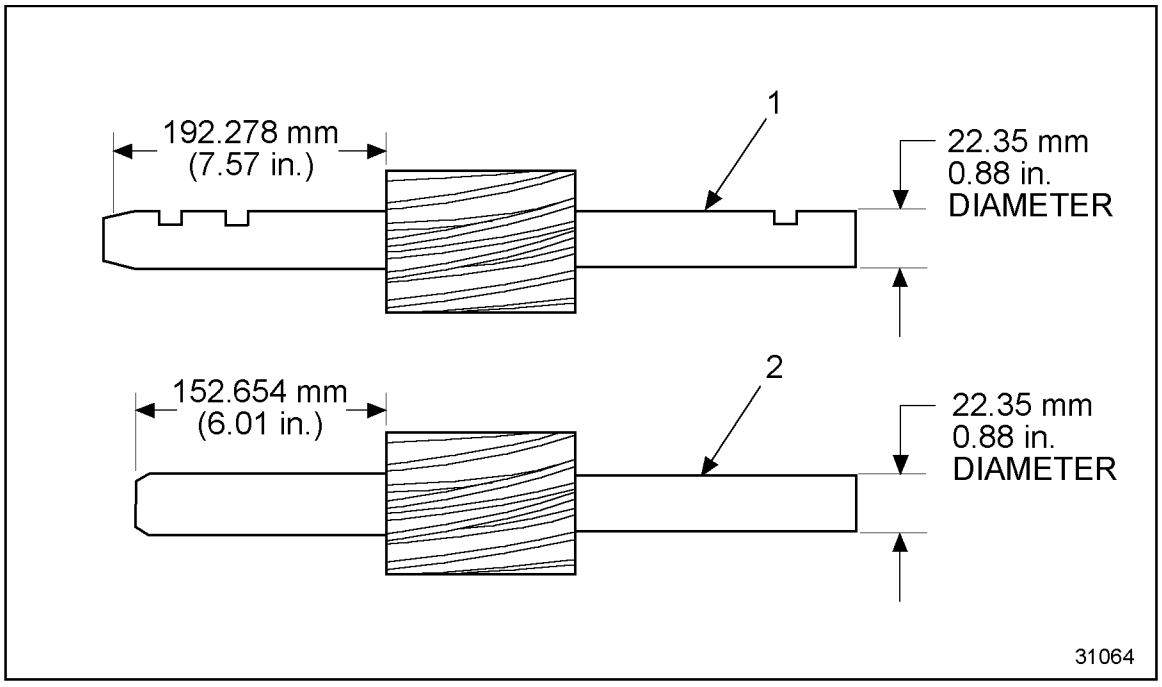


Figure 3-22 Diameter and Location of Bushing in Oil Pump(12V and 16V Engines)

[b] If bushings are not excessively worn, reuse the parts.

4. Inspect the gear teeth for scoring or wear.

NOTICE:
The use of excessively worn gears will result in low engine oil pressure. This, in turn, may lead to serious engine damage.

[a] If gear teeth are excessively scored or worn, they must be replaced. Refer to section 1.29.8.

[b] If gear teeth are not scored or worn, they may be reused.

5. Inspect the pump shafts and keyways for wear.

[a] If worn, replace the shafts.Refer to section 3.3.4.

[b] If not worn, the shafts may be reused.

6. Inspect the external pump drive-driven gear for wear.

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[a] If worn, the gear must be replaced. Refer to section 1.29.8.

[b] If not worn, the gear may be reused.

3.3.4 Assembly of Oil Pump (12V and 16V Engines)

Assemble the oil pump as follows:

1. Install the oil pump gear key in the oil pump drive shaft.
2. Lubricate the drive shaft.
3. Press the oil pump drive gear on the shaft with tool J 9380. See Figure 3-23.

NOTE:
Tool J 9380 will position the gear 139.7 mm (5.50 in.) from the end of the shaft and prevent the shaft from bending during gear installation.

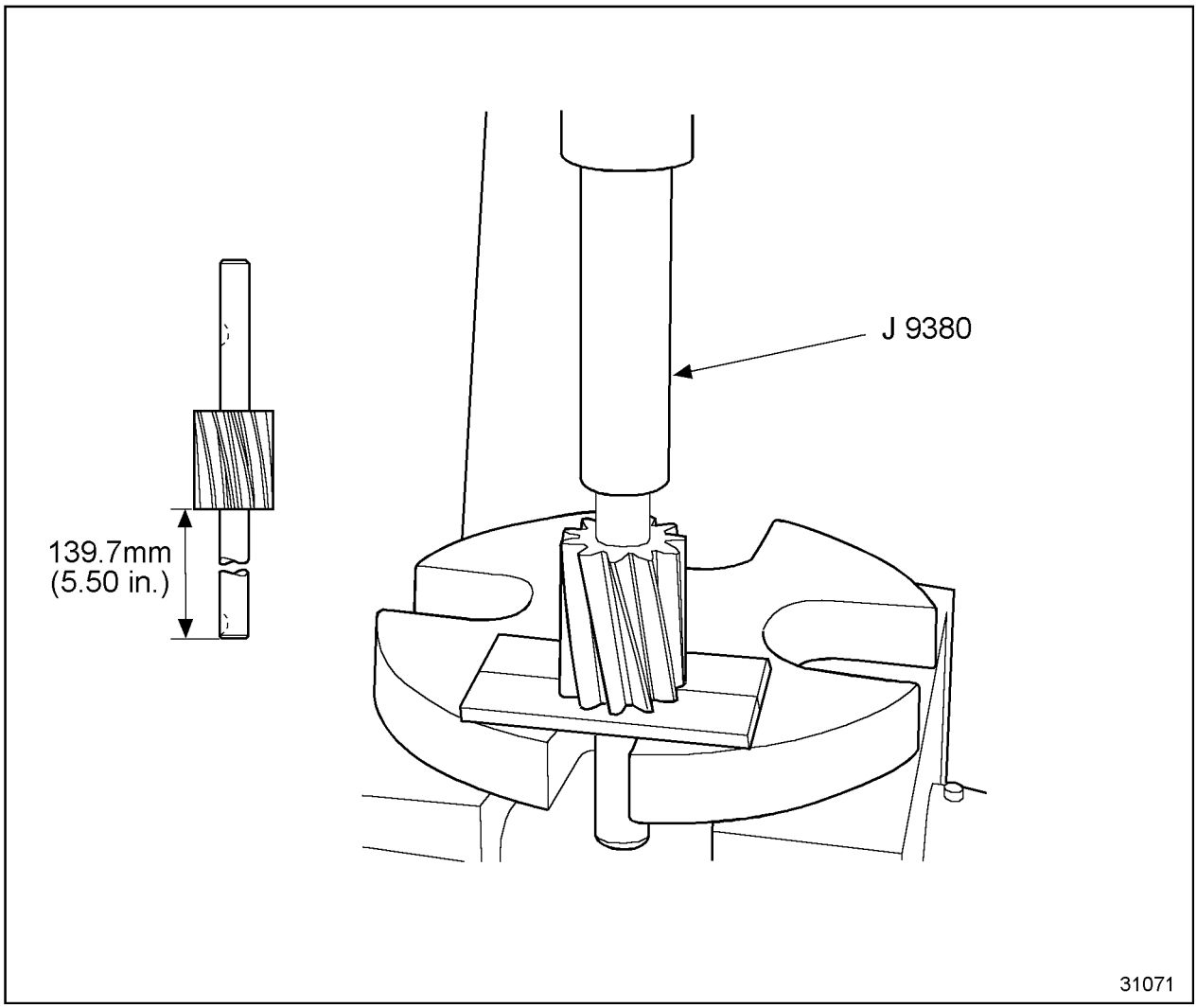
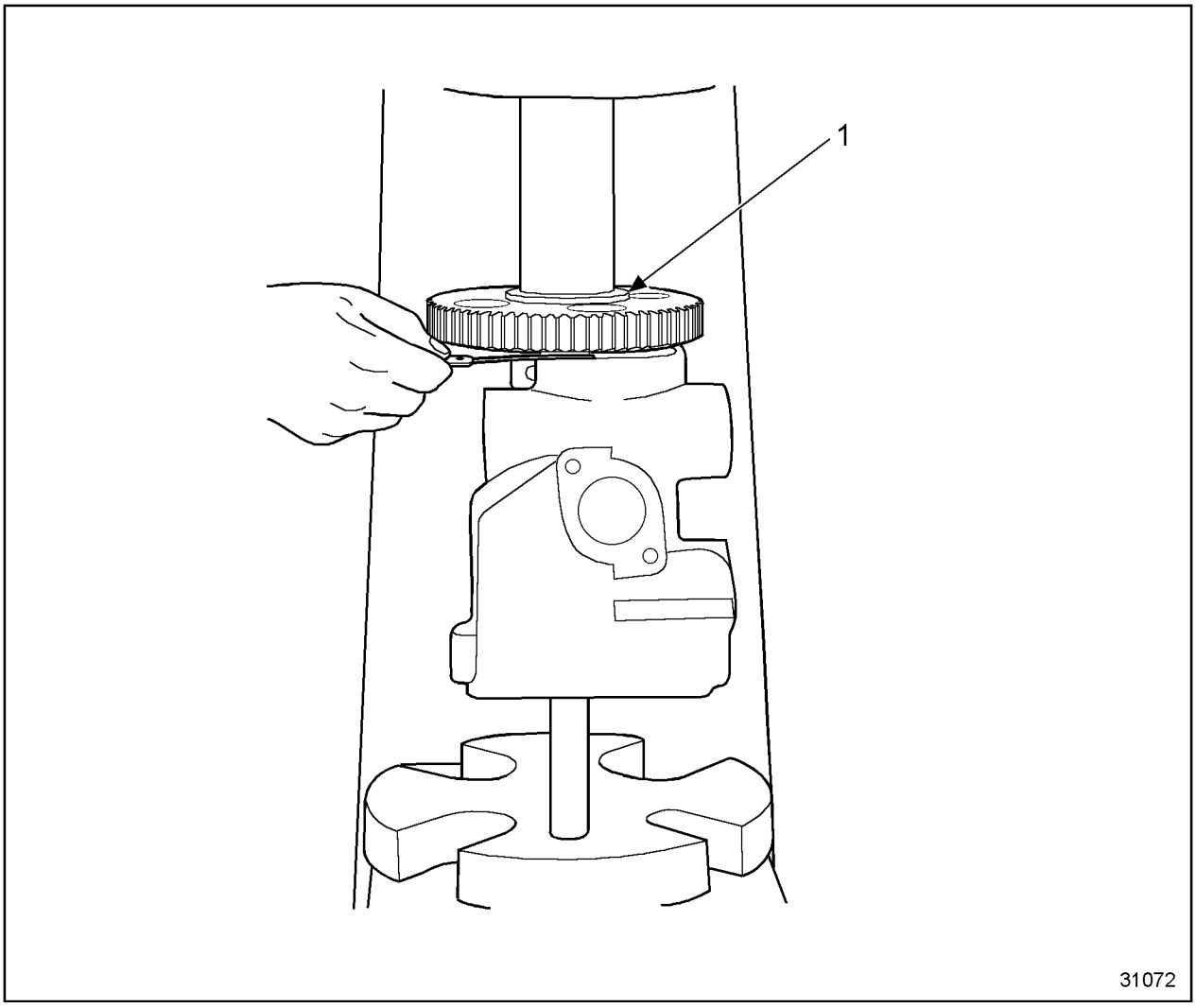


Figure 3-23 Installing Oil Pump Gear on Shaft using Tool J 9380

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4. Lubricate the driven shaft, and press the oil pump driven gear on the shaft. Use tool J 9381 to position the gear 118.872 mm (4.68 in.) from the end of the shaft.
5. Install the drive shaft and gear assembly in its original position on the pump body.
6. Install the key in the driven gear end of the drive shaft.
7. Press the driven gear on the drive shaft until the clearance between the gear hub and the pump body is 0.25 mm (0.010 in.). See Figure 3-24.



1. Washer

Figure 3-24 Installing Oil Pump Drive-Driven Gear on Shaft

8. Install the driven shaft and gear assembly in the pump body.
9. Slide the spacer on the shafts.

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10. Install the keys in the drive shaft, and slide the scavenging pump gears on the shafts.

NOTE:
The right-hand and left-hand scavenging pump gears must be in the same relative position as the oil pump gears.

11. Secure the scavenging pump body to the oil pump body with five bolts and lock washers.
12. Rotate the oil pump driven gear by hand to ensure the gears and the shafts rotate freely.
13. If necessary, loosen the scavenging pump body bolts. Tap the body bolts with a soft hammer, and tighten the bolts.

3.3.5 Installation of Oil Pump (12V and 16V Engines)

Install the oil pump as follows:

1. Position the rear mounted oil pump on the number seven and eight main bearing caps (12V) and number nine and ten main bearing caps (16V) so that the oil pump drive gear teeth mesh with the oil pump driven gear teeth.
2. Secure the oil pump to the bearing caps with four nuts and lock washers.
3. Check the backlash between the oil pump drive and driven gears with a feeler gage or a suitable dial indicator. The backlash should be 0.1524-0.3048 mm (0.006-0.012 in.).
4. Install shims between the oil pump mounting feet and the main bearing caps, as required, to obtain the proper backlash.

NOTE:
Install or remove the same number of shims, under both mounting feet, to keep the pump level. The addition or removal of each 0.13 mm (0.005 in.) shim will change the gear backlash 0.089 mm (0.0035 in.).

5. If removed, install the junction block.

NOTE:
When installing the junction block, use new junction block-to-cylinder block gaskets to prevent oil leaks.

6. Install the oil pump inlet and outlet pipes.

NOTE:
Use a new inlet pipe-to-oil pump gasket. Use a new gasket at each end of the oil pump outlet tube.

7. Install the oil pump screen cover gasket, screen cover, inlet pipe flange, and screen stop on the oil pump inlet pipe.
8. Place the screen in the screen cover, and lock it in place with the screen retainer.

9. Install the scavenging pump inlet and outlet pipes. Use a new inlet pipe-to-scavenging pump gasket and a new outlet pipe-to-scavenging pump gasket.
10. Install the scavenging pump inlet pipe support.
11. Place a new gasket on the upper oil pan, and install the pan on the cylinder block.
12. Start all oil pan bolts before tightening them. Tighten the center bolts first, and work toward each end of the oil pan.
13. Attach the screen cover gasket, screen cover, inlet flange, screen stop, and tube supports to the scavenging pump inlet tube.
14. Secure the ends of the scavenging pump inlet tube supports to the upper oil pan.
15. Place the screen in the scavenging pump inlet screen cover, and lock it in place with the screen retainer.
16. Place a new gasket on the lower oil pan, and attach the lower oil pan to the upper oil pan.

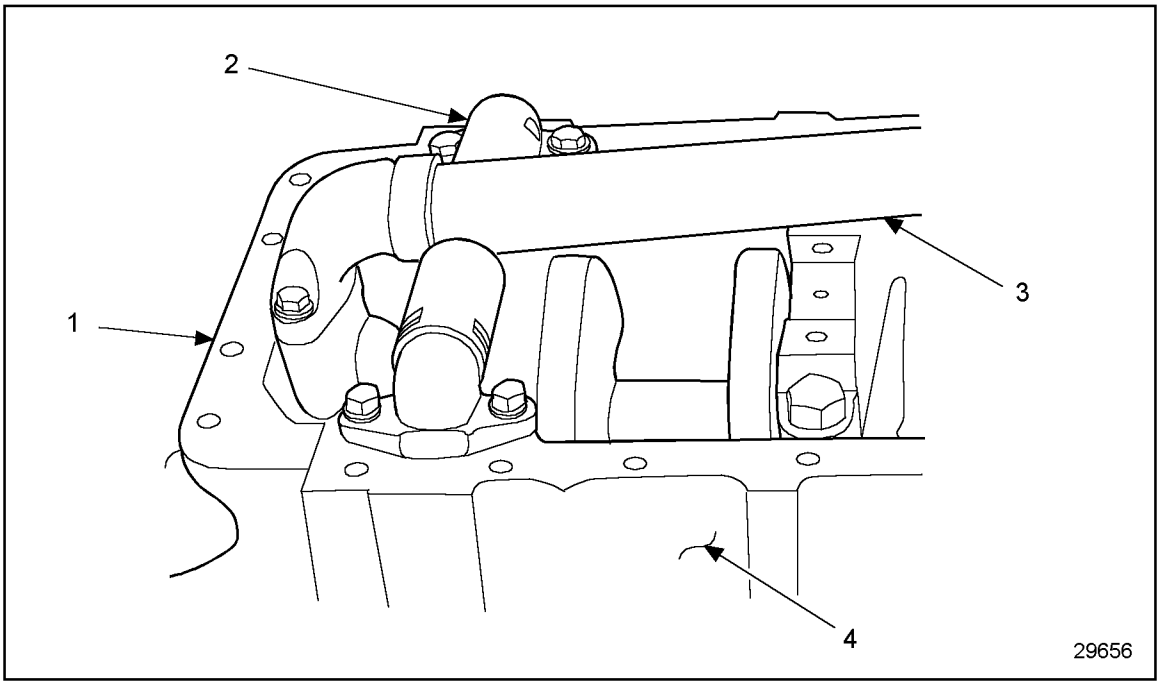
NOTE:
On engines with an oil pan baffle between the upper and lower oil pan(s), use a gasket on both sides of the baffle.

17. Fill the oil pan to the proper level with the recommended oil. Refer to section 13.5.1 and refer to section 5.2.

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3.4 LUBRICATING OIL PRESSURE REGULATOR VALVE

On 6V and 8V engines, an oil pressure regulator valve maintains stabilized lubricating oil pressure within the engine at all speeds, regardless of the oil temperature. The valve is installed at the end of the vertical oil gallery near the front of the cylinder block on the side opposite the oil cooler. See Figure 3-25.

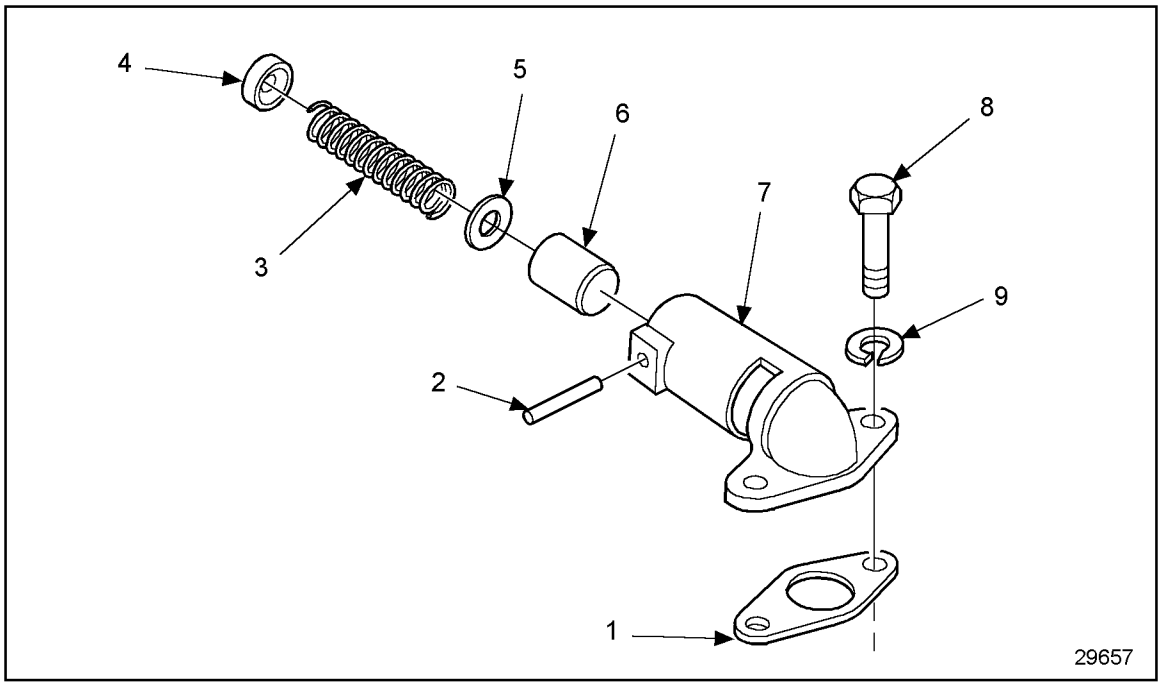


1. Front Cover and Oil Pump Assembly
2. Regulator Valve
3. Oil Pump Inlet Pipe
4. Cylinder Block

Figure 3-25 Oil Pressure Regulator Valve Mounting (6V or 8V Engine with Oil Pump in Front Cover)

Two oil pressure regulator valves are used on 12V and 16V engines. When the oil pressure at the regulator valves exceeds 345 kPa (50 lb/in.^{2}), the valves open, discharging excess oil into the oil pan.

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 3-26.



1. Gasket
2. Pin
3. Spring
4. Spring Seat
5. Washer
6. Valve
7. Regulator Valve Body
8. Bolt
9. Lock Washer

Figure 3-26 Oil Pressure Regulator Valve (6V and 8V Engines)

Current regulator valve assemblies (identified by a blue paint mark on the valve body) include a flat washer between the valve and the valve spring. The washer raises valve operating pressure by 34.5 kPa (5 lb/in.^{2}). Because of the increased lubrication that results from the higher operating pressure, DDC recommends modifying the former valve assembly when the oil pan is removed for engine repair or service. Install one (1) 0.406 in. x 0.812 in. x 0.065 in. flat washer between the valve and the spring to modify the former valve.

A spring, which is compressed by the pin in back of the spring seat, holds the valve on its seat. The entire assembly is bolted to the cylinder block lower flange and sealed against leaks by a gasket between the block and the valve body. When conditions are such that the oil pressure at the valve exceeds 345 kPa (50 lb/in.^{2}), the valve is forced from its seat, and oil from the engine gallery is bypassed to the engine oil pan. Stabilized lubricating oil pressure is maintained at all times.

Under normal conditions, the oil pressure regulator should require little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

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Whenever the lubricating oil pump is removed for inspection, remove the regulator valve and spring. Thoroughly clean and inspect the regulator valve and spring.

3.4.1 Repair or Replacement of Oil Pressure Regulator Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-27.

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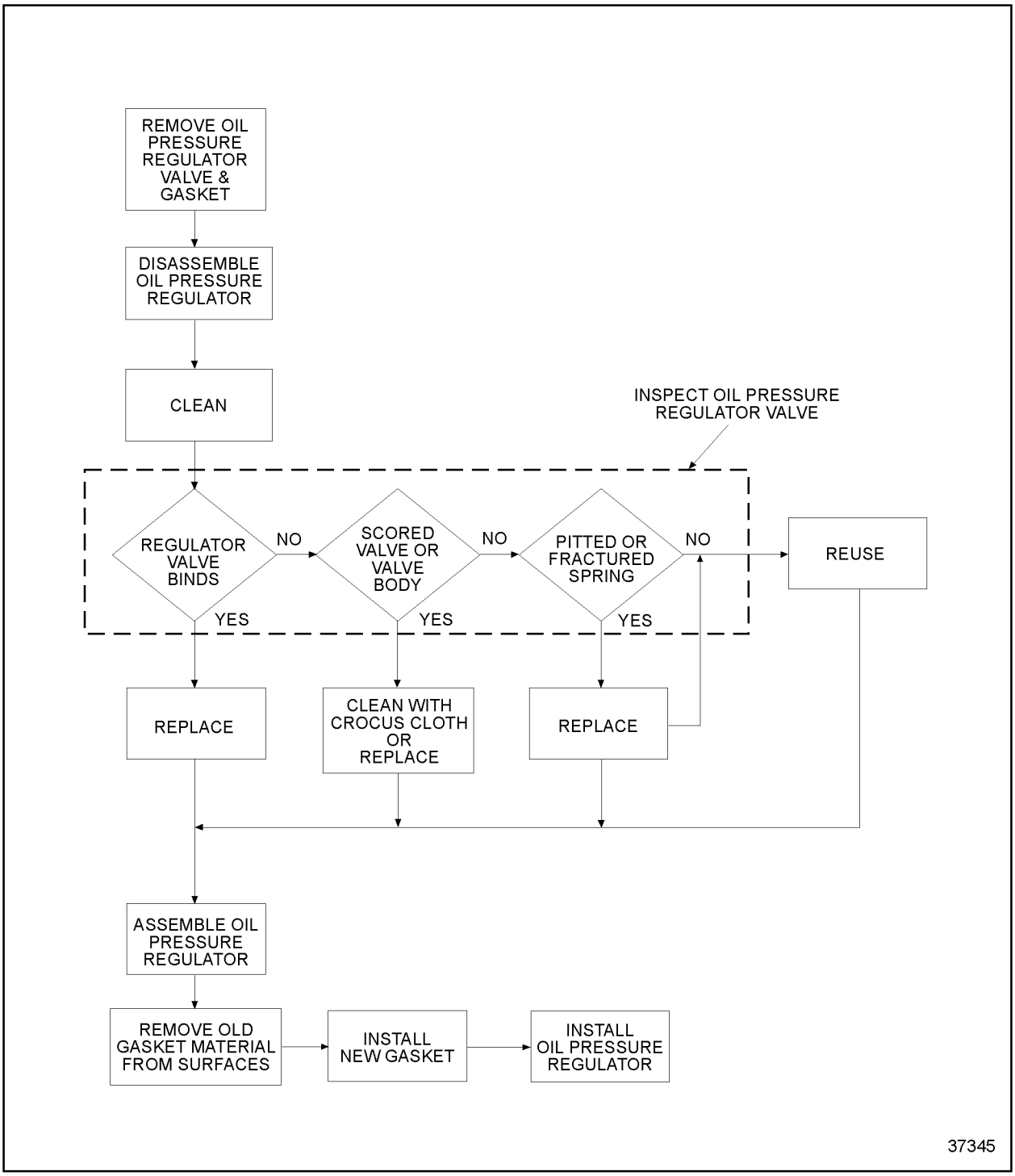


Figure 3-27 Flowchart for Repair or Replacement of Oil Pressure Regulator Valve (6V and 8V Engines)

3.4.2 Removal of Oil Pressure Regulator Valve (6V and 8V Engines)

Remove the oil pressure regulator valve as follows:

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1. Remove the two regulator-to-cylinder block attaching bolts and lock washers.
2. Tap the regulator body lightly to loosen it from the gasket and the cylinder block.
3. Remove the regulator and the gasket.

3.4.3 Removal of Oil Pressure Regulator Valve (12V and 16V Engines)

Remove the oil pressure regulator valve as follows:

1. Remove the regulator valve-to-cylinder block bolts and lock washers.
2. Tap the regulator body lightly to loosen it from the gasket and the cylinder block.
3. Remove the regulator and the gasket. Discard the old gasket.

3.4.4 Disassembly of Oil Pressure Regulator Valve (6V and 8V Engines)

Disassemble the oil pressure regulator valve as follows:

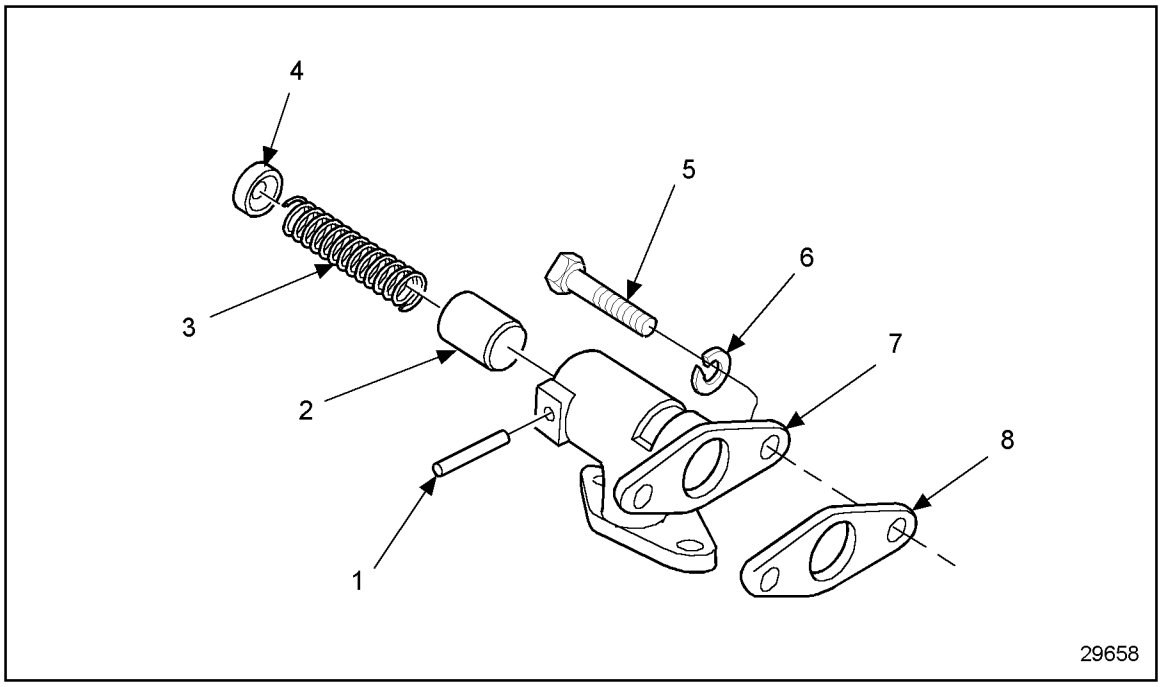
1. Clamp the regulator assembly in a soft-jawed bench vise, and remove the spring seat retaining pin from the regulator body.
2. Remove the spring seat, spring, washer, and valve from the regulator body.

3.4.5 Disassembly of Oil Pressure Regulator Valve (12V and 16V Engines)

Disassemble the oil pressure regulator valve as follows:

1. Drive the spring seat retaining pin out of the valve body.

2. Remove the spring seat, spring and valve from the valve body. See Figure 3-28.



1. Pin
2. Valve
3. Spring
4. Spring Seat
5. Bolt
6. Lock Washer
7. Regulator Valve Body
8. Gasket

Figure 3-28 Oil Pressure Regulator Valve (12V and 16V Engines)

3.4.5.1 Cleaning of Oil Pressure Regulator Valve

Clean the oil pressure regulator valve as follows:

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean all of the regulator 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 with compressed air.

3.4.5.2 Inspection of Oil Pressure Regulator Valve

Inspect the oil pressure regulator valve as follows:

1. Inspect the regulator valve movement in the valve body.
   [a] If the regulator valve does not move freely in the body, replace the valve. Refer to section 3.4.8.
   [b] If the regulator valve moves freely in the body, continue inspection.
2. Visually inspect the valve for scoring.
   [a] If scored, clean with a crocus cloth.
   [b] If excessively scored, replace the valve. Refer to section 3.4.8.
   [c] If not scored, proceed with inspection.
3. Inspect the valve body for scoring and cracks.
   [a] If the valve body is scored, clean with a crocus cloth.
   [b] If cracked or excessively scored, replace the valve body. Refer to section 3.4.8.
   [c] If not cracked or scored, continue inspection.

4. Inspect the spring for pitting or fractures.
   [a] If fractured or pitted, replace the spring. Refer to section 3.4.8.
   [b] If not fractured or pitted, reuse the spring.

3.4.6 Assembly of Oil Pressure Regulator Valve (6V and 8V Engines)

Assemble the oil pressure regulator valve as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply clean engine oil to the outer face of the valve, and slide it into the regulator body, closed end first.
2. Insert the washer and spring in the valve, and install the spring seat.
3. While compressing the spring, install the retaining pin behind the spring seat.
4. Press the pin flush to 0.25 mm (0.010 in.) below the surface of the valve body.

NOTE:
The valve body used on the 6V and 8V engines (with an oil pump in the front cover) has two retaining pin holes. Install the pin in the outermost hole for the regulator valve. The inner hole is used when the valve is assembled as an oil pump relief valve assembly.

3.4.7 Assembly of Oil Pressure Regulator Valve (12V and 16V Engines)

Assemble the oil pressure regulator valve as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply clean engine oil to the outer face of the valve, and insert the spring seat, spring and valve into the valve body.
2. Insert the spring seat retaining pin into the valve body.
3. While compressing the spring, install the retaining pin behind the spring seat.
4. Press the pin flush to 0.25 mm (0.010 in.) below the surface of the valve body.

3.4.8 Installation of Oil Pressure Regulator Valve (6V and 8V Engines)

Install the oil pressure regulator valve as follows:

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1. Remove all oil gasket material from the regulator body and cylinder block.
2. Affix a new gasket to a cast iron regulator body, and secure the regulator assembly to the cylinder block with two bolts and lock washers.

NOTE:
When installing a regulator assembly with an aluminum housing, use 3/8 in. plain washers on the bolts. Ensure washers are against the aluminum housing.

3.4.9 Installation of Oil Pressure Regulator Valve (12V and 16V Engines)

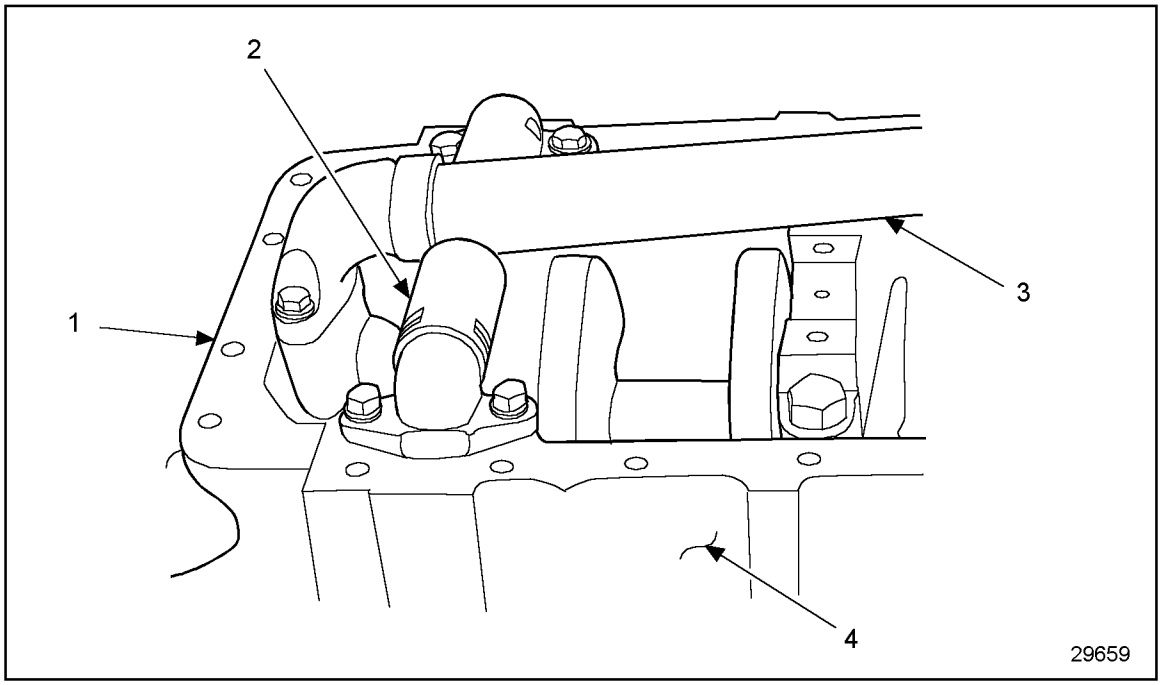
Install the oil pressure regulator valve as follows:

1. Remove all traces of old gasket material from the regulator body and cylinder block.
2. Affix a new gasket to the regulator valve body, and secure the regulator valve assembly to the cylinder block with two bolts and lock washers.

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3.5 LUBRICATING 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 approximately 724 kPa (105 lb/in.^{2}). It directs the excess oil to the oil pan. The pressure relief valve is located at the lower end of the vertical oil gallery near the front of the cylinder block on the oil cooler side. See Figure 3-29.



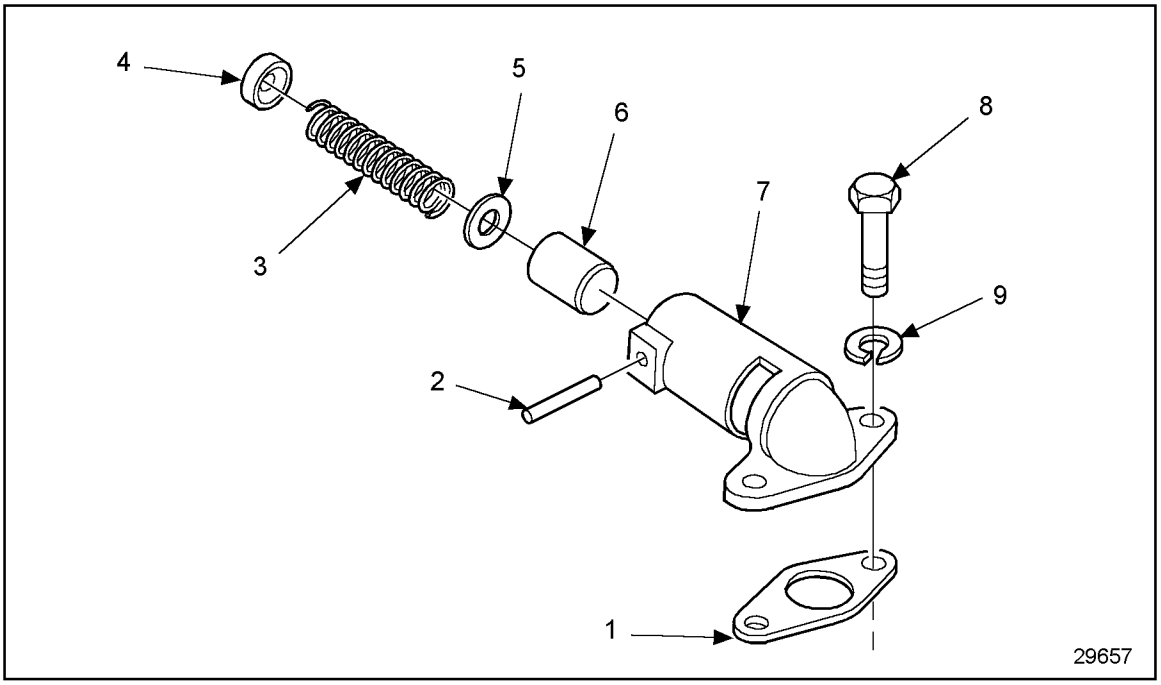
1. Front Cover and Oil Pump Assembly
2. Relief Valve
3. Oil Pump Inlet Pipe
4. Cylinder Block

Figure 3-29 Oil Pressure Relief Valve Mounting (6V or 8V Engine with Oil Pump in Front Cover)

The pressure relief valve consists of a valve body, a hollow piston-type valve, a spring, spring seat, and a pin to retain the valve assembly within the valve body.

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The relief valve assembly used on 6V and 8V engines is composed of the same parts as the regulator valve assembly. However, the retaining pin is located in the valve body inner pin hole to provide the necessary tension on the spring. See Figure 3-30.



1. Gasket
2. Pin
3. Spring
4. Spring Seat
5. Washer
6. Valve
7. Valve Body
8. Bolt
9. Lock Washer

Figure 3-30 Oil Pressure Relief Valve (6V and 8V)

To provide sufficient clearance between the relief valve housing and the stabilizer bolts, a new relief valve is now being used on engines equipped with a main bearing cap mounted lubricating oil pump. To eliminate cracking the valve housing at assembly, the casting is thickened and the valve housing corner at the stabilizer bolt location is removed. The former and new relief valves are not interchangeable and only the new relief valve is serviced.

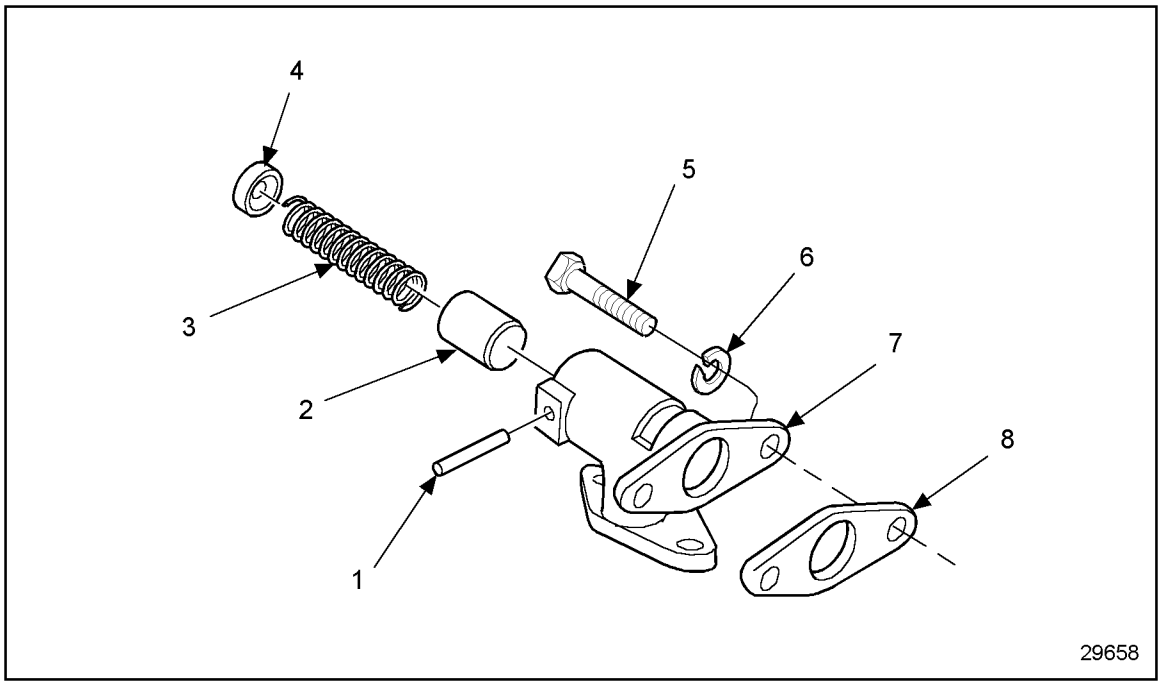
NOTE:
Use the correct main bearing cap bolt and washer at the stabilizer positions to obtain minimum clearance.

Service operations for the pressure relief valve are similar to those of the regulator valve.

The spring in the 6V and 8V relief valve assemblies is the same as used in the oil pressure regulator assemblies.

On 12V and 16V engines, the oil pressure relief valve, mounted on the junction block, bypasses excess oil directly into the oil sump when the oil pressure in the cylinder block main oil galleries exceeds approximately 827 kPa (120 lb/in.^{2}).

The valve, spring, spring seat, and pin used in the oil pressure relief valve are identical to the parts used in the oil pressure regulator valve. The removal, disassembly, inspection, assembly, and installation procedures are identical for both. See Figure 3-31.



1. Pin
2. Valve
3. Spring
4. Spring Seat
5. Bolt
6. Lock Washer
7. Valve Body
8. Gasket

Figure 3-31 Oil Pressure Relief Valve and Relative Location of Parts(12V and 16V Engines)

3.5.1 Repair or Replacement of Oil Pressure Relief Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-32.

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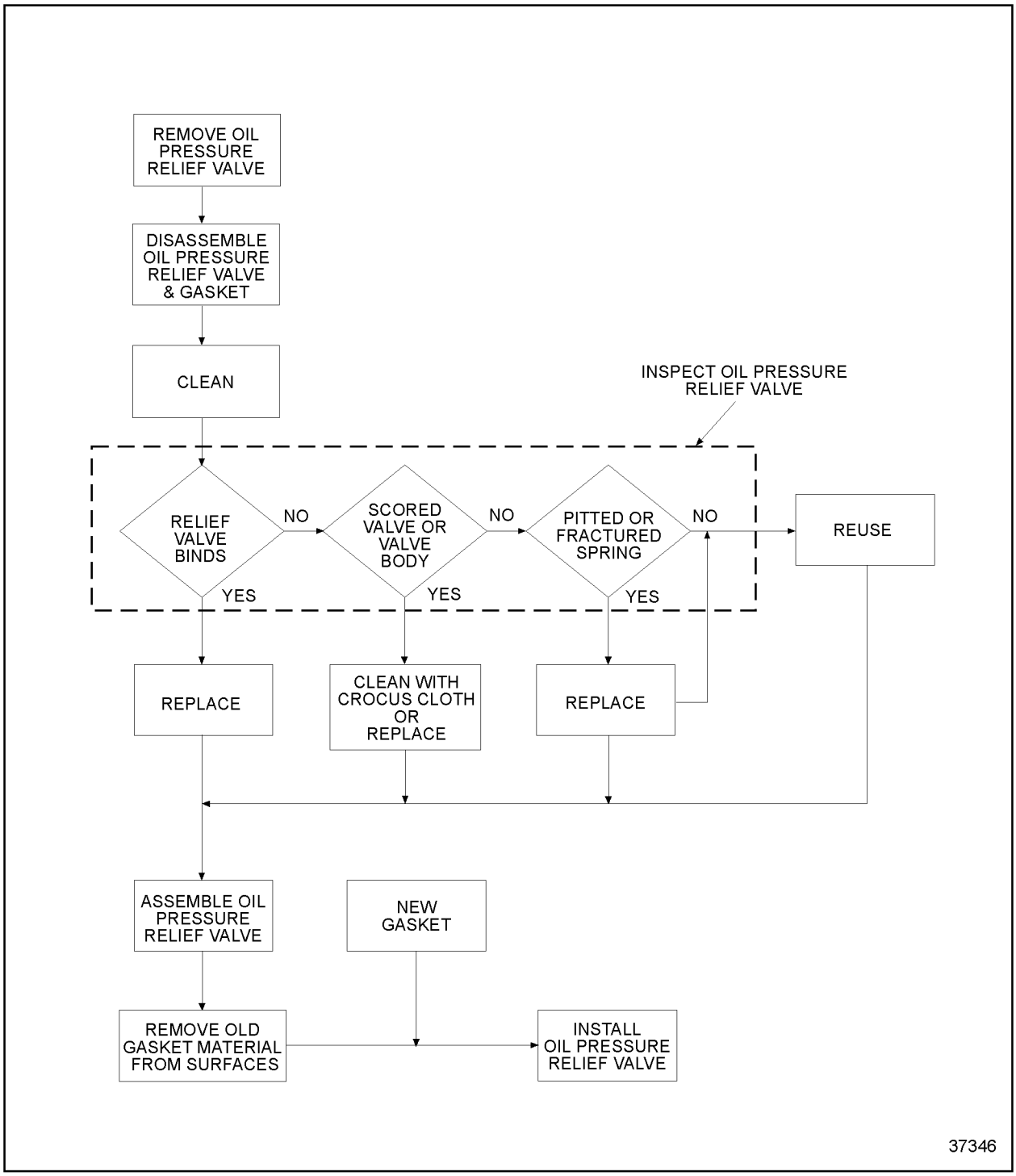


Figure 3-32 Flowchart for Repair or Replacement of Oil Pressure Relief Valve

3.5.2 Removal of Oil Pressure Relief Valve (6V and 8V Engines)

Remove the oil pressure relief valve as follows:

1. Remove the two relief valve-to-cylinder block attaching bolts and lock washers.

2. Tap the relief body lightly to loosen it from the gasket and the cylinder block.

3.5.3 Removal of Oil Pressure Relief Valve (12V and 16V Engines)

Remove the oil pressure relief valve as follows:

1. Remove the relief valve-to-cylinder block bolts and lock washers.
2. Tap the relief body lightly to loosen it from the gasket and the cylinder block.
3. Remove the relief valve and the gasket. Discard the old gasket.

3.5.4 Disassembly of Oil Pressure Relief Valve (6V and 8V Engines)

Disassemble the oil pressure relief valve as follows:

1. Clamp the relief valve assembly in a soft-jawed bench vise, and remove the spring seat retaining pin from the relief body.
2. Remove the spring seat, spring, washer, and valve from the relief body.

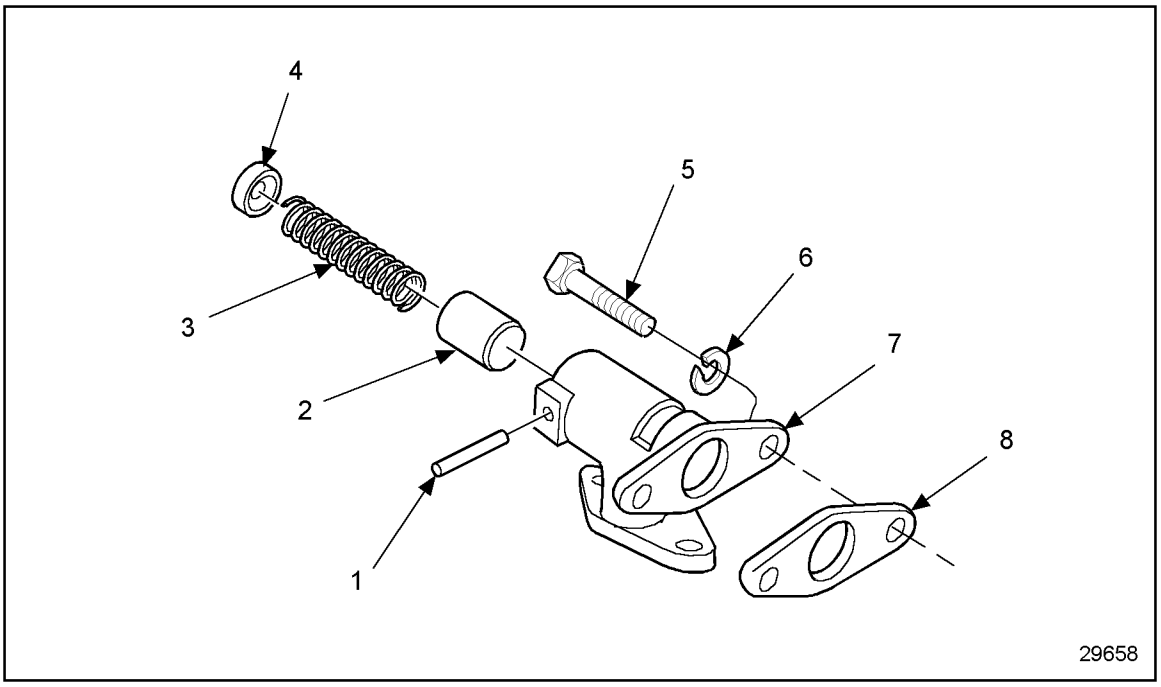
3.5.5 Disassembly of Oil Pressure Relief Valve (12V and 16V Engines)

Disassemble the oil pressure relief valve as follows:

1. Drive the spring seat retaining pin out of the valve body.

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2. Remove the spring seat, spring and valve from the valve body. See Figure 3-33.



1. Pin
2. Valve
3. Spring
4. Spring Seat
5. Bolt
6. Lock Washer
7. Valve Body
8. Gasket

Figure 3-33 Oil Pressure Relief Valve and Relative Location of Parts(12V and 16V Engines)

3.5.5.1 Cleaning of Oil Pressure Relief Valve

Clean the oil pressure relief valve as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean all 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 with compressed air.

3.5.5.2 Inspection of Oil Pressure Relief Valve

Inspect the oil pressure relief valve as follows:

1. Inspect the oil pressure relief valve as follows:
   [a] If the relief valve does not move freely in the body, replace the valve. Refer to section 3.5.8.
   [b] If the relief valve moves freely in the body, continue inspection.
2. Visually inspect the valve for scoring.
   [a] If scored, clean with a crocus cloth.
   [b] If excessively scored, replace the valve. Refer to section 3.5.8.
   [c] If not scored, proceed with inspection.
3. Inspect the valve body for scoring and cracks.
   [a] If the valve body is scored, clean with a crocus cloth.
   [b] If cracked or excessively scored, replace the valve body. Refer to section 3.5.7.
   [c] If not cracked or scored, continue inspection.

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4. Inspect the spring for pitting or fractures.
   [a] If fractured or pitted, replace the spring. Refer to section 3.5.7.
   [b] If not fractured or pitted, reuse the spring.

3.5.6 Assembly of Oil Pressure Relief Valve (6V and 8V Engines)

Assemble the oil pressure relief valve as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply clean engine oil to the outer face of the valve, and slide it into the relief body, closed end first.
2. Insert the spring in the valve, and install the spring seat.
3. While compressing the spring, install the retaining pin behind the spring seat.
4. While compressing the spring, install the retaining pin behind the spring seat. Press the pin flush to 0.25 mm (0.010 in.) below the surface of the valve body.

NOTE:
The valve body used on the 6V and 8V engines (with an oil pump in the front cover) has two retaining pin holes. Install the pin in the inner hole for the relief valve. The outermost hole is used when the valve is assembled as an oil pump regulator valve assembly.

3.5.7 Assembly of Oil Pressure Relief Valve (12V and 16V Engines)

Assemble the oil pressure relief valve as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply clean engine oil to the outer face of the valve and insert the spring seat, spring and valve into the valve body.
2. Insert the spring seat retaining pin into the valve body.

3.5.8 Installation of Oil Pressure Relief Valve (6V and 8V Engines)

Install the oil pressure relief valve as follows:

1. Remove all old gasket material from the relief body and cylinder block.

2. Affix a new gasket to a cast iron relief body, and secure the relief assembly to the cylinder block with two bolts and lock washers.

NOTE:
When installing a relief assembly with an aluminum housing, use 3/8 in. plain washers on the bolts. Ensure washers are against the aluminum housing.

3.5.9 Installation of Oil Pressure Relief Valve (12V and 16V Engines)

Install the oil pressure relief valve as follows:

1. Remove all traces of old gasket material from the relief body and cylinder block.
2. Affix a new gasket to the relief valve body, and secure the relief valve assembly to the cylinder block with two bolts and lock washers.

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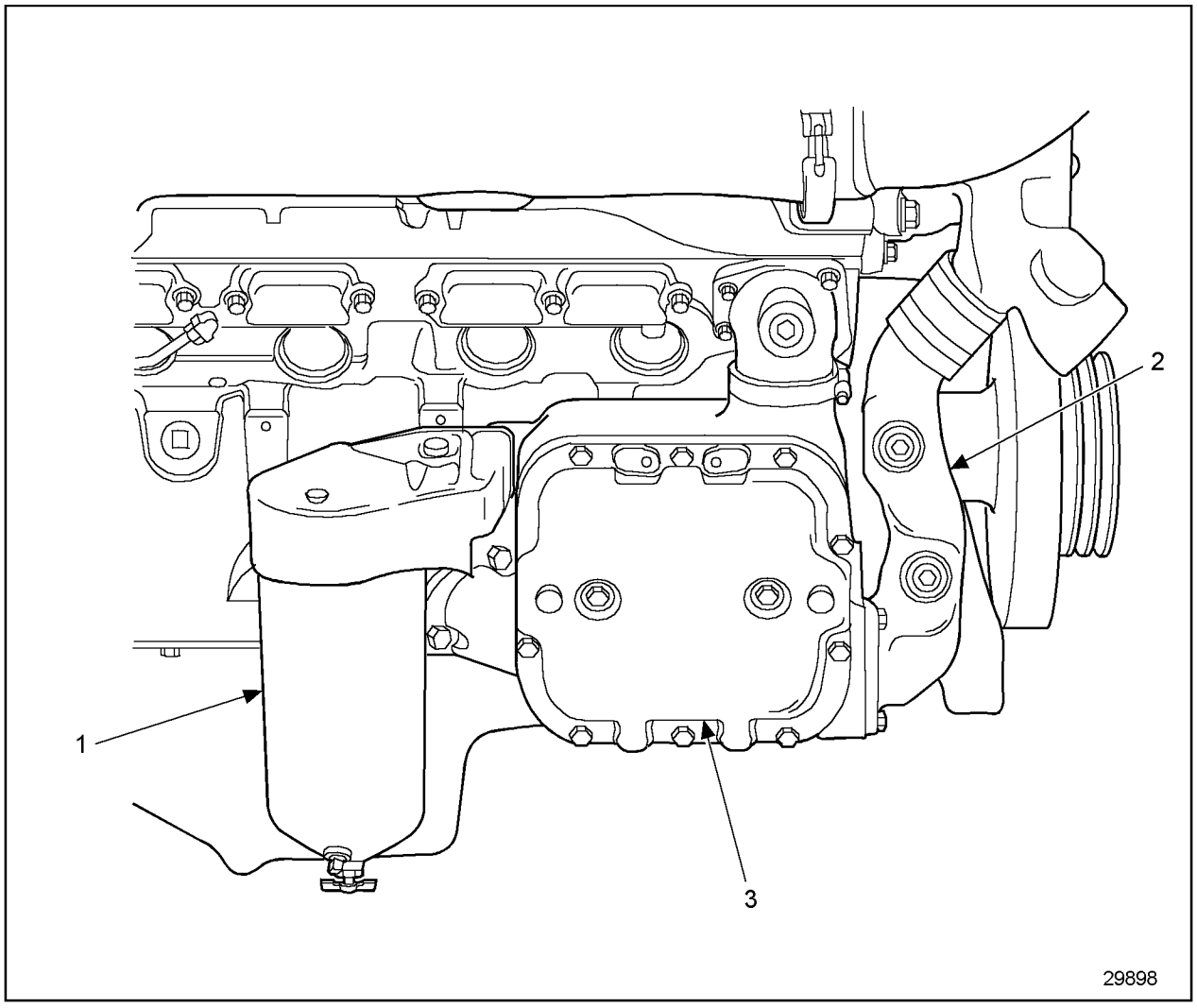
3.6 LUBRICATING OIL FILTERS

Replace the oil filter element when changing the engine oil to ensure that abrasive dust, metal particles, and carbon are removed.

Select a reliable oil supplier, observe oil change period recommendations, and perform proper filter maintenance procedures to ensure trouble-free lubrication and long engine life.

The Full Flow Oil Filter is described as follows:

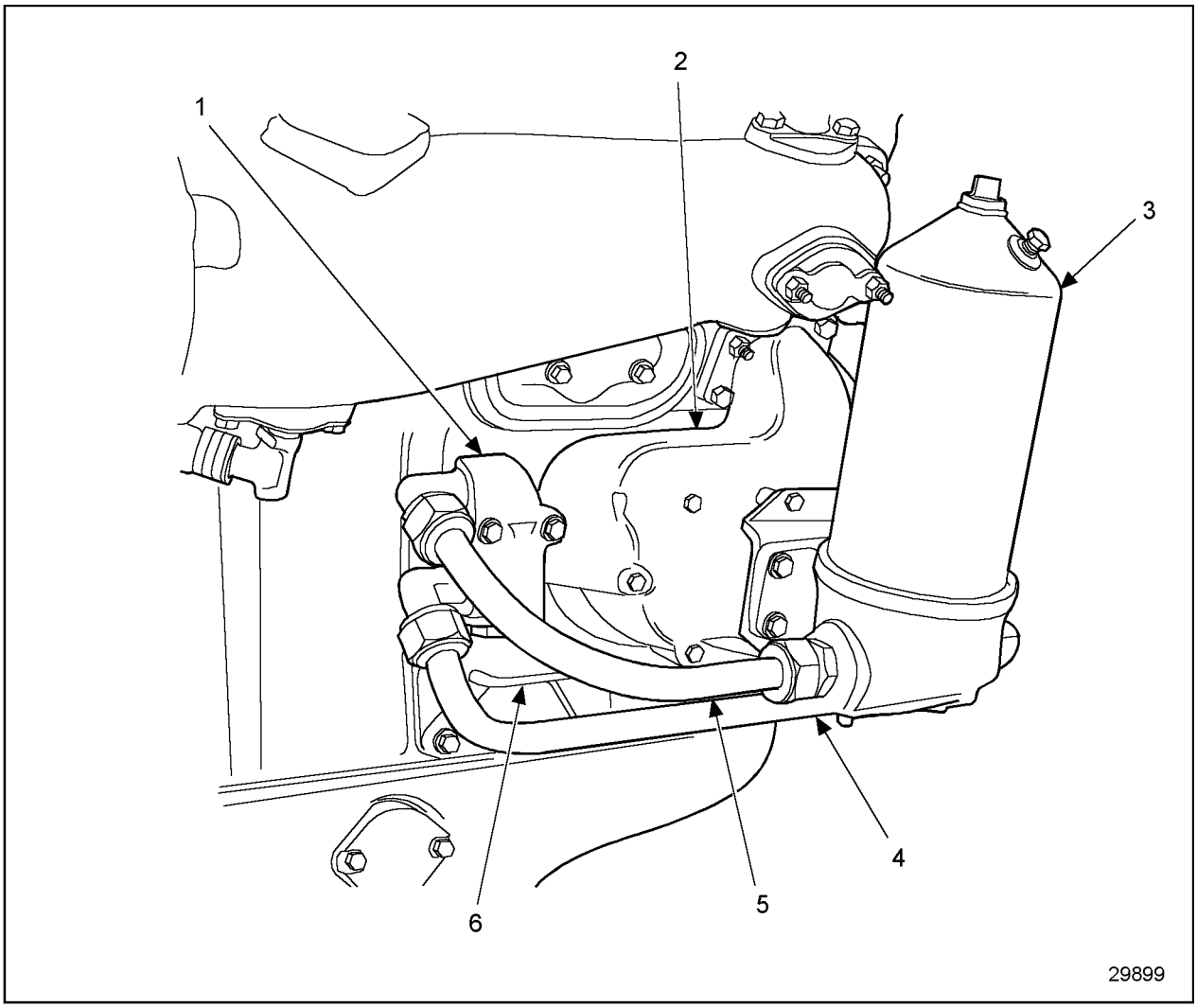
The full flow type lubricating oil filter is installed in front of the oil cooler in the lubrication system. The 6V and 8V engines are equipped with a single filter. See Figure 3-34. The 12V and 16V engines use either two single or two dual oil filters. The filters may be mounted directly to the oil cooler adaptor or remotely mounted on the oil cooler cover. Flexible hoses connect the filters to a filter junction, which is attached to the oil cooler adaptor. See Figure 3-35. Certain units may be equipped with an oil cooler cover that also functions as an oil filter adaptor.



1. Oil Filter
2. Water Pump Elbow
3. Oil Cooler

Figure 3-34 Typical Full Flow Oil Filter Mounting (6V or 8V Engines)

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1. Filter Junction
2. Oil Cooler
3. Oil Filter
4. Filter Outlet
5. Filter Inlet
6. Filter and Oil Cooler Adaptor

Figure 3-35 Typical Full Flow Remote Mounted Oil Filter

The filter assembly consists of a replaceable element enclosed within a shell, which is mounted on an adaptor or base. When the filter shell is in place, a coil spring restrains the element from movement.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving engine parts. The pump forces the pressurized oil through a passage in the filter adaptor or base to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud, out a passage in the filter adaptor or base, and to the oil cooler.

A valve, which opens at approximately 124-145 kPa (18-21 lb/in.^{2}), is located in the filter adaptor or base. The valve will pass the oil directly to the oil cooler should the filter become clogged.

Conversion adaptor kits (K-4 for the 6V and the K-5 for the 8V) for spin-on, full flow lube oil filters are available as field replacement items.

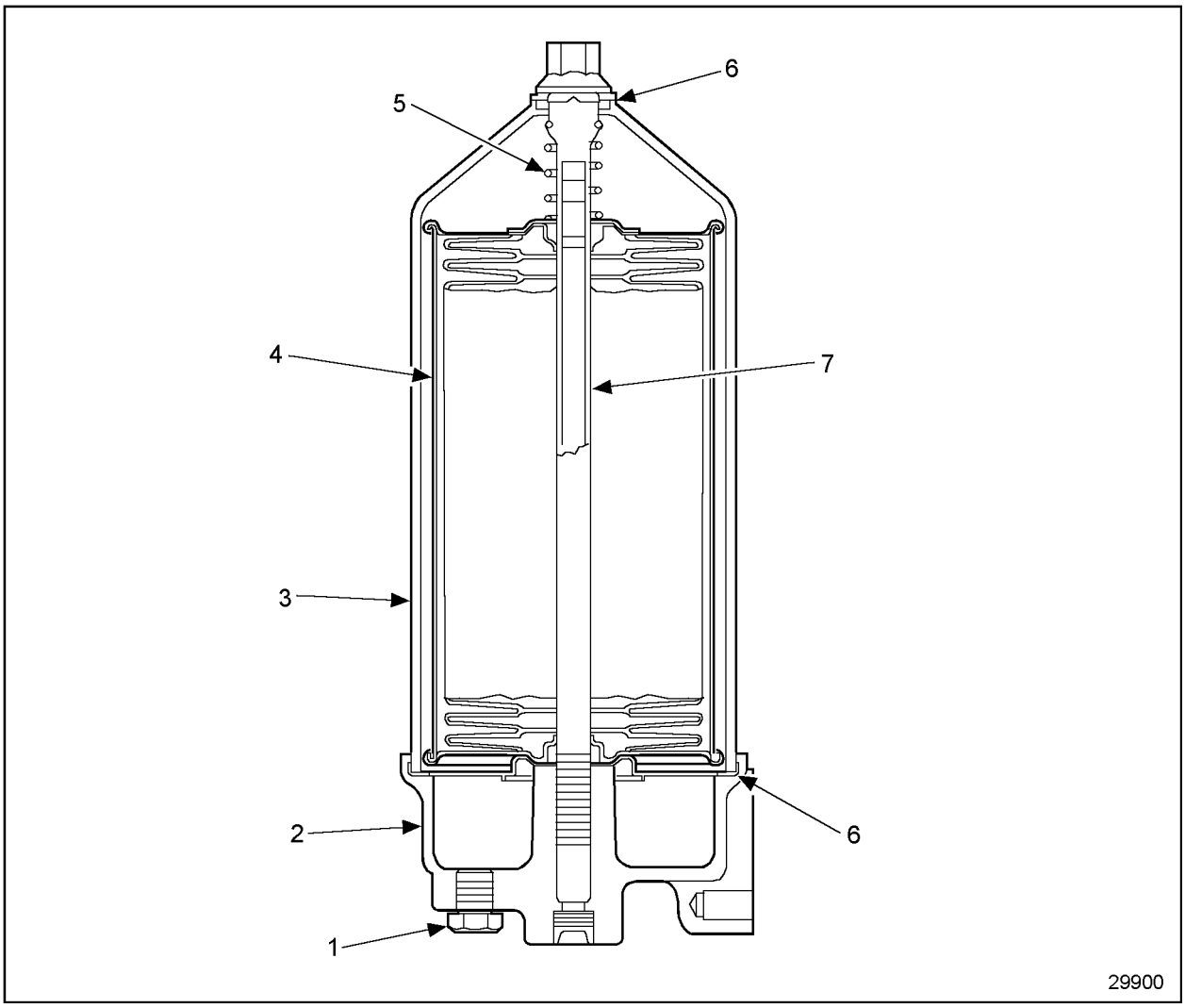
NOTE:
Spin-on filters should not replace filter assemblies on transmissions.

The spin-on lubricating oil filter (throwaway type) and mounting adaptor are installed on some engines. The spin-on filter requires a new mounting adaptor which, in some cases, is part of the oil cooler cover.

The Bypass Oil Filter is described as follows:

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When additional filtration is desired, a bypass oil filter may be installed on the engine. See Figure 3-36. To control the oil flow rate and to provide sufficient oil pressure when the engine is running at idle speed, the orifice size on the discharge side of the filter must not exceed 2.5654 mm (0.101 in.) on 6V and 8V engines or 3.18 mm (0.125 in.) on 12V and 16V engines.



1. Drain Plug
2. Base
3. Shell
4. Element
5. Spring
6. Gasket
7. Stud

Figure 3-36 Bypass Type Oil Filter

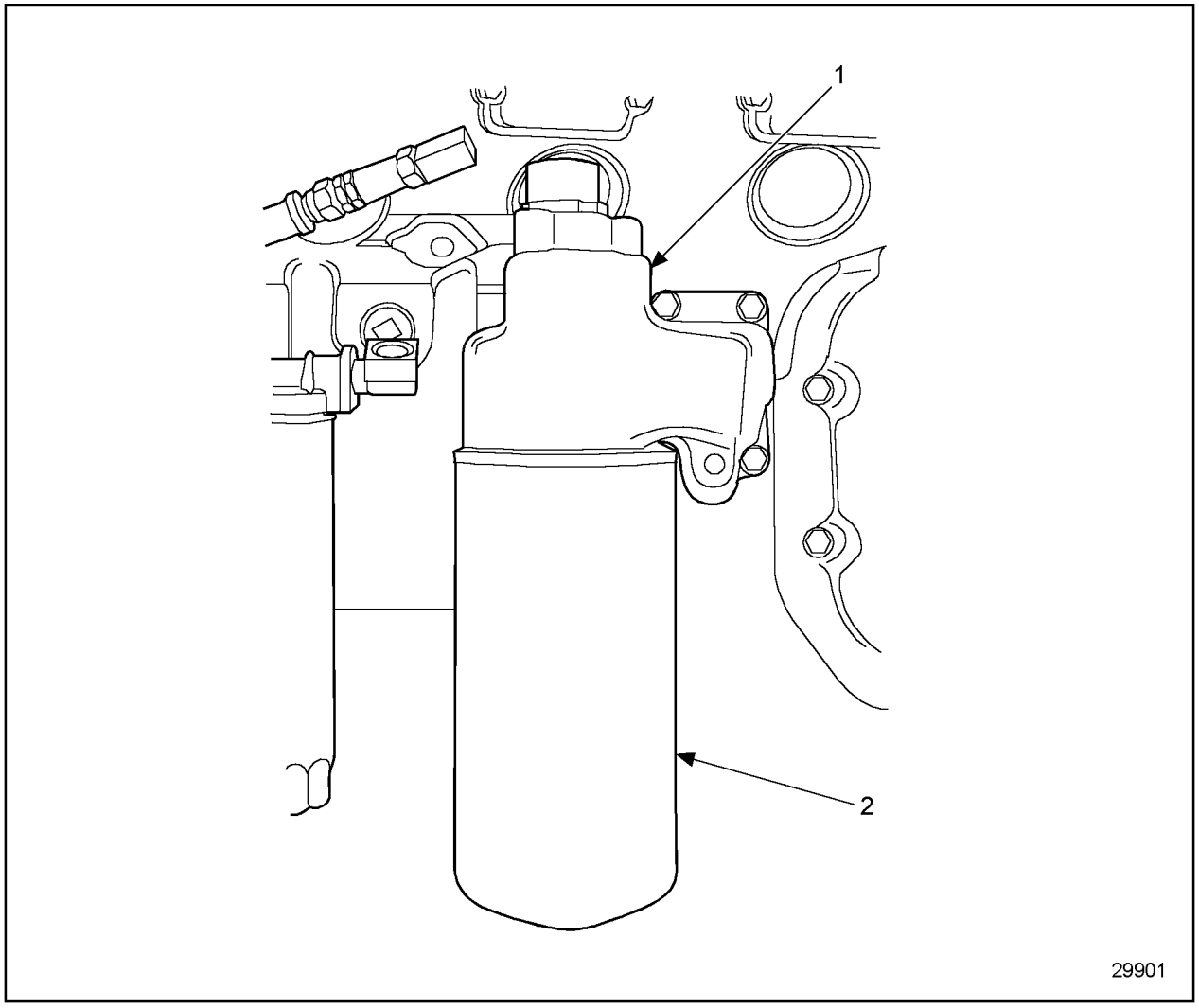
When the engine is running, a portion of the lubricating oil is bled off the oil gallery and passed through the bypass filter. Eventually all oil passes through the filter, filtering out fine foreign particles that may be present.

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The bypass filter assembly consists of a replaceable element contained in a shell mounted on a combination base and mounting bracket. When the shell is in place, a coil spring at the top restrains the filter element movement. A hollow center stud serves as the outlet passage from the filter as well as securing the shell in place.

The Thermatic Oil Control Valve is described as follows:

A spin-on lube oil filter adaptor assembly with a temperature-sensitive thermatic oil control valve is available as an option on certain industrial engines. See Figure 3-37. This valve was formerly used on certified automotive models, but was discontinued effective with 1988 production build engines. A service kit is available from DDC distributors to completely replace the thermatic valve when no longer required.



1. Thermatic Oil Control Adaptor
2. Spin-on Filter

Figure 3-37 Spin-on Oil Filter and Adaptor Assembly with Thermatic Valve

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The thermatic valve is installed in the top of the oil filter adaptor assembly, where it operates like a thermostat to control the lube oil flow through the engine and oil cooler. See Figure 3-38. The valve operates as follows:

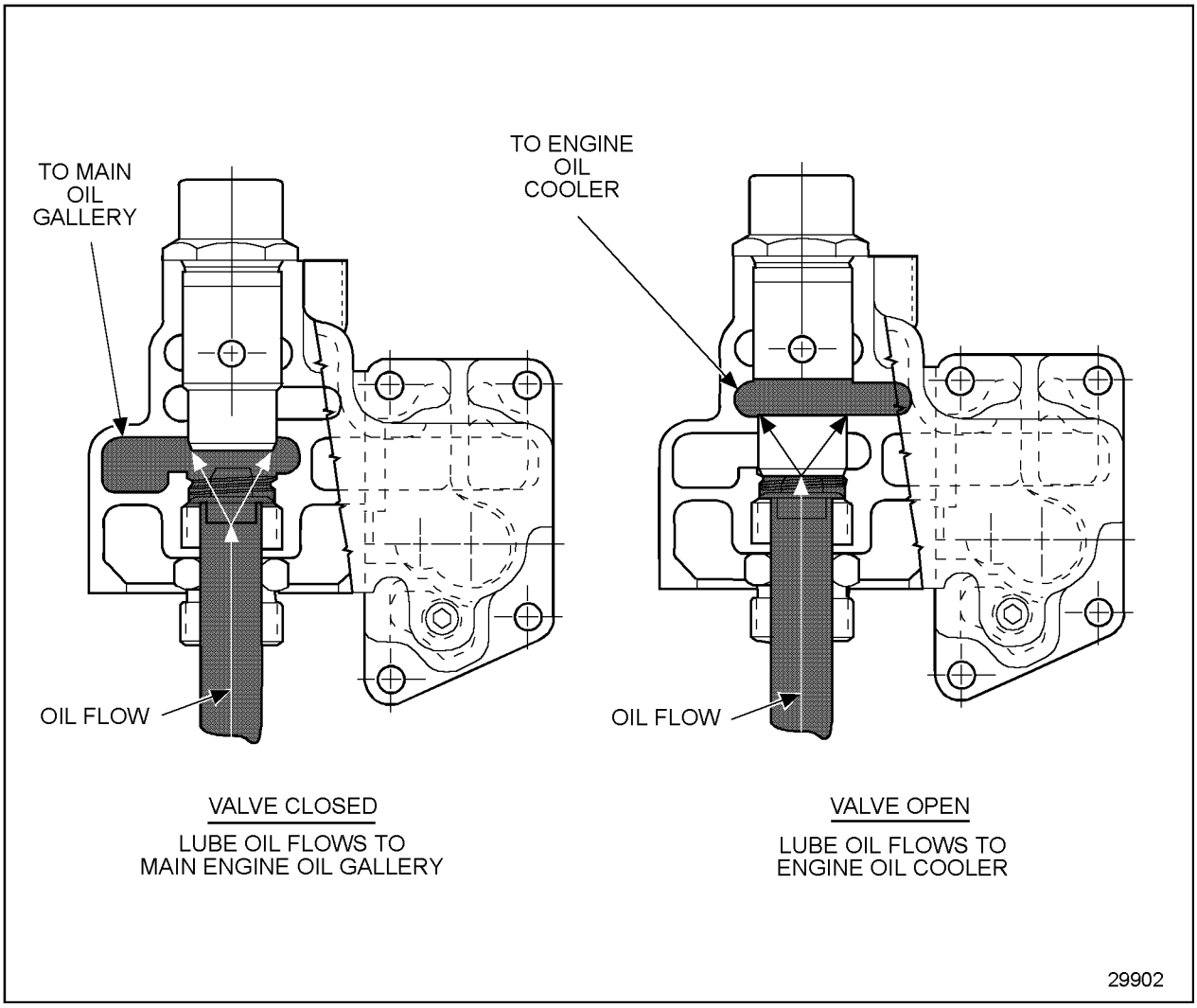


Figure 3-38 Thermatic Valve Operation

At lube oil temperatures below 102°C (215°F), the valve stays in the bypass mode. Filtered engine oil bypasses the oil cooler and flows directly to the main oil gallery. With no oil passing through the oil cooler, engine oil warms rapidly. When oil temperature is between 102°C-110°C (215°F-230°F) the thermatic valve opens partially. The valve senses oil temperature and modulates oil through and around the oil cooler. At oil temperatures above 110°C (230°F), the valve opens completely, and all oil flows through the oil cooler.

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The thermatic valve allows the engine lube oil to reach its normal range quickly, reducing the time the engine operates on heavier, cold engine oil. During light load engine operation, the valve keeps the oil within the proper temperature range for optimum lubrication. Maintaining the oil temperature within the 102°C-110°C (215°F-230°F) range minimizes friction and pumping losses. The thermatic oil control valve assembly incorporates a relief valve, which permits oil to bypass the oil cooler if the cooler becomes plugged.

When installing the thermatic oil control valve on the adaptor, tighten the valve to 41-47 N·m (30-35 lb·ft) torque.

3.6.1 Repair or Replacement of Oil Filter

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-39.

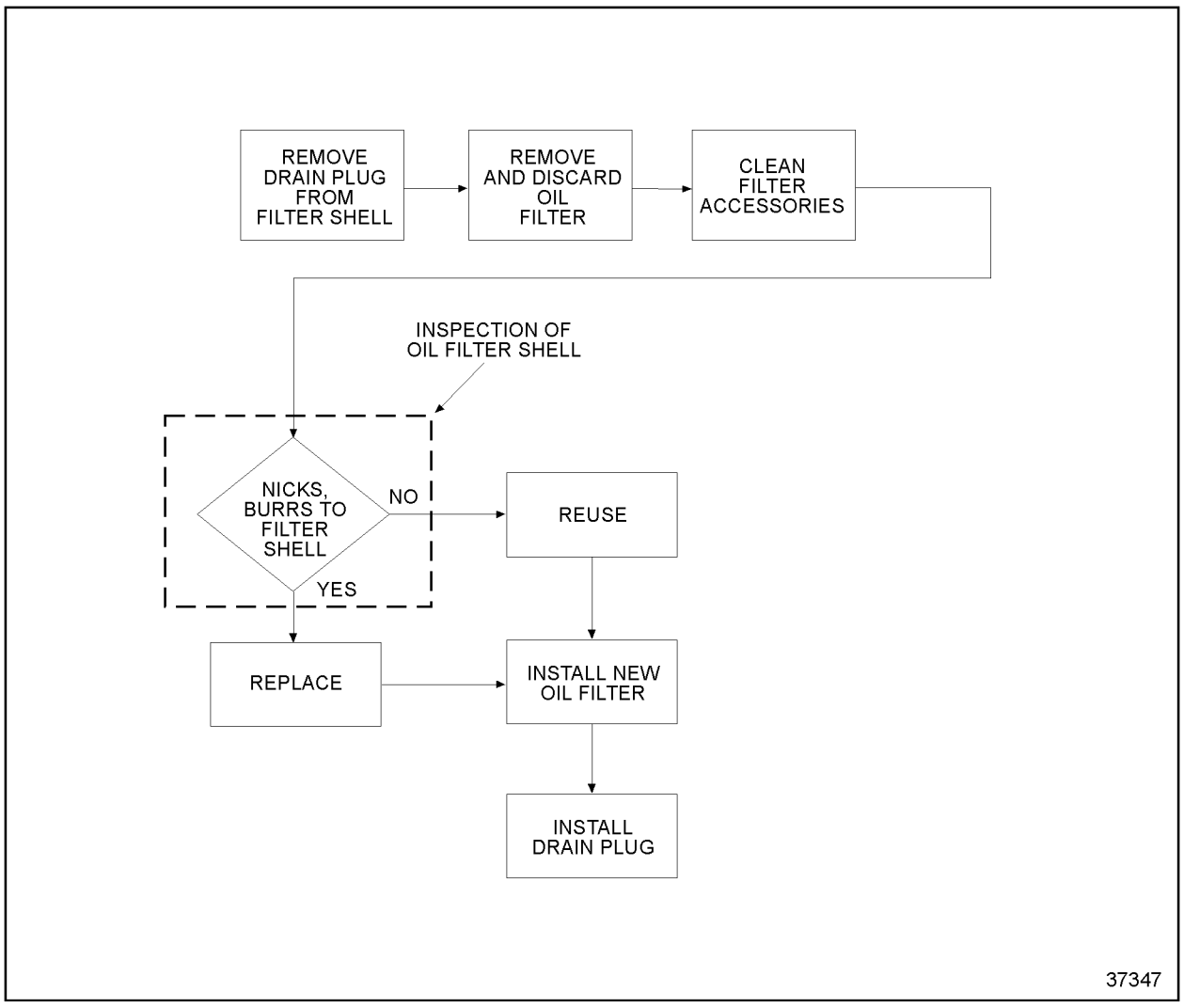
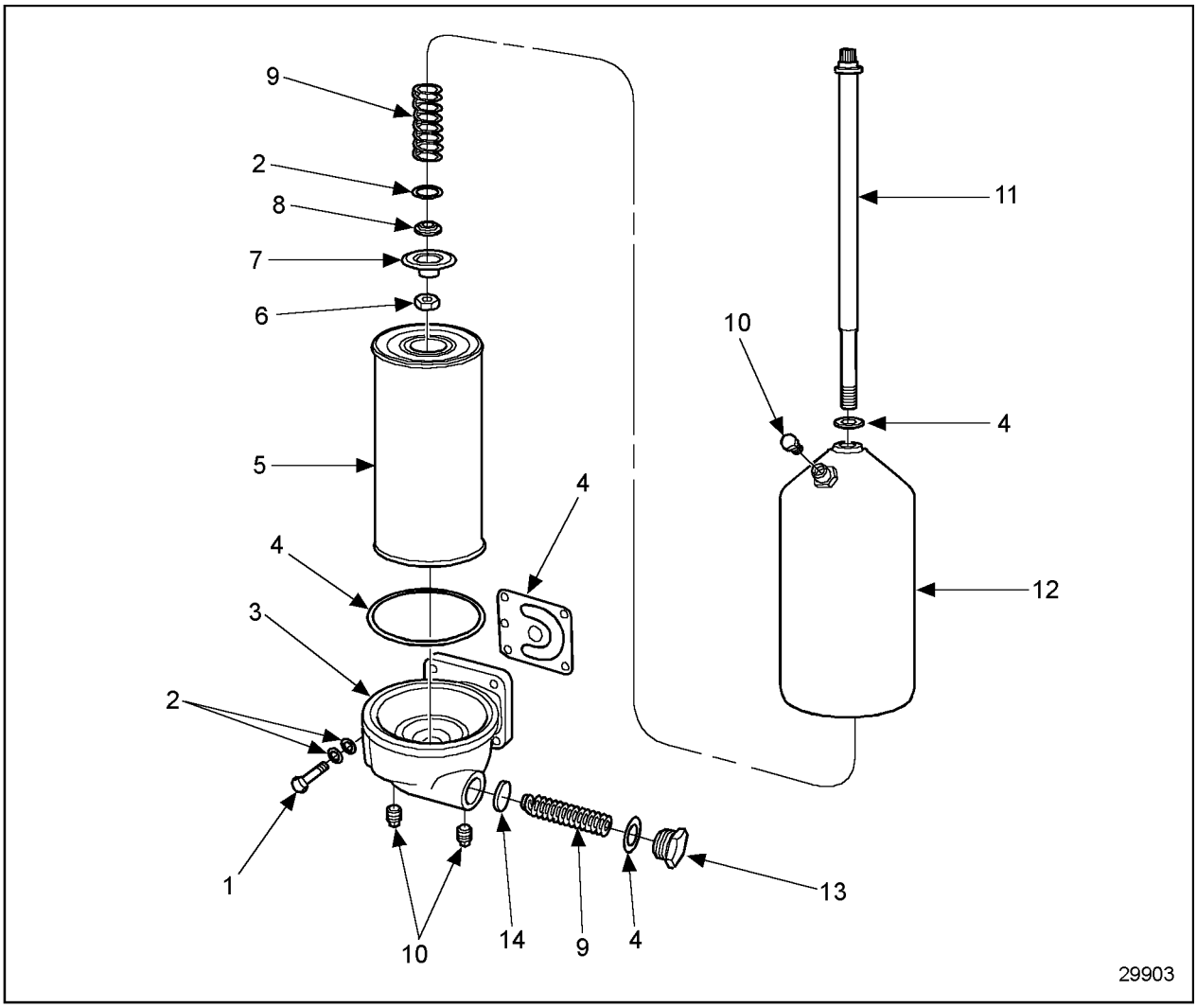


Figure 3-39 Flowchart for Repair or Replacement of Oil Filter

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3.6.2 Removal of Full Flow or Bypass Oil Filter

See Figure 3-40. Remove the full flow or bypass oil filter as follows:



1. Bolt
2. Washers (3)
3. Adaptor
4. Gasket (3)
5. Element
6. Nut
7. Retainer
8. Seal
9. Spring
10. Drain Plug
11. Center Stud
12. Shell
13. Plug
14. Bypass Valve

Figure 3-40 Full Flow Oil Filter

1. Remove the drain plug from the filter shell or the filter adaptor or base, and drain the oil.

2. Back out the center stud, and withdraw the shell, element, and stud as an assembly. Discard the element and the shell gasket.
3. Remove the center stud and gasket.

NOTE:
Retain the gasket unless it is damaged and oil leaks have occurred.

4. Remove the nut on the full flow filter center stud.
5. Remove and discard the element retainer seal. Install a new seal.

3.6.3 Removal of Spin-on Oil Filter

Remove the spin-on oil filter as follows:

1. Remove the oil filter using strap wrench tool J 29917, which must be used with a 1/2 in. drive socket wrench and extension.
2. Discard the used oil filter.

3.6.4 Removal of Bypass Valve

Remove the bypass valve as follows:

1. Remove the plug and gasket or the screw and retainer.
2. Withdraw the spring and bypass valve.

3.6.4.1 Cleaning of Oil Filter

Clean the oil filter as follows:

1. On full flow or bypass oil filters, clean the filter shell and the adaptor or base.
2. On spin-on filters, clean the filter adaptor with a clean, lint-free cloth.

⚠ 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. On the bypass valve, wash all parts in clean fuel oil, and dry them with compressed air.

3.6.4.2 Inspection of Oil Filter

Inspect the oil filter as follows:

1. Inspect the filter shell for nicks, burrs, and other damage.

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[a] If nicked, burred, or damaged, replace the filter shell. Refer to section 3.6.5.

[b] If not nicked, burred, or damaged, reuse the filter shell.

3.6.5 Installation of Full Flow or Bypass Oil Filter

Install the full flow or bypass oil filter as follows:

1. Install the center stud gasket, and slide the stud (with the spring, washer, seal, and retainer installed on the full flow filter stud) through the filter shell.
2. Install a new shell gasket in the filter adaptor or base.
3. Position the new filter element carefully over the center stud and within the shell.
4. Place the shell, element, and stud assembly in position on the filter adaptor or base. Tighten the stud to 68-81 N·m (50-60 lb·ft) torque.
5. Install the drain plug.
6. Start and run the engine for a short period, and check for oil leaks.
7. After any oil leaks have been corrected and the engine has been stopped long enough (approximately twenty minutes) for the oil from various engine parts to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

3.6.6 Installation of Spin-on Oil Filter

Install the spin-on oil filter as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lightly coat the oil filter gasket (seal) with clean engine oil.

NOTE:
When installing an oil filter on a DDEC engine, fill 2/3 full with clean engine oil before installing. This will insure full bearing surface lubrication when the engine is started and prevent a faulty low oil pressure code (45).

NOTICE:

Tighten the filter by hand. Mechanical tightening will distort or crack the filter adaptor.

2. Start the new filter on the adaptor, and tighten by hand until the gasket touches the mounting adaptor head. Tighten an additional two-thirds turn.
3. Start and run the engine for a short period, and check for oil leaks.

4. After any oil leaks have been corrected and the engine has been stopped long enough for oil from the various engine parts to drain back to the crankcase (approximately twenty minutes), add sufficient oil to raise the oil level to the proper mark on the dipstick.

3.6.7 Installation of Bypass Valve

Install the bypass valve as follows:

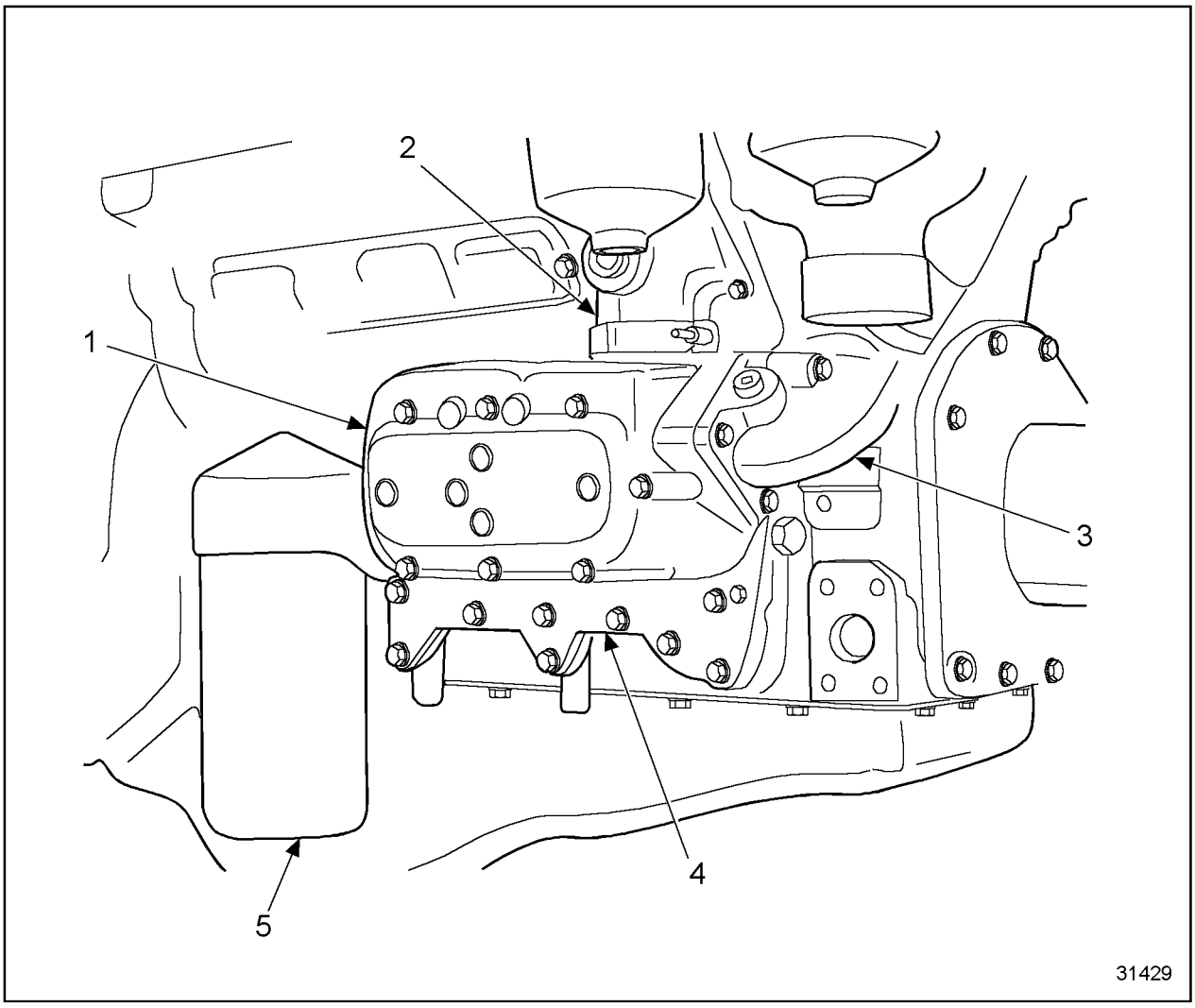
1. Using a new gasket, install the bypass valve.
2. Tighten the 1-1/4 in.-16 bypass valve plug to 129-143 N·m (95-105 lb·ft) or the 1-1/2 in.-16 plug to 150-177 N·m (110-130 lb·ft) torque.

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3.7 LUBRICATING OIL COOLER (PLATE TYPE)

In order to perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, carry away enough heat, and may flow too heavily. As a consequence, oil pressure may drop below acceptable limits and oil consumption may become excessive.

An oil cooler dissipates heat from the engine oil. Each engine is provided with an oil cooler mounted on the right-hand side of the cylinder block at the lower front corner as viewed from the flywheel end of the engine. See Figure 3-41. Two engine oil coolers are used on the 12V and 16V engines and are centrally located on the side of the cylinder block.



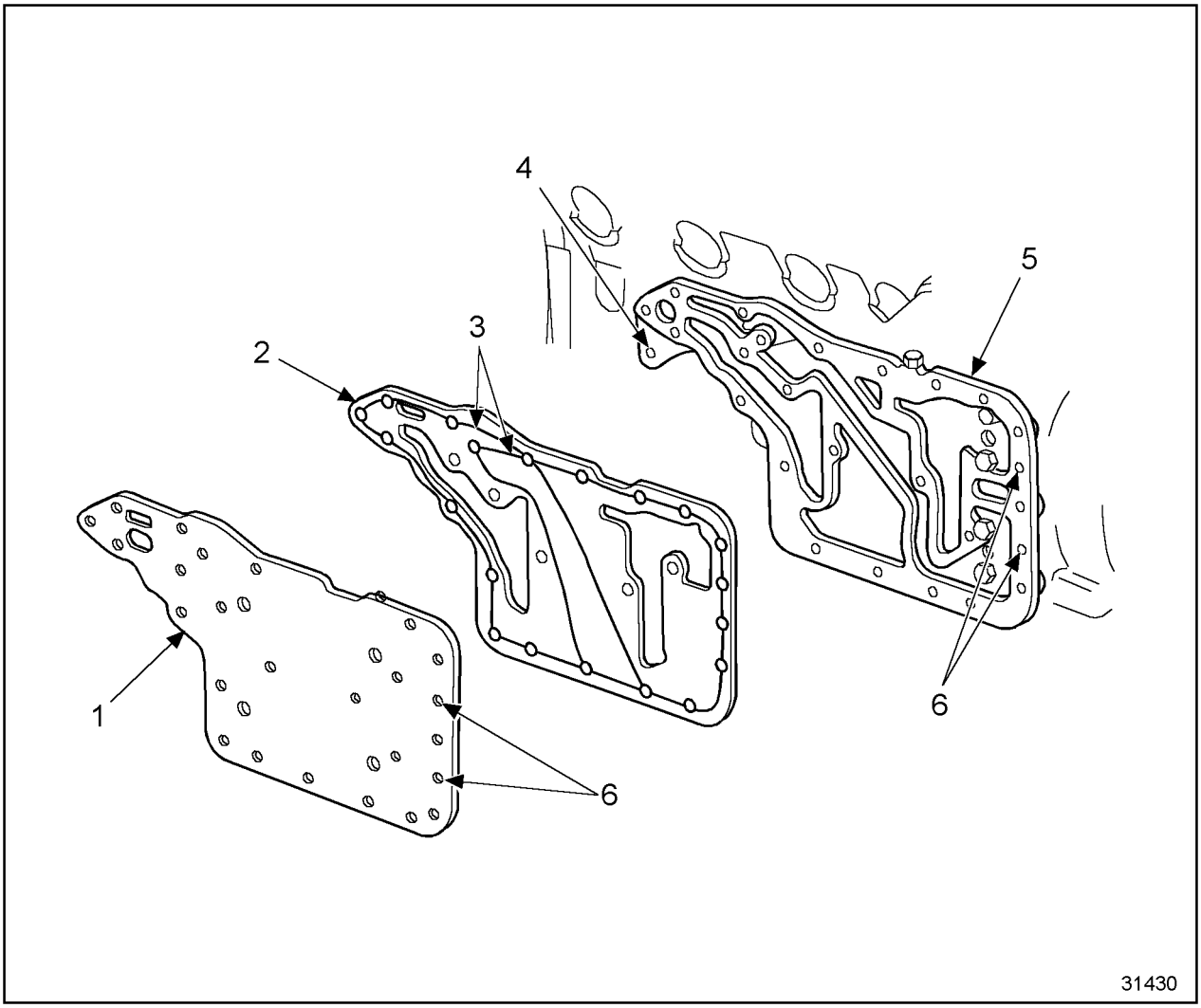
1. Oil Cooler
2. Water Outlet Elbow
3. Water Inlet Elbow
4. Cooler Adaptor
5. Oil Filter

Figure 3-41 Typical Oil Cooler Mounting (6V and 8V Engine)

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The 6V and 8V naturally aspirated engines usually are equipped with an 18 or 24 plate oil cooler. Most current 6V turbocharged engines are equipped with an 18 plate oil cooler (three plates per cylinder). Some 6V and all 8V turbocharged engines are equipped with a 24 plate oil cooler (four plates per cylinder).

To improve sealing between the oil cooler housing adaptor, gasket and plate on certain vehicle engines, additional bolt holes, and 5/16 in.-18 bolts have been added. See Figure 3-42. Only the new adaptor, plate, and gasket are serviced. To use the former adaptor plate with the new gasket and adaptor, drill two additional holes.



1. Plate
2. Gasket
3. Bead of Sealing Material
4. "Dog Ear" with Bolt Hole
5. Adaptor
6. Additional Bolt Holes

Figure 3-42 Oil Cooler Adaptor (Certain Vehicle Engine)

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A new, one-piece cast oil cooler adaptor, which eliminates the need for a separate cover plate and gasket, is used on 6V and 8V engines. The new adaptor eliminates the potential for external oil leakage between the former adaptor and oil cooler adaptor plate gasket surfaces. See Figure 3-43. The new adaptor is completely interchangeable with the former adaptor, and only the new versions serviced. The gasket and plate used with the former adaptor are still serviced.

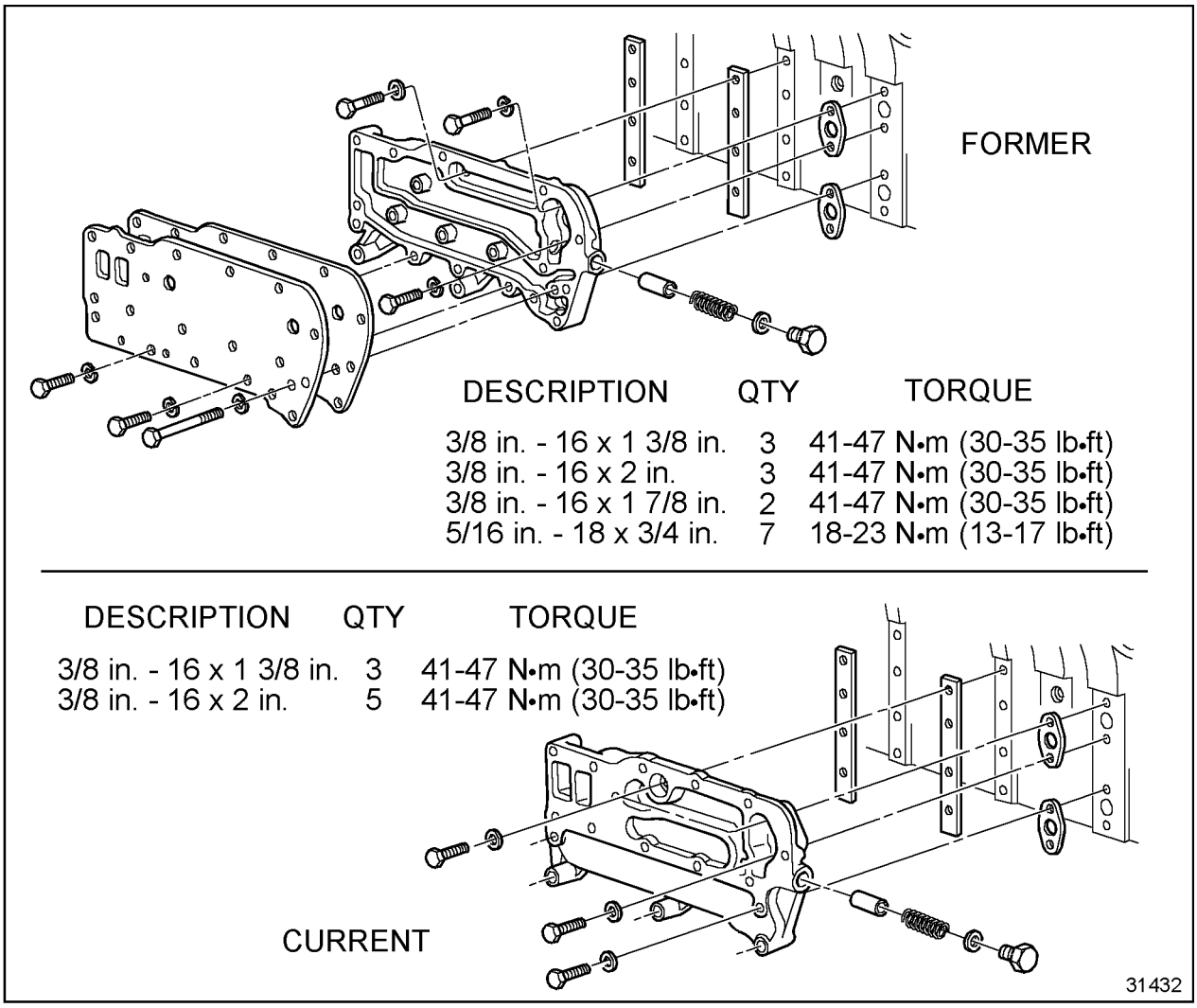


Figure 3-43 Former and Current Oil Cooler Configuration

Oil from the lubricating oil pump flows through a passage in the oil cooler adaptor to the oil filter, through the oil cooler, and through the outlet passage in the cooler adaptor which leads to the cylinder block oil galleries. The engine coolant is pumped through the oil cooler and completely surrounds the oil cooler core.

3.7.1 Repair or Replacement of Lubricating Oil Cooler (Plate Type)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-44.

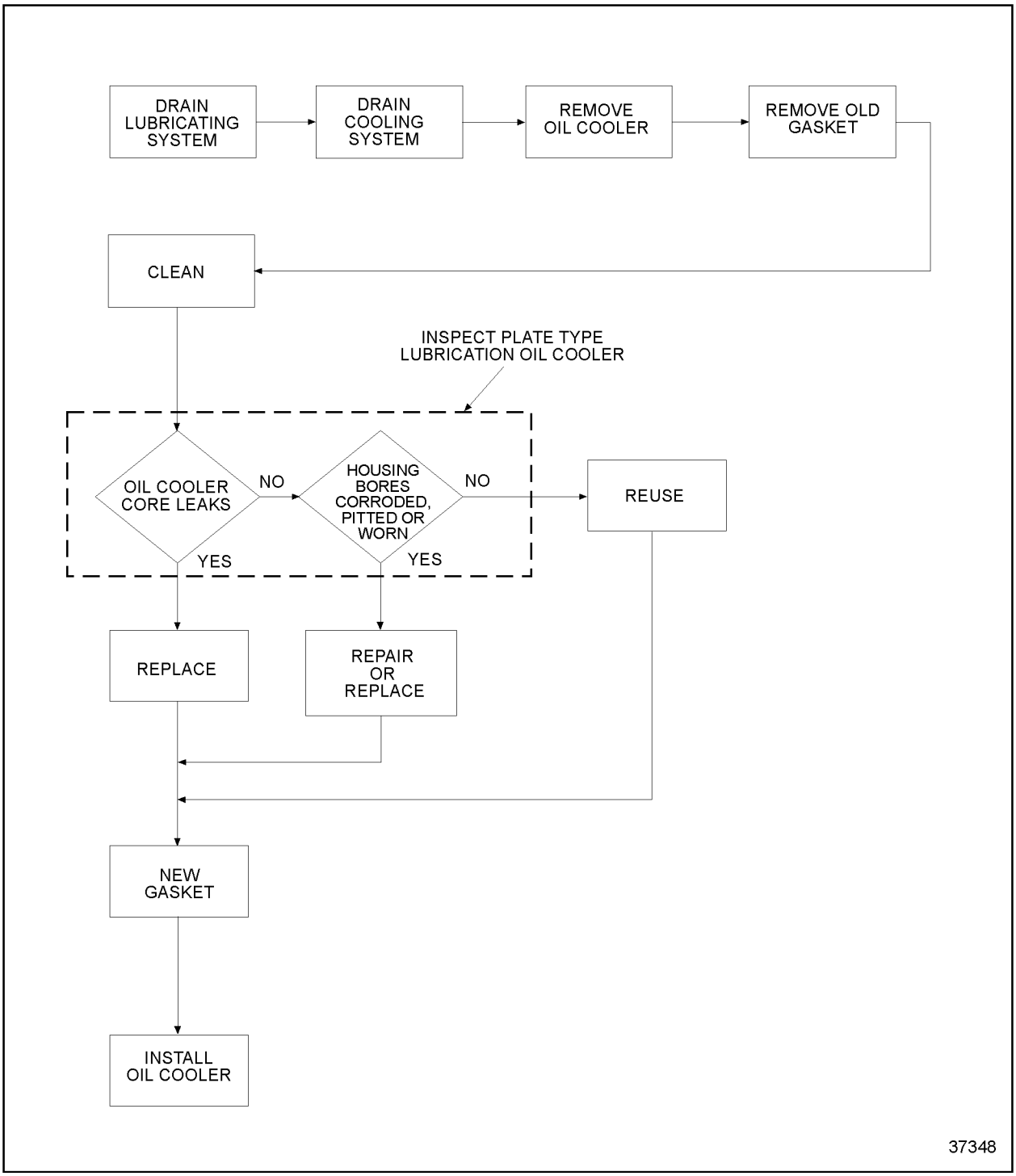


Figure 3-44 Repair or Replacement of Lubricating Oil Cooler (Plate Type)

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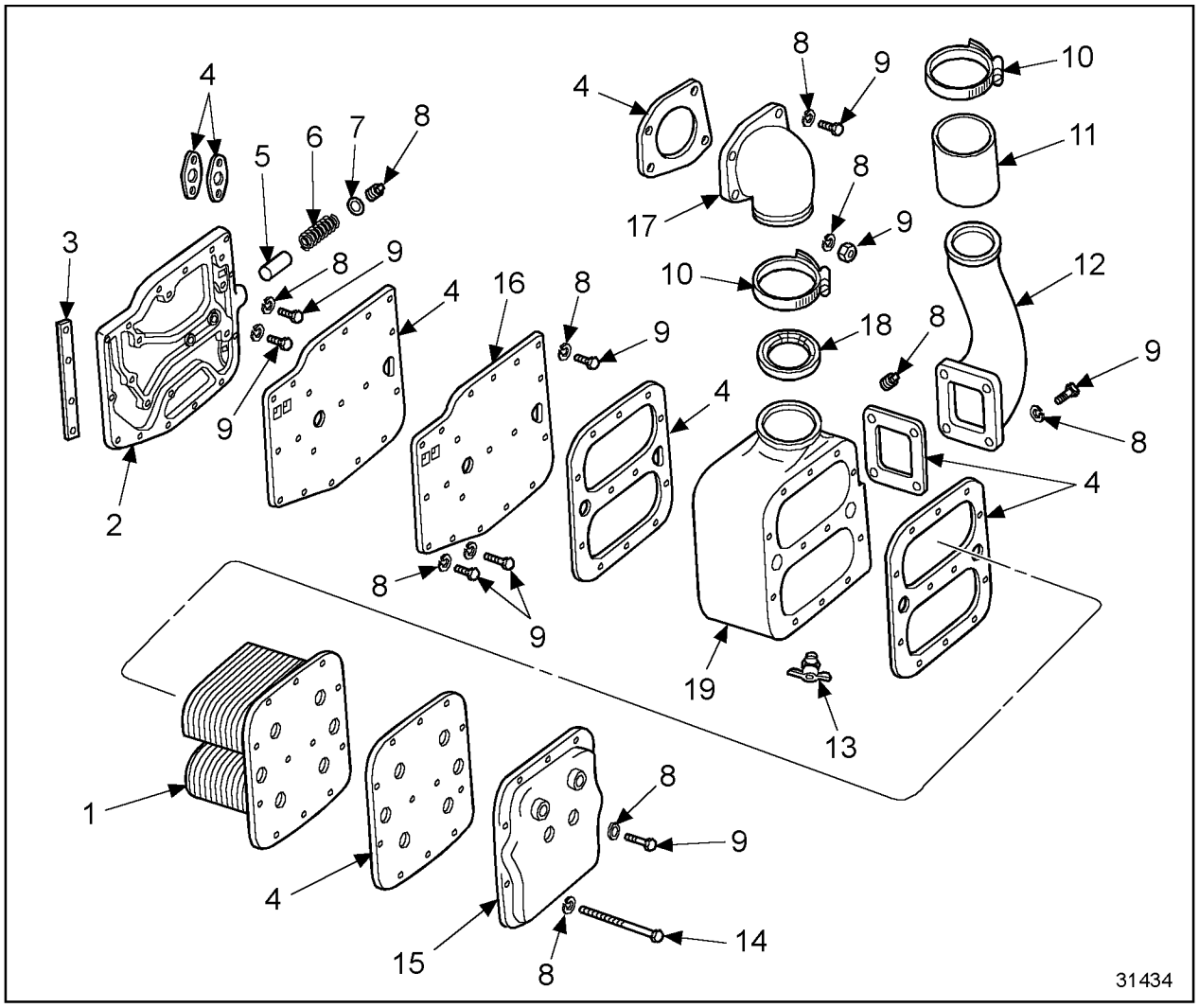
3.7.2 Removal of Lubricating Oil Cooler (Plate Type)

Remove the plate-type oil cooler as follows:

1. Open the drain cock, and drain the cooling system. Refer to section 13.12.3.
2. Remove the full flow oil filter. Refer to section 3.6.3.
3. Remove any accessories or equipment necessary to provide access to the oil cooler.
4. Loosen the clamps, and slide the hose down the water inlet elbow.
5. Remove the bolts and lock washers which retain the water inlet elbow to the oil cooler housing.
6. Remove the elbow and gasket.
7. If a water outlet elbow is used, loosen the seal clamp, remove the bolts, nuts, and lock washers, and withdraw the water outlet flange and seal, or water outlet elbow, seal, and gasket.
8. Remove the bolts and lock washers. Withdraw the oil cooler housing and oil cooler core as an assembly, using care to avoid dropping the oil cooler core.
9. If the engine is equipped with a twin plate oil cooler, remove the two outer bolts at the top of the oil cooler cover, and install two studs (approximately 8-1/2 in. long and

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with a 5/16 in.-18 thread at one end) to support the housing, oil cooler core, and cover. See Figure 3-45.



1. Oil Cooler Core
2. Adaptor
3. Spacers
4. Gaskets
5. Bypass Valve
6. Spring
7. Seal Ring
8. Plug
9. Lock Washer
10. Bolt
11. Clamp
12. Hose
13. Water Inlet Elbow
14. Drain Cock
15. Long Bolt
16. Cover
17. Plate
18. Water Outlet Elbow
19. Housing

Figure 3-45 Twin Plate Oil Cooler

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10. Remove the remaining bolts, lock washers, and two copper washers.
11. Remove the cover, oil cooler core, housing, and gaskets.
12. If the oil cooler adaptor is to be removed, remove the oil filter.
13. Remove the bolts and lock washers which attach the adaptor to the cylinder block, and withdraw the adaptor and gaskets.

NOTE:
To remove the oil cooler adaptor used with the twin plate cooler, the adaptor plate must be removed first.

14. Clean all gasket material from the cylinder block and the oil cooler components.

3.7.2.1 Cleaning of Lubricating Oil Cooler (Plate Type)

Prior to inspection, clean the plate-type oil cooler as follows:

⚠ 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. Circulate a solution of Tech Solv 340 through the cooler core oil passages with a force pump.

NOTICE:

Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. Replace the oil cooler core.

2. Clean the oil cooler core before the sludge hardens.

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

3. If the oil passages are badly clogged, circulate an alkaline cleaning solution through the oil cooler core, and flush it thoroughly with clean, hot water.

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⚠ 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:

Precautions must be taken so the cleaning agents do not corrode the tubes. If an acid solution is used, the residue must be neutralized.

NOTICE:

Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. In this instance, replace the oil cooler core.

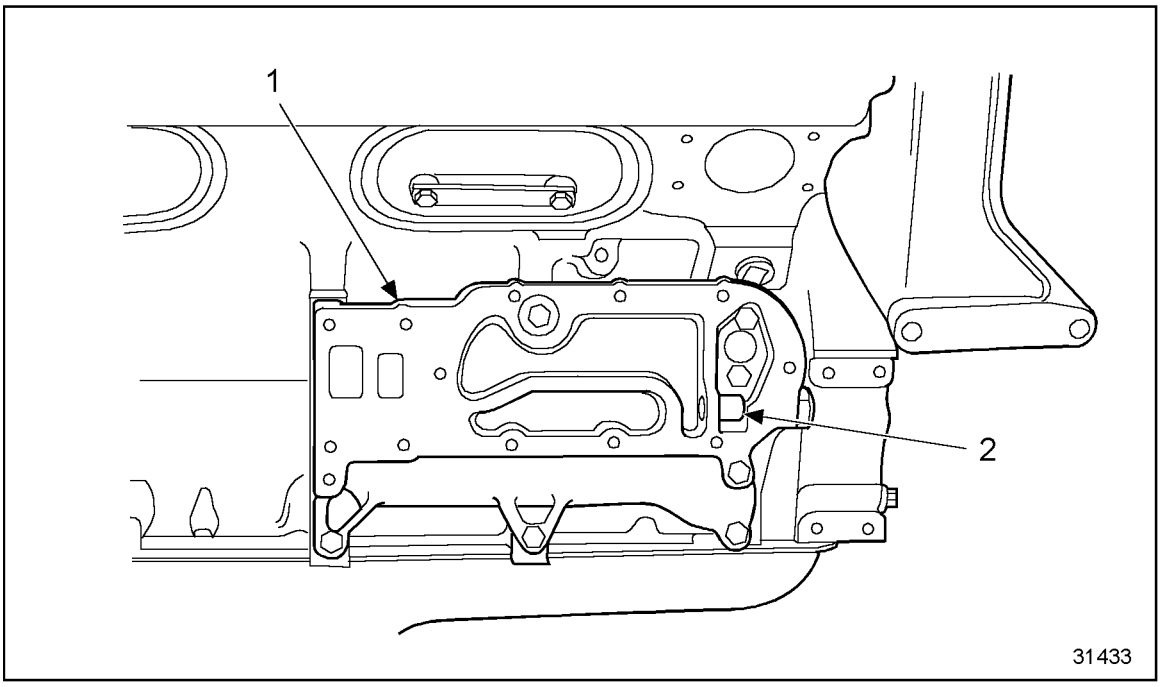
4. After cleaning the oil passages, immerse the water side of the oil cooler in a solution of 1/2 pound oxalic acid to each 2-1/2 gallons of a 1/3 muriatic acid and 2/3 water solution.
5. Observe the bubbling and foaming process, and remove the oil cooler core from the solution when the bubbling stops. This usually takes from 30 to 60 seconds.
6. Thoroughly flush the oil cooler core with clean, hot water.
7. Dip the oil cooler core in light oil.

3.7.2.2 Inspection of Lubricating Oil Cooler (Plate Type)

Inspect the oil cooler as follows:

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1. Inspect the vertical oil passage in the cylinder block for the cup plug that directs the flow of oil through the oil cooler. See Figure 3-46.



1. Oil Cooler and Filter Adaptor
2. Bypass Valve

Figure 3-46 Oil Cooler Adaptor and Bypass Valve Mounting

NOTE:
High oil temperature or low oil pressure resulting from high oil temperature will occur if the plug is missing.

[a] If missing, replace the cup plug. Refer to section ADDITIONAL INFORMATION.

[b] If not missing, refer to section 3.7.2.3 and pressure check oil cooler.

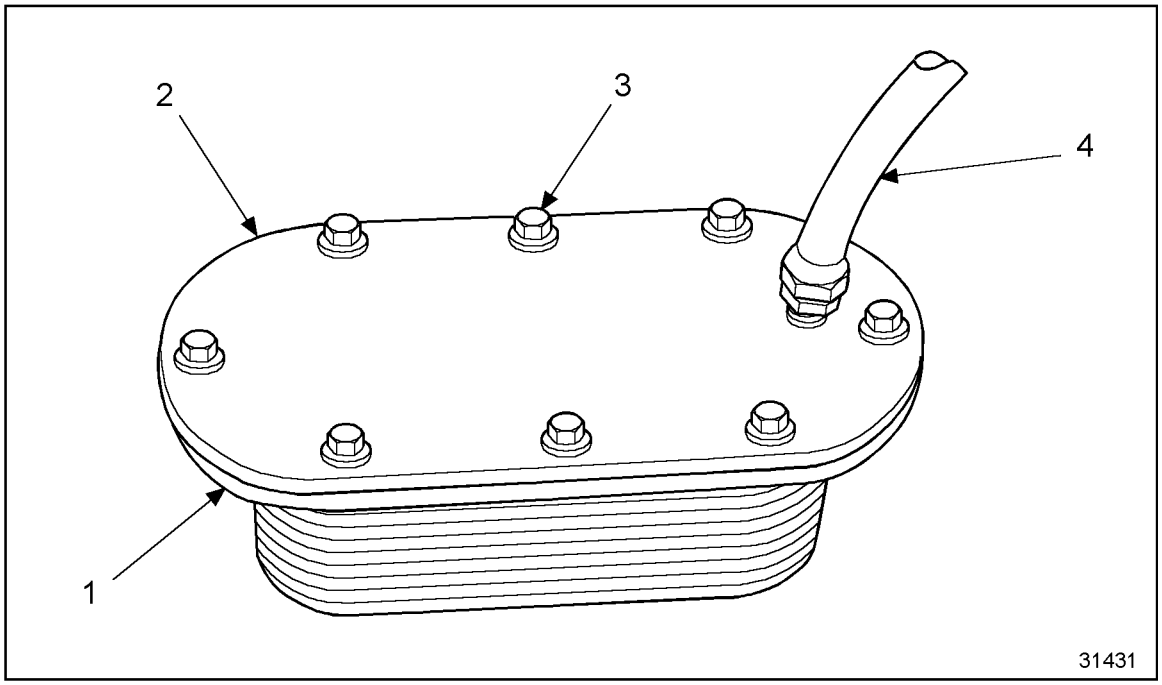
3.7.2.3 Test Pressure Lubricating Oil Cooler (Plate Type)

Pressure check the oil cooler as follows:

NOTICE:
If a leaking oil cooler core has contaminated the engine, the engine must be flushed immediately to prevent serious damage. Refer to section 13.5.4 or refer to section 13.5.5.

1. Make a suitable plate, and attach it to the flanged side of the oil cooler core.
2. Use a rubber gasket to ensure a tight seal.

3. Drill and tap the plate to attach an air hose fitting at the inlet side of the oil cooler core. See Figure 3-47.



1. Oil Cooler Core
2. Pressure Test Plate
3. Bolt and Nut Assemblies
4. Air Line

Figure 3-47 Oil Cooler Core Prepared for Pressure Check

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. Attach an air hose, and apply approximately 517-1.034 kPa (75-150) air pressure.
5. Submerge the oil cooler core and plate assembly in a tank of water heated to 82°C (180°F). Air bubbles indicate leaks.
   [a] If leaks are detected, replace the oil cooler core.
   [b] If no leaks are detected, reuse the oil cooler core.
6. After the pressure check is completed, remove the plate and air hose.

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CAUTION:

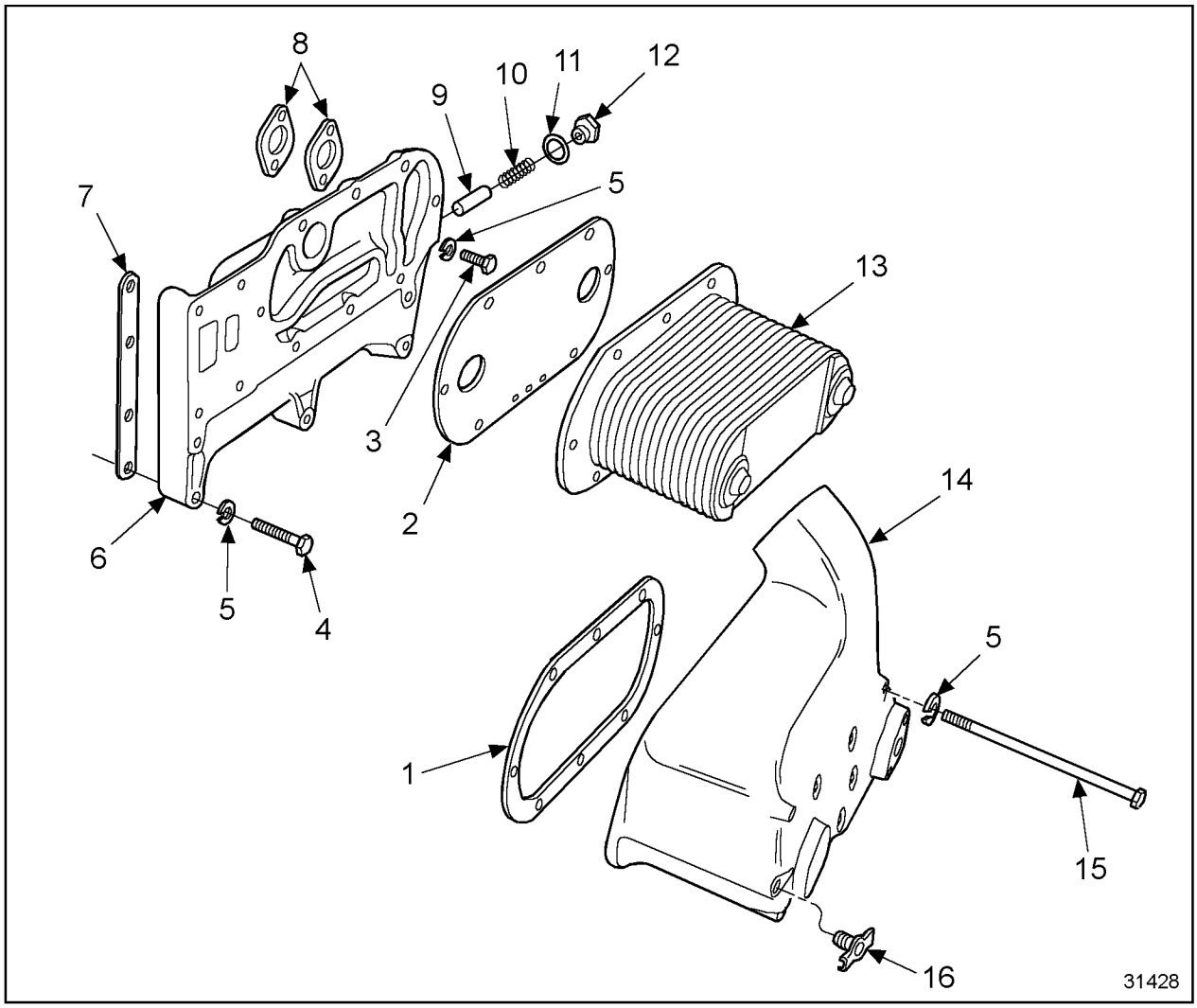
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

7. Dry the oil cooler core with compressed air.

3.7.3 Installation of Lubricating Oil Cooler (Plate Type)

Install the plate-type oil cooler as follows:

1. Using new gaskets, attach the adaptor, if removed, to the cylinder block with bolts and lock washers. See Figure 3-48.



1. Housing Gasket
2. Adaptor to Core Gasket
3. Short Bolt
4. Adaptor Bolt
5. Lock Washer
6. Adaptor Plate
7. Spacer
8. Adaptor to Block Gaskets
9. Bypass Valve
10. Spring
11. O-ring Seal
12. Plug
13. Oil Cooler Core
14. Oil Cooler Housing
15. Long Bolt
16. Drain Cock

Figure 3-48 Oil Cooler

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2. If a twin plate oil cooler is used, use a new gasket, and attach the adaptor plate to the oil cooler adaptor.

NOTE:
The current adaptor-to-block bolts with hardened washers will continue to be used. These bolts are precoated with a lock and seal compound. If reusing the bolts, use Loctite No. 567, (or equivalent) in the block bolt holes before bolt installation.

3. Affix new gaskets to the inner and outer flange faces, and insert the oil cooler core in the oil cooler housing.

NOTICE:
The inlet and outlet openings in the oil cooler core are marked "IN" and "OUT". Ensure the oil cooler core is reinstalled in its original position, otherwise the oil flow will be reversed and could allow foreign particles that may not have been removed to loosen and circulate through the engine. If the openings are unidentified, DDC suggests that they be marked before reinstalling the oil cooler core.

4. Place the housing and oil cooler core against the adaptor, and secure them with bolts and lock washers.
5. If a twin plate oil cooler is used, install two guide studs. Using new gaskets, slide the housing, oil cooler core, and cover over the dowels in order.
6. Secure in place with bolts, lock washers, and new copper washers.
7. Remove the studs, and install the remaining two bolts and lock washers.

NOTE:
A tab is provided on current cover gaskets to ensure the gasket is installed correctly.

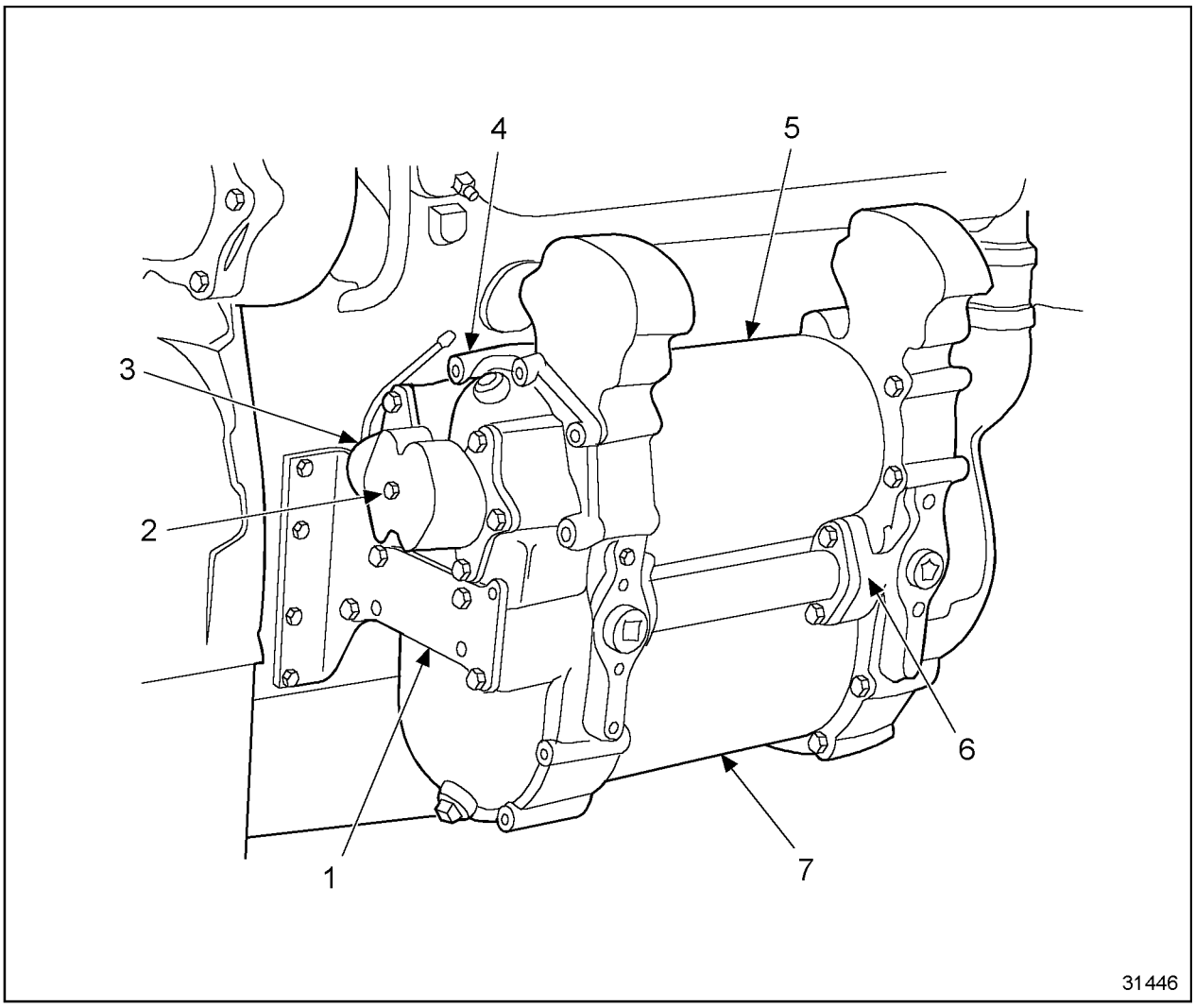
8. Install the water outlet flange and seal, or water outlet elbow, seal, and gasket. Secure the flange or elbow to the cylinder block with bolts, nuts, and lock washers. If an elbow is used, tighten the seal clamp.
9. Affix a new gasket to the oil cooler housing at the water inlet opening, and secure the water inlet elbow to the housing with bolts and lock washers.
10. Slide the water inlet elbow hose in position, and tighten the clamps.
11. Install any accessories which were removed to provide access to the oil cooler.
12. Close the drain cock in the oil cooler housing, and fill the cooling system to the proper level. Refer to section 13.12.
13. Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick. Refer to section 13.5.1.
14. Start and run the engine for a short period, and check for oil and water leaks.

15. After any leaks have been corrected and the engine has been stopped long enough (approximately twenty minutes) for the oil from various engine parts to drain back to the crankcase, bring the oil level up to the proper level on the dipstick.

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3.8 LUBRICATING OIL COOLER (TUBE TYPE)

Some engines are equipped with a tube-type oil cooler mounted on the side of the engine. Torqmatic converter units use a single basic oil cooler which consists of two sections; one section for the engine oil and the other section for the converter oil. See Figure 3-49.

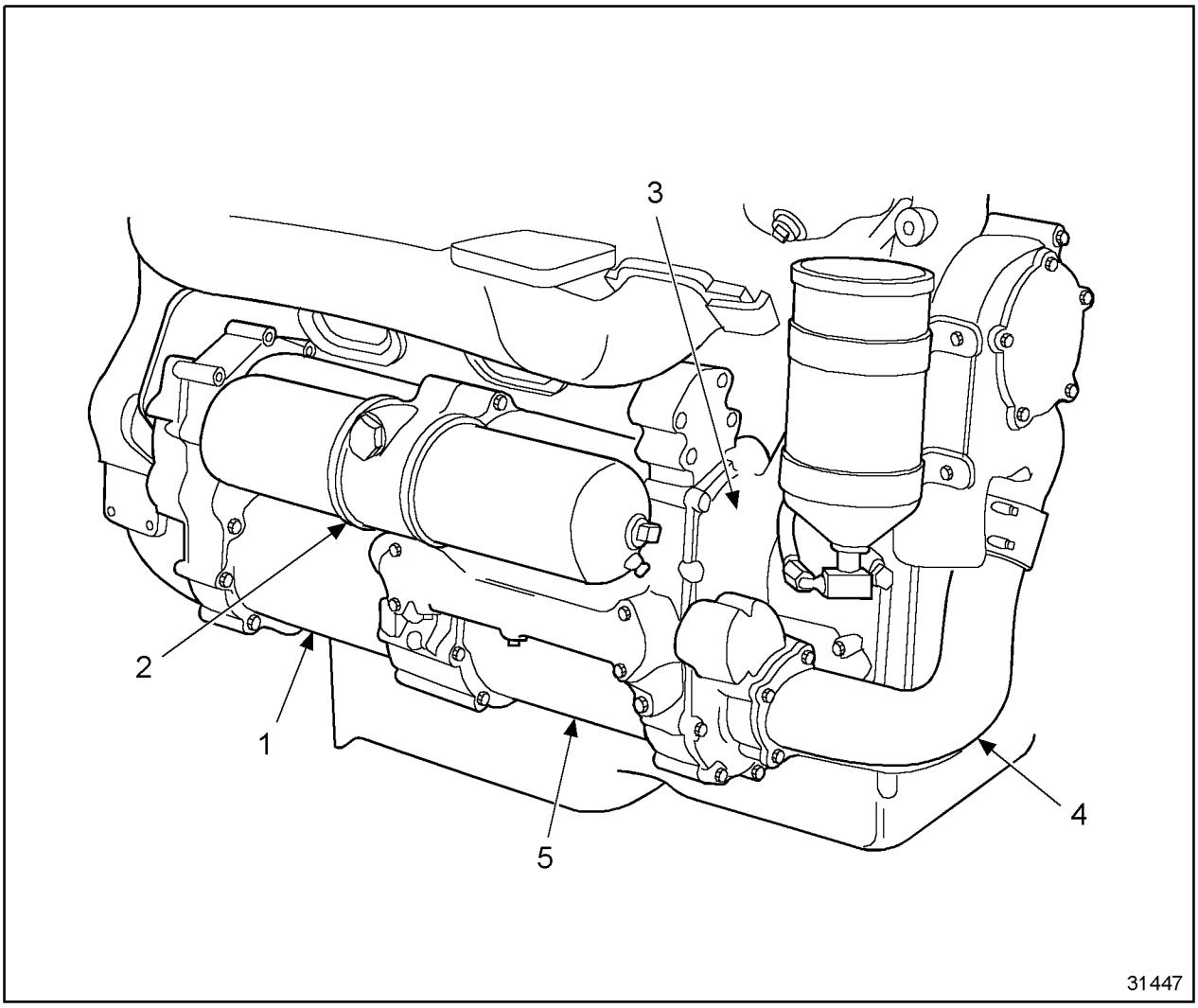


1. Support Plate
2. Center Bolt
3. Junction Block
4. Rear Cover
5. Convertor Oil Cooler
6. Bypass Valve
7. Engine Oil Cooler

Figure 3-49 Tube Type Oil Cooler Mounting

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The hydraulic retarder units use a dual oil cooler which one section cools the engine oil and three sections cool the brake oil. See Figure 3-50.

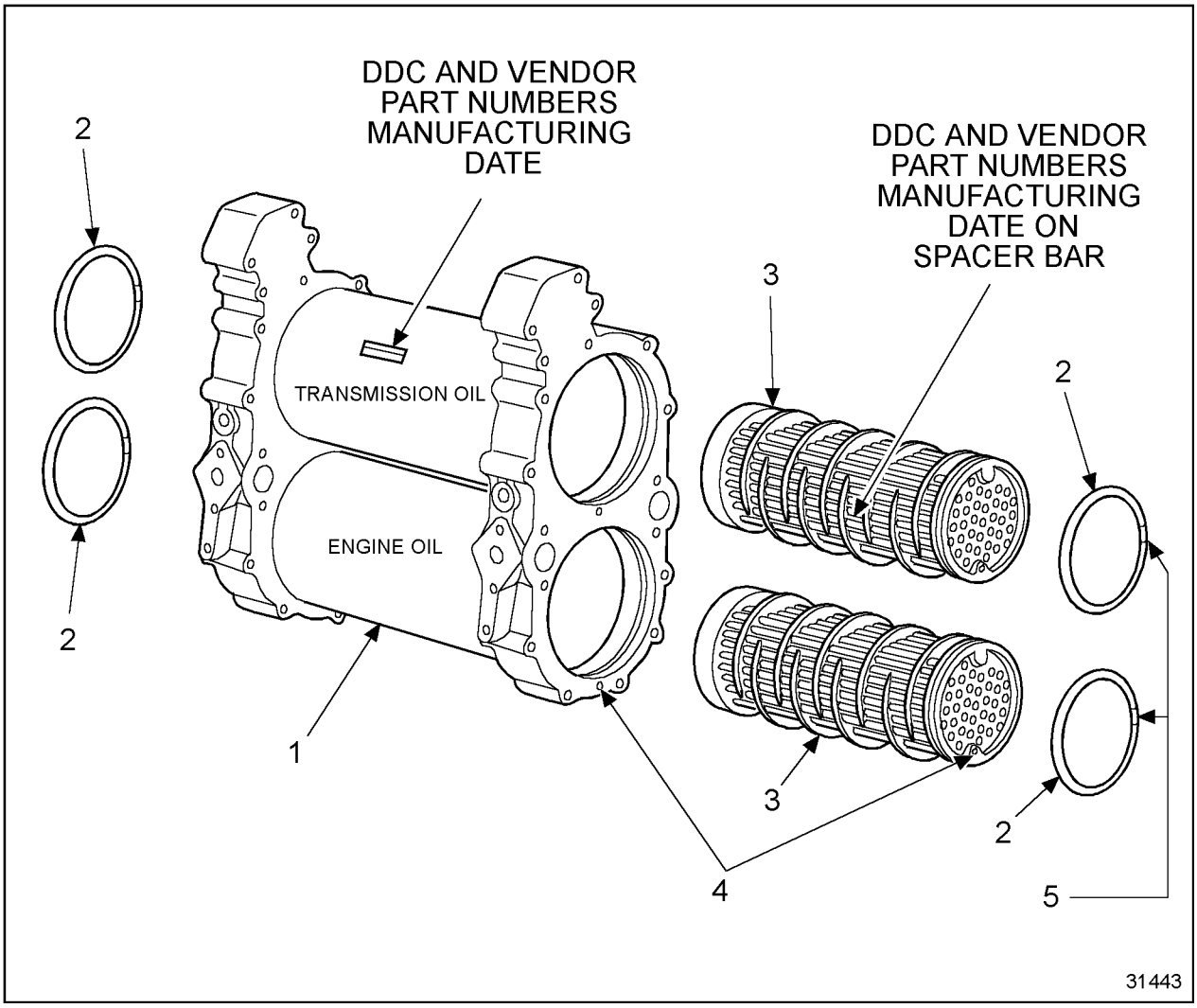


1. Hydraulic Retarder Oil Cooler
2. Oil Filters
3. Cooler Front Cover
4. Water Inlet Elbow
5. Engine Oil Cooler

Figure 3-50 Dual Tube Type Oil Cooler Mounting

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A serviceable tube type oil cooler with removable tube bundles is used on certain 8V engines. The tube type oil cooler consists of a shell, two tube bundles, four seal rings, and a front and rear cover. See Figure 3-51.



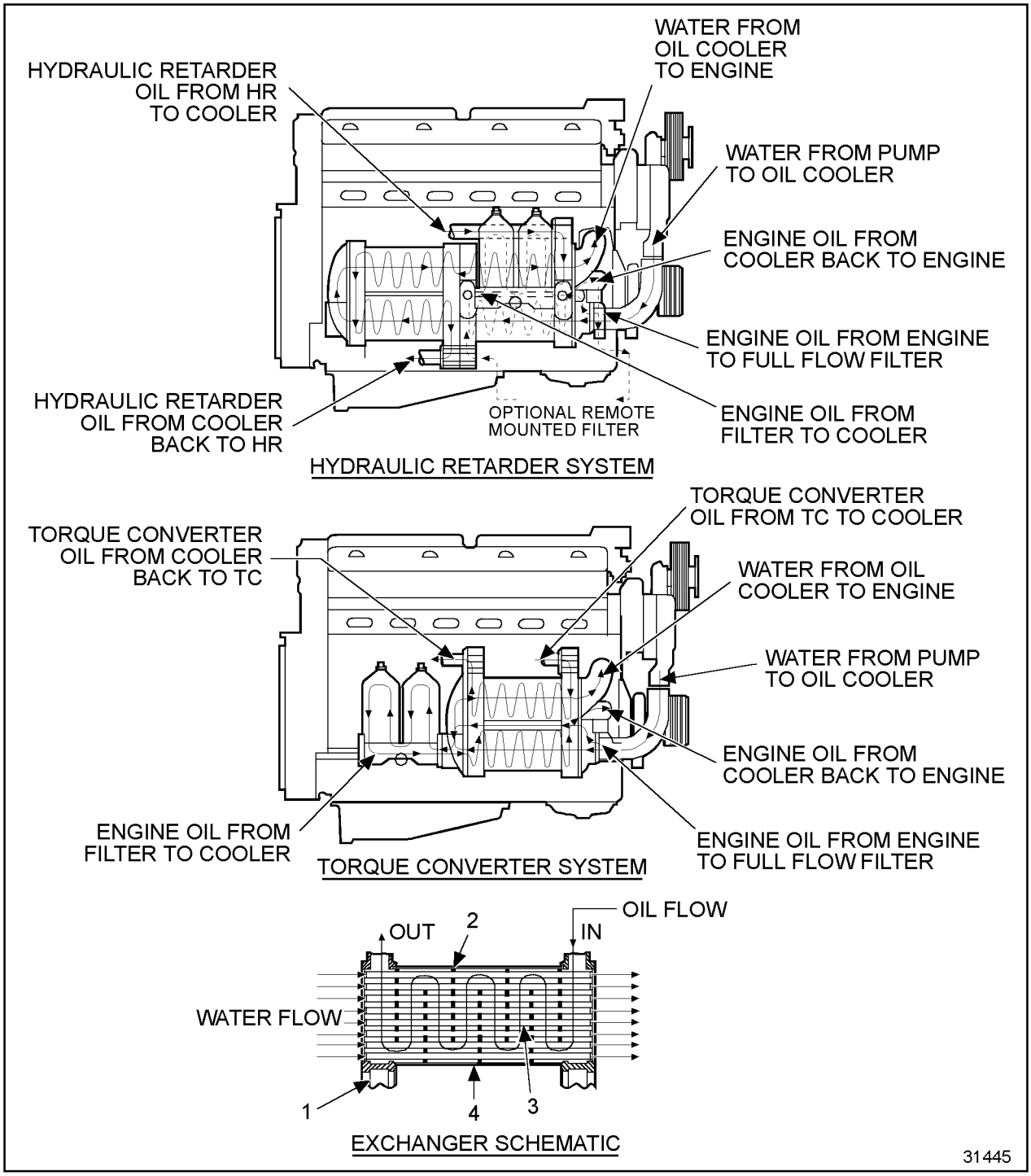
1. Shell Housing
2. O-ring
3. Tube Bundles
4. "O" Mark
5. Double Dot or Stripes

Figure 3-51 Tube Type Oil Cooler (Removable Bundles)

NOTE:
An improved fluoroelastomer seal ring is used in the single and dual tube type oil coolers. The improved seal ring is used at four locations on the oil cooler and should be used at overhaul or whenever the oil cooler is serviced. Only the current seal ring is serviced.

The coolant from the engine water pump flows through a passage in the oil cooler front cover, passes through the oil cooler tubes, to the front cover outlet passage, and to the water jackets in the cylinder block. See Figure 3-52.

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1. End Casting
2. Baffle
3. Tube Bundle
4. Shell

Figure 3-52 Tube Type Oil Flow Diagrams

The engine oil from the lubricating oil pump enters a passage in the oil cooler front cover, passes through the remote mounted oil filter, around the tubes in the engine section of the oil cooler, through the outlet passage in the front cover, and to the cylinder block oil galleries.

A bypass valve permits the engine oil to flow directly through the oil cooler should the oil filter become clogged.

Oil from the torqmatic converter or hydraulic retarder flows through a flexible hose connected to an oil passage in the oil cooler front end-casting, through the converter or retarder oil cooler sections, out an oil passage in the oil cooler rear end-casting, and to a flexible hose which carries the cool oil back to the converter or hydraulic retarder.

3.8.1 Repair or Replacement of Oil Cooler (Tube Type)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-53.

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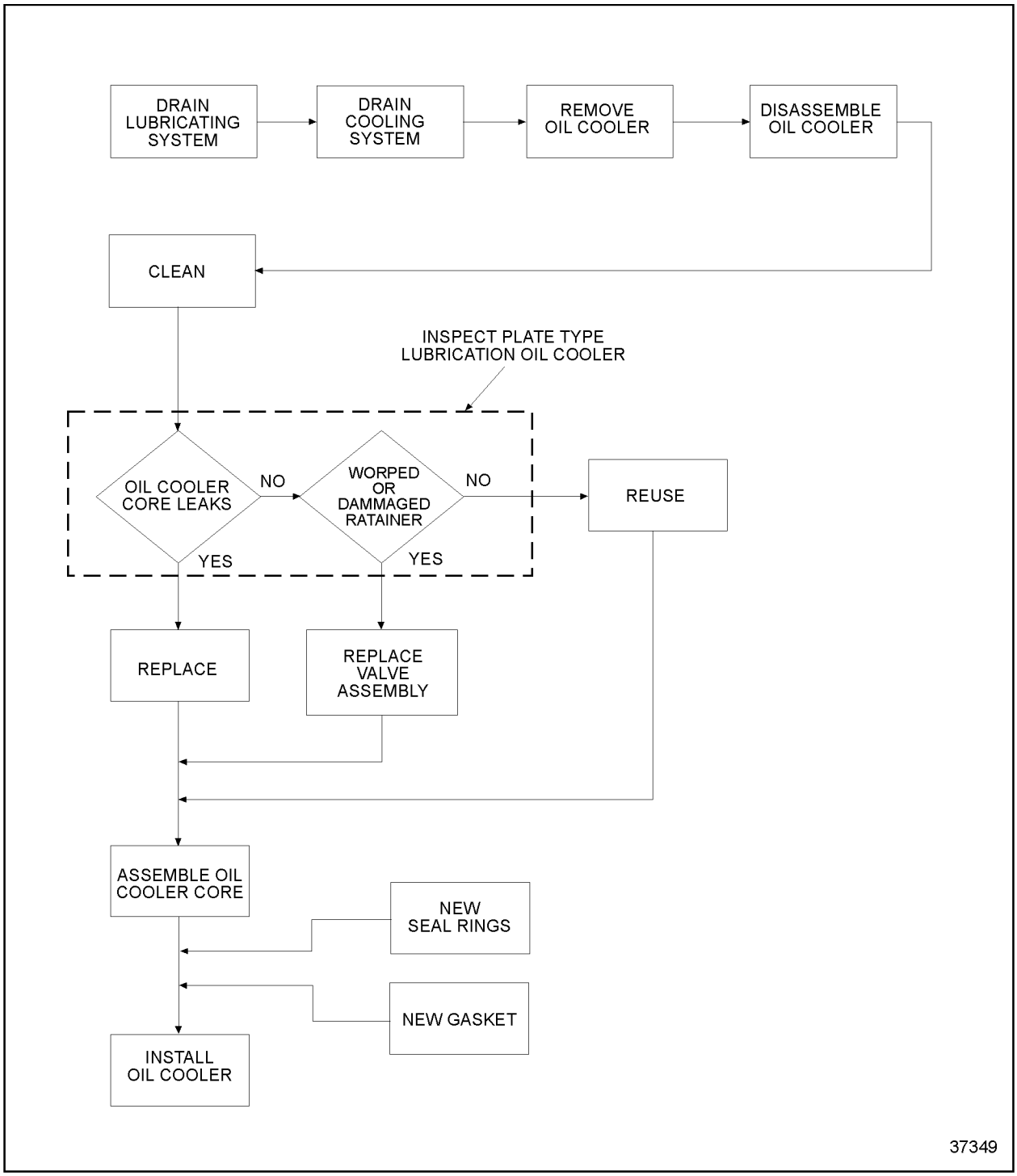


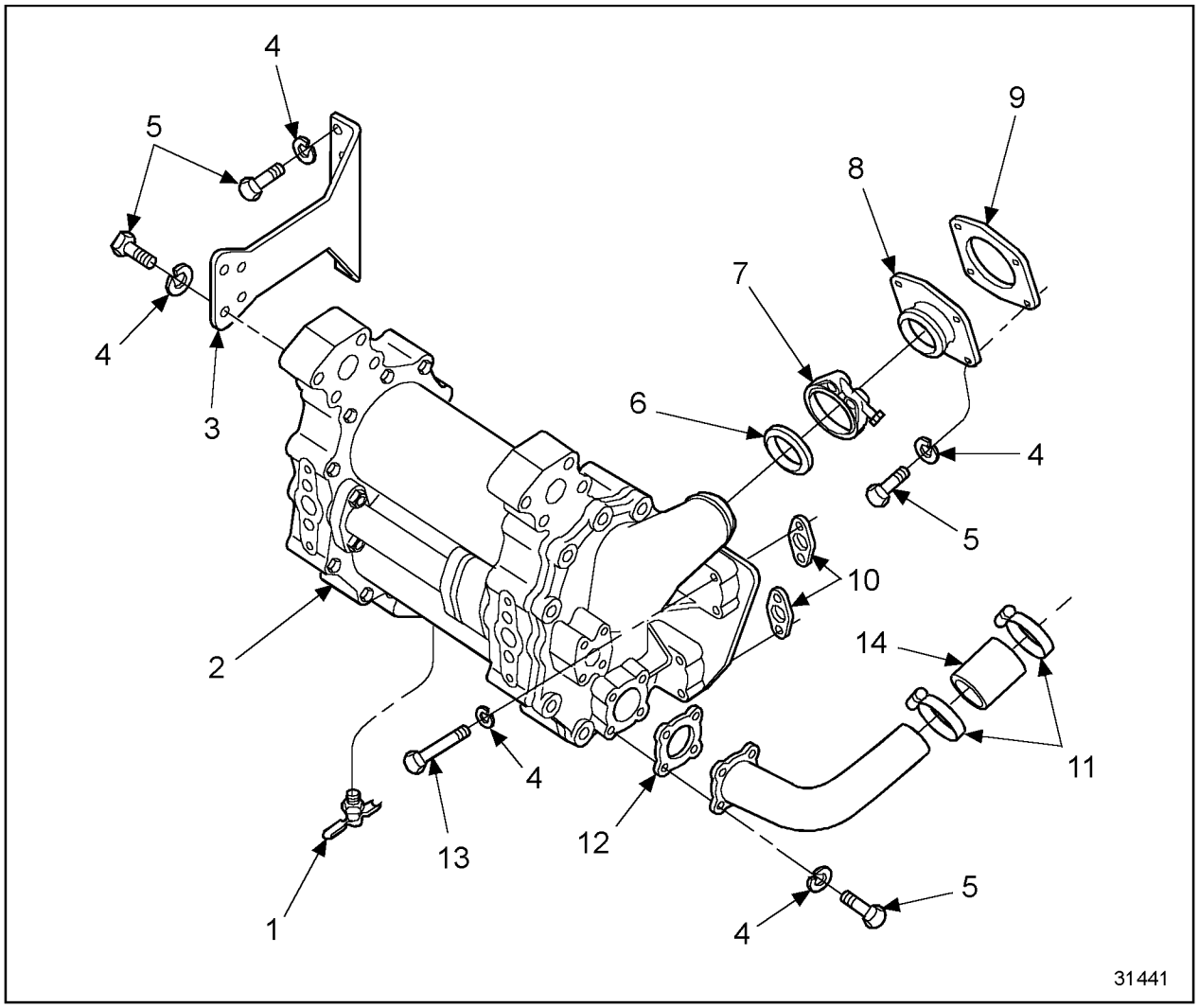
Figure 3-53 Flowchart for Repair or Replacement of Oil Cooler (Tube Type)

3.8.2 Removal of Oil Cooler (Tube Type)

Remove the tube-type oil cooler as follows:

1. Open the drain cock, and drain the cooling system. Refer to section 13.12.3.

2. Disconnect the oil filter lines and the torque converter oil lines at the cooler. See Figure 3-54.



1. Drain Cock
2. Oil Cooler Assembly
3. Support Bracket
4. Lock Washer
5. Bolt
6. O-ring
7. Clamp
8. Outlet Flange
9. Flange Gasket
10. Gaskets
11. Hose Clamps
12. Inlet Tube Gasket
13. Long Bolt
14. Hose

Figure 3-54 Removal of Typical Tube Type Oil Cooler Assembly

3. Remove any accessories necessary to provide access to the oil cooler.
4. Loosen the clamps, and slide the hose down the water inlet elbow.

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5. Remove the bolts and lock washers that attach the elbow to the oil cooler front cover, and withdraw the elbow and gasket.
6. Loosen the clamp on the water outlet flange seal. Remove the bolts, nuts, and washers that attach the flange to the cylinder block.
7. Remove the flange, gasket, seal, and clamp.
8. Remove the bolts and lock washers that attach the oil cooler to the cylinder block and the oil cooler support bracket. Remove the oil cooler and the gaskets.
9. Drain the oil from the oil cooler.

NOTE:
The oil cooler tube bundles must be reinstalled in their respective positions. If necessary, matchmark them before removing the tube bundles from the shell.

3.8.3 Disassembly of Oil Cooler (Tube Type)

Disassemble the removable tube type bundles as follows:

NOTE:
The tube bundles are serviced separately.

1. Place the shell vertically on the floor.
2. Remove the upper seal ring in the seal ring groove.
3. Remove the tube bundle from the shell.

NOTE:
The tube bundles fit snugly in the shell, but are easily removed. Use puller holes, located in the ends of the tube bundles, to aid removal.

4. Remove the bottom seal ring from the seal ring groove.

3.8.3.1 Cleaning of Oil Cooler (Tube Type)

Prior to inspection, clean the tube-type oil cooler as follows:

1. Clean the engine oil portion of the tube-type oil cooler as follows:

⚠ 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:

Precautions must be taken so the cleaning agents do not corrode the tubes. If an acid solution is used, the residue must be neutralized.

NOTICE:

Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. In this instance, replace the oil cooler core.

2. Replace the oil bypass tube and the oil bypass valve assembly with a long tube connected between the front and rear end castings of the oil cooler.
3. Seal the oil outlet-to-filter and oil inlet-to-filter openings in the front and rear oil cooler covers with steel plates and gaskets.
4. Attach a steel plate, which is fitted with an air hose connection, to the oil outlet-to-engine in the front cover.

⚠ 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. Attach an air hose, which is connected to an air supply capable to maintain approximately 689 kPa (100 lb/in.^{2}) pressure during solvent expulsion process.
6. Stand the oil cooler on end so the baffles inside the cooler shell are horizontal.

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⚠ 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.

7. Fill the oil cooler with a cleaning solvent, and apply air pressure to expel the solvent and sludge.
8. Refill the oil cooler with clean solvent, and attach the air hose fitting to the inlet side of the cooler.

⚠ 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.

9. Apply air pressure to expel the solvent.
10. Repeatedly flush in alternate directions until the solvent comes out clean twice from each direction.
11. Remove the tube which replaced the oil bypass tube and valve assembly.
12. Circulate a cleaning solvent through the oil passages to clean the torque converter.
13. Circulate a solvent, such as Oakite, through the tubes to clean the water side of the oil cooler.
14. Remove the end covers, and run a brush through the tubes.
15. Rinse the tubes with clean, hot water.

3.8.3.2 Inspection of Oil Cooler (Tube Type)

Inspect the oil cooler as follows:

1. Visually inspect the spring retainer for warpage.
   [a] If the retainer is warped, install a new valve assembly. Refer to section 3.8.5.
   [b] If the retainer is not warped, continue inspection.

3.8.3.3 Inspection of Bypass Valve Spring Load (Tube Type)

Inspect the oil bypass valve as follows:

1. Remove the spring retainer screw, and withdraw the retainer, spring, and valve from the valve housing.

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2. Use spring tester J 22738-02 to check the valve spring load.

NOTE:
The bypass valve spring has a free length of approximately 2.015625 in.

[a] Replace the spring if a load of less than 2.9445 kg (6.5 pounds) will compress it to a length of 20.6375 mm (0.8125 in.).

[b] If the spring passes the test, continue inspection.

3. Examine the spring retainer

[a] If the retainer is bent, install a new valve assembly.

[b] If the retainer is not bent, the valve assembly may be reused.

NOTE:
The current valve assembly has an increased bypass area around the spring retainer to permit a larger volume of cold oil to bypass during engine starting.

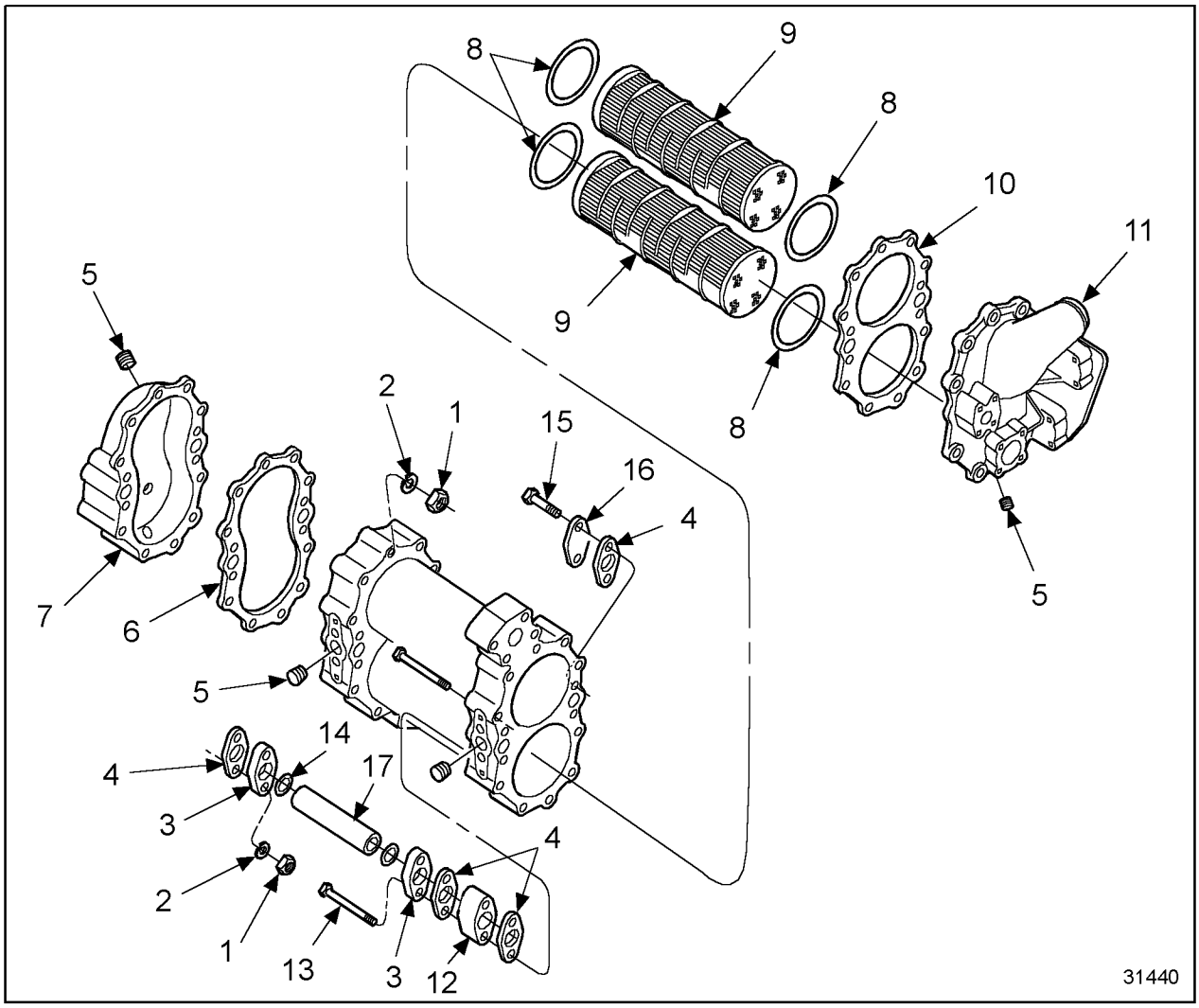
3.8.4 Assembly of Oil Cooler Bundles (Tube Type)

Assemble tube-type oil cooler bundles as follows:

NOTE:
When rebuilding a tube type oil cooler, the current design oil cooler cannot be used with a former design oil cooler in a twin oil cooler application. If one half of a former twin oil cooler application needs replacing, replace both oil cooler halves.

NOTE:
For ease in assembling, each tube bundle is marked with an "O" and the cooler shell is marked with an "O". See Figure 3-55. The "O's" must line up to ensure proper baffle location in the shell. The tube bundles can be installed either end first.

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1. Nut
2. Lock Washer
3. Spacer
4. Gasket
5. Pipe Plug
6. Rear Housing Gasket
7. Rear End Cover
8. O-ring Seals
9. Tube Bundles
10. Front Housing Gasket
11. Front Cover
12. Spacer Block
13. Long Bolt
14. Small O-ring Seals
15. Bolt
16. Cover
17. Tube

Figure 3-55 Exploded View Assembly of Typical Tube Type Oil Cooler

1. Place the shell vertically on the floor.

2. Install the bottom seal ring in the seal ring groove, and coat it with lubricating oil.

NOTE:
The seal ring groove must be free of burrs and foreign material.

3. Prior to inserting the tube bundle, inspect both ends of the element at the lead in chamfer for nicks, dents, or burrs.

NOTE:
Ensure the correct bundle is used in its proper location prior to installation using the bundle part number identification on the spacer bar for reference only.

NOTICE:
Do not directly hammer on the tubes in the bundles. Solder breakage or tube damage could occur.

4. Insert the tube bundle into the shell, and carefully press the bundle just past the upper seal ring groove.
5. Install the upper seal ring in the seal ring groove, and coat with lubricating oil.
6. Invert the tube and shell assembly, and press the tube bundle in the opposite direction. The tube bundle should be flush with the shell at both ends.

NOTE:
The new front and rear covers have a 3/8 in. tang on the top and bottom surface to retain the tube bundles in their proper position.

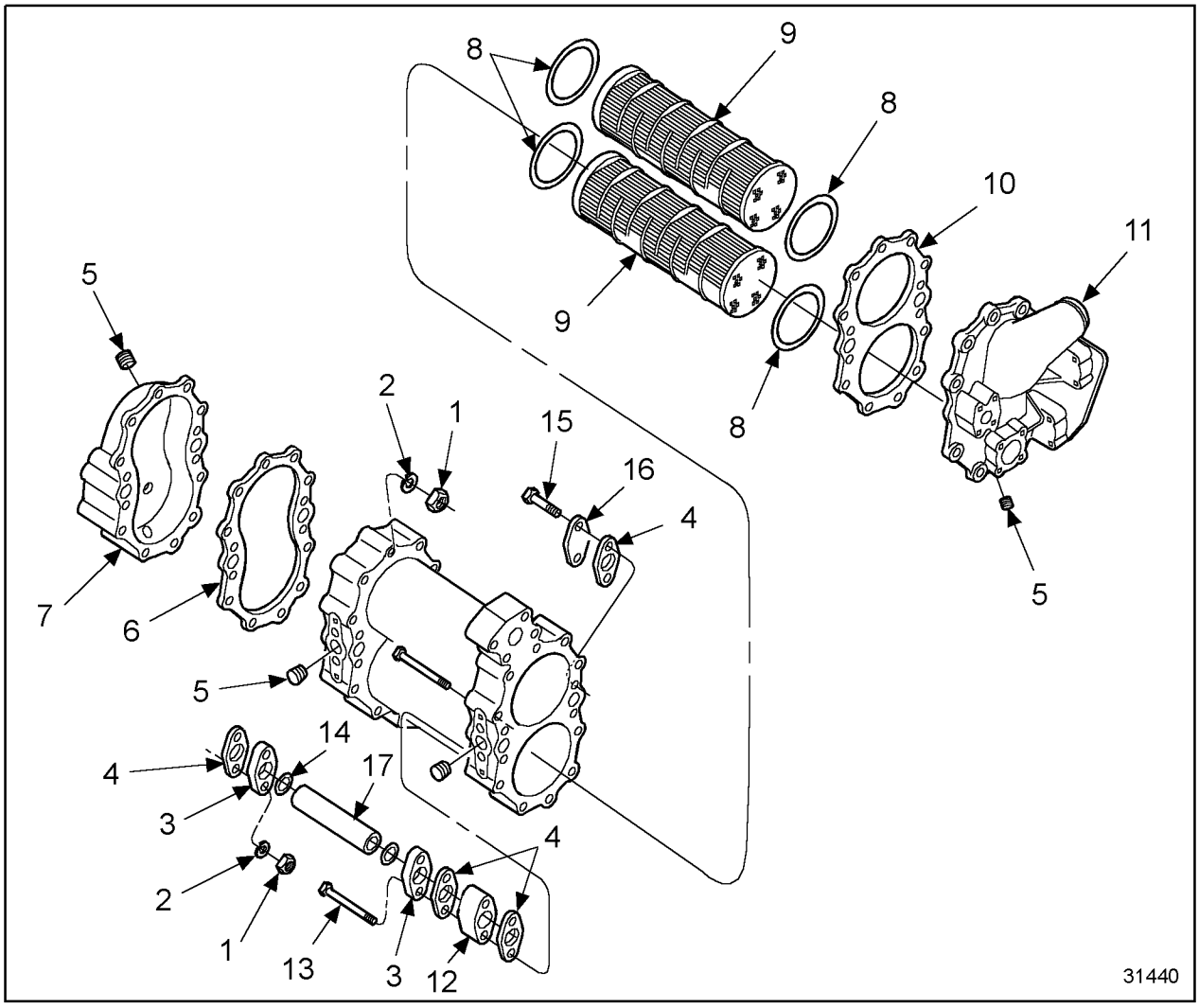
3.8.5 Assembly of Oil Cooler (Tube Type)

Assemble the oil cooler as follows:

1. Place the bypass valve and spring in the valve housing.
2. Install the spring retainer.
3. Install a new seal ring in each oil bypass tube flange, and slide one flange over each end of the tube.
4. Attach a new gasket to each flange.
5. Install two 3/8 in.-16 x 5 in. bolts, with lock washers, through the flange and gasket at one end of the tube. Place the bypass valve assembly and a new gasket over the ends of the bolts.
6. Place the oil bypass valve and tube assembly in position, and thread the bolts into the front end casting of the oil cooler.
7. Install two 3/8 in.-16 x 3.5 in. bolts and lock washers in the flange at the other end of the tube. Tighten all four bolts to 41-47 N·m (30-35 lb·ft) torque.
8. Install the oil hole covers and gaskets used on the opposite side of the oil cooler, if previously removed.

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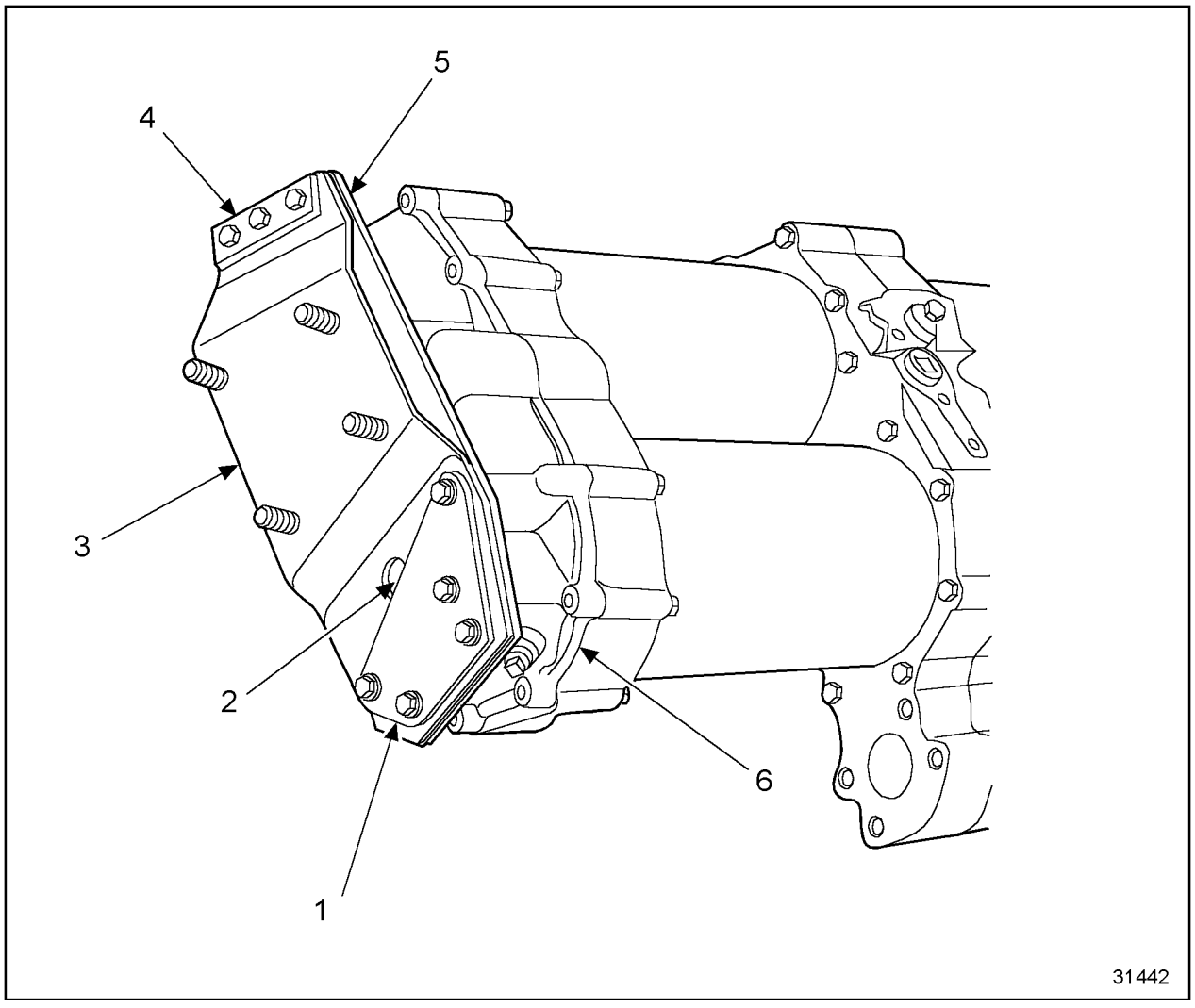
9. Use a new front gasket and attach the front cover to the oil cooler with ten 3/8 in.- 16 x 3 in. bolts and lock washers. See Figure 3-56. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.



1. Nut
2. Lock Washer
3. Spacer
4. Gasket
5. Pipe Plug
6. Rear Housing Gasket
7. Rear End Cover
8. O-ring Seals
9. Tube Bundles
10. Front Housing Gasket
11. Front Cover
12. Spacer Block
13. Long Bolt
14. Small O-ring Seals
15. Bolt
16. Cover
17. Tube

Figure 3-56 Exploded View Assembly of Typical Tube Type Oil Cooler

10. Use a new rear gasket, and attach the rear cover to the oil cooler with ten 3/8 in.-16 x 3 in. bolt and lock washers. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.
11. On the single tube type oil cooler, use a new gasket, and attach the junction block to the oil cooler rear cover with six 3/8 in.-16 x 1 in. bolts and lock washers.
12. Install the 3/8 in.-16 x 2 in. center bolt and lock washer. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.
13. On a dual tube type oil cooler, assemble the two rear cooler cover support plates, the upper retainer plate, and the necessary 1.5748 mm (0.062 in.) shims with three 3/8 in.-16 x 1.625 in. bolts. See Figure 3-57.



1. Retainer Plate (Lower)
2. Center Bolt
3. Support Plate to Flywheel Housing
4. Retainer Plate (Upper)
5. Rear Cover Support Plate
6. Rear Cover

Figure 3-57 Dual Tube Type Oil Cooler

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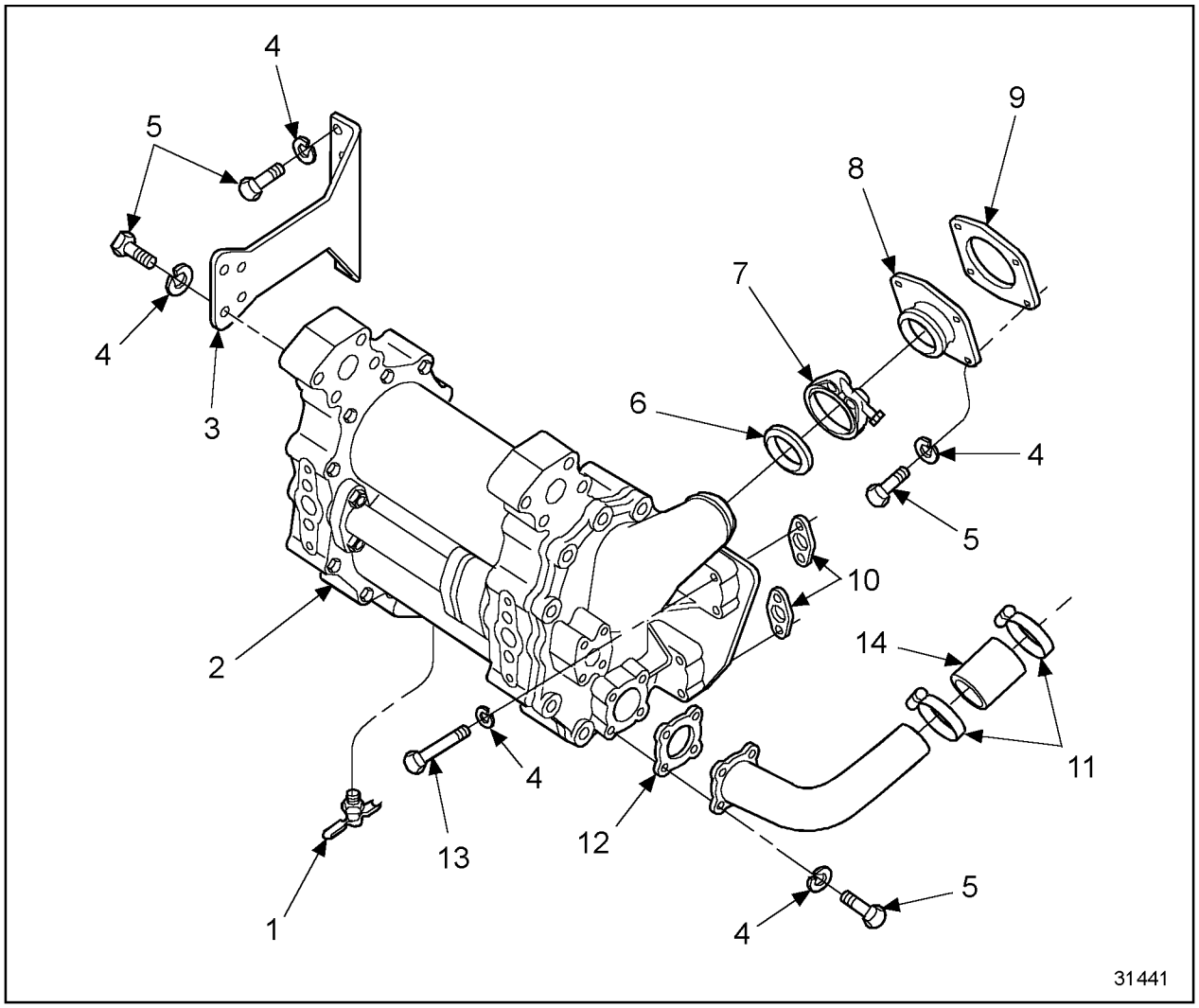
14. Assemble the lower retainer plate and necessary 1.5748 mm (0.062 in.) shims, using a new gasket between the oil cooler cover and support plate, with five 3/8 in.-16 x 1.125 in. bolts and lock washers. Include the center bolt and lock washer. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque.

3.8.6 Installation of Oil Cooler (Tube Type)

Install the tube-type oil cooler as follows:

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1. Attach new gaskets to the mounting pads on the oil cooler front cover. Place the oil cooler in position against the cylinder block. See Figure 3-58.



1. Drain Cock
2. Oil Cooler Assembly
3. Support Bracket
4. Lock Washer
5. Bolt
6. O-ring
7. Clamp
8. Outlet Flange
9. Flange Gasket
10. Gaskets
11. Hose Clamps
12. Inlet Tube Gasket
13. Long Bolt
14. Hose

Figure 3-58 Installation of Typical Oil Cooler Assembly

2. Secure the front end of the oil cooler to the cylinder block with four 3/8 in.-16 x 2.25 in. bolts and lock washers.

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3. Secure the rear end of the oil cooler to the support bracket with four 3/8 in.-16 x 1 in. bolts and lock washers. Tighten all oil cooler mounting bolts to 41-47 N·m (30-35 lb·ft) torque.
4. Place the water outlet flange seal and clamp in position. Use a new gasket and install the flange.
5. Install new copper washers with the two bolts. Tighten the bolts to 41-47 N·m (30-35 lb·ft) torque and the nuts to 47-53 N·m (35-39 lb·ft) torque.
6. Use a new gasket, and attach the water inlet elbow to the oil cooler front cover with four 3/8 in.-16 x 1.125 in. bolts and lock washers. Tighten the bolts to 41-47 N·m (30·35 lb-ft) torque.
7. Slide the water inlet elbow hose in place, and tighten the clamps.
8. Connect the oil filter and torque converter oil lines to the oil cooler.
9. Install any accessories that were removed to provide access to the oil cooler.
10. Install any pipe plugs that were removed.
11. Close the drain cock in the oil cooler rear cover, and fill the cooling system to the proper level. Refer to section 13.12.
12. Add sufficient oil to the crankcase to bring the oil level to the proper level on the dipstick. Refer to section 13.5.1.
13. Start and run the engine for a short period, and check for oil leaks.
14. After any oil leaks have been corrected, and the engine has been stopped long enough (approximately twenty minutes) for the oil from various engine parts to drain back to the crankcase, bring the oil level up to the proper level on the dipstick.

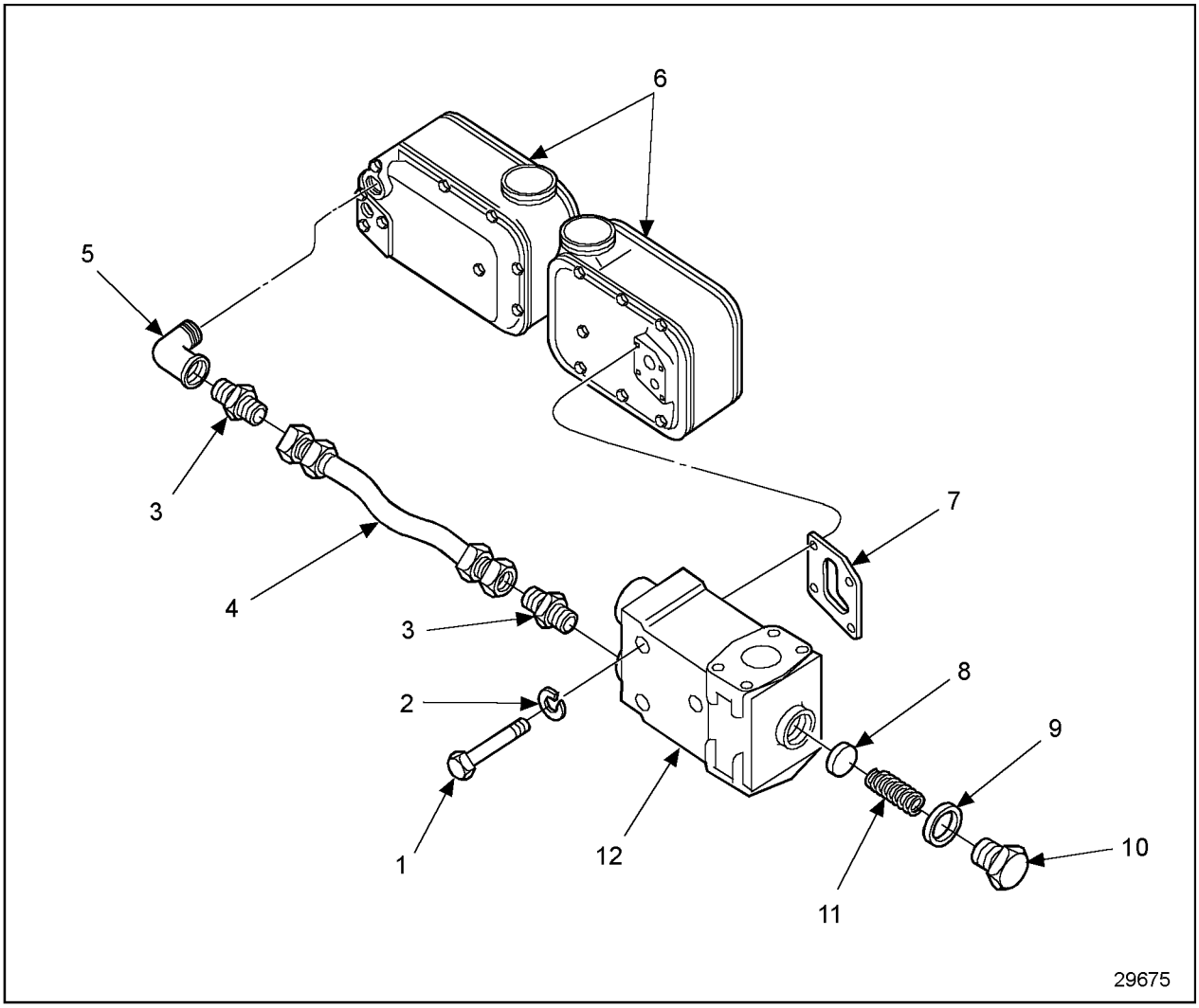
3.9 LUBRICATING OIL COOLER BYPASS VALVE

To ensure engine lubrication should the oil cooler become plugged, a bypass valve is installed in the inlet passage of the oil cooler adaptor. The valve opens and allows the oil to bypass the oil cooler when the pressure at the inlet side exceeds the pressure at the outlet side by 276 kPa (40 lb/in.^{2}).

The bypass valve assembly, which consists of a valve, spring, retaining plug, and gasket, should be removed, cleaned, and reassembled whenever the oil cooler core is cleaned or replaced. The bypass valve can be disassembled without removing the oil cooler on most models.

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A current bypass valve spring has been released to provide increased oil circulation through the lube oil coolers. The current valve spring (65.02 mm [2.56 in.], orange paint identification) replaces the former spring (50.8 mm [2 in.], no paint identification) in the engine models that use the adaptors. See Figure 3-59.



1. Bolt
2. Lock Washer
3. Fittings (2)
4. Bypass Line
5. Elbow Fitting
6. Oil Cooler Assembly
7. Gasket
8. Bypass Valve
9. Seal
10. Plug
11. Spring
12. Bypass Valve Housing

Figure 3-59 Oil Cooler Bypass Valve

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3.9.1 Repair or Replacement of Lubricating Oil Cooler Bypass Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-60.

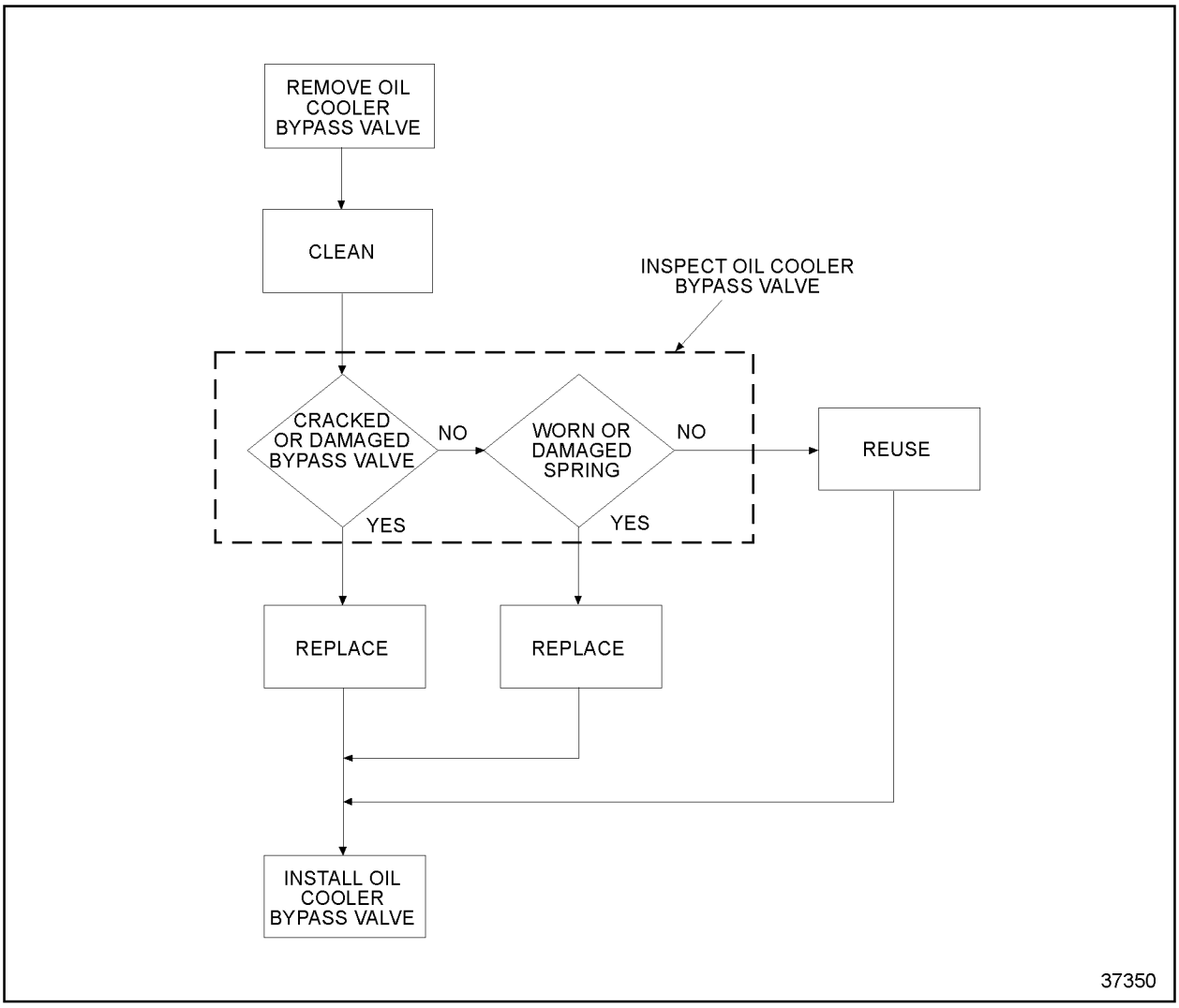


Figure 3-60 Flowchart for Repair or Replacement of Lubricating Oil Cooler Bypass Valve

3.9.2 Removal of Lubricating Oil Cooler Bypass Valve

Remove the lubricating oil cooler bypass valve as follows:

1. Remove the retaining plug.
2. Withdraw the seal, spring, and valve from the oil cooler adaptor.

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3.9.2.1 Cleaning of Lubricating Oil Cooler Bypass Valve

Clean the lubricating oil cooler bypass valve as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean the bypass valve 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 with compressed air.

3.9.2.2 Inspection of Lubricating Oil Cooler Bypass Valve

Inspect the lubricating oil cooler bypass valve as follows:

1. Remove the spring retainer screw, and withdraw the retainer, spring, and valve from the valve housing.

NOTE:
The bypass valve spring has a free length of approximately 2-1/64 in.

2. Use spring tester J 22738-02 to check the valve spring load.
   [a] Replace the spring if a load of less than 2.9445 kg (6.5 pounds) will compress it to a length of 20.6375 mm (0.8125 in.).
   [b] If the spring passes the test, it may be reused.

3.9.3 Installation of Lubricating Oil Cooler Bypass Valve

Install the lubricating oil cooler bypass valve as follows:

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply clean engine oil to the outside surface of the valve, and place it in the oil cooler adaptor valve cavity, closed end first.

NOTE:
Some oil cooler adaptors should be updated with the new spring at time of overhaul. This spring should also be replaced at each major engine overhaul.

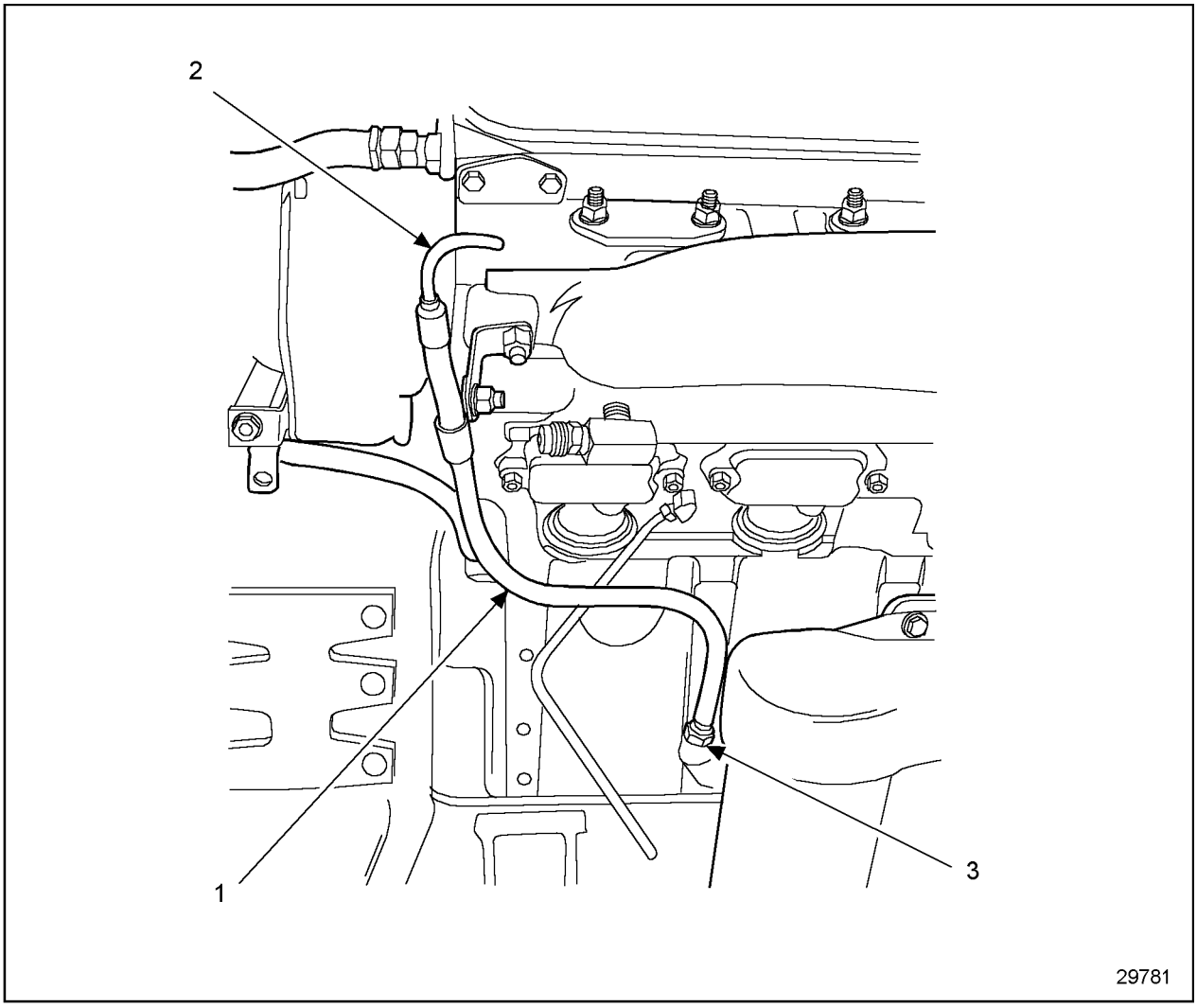
2. Place the spring inside the valve, and place a new seal ring on the retaining plug.
3. Install and tighten the plug to 41-54 N·m (30-40 lb·ft) torque.

NOTE:
A slotted bypass valve plug is used with the oil cooler adaptor plug on some engines. Tighten this plug to 34-41 N·m (25-30 lb·ft) torque.

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3.10 OIL LEVEL DIPSTICK

A steel ribbon type oil level dipstick is used to check the oil quantity in the engine oil pan. The dipstick is in the cylinder block or the oil pan. See Figure 3-61. Current engines include a 19.1 mm (0.75 in.) long rubber oil seal inside the dipstick cap. This prevents vapors from escaping.



1. Dipstick Tube
2. Oil Level Dipstick
3. Adaptor

Figure 3-61 Typical Dipstick Mounting

Maintain the oil level between the full and low marks on the dipstick, and never allow it to drop below the low mark. Overfilling will cause the crankshaft to churn the oil, causing foaming or oil aeration. Operation below the low mark will expose the pump pick-up causing aeration and/or pressure loss.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various engine parts to drain back into the oil pan.

Use dipsticks only when the engine powered equipment is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade.

Dipsticks in marine engines are located and marked to provide the proper oil level at any angle within the recommended maximum installation angle applicable to the specific boat.

In a properly filled crankcase, the oil level must be below the crankshaft rear oil seal when the boat is at rest.

Refer to section ADDITIONAL INFORMATION for running level dimensions and applications.

3.10.1 Repair or Replacement of Oil Level Dipstick

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-62.

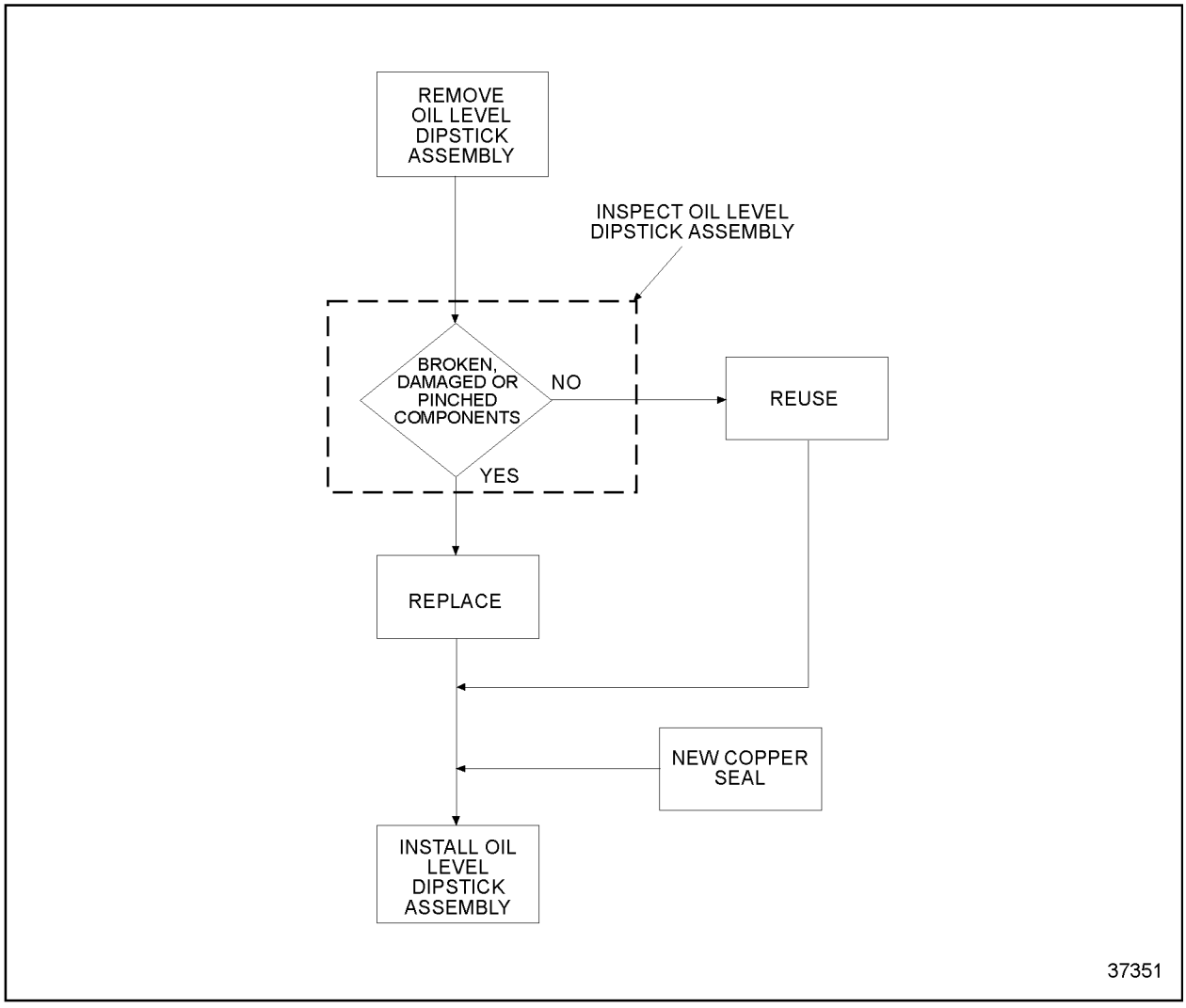


Figure 3-62 Flowchart for Repair or Replacement of Oil Level Dipstick

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3.10.2 Removal of Oil Level Dipstick

Remove the oil level dipstick as follows:

1. Remove the dipstick from the dipstick tube.
2. Remove the dipstick tube assembly, copper seal, and dipstick adaptor from the cylinder block.
3. Discard the copper seal.

3.10.2.1 Inspection of Oil Level Dipstick

Inspect the oil level dipstick as follows:

1. Inspect the dipstick assembly for any damaged parts.
   [a] If damaged, replace the parts. Refer to section 3.10.3.
   [b] If not damaged, continue inspection.
2. Check components for any broken or pinched parts.
   [a] If broken or pinched, replace with new parts. Refer to section 3.10.3.
   [b] If not broken or pinched, reuse the dipstick and components.

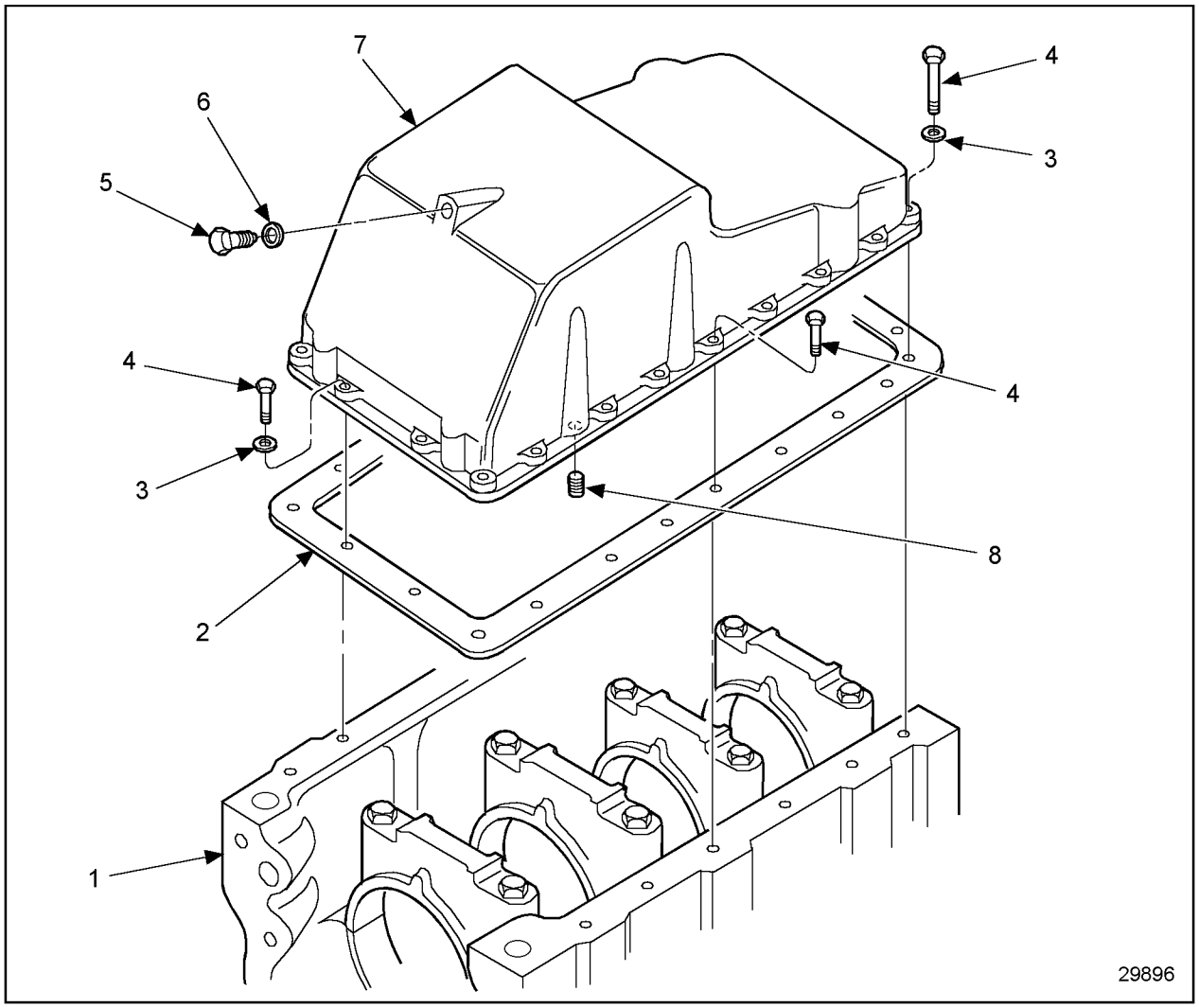
3.10.3 Installation of Oil Level Dipstick

Install the oil level dipstick as follows:

1. Install the dipstick adaptor into the cylinder block. Tighten to 22 N·m (16 lb·ft) torque.
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. Securely tighten the nut on the tube.
5. Install the dipstick and tube assembly.

3.11 OIL PAN

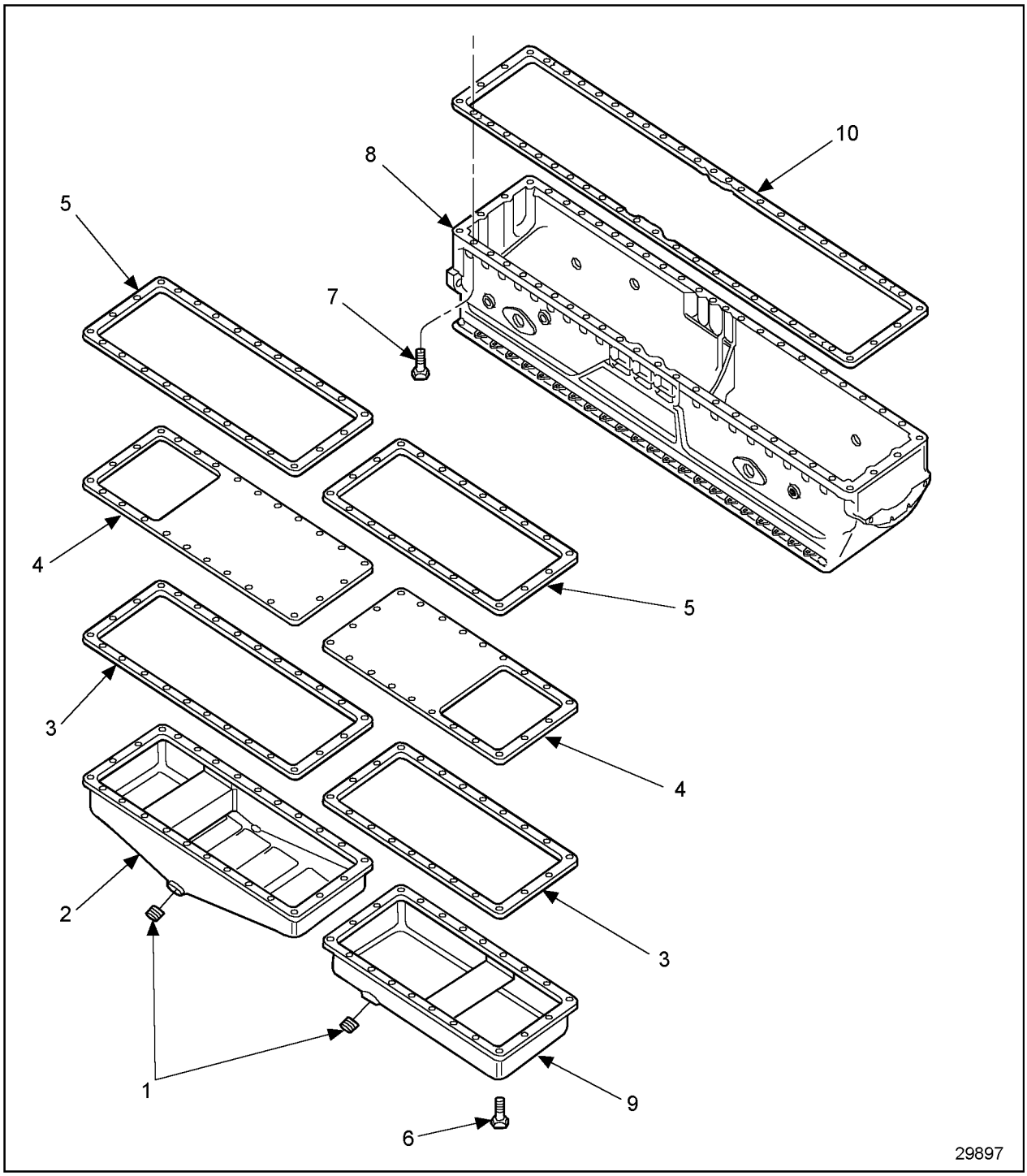
The engine may be equipped with a stamped steel, cast iron, or aluminum oil pan. Either a one-piece oil pan or an upper and lower pan bolted together may be used. See Figure 3-63. Certain 16V engines are equipped with an upper oil pan and two lower pans. See Figure 3-64. Depending upon the model application, oil pans permit an engine inclination up to 45 degrees.



1. Cylinder Block
2. Gasket
3. Washer
4. Bolt
5. Drain Plug
6. Copper Washer
7. Oil Pan
8. Pipe Plug

Figure 3-63 Oil Pan Assembly (6V and 8V Engines)

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1. Drain Plugs
2. Rear Lower Oil Pan
3. Lower Pan Gasket
4. Baffle
5. Lower to Upper Pan Gasket
6. Bolt
7. Bolt
8. Upper Oil Pan
9. Front Lower Oil Pan
10. Upper Oil Pan Gasket

Some oil pans are provided with an oil level dipstick adaptor and oil filler adaptor mounting holes.

Figure 3-64 Oil Pan Assembly (16V Engines)

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3.11.1 Repair or Replacement of Oil Pan

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-65.

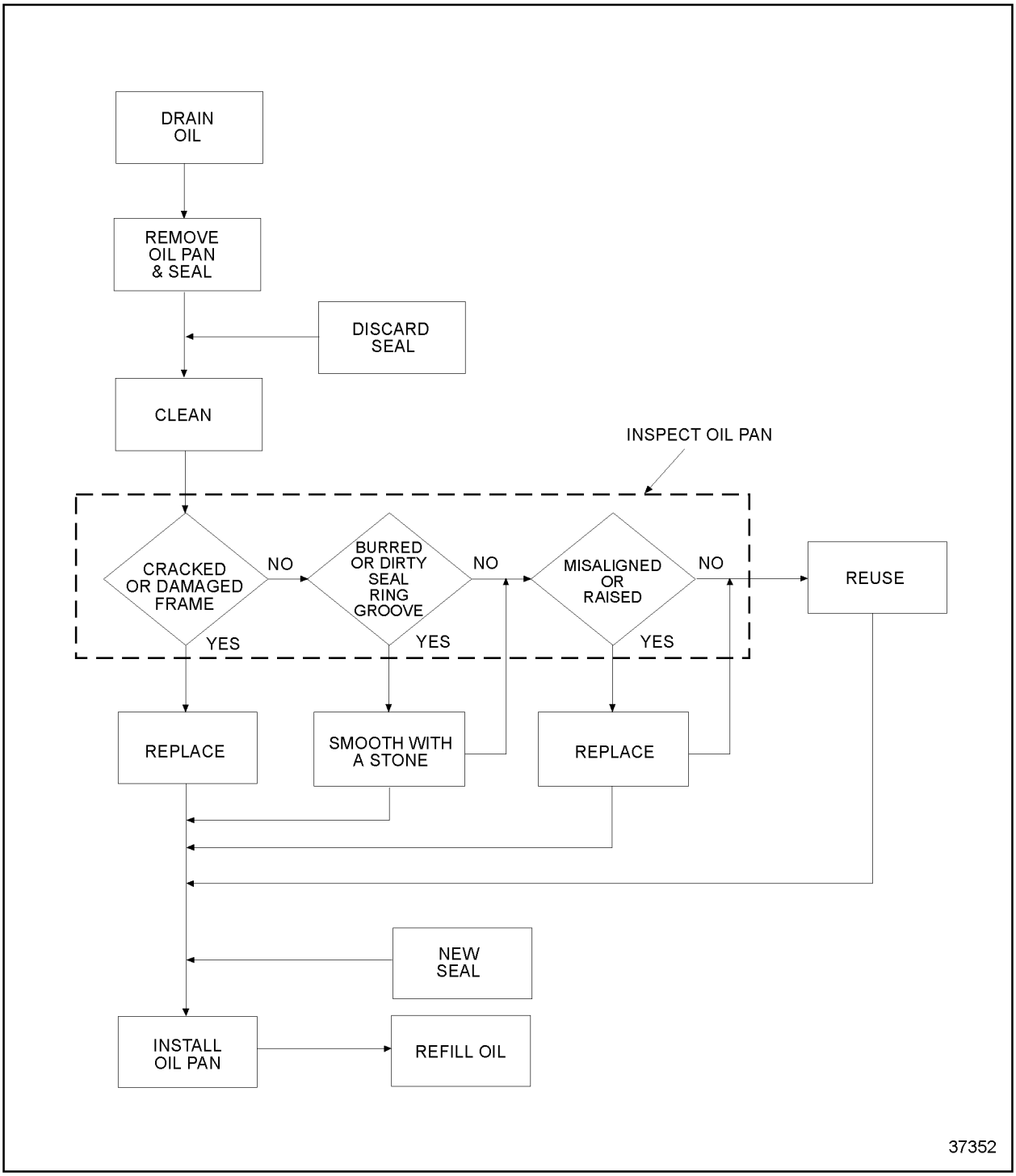


Figure 3-65 Flowchart for Repair or Replacement of Oil Pan

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3.11.2 Removal of Oil Pan

Remove the oil pan as follows:

NOTICE:
The stamped metal oil pans used on some marine engines have a thin protective coating to shield the metal against the salt water atmosphere. Do not rest, slide, or rock the engine on its oil pan. If the surface of the oil pan is scratched, electrolysis will occur and damage the oil pan. Exercise care when performing engine repairs to avoid scratching the outer oil pan surfaces.

1. Remove the drain plug, and drain the oil. Refer to section 13.5.2.

NOTICE:
Remove the oil pump carefully to avoid damage to the oil pump piping and inlet screen.

2. Remove the bolt and washer assemblies, and detach the oil pan.

3.11.2.1 Cleaning of Oil Pan

Clean the oil pan as follows:

1. Clean all old gasket material from the cylinder block and the oil pan.

⚠ CAUTION:
To avoid injury from fire caused by heated diesel-fuel vapors: ☐ **Keep those people who are not directly involved in servicing away from the engine.** ☐ **Stop the engine immediately if a fuel leak is detected.** ☐ **Do not allow open flames or smoke when working on an operating engine.** ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).** ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.** **Diesel fuel is relatively harmless at ambient temperatures.**

2. Clean the oil pan 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.

3. Dry with compressed air.

3.11.2.2 Inspection of Oil Pan

Inspect the oil pan as follows:

1. Inspect a cast oil pan for porosity or cracks and a stamped oil pan for dents or other damage.
   [a] If cracked, porous, dented, or damaged, replace the oil pan.
   [b] If not cracked, porous, dented, or damaged, continue inspection.
2. Check for misaligned flanges or raised surfaces surrounding the bolt holes.

NOTE:
Place the pan on a surface plate or other large flat surface.

   [a] If misaligned or raised, replace. Refer to section 3.11.3.

3.11.3 Installation of Oil Pan

Install the oil pan as follows:

1. When installing the oil pan on a 6V or 8V engine, use a new gasket(s).

NOTE:
Do not overtighten the bolts.

2. Starting with the center bolt on each side, and working alternately toward each end of the pan, tighten the bolts to 14-27 N·m (10-20 lb·ft) torque.

NOTE:
Current oil pan bolts (stamped metal pans) are coated with locking material. To re-activate the bolt locking ability, apply a few drops of Loctite 567 (or equivalent) to the bolt threads at assembly.

3. When installing the upper oil pan on a 16V engine, use a new gasket(s), and position the oil pan against the cylinder block and flywheel housing.
4. Install all of the 3/8 in.-16 oil pan attaching bolts and lock washers finger-tight only.
5. Install the two 3/4 in.-10 oil pan-to-flywheel housing bolts and lock washers to draw the oil pan tight against the flywheel housing.

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6. Tighten the 3/8 in.-16 oil pan bolts to draw the oil pan tight against the cylinder block.
7. Tighten the 3/4 in.-10 bolts to 325-339 N·m (240-250 lb·ft) torque and the 3/8 in.-16 oil pan bolts to 14-27 N·m (10-20 lb·ft) torque.

NOTE:
When tightening the oil pan bolts, tighten the center bolts first working alternately toward each end of the oil pan.

8. Install the lower oil pans, and tighten the 5/16 in.-18 attaching bolts to 14-16 N·m (10-12 lb·ft).
9. Install and tighten the drain plug to 34-47 N·m (25-35 lb·ft) torque.
10. Fill the oil pan with new oil to the full mark on the dipstick. Refer to section 13.5.1.
11. Start and run the engine for a short period to check for oil leaks.
12. Stop the engine and, after approximately twenty minutes, check the oil level. Add oil, if necessary.

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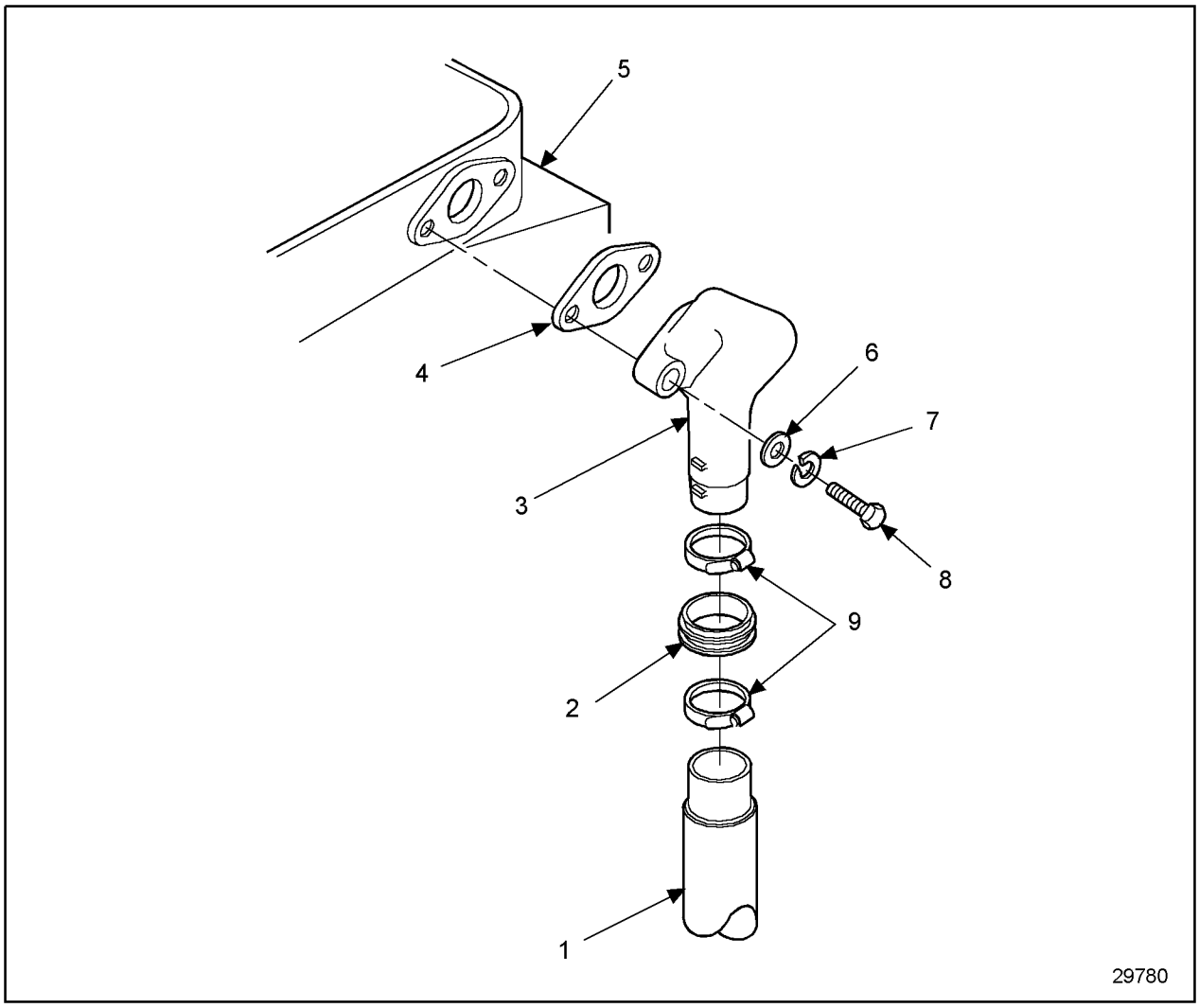
3.12 VENTILATING SYSTEM

A continuous pressurized ventilating system removes the harmful vapors that may form within the crankcase, gear train, and valve compartment.

Breathing is accomplished through two openings in the crankcase rear main bearing bulkhead and one large hole in the cylinder block rear end plate. They connect to a central chamber that leads to an exit at the top of the cylinder block.

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The external tube(s) connects the cylinder block exit hole at the rear of the cylinder head(s). See Figure 3-66.

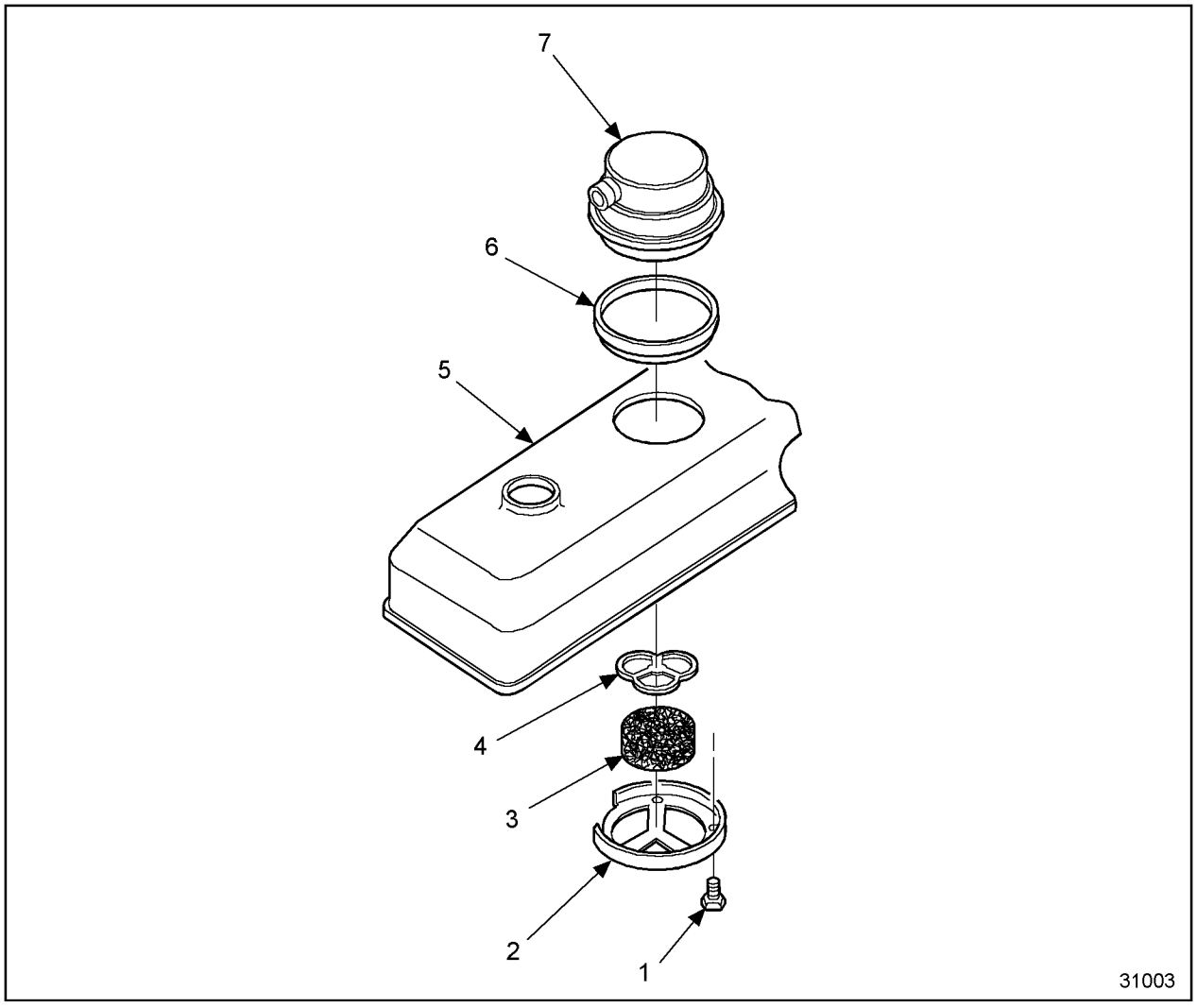


1. Breather Tube
2. Hose
3. Breather Elbow
4. Gasket
5. Cylinder Head
6. Washer
7. Lock Washer
8. Bolt
9. Clamps

Figure 3-66 Ventilating System (Cylinder Head Mounted)

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The current left-bank cylinder head-to-cylinder block breather system used on 6V engines is used in 8V engines effective with 8VF-017875. See Figure 3-67. An elbow is bolted to the side of the cylinder head and a tube pressed in the opening at the top rear end of the cylinder block. They are joined with a rubber hose and clamps. Because of clearance considerations, the former breather system is still used for the right-bank cylinder head-to-cylinder block breather system. It will continue to be used on both banks for certain engine applications.



1. Screw
2. Retainer
3. Mesh Element
4. Retainer Holder
5. Rocker Cover
6. Seal
7. Breather Assembly

Figure 3-67 Ventilating System (Rocker Cover Mounted)

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

The rocker cover(s) provides a large cross-sectional air flow area at maximum height for efficient breathing and oil separation. A breather assembly is mounted at the openings in the rocker cover(s).

No disassembly is required to index the breather assembly exhaust outlet on the current aluminum die cast valve rocker covers. Insert a 28.575 mm (1.125 in.) outer diameter pipe or wood dowel into the exhaust outlet. Apply pressure, and rotate the outlet to the desired location.

A closed crankcase vapor collector system is used on all maximum rated marine engines, effective June, 1991. The current closed breather system consists of a collector assembly mounted to the inlet side of each turbocharger, plus oil drain tube(s), check valve(s), breather piping, and mounting hardware. The system collects the crankcase vapors normally emitted to atmosphere, filters the outside air entering the turbocharger, and reduces air induction noise.

3.12.1 Repair or Replacement of Ventilating System

Refer to OEM for repair or replacement procedures.

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3.A ADDITIONAL INFORMATION

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SHOP NOTES

The shop notes for the lubrication system are as follows:

RUNNING LEVEL DIPSTICK DIMENSION AND APPLICATIONS

Running level dipsticks are available on certain coach engines. These dipsticks permit accurate oil level reading with the engine at idle (running level) or at rest (static level). Running level dipsticks are identified by a number on the end of their handle listed in Table 3-1 and listed in Table 3-2. See Figure 3-68.

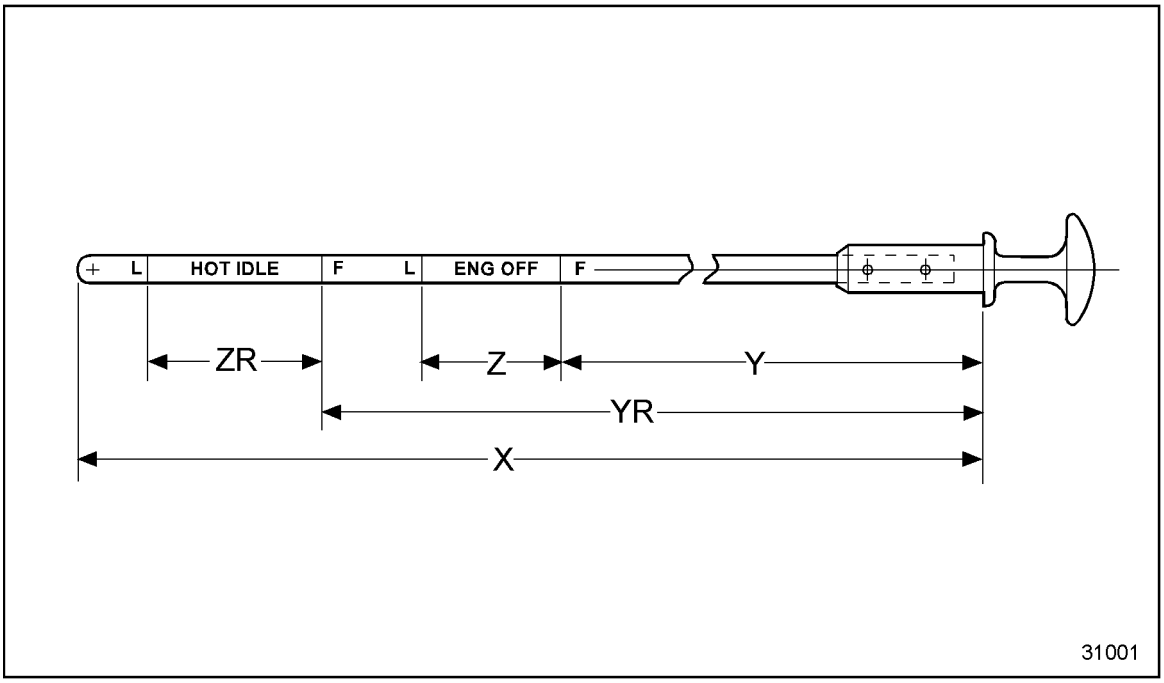


Figure 3-68 Running Oil Level Dipstick

Dipstick Part No.	Tag Identification	X mm (in.)	Y mm (in.)	Z mm (in.)	Yr mm (in.)	Zr mm (in.)
8927986	6V-92 RTS	763.778 (30.07)	644.398 (25.37)	30.48 (1.20)	706.374 (27.81)	32.512 (1.28)
23500738	6V-92 FLX	731.012 (28.78)	579.628 (22.82)	30.48 (1.20)	666.75 (26.25)	38.862 (1.53)
23504602	6V-92 Breda	680.466 (26.79)	521.716 (20.54)	40.132 (1.58)	599.694 (23.61)	40.132 (1.58)
23506189	Blank	763.778 (30.07)	No Mark	30.48 (1.20)	706.374 (27.81)	32.512 (1.28)
23506866	Orion 6V-92	765.048 (30.12)	682.752 (26.88)	28.448 (1.12)	730.25 (28.75)	28.448 (1.12)
23506867	Eagle 6V-92	863.6 (34.00)	774.7 (30.50)	28.448 (1.12)	822.452 (32.38)	28.448 (1.12)
23507426	6V-71 FLX	692.658 (27.27)	609.6 (24.00)	17.018 (0.67)	635.00 (25.00)	17.018 (0.67)

Table 3-1 Dipstick Dimensions

Coach	Dipstick Part No.	Tag Identification	Tube	Shroud	UPC Group	P/Catalog Type
TMC/RTS	8927986	6V-92 RTS	8923098	5120861	6G4-1124	1165
TMC/RTS	8927986	6V-92 RTS	23503748	5120861	6G4-1155	1188
TMC/RTS	23506189	Blank	8923098	5120861	6G4-1188	1216
Flexible	23500738	6V-92 FLX	5129525	5176827	6G4-1123	1163
Flexible	23507426	6L-71 FLX	23507427	5176827	6G4-1199	1236
Orion	23506866	Orion 6V-92	5127271	23506868	6G4-1200	1228
Eagle	23506867	Eagle 6V-92	8921838	5120861	6G4-1201	1243
Breda	23504602	6V92 BREDA	5129525	23504601	6G4-1174	1199

Table 3-2 Dipstick Application

When running level dipsticks are installed in place of static level dipsticks, the appropriate shroud must be used. In most cases, the tube already installed may be used.

NOTE:
Failure to install the correct shroud will result in inaccurate running level oil measurement.

Contaminated Cooling System

If the engine has had a failure resulting in the contamination of the cooling system with lubrication oil, the following flushing procedure is recommended:

1. Prepare a mixture of Calgon, or its equivalent, and water at the rate of 2 ounces (dry measure) to one gallon of water.
2. Remove the engine thermostat (refer to section 4.5.2) to permit the Calgon and water mixture to circulate through the engine and the radiator.
3. Fill the cooling system with the Calgon solution.
4. Run the engine for five minutes.

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5. Drain the cooling system.
6. Refer to step 3 through step 5, repeat these steps.
7. Fill the cooling system with clean water.
8. Run the engine for five minutes.
9. Drain the cooling system completely.
10. Install the engine thermostat. Refer to section 4.5.3.
11. Close all of the drains and refill the engine with fresh coolant. Refer to section 13.12.2.

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

Listed in Table 3-3 are the exceptions to standard bolt and nut torque specifications.

Application	Thread Size	Torque
Oil Pan Bolts (Lower Pan)	5/15-18	14-16 N·m (10-12 lb·ft)
Oil Pan Bolts	3/8-16	14-27 N·m (10-20 lb·ft)
Lubricating Oil Filter Center Stud	5/8-18	68-81 N·m (50-60 lb·ft)
Oil Pan Drain Plug (Nylon Washer)	18 mm	34-47 N·m (25-35 lb·ft)

Table 3-3 Bolt and Nut Torque Specifications

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4 COOLING SYSTEM

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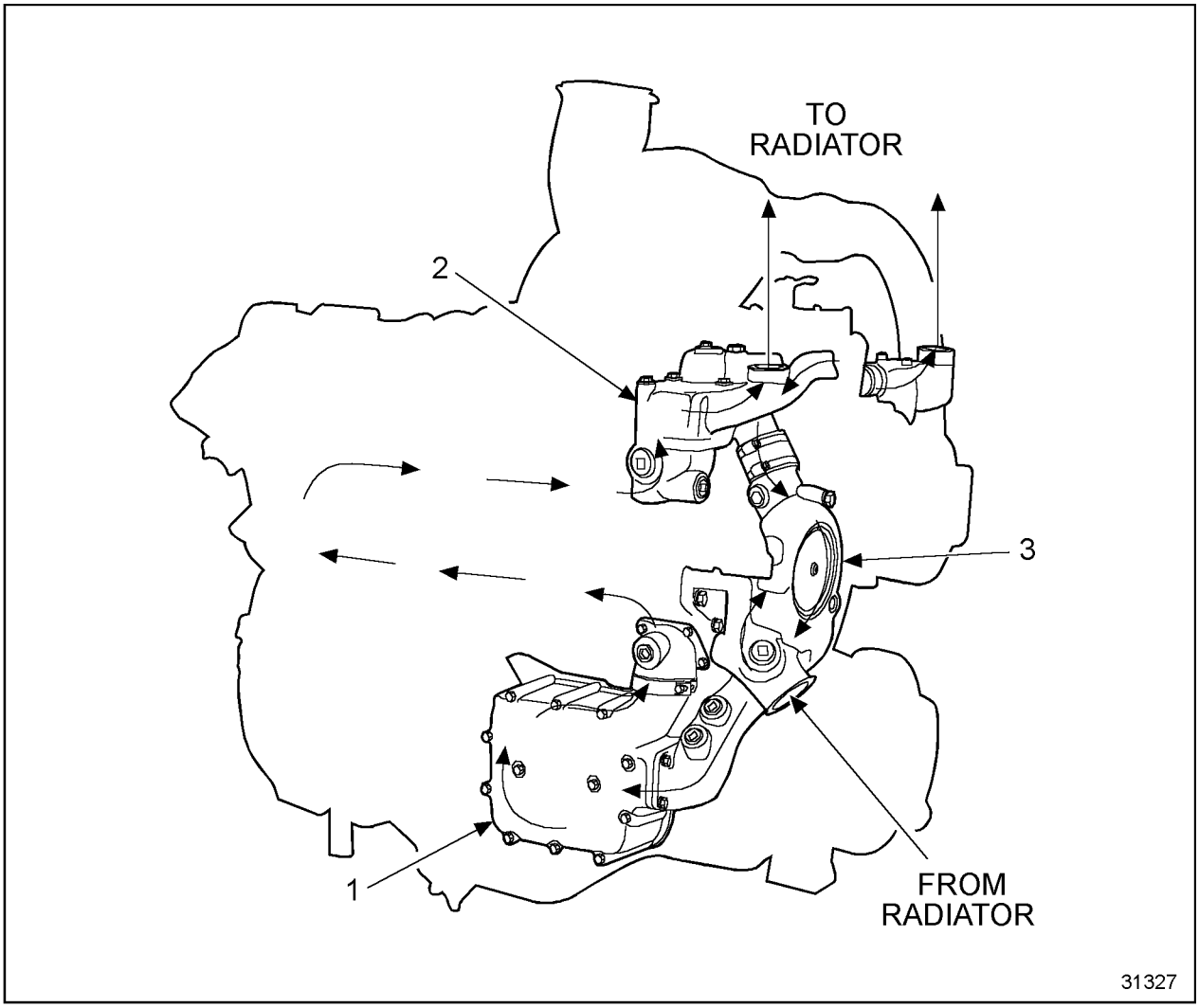
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4.1 COOLING SYSTEM

To effectively dissipate the engine heat, one of three different types of cooling systems is used on the engine: radiator and fan, heat exchanger and raw water pump, or keel cooling. Each system is provided with a centrifugal-type water pump that circulates the engine coolant. Each system incorporates thermostats to maintain a normal engine operating temperature. Refer to section 11.5.

Upon starting a cold engine or when the coolant is below operating temperature, the thermostat blocks or restricts the coolant flow to the radiator. A bypass provides coolant circulation within the engine during the warm-up period.

In a radiator cooling system, the water pump draws and forces the coolant from the lower portion of the radiator through the oil cooler housing and into the cylinder block. See Figure 4-1.



1. Oil Cooler
2. Thermostat
3. Water Pump

Figure 4-1 Typical Cooling System

From the cylinder block, the coolant passes through the cylinder heads and, when the engine is at normal operating temperature, through the thermostats into the upper portion of the radiator. The coolant passes a series of tubes, where the air stream created by the revolving fan lowers the coolant temperature.

In the heat exchanger cooling system, the water pump draws the coolant from the heat exchanger and forces it through the engine oil cooler, cylinder block, cylinder heads, and exhaust manifolds to the thermostat housings. A bypass from the thermostat housings to the inlet side of the water pump permits coolant circulation through the engine when the thermostats are closed.

When the thermostats are open, the coolant flows through the heat exchanger, where it is cooled.

An engine-driven raw water pump circulates raw water (sea water) through the heat exchanger to lower the engine coolant temperature.

In the keel cooling system, the water pump draws the coolant from the keel cooler and forces it through the engine oil cooler, cylinder block, cylinder heads, and exhaust manifolds to the thermostat housings. A bypass from the thermostat housings to the inlet side of the water pump permits coolant circulation through the engine when the thermostats are closed. When the thermostats open, the coolant flows through the keel cooling coils. Engine coolant heat is transferred through the keel cooler coils to the surrounding sea water.

The engine coolant absorbs the heat developed from the combustion process in the cylinders and from engine components, such as, exhaust valves, pistons, and cylinder liners, which are surrounded by water jackets. The engine coolant in the oil-to-water oil cooler dissipates oil absorbed heat. When operating within the proper temperature range and not exceeding the recommended horsepower output of the unit, all engine parts will be within their designated operating temperature range and at their proper operating clearances. Coolant must be properly selected and maintained. Refer to section 5.3 for coolant recommendations.

⚠ CAUTION:

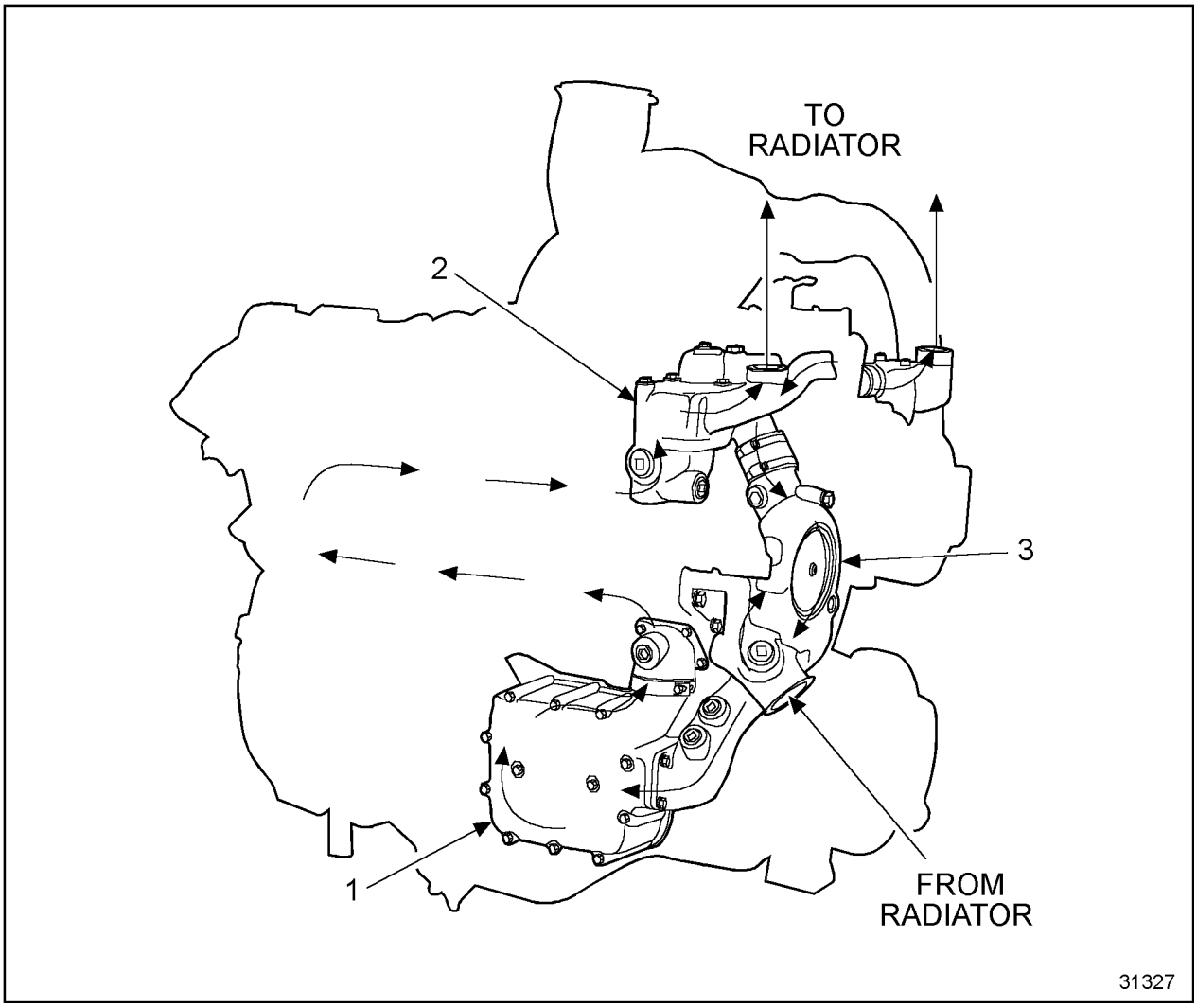
To avoid injury from the expulsion of hot coolant, never remove the cooling system pressure cap while the engine is at operating temperature. Remove the cap slowly to relieve pressure. Wear adequate protective clothing (face shield or safety goggles, rubber gloves, apron, and boots).

A pressurized cooling system, which normally operates at temperatures higher than a non-pressurized system, is used. The cooling system must be kept clean and leak proof. The filler cap and pressure relief mechanism must be correctly installed, and the coolant level must be properly maintained.

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4.2 WATER PUMP (6V AND 8V ENGINES)

On 6V and 8V engines, the centrifugal-type pump circulates the engine coolant through the cylinder block, cylinder heads, radiator or heat exchanger, and the oil cooler. See Figure 4-2.



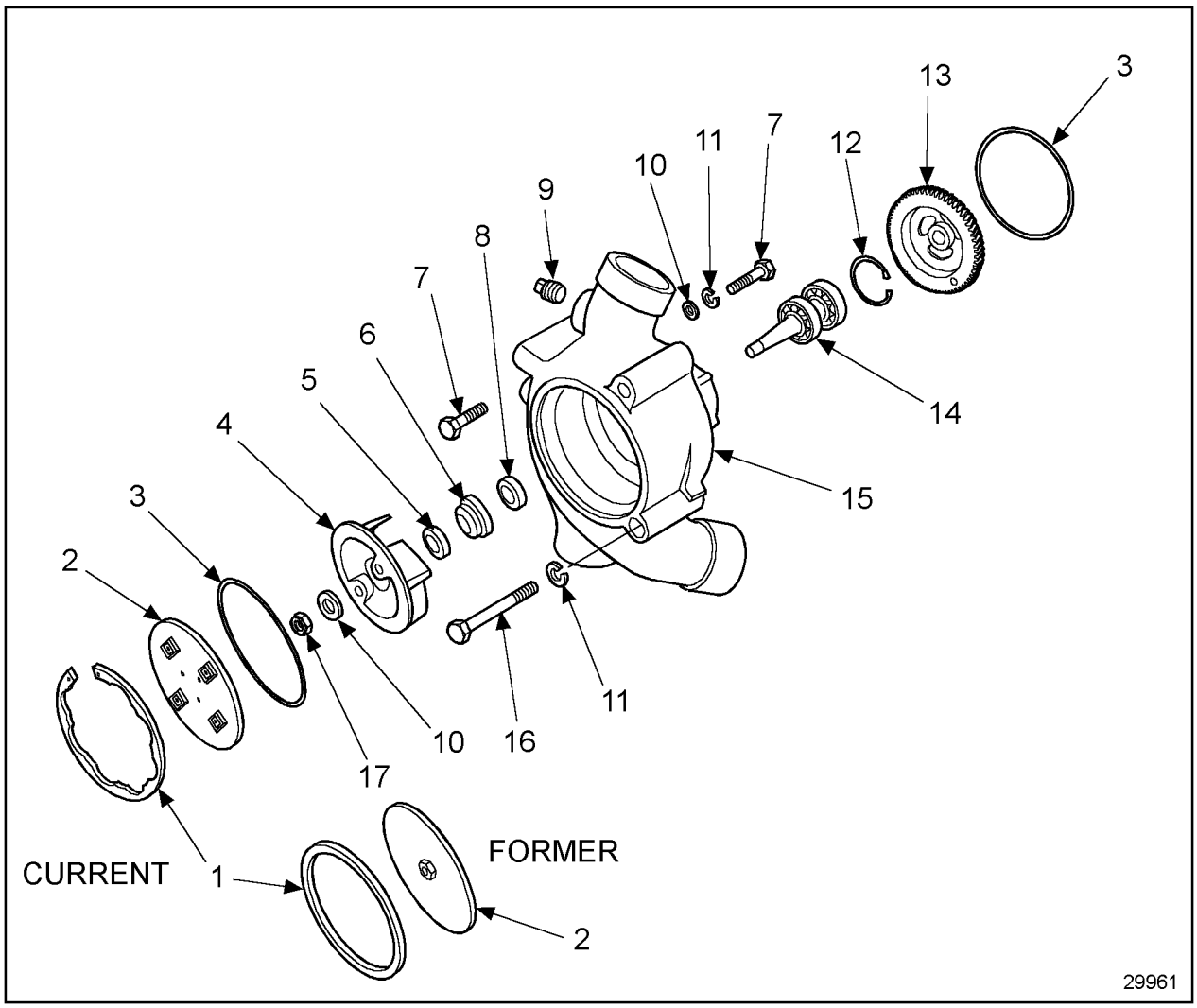
1. Oil Cooler
2. Thermostat
3. Water Pump

Figure 4-2 Typical Cooling System

The pump is mounted on the engine front cover. The 66–tooth front camshaft gear (water pump drive) drives the water pump. The water pump gear has 42 teeth and meshes with the water pump drive gear.

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A bronze impeller is secured to one end of a stainless steel shaft by a locknut. The water pump gear is pressed on the opposite end of the shaft. Two ball bearings are used to carry the shaft. The larger bearing is used at the drive gear end of the shaft to accommodate the thrust load. See Figure 4-3.



1. Retaining Ring
2. Pump Cover
3. Seal Ring (2)
4. Impeller
5. Insert
6. Water Seal Assembly
7. Short Bolt
8. Oil Seal
9. Plug
10. Washer
11. Lock Washer
12. Retaining Ring
13. Gear
14. Shaft and Bearing Assembly
15. Pump Body
16. Long Bolt
17. Locknut

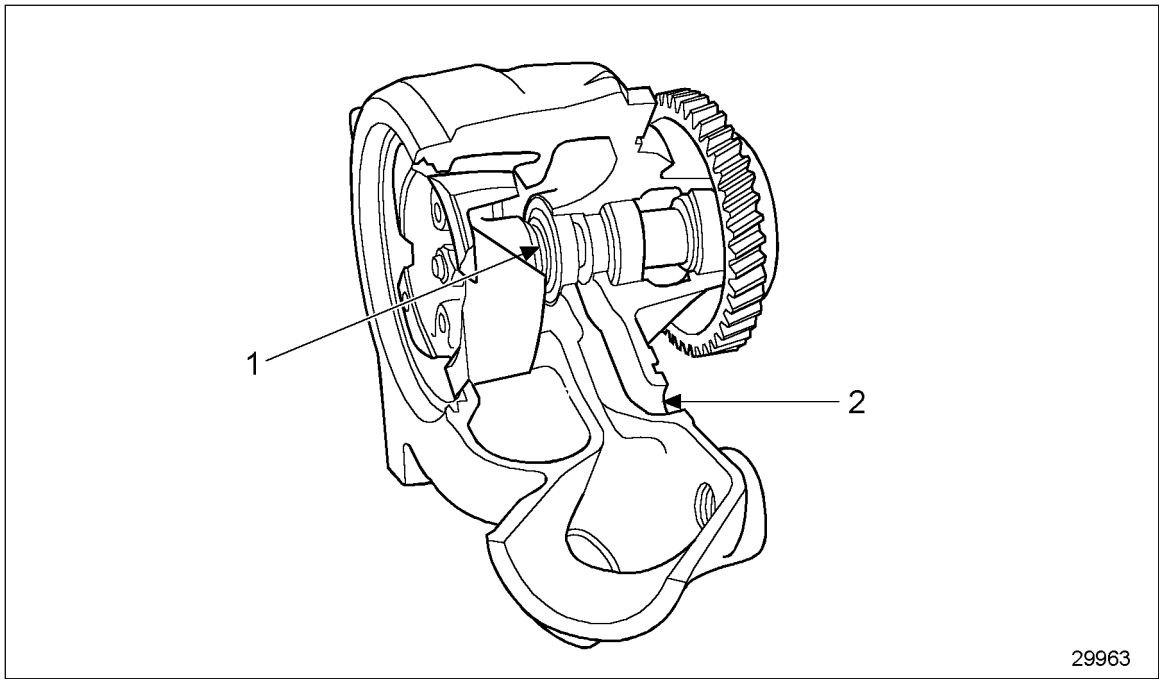
Figure 4-3 Current/Former High-Capacity Water Pump

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An oil seal is located in front of the smaller bearing. A spring-loaded face-type water seal is used behind the impeller.

Current engines use a higher capacity water pump, which provides increased coolant circulation. The pump has a larger impeller, larger diameter inlet and outlet openings, and a retaining-ring-secured pump cover.

Current fresh water pumps with increased coolant flow and sealing characteristics are used on engines using high-capacity pumps. The current pump bodies incorporate a cast-in upper "dam" and cast-in seal cavity and drain boss which act to divide incoming coolant flow and direct it more efficiently through the pump. See Figure 4-4. The "Y" drilled drain passage has been eliminated.



1. Seal
2. Cast-in Drain

Figure 4-4 Divided Inlet High-Capacity Water Pump

The unitized seal has a high grade carbon face, a stainless steel case, and a shroud. See Figure 4-5. Because of its design, the unitized seal provides improved resistance to leakage even after high engine hours or mileage.

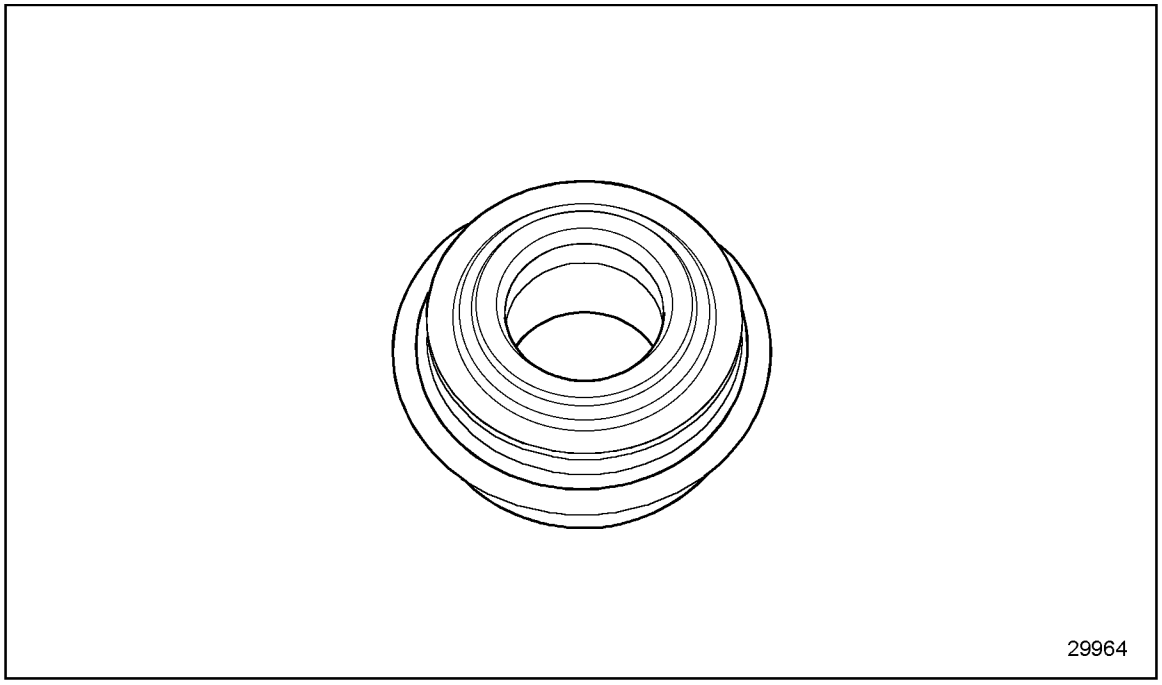
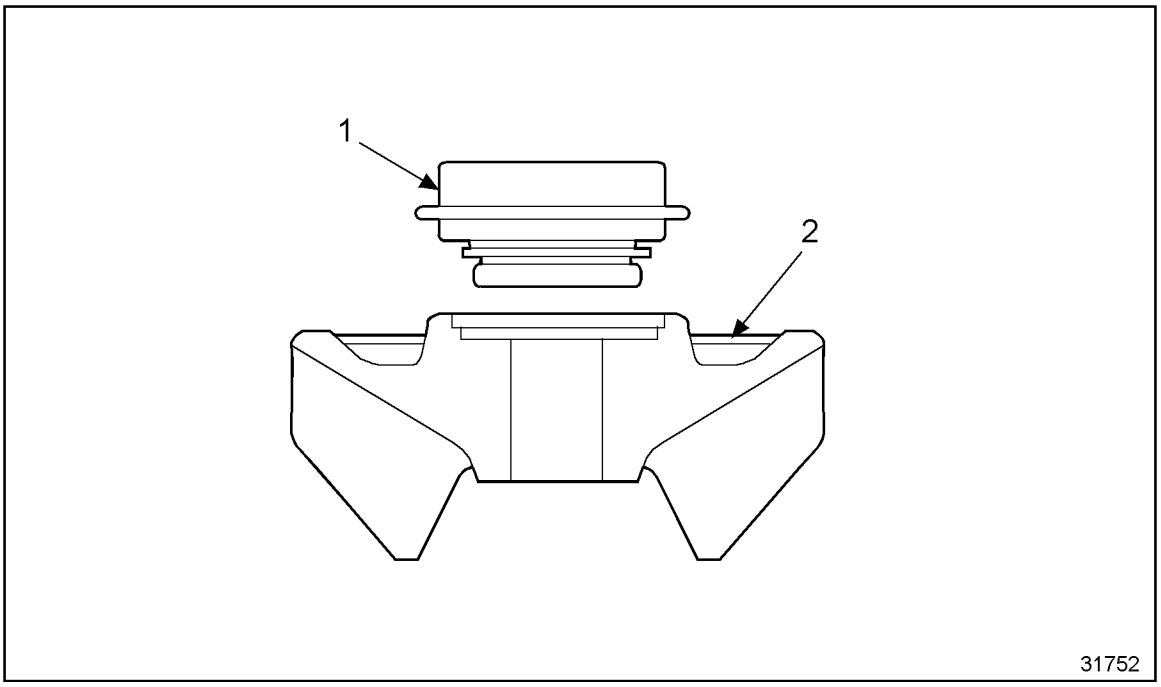


Figure 4-5 Water Pump Seal

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The seal incorporates two silicon carbide faces as part of its assembly. See Figure 4-6.



1. Seal
2. Impeller

Figure 4-6 Water Pump Seal and Impeller

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In order to further improve water pump cover sealing, a non-metallic cover and a scalloped retaining ring is used on the fresh water pump. See Figure 4-7.

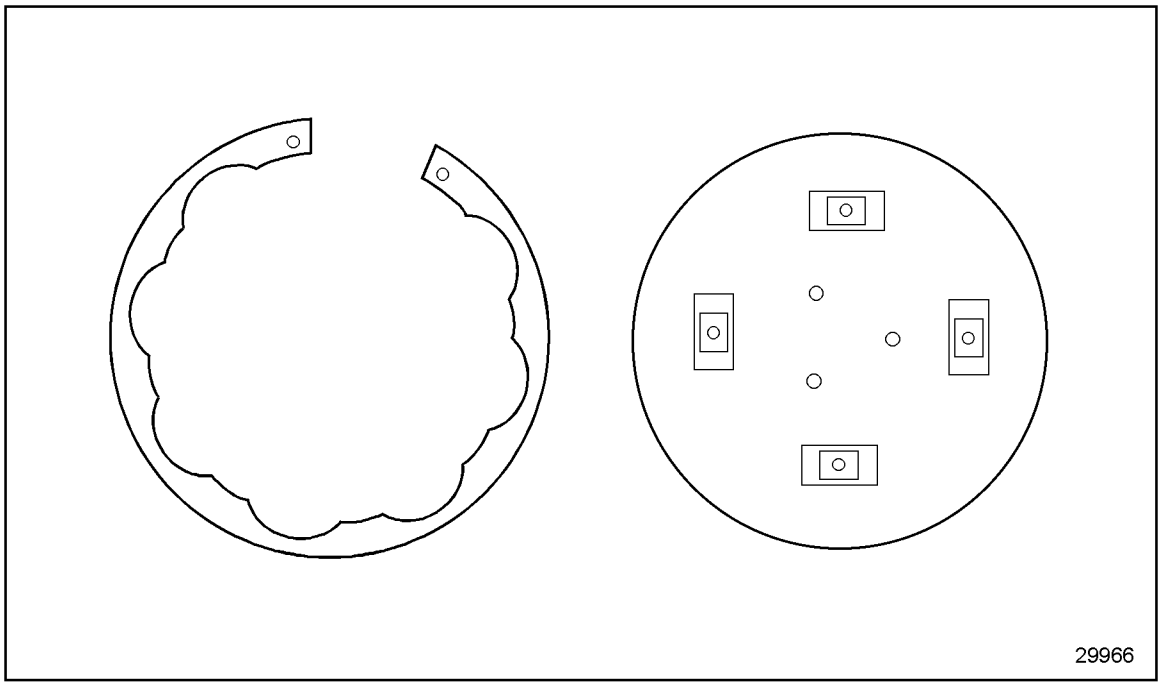


Figure 4-7 Cover and Retaining Ring

4.2.1 Repair or Replacement of Water Pump (6V and 8V Engine)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-8.

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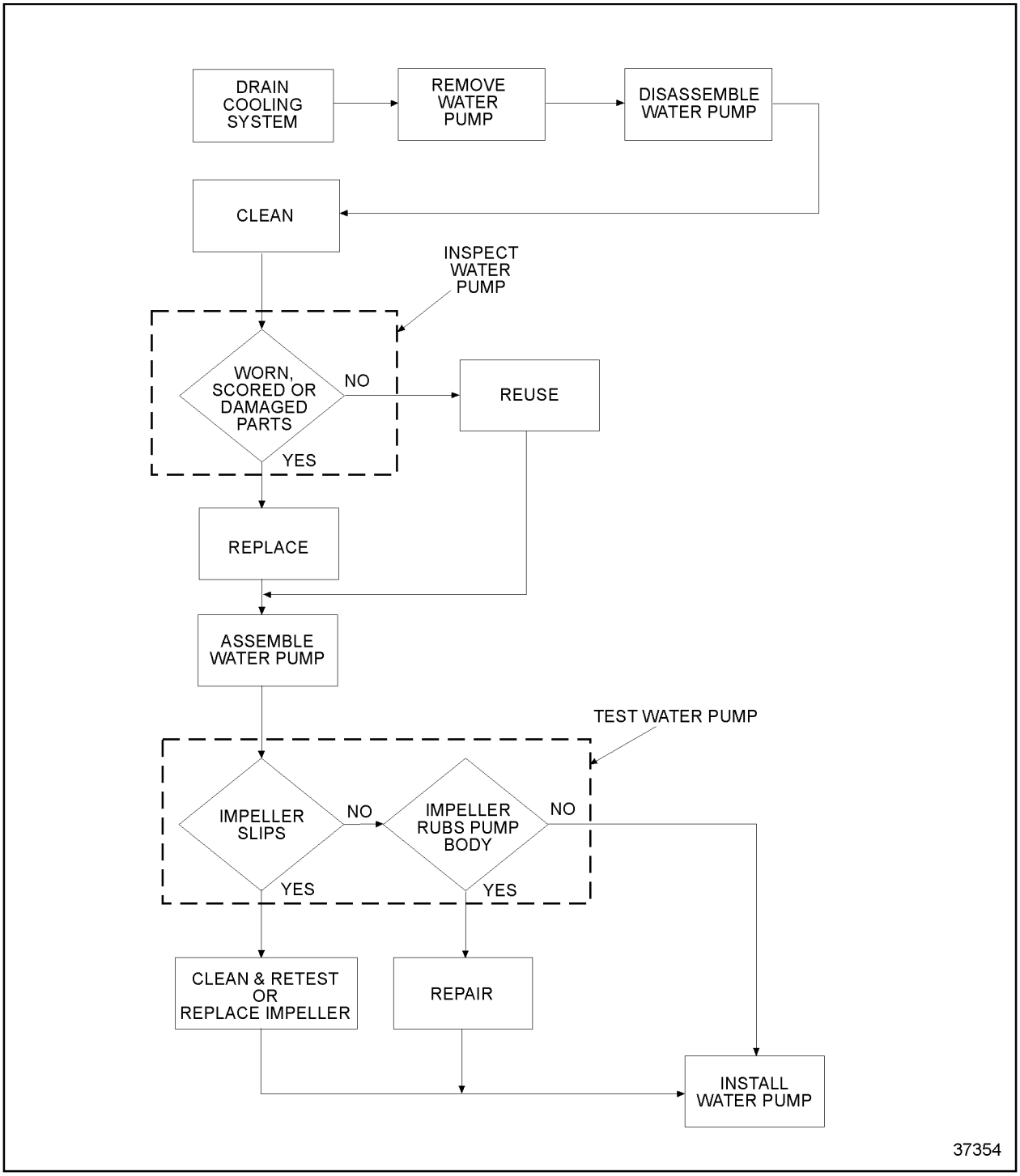


Figure 4-8 Flowchart for Repair or Replacement of Water Pump(6V and 8V Engine)

4.2.2 Removal of Water Pump (6V and 8V Engines)

Remove the water pump as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Remove the radiator, fan shroud, and fan or heat exchanger, if necessary.
3. Loosen the hose clamps, and remove the hoses from the pump body.

NOTICE:
Use care to prevent damage to the gear teeth when disengaging the pump gear from the front camshaft gear (water pump drive gear).

4. Remove the pump body-to-engine front cover mounting bolts, and detach the pump.
5. Grasp the pump firmly, and remove the two pump body-to-engine front cover bolts and lock washers.

NOTICE:
Use care to prevent damage to the gear teeth when removing the two pump body-to-engine front cover bolts and lock washers.

6. Detach the water pump.

4.2.3 Disassembly of Water Pump (6V and 8V Engines)

Disassemble the water pump as follows:

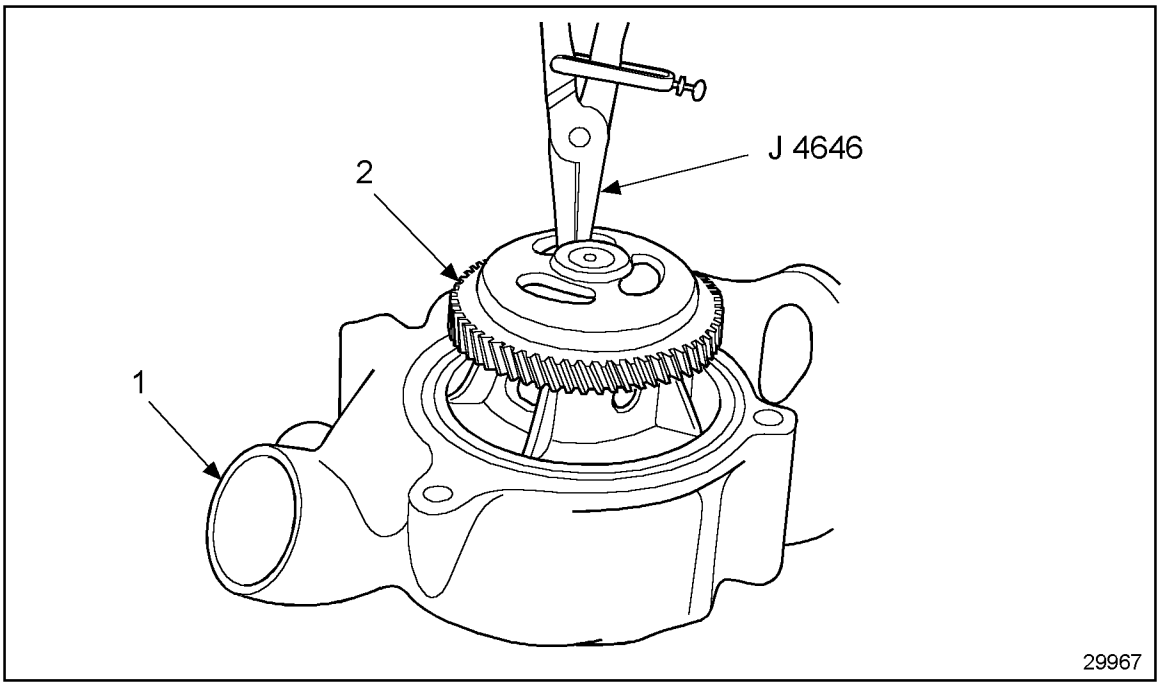
1. Turn the pump gear so the slot is over the bearing retaining-ring ends.

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CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

2. Insert pliers J 4646 into the slot, and with the aid of a small screwdriver, remove the retaining ring from the groove. See Figure 4-9.



1. Water Pump Assembly
2. Water Pump Gear

Figure 4-9 Removing Retaining Ring using Tool J 4646

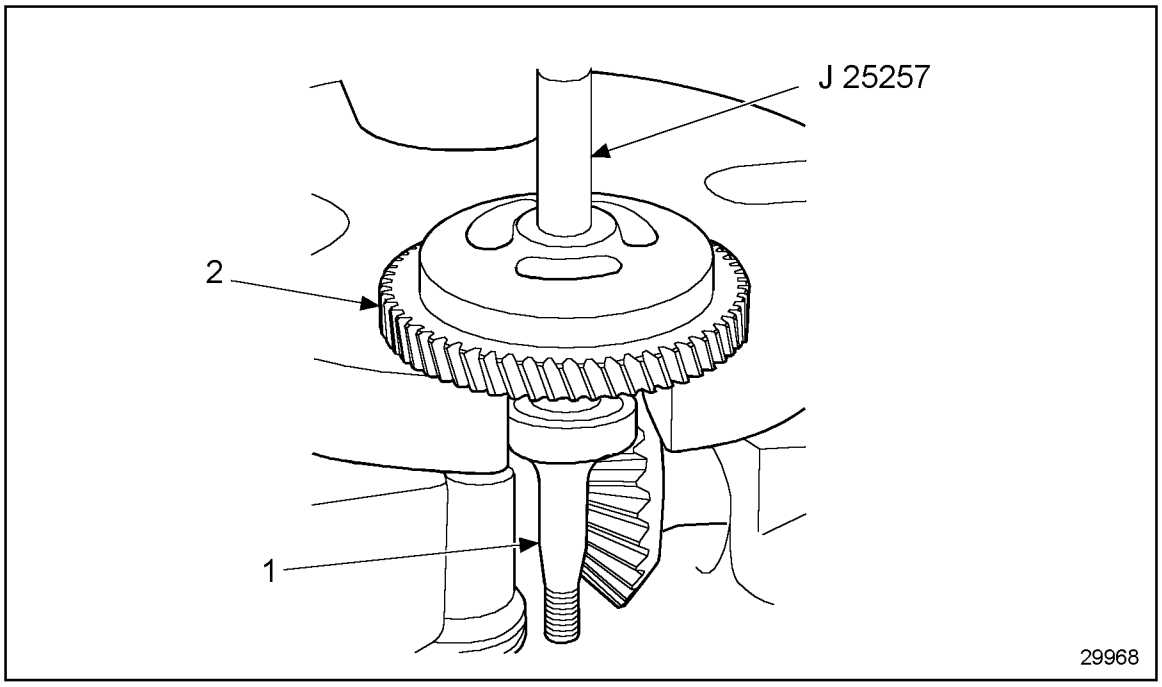
3. Remove the pump cover bolts, pump cover, and gasket. Discard the gasket.
4. Remove the scalloped cover retaining snap ring.

NOTE:
On high-capacity water pumps, use extreme care when removing or installing the scalloped cover retaining snap ring, but *do not* remove the seal ring.

5. Remove the pump cover, but *do not* remove the seal ring.

NOTICE:
While holding the gear, use care to prevent damage to the gear teeth.

6. Hold the gear securely, and remove the impeller locknut and washer.
7. Use puller J 24420-C to remove the impeller.
8. Press the shaft, bearings, and pump gear assembly out of the pump body.
9. Place the gear on an arbor press bed with the shaft extending downward, and place a short piece of 15.88 mm (0.625 in.) diameter bar stock between the shaft and the press ram.
10. Press the shaft out of the gear. See Figure 4-10.



1. Bearing and Shaft Assembly
2. Water Pump Gear

Figure 4-10 Pressing Gear on Pump Shaft using Tool J 25257

11. Support the shaft assembly on the inner race of the larger bearing with the threaded end down.
12. Place flat stock between the press ram and the shaft. Press the pump shaft out of the large bearing.
13. Invert the shaft, and support it on the inner race of the small bearing.
14. Place flat stock between the press ram and the shaft.

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15. Press the pump shaft out of the small bearing.

NOTE:
If necessary, remove the water seal. Use channel-lock-type pliers to grasp the metal flange around the upper portion of the seal, and twist it firmly to break the seal and boot assembly away from the case. Avoid damaging the pump shaft during this operation.

16. Insert seal removal tool J 22150-B in the pump, and secure it in place with the pump cover snap ring, bolts, or retaining nuts.

NOTE:
On the 6V and 8V high-capacity water pump, the cover seal ring should be left in place to avoid damage to the seal ring groove.

17. Turn puller shaft nut J 22150-B counterclockwise until the spears pierce the water seal case.
18. Turn the puller shaft clockwise one eighth of a turn to lock the spears in place.
19. Rotate the puller shaft nut clockwise to remove the water seal.
20. Disengage the seal removal tool from the pump.
21. On the 6V and 8V high-capacity water pump, remove and discard the cover seal ring.
22. Push the oil seal out of the pump body.

NOTE:
New seals and a new impeller must be used each time the water and oil seals are removed or at water pump overhaul.

4.2.3.1 Cleaning of Water Pump (6V and 8V Engines)

Clean the water pump as follows:

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash all 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 them with compressed air.

4.2.3.2 Inspection of Water Pump (6V and 8V Engines)

Inspect the water pump as follows:

1. Inspect the water seal for cracks, wear, or damage.
   [a] If cracked, worn, or damaged, replace the water seal. Refer to section ADDITIONAL INFORMATION.
   [b] If not cracked, worn, or damaged, continue inspection.
2. Inspect the water pump impeller for wear and erosion.
   [a] If worn or eroded, replace the impeller. Refer to section 4.2.4.
   [b] If not worn or eroded, continue inspection.
3. Inspect the bolts with nylon inserts for sufficient protrusion beyond the threads.
   [a] If not protruding sufficiently, securely tighten the nuts or bolts.
   [b] If sufficiently protruding, continue inspection.
4. Visually inspect the bearings for corrosion, pitting, wear, and freedom of movement.

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[a] If excessively corroded, pitted, worn, or lacks freedom of movement, replace the bearings. Refer to section 4.2.4.

NOTE:
When replacing one bearing, both must be replaced.

[b] If bearings are not corroded, pitted, worn, or lack freedom, proceed with inspection.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

5. Apply engine oil to the bearings. Hold the inner race, and slowly revolve the outer race to check for roughness.

   [a] If rough, replace the bearings. Refer to section 4.2.4.

NOTE:
When replacing one bearing, both must be replaced.

[b] If not rough, they may be reused. Continue inspection, refer to section 4.2.5.1.

4.2.4 Assembly of Water Pump (6V and 8V Engines)

Assemble the water pump as follows:

⚠ CAUTION:

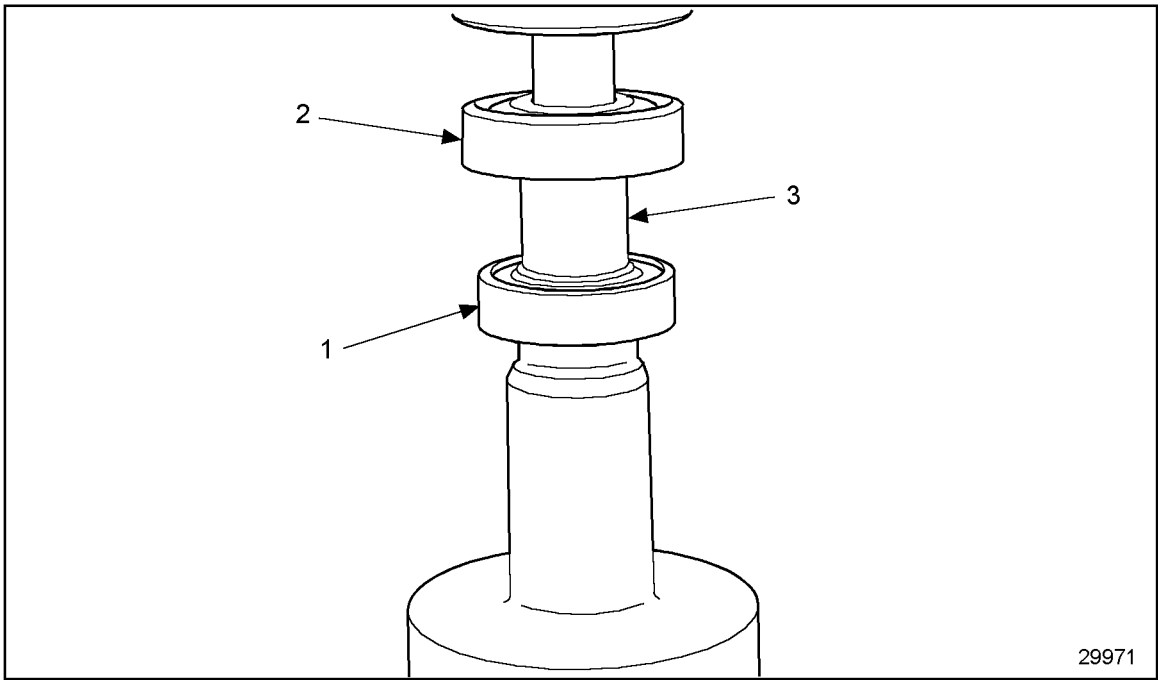
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the bearing bores in the pump body and the bearing surfaces on the shaft with clean engine oil.

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NOTICE:
To avoid bearing damage, apply pressure to the inner race of the bearings during assembly onto the shaft.

2. Use bearing and gear installer J 25257, and install the bearings on the shaft. See Figure 4-11.



1. Inner Bearing
2. Outer Bearing
3. Shaft

Figure 4-11 Pressing Bearing on Pump Shaft using J 25257

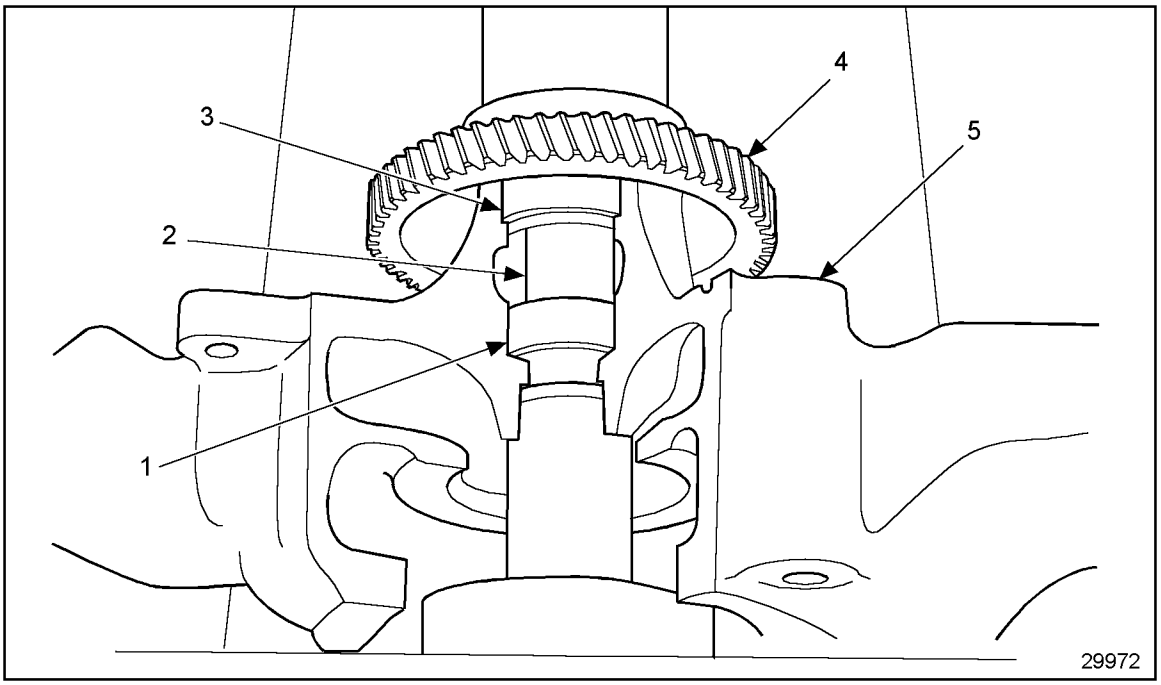
3. Support the pump body on an arbor press bed with the cover side down.

NOTICE:
To avoid bearing damage, apply pressure to the outer race of the large bearing when installing the shaft and bearing assembly in the retainer.

4. Apply pressure on the large bearing outer race to press the shaft and bearing assembly in place.
5. Install the bearing retaining (snap) ring.

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6. With gear installer J 25257 positioned on the impeller end of the shaft, place the gear between the shaft and the ram of the press. See Figure 4-12.



1. Inner Bearing
2. Shaft
3. Outer Bearing
4. Gear
5. Pump Body

Figure 4-12 Pressing Gear on Pump Shaft using Tool J 25257

7. Press the gear on the shaft so it is flush with the end of the shaft.

NOTE:
Tool J 25257 will hold the shaft vertically to ensure the gear is pressed squarely on the shaft.

Assemble seal as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply a film of clean engine oil to the sealing lip of the oil seal and the lip contact surface of the shaft.
2. Slip the seal over the shaft and press into the pump body with the spring-loaded lip toward the bearing.

3. Use a suitable sleeve, and tap the seal into place ensuring that the oil seal is flush with the water seal counterbore body.
4. Place the pump body on an arbor press bed.
5. To reduce possible coolant leakage, apply a light coat of Loctite 290 sealant on the outside diameter of a new water seal.
6. Slip the unitized seal over the shaft and into the pump body with the wide flange side facing the bearings.

NOTICE:
Seal installer J 38858 must be used to set the seal to its proper installed height. Failure to do so may cause coolant leakage leading to engine damage.

7. Using seal installer J 38858, press the seal into place.

Assemble impeller as follows:

1. Ensure that the mating surfaces of the water seal and the impeller are free of dirt, metal particles, and oil film.
2. Apply a small quantity of INTERNATIONAL COMPOUND #2®, or equivalent to the threads of the pump shaft.
3. Place the impeller washer and new locknut on the shaft.

NOTICE:
Do not damage the gear teeth while holding the gear.

4. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the locknut to 47-61 N·m (35-45 lb·ft) torque.
5. Install the hose on the water outlet opening, and secure it with clamps.

4.2.5 Installation of Water Pump (6V and 8V Engines)

Install the water pump as follows:

1. Affix the seal ring to the pump body.
2. Mount the pump on the engine so the pump gear meshes with the camshaft gear. Install and tighten the mounting bolts.
3. Replace the hoses, and secure them with clamps.
4. Check the gear backlash by installing bolts, or equivalent, in the impeller puller holes. Measure the backlash with an indicator.

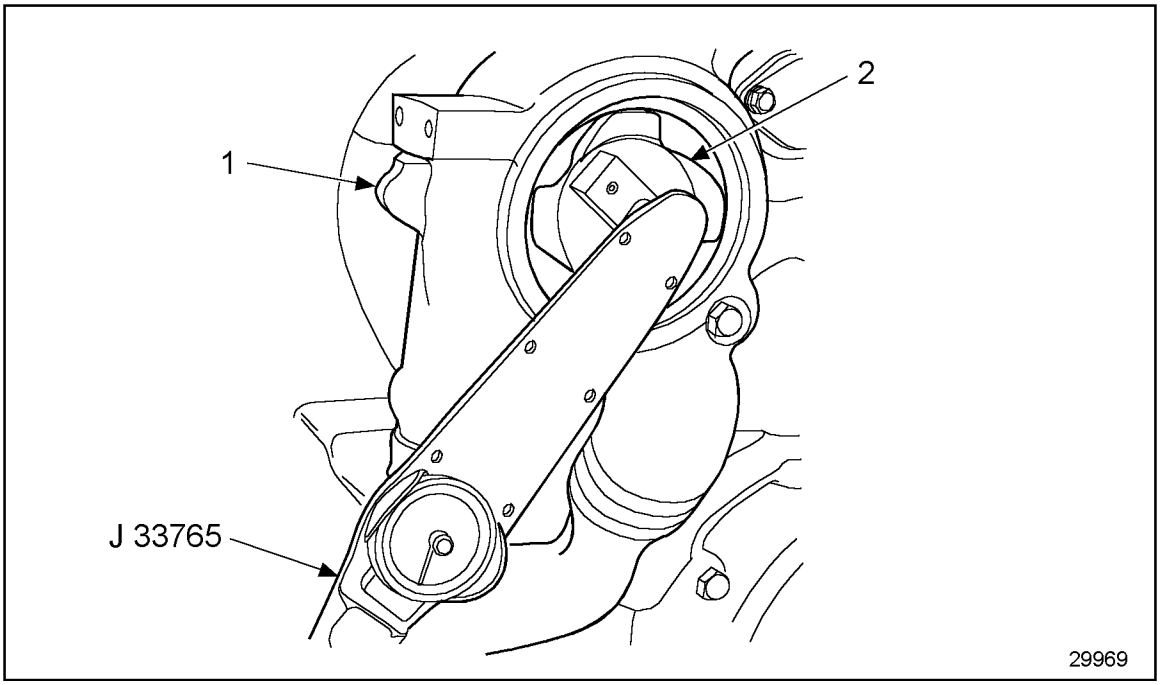
NOTE:
The gear backlash setting should be 0.0254-0.1524 mm (0.001-0.006 in.) when measured.

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5. When the specified backlash reading cannot be obtained, loosen the pump-attaching bolts and pivot the pump at the dowel as required to obtain the proper lash adjustment. Retighten the mounting bolts.
6. Install the pump cover.
7. Slide the hoses into position, and tighten the hose clamps.
8. Fill the cooling system. Refer to section 13.12.2.

4.2.5.1 Test Water Pump Impeller and Gear Slip Torque (6V and 8V)

See Figure 4-13. Test the water pump impeller and gear slip torque as follows:



1. Water Pump Assembly
2. Impeller

Figure 4-13 Checking Impeller and Gear Slip Torque with Tool J 33765

1. Scribe a line across the impeller, nut, and shaft.
2. Scribe a second line across the impeller, nut, and shaft.
3. Attach adaptor J 33765 to an accurately calibrated torque wrench.
4. Insert the adaptor dowel pins into the impeller puller holes, and apply a torque of 108 N·m (80 lb·ft).

NOTE:
The crankshaft may move slightly until the next cylinder in the firing order comes up on compression.

5. If slippage occurs, examine the marks scribed across the impeller and shaft.

   [a] If the marks are *no longer in alignment*, the *impeller* has turned on the shaft. Remove the pump from the engine, refer to section 4.2.2.

   □ With pump removed, replace the shaft and impeller, refer to section 4.2.4.

   [b] If the marks are *still in alignment* the *gear* has turned on the shaft. Remove the pump from the engine, refer to section 4.2.2.

   □ With pump removed, replace the shaft and gear. Refer to section 4.2.4.

   [c] If the shaft and either the gear or impeller has not turned in the shaft, continue inspection.

6. Bench test the completed pump assembly.

7. Loosen the clamps and remove the hose from the water outlet opening of the pump.

8. Insert a feeler gage into the water outlet opening of the pump. The minimum clearance between the impeller and the pump body must be 0.381 mm (0.015 in.).

   [a] If the clearance between the impeller and the pump body exceeds 0.381 mm (0.015 in.), replace pump assembly. Refer to section 4.2.5.

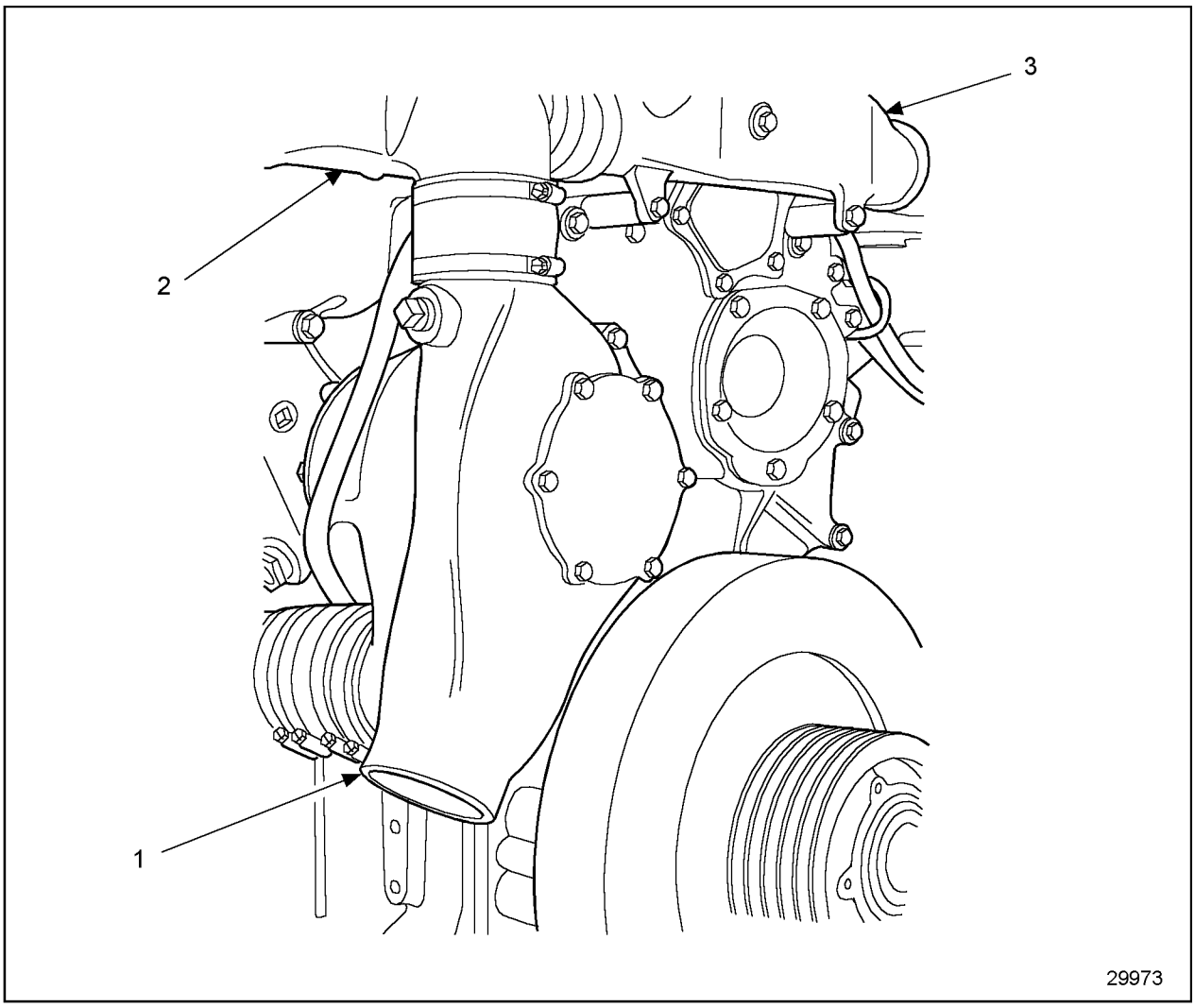
   [b] If the clearance between the impeller and the pump body does not exceed 0.38 mm (0.015 in.), continue inspection.

9. Use a new O-ring seal, and install the water pump cover and secure in place with the retaining ring. Refer to section 4.2.5.

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4.3 WATER PUMP (12V AND 16V ENGINES)

The centrifugal-type water pump is mounted on the front engine cover. The right front camshaft gear drives the water pump. See Figure 4-14. The pump circulates engine coolant through the cylinder block, cylinder heads, radiator or heat exchanger, and the oil cooler.



1. Water Pump Assembly
2. Thermostat Housing
3. Crossover Tube

Figure 4-14 Water Pump Mounting (12V and 16V Engines)

The pump consists of a bronze impeller secured to a stainless steel shaft with a locknut. A gear is pressed on the opposite end of the shaft, and the shaft turns on two ball bearings which are supported in a bearing and water and oil seal container. The container is secured to the pump housing with nuts and washers on studs installed in the pump body. An oil seal is used in front of the front bearing. A spring-loaded face type water seal is used in back of the impeller.

The pump ball bearings are lubricated with oil splash from the front gear train.

4.3.1 Repair or Replacement of Water Pump (12V and 16V Engines)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-15.

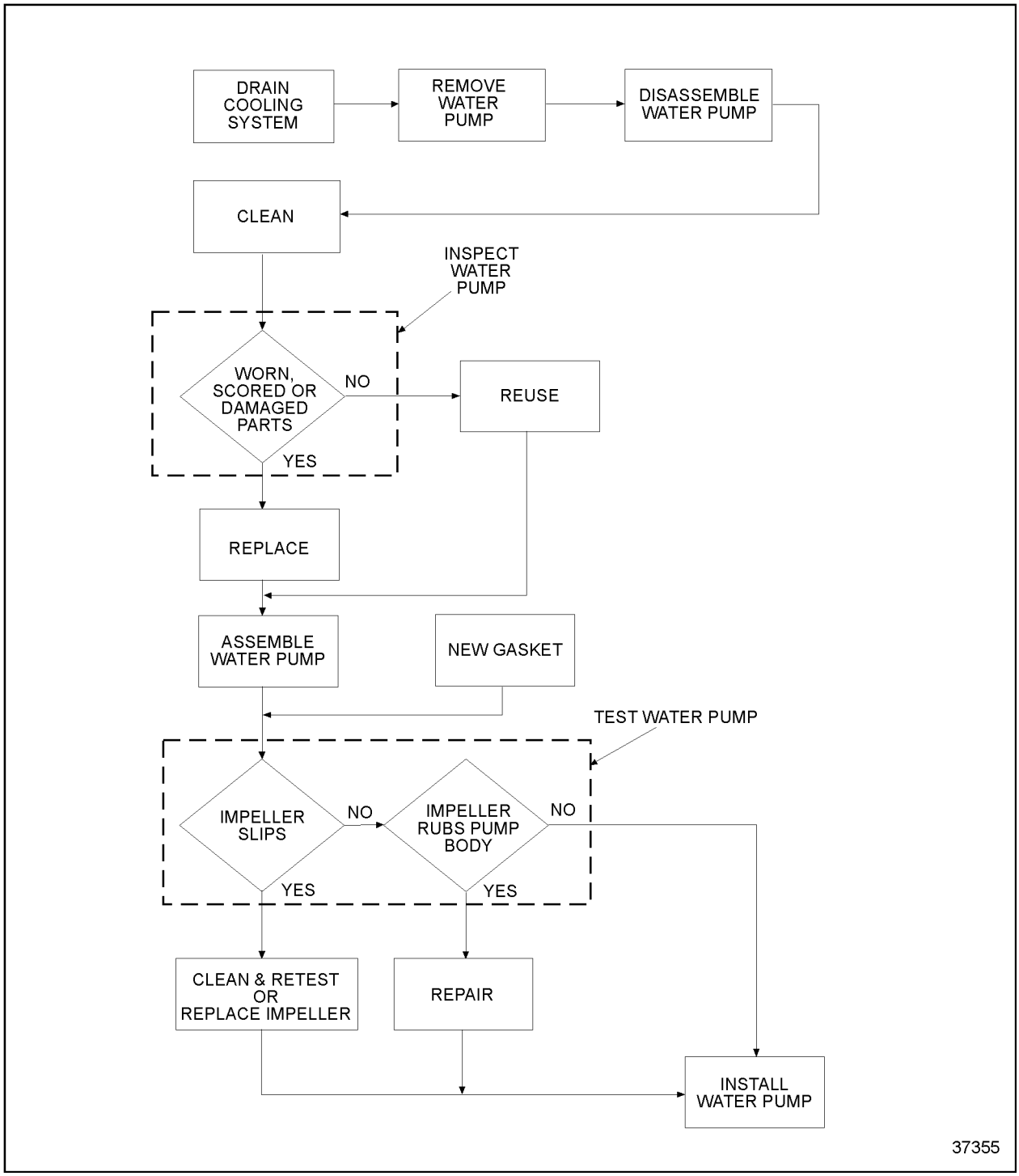


Figure 4-15 Flowchart for Repair or Replacement of Water Pump(12V and 16V Engines)

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4.3.2 Removal of Water Pump (12V and 16V Engines)

Remove the water pump as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. If necessary, remove the radiator, fan shroud and fan, or heat exchanger.
3. Remove the pump cover.
4. Remove the nuts and lock washers from the rear bearing support cover-to-end-plate studs. Remove the bolts and copper washers.
5. Grasp the pump firmly, and remove the two pump body-to-engine front cover bolts and lock washers.

NOTICE:
While holding gear, use care to prevent damage to the gear teeth.

6. Detach the water pump.

4.3.3 Disassembly of Water Pump (12V and 16V Engines)

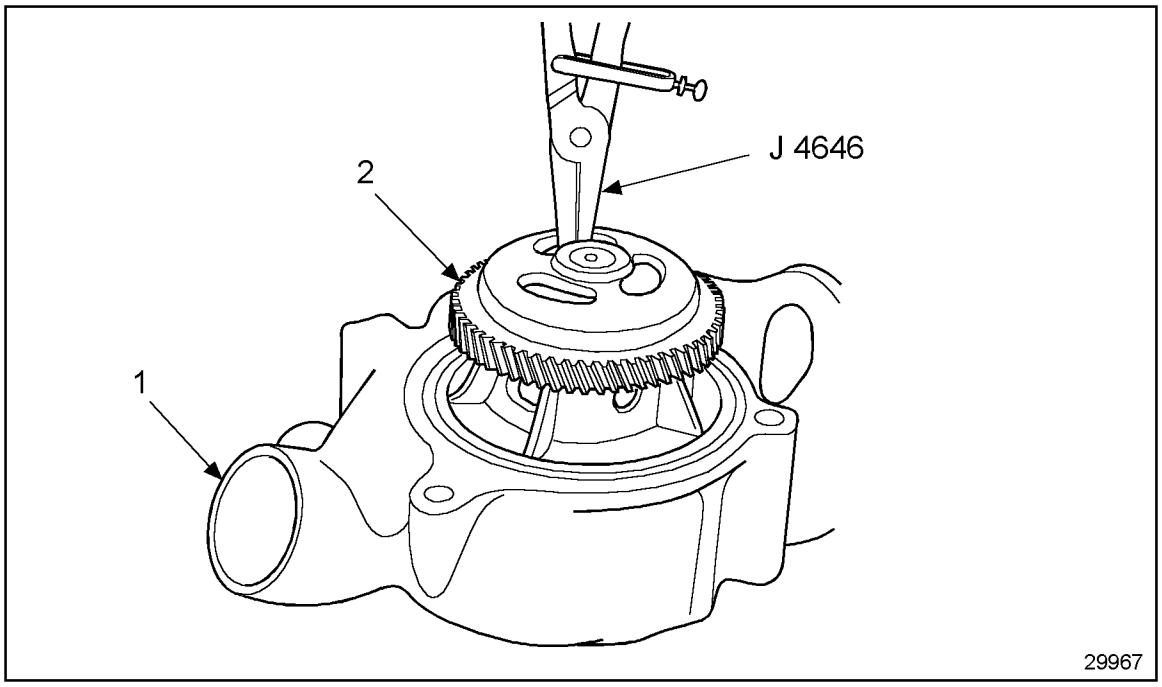
Disassemble the water pump as follows:

1. Remove the impeller deflector ring.
2. Turn the pump gear so the slot is over the bearing retaining ring ends.

⚠ CAUTION:

To avoid injury from flying parts when working with components under spring tension, wear adequate eye protection (face shield or safety goggles).

3. Insert pliers J 4646 into the slot, and with the aid of a small screwdriver, remove the ring from the groove. See Figure 4-16.



1. Water Pump Assembly
2. Water Pump Gear

Figure 4-16 Removing Retaining Ring using Tool J 4646

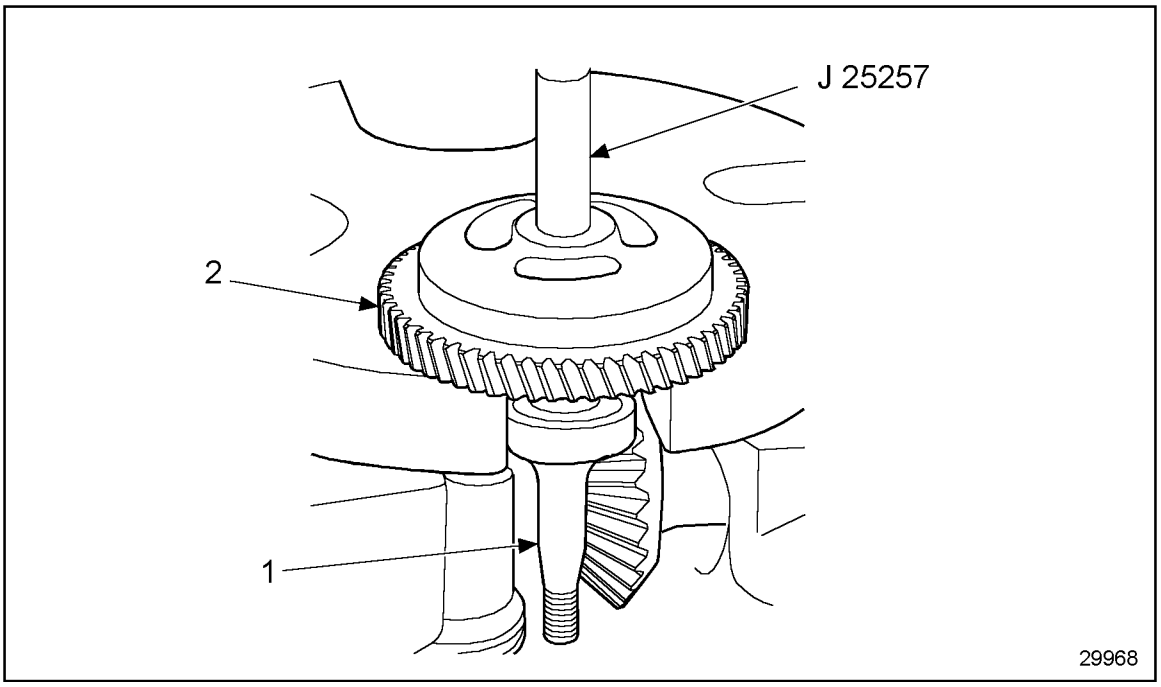
NOTICE:

While holding gear, use care to prevent damage the gear teeth.

4. Hold the gear securely, and remove the impeller locknut and washer.
5. Use puller J 24420-C to remove the impeller.
6. Remove the bearing retainer from the pump body.
7. While supporting the bearing and rubber seal retainer, tap the threaded end of the shaft lightly with a soft hammer to separate the shaft and bearing assembly from the retainer.
8. Place the gear on an arbor press bed with the shaft extending downward, and place a short piece of 15.88 mm (0.625 in.) diameter bar stock between the shaft and the press ram.

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9. Press the shaft out of the gear. See Figure 4-17.



1. Bearing and Shaft Assembly
2. Water Pump Gear

Figure 4-17 Pressing Gear on Pump Shaft using Tool J 25257

10. Support the shaft assembly on the inner race of the large bearing with the threaded end down.
11. Place flat stock between the press ram and the shaft. Press the pump shaft out of the large bearing.
12. Invert the shaft, and support it on the inner race of the small bearing.
13. Place flat stock between the press ram and the shaft.
14. Push the oil seal out of the retainer.

NOTE:
New seals and impeller must be used each time the water and oil seals are removed or at water pump overhaul.

4.3.3.1 Cleaning of Water Pump (12V and 16V Engines)

Clean the water pump as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash all 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 them with compressed air.

4.3.3.2 Inspection of Water Pump (12V and 16V Engines)

Inspect the water pump as follows:

1. Inspect the water seal for cracks, wear, or damage.
   [a] If cracked, worn, or damaged, replace the water seal. Refer to section ADDITIONAL INFORMATION.
   [b] If not cracked, worn, or damaged, continue inspection.
2. Inspect the water pump impeller for wear and erosion.
   [a] If worn or eroded, replace the impeller. Refer to section 4.3.4.

NOTE:
New seals and impeller must be used each time the water and oil seals are removed or at water pump overhaul.

   [b] If not worn or eroded, continue inspection.

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4.3.3.3 Inspection of Bearings (12V and 16V Engines)

Inspect the bearings as follows:

1. Visually inspect the bearings for corrosion, pitting, wear, and freedom of movement.

   [a] If excessively corroded, pitted, worn, or lacks freedom of movement, replace the bearings. Refer to section 4.3.4.

NOTE:
When replacing one bearing, both must be replaced.

   [b] If not corroded, pitted, worn, or lacking freedom, proceed with inspection.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Apply engine oil to the bearings. Hold the inner race, and slowly revolve the outer race to check for roughness.

   [a] If rough, replace the bearings. Refer to section 4.3.4.

NOTE:
When replacing one bearing, both must be replaced.

   [b] If not rough, they may be reused. Continue inspection, refer to section 4.3.5.1.

4.3.4 Assembly of Water Pump (12V and 16V Engines)

Assemble the water pump as follows:

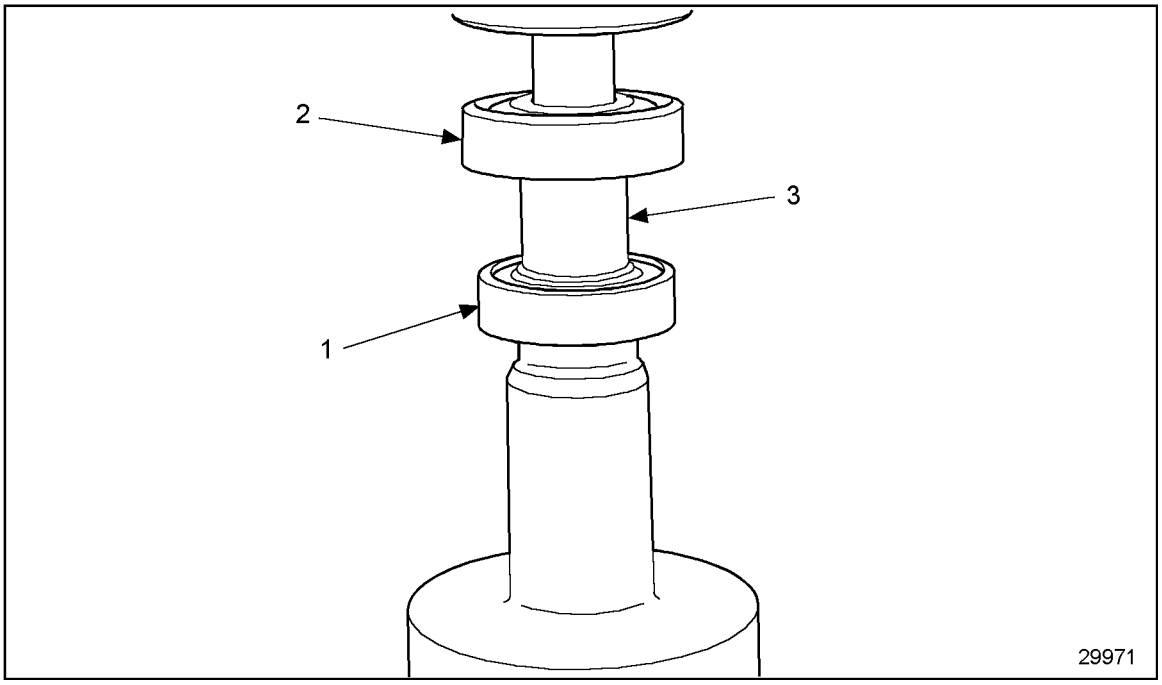
⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the bearing bores in the pump body and the bearing surfaces on the shaft with clean engine oil.

NOTICE:
To avoid bearing damage, apply pressure to the inner race of the bearings during assembly onto the shaft.

2. Use bearing and gear installer J 25257, and install the bearings on the shaft. See Figure 4-18.



1. Inner Bearing
2. Outer Bearing
3. Shaft

Figure 4-18 Pressing Bearing on Pump Shaft using J 25257

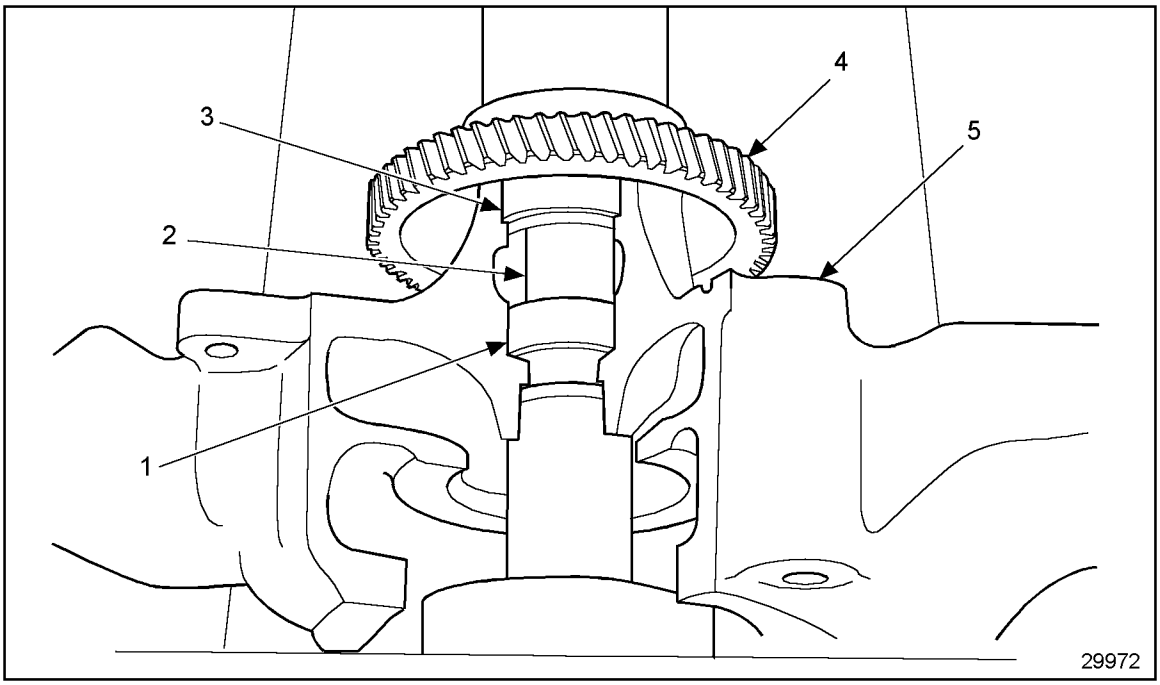
3. Support the pump body on an arbor press bed with the cover side down.

NOTICE:
To avoid bearing damage, apply pressure to the outer race of the large bearing when installing the shaft and bearing assembly in the retainer.

4. Apply pressure on the large bearing outer race to press the shaft and bearing assembly in place.
5. Install the bearing retaining (snap) ring.

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6. With gear installer J 25257 positioned on the impeller end of the shaft, place the gear between the shaft and the ram of the press. See Figure 4-19.



1. Inner Bearing
2. Shaft
3. Outer Bearing
4. Gear
5. Pump Body

Figure 4-19 Pressing Gear on Pump Shaft using Tool J 25257

7. Press the gear on the shaft so it is flush with the end of the shaft.

NOTE:
Tool J 25257 will hold the shaft vertically to ensure the gear is pressed squarely on the shaft.

Assemble seal as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Apply a film of clean engine oil to the sealing lip of the oil seal and the lip contact surface of the shaft.
2. Slip the seal over the shaft and press into the pump body with the spring-loaded lip toward the bearing.

3. Use a suitable sleeve, and tap the seal into place ensuring the oil seal is flush with the water seal counterbore body.
4. Place the pump body on an arbor press bed.
5. To reduce possible coolant leakage, apply a light coat of Loctite 290 sealant on the outside diameter of a new water seal.
6. Slip the unitized seal over the shaft and into the pump body with the wide flange side facing the bearings.

NOTICE:
Seal installer J 38858 must be used to set the seal to its proper installed height. Failure to do so may cause coolant leakage leading to engine damage.

7. Using seal installer J 38858, press the seal into place.

Assemble impeller as follows:

1. Ensure the mating surfaces of the water seal and the impeller are free of dirt, metal particles, and oil film.
2. Apply a small quantity of International Compound #2, or equivalent to the threads of the pump shaft.
3. Place the impeller washer and new locknut on the shaft.

NOTICE:
Do not damage the gear teeth while holding the gear.

4. Hold the pump gear securely while drawing the impeller down on the tapered shaft with the locknut. Tighten the locknut to 47-61 N·m (35-45 lb·ft) torque.
5. Install the hose on the water outlet opening, and secure it with clamps.

4.3.5 Installation of Water Pump (12V and 16V Engines)

Install the water pump as follows:

1. Place a new gasket on the pump body.
2. Position the pump, and slide the long studs into the holes in the front cover.

NOTE:
Ensure pump gear and camshaft gear teeth are correctly engaged.

3. Install the pump body-to-engine front cover bolts and lock washers.
4. Secure the nuts and lock washers on the water pump body studs that extend through the front cover. Install the two bolts and lock washers from the back side of the end plates.
5. Replace the hoses, and secure them with clamps.

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6. Check the gear backlash (clearance) between the water pump gear and the camshaft gear by installing bolts, or equivalent, in the impeller puller holes. Measure the backlash with an indicator.

NOTE:
The gear backlash setting should be 0.0254-0.1524 mm (0.001-0.006 in.) when measured.

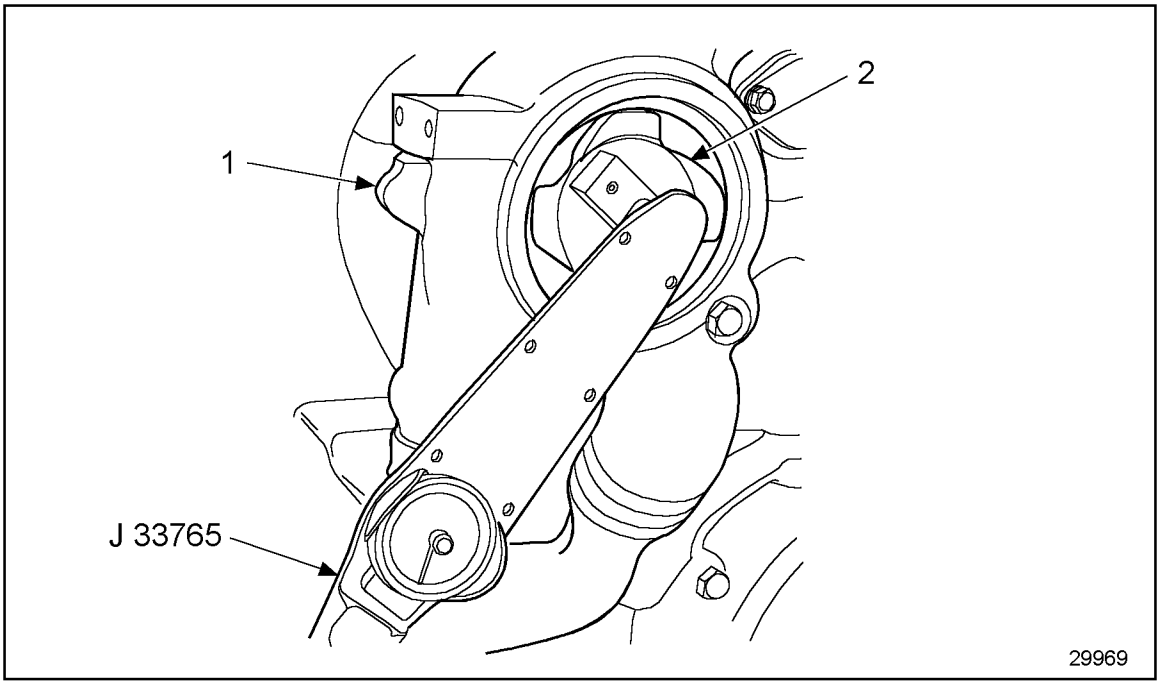
7. When the specified backlash reading cannot be obtained, loosen the pump attaching bolts and pivot the pump at the dowel as required to obtain the proper lash adjustment. Retighten the mounting bolts.
8. Install the water pump cover and a new gasket.

NOTE:
The word "TOP" is cast into the top of the cover.

9. Replace any other components removed during pump removal.
10. Fill the cooling system. Refer to section 13.12.2.

4.3.5.1 Test Water Pump Impeller and Gear Slip Torque(12V and 16V Engines)

See Figure 4-20. Test the water pump impeller and gear slip torque as follows:



1. Water Pump Assembly
2. Impeller

Figure 4-20 Checking Impeller and Gear Slip Torque with Tool J 33765

1. Scribe a line across the impeller, nut, and shaft.
2. Scribe a second line across the impeller, nut, and shaft.
3. Attach adaptor J 33765 to an accurately calibrated torque wrench.
4. Insert the adaptor dowel pins into the impeller puller holes, and apply a torque of 108 N·m (80 lb·ft).

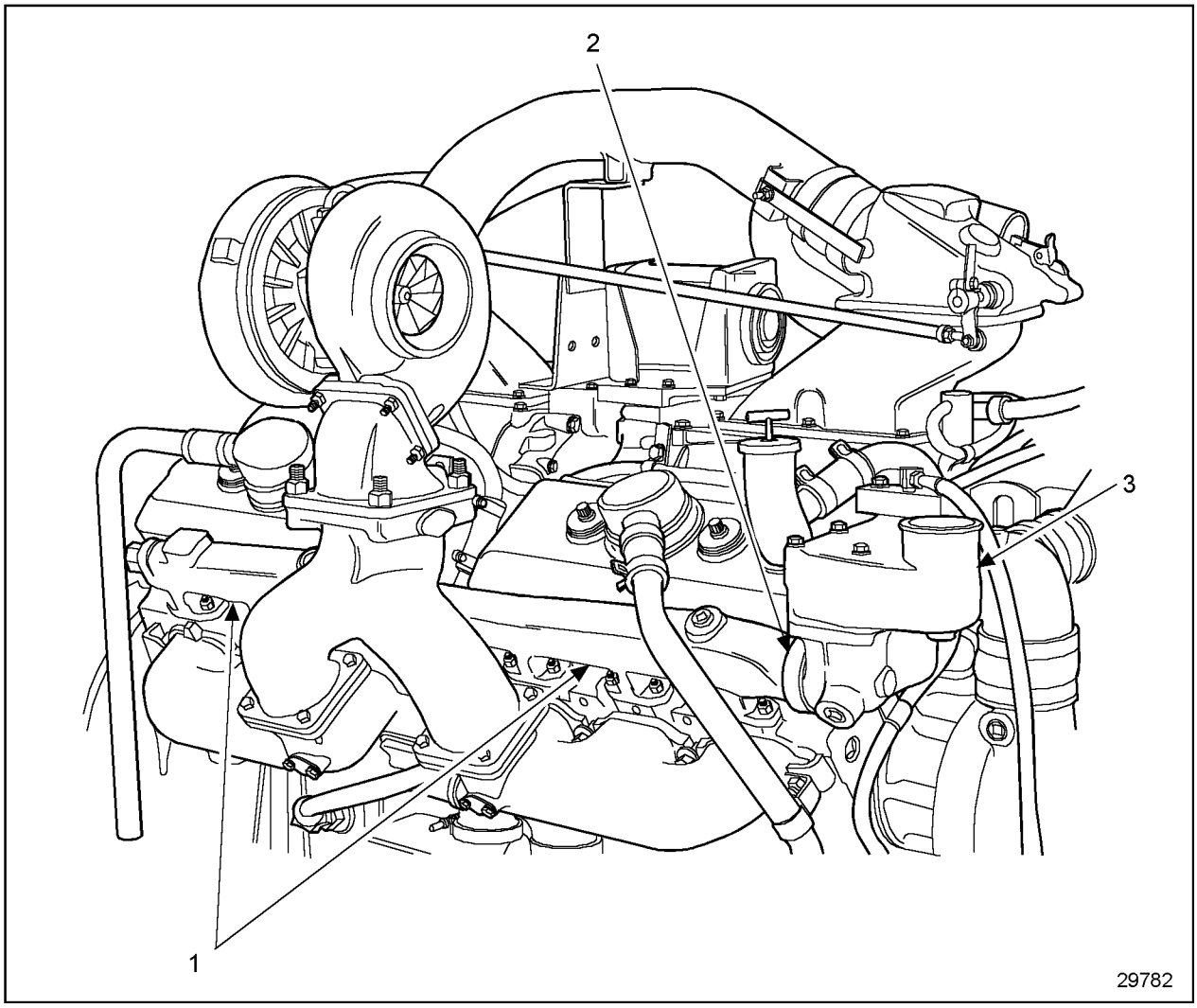
NOTE:
The crankshaft may move slightly until the next cylinder in the firing order comes up on compression.

5. If slippage occurs, examine the marks scribed across the impeller and shaft.
   [a] If the marks are *no longer in alignment*, the *impeller* has turned on the shaft. Remove the pump from the engine, refer to section 4.3.2.
   □ With pump removed, replace the shaft and impeller, refer to section 4.3.1.
   [b] If the marks are *still in alignment* the *gear* has turned on the shaft. Remove the pump from the engine, refer to section 4.3.2.
   □ With pump removed, replace the shaft and gear. Refer to section 4.3.1.
   [c] If the shaft and either the gear or impeller has not turned in the shaft, continue inspection.
6. Bench test the completed pump assembly.
7. Loosen the clamps and remove the hose from the water outlet opening of the pump.
8. Insert a feeler gage into the water outlet opening of the pump. The minimum clearance between the impeller and the pump body must be 0.381 mm (0.015 in.).
   [a] If the clearance between the impeller and the pump body exceeds 0.381 mm (0.015 in.), replace pump assembly. Refer to section 4.3.5.
   [b] If the clearance between the impeller and the pump body does not exceed 0.38 mm (0.015 in.). continue inspection.
9. Use a new O-ring seal, and install the water pump cover and secure in place with the retaining ring. Refer to section 4.3.5.

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4.4 WATER MANIFOLD

The 6 and 8V engines do not require external water manifolds. All 12V and 16V engines are equipped with external water manifolds (one per cylinder head). See Figure 4-21.



1. Water Manifolds
2. Clamp
3. Thermostat Housing

Figure 4-21 Water Manifolds Location (12V and 16V Engines)

Coolant, leaving the cylinder head through an opening directly over each exhaust port, enters the water manifold, which is attached to the cylinder head with two studs, lock washers, and nuts at each water opening. A separate gasket is used at each attaching flange between the manifold and cylinder head.

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A four-leg manifold has replaced the former six-leg manifold. Only the current manifold will be serviced. The two leg reduction has no detrimental effect upon engine cooling. However, when replacing the old manifold with the current, two plates, gaskets, and four 3/8 in.-16 x 0.88 in. bolts must be added to seal the unused openings in the cylinder head. Tighten these bolts to 27-34 N·m (20-25 lb·ft) torque.

4.4.1 Repair or Replacement of Water Manifold

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-22.

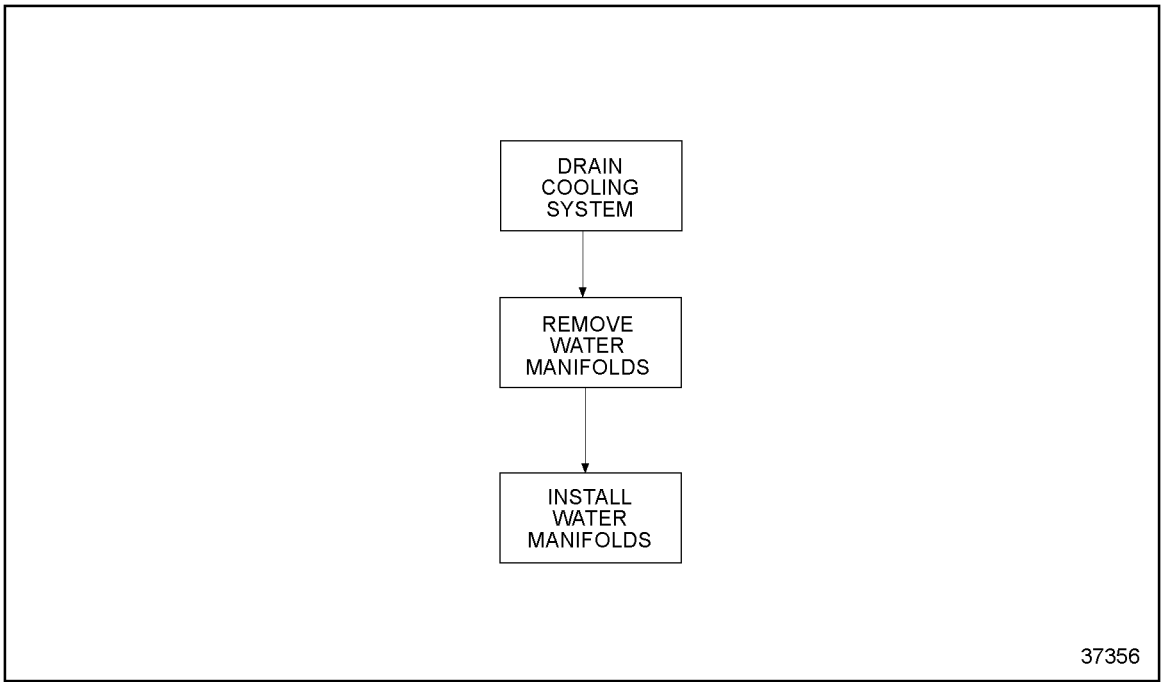


Figure 4-22 Flowchart for Repair or Replacement of Water Manifold

4.4.2 Removal of Water Manifold

Remove the water manifold as follows:

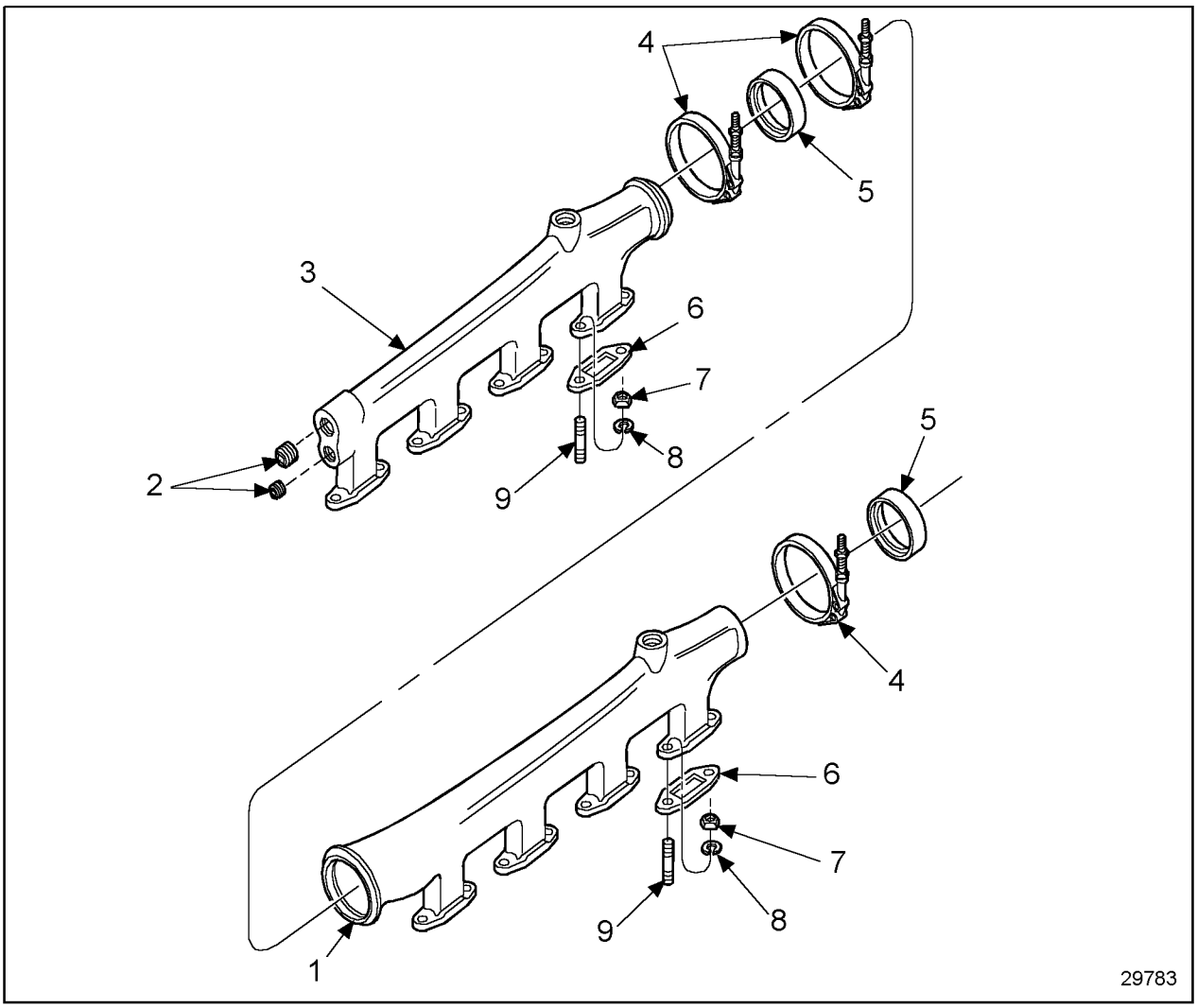
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⚠ CAUTION:

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. Drain the cooling system to the necessary level. Refer to section 13.12.3.

2. Loosen the seal clamp at the front end of the water manifold. See Figure 4-23.



1. Water Manifold (Front)
2. Pipe Plugs
3. Water Manifold (Rear)
4. Clamps
5. Sleeve
6. Gasket
7. Nut
8. Lock Washer
9. Stud

Figure 4-23 Water Manifolds (12V and 16V Engines)

3. Slide the seal over the neck of the thermostat housing or the water manifold.
4. Remove the water manifold attaching nuts and lock washers, and lift the manifold off the cylinder head.
5. Remove and discard the water manifold gaskets.

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4.4.3 Installation of Water Manifold

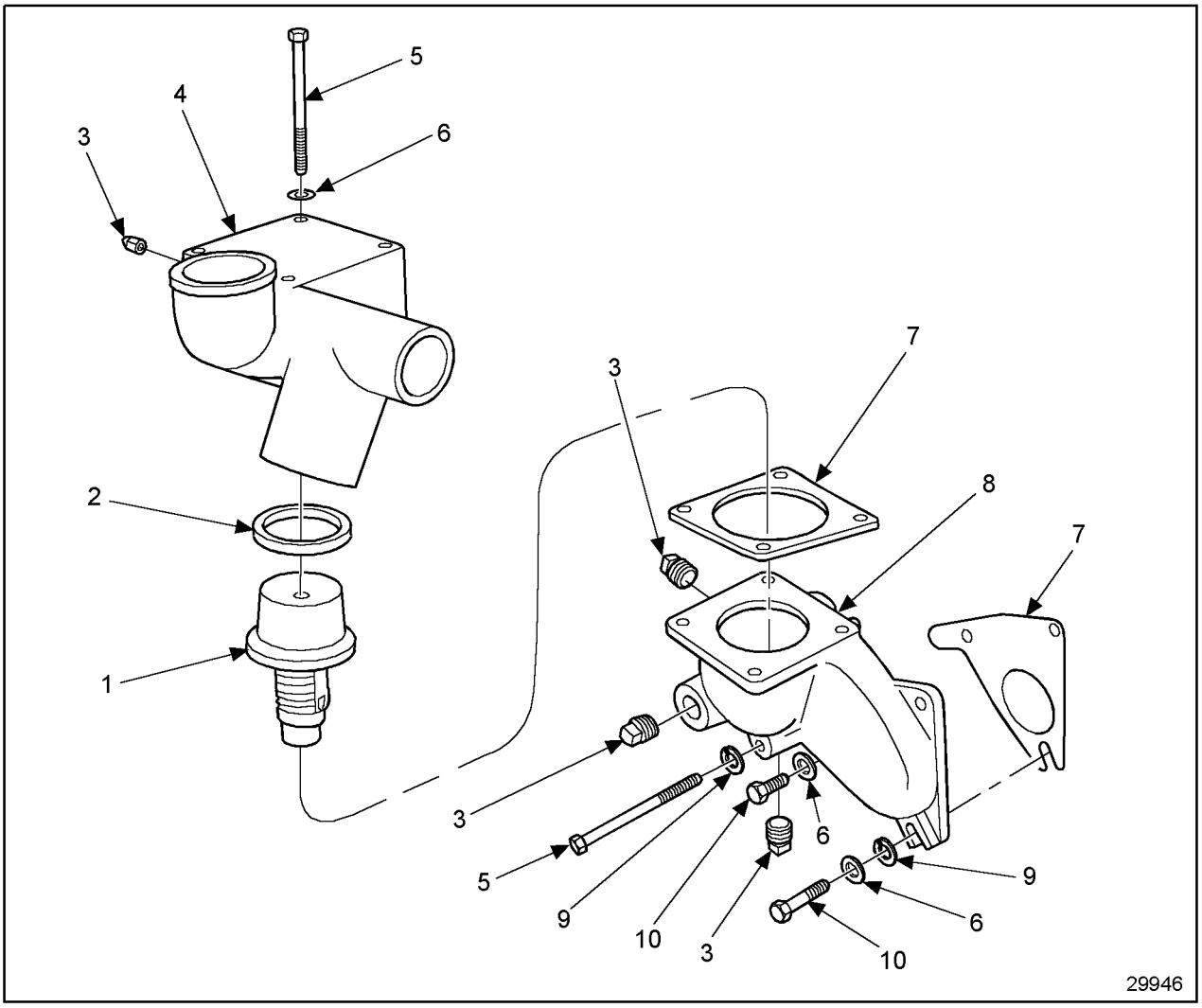
Install the water manifold as follows:

1. Install new water manifold gaskets.
2. Attach the water manifold to the cylinder head with the lock washers and nuts. Tighten the nuts to 27-34 N·m (20-25 lb·ft) torque.
3. Slide the seal onto the outlet end of the water manifold, and secure the seal with the clamp.
4. Fill the cooling system to the proper level. Refer to section 13.12.2.

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4.5 THERMOSTAT

A thermostat, located in a housing attached to the water outlet end of each cylinder head, controls the engine coolant temperature. See Figure 4-24.

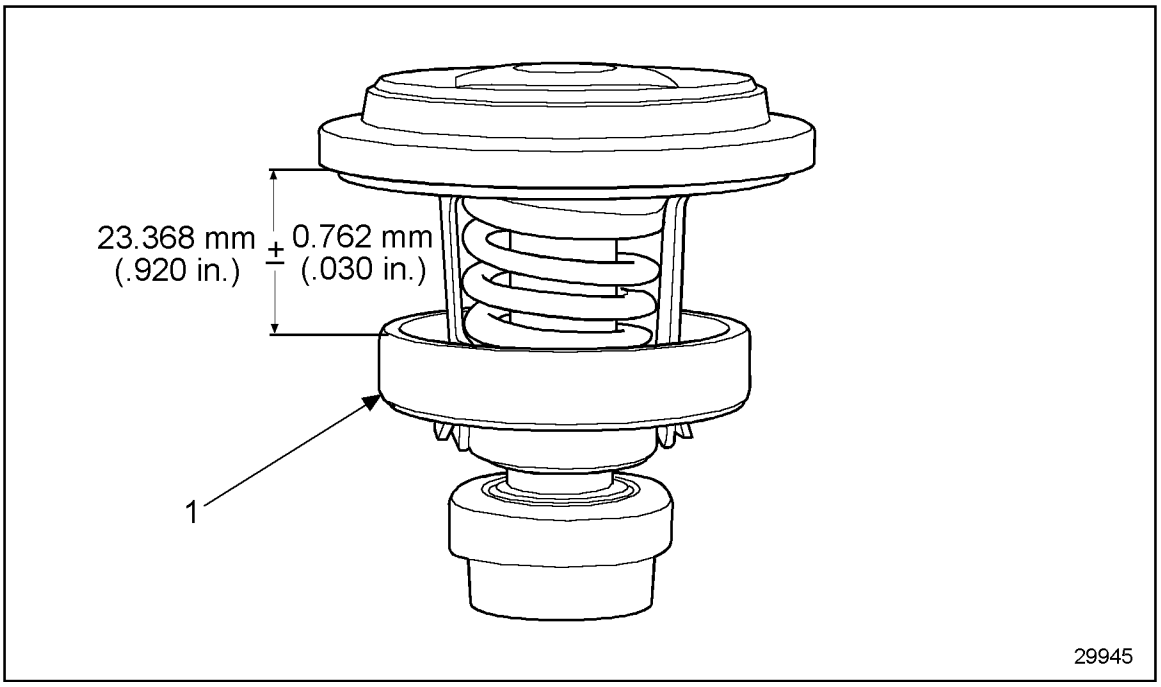


1. Thermostat
2. Seal
3. Pipe Plug
4. Cover
5. Bolt
6. Washer
7. Gasket
8. Housing
9. Lock Washer
10. Short Bolt

Figure 4-24 Typical Thermostat Housing

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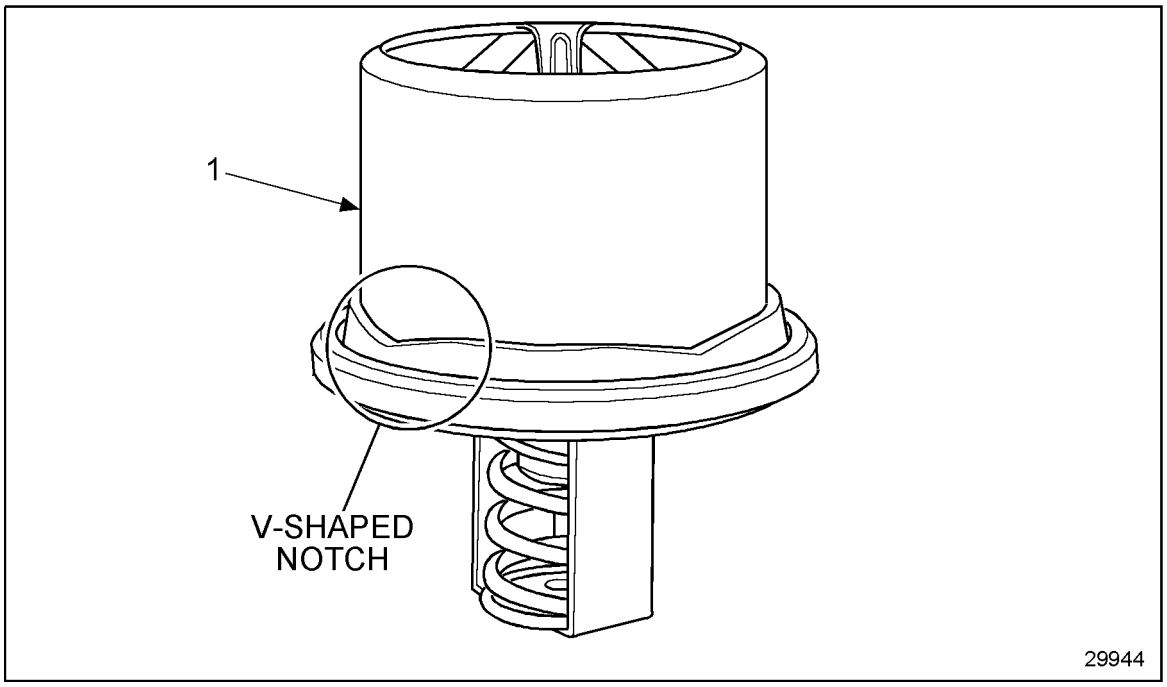
Blocking type thermostats are used when a standard cooling system is employed. See Figure 4-25 and see Figure 4-26. Full blocking type thermostats are used with the rapid warm-up cooling system. Two thermostats are employed in 6V and 8V engines, and four thermostats are used in the 12V and 16V engines.



1. Thermostat

Figure 4-25 Semi-Blocking or Partial Blocking (Shielded) Type Thermostat

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1. Thermostat

Figure 4-26 Full Blocking (Weir) Type Thermostat

A thermostat is an automatic valve which controls the coolant flow through a radiator or other heat exchanger. The thermostat senses changes in engine coolant temperature and regulates coolant flow to maintain efficient engine operating temperature.

Thermostats used in Detroit Diesel engines consist of a brass cup filled with a heat-expansive, wax-like material. An elastomeric seal retains the wax compound within the cup. The thermostat valve is attached to a piston.

The basic expansive wax principle remains the same for all thermostats. The valve is in the closed position when the thermostat is cold and wax is solid. When engine coolant heats the wax-filled brass cup, the wax-like material expands. As the coolant temperature in the engine reaches the calibrated "start to open" thermostat setting, the force of the expanding wax on the piston exceeds the closing force of the spring, and the valve opens. As the coolant temperature continues to increase, the wax-like material continues to expand, opening the valve further until it reaches its maximum design travel.

As the engine coolant temperature drops, wax cooling causes it to contract. This reduces the pressure on the piston and allows the spring to draw the valve back toward its seat (closed thermostat).

In order to perform effectively, a thermostat must meet the following requirements:

- ☐ Start to open at a specified temperature.
- ☐ Be fully open at a specified number of degrees above the "start to open" temperature.
- ☐ Permit the passage of a specified coolant amount under a specified pressure when fully open.

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- Depending on cooling system requirements, allow little or no coolant to flow to the radiator core when in the closed position.

Three basic types of thermostats are used in Detroit Diesel engines: full-blocking, non-blocking and partial blocking. See Figure 4-27, see Figure 4-28, and see Figure 4-29.

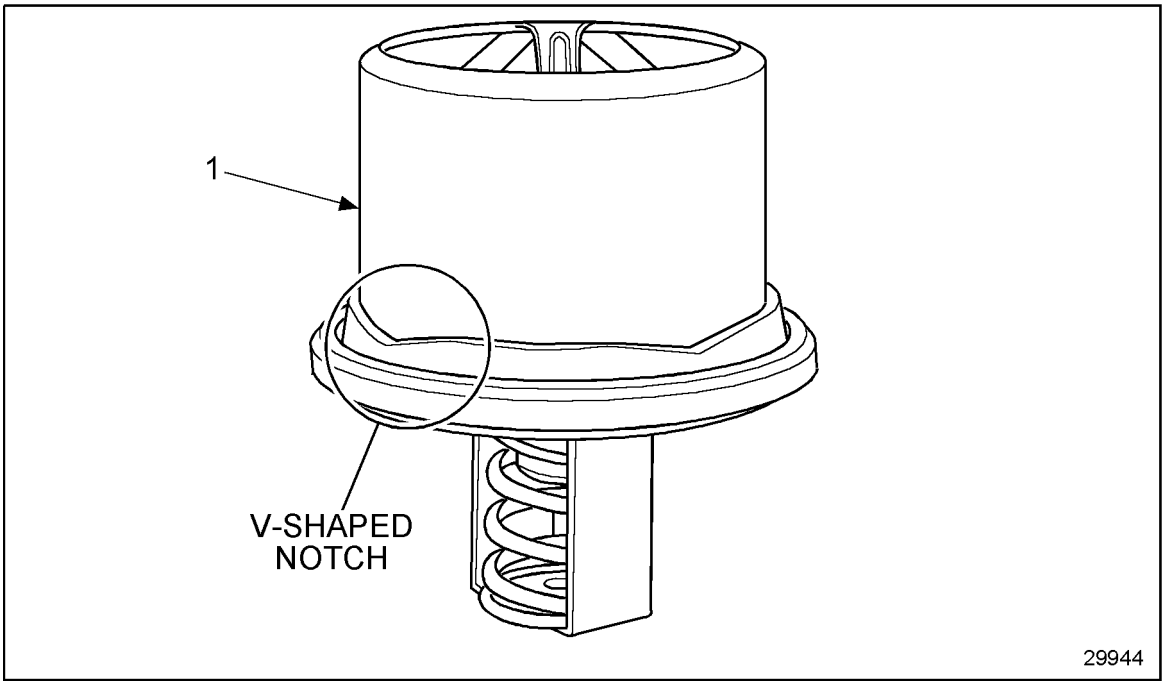


Figure 4-27 Full Blocking (Weir) Type Thermostat

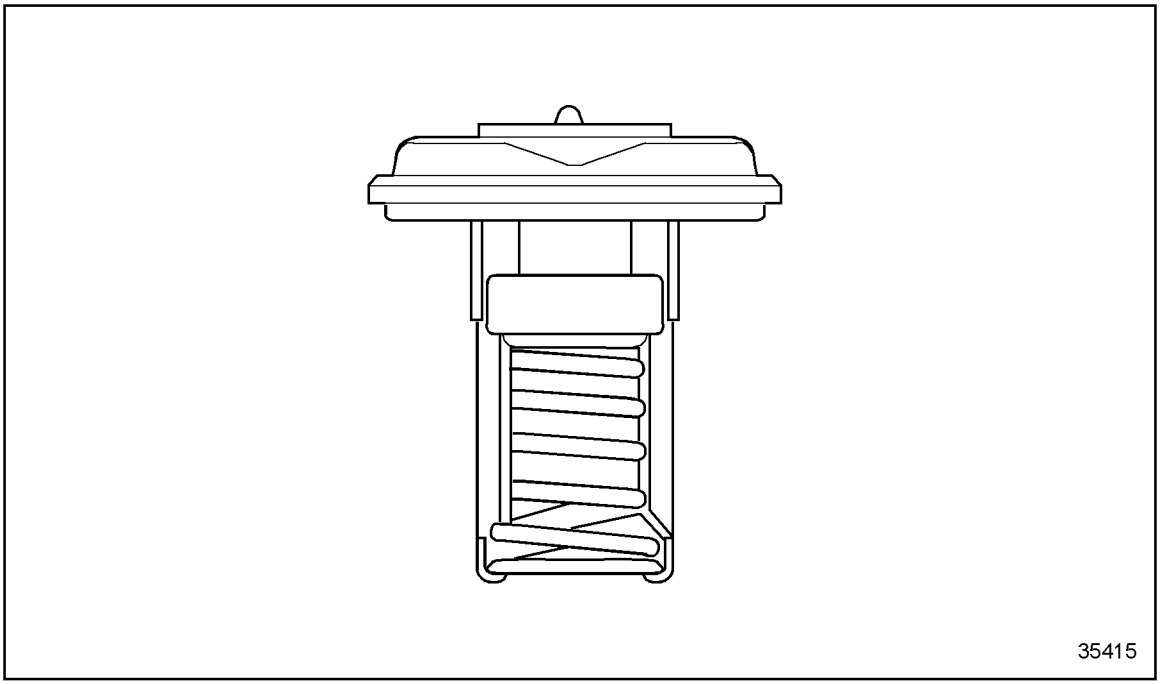


Figure 4-28 Non-Blocking (Choke or Poppet) Type Thermostat

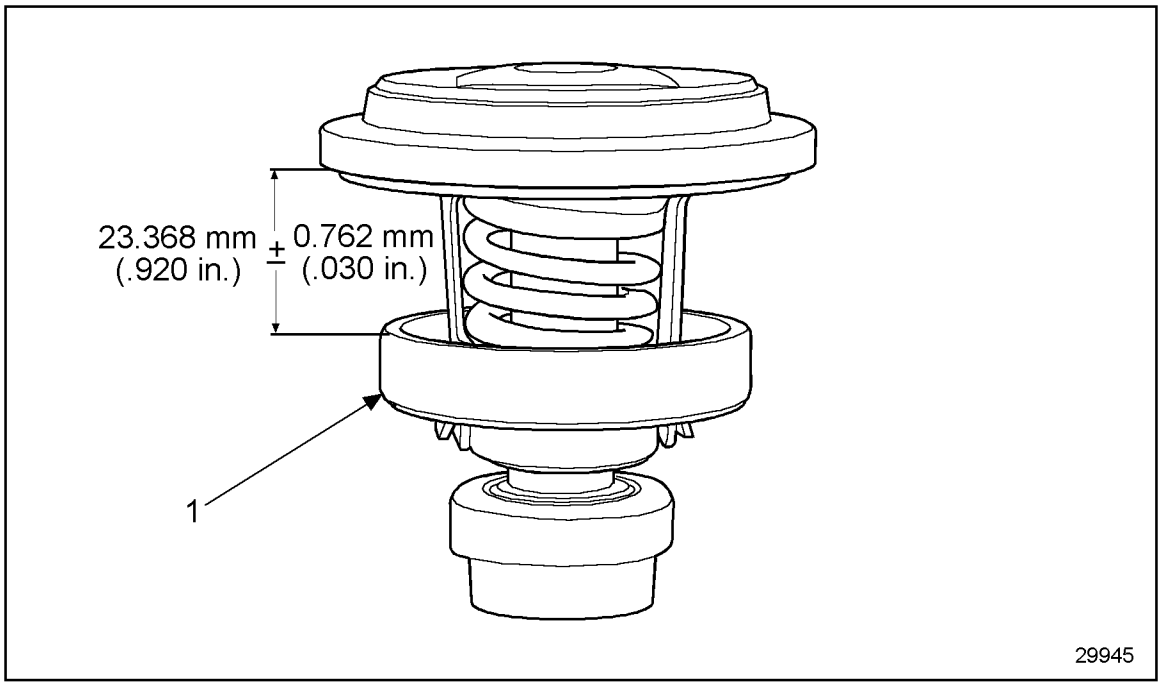


Figure 4-29 Semi-Blocking or Partial Blocking (Shielded) Type Thermostat

The ***full-blocking***type thermostat simultaneously controls the coolant flow to the radiator and the bypass circuit. During the engine warm-up, all engine coolant flows through the bypass circuit. As the thermostat opens, increasing amounts of coolant flow to the radiator, and the bypass flow is correspondingly reduced. At approximately 9.4°-11.1°C (17°-20°F) above the thermostat opening temperature, the bypass opening is fully blocked, and the total coolant flow is directed into the radiator.

The ***non-blocking***(choke or poppet) type thermostat controls the coolant flow only to the radiator, while the continuously open bypass sends coolant directly back to the fresh water pump and engine block. Coolant flow to the radiator discharges through the thermostat valve when coolant temperature is above the thermostat opening temperature. This thermostat type is fully open at 9.4°-11.1°C (17°-20°F) above the thermostat opening temperature.

The ***partial blocking***type thermostat is a variation of the two previously mentioned thermostats. When the thermostat opens to permit coolant flow to the radiator, it partially blocks the bypass.

Thermostats may be *vented*or *non-vented*. A small hole in the valve or a notch in the valve at its seat ventilates the thermostat. Non-vented thermostats should be installed only in rapid warm-up type cooling systems. Vented thermostats are used primarily in conventional cooling systems.

The coolant amount leaking to the radiator when the thermostat is in the "closed" position has a direct bearing on the engine's ability to warm up. For suitable engine warm-up, coolant leakage past the thermostat valve must be at a minimum.

The rapid warm-up cooling system may use any one of the three thermostat styles, which generally must be non-vented. This characteristic eliminates radiator shutters.

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The bypass circuit provides a route for coolant circulation before the thermostat opens. Coolant from the top of the engine flows to the water pump without passing through the radiator or other heat exchanger. This bypass coolant flow permits the engine to warm up to operating temperature while preventing "hot spots" which might damage the engine during this operation period.

At coolant temperatures below 71°-82°C (160°-180°F), depending upon the thermostat used, the valves remain closed and block the coolant flow to the radiator. During this period, all coolant in the standard system is circulated through the engine and directed back to the suction side of the water pump via the bypass tube. In the rapid warm-up system, a separate external de-aeration line bypasses enough coolant to vent the system to the radiator top tank and back to the water pump without going through the radiator cores. As the coolant temperature rises above 71°-82°C (160°-180°F), the thermostat valves start to open, restricting the bypass system, and permit a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 82°-92°C (185°-197°F), the thermostat valves are fully open, the bypass system is completely blocked off, and all coolant is directed through the radiator.

NOTE:
Engines using shutters and equipped with 82°-92°C (180°-197°F) thermostats may have an effect on the shutter operation.

A defective thermostat which remains closed, or only partially open, will restrict the coolant flow and overheat the engine. A thermostat which is stuck in a full open position restricts the engine from reaching its normal operating temperature. The incomplete fuel combustion due to cold engine operation will result in excessive carbon deposits on the pistons, rings, and valves.

Properly operating thermostats are essential for efficient engine operation. If the engine operating temperature deviates from the normal range of 71°-92°C (160°-197°F), the thermostats should be removed and checked.

⚠ CAUTION:

To avoid injury while performing the test or procedure, wear adequate eye, face protection, and heat-resistant gloves.

NOTE:
There are areas where approved fuel (less than 0.5% sulfur) is not commercially available or economically feasible to obtain. It is important to keep these engine's cooling system temperature higher than normal to prevent sulfur trioxide gas condensation, which combines with combustion water to form sulfuric acid. Install a 82°-88°C (180°-190°F) temperature thermostat, and modify the cooling system to provide rapid warm-up and maintain coolant temperature at a minimum of 80°C (174°F).

4.5.1 Repair or Replacement of Thermostat

To determine if replacement is necessary, perform the following procedure. See Figure 4-30.

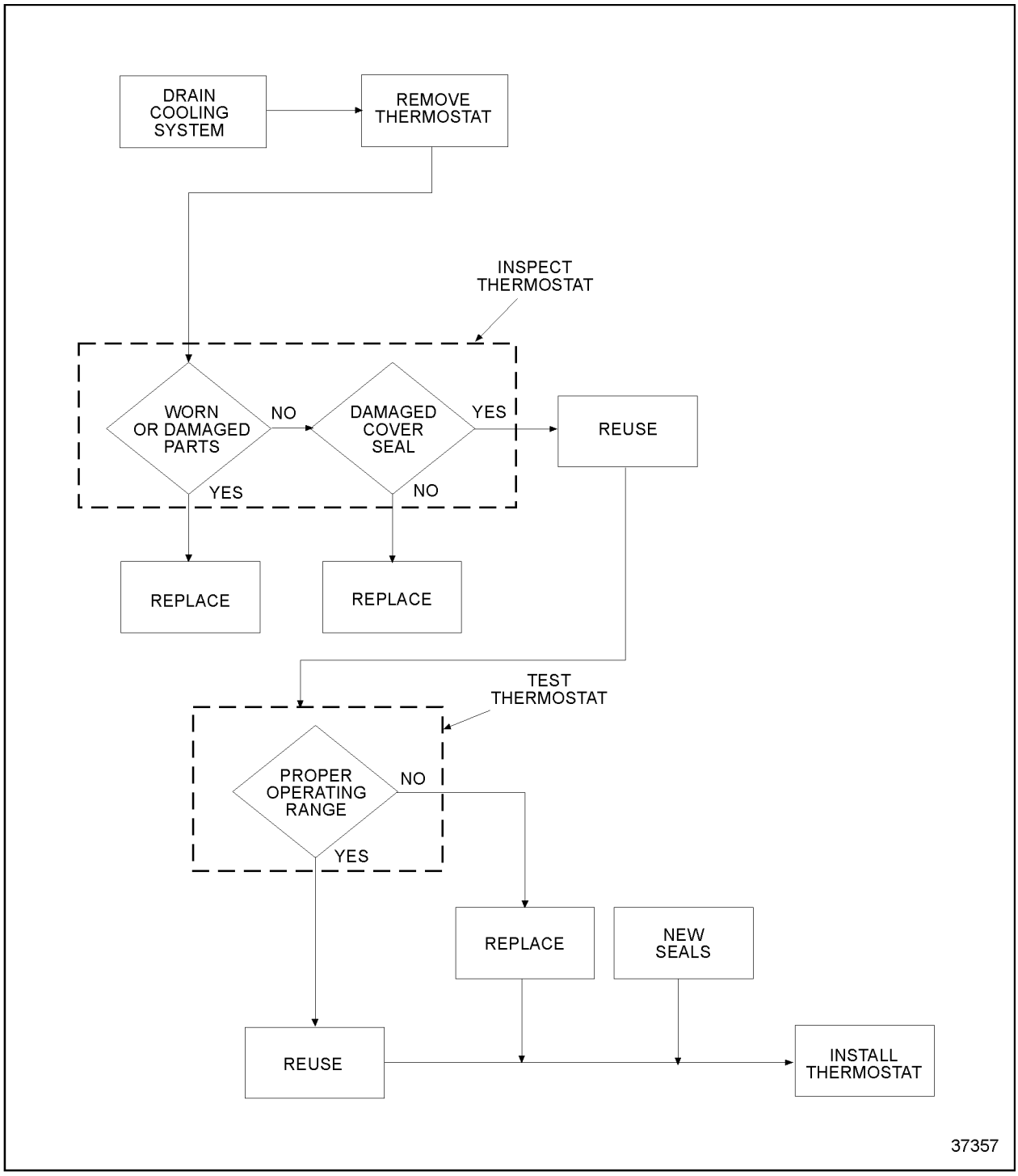


Figure 4-30 Flowchart for Repair or Replacement of Thermostat

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4.5.2 Removal of Thermostat

Remove the thermostat as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Loosen the hose clamps, and remove the bypass tube.
3. Loosen the hose between the water pump and right bank thermostat housing cover.
4. Remove the thermostat housing cover bolts and lock washers.
5. Remove the thermostat housing covers.
6. Remove the thermostats.

4.5.2.1 Test Thermostat

Perform the following procedure to check the operation of the thermostat:

1. Immerse thermostat in a container of hot water. See Figure 4-31.

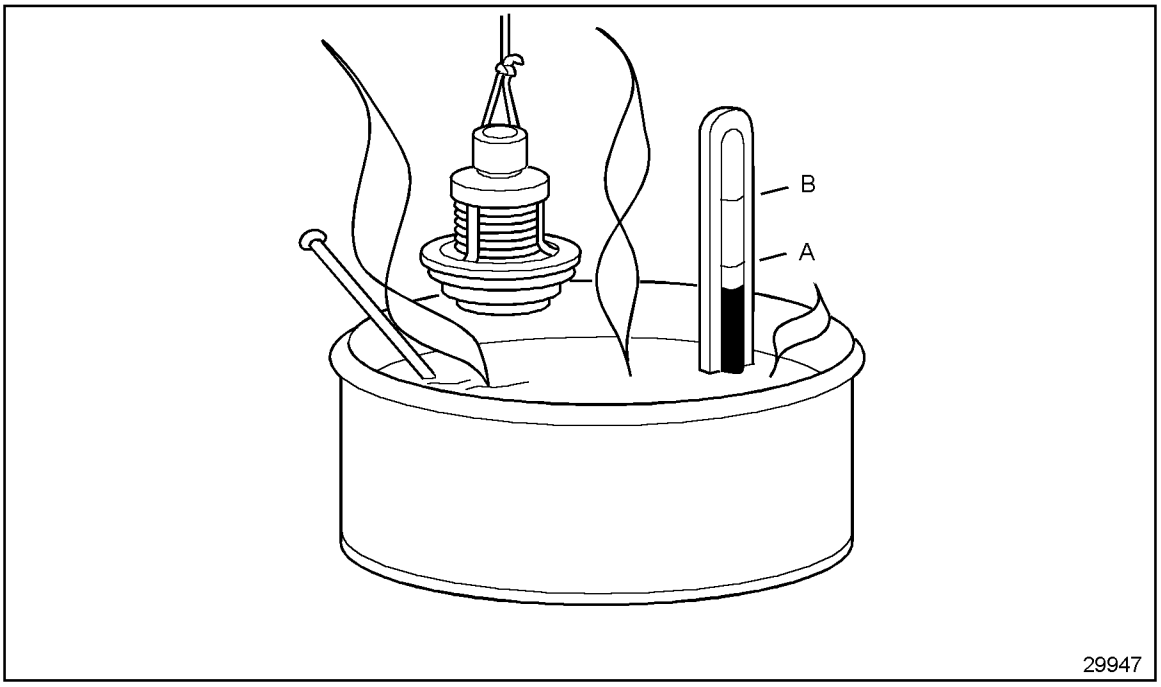


Figure 4-31 Method of Checking Thermostat Operation

2. Place a thermometer in the container.

NOTE:
Do not allow thermometer to touch the bottom of the container.

3. Agitate the water to maintain an even temperature throughout the container.

NOTE:
As the water is heated, the thermostat should begin to open.

NOTE:
The thermostat should be fully open at approximately 85°-92°C (185°-197°F)

NOTE:
Allow at least 10 minutes for thermostat to react.

4. If thermostat fails to open, replace. Refer to section 4.5.3.
5. If thermostat is functioning properly, refer to section 4.5.2.2 and perform inspection procedure.

4.5.2.2 Inspection of Thermostat

Inspect the thermostat as follows:

1. Inspect the thermostats for damage and wear.
   [a] If damaged or worn, replace the thermostat. Refer to section 4.5.3.
   [b] If not damaged or worn, continue inspection.
2. Inspect the thermostat housing cover bypass cast seal ring for wear or damage.
   [a] If worn or damaged, replace the thermostat housing cover bypass cast seal ring. Refer to section 4.5.3.
   [b] If not worn or damaged, continue inspection.
3. Inspect the thermostat for proper alignment and wear.
   [a] If worn or out of alignment, replace thermostat. Refer to section 4.5.3.
   [b] If not worn or out of alignment, proceed with inspection.
4. Inspect the thermostat cover for proper operation.
   [a] Replace the cover if the thermostat will not properly block off the bypass cavity during full-open thermostat operation. Refer to section 4.5.3.
   [b] If the thermostat blocks off the bypass cavity during full-open thermostat operation, reuse the thermostat.

4.5.3 Installation of Thermostat

Install the thermostat as follows:

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1. Install new seals in the thermostat housing cover with installer J 8550 and driver handle J 7079-2.

NOTE:
Position the seal so that the lip of the seal faces up (away from the thermostat) when the cover is installed on the thermostat housing. The seal installing tool assures that the seal is positioned the correct distance from the bottom face of the cover and parallel with the cover face.

2. Place a new gasket on the thermostat housing.
3. Set the thermostats in the thermostat housing.
4. Attach the covers to the thermostat housings with bolts and lock washers. Tighten the 3/8 in.-16 bolts to 41-47 N·m (30-35 lb·ft) torque.
5. Slide the hose in place between the water pump and the right bank thermostat housing cover. Tighten the clamps.
6. Install the bypass (cross-over) tube, and tighten the hose clamps.
7. Close the drain cocks in the cylinder block.
8. Fill the cooling system. Refer to section 13.12.2.
9. Start the engine, and check for leaks.

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4.6 RADIATOR

On some engines, the radiator and fan lower the coolant temperature circulating through the engine. The radiator is mounted so that the fan will draw or push air through it, maintaining the coolant temperature for efficient engine operation.

Refer to section 5.3 for the recommended type of coolant. Use recommended coolant for prolonged radiator life.

To increase the radiator cooling efficiency, a metal shroud is placed around the fan. The fan shroud must be airtight against the radiator to prevent hot air recirculation. Hot air, which is permitted to pass around the sides or bottom of the radiator and repeatedly drawn through the radiator, will cause engine overheating.

Another overheating cause is fan drive belt slippage. Incorrect belt tension, worn belts, worn fan belt pulley grooves, or fan belts of unequal length when two or more belts are used, cause fan drive belt slippage. The belt tension and condition should be checked periodically. Refer to section 13.18.

A leaking radiator, a radiator that has a dirty, obstructed core, a leaking cooling system, or an inoperative thermostat will cause the engine to overheat. The radiator must be cleaned, the leaks eliminated, and defective thermostats replaced immediately to prevent serious damage.

NOTICE:

Winterfronts (cardboard, canvas, etc.) are not recommended with any DDC engine installation. They cause excessive engine coolant, oil, and charge air temperatures. This can lead to turbocharger surge, poor fuel economy, power loss, and reduced engine life. Winterfronts can put abnormal stress on fan and fan drive components, creating the potential for premature malfunction and/or damage.

The external cleanliness of the radiator should be checked if the engine overheats and no other causes are apparent.

Certain vehicle engines incorporate a cross-flow radiator rather than the conventional down-flow radiator.

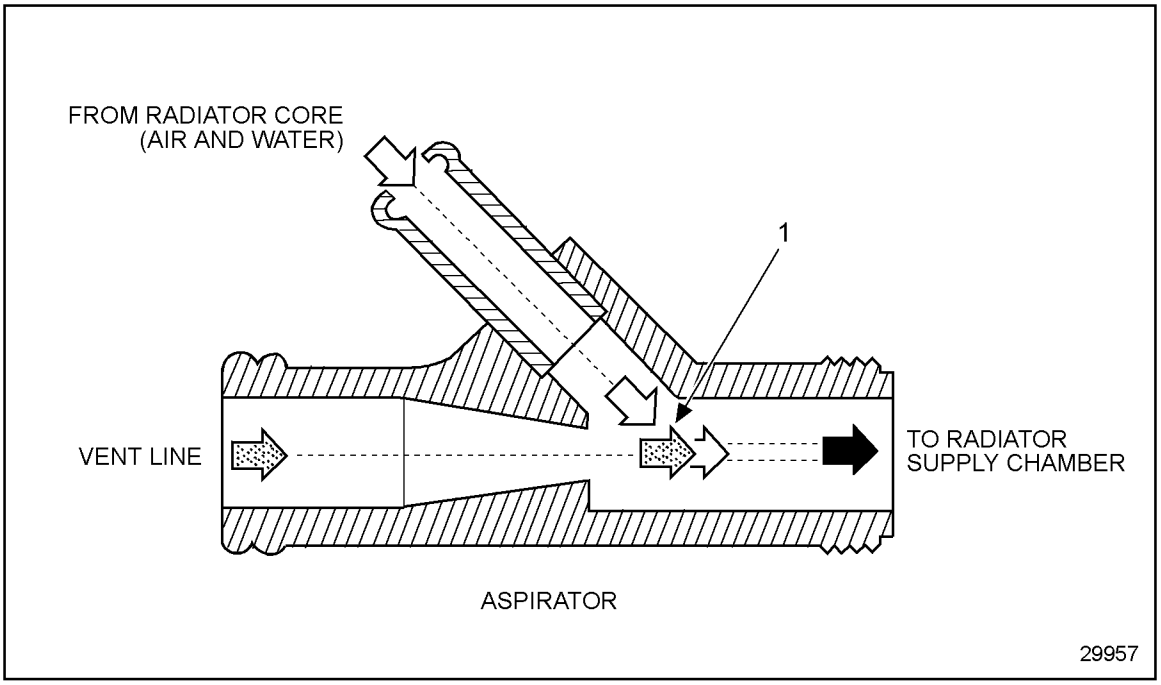
A cross-flow radiator has a core of horizontally positioned tubes, and coolant flow moves across rather than down the radiator.

Two reasons for using the cross-flow design radiator are as follows:

- The reduced radiator height permits a lower hood line design, providing better road visibility.
- The area in front of the engine crankshaft and below the radiator is open for mounting a power takeoff unit, if desired.

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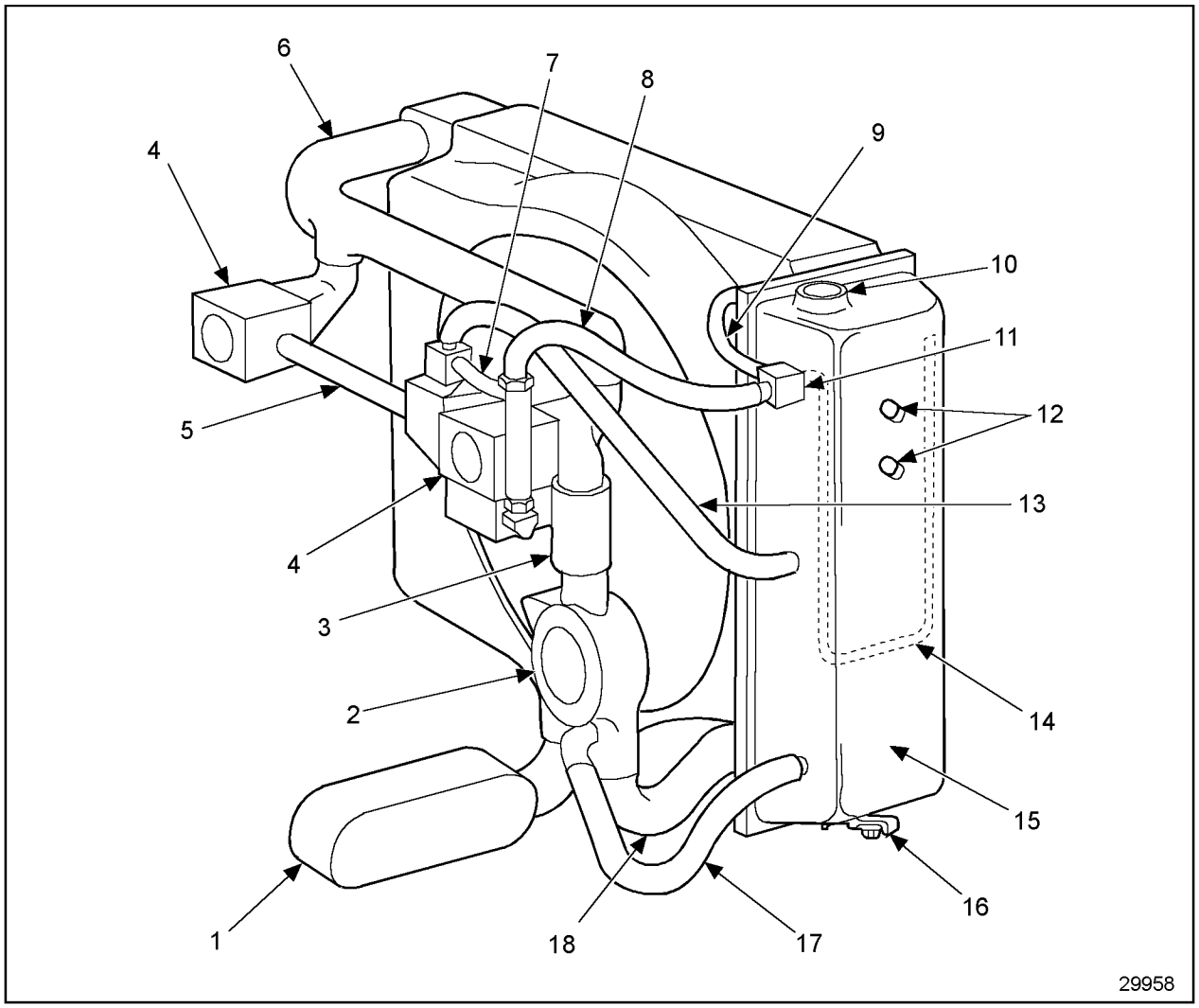
One unique cross-flow radiator component is a Y-shaped device called an aspirator which is mounted externally on the filler cap side of the radiator and serves to rid the cooling system of air. See Figure 4-32. The aspirator directs coolant under pressure through a venturi. In the venturi, entrapped air inside the radiator is picked up and moved to the radiator supply chamber, where it is vented. The coolant line providing the drive flow originates at the engine thermostat housing. This hookup provides coolant flow to the aspirator, regardless of whether the thermostat is open or closed. As the coolant flow passes through the aspirator, its action pulls coolant and any air that is present from the top of the radiator core outlet chamber into an internal "U" tube, which vents near the filler cap inside the radiator supply chamber and completes the de-aeration process. This "U" tube ensures the entire cooling circuit, other than the supply chamber, remains completely full when the engine is stopped. It keeps the coolant from seeking a common level throughout the system, eliminating an aerated system at the next engine start-up.



1. Low Pressure Chamber

Figure 4-32 Aspirator for Cross-Flow Design Radiator

The cross-flow system requires a bypass restriction to provide sufficient pressure in the system for adequate engine de-aeration and aspirator performance. See Figure 4-33.



1. Oil Cooler
2. Water Pump
3. Orifice in Water Pump Bypass
4. Thermostat Housing
5. Bypass
6. Engine Coolant Out
7. De-aeration Jump Line
8. Aspirator Supply
9. Radiator De-aeration
10. Filler
11. Aspirator
12. Sight Glass
13. Engine De-aeration
14. U-Tube
15. Supply Chamber
16. Drain Cock
17. Supply to Engine
18. Engine Coolant In

Figure 4-33 Cross-Flow Design Radiator

Properly installed hose connections are required for adequate cross-flow radiator efficiency.

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The cross-flow cooling system should always be drained at the radiator drain cock. This will ensure that both the radiator and internal "U" tube is empty. If the "U" tube is not emptied, refilling the system will be difficult.

Due to the cross-flow radiator design, air may be trapped inside the radiator during the fill process, resulting in a false coolant level reading. After filling the cooling system, the engine should be run approximately ten minutes at 1200-1400 RPM to vent any entrapped air. Additional coolant, approximately 2.8 to 3.8 liters (3 to 4 quarts), should be added to bring the coolant to the proper level.

For cross-flow radiator system efficiency, leaks must not exists between the radiator core and the supply tank. If an internal leak develops between the radiator core and the supply tank, the cooling system will become aerated at low speed and following engine shut down. The radiator should be tested periodically for possible internal leaks.

4.6.1 Repair or Replacement of Radiator

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-34.

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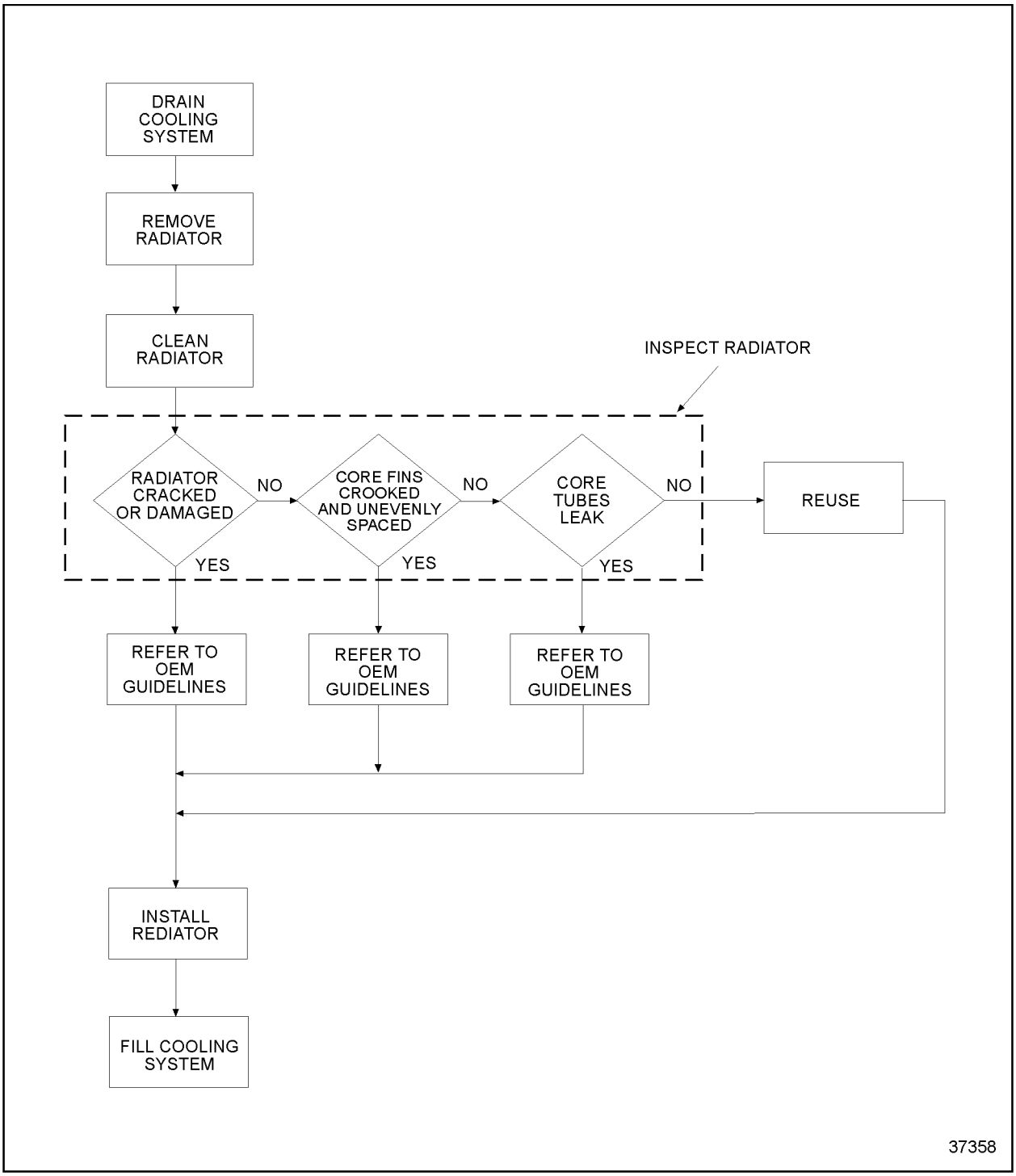


Figure 4-34 Flowchart for Repair or Replacement of Radiator

4.6.2 Removal of Radiator

Remove the radiator as follows:

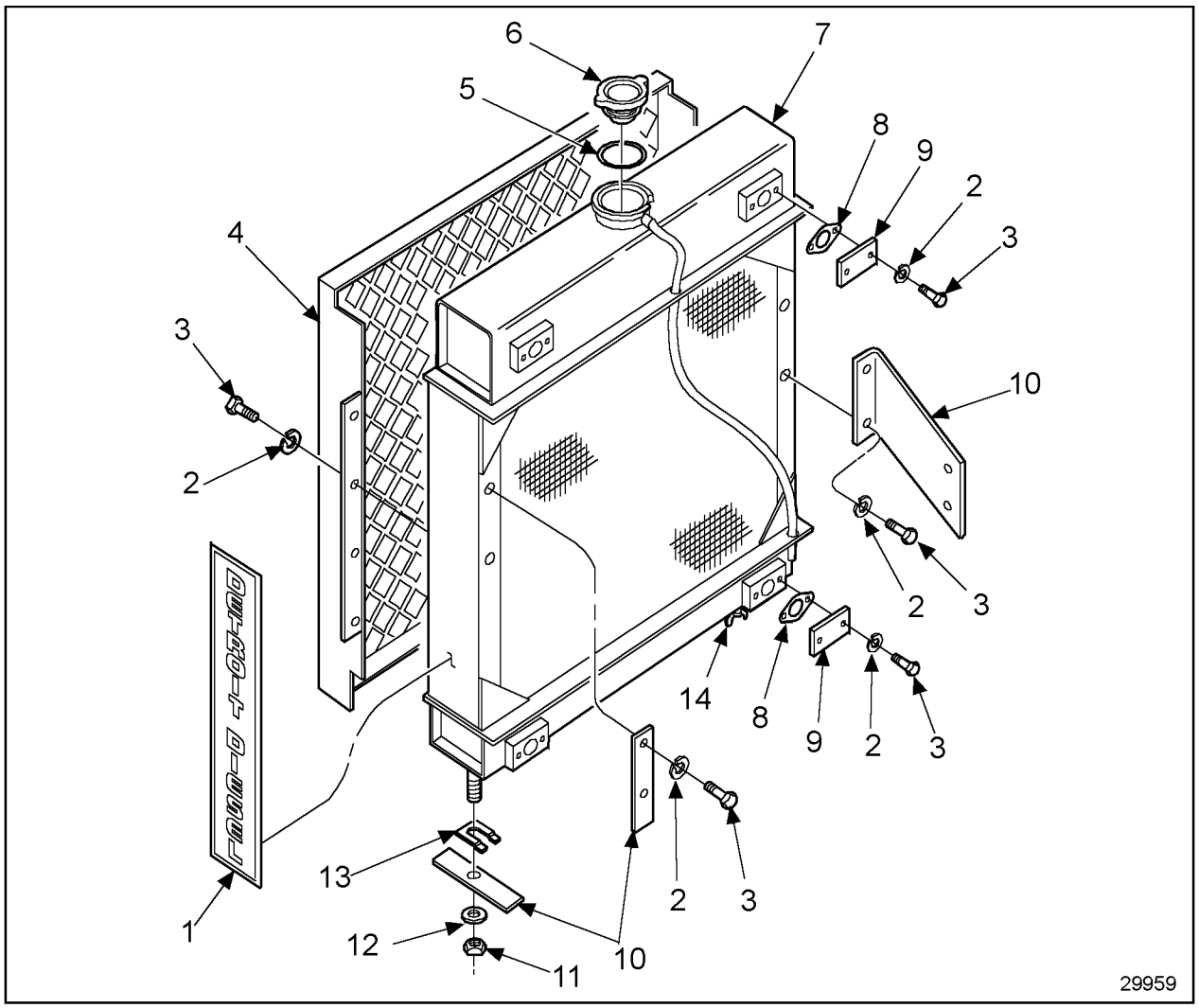
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CAUTION:

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).

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1. Remove the radiator filler cap, and open the drain cock. See Figure 4-35.



1. Data Plate
2. Lock Washer
3. Bolt
4. Shroud
5. Seal
6. Radiator Cap
7. Radiator
8. Gasket
9. Plate
10. Support Bracket
11. Nut
12. Washer
13. Support Clip
14. Drain Cock

Figure 4-35 Typical Radiator Assembly

2. Drain the cooling system. Refer to section 13.12.3.
3. Open the drain cock on the oil cooler and the engine block.
4. Remove the bolts, lock washers, and nuts that attach the fan guards to the fan shroud.

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5. Loosen the hose clamps at the radiator outlet hose, and remove the hose.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

To avoid damage to the radiator, a spreader bar should be used with a sling and adequate chain hoist when lifting the radiator. The lifting device should be adjusted so the lifting hooks are vertical to prevent bending the radiator lift brackets. To ensure proper weight distribution, all radiator lifter brackets provided must be used in lifting the radiator. Never lift a radiator by any other means. Part damage may result if radiator breaks away from the lifting device and falls.

6. Use a chain hoist and a suitable lifting device (through the filler neck or otherwise), and draw the hoisting chain taut to steady the radiator.
7. Remove the bolts, lock washers, plain washers, nuts, and bevel washers, if used, which attach the radiator shell to the engine base.

NOTICE:

Since the shroud is very close to the fan blade tips, exercise care whenever removing the radiator to prevent part damage.

8. Lift the radiator enough to clear the engine base, and move it away from the engine.
9. Remove the bolts securing the fan shroud and the radiator core.
10. Remove the fan shroud and the radiator core.

4.6.2.1 Cleaning of Radiator

Clean the radiator as follows:

NOTE:
The radiator should be cleaned whenever foreign deposits hinder air flow or heat transfer to the air. In a hot, dusty area, periodic radiator cleaning will prevent an efficiency decrease and prolong engine life.

1. Remove the fan shroud and grill to facilitate radiator core cleaning.

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. Use an air hose with a suitable nozzle to remove loose dust from the radiator 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.

CAUTION:

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

3. If oil is present, use a solvent, such as mineral spirits, to loosen the dirt.
4. Apply the solvent to the radiator core with a spray gun.

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:

To avoid damage to the radiator fins, do not use high air or water pressure.

5. Use air to remove the remaining dirt.
6. Repeat as many times as necessary.

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⚠ 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.

7. Rinse the radiator with clean water, and dry it with air.
8. Another radiator cleaning method is steam cleaning. If the foreign deposits are hardened, apply solvents.

NOTE:
Scale deposits inside the radiator result from using hard, high-mineral water in the cooling system. Heat on the minerals in the water causes scale formation, or a hard coating, on metal surfaces within the radiator, reducing heat transfer. Some hard water produces a silt-like deposit which restricts the water flow. Flush this out at least twice a year - more often if necessary.

Flush the radiator as follows:

NOTICE:

For extremely hard, stubborn coatings, such as lime scale, it may be necessary to use a stronger solution. A stronger solution will corrode the thin radiator metals, reducing its operating life. Completely flush and rinse.

1. Use a flushing compound such as sal-ammoniac, at the ratio of 1/4 pound per each gallon radiator capacity.
2. Add this solution to the coolant water while the engine is running.
3. Operate the engine for at least fifteen minutes.
4. Drain and flush the system with clean water.
5. Run a neutralizer through the system.

NOTE:
Other flushing compounds are commercially available and should be procured from a reliable source. Most compounds attack metals and should not remain in the engine for more than a few minutes. A neutralizer should be used in the cooling system immediately after a de-scaling solvent is used.

6. Completely drain the entire system, and fill it with coolant. Refer to section 13.12.

NOTE:
When draining or filling, the cooling system must be vented.

7. Examine the radiator and engine for coolant leaks.

8. Install the fan shroud and grill, if removed.

4.6.2.2 Inspection of Radiator

Inspect the radiator as follows:

1. Examine the radiator for cracks or other damage.
   [a] If cracked or damaged, replace the radiator. Refer to section 4.6.3.
   [b] If not cracked or damaged, continue inspection.
2. Inspect the core fins for straightness and even spacing.
   [a] If bent or unevenly spaced, replace the radiator. Refer to section 4.6.3.
   [b] If not bent or unevenly spaced, proceed with inspection.
3. Inspect the core tubes for cleanliness inside and outside.
   [a] If necessary, clean the core tubes.
   [b] If clean, continue inspection.
4. Inspect the core tubes for leaks.
   [a] If core tubes are leaking, the radiator must be replaced.
   [b] If core tubes are not leaking, continue inspection.

NOTE:
If repainting the radiator core becomes necessary, DDC recommends using a thin coat of dull black radiator paint or another high-quality flat black paint. Ordinary oil paints have an undesirable glossy finish and do not transmit heat as well.

5. Inspect all radiator hoses and clamps for cracks, deterioration, and damage.
   [a] If cracked, deteriorated, or damaged, replace the hoses and clamps. Refer to section 4.6.3.
   [b] If not cracked, deteriorated, or damaged, reuse the parts.

4.6.2.3 Test Radiator for Leaks (Cross-Flow Design)

Test the cross-flow radiator for leaks as follows:

1. Remove the radiator cap, and run the engine for approximately ten minutes at high idle to completely de-aerate the cooling system.
2. With the engine running, add additional coolant to the supply chamber to bring the level to the bottom of the filler neck.
3. Stop the engine, and drain 3.8 liters (4 quarts) of coolant from the radiator.
4. Stop the engine, and observe the coolant level.

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NOTICE:
If a leak is detected, it should be repaired immediately. Extended operation with aerated coolant can cause engine failure.

[a] If the coolant rises substantially in the supply tank, an internal leak is indicated.

[b] If the coolant level remains constant or falls, the system is satisfactory.

5. After completing the test, refill the cooling system to the proper level.

4.6.3 Installation of Radiator

Install the radiator as follows:

1. Attach the fan shroud and the radiator core. Secure with bolts.

⚠ CAUTION:
To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:
Ensure radiator is secure before releasing the lifting sling. Part damage may result if the radiator breaks away from the engine and falls.

2. Use a chain hoist and suitable lifting device to lift the radiator over the engine.
3. Lower the radiator onto the engine.
4. Attach the radiator to the shell with bolts, lock washers, plain washers, nuts, and bevel washers, if used.
5. Attach the radiator outlet hose. Secure with clamps.
6. Attach the radiator inlet hose. Secure with clamps.
7. Attach the fan guard to the fan shroud with bolts, lock washers, and nuts.
8. Check for clearance between the fan blade tips and radiator shroud after the radiator is in place.

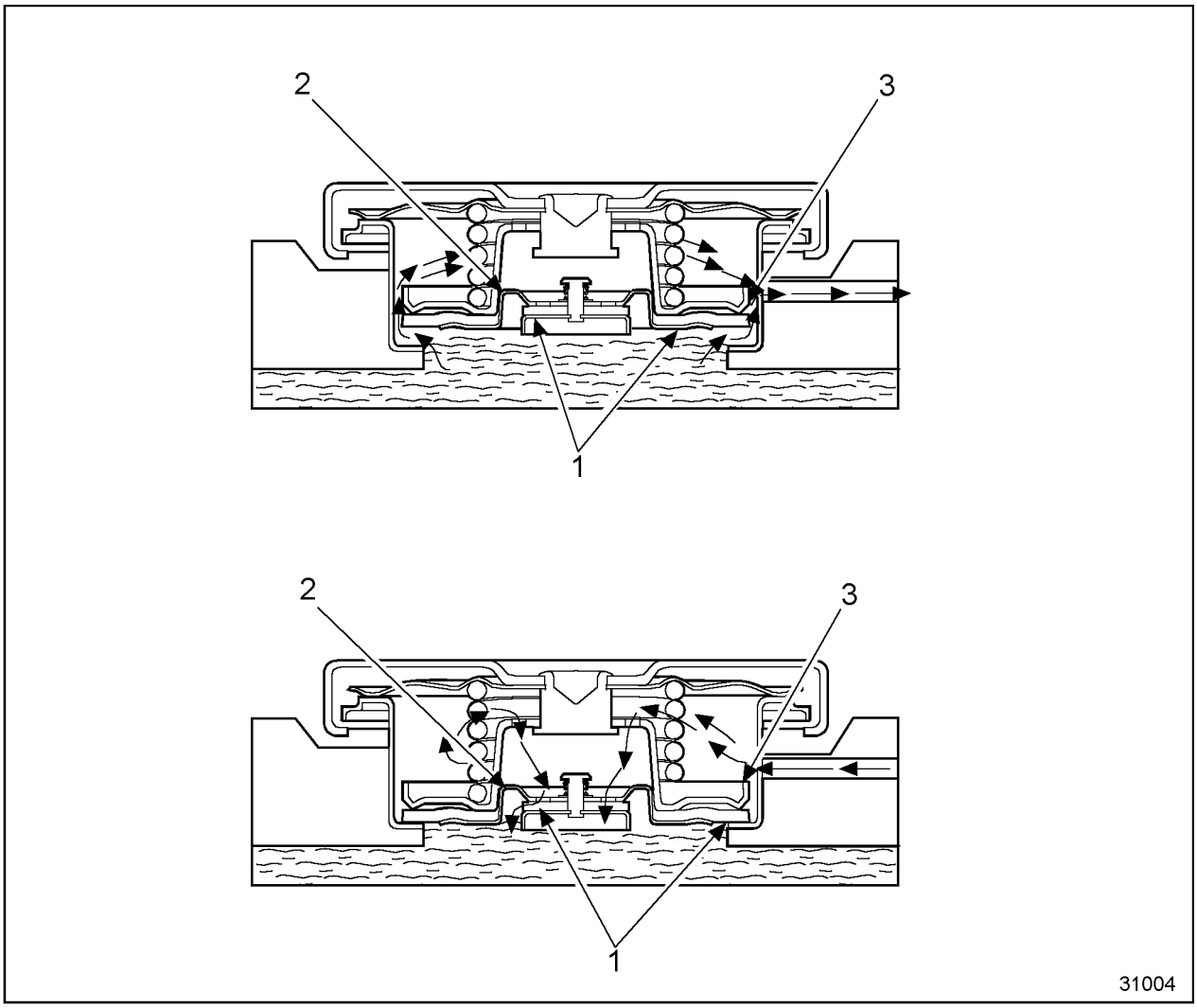
NOTICE:
There must be sufficient clearance between the fan blade tips and radiator, or damage to the fan and shroud will result when the engine is started. Use shims between the radiator and base, if necessary, to obtain the proper clearance.

9. Close the drain cocks, and fill the cooling system. Refer to section 13.12.2.

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4.7 COOLANT PRESSURE CONTROL CAP

The radiator or expansion tank has a pressure control cap with a normally closed valve. The cap, with a number 7 stamped on its top, is designed to permit approximately 48 kPa (7 lbs) pressure in the system before the valve opens, whereas the number 9 cap needs 62 kPa (9 lbs) before the valve opens. This pressure raises the cooling liquid boiling point and permits higher engine operating temperatures without coolant loss from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools. See Figure 4-36.



1. Vacuum Valve
2. Pressure Valve
3. Seat

Figure 4-36 Coolant Pressure Cap Coolant Flow Process

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4.7.1 Repair or Replacement of Coolant Pressure Control Cap

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-37.

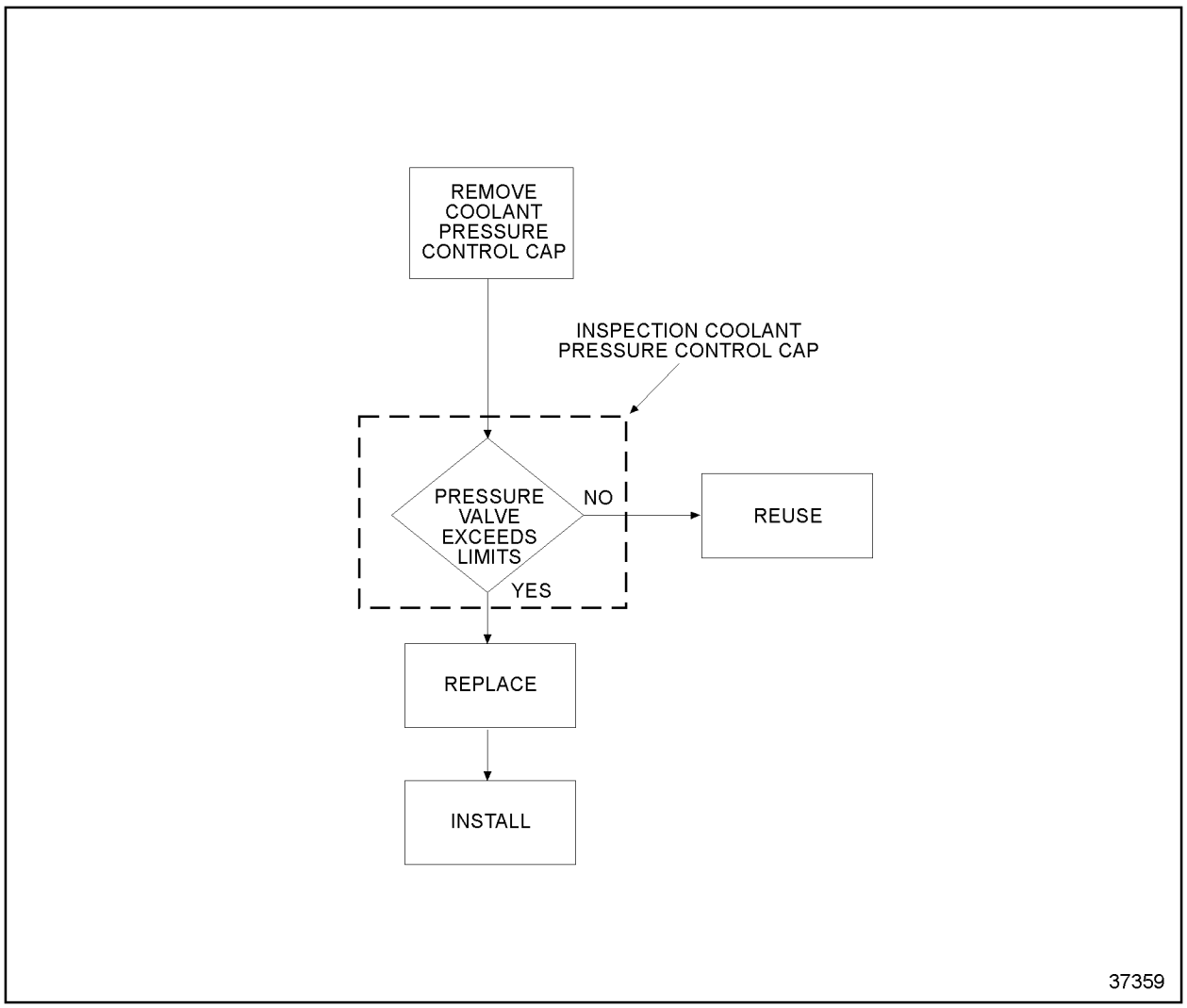


Figure 4-37 Flowchart for Repair or Replacement of Coolant Pressure Control Cap

4.7.2 Removal of Coolant Pressure Control Cap

Remove the coolant pressure control cap as follows:

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⚠ 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 of the pressure control cap.
2. Push down on pressure control cap while turning counterclockwise.

4.7.2.1 Inspection of Coolant Pressure Control Cap

Inspect the coolant pressure control cap as follows:

1. Inspect both valves periodically for proper opening and closing pressures to ensure against possible damage to the cooling system from either excessive pressure or vacuum.
   [a] If the pressure valve does not open between 43.1 kPa (6.25 lb/in.^{2}) and 51.7 kPa (7.5 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. Refer to section 4.7.2.1.
   [b] If the pressure valve opens as specified, reuse the pressure control cap.

4.7.3 Installation of Coolant Pressure Control Cap

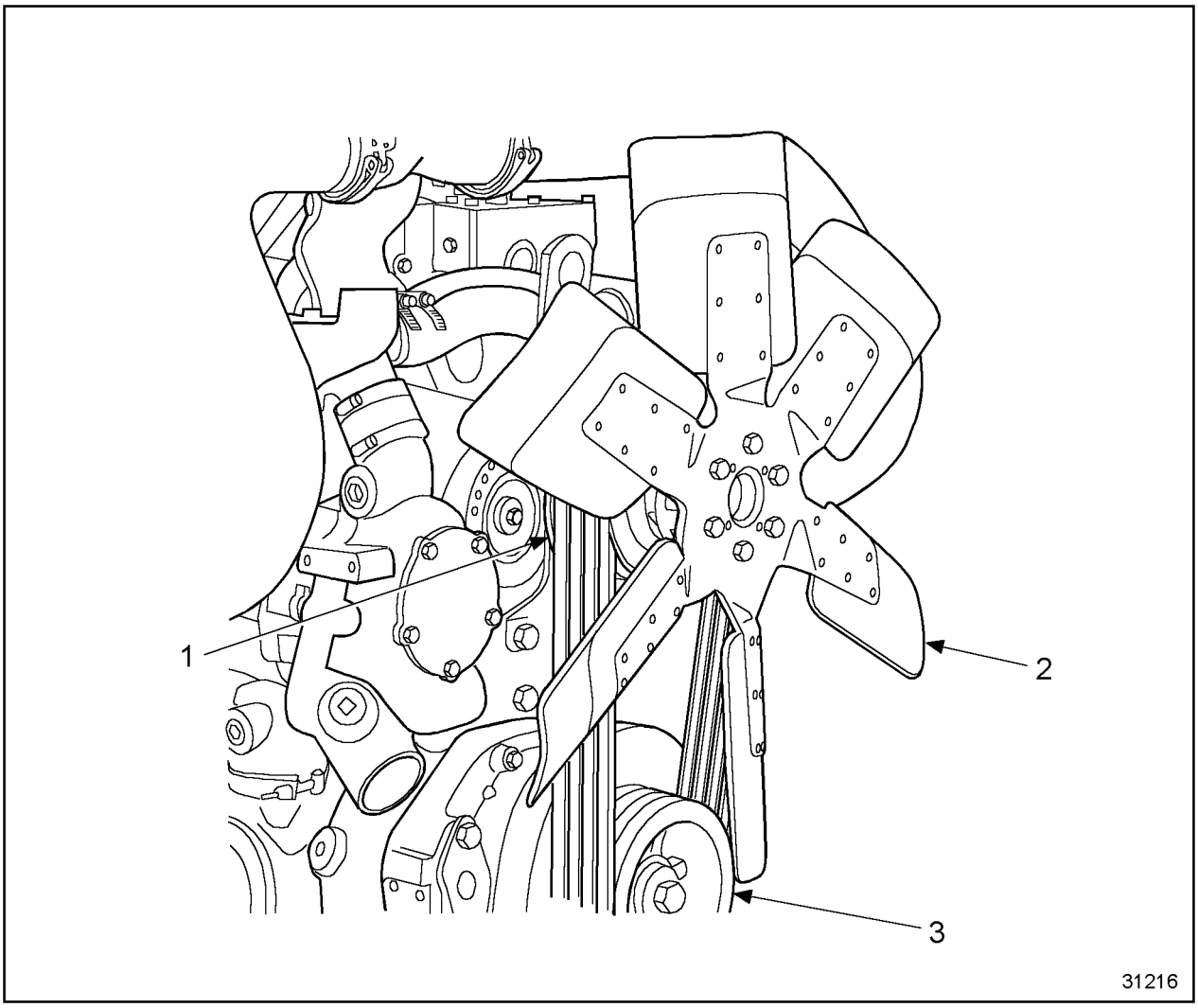
Install the coolant pressure control cap as follows:

1. Press down on pressure control cap while turning clockwise.

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4.8 ENGINE COOLING FAN

The engine cooling fan is belt driven from the crankshaft pulley. See Figure 4-38.

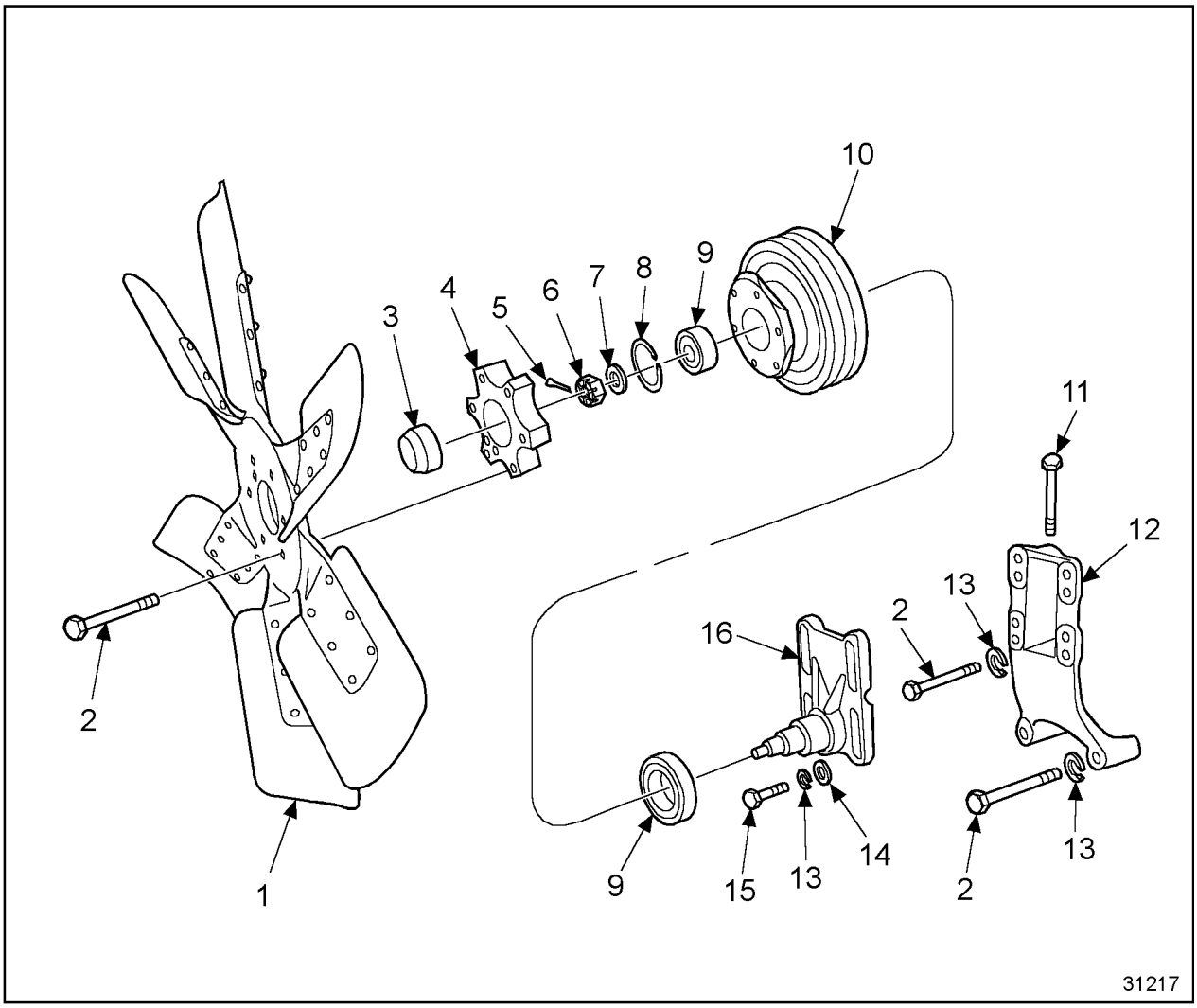


1. Pulley Hub
2. Fan
3. Crankshaft Pulley

Figure 4-38 Typical Fan Mounting

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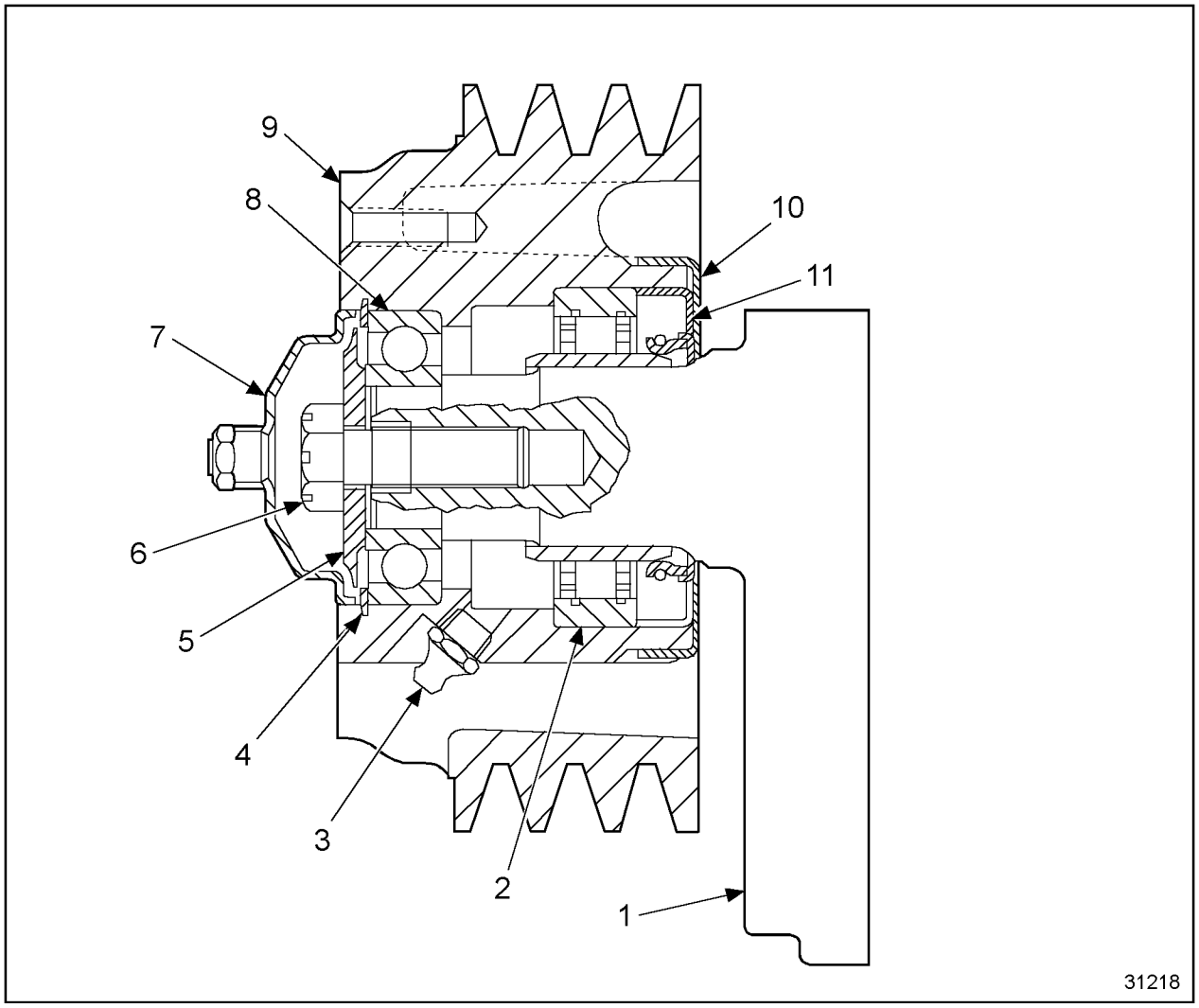
The three-groove pulley hub, used on 6V, 8V and certain 16V engines, turns on a double-row ball bearing at the front and a single-row (shielded) ball bearing at the rear of the hub. See Figure 4-39.



1. Fan
2. Long Bolt (3)
3. Hub Cap
4. Spacer
5. Cotter Pin
6. Retaining Nut
7. Washer
8. Retaining Ring
9. Bearing
10. Pulley Hub
11. Adjusting Bolt
12. Support Bracket
13. Lock Washer (3)
14. Plain Washer
15. Short Bolt
16. Adjusting Bracket Assembly

Figure 4-39 Typical Fan, Three-Groove Pulley and Adjusting Bracket (Former)

A new three-groove pulley hub for all engines, including the 12V engines, turns on a front ball bearing and a rear roller bearing. It includes a hub cap (with relief valve), a dust cup, and a grease fitting. See Figure 4-40.

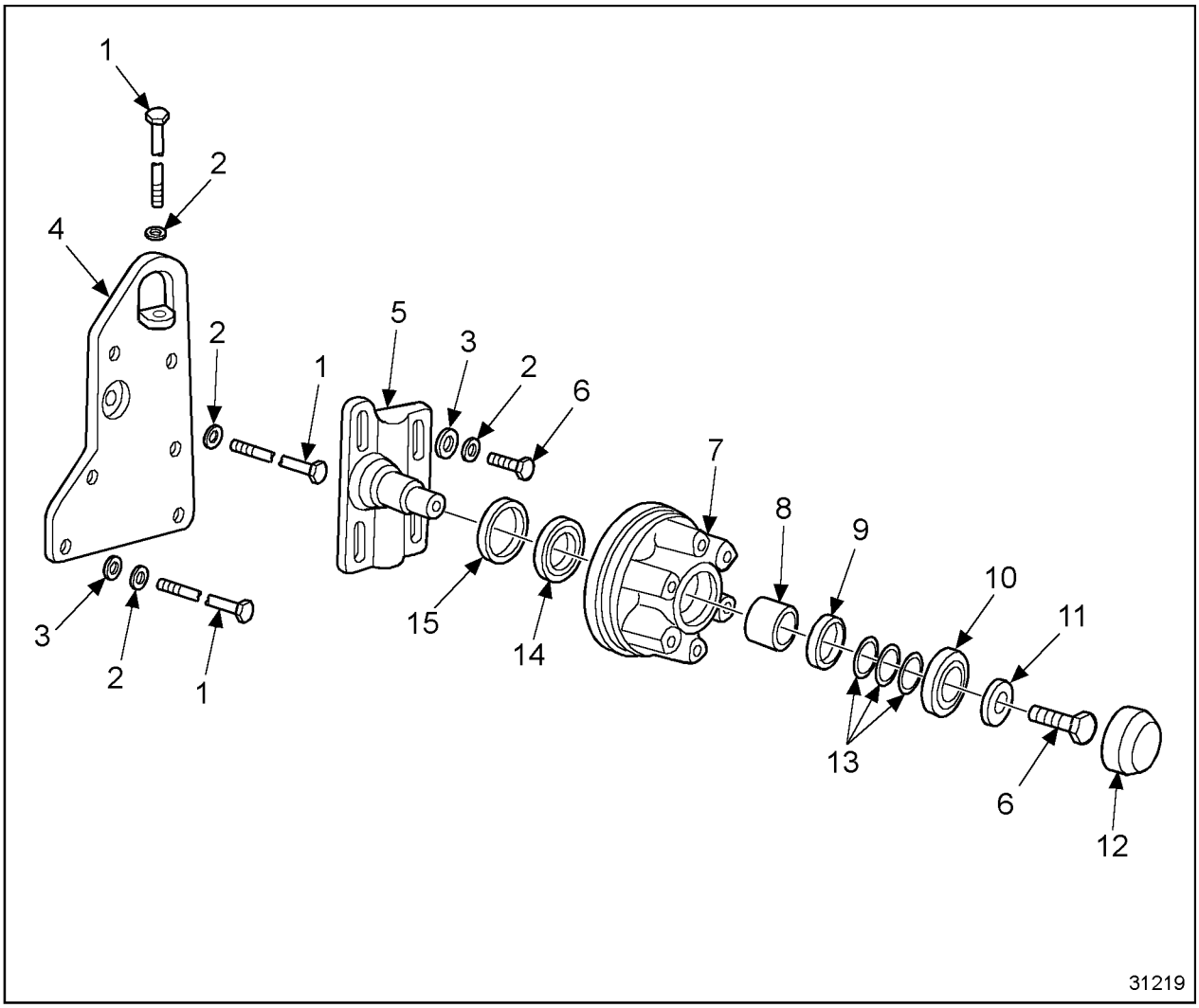


1. Shaft and Bracket
2. Rear Roller Bearing
3. Grease Fitting
4. Snap Ring
5. Washer
6. Lock Bolt
7. Hub Cap
8. Front Ball Bearing
9. Hub Pulley
10. Dust Cap
11. Oil Seal

Figure 4-40 Three-Groove Pulley Hub (Current)

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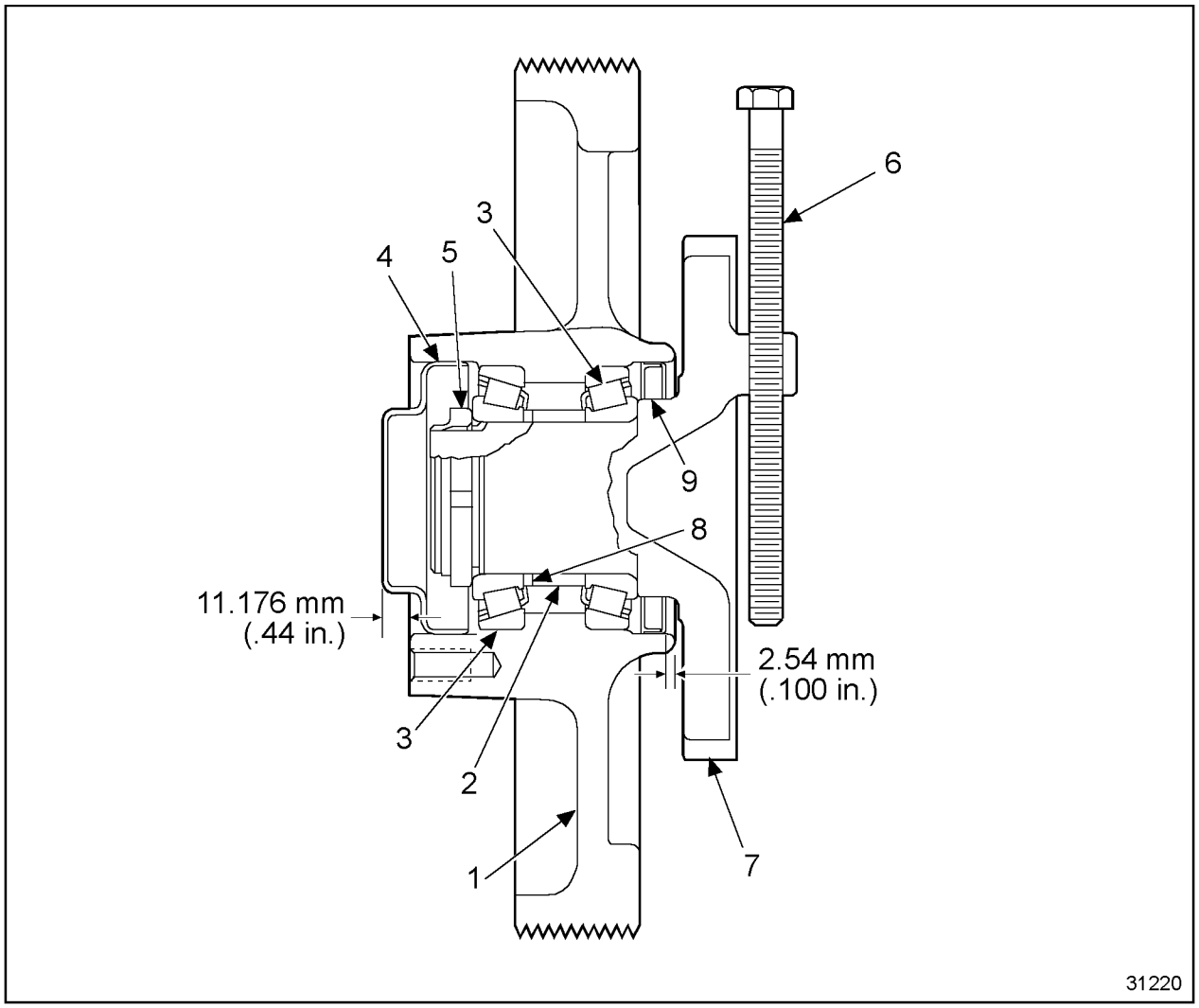
On 6V and 8V compact front end engines, the pulley hub turns on tapered roller bearings. See Figure 4-41.



1. Long Bolt (3)
2. Lock Washer (4)
3. Washer
4. Support Bracket
5. Adjusting Bracket Assembly
6. Short Bolt (2)
7. Pulley Hub
8. Bearing Spacer
9. Grease Retainer
10. Outer Bearing
11. Retainer
12. Hub Cap
13. Shims
14. Inner Bearing
15. Oil Seal

Figure 4-41 Fan Pulley, Hub and Adjusting Bracket Details for Compact Front Engines

The poly-vee groove pulley hub used on some 16V engines turns on two single-row tapered roller bearings. See Figure 4-42.



1. Pulley Hub
2. Spacer
3. Bearing (2)
4. Hub Cap
5. Locknut
6. Adjusting Bolt
7. Adjusting Bracket Assembly
8. Shims
9. Seal

Figure 4-42 Typical 16V Engine Poly-Vee Groove Pulley Hub and Adjusting Bracket

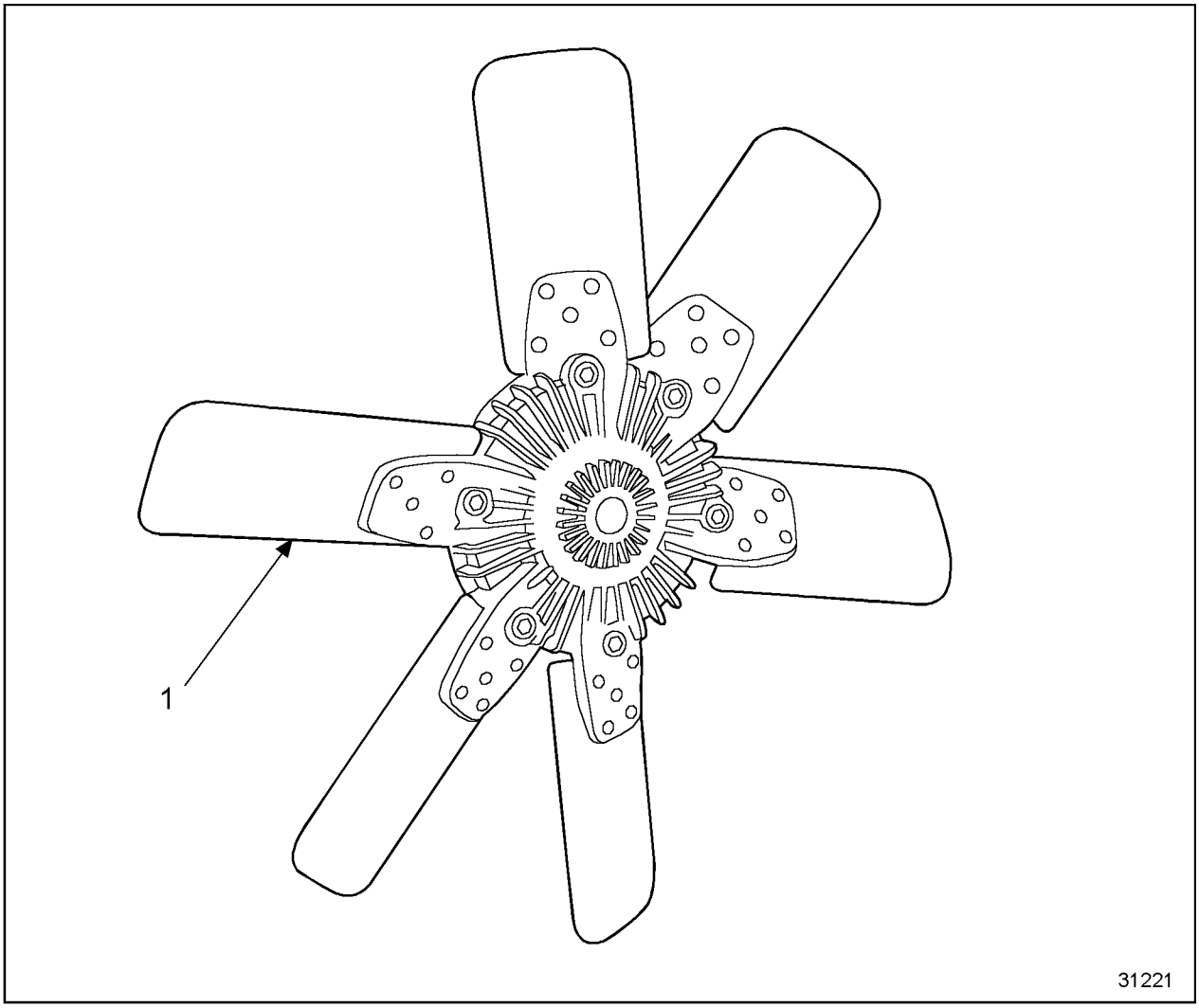
Spacers help set the proper clearance between the fan blades and the front groove of the crankshaft pulley.

The bearings and the cavity between the bearings are packed with grease at assembly. Refer to section 13.33 for the maintenance schedule.

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Adjust the fan belts periodically. Refer to section 13.18.

A thermo-modulated suction fan assembly has been provided on some engines. See Figure 4-43.



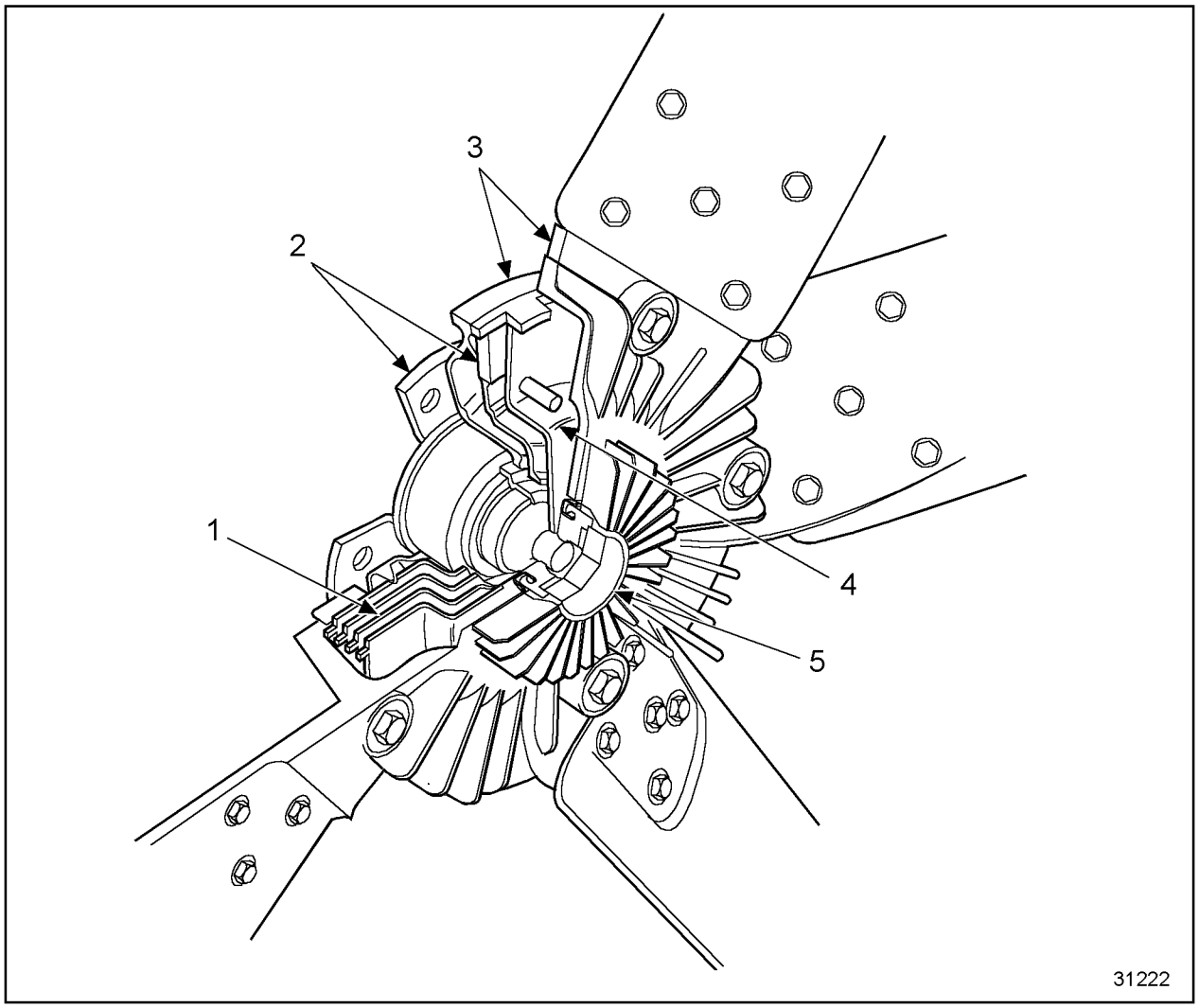
1. Thermo-Modulated Fan Assembly

Figure 4-43 Typical Thermo-Modulated Fan Assembly

This fan assembly regulates the fan speed and maintains an efficient engine coolant temperature regardless of the engine load variations or outside air temperature.

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The entire fan drive assembly is a compact integral unit which requires no external piping or controls. See Figure 4-44.



1. Drive and Driven Plates
2. Input Shaft and Drive Flange Assembly
3. Fan Drive Housing Assembly
4. Drive Cup
5. Temperature Control Assembly

Figure 4-44 Cutaway View of Thermo-Modulated Fan Drive Assembly

The shearing of a silicon fluid film between the input and output plates in a sealed multiplate fluid-filled clutch housing, transmits torque from the input shaft to the fan.

The thermostatic control element, which is an integral part of the fan drive, reacts to changes in engine temperature and varies the fluid film thickness between the plates. This changes the fan speed. The vehicle manufacturer selects the proper element setting to maintain optimum cooling. No further adjustment should be necessary.

The thermo-modulated fan is mounted and driven in the same manner as the conventional fan.

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The manufacturer prelubricates the fan drive assembly. The drive fluid level and the roller bearing should be checked periodically. Refer to section 13.33.

4.8.1 Repair or Replacement of Engine Cooling Fan

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-45.

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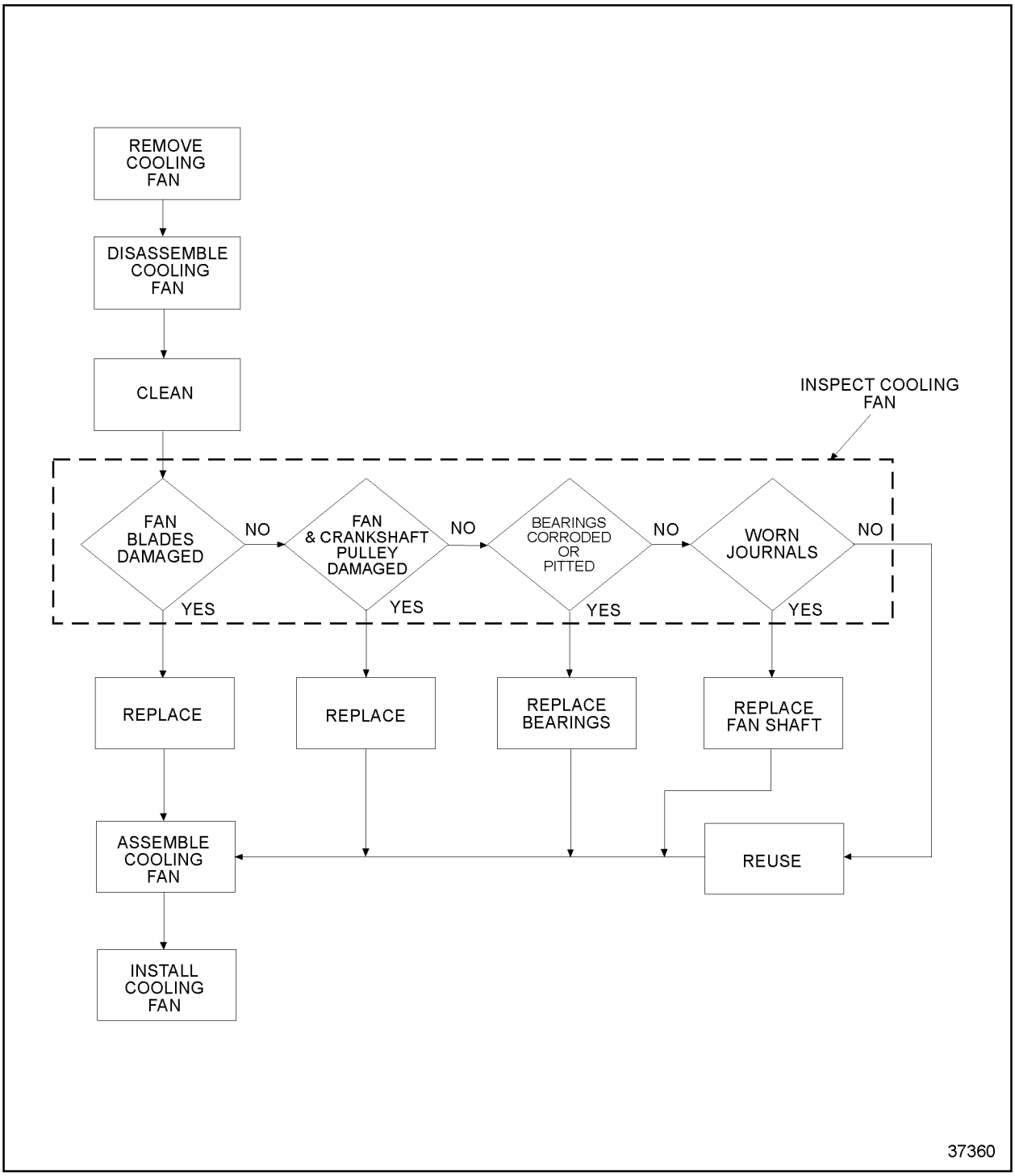


Figure 4-45 Flowchart for Repair or Replacement of Engine Cooling Fan

4.8.2 Removal of Engine Cooling Fan

Remove the engine cooling fan as follows:

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NOTICE:
The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the cooling system efficiency, throw the fan out of balance, and may damage the radiator core. Before removing the fan, check the blade alignment. Do not pull on the fan blades.

1. Remove the attaching bolts, lock washers, and nuts.

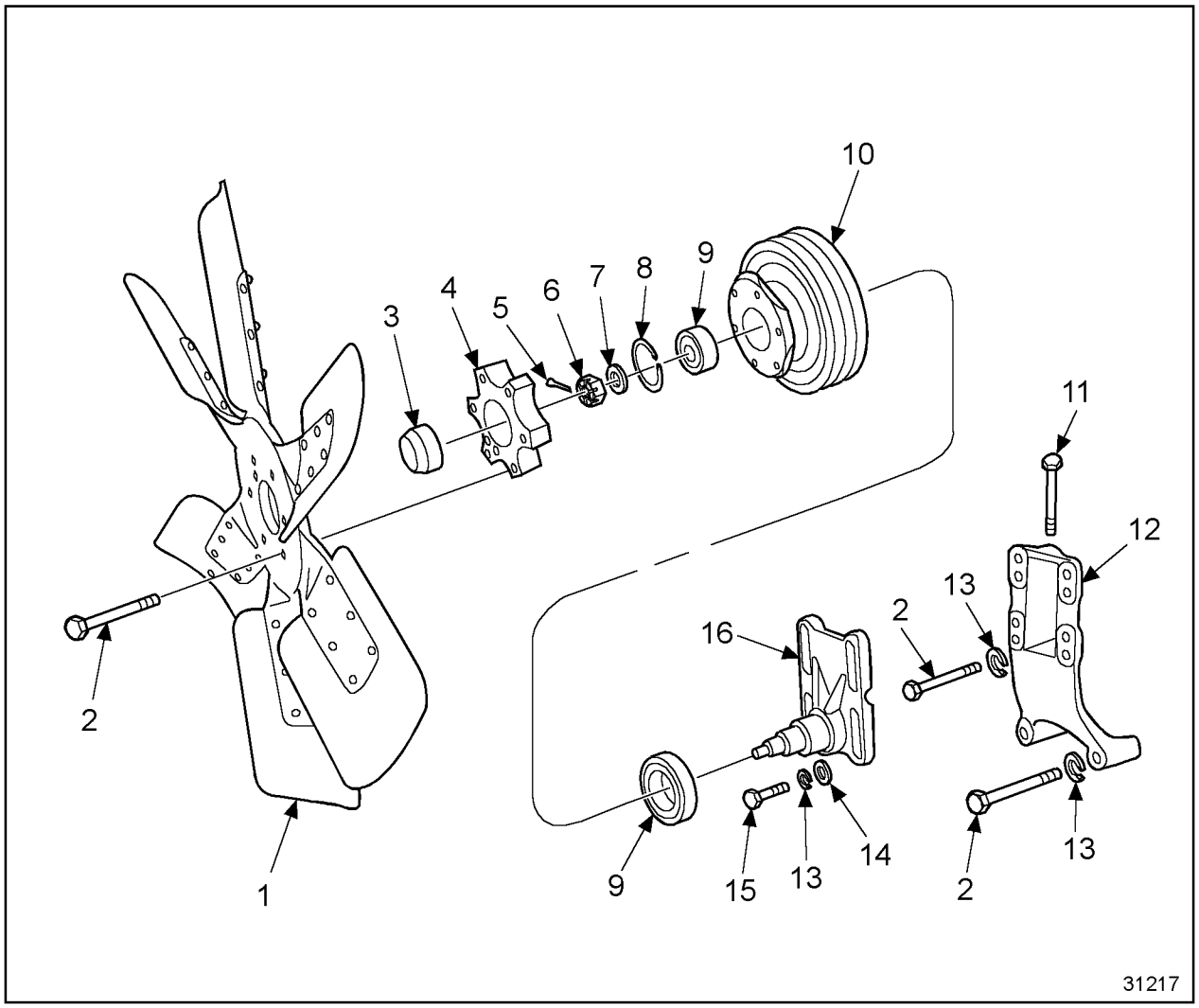
NOTE:
If insufficient clearance exists between the fan and the radiator, remove the fan, hub, and adjusting bracket as an assembly.

2. Remove the fan and spacer, if used.
3. Loosen the fan hub adjusting bracket bolts, and remove the drive belts.
4. Withdraw the bolts and washers, and remove the hub and bracket assembly from the engine.

4.8.3 Disassembly of Cooling Fan, Three-Groove Pulley Hub, and Bracket (Former Design)

Disassemble the cooling fan as follows:

1. Remove the fan-to-hub mounting bolts, nuts, and lock washers. Detach the fan and spacer. See Figure 4-46.



1. Fan
2. Long Bolt (3)
3. Hub Cap
4. Spacer
5. Cotter Pin
6. Retaining Nut
7. Washer
8. Retaining Ring
9. Bearing
10. Pulley Hub
11. Adjusting Bolt
12. Support Bracket
13. Lock Washer (3)
14. Plain Washer
15. Short Bolt
16. Adjusting Bracket Assembly

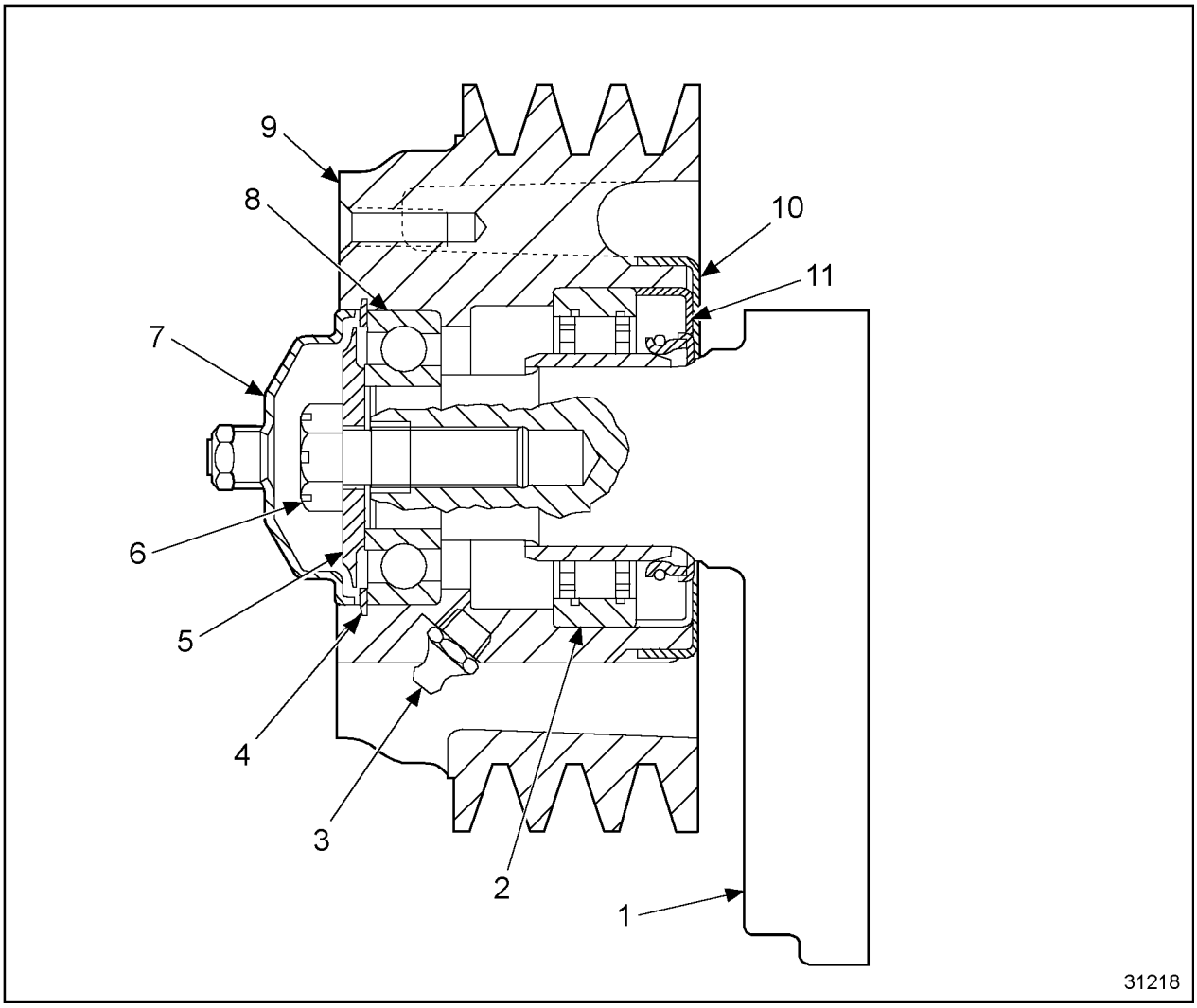
Figure 4-46 Typical Fan, Three-Groove Pulley and Adjusting Bracket(Former Design)

2. Remove and discard the hub cap.

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3. Remove the cotter pin and nut.
4. If removing the bearings, remove the retaining ring.
5. Support the hub, front face up, on wood blocks high enough to allow bracket removal.
6. Tap the fan shaft with a plastic hammer to free the fan shaft and bracket assembly from the bearings in the hub.

See Figure 4-47, and remove the ball bearings from the pulley hub (current design) as follows:



1. Shaft and Bracket
2. Rear Roller Bearing
3. Grease Fitting
4. Snap Ring
5. Washer
6. Lock Bolt
7. Hub Cap
8. Front Ball Bearing
9. Hub Pulley
10. Dust Cap
11. Oil Seal

Figure 4-47 Three-Groove Pulley Hub (Current Design)

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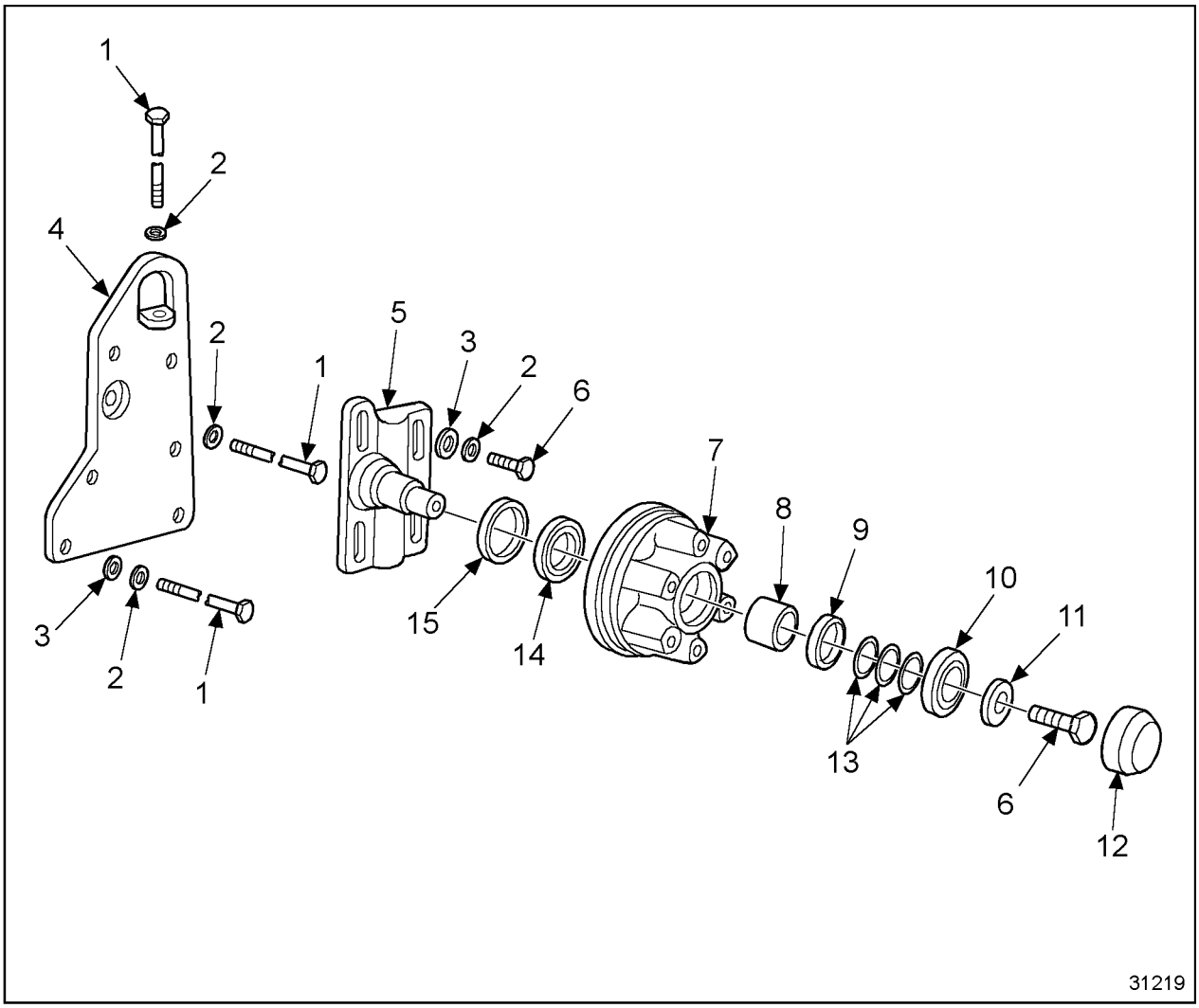
1. Support the pulley hub, rear face up, on two wood blocks spaced far enough apart to permit bearing removal from the hub.
2. Tap alternately around the rear face of the bearing outer race with a small brass rod and hammer to remove the front bearing from the hub.
3. Reverse the pulley hub on the wood blocks, and remove the rear bearing from the hub.

4.8.4 Disassembly of Cooling Fan, Hub, and Bracket (Compact Front End Engines)

Disassemble the cooling fan as follows:

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1. Remove the fan-to-hub mounting bolts, nuts, and lock washers. Detach the fan and spacer. See Figure 4-48.



1. Long Bolt (3)
2. Lock Washer (4)
3. Washer
4. Support Bracket
5. Adjusting Bracket Assembly
6. Short Bolt (2)
7. Pulley Hub
8. Bearing Spacer
9. Grease Retainer
10. Outer Bearing
11. Retainer
12. Hub Cap
13. Shims
14. Inner Bearing
15. Oil Seal

Figure 4-48 Fan Pulley, Hub and Adjusting Bracket Details for Compact Front Engines

2. Remove and discard the hub cap.

3. Remove the pulley retaining bolt and retainer.
4. Support the pulley hub, front face up, on wood blocks high enough to allow adjusting bracket assembly removal.
5. Tap the shaft with a plastic hammer to free the adjusting bracket assembly from the bearings in the pulley hub.

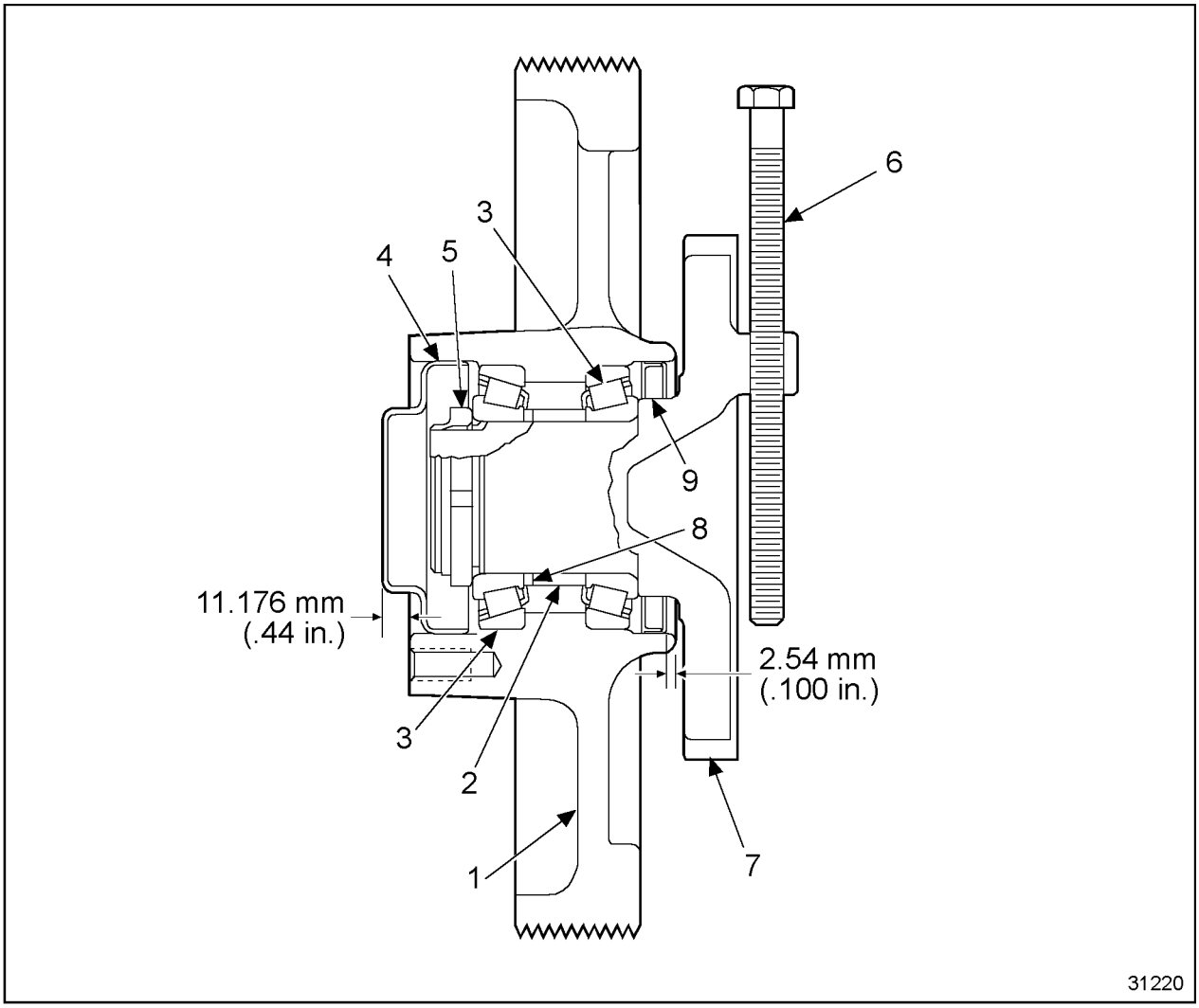
Remove the bearings and oil seal as follows:

1. Remove the inner race from the front (outer) bearing.
2. Remove the shims and bearing spacer.
3. Tap alternately around the rear face of the bearing outer race with a small brass rod and hammer to remove the front bearing outer race from the bearing.
4. Reverse the pulley hub, and drive the oil seal from the hub. Discard the oil seal.
5. Tap alternately around the rear face of the bearing outer race with a small brass rod and hammer to remove the rear (inner) bearing.
6. Remove the grease retainer from the pulley hub.

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4.8.5 Disassembly of Cooling Fan, Poly-Vee Groove Pulley Hub, and Bracket (16V Engine)

See Figure 4-49, and disassemble the fan on a 16V engine as follows:



1. Pulley Hub
2. Spacer
3. Bearing (2)
4. Hub Cap
5. Locknut
6. Adjusting Bolt
7. Adjusting Bracket Assembly
8. Shims
9. Seal

Figure 4-49 Typical 16V Engine Poly-Vee Groove Pulley Hub and Adjusting Bracket

1. Remove the fan to pulley hub mounting bolts, nuts, and lock washers. Detach the fan and spacer.

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2. Remove and discard the hub cap.
3. Pry the locknut part staked into the shaft, and remove the nut.
4. Support the pulley hub, front face up, on wood blocks high enough to allow adjusting bracket removal.
5. Tap the shaft with a plastic hammer to free the bracket assembly from the pulley hub bearings.
6. Support the pulley hub, front face up, on two wood blocks spaced far enough apart to remove the seal and bearing from the hub.
7. Remove and discard the felt oil seal in the rear of the hub.
8. Tap alternately around the rear face of the bearing outer race with a small brass rod and hammer to remove the inner roller bearing from the hub.
9. Remove the spacer and shims.
10. Reverse the pulley hub on the wood blocks and remove the front roller bearing from the hub.

4.8.5.1 Cleaning of Cooling Fan

Clean the cooling fan as follows:

NOTE:
Shielded bearings must not be washed. Dirt may wash in and the cleaning fluid could not be entirely removed from the bearing.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean the fan and related parts with clean fuel oil.

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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.

4.8.5.2 Inspection of Cooling Fan

Inspect the cooling fan as follows:

1. Visually inspect the bearings for corrosion or pitting.
   [a] If corroded or pitted, replace the bearings. Refer to section 4.8.6.
   [b] If not corroded or pitted, continue inspection.
2. Hold the inner race or cone so it does not turn, and revolve the outer race or cup slowly by hand.
   [a] If rough spots are found, replace the bearings. Refer to section 4.8.6.
   [b] If no rough spots are found, continue inspection.
3. Inspect the fan blades for cracks and bending.
   [a] If the blades are bent or cracked, replace the fan. Refer to section 4.8.10.
   [b] If not bent or cracked, continue inspection.
4. Remove any rust or rough spots in the fan pulley and crankshaft pulley grooves. Check for damage and wear.
   [a] If the grooves are damaged or severely worn, replace the pulleys. Refer to section 4.8.6.
   [b] If not damaged or severely worn, continue inspection.
5. Visually inspect and measure the fan hub shaft front and rear journal (industrial engines).

NOTE:
The front journal diameter of a new shaft is 19.97964–19.99234 mm (0.7866–0.7871 in.) and the rear journal is 44.9707–44.99102 mm (1.7705–1.7713 in.).

   [a] If the journals are worn excessively, replace the fan shaft. Refer to section 4.8.6.
   [b] If not worn, continue inspection.
6. Inspect for cracks in the adjusting and support bracket castings.

[a] If cracked, replace the adjusting and support bracket casting. Refer to section 4.8.6.

NOTE:
When replacement of either the fan shaft or adjusting bracket is necessary, a new fan shaft and bracket assembly must be used.

[b] If not cracked, continue inspection.

7. Inspect the current fan shaft rear bearing inner race for any measurable wear.

[a] Replace the inner race if the outer diameter is less than 43.93438-66.88582 mm (1.7297 in. or 2.6333 in.) (Heavy Duty). Refer to section 4.8.6.

NOTE:
The inner and outer races are only serviced as a rear roller bearing assembly.

NOTE:
When installing the rear bearing inner race, press it on the shaft, and position it 48.768–49.276 mm (1.92–1.94 in.) or 58.674–59.182 mm (2.31–2.33 in.) (Heavy Duty) from the end of the shaft.

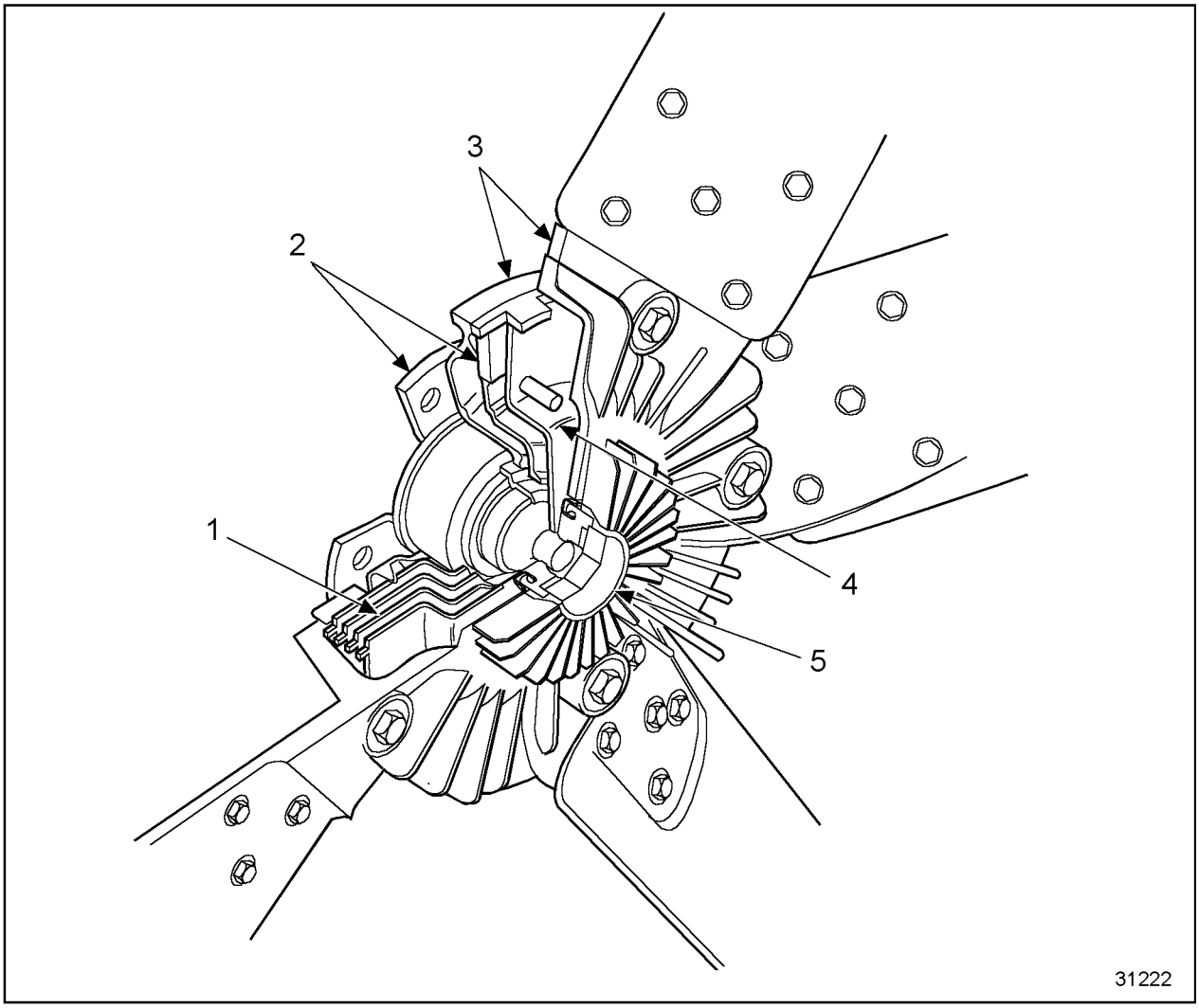
[b] If not worn, reuse the parts.

4.8.6 Assembly of Cooling Fan, Three-Groove Hub, and Bracket(Former Design)

Assemble the cooling fan with the former three-groove hub and bracket as follows:

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1. Install the rear bearing in the pulley hub. See Figure 4-50.



1. Drive and Driven Plates
2. Input Shaft and Drive Flange Assembly
3. Fan Drive Housing Assembly
4. Drive Cup
5. Temperature Control Assembly

Figure 4-50 Cutaway View of Thermo-Modulated Fan Drive Assembly

NOTE:
When rebuilding a three-groove pulley fan hub assembly for any reason, add the new hardened washer under the retaining nut.

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2. To prevent the inner bearing race from spinning on the shaft, apply a small quantity of Loctite No. RC 601, or equivalent, to the circumference of the shaft rear bearing surface.

NOTE:
The bearing and shaft surfaces must be clean and dry.

NOTE:
Ensure no Loctite gets into the bearing.

3. Pack the pulley hub cavity 75% (minimum) full of grease.

NOTE:
Use Mobilgrease® HP or an equivalent Lithium base multi-purpose grease.

4. Place the adjusting bracket on wood blocks on an arbor press bed.
5. Press the pulley hub onto the fan shaft.
6. Install the front ball bearing in the pulley hub.
7. Install the retaining ring and nut. Tighten the nut to 81-122 N·m (60-90 lb·ft) torque, and secure it with a cotter pin.

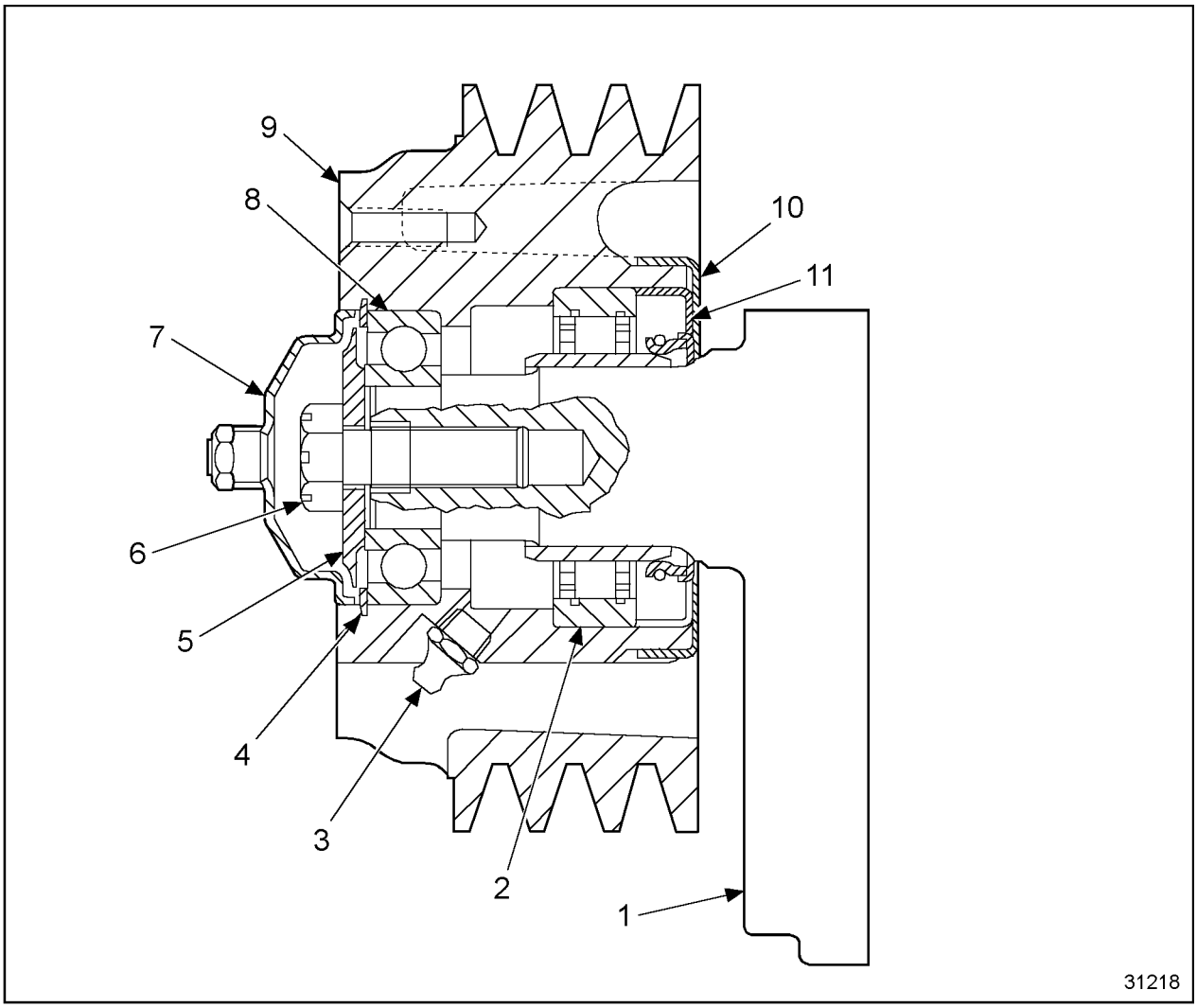
NOTE:
If the holes in the nut and shaft do not line up for the cotter pin, do not back off on the nut. Advance to the next position. Low nut torque will permit the front bearing to turn on the shaft.

8. Pack the front cavity 75% (minimum) full of grease, and install a new hub cap.

4.8.7 Assembly of Cooling Fan, Three-Groove Hub, and Bracket(Current Design)

See Figure 4-51, and assemble the cooling fan with the current three groove hub and bracket as follows:

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1. Shaft and Bracket
2. Rear Roller Bearing
3. Grease Fitting
4. Snap Ring
5. Washer
6. Lock Bolt
7. Hub Cap
8. Front Ball Bearing
9. Hub Pulley
10. Dust Cap
11. Oil Seal

Figure 4-51 Three Groove Pulley Hub (Current)

NOTE:
Do not over grease.

1. Apply Mobil HP grease or an equivalent Lithium base multipurpose grease to the front ball bearing and the rear bearing rollers before installing them in the pulley hub.
2. Install the front ball bearing against the shoulder counterbore in the pulley hub.
3. Install the snap ring in the pulley hub.

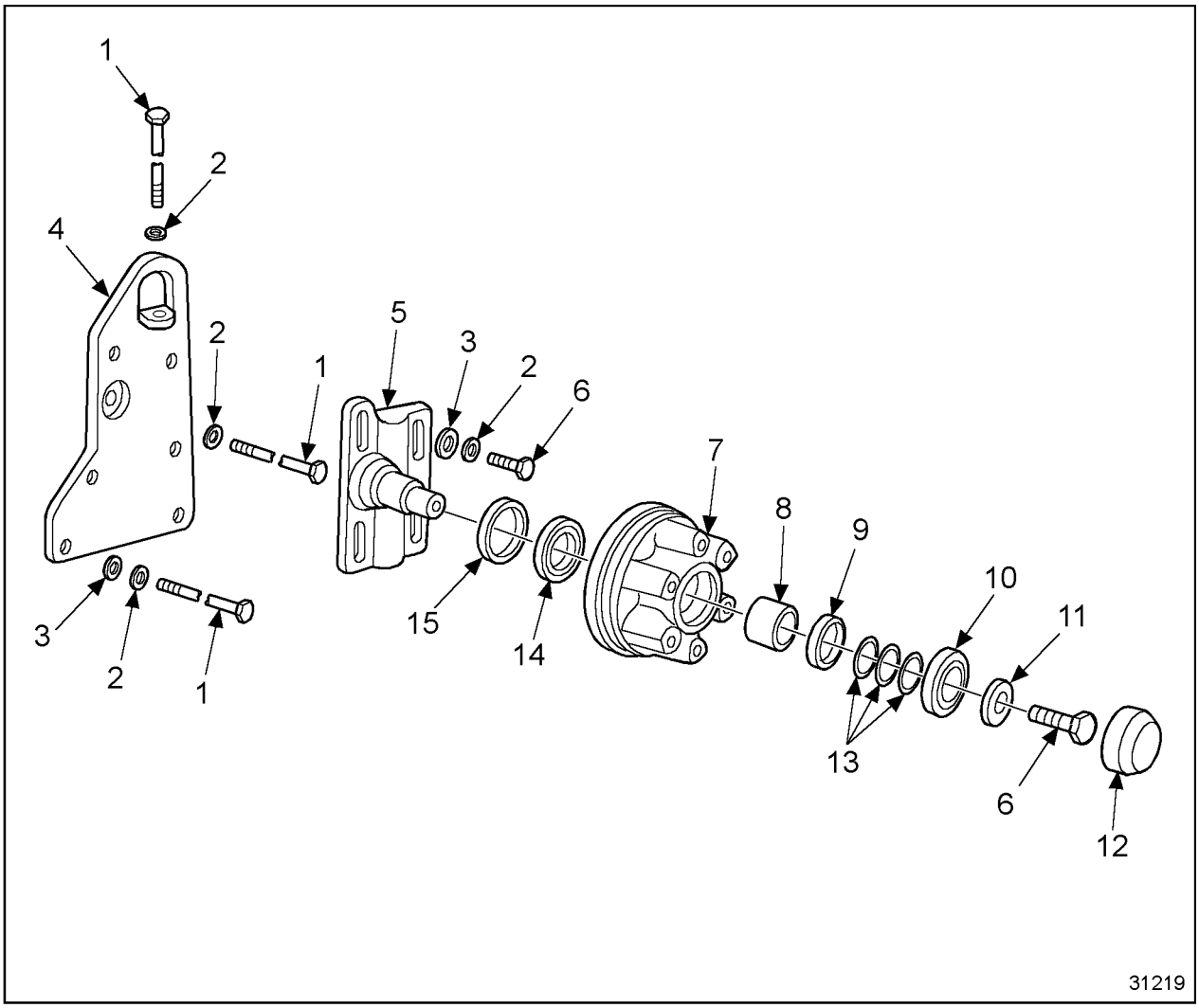
4. Install the rear roller bearing outer ring and roller assembly against the shoulder in the pulley hub counterbore.
5. Install a new oil seal with rubber side flush with the hub outer edge.
6. Install the dust cap, if used, over the oil seal in the hub.
7. Place the shaft and bracket on wood blocks set on an arbor press bed.
8. Press the rear bearing inner ring or race onto the fan shaft.
9. Pack the hub cavity 75% (minimum) full with Mobil HP grease.
10. Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pulley hub shaft.
11. Secure the hub with the washer and 1/2 in.-20 lock bolt. Tighten the bolt to 113-126 N·m (83-93 lb·ft) torque while rotating the pulley hub.
12. Fill a new fan hub cap 75% (minimum) full of grease, and install it in the end of the pulley hub.

4.8.8 Assembly of Cooling Fan, Hub, and Bracket (Compact Front End Engine)

Assemble the hub and bracket on a compact front end as follows:

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1. Apply Mobil HP or an equivalent Lithium base multi-purpose grease to both bearing rollers before installing them in the pulley hub. See Figure 4-52.



1. Long Bolt (3)
2. Lock Washer (4)
3. Washer
4. Support Bracket
5. Adjusting Bracket Assembly
6. Short Bolt (2)
7. Pulley Hub
8. Bearing Spacer
9. Grease Retainer
10. Outer Bearing
11. Retainer
12. Hub Cap
13. Shims
14. Inner Bearing
15. Oil Seal

Figure 4-52 Fan Pulley, Hub and Adjusting Bracket Details for Compact Front Engines

2. Tap alternately around the face of the bearing outer race with a small brass rod and hammer to install the rear inner bearing assembly, with the protruding face of the inner race facing outward from the hub.
3. Install a new oil seal with the rubber side flush with the hub outer edge.
4. Place the adjusting bracket assembly on wood blocks setting on an arbor press bed.
5. Press the pulley hub on the fan shaft, and install the bearing spacer.
6. Pack the cavity between the bearings 20-30% full of grease, and install the grease retainer.

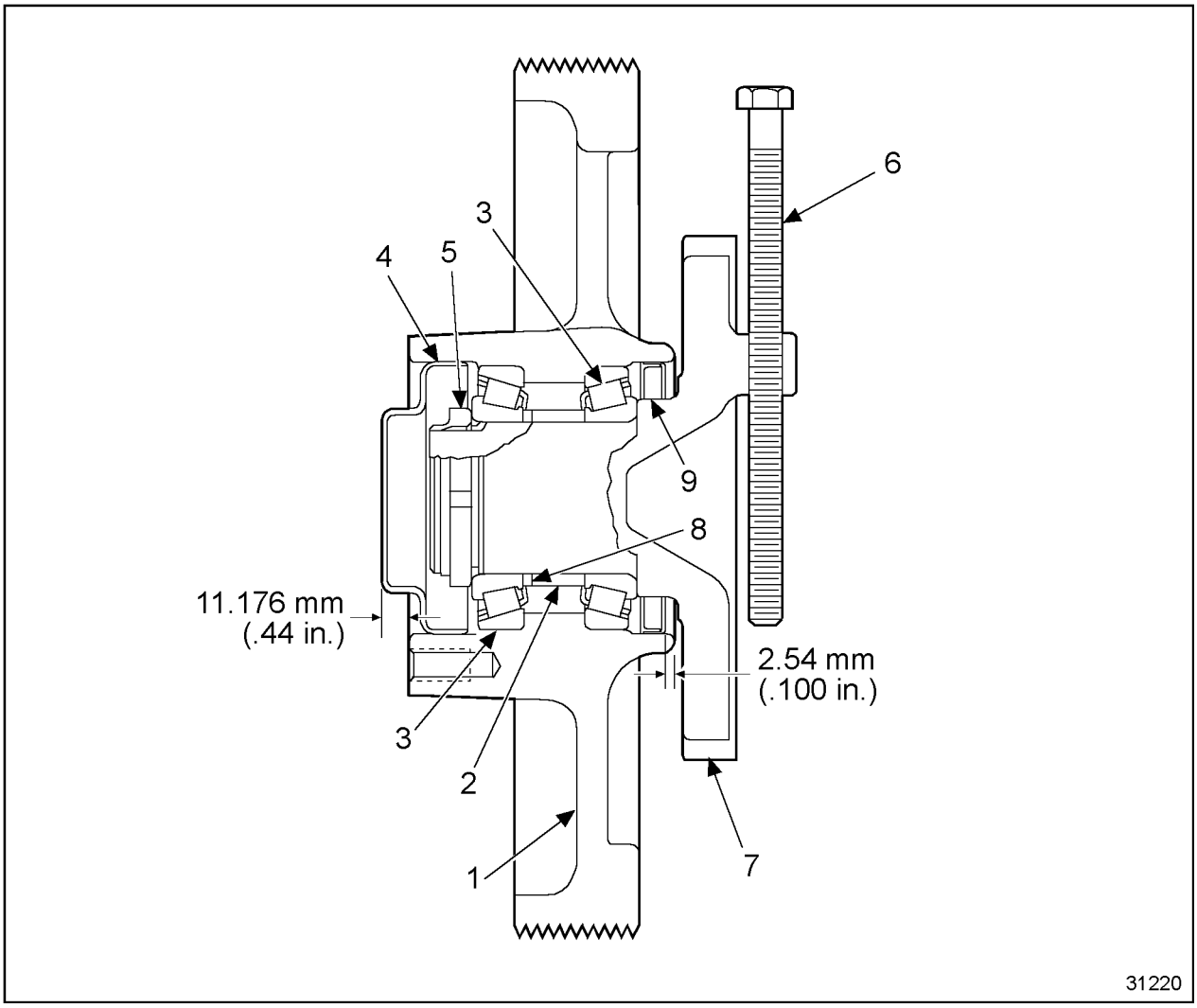
NOTE:
The grease retainer is not required when a grease fitting is installed in the pulley hub. Refer to section ADDITIONAL INFORMATION.

7. Place the shims against the bearing spacer. Install the front outer bearing assembly with the inner and outer race, protruding face of the inner race facing outward from the hub.
8. Tap alternately around the face of the bearing outer race with a small brass rod and hammer to install the front outer bearing assembly.
9. Secure the hub with the retainer and bolt. Tighten the 1/2 in.-20 bolt to 113-126 N·m (83-93 lb·ft) torque while rotating the pulley.
10. Rotate the assembly, and check the end play with the spindle horizontal. The end play must be within 0.0254–0.1524 mm (0.001–0.006 in.).
11. If necessary, remove the bolt, washer, and front outer bearing, and adjust the shim number and thickness to obtain the required end play. Shims are available in 0.381 mm, 0.508 mm, and 0.635 mm (0.015 in., 0.020 in. and 0.025 in.) thickness.
12. Assemble the fan hub, and check the end play.
13. Fill a new fan hub cap 75% (minimum) full of grease, and install it in the end of the fan hub (pulley).

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4.8.9 Assembly of Cooling Fan, Poly-Vee Groove Pulley Hub, and Bracket (16V Engine)

See Figure 4-53, and assemble the poly-vee groove pulley hub and bracket on 16V engines as follows:



1. Pulley Hub
2. Spacer
3. Bearing (2)
4. Hub Cap
5. Locknut
6. Adjusting Bolt
7. Adjusting Bracket Assembly
8. Shims
9. Seal

Figure 4-53 Typical 16V Engine Poly-Vee Groove Pulley Hub and Adjusting Bracket

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1. Before assembling the roller bearings into the pulley hub, pressure lubricate the bearings, and pack the hub cavity 25% full of grease.

NOTE:
Use Mobil HP or an equivalent Lithium base multi-purpose grease.

2. Install the rear roller bearing in the pulley hub.
3. Press a new oil seal in 2.54 mm (0.100 in.) from the end of the pulley hub. See Figure 4-53.
4. Place the adjusting bracket on wood blocks on an arbor press bed.
5. Press the pulley hub on the fan shaft.
6. Install the spacer and necessary shims on the fan shaft.
7. Install the front roller bearing in the pulley hub.
8. Apply International Compound No. 2 to the locknut threads, and tighten it with socket J 22556-2 and tool J 6534-8 (from set J 22556) to 339-352 N·m (250-260 lb·ft) torque while rotating the pulley hub.

NOTE:
When tool J 6534-8 is used to tighten the 16V poly-vee groove pulley hub locknut, use tool set J 22556 and reverse tool J 6534-8 in socket J 22556-2 (chamfered holes in J 6534-8 facing the socket).

9. Check the end play. It must be 0.0254–0.1524 mm (0.001–0.006 in.).
10. If necessary, remove the locknut and front bearing, and add or remove shims as required.
11. After the specified end play is obtained, remove the locknut and front bearing, and fill the pulley hub cavity 20-30% full of grease.
12. Install the front bearing and locknut.
13. Tighten the locknut to 339-352 N·m (250-260 lb·ft) torque, and stake the locknut to the fan shaft.
14. Fill a new hub cap 75% (minimum) full of grease, and install it in the pulley hub.

4.8.10 Installation of Engine Cooling Fan

Install the engine cooling fan as follows:

1. Secure the fan and spacer to the pulley hub with the six bolts, nuts, and lock washers. Tighten the nuts to 20-26 N·m (15-19 lb·ft) torque.
2. Place the fan belts on the pulley.

NOTE:
Before a poly-vee belt is installed (16V engines), the crankshaft pulley and fan pulley must be aligned. Refer to section 1.15.3.

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3. Position the fan, hub, and adjusting bracket against the support bracket, and install the bolts finger tight in the support.

NOTE:
The new bolts differ from the former in that their effective lengths in inches are indicated in 0.25 in. high raised numbers on the bolt heads. This makes them easier to identify than the former bolts which had to be measured.

4. Adjust the bracket to provide the proper tension on the fan belts. Refer to section 1.15.3. Tighten the bracket and bracket adjusting bolts.

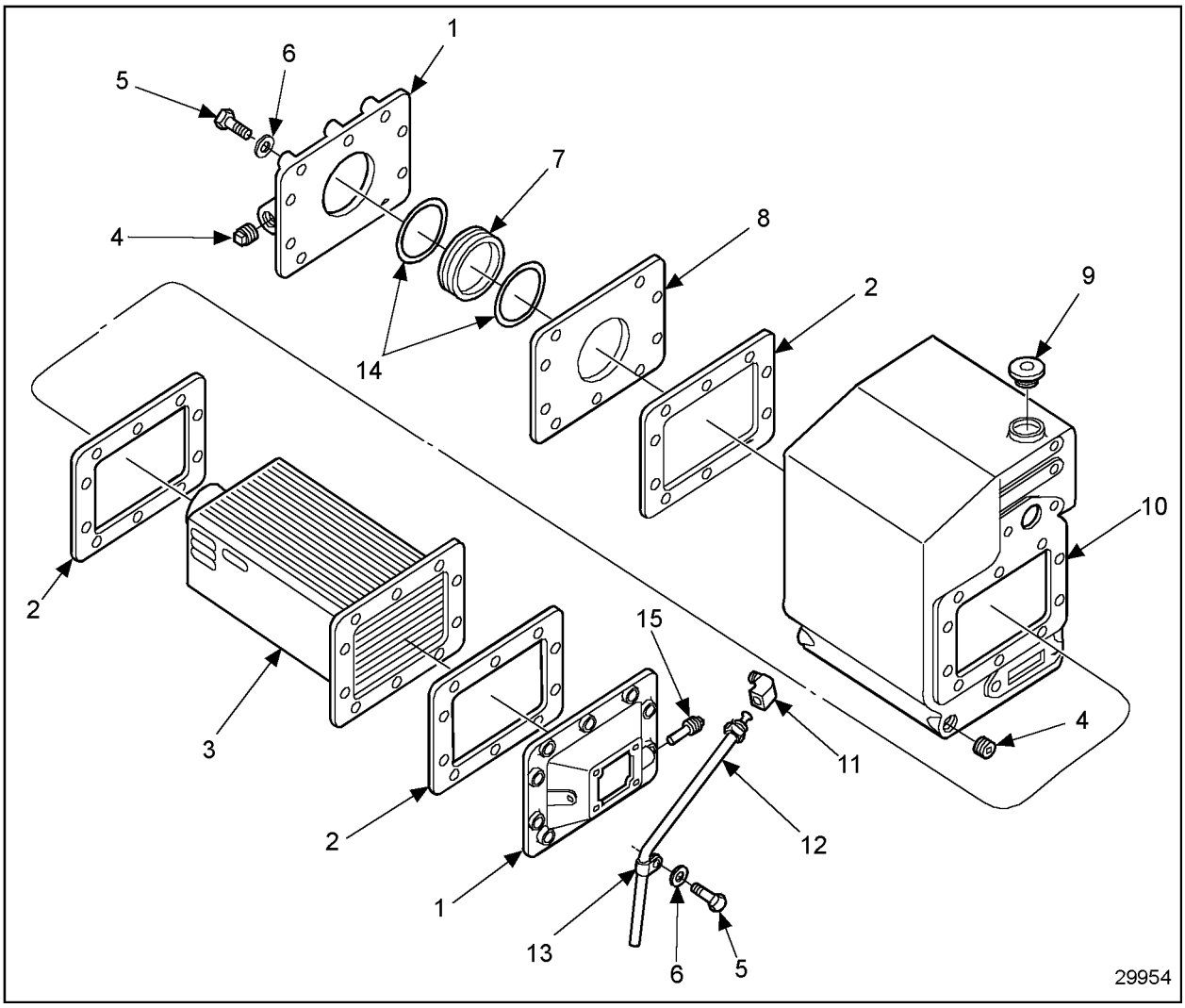
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4.9 HEAT EXCHANGER

The heat exchanger core consists of a series of cells with a header at one end and a circular water outlet at the opposite end. The core is mounted inside the expansion tank with the inlet end bolted to the tank and the outlet end sealed inside a retainer.

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A gasket between the expansion tank and the core flange, another gasket between the core flange and the cover at the inlet side, and seals surrounding the circular outlet at the opposite end prevent the coolant from mixing with the raw cooling water on its horizontal course between the element cells. See Figure 4-54.



1. End Cover (2)
2. Gasket (3)
3. Core
4. Pipe Plug (2)
5. Bolt (2)
6. Washer (2)
7. Gland Seal
8. Retainer
9. Cap
10. Expansion Tank
11. Elbow
12. Expansion Tank Tube
13. Clamp
14. O-ring Seals
15. Electrode

Figure 4-54 Typical Heat Exchanger Assembly

The hot coolant leaving the thermostat housing passes through the expansion tank and through the cooling core cells. After leaving the heat exchanger, the engine coolant is picked up by the fresh water pump and circulated through the cylinder block and cylinder heads. The raw water is forced horizontally between the core cells and serves to lower the coolant temperature as it passes through the cells.

A coolant level sensor is installed in the heat exchanger tank of DDEC III and DDEC IV Marine Engines. This signals a low engine coolant level in the tank.

To protect the heat exchanger core from electrolytic raw water, a zinc electrode is placed in the heat exchanger inlet elbow and the raw water pump inlet elbow. It extends into the raw water passage.

The expansion tank helps fill the engine cooling system. It serves as a space for coolant expansion as its temperature rises. An overflow pipe, near the top of the tank, provides a vent to the atmosphere.

NOTE:
When installing a new filler neck in the expansion tank, drill a 3/16 in. hole in the side of the new filler neck for the overflow pipe.

Soft water plus required corrosion inhibitor or antifreeze should be used as the engine coolant to prevent lime deposits in the heat exchanger core as well as in the engine. Refer to section 5.3.

Enough coolant should be maintained in the engine to fill the cylinder block and head and to partially fill the water tank. Allow air space above the coolant in the tank for the volume increase as the coolant temperature rises.

Whenever the heat exchanger fails to cool the engine properly and the raw water pump is circulating a normal amount of cooling water around the heat exchanger core, the core should be examined for foreign deposits.

Heat Exchanger Tank Mounting System in 16V-92 Marine Engines

A tank mounting system is used on all 16V-92 marine engines having the tube bundle design heat exchanger tank assembly. This is done to minimize the transmission of normal mechanical vibration to the heat exchanger tank during engine operation.

When properly installed, the components of this system will reduce stress on the joint between the heat exchanger and the saddle feet. This system will also reduce much of the vibration transferred to the tank from the engine.

4.9.1 Repair or Replacement of Heat Exchanger

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-55.

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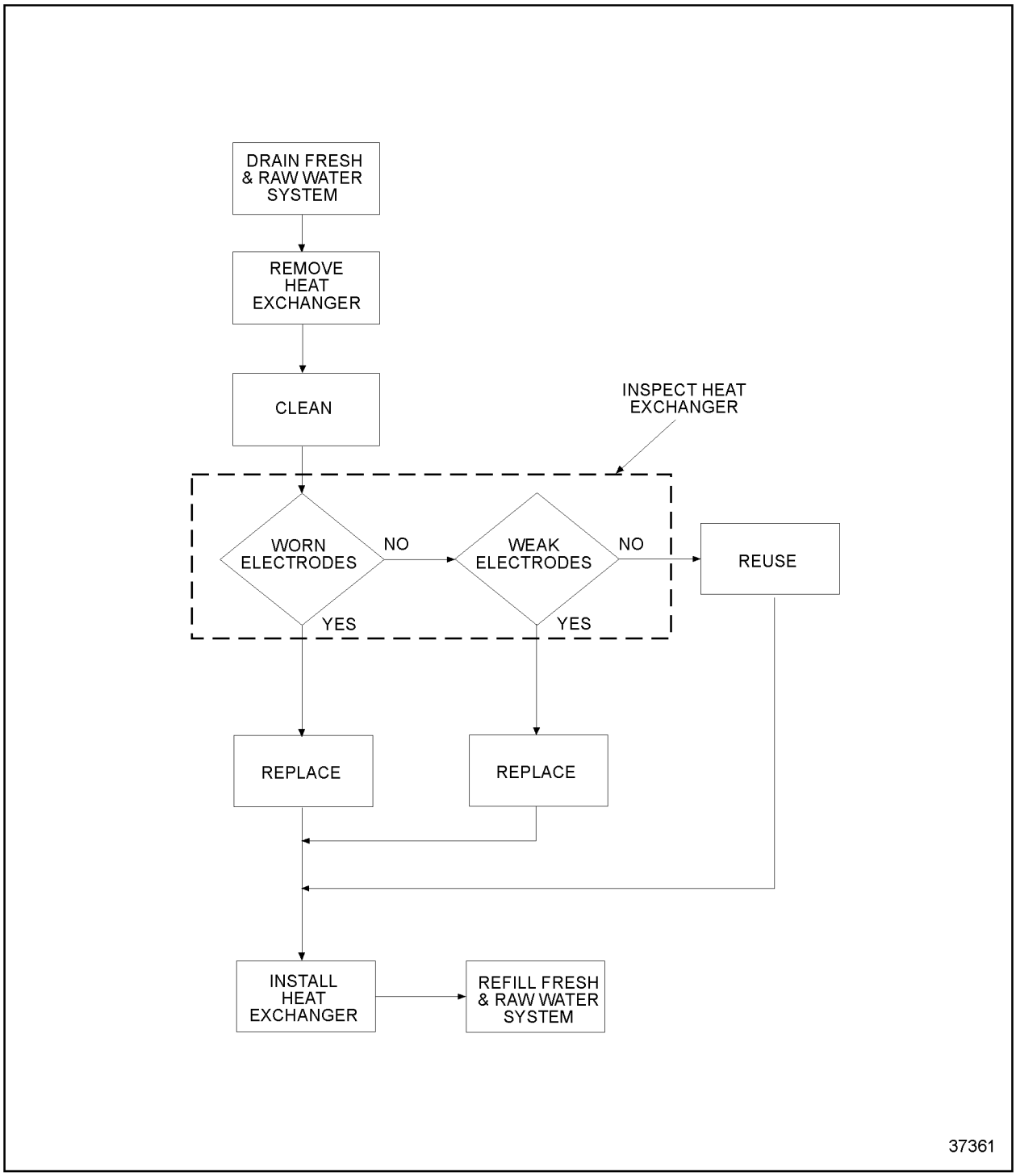


Figure 4-55 Flowchart for Repair or Replacement of Heat Exchanger

4.9.2 Removal of Heat Exchanger (6V and 8V Engines)

Remove the heat exchanger 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. Drain the engine coolant and the raw water system. Refer to section 13.12.7 and refer to section 13.54.
2. Remove the four bolts and lock washers that hold the raw water inlet tube to the heat exchanger. Withdraw the inlet tube and gasket.
3. Remove the ten bolts and lock washers that hold the heat exchanger inlet cover to the expansion tank.
4. Remove the four bolts and lock washers that hold the outlet tube to the cover. Remove the outlet tube and gasket.
5. Remove the ten bolts and lock washers that hold the outlet cover and seal retainer to the expansion tank.
6. Withdraw the outlet cover and seal retainer with the seals and seal gland from the expansion tank. Remove the gasket.
7. Withdraw the heat exchanger core and gasket from the expansion tank.

4.9.3 Removal of Heat Exchanger (8VTI and 16V Engines)

Remove the heat exchanger 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. Drain the fresh and raw water systems. Refer to section 13.54.
2. Remove the bolts that hold the inlet cover and the heat exchanger core to the tank. Remove the cover and the gasket.
3. Remove the bolts that hold the outer cover to the seal retainer. Remove the cover and gasket.
4. Remove the bolts that hold the seal retainer to the tank. Remove the seal retainer with the seals and the seal gland away from the tank.

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5. Withdraw the heat exchanger core and gasket from the tank.

4.9.3.1 Cleaning of Heat Exchanger

Clean the heat exchanger core as follows:

⚠ 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. Immerse the heat exchanger core in a scale solvent consisting of one-half pound oxalic acid to each two and one-half gallons of one-third muriatic acid and two-thirds water solution.
2. Remove the core when foaming and bubbling stops. This usually takes thirty to sixty seconds.

⚠ CAUTION:

To avoid injury, wear a face shield or goggles.

3. Flush the core thoroughly with clean hot water under pressure.

NOTE:
To prevent foreign substances from drying and hardening, clean the heat exchanger core as soon as possible after removing it from service.

4.9.3.2 Inspection of Heat Exchanger

Inspect the heat exchanger as follows:

1. Inspect the heat exchanger core for foreign deposits.
   [a] If foreign deposits are evident, the heat exchanger core must be thoroughly cleaned. Refer to section 4.9.3.1.
   [b] If no foreign deposits have accumulated, continue inspection.
2. Remove the zinc electrodes from the inlet side of the raw water pump and the heat exchanger, and Inspect the electrode for dirt wear.
   [a] Clean the electrodes with a wire brush or, if worn excessively, replace with new electrodes.
   [b] If not worn or dirty, continue inspection.
3. To determine the condition of a used electrode, strike it sharply against a hard surface. A weakened electrode will break.

[a] If it breaks, replace the electrode.

[b] If it does not break, reuse the electrode.

4.9.4 Installation of Heat Exchanger (6V and 8V Engines)

Install the heat exchanger as follows:

1. Install the heat exchanger core and gasket on the expansion tank.
2. Install the outlet cover and seal retainer with the seal and seal gland.
3. Install the ten bolts and lock washers on the outlet cover and seal retainer. Tighten the bolts.
4. Install the inlet cover on the expansion tank.
5. Install the ten bolts and lock washers in the inlet cover and expansion tank. Tighten the bolts.
6. Install the inlet tube and gasket.
7. Install the four bolts and lock washers that hold the raw water inlet tube on the heat exchanger. Tighten the bolts.
8. Fill the cooling system. Refer to section 13.12.2.
9. Check for leaks.

4.9.5 Installation of Heat Exchanger (8VTI and 16V Engines)

Install the heat exchanger as follows:

1. Install the heat exchanger core and gasket in the tank.
2. Install the seal retainer with the seals and seal gland in the tank. Secure with bolts.
3. Install the outer cover and gasket. Secure with bolts.
4. Install the cover and gasket that hold the heat exchanger core on the tank. Secure with bolts.
5. Fill the cooling system. Refer to section 13.12.2.

NOTE:
To minimize electrolytic action of the raw water, brass pipe plugs are used in the raw water system components wherever pipe plugs are required. Replace any steel plugs that may be found on early units with brass plugs.

NOTE:
If the coolant level sensor in the heat exchanger tank of a DDEC marine engine has been removed, inspect for cracking or thread distortion before installing. Cracked or damaged sensors ***must not*** be reused.

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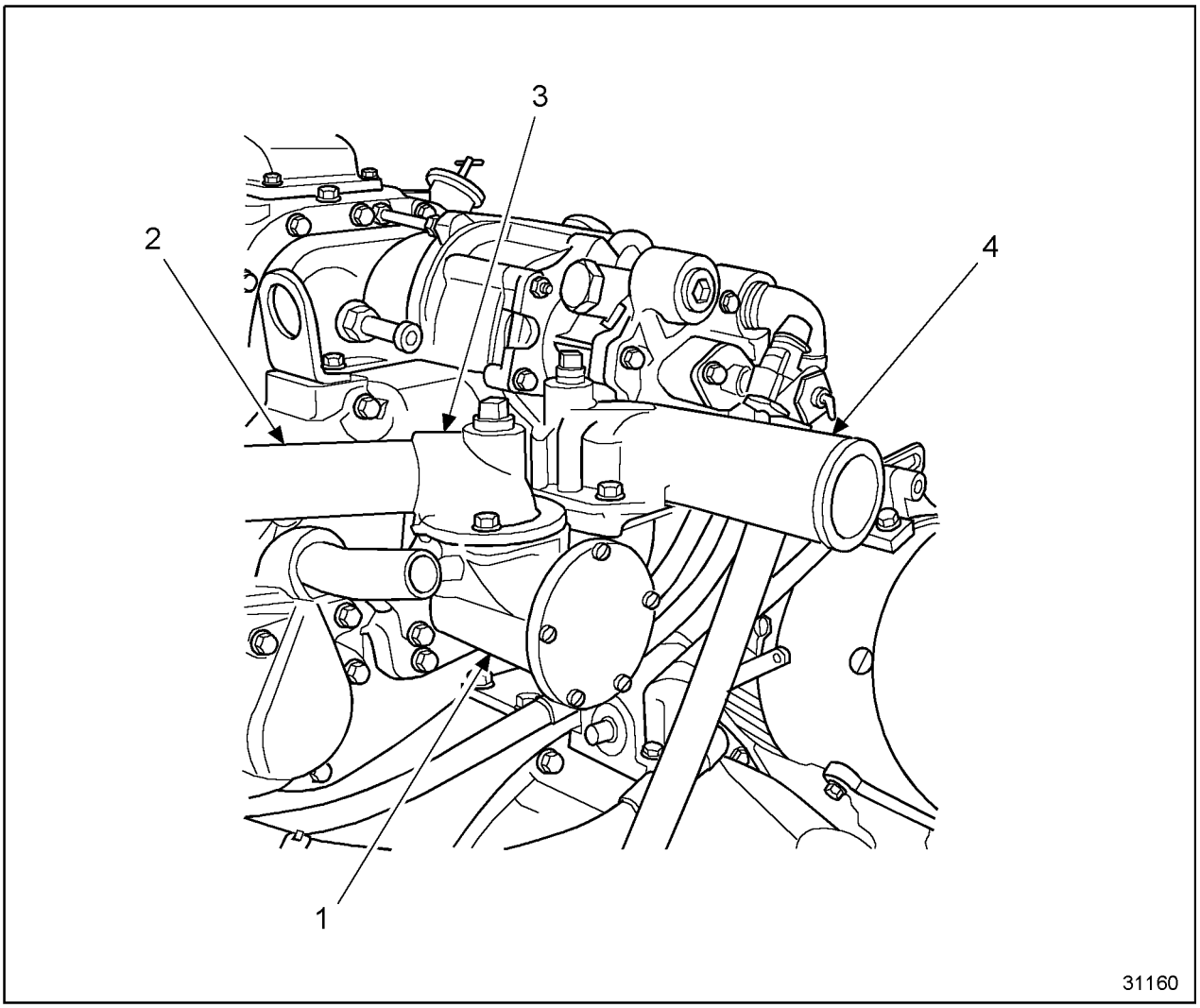
NOTICE:
Failure to tighten the coolant level sensor properly may result in sensor damage (stripped threads or cracking). Sensor distortion or damage may cause logging of a false high or low voltage code.

NOTE:
Fresh coolant level sensors have a special sealant applied to threads, and no additional sealant is required for initial installation. When reinstalling a sensor, however, Loctite 567 pipe sealant with Teflon or equivalent must be applied to the threads to ensure proper sealing.

6. Install and tighten the sensor to 5-8 N·m (4-6 lb·ft) torque.
7. Check for leaks.

4.10 RAW WATER PUMP

A positive displacement pump circulates raw water for lowering the temperature of the engine coolant through the heat exchanger. The pump is attached to an adaptor which is bolted to the flywheel housing and is driven through a coupling attached to the left-hand camshaft gear. See Figure 4-56.



1. Raw Water Pump Assembly
2. Outlet Tube
3. Outlet Elbow
4. Inlet Elbow

Figure 4-56 Raw Water Pump Mounting

A prelubricated, shielded double-row ball bearing supports the pump drive shaft. An oil seal prevents oil leakage from the bearing compartment and a rotary type seal prevents water leaks along the shaft.

The pumped water lubricates the impeller splined to the end of the drive shaft.

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A wear plate in the impeller compartment prevents pump housing wear and can be reversed if plate wear becomes excessive. A slot machined in the outer periphery of the wear plate registers with a dowel in the pump housing, preventing it from rotating with the shaft.

The pump can be operated clockwise or counterclockwise. Raw water is drawn into the pump through an inlet opening and discharged through the outlet opening, both openings are located at the top of the pump housing.

Two current high-volume Jabsco raw water pumps (8923363 and 8927296) are used on Detroit Diesel series 71 and 92 marine engines. The two pumps differ in output (100 gpm vs 125 gpm, respectively) and have a slightly different body configuration, but are otherwise similar in design.

Major features of the current pumps include:

- Heavy-duty cast bronze body and cast iron bearing housing
- Neoprene compound impeller
- Stainless steel drive shaft
- Wear-resistant polyurethane cam/liner
- Reversible ceramic wear plate on the 100 gpm pump

Raw Water Pump Standardization

To reduce the number of raw water pumps requiring service, three new pump assemblies have replaced ten existing pumps.

The new assemblies are identical to the former, except that the new ones do not include the adaptor flange, adaptor/pump mounting bolts, or washers. When former pumps are replaced, the original adaptor flange, mounting bolts, and washers *must* be reused. If damaged, these parts must be ordered separately.

NOTE:
Former and new raw water pump assemblies are completely interchangeable, and only the new assemblies will be serviced. Components of the former pumps will continue to be serviced.

4.10.1 Repair or Replacement of Raw Water Pump

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 4-57.

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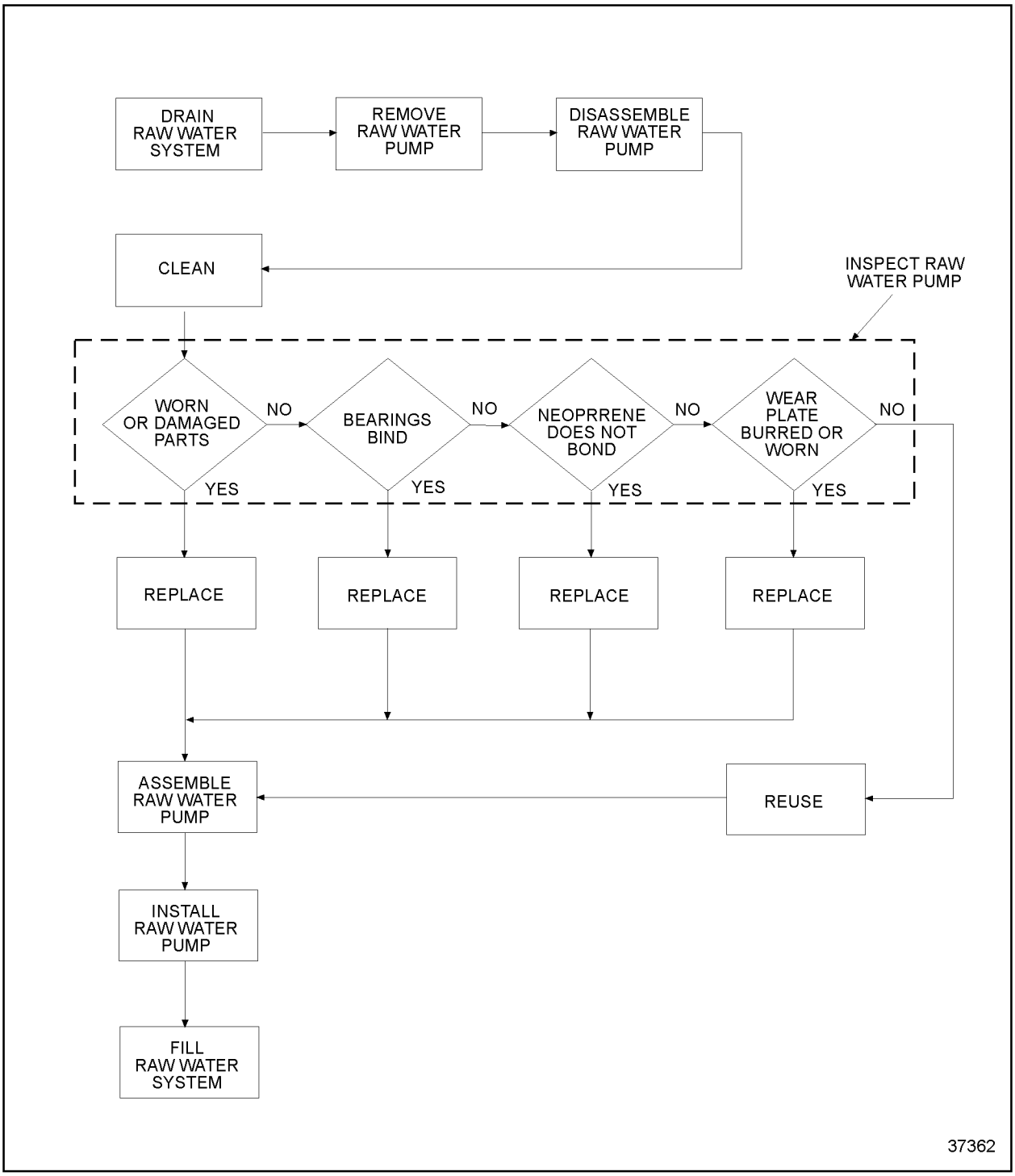


Figure 4-57 Flowchart for Repair or Replacement of Raw Water Pump

4.10.2 Removal of Raw Water Pump

Remove the raw water pump as follows:

1. Drain the raw water system. Refer to section 13.54.

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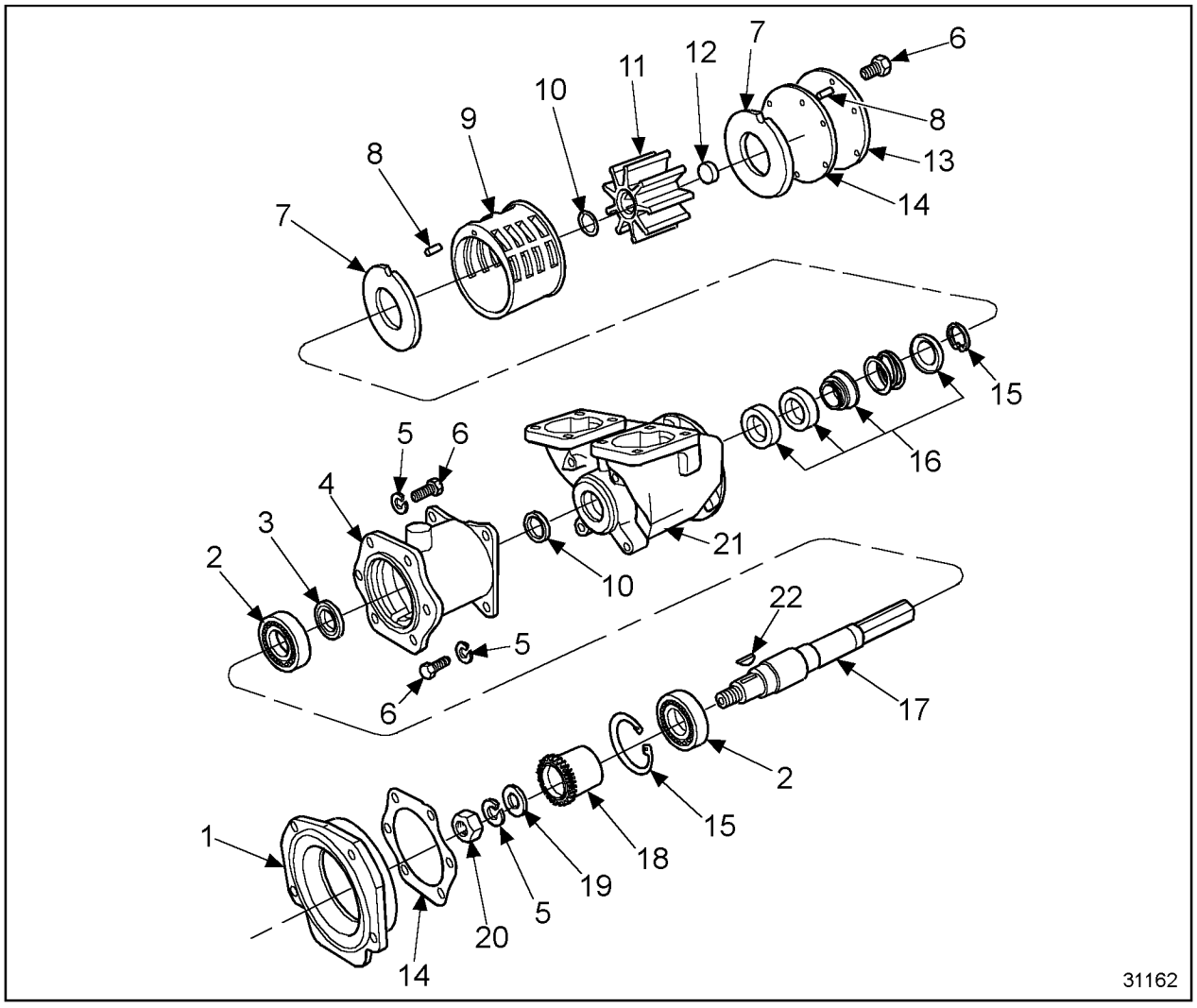
2. Loosen the hose clamps at the outlet elbow and intermediate tube, and slide the hose along the tube.
3. Loosen the hose clamps at the inlet elbow and the inlet tube, and slide the hose along the tube.
4. Remove the bolts and lock washers holding the inlet and outlet elbows to the pump.
5. Lift the elbows from the pump. Remove the gaskets.
6. Remove the adaptor-to-flywheel housing bolts and lock washers.
7. Tap the edge of the adaptor with a soft hammer to loosen the pump from the flywheel housing.
8. Withdraw the pump straight out from the flywheel housing, disengaging the drive gear from the coupling.

NOTE:
Cover the pump opening in the flywheel housing with a clean cloth to prevent foreign matter from entering.

4.10.3 Disassembly of 100 GPM and 125 GPM Pump

See Figure 4-58 and see Figure 4-59, and disassemble the 100 gpm and 125 gpm pumps as follows:

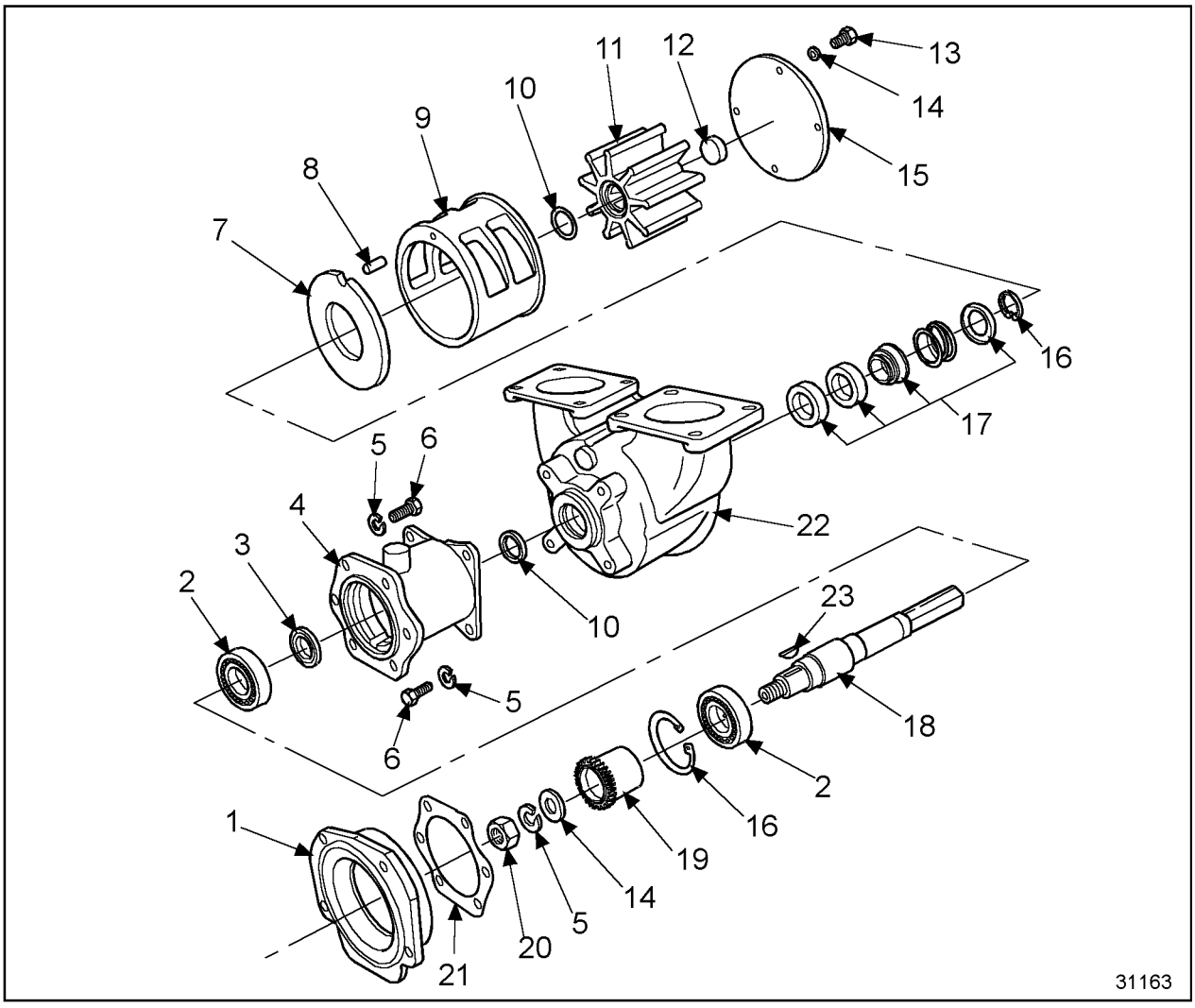
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1. Adaptor
2. Bearing
3. Seal
4. Bearing Housing
5. Lock Washer
6. Hex Head. Screw
7. Wear Plate
8. Dowel Pin
9. Cam Liner
10. O-ring
11. Impeller
12. Seal Spline
13. End Cover
14. Gasket
15. Retaining Ring
16. Mechanical Seal
17. Shaft
18. Gear
19. Flat Washer
20. Hex Nut
21. Body
22. Woodruff Key

Figure 4-58 100 GPM Raw Water Pump

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1. Adaptor
2. Bearing
3. Seal
4. Bearing Housing
5. Lock Washer
6. Hex Head Screw
7. Wear Plate
8. Dowel Pin
9. Cam Liner
10. O-ring
11. Impeller
12. Seal Spline
13. Hex Bolt
14. Flat Washer
15. End Cover
16. Retaining Ring
17. Mechanical Seal
18. Shaft
19. Gear
20. Hex Nut
21. Gasket
22. Body
23. Woodruff Key

Figure 4-59 125 GPM Raw Water Pump

1. Remove end cover bolts or screws and end cover. On 100 gpm pump only, remove gasket and outer wear plate.
2. Grasp impeller hub with pliers, and remove from impeller bore. If impeller O-ring remains on shaft, remove it.
3. Remove cam/liner from pump body.
4. Remove inner wear plate.
5. Remove seal retaining ring, taking care not to scratch shaft.
6. Remove carbon portion of mechanical seal with tensioning spring attached.
7. Remove bolts securing adaptors to pump inlet and outlet ports. With pump body held securely, remove four 5/16 in. screws and lock washers holding pump body to bearing housing.
8. Remove pump body from bearing housing and shaft subassembly. Remove any remaining gasket material from port adaptors.
9. Remove slinger O-ring from shaft.
10. Press out remaining portions of mechanical seal (boot and ceramic seat) from the pump body drive end.
11. Hold housing securely, and remove the six 3/8 in. screws and lock washers in the housing flange.
12. Remove the bearing housing and the shaft subassembly from the adaptor.
13. Hold the shaft with a wrench on impeller end shaft flats to keep it from rotating. Remove the drive gear retaining nut, lock washers, and retaining flat washer.
14. Remove the drive gear from the shaft. A punch and small mallet may be used to gently tap the underside of the drive gear teeth to loosen the gear from the shaft. Remove woodruff key.
15. Remove the retaining ring securing the bearing in the bearing housing.
16. Press against impeller end of shaft to remove the shaft and bearing subassembly from the bearing housing.
17. Support the bearing inner race, and press the shaft out of the bearing. Repeat with second bearing.
18. Push the oil seal out of the bearing housing from the pump end of the bearing housing.

4.10.3.1 Cleaning of Raw Water Pump

Prior to inspection, clean the parts as follows:

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NOTICE:

The shielded bearing must not be washed. Dirt may be washed in, and the cleaning fluid may not be entirely removed from the bearing. Dirt in the shielded bearing will cause bearing damage.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean all parts thoroughly in clean fuel oil.
2. Wipe the bearing clean on the outside.

4.10.3.2 Inspection of Raw Water Pump

Inspect the raw water pump as follows:

1. Inspect the bearing. Hold the inner race, and revolve the outer race slowly to detect possible wear or rough spots
   [a] If worn or does not roll freely, replace the bearing. Refer to section 4.10.4.
   [b] If not worn and rolls freely, continue inspection.
2. Inspect the seal assembly parts for cuts, cracks, or damage.
   [a] If cut, cracked, or otherwise damaged, replace the parts. Refer to section 4.10.4.
   [b] If not cut, cracked, or damaged, proceed with inspection.
3. Inspect the oil seal contact surfaces for scratches or grooves.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

[a] Smooth scratched surface with crocus cloth wet with fuel oil.

[b] If excessively scratched or grooved, replace the pump. Refer to section 4.10.5.

[c] If not scratched or grooved, continue inspection.

4. Inspect the impeller for a good bond between the neoprene and the metal.

   [a] If bond is damaged, replace. Refer to section 4.10.5.

   [b] If the bond is not damaged, continue inspection.

5. Inspect the impeller blades for a permanent set.

   [a] If the impeller blades have a permanent set, install a new impeller. Refer to section 4.10.4.

   [b] If the blades do not have a permanent set, continue inspection.

6. Inspect the wear plate for burrs and wear.

   [a] If burred, remove with a crocus cloth.

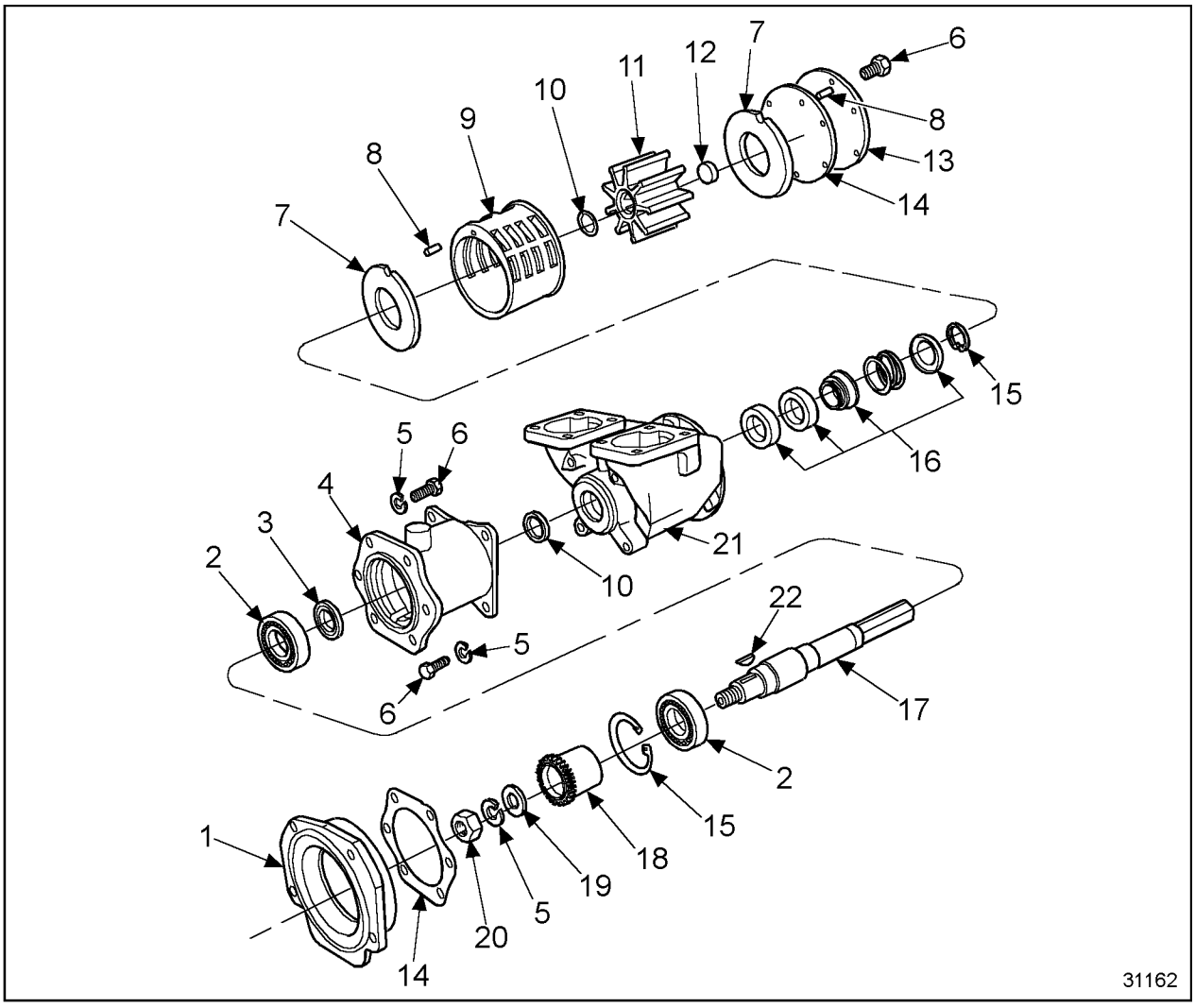
   [b] If excessively burred or worn, reverse the plate when the pump is assembled.

   [c] If not burred or worn, reuse the parts.

4.10.4 Assembly of 100 GPM and 125 GPM Raw Water Pump

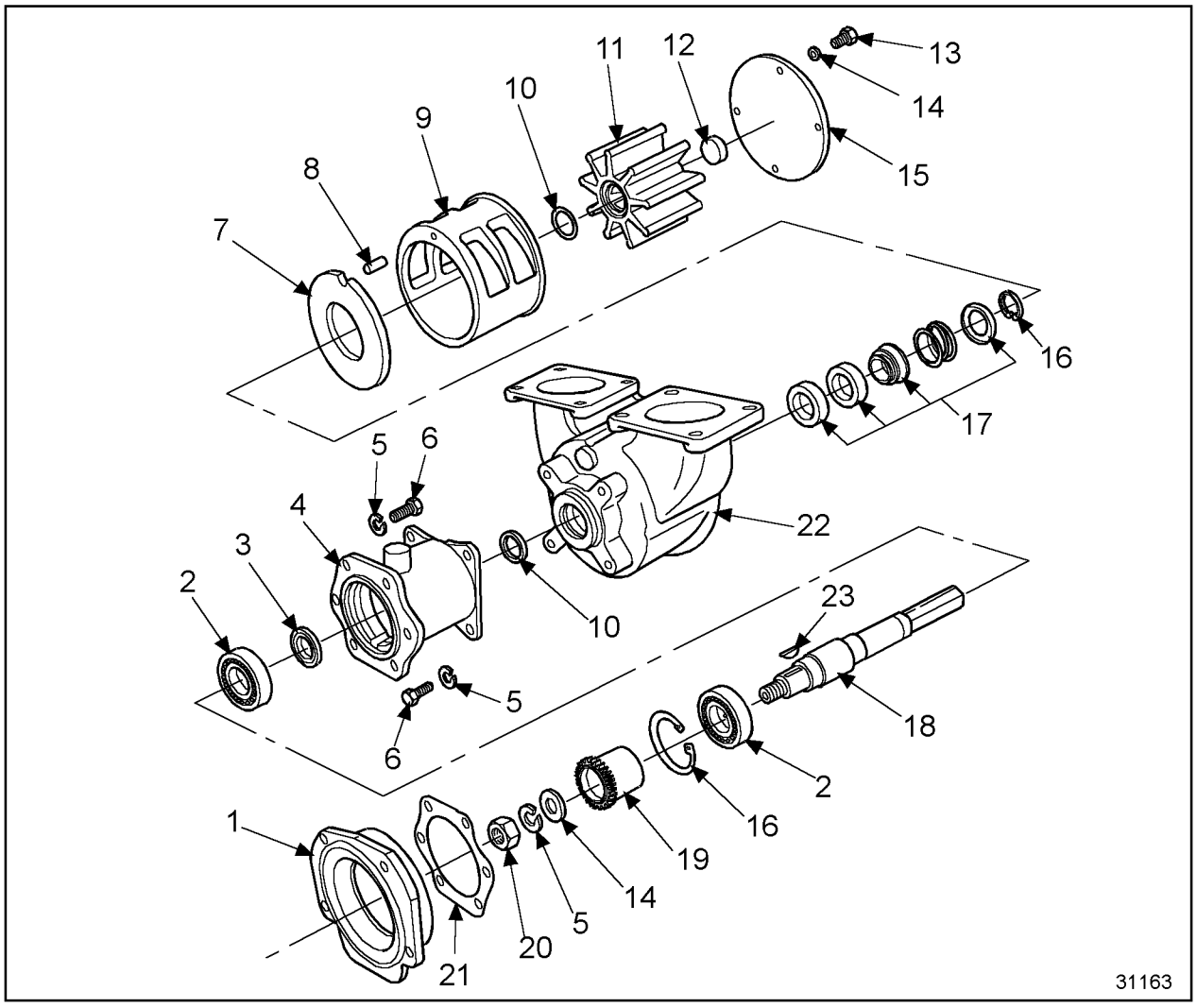
See Figure 4-60, and see Figure 4-61. Assemble the 100 gpm and 125 gpm raw water pump as follows:

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1. Adaptor
2. Bearing
3. Seal
4. Bearing Housing
5. Lock Washer
6. Hex Head. Screw
7. Wear Plate
8. Dowel Pin
9. Cam Liner
10. O-ring
11. Impeller
12. Seal Spline
13. End Cover
14. Gasket
15. Retaining Ring
16. Mechanical Seal
17. Shaft
18. Gear
19. Flat Washer
20. Hex Nut
21. Body
22. Woodruff Key

Figure 4-60 100 GPM Raw Water Pump



1. Adaptor
2. Bearing (2)
3. Seal
4. Bearing Housing
5. Lock Washer (3)
6. Hex Head Screw
7. Wear Plate
8. Dowel Pin
9. Cam Liner
10. O-ring
11. Impeller
12. Seal Spline
13. Hex Bolt
14. Flat Washer (2)
15. End Cover
16. Retaining Ring (2)
17. Mechanical Seal
18. Shaft
19. Gear
20. Hex Nut
21. Gasket
22. Body
23. Woodruff Key

Figure 4-61 125 GPM Raw Water Pump

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lightly coat the outside diameter of a new oil seal with clean engine oil.
2. Press the oil seal into the seal bore from the drive end of the bearing housing.

NOTE:
The seal lip must point to the housing drive end.

3. With pressure applied to the bearing inner race, press the bearings onto the shaft.
4. Apply pressure to the outer race of the outer bearings, and install the bearing and shaft subassembly into the bearing housing.
5. Install the bearing retaining ring in the bearing housing, ensuring it is securely seated in the ring groove.
6. Insert the woodruff key into the groove on the shaft end.
7. Gently tap the drive gear with a small plastic-face mallet to install it into the shaft.
8. Install the flat washer, lock washer, and retaining nut onto the shaft. Hold the shaft with a wrench on the impeller end shaft flats to prevent it from rotating, and tighten retaining nut to 33-41 N·m (24-30 lb·ft) torque.
9. Install new slinger O-ring on shaft near bearing housing.
10. Install mechanical seal components.

NOTE:
Do not allow seal components to become soiled during assembly.

11. Lubricate ceramic seal seat booth with water only, and press into pump body seal bore.
12. Install ceramic seal seat.

NOTE:
Exposed ceramic surface should face toward impeller bore.

13. Slide pump body over shaft, taking care not to dislodge seal seat as body is moved toward (and aligned with) bearing housing.
14. Attach pump body to bearing housing with four 5/16 in. screws and lock washers. Tighten to 19-22 N·m (14-16 lb·ft) torque.
15. Install carbon portion of mechanical seal with tensioning spring and spring washer over the shaft, and position it in the seal bore with the carbon face against the ceramic seal seat.
16. Slide seal retaining ring over shaft against seal thrust ring, and position in retaining ring groove.

17. Install inner wear plate in pump body. Align the wear plate notch with the pin in the body.
18. Lubricate bore of body with a premium water pump bearing grease.
19. Align hole in top of cam/liner with pump body pin, and push cam/liner into body.

NOTE:
The 100 gpm pump cam/liner should recess about 1/8 in. from the end cover surface to permit wear plate installation.

20. Liberally coat inside of cam/liner with a premium water pump bearing grease.
21. Insert impeller O-ring in the groove in the impeller recess.
22. With O-ring end of impeller facing pump housing, rotate impeller in the direction of pump rotation to bend vanes under the cam, and push it into the bore until the impeller insert flats align with shaft flats.
23. Push the impeller into the impeller bore.

NOTE:
The impeller end should be even with cam/liner.

24. Install rubber spline plug into the impeller end.
25. On the 100 gpm pump only, align the wear plate notch with the hole in the top of cam/liner. Install the outer wear plate, and place end cover gasket over the end cover pin.
26. Install the end cover. Align the pin with the hole in the cam/liner.
27. Install six 1/4 in. fillister head screws (100 gpm pump) or four 1/4 in. bolts (125 gpm pump) in the end plate cover. Tighten to 8.13-8.81 N·m (72-78 lb·in) torque.

NOTE:
Do not over torque.

28. Install a new adaptor flange gasket, and secure pump assembly to adaptor with six 3/8 in. screws, flat washers, and lock washers. Tighten to 18-20 N·m (13-15 lb·ft) torque.
29. Using new gaskets, attach the raw water pump inlet and outlet adaptors.

4.10.5 Installation of Raw Water Pump

Install the raw water pump as follows:

NOTE:
The end cover is marked to show the outlet port for RH rotation and the outlet port for LH rotation. Follow these markings when installing the raw water pump to avoid any difficulty regarding direction of flow.

NOTE:
When installing the inlet elbow or the outlet elbow, be sure to use two flat washers on the bolt being installed in the blind hole in pump housing.

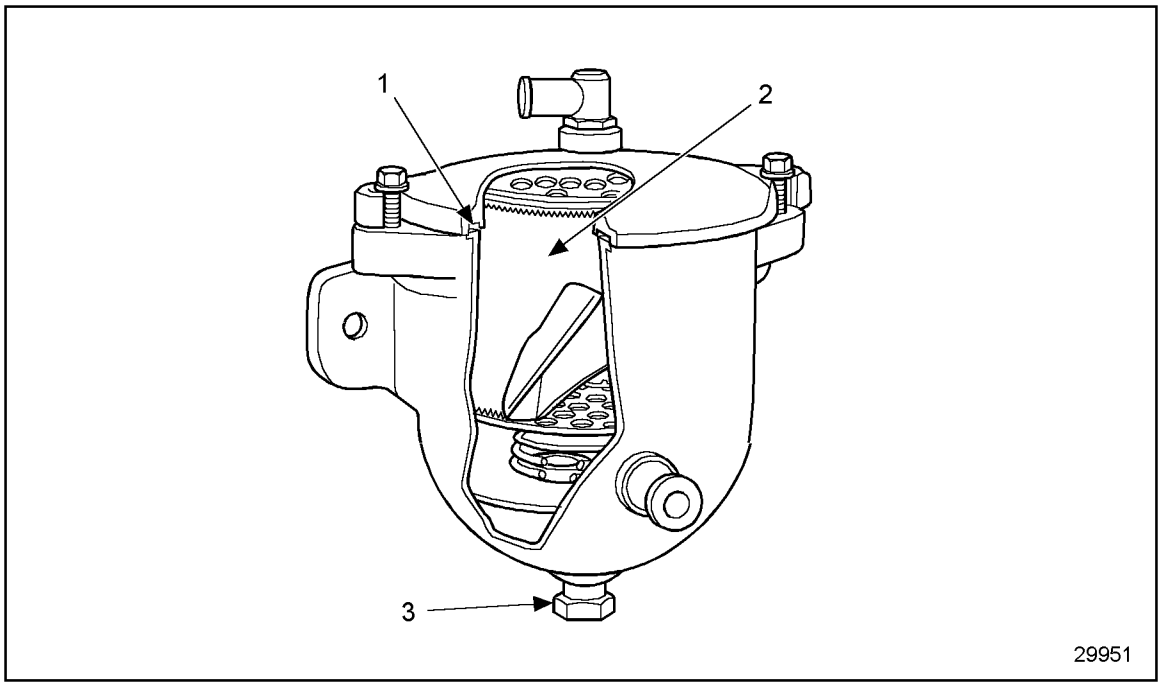
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1. Remove the cover in the flywheel housing pump opening.
2. Install the pump into the flywheel housing, and attach the drive gear to the coupling.
3. Install the adaptor to flywheel housing bolts and lock washers.
4. Install new gaskets and place the elbows on the pump.
5. Secure the inlet and outlet elbows to the pump with bolts and lock washers.
6. Slide the hose onto the inlet elbow and the inlet tube, and tighten the hose clamps.
7. Slide the hose onto the outlet elbow and the outlet tube, and tighten the hose clamps.
8. Fill the raw water system. Refer to section 13.54.

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4.11 COOLANT FILTER AND CONDITIONER

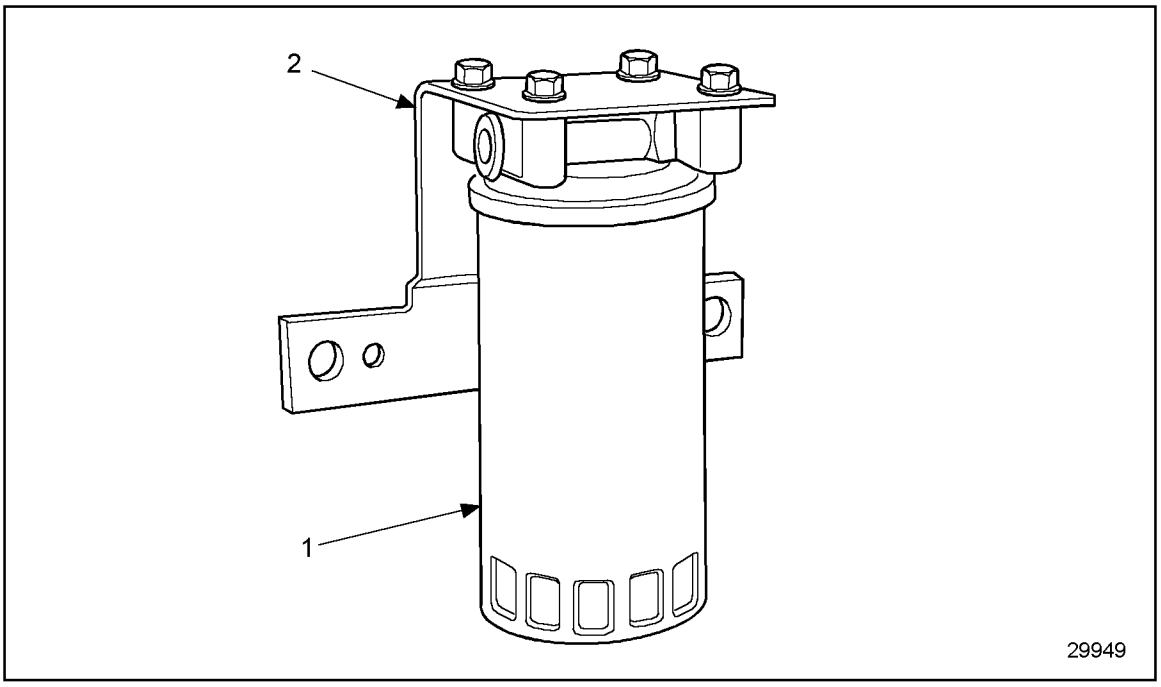
The engine cooling system filter and conditioner is a compact by-pass type unit with a replaceable canister type element, a spin-on type element, or a clamp-on type element. See Figure 4-62, see Figure 4-63, and see Figure 4-64.



1. Gasket
2. Element
3. Drain Plug

Figure 4-62 Coolant Filter and Conditioner (Canister Type)

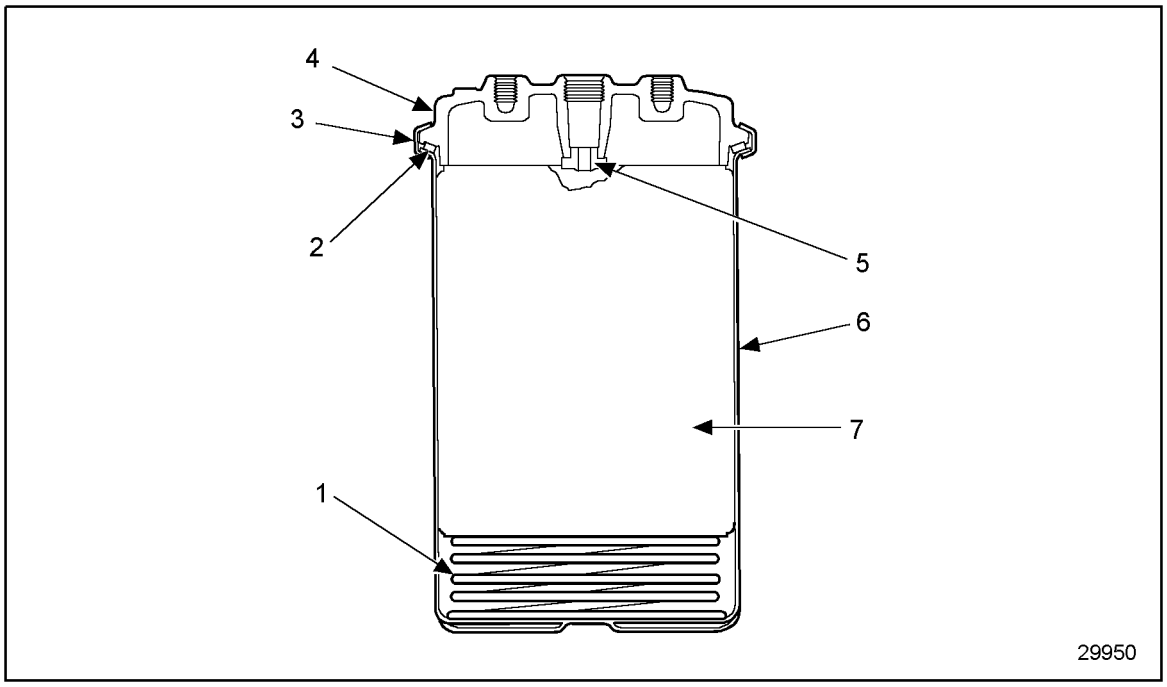
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1. Filter
2. Filter Mount

Figure 4-63 Coolant Filter and Conditioner (Spin-on Type)

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1. Spring
2. Gasket
3. Clamp
4. Clover
5. Grommet
6. Shell
7. Element

Figure 4-64 Coolant Filter and Conditioner (Clamp-on Type)

A correctly installed and properly maintained coolant filter and conditioner provide a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity, and engine part longevity.

A closely packed element in the filter, through which the coolant passes, provides mechanical filtration. The element removes any impurities, such as sand and rust particles, suspended in the cooling system. Removing these impurities will contribute to longer water pump life and proper thermostat operation.

The filter conditions the coolant, softens the water to minimize scale deposits, maintains an acid-free condition, and acts as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all cooling system metal surfaces. Refer to section 5.3. Other element components clean the cooling passages, whereas the corrosion inhibitors protect them.

NOTE:
The coolant filter may be grounded at the user's option.

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The current coolant filter includes a non-chromate type element. This element can be used in place of either of the former filter elements (permanent type antifreeze or plain water type) and thus provides year around cooling system protection. The current and the former filter elements are completely interchangeable in the former filter. Refer to section 5.3.2.7.

Coolant filter/inhibitor precharge elements are available as optional equipment. These elements provide the engine with the proper charge of required inhibitors and water softeners at initial cooling system fill. Refer to section 13.15 for maintenance.

4.11.1 Repair or Replacement of Coolant Filter and Conditioner

Refer to section 13.14 for coolant filter and conditioner service procedures.

4.11.2 Removal of Coolant Filter and Conditioner

Remove the coolant filter and conditioner as follows:

NOTICE:
Use care to avoid puncturing hoses with the vise grip pliers.

NOTE:
If shut-off valves are not provided, vise grip pliers without serrations can be used to clamp each hose closed during the filter change.

1. Remove the drain plug in the bottom of the filter body, and let drain.
2. Remove the filter cover-to-filter body bolts.
3. Remove and discard the element.
4. Remove and discard the corrosion resistor plates.Remove the spin-on type element as follows:
5. Remove the retaining clamp.
6. Remove and discard the element.

4.11.2.1 Cleaning of Coolant Filter and Conditioner

Clean the coolant filter and conditioner as follows:

1. Remove the sludge and sediment from the element and parts.
2. Wash the filter body.

⚠ 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 it thoroughly with compressed air.
4. On spin-on type filters, clean the gasket seal on the filter cover.

4.11.3 Installation of Coolant Filter and Conditioner

Install the canister type element as follows:

NOTE:
If a coolant filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to filter installation. Refer to section 13.12.3.

1. Replace the drain plug in the bottom of the filter.
2. Insert the new element.
3. Use a new filter cover gasket and install the filter cover. Tighten the bolts evenly.Install the spin-on type element as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Apply clean engine oil to the filter element gasket, and install the new element.
5. Turn 1/2 to 3/4 after gasket contact to assures a positive leak proof seal.Install the clamp-on type element as follows:
6. Insert the new element.
7. Secure the filter body with the clamp.Finish installation on all type filters as follows:
8. Open the shut-off valves or remove the vise grip plier clamps to open the inlet and outlet lines.
9. Operate the engine and check for leaks.

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10. The top of the filter and the outlet line should feel warm to the touch with the rise in coolant temperature.

NOTE:
If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system, and reconnect the line.

NOTE:
Use care to minimize coolant loss.

⚠ 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).

11. Verify coolant level.

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4.A ADDITIONAL INFORMATION

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SHOP NOTES

Shop notes for the cooling system are as follows:

CONTAMINATED LUBRICATING SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution or other soluble material, the following cleaning procedure, using DPM (Diproplyene Glycol Methyl Ether) or its equivalent, is recommended.

If the engine is still in running condition, proceed as follows:

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Drain contaminated lubricating oil. Refer to section 13.5.4 and refer to section 13.5.5.
2. Remove and discard the oil filter element.

⚠ 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 and dry the filter shell with compressed air.
4. Install a new element.
5. Mix two parts of DPM, or its equivalent, with one part SAE 10W engine oil.
6. Fill the engine crankcase to the proper operating level with the mixture. Refer to section 13.5.1.
7. Start and run the engine at a fast idle (1,000-1,200 RPM) for 30 minutes to one hour.

NOTE:
Check the oil pressure frequently.

8. After the specified time, stop the engine and immediately drain the crankcase and the filter. Refer to section 13.5.2. and refer to section 13.7.2.

NOTE:
Sufficient time must be allowed to drain all of the fluid.

9. Refill the crankcase (refer to section 13.5.1.) with SAE 10W engine oil after the drain plug is replaced, and run the engine at the same fast idle speed for 10-15 minutes. Then, stop the engine and drain the oil thoroughly.
10. Stop the engine and drain the oil thoroughly. Refer to section 5.2.1.
11. Remove and discard the filter element.

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⚠ 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.

12. Clean and dry the filter shell with compressed air, and install a new element.
13. Install the drain plug and fill the crankcase to the proper level with the oil recommended for normal engine operation. Refer to section 13.5.1 and refer to section 5.2.1.

AUXILIARY COOLER KIT

The auxiliary cooler replaces the water manifold in the outboard side of the engine. It is attached to a bracket bolted to the head, similar to the way the boost cooler is mounted on the opposite side. The system operates as follows.

Raw water from the outlet side of the heat exchanger flows into the cooler, lowering the exhaust coolant and marine gear oil temperatures as it passes through. Raw water leaving the cooler then flows into the exhaust elbow and is discharged overboard.

Exhaust system coolant (fresh water) leaving the crossover pipe flows into the cooler at the top. Turbocharger coolant leaving the turbine housing enters the cooler at the bottom. The coolant from these two sources mix together, is cooled, and then flows to the thermostat housing.

Marine gear oil flows from the gear pump to the cooler, is cooled and returns to the gear oil filter.

Auxiliary Cooler Kits for High Output 6V-92TA Marine Engines Rated at 550 BHP

When operated under certain conditions, the 6V-92 TA high output marine engine rated at 550 BHP may show signs of deficient cooling. Symptoms can occur in very warm seas and when engines are operated with raw water intake restriction and exhaust back pressure near the maximum limits. To eliminate the potential for overheating engines under these conditions, an auxiliary cooler kit has been released. These kits contain a tandem tube and shell type heat exchanger, all required hardware and hoses. The heat exchanger cools exhaust system coolant returning from the exhaust manifolds and turbochargers and incorporates a marine gear oil cooler. The gear cooler *must* be used when the auxiliary cooler is installed.

Auxiliary cooler kits should not be used unless the minimum water-to-water cooling index is :

- ☐ 35.0°C (95°F) with fresh water used as coolant.
- ☐ 40.6°C (105°F) with a 50/50 glycol/water mix used as coolant.

NOTE:
Cooling index = coolant-out temperature minus raw water-in temperature.

NOTE:
Cooling index, raw water pump restriction, inlet restriction, and back pressure data are required to confirm that inherent problems exist in the cooling system. Checking the engine to ensure that all systems operate efficiently and making necessary repairs may

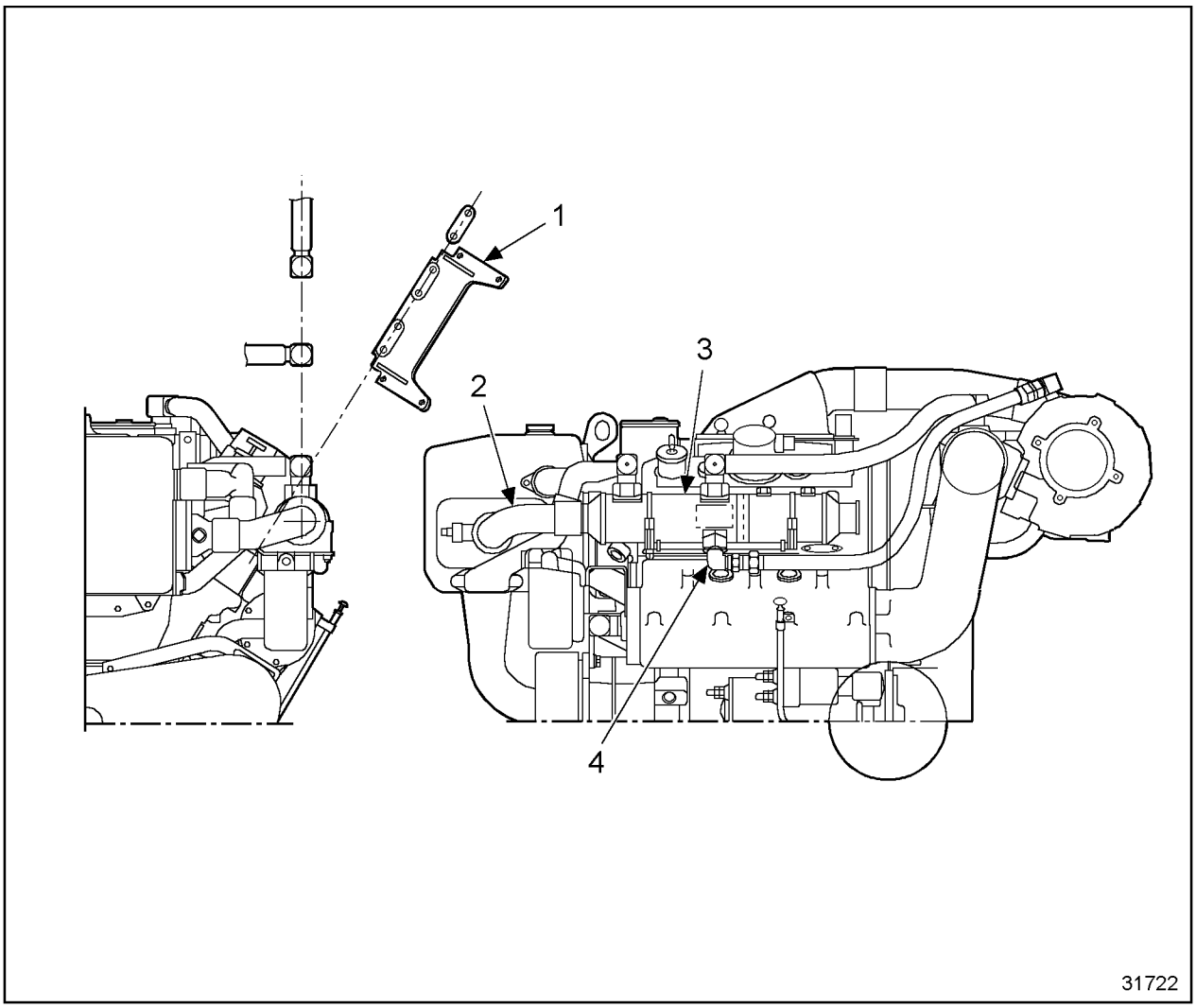
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eliminate the need for auxiliary coolers. Refer to section ADDITIONAL INFORMATION for installation of auxiliary kit.

Installation of Auxiliary Cooler Kit

Perform the following procedure for installing the auxiliary cooler kit:

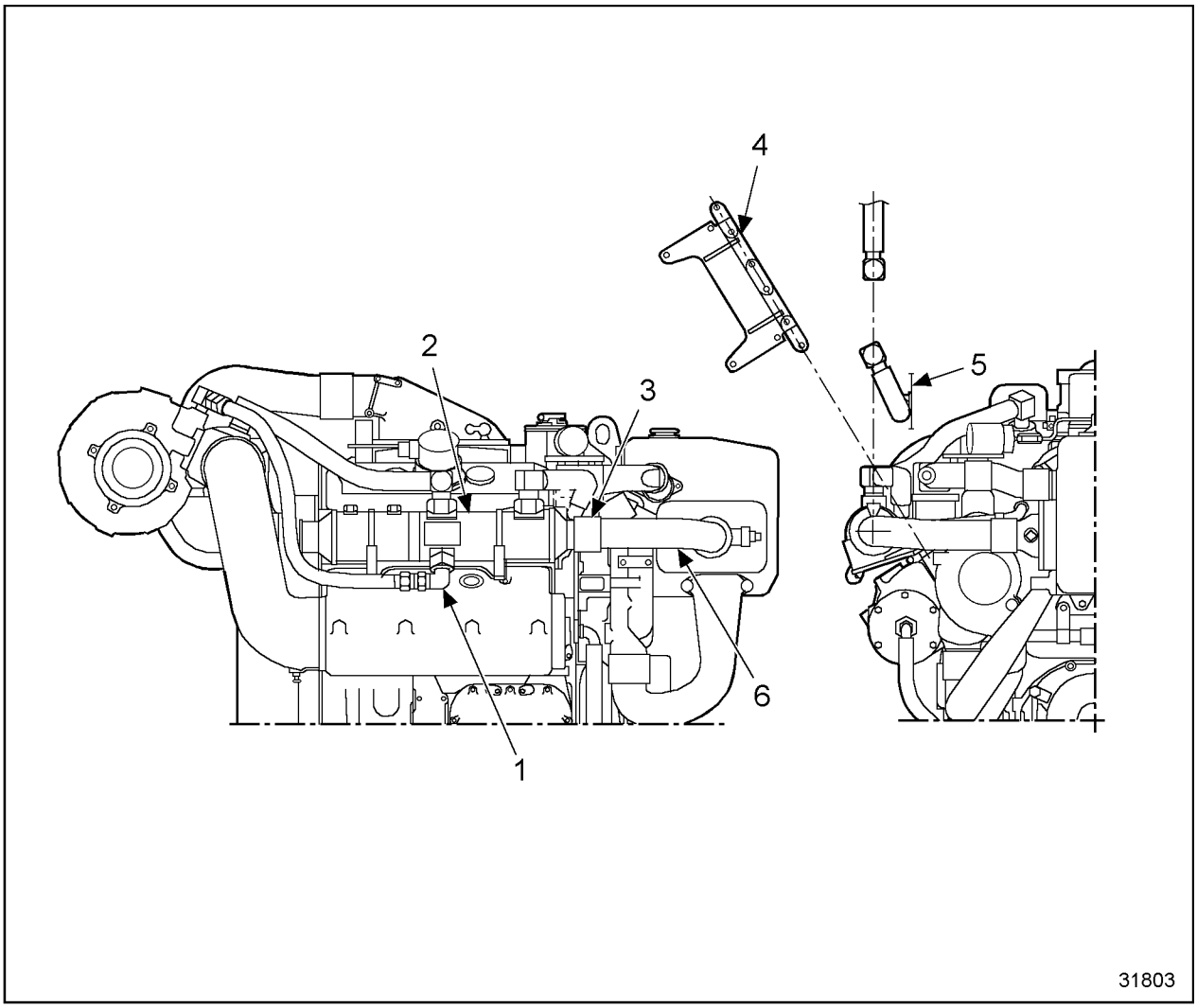
1. Remove the elbow that attaches the water manifold to the turbocharger water return hose, and install it on the bottom inlet of the auxiliary cooler. See Figure 4-65 and see Figure 4-66.



1. Cooler Mounting Bracket
2. Tube Heat Exchanger-to-Cooler; Raw Water
3. Cooler
4. Elbow (90 Degree)

Figure 4-65 Port Engine

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1. Elbow
2. Cooler
3. Hose (2)
4. Cooler Mounting Bracket
5. Thermostat Housing
6. Tube

Figure 4-66 Starboard Engine

2. Install the water return elbow into the thermostat housings before installing the coolers.
3. Remove the water manifold studs in the head, and install cover plates to the head with bolts of the appropriate size.

NOTE:
The cooler support bracket will be attached with these bolts, also.

4. Attach the auxiliary cooler loosely to the bracket, then attach the bracket to the cylinder head. Index the cooler and secure it to the bracket by tightening the outboard nut of the U-bolt clamp.

NOTE:
Ensure there is about 3.18 mm (0.125 in.) clearance between the inboard nut of the U-bolt clamp and the exhaust manifold.

5. Remove the old lines from the heat exchanger-mounted gear cooler, and plug the cooler with pipe plugs.

PRIMING THE RAW WATER PUMP

Prime the pump as follow:

NOTICE:
Always prime the raw water pump before starting the engine. Since water acts as a lubricant for the impeller, failure to prime the pump (or at least wet the impeller vanes to induce a self-priming suction) can result in severe impeller damage when the engine is started. Insufficient raw water flow into the heat exchanger caused by a damaged impeller can lead to overheating and subsequent engine damage.

1. Remove the pipe plug from the water inlet elbow.
2. Pour in at least a pint of water.
3. Replace the plug.

NOTE:
The raw water pump should not be run dry for longer than normally required for the pump to prime itself.

RAW WATER PUMP IMPELLERS

The Jabsco raw water pump is equipped with synthetic rubber impellers. Since synthetic rubber begins to lose its elasticity at low temperatures, impellers made of natural rubber may be installed when it is necessary to pump raw water that has a temperature below 4°C (40°F). However, the standard impellers must be used when the pump operates in warmer water.

New service impellers of natural rubber are identified by a stripe of green paint.

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THERMOSTAT FUNCTION TESTING

Thermostat print specifications normally call for three specific operating conditions: start-to-open temperature, full-open temperature, and full-open dimension. The most important of these is the *start-to-open* temperature. This is the temperature at which the motor mechanism (wax compound) experiences a change from a solid to a liquid, expanding and opening the thermostat to allow coolant flow. At full-open temperature, the liquid wax is fully expanded and the full-open dimension is reached, ensuring proper coolant flow to the radiator. The start-to-open temperature is normally stamped or printed on the thermostat.

A relationship exists between the thermostat start-to-open temperature and operating stroke (full-open travel). See Figure 4-67.

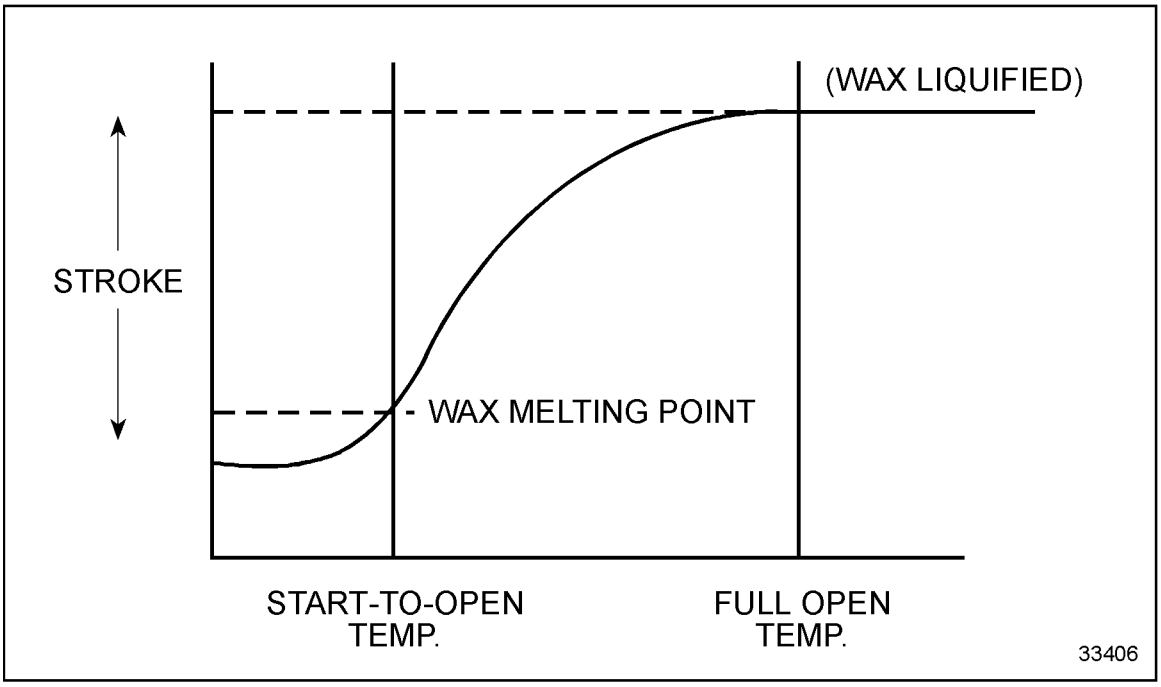


Figure 4-67 Relationship Between Start-to-Open and Operating Stroke (Full-Open)

The normal tolerance for the start-to-open temperature is +1.11°C or -1.67°C (+2°F or -3°F).

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To ensure sufficient coolant flows through the radiator, the thermostat start-to-open temperature and the full-open dimension should be checked. Thermostats may be tested on a simple fixture. See Figure 4-68.

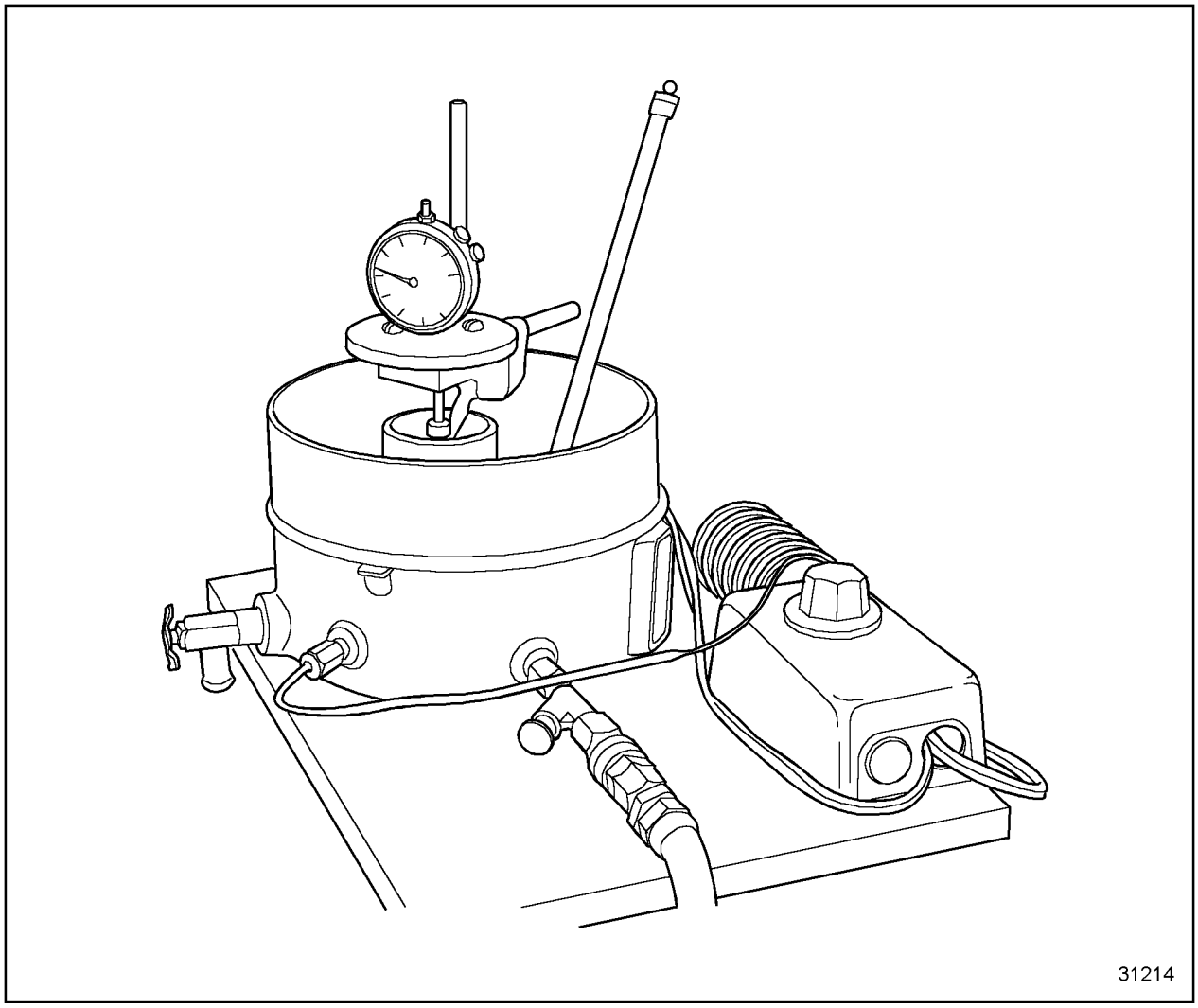


Figure 4-68 Testing a Thermostat in the Test Fixture

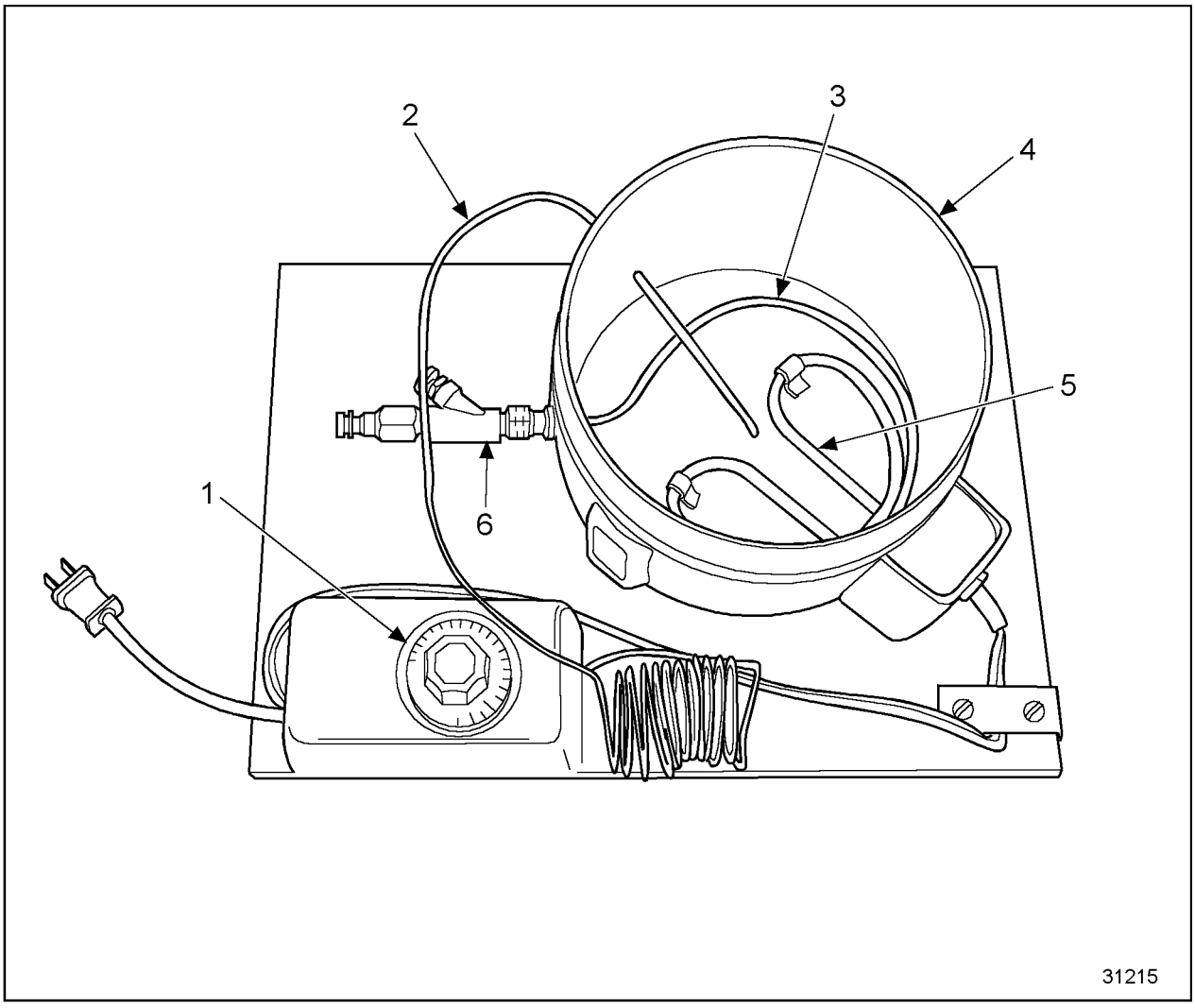
Materials

This fixture can be made from the following readily available materials:

- ☐ 1 - Stainless steel or non-ferrous metal vessel approximately 203.2 mm (8 in.) diameter by 152.4 mm (6 in.) deep
- ☐ 1 - 2000 watt immersion-type heating element
- ☐ 1 - Thermostatic control having a 15.6°-110°C (60°-230°F) temperature range and a capillary tube sensing device
- ☐ 1 - 304.8 mm (12 in.) length of 6.4 mm (0.25 in.) copper tubing
- ☐ 1 - 9.53 mm (0.375 in.) drain valve

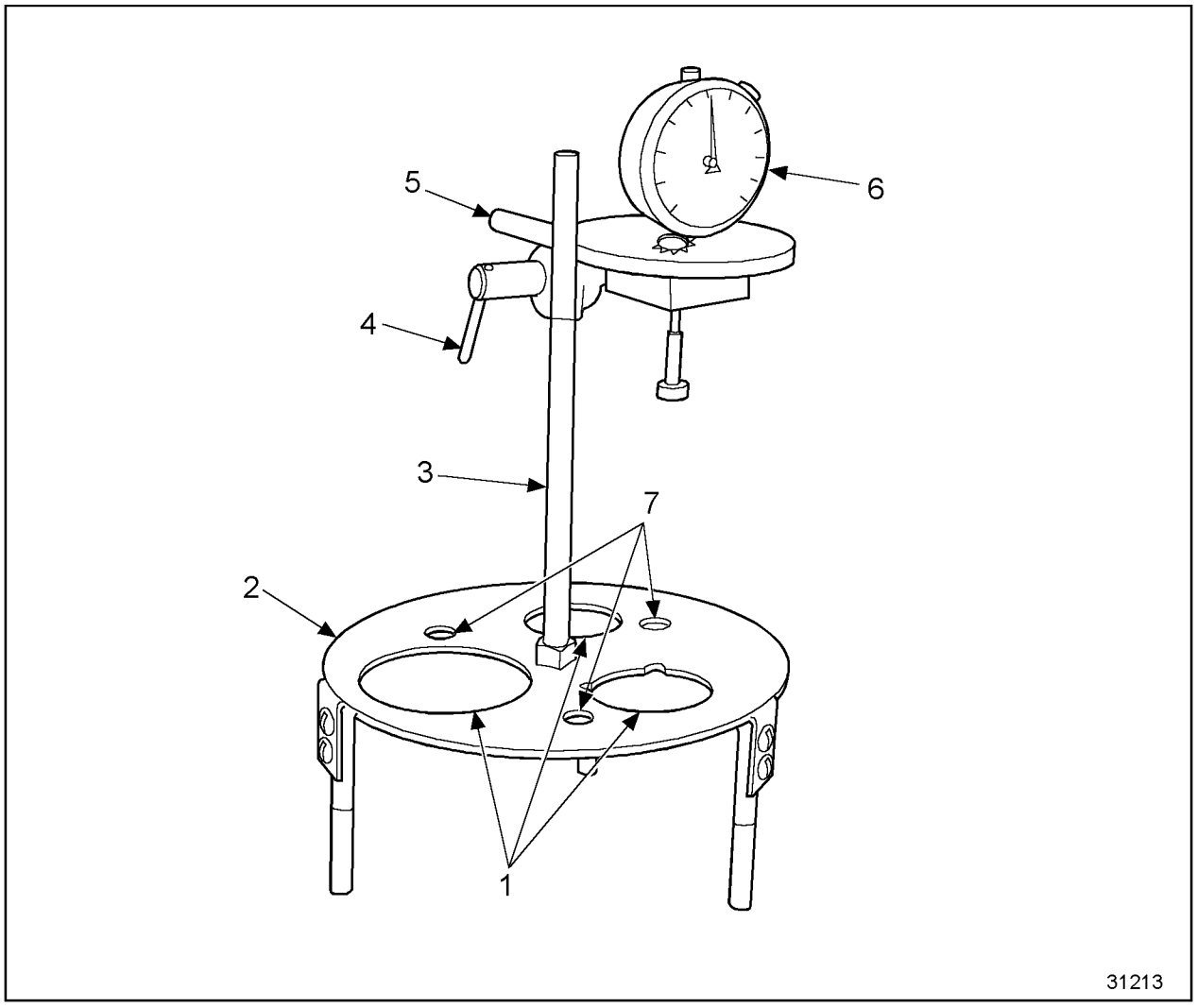
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- ☐ 1 - 190.5 mm (7.5 in.) diameter piece of 12-gage galvanized sheet steel or 3.18 mm (0.125 in.) aluminum (for bed plate)
- ☐ 1 - Bulkhead fitting
- ☐ 1 - Air control valve
- ☐ 1 - Laboratory thermometer with a range of 15.6°-110°C (60°-230°F)
- ☐ 1 - Dial indicator having a one inch travel with a 9.53 mm (0.375 in.) gage holding rod and swivel post lock screwThe thermostat test fixture consists of the test vessel with control and the test plate assembly. See Figure 4-69 and see Figure 4-70.



1. Thermostatic Control
2. Capillary Tube
3. Aeration Line
4. Vessel
5. Immersion Heating Element
6. Air Valve

Figure 4-69 Test Vessel and Control



1. Thermostat Bore
2. Bed Plate
3. Upright Base Post
4. Swivel Post Snug
5. Gage Holding Rod
6. Dial Indicator
7. Thermometer Holes

Figure 4-70 Test Plate Assembly

Making the Test Fixture

Perform the following steps for making the test fixture:

1. Drill a 3.18 mm (0.125 in.) hole in the vessel side, and braze a bulkhead fitting to the vessel to accept an air control valve.

NOTE:
Shop air will be used to agitate the water and relieve temperature stratification within the vessel.

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2. Manufacture an aeration line from a 304.8 mm (12 in.) length of 6.4 mm (0.25 in.) copper tubing by drilling four equally spaced 3.18 mm (0.125 in.) holes in the tube and crimping or blocking one end.
3. Attach the open end of the tube to the air valve, and bend the tube to the inside contour of the vessel.
4. Install a 9.53 mm (0.375 in.) drain valve in the lower portion of the vessel.
5. Fabricate the bed plate from 12-gage galvanized steel or 9.53 mm (0.375 in.) aluminum sheet stock.

NOTE:
The bed plate is used to suspend the thermostat at a mid-point in the vessel. This component must fit squarely in the vessel and have legs of sufficient length to ensure that stats will not contact the heating element and aeration line.

6. Bore 39.6875 mm, 50.8 mm, and 69.85 mm (1.5625 in., 2 in., and 2.75 in.) holes in the plate spaced 120 degrees from each other to facilitate the variety of stats installed.
7. Drill three 11.113 mm (0.4375 in.) holes at 60 degrees from each thermostat mounting bore for conveniently locating a thermometer during testing.
8. Install a 3/8 in. x 8 in. upright base post in the center of the plate to provide the mounting for a dial indicator.
9. Attach the dial indicator gage to the upright center post of the plate to permit accurate thermostat travel measurement.

NOTE:
The bed plate and dial indicator shown have components added to raise the indicator vertically above the gage holding rod. The extra items are not required.

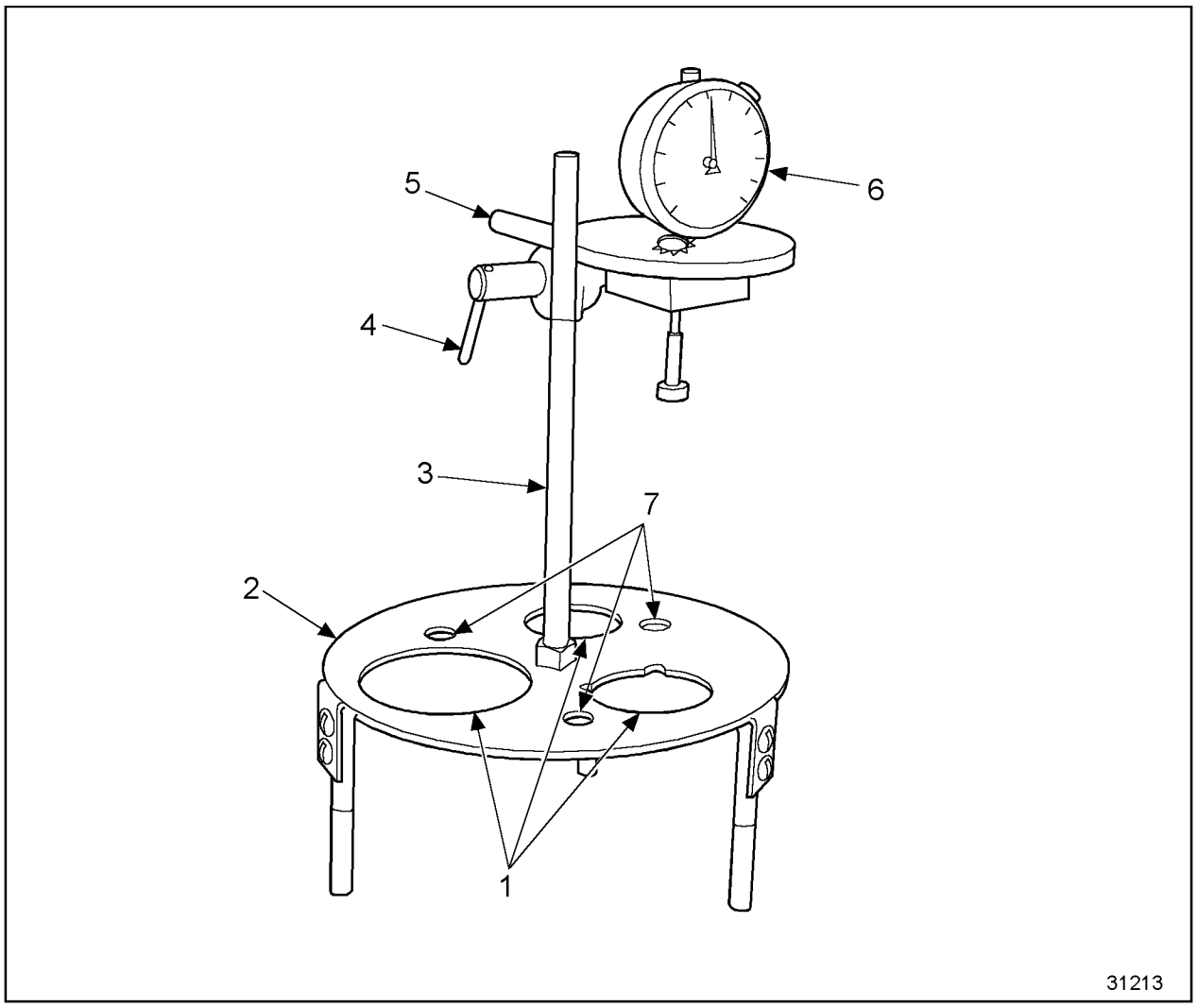
Thermostat Testing Procedure

Test the thermostat as follows:

NOTE:
This procedure will take time to do properly.

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1. Place the vessel on a level surface and lower the bed plate into position. See Figure 4-71.



1. Thermostat Bore
2. Bed Plate
3. Upright Base Post
4. Swivel Post Snug
5. Gage Holding Rod
6. Dial Indicator
7. Thermometer Holes

Figure 4-71 Test Plate Assembly

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⚠ CAUTION:

To avoid injury from scalding, use lifting tools and wear heat-resistant gloves when retrieving the thermostat from boiling water.

2. Fully submerge the thermostat in warm water, and place a laboratory thermometer in one of the 11.113 mm (0.4375 in.) holes on the bed plate.
3. Position the dial indicator over the thermostat.
4. Center the contact point on the motor mechanism, and set the dial to zero.

NOTE:
To ensure accurate test results, allow the thermostat to warm up to water temperature before testing.

5. Turn on the heating element (if necessary), and bring water temperature to a few degrees below the start-to-open temperature of the thermostat being tested. Hold at this temperature for 2-3 minutes.
6. With the heating element on, adjust the air valve to sufficiently agitate the water for equal heat distribution.
7. Bring bath temperature to the maximum specified start-to-open temperature of the thermostat.
8. Observe the dial indicator, and note the temperature at which the needle begins to move.

NOTE:
This is referred to as the *start-to-open temperature.* The total indicator travel, from start-to-open to full-open is referred to as the *full open travel.*

9. For full-open temperature and travel, raise bath temperature a few degrees above the specified full-open temperature. Hold at that temperature for 2 to 3 minutes.

NOTE:
To efficiently test a number of thermostats, simply add cold water to the vessel. This will reduce the water temperature to a level below the next thermostat opening temperature, thus saving time.

10. Turn the heating element off after completing the tests.

CONDUCTING COOLING TESTS

When conducting cooling tests on an engine, radiator/heat exchanger coolant must flow. Coolant flow and the accuracy of cooling system test results depend largely upon the condition of the thermostat installation. If maximum flow does not occur, check for these causes:

1. Thermostat(s) not blocked open to correct dimension.

2. Thermostat housing seal(s) is missing.
3. Thermostat housing seal(s) is worn.
4. Thermostat housing cover bypass cavity sealing surface(s) is not centered and/or worn.

FIND COOLANT LEAKS WITH FLUORESCENT DYE, BLACK LIGHT

Finding the source of an engine coolant leak is often a time-consuming affair. To speed the process, a fluorescent dye such as *15174 Uranine* (or equivalent) may be added to the coolant. Under an ultraviolet "black light," the Uranine dye-treated coolant turns a highly visible, bright yellow-green color, making the leak path easy to trace.

15174 Uranine is manufactured by Chemcentral Corporation and is available through their distributor network. For further information contact:

CHEMCENTRAL CORPORATION

7050 West 71st Street

Chicago, Illinois 60638

FAN HUB GREASE FITTING

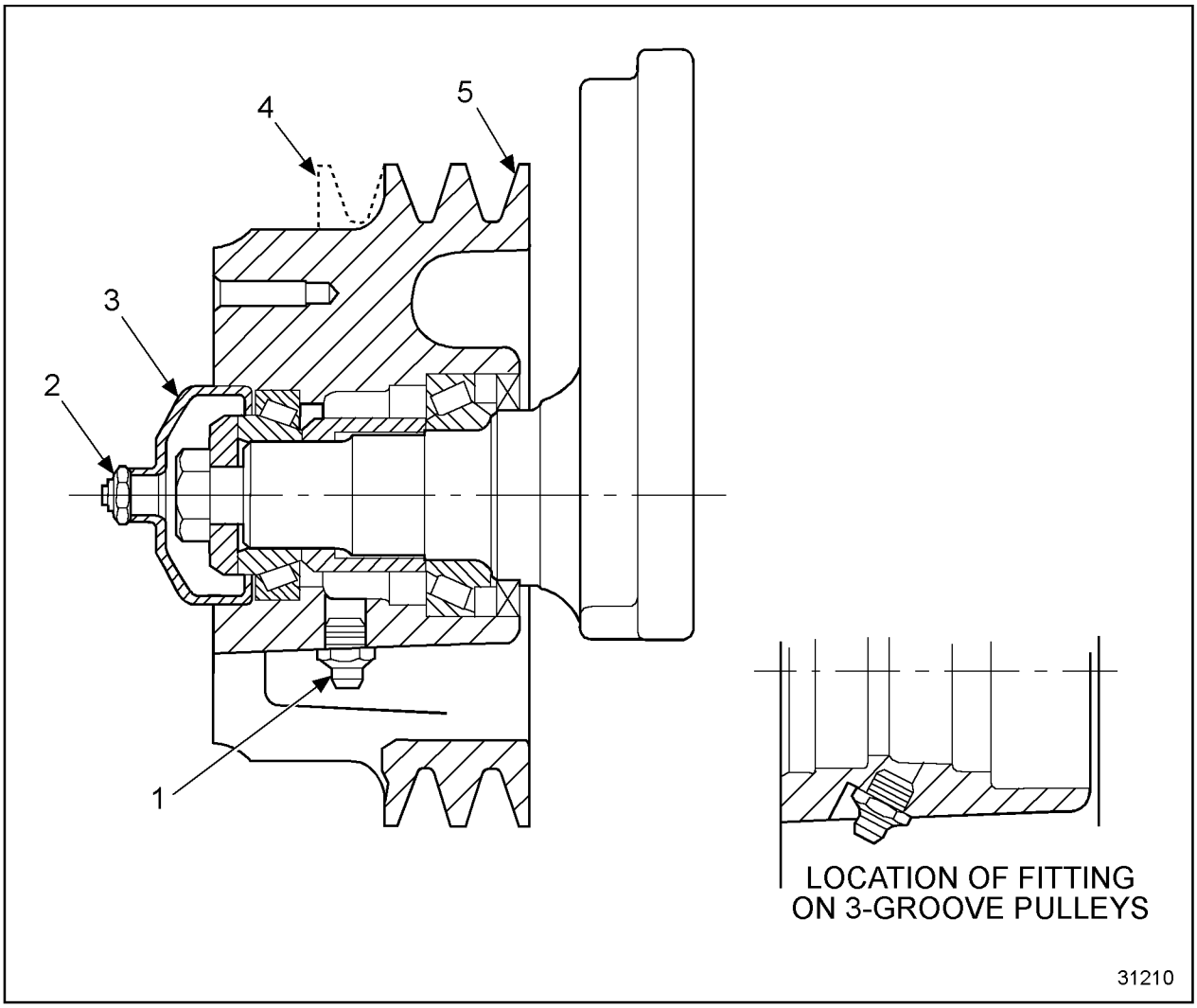
A grease fitting may be added to former fan hub assemblies used on vehicle engines to permit periodic lubrication of the bearings.

Rework the fan hub as follows:

1. Disassemble the fan hub assembly, and clean the parts thoroughly. Refer to section 4.8.3.

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2. Drill and tap the fan hub to accept a 1/8 in. PTF x 11/16 in. threaded lubricator fitting. See Figure 4-72.



1. Grease Fitting
2. Relief Valve
3. Fan Hub Cap
4. Pulley (3 Groove)
5. Pulley (2 Groove)

Figure 4-72 Location of Fan Hub Grease Fitting and Relief Valve

3. Clean the hub to remove any metal chips.
4. Assemble the fan hub. Refer to section 4.8.7.

NOTE:
Discard the former grease retainer. It is not required when a grease fitting is used.

5. Install a new fan hub cap which is threaded for a relief valve.

6. Install a grease fitting in the fan hub and a relief valve in the fan hub cap. For the maintenance schedule, refer to section 13.33.

DRAINING JABSCO RAW WATER PUMP

Although all engine units are provided with draincocks for draining the cooling system, a small amount of coolant may remain in the impeller housing of a Jabsco pump.

Under normal circumstances, there is no need to completely drain the impeller housing of a raw water pump. Therefore, no drain plug has been incorporated. However, certain models employ a raw water pump in conjunction with a fresh water cooling system.

If the engine is to be stored in below freezing temperatures, in addition to draining the cooling system of the engine unit, the impeller housing of the Jabsco pump should be completely drained.

1. Loosen the five (5) fillister head screws that attach the end cover to the pump housing at the impeller end of the pump.
2. Pull the end cover away from the pump body, taking care to avoid damaging the gasket.

NOTE:
The screws need only be loosened sufficiently to completely drain the impeller housing.

3. Tighten the screws.

RAW WATER PUMP IMPELLERS

The Jabsco raw water pump is equipped with synthetic rubber impellers. Since synthetic rubber begins to lose elasticity at low temperatures, impellers made of natural rubber may be installed when pumping raw water with a temperature below 4°C (40°F).

New service impellers of natural rubber are identified by a stripe of green paint.

Standard impellers must be used when the pump operates in warmer water.

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LEFT-BANK MANIFOLD WATER SUPPLY (MARINE ENGINES 12V)

In April 1991, the left-bank manifold water supply changed location from the S tube between the water pump and the oil coolers. This change supplies more water to the manifold and eliminates the possibility of a flow restriction. If a left-bank manifold cracks, update the engine to the new water supply. When repairing one engine on a boat, rework the other engine also. See Figure 4-73.

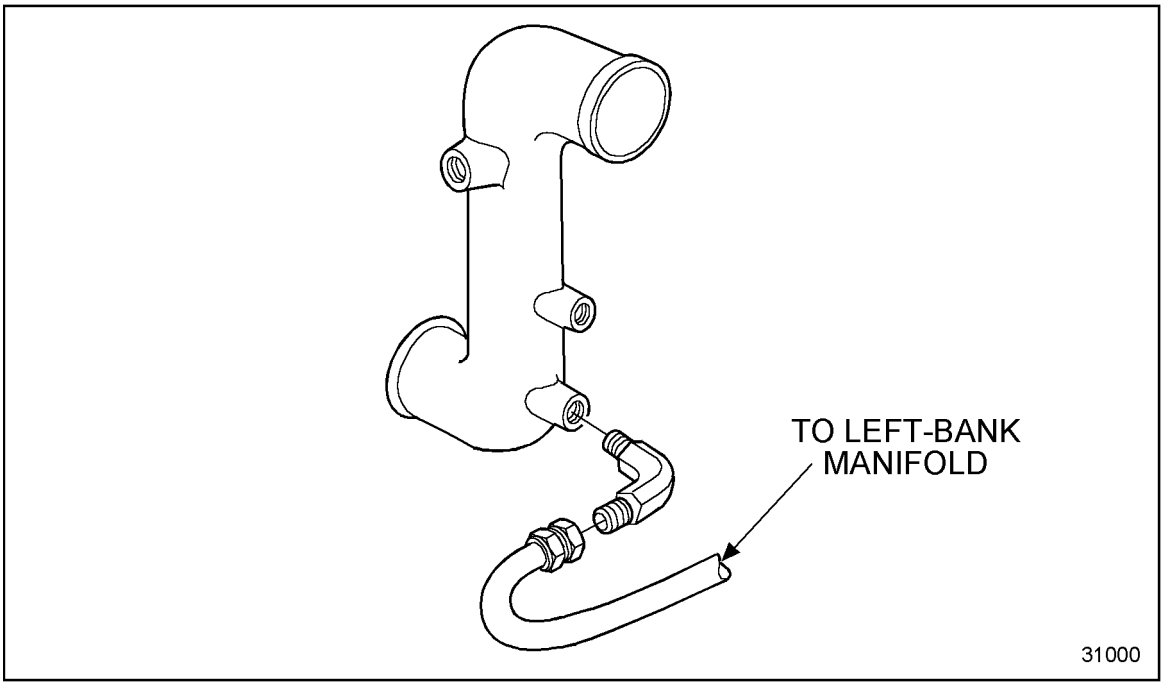


Figure 4-73 Current S Tube with Left-Bank Manifold

NEW CONSTANT-TORQUE HOSE CLAMPS ON FORWARD PLAN(MARINE ENGINES)

New constant-torque hose clamps are installed on all forward plan marine engines. These worm-drive, stainless steel clamps feature a series of Belleville spring washers that maintain consistent sealing pressure and an integral liner that covers the band slots, protecting the hose from damage.

Constant-torque clamps automatically adjust their diameters to compensate for the normal expansion and contraction of hose and metal connections that occurs during engine operation and shutdown. This greatly minimizes clamp maintenance.

The new clamps replace the standard worm-drive clamps on all forward plan marine water hose connections and on certain breather, oil drain, and air inlet hose connections.

Constant-torque clamps are properly tightened during engine assembly. There is no need to torque clamps on a regular basis.

The former standard worm-drive hose clamps will continue to be used in other engine applications. However, because of the virtually maintenance-free sealing provided by the new clamps, DDC recommends using them when replacing a forward plan marine engine water hose.

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Install the clamps as follows:

NOTICE:
Do not overtighten or attempt to torque. Hose clamps will break.

Using an accurately calibrated torque wrench, tighten the clamp screw to 10.17 ± 1.13 N·m (90 ± 10 lb·in).

NOTE:
When torqued to specification, the Belleville washer stacks should be nearly collapsed flat and the screw tip should extend beyond the housing approximately 3/16 in. This indicates the clamp is properly installed and is maintaining a leak-proof connection.

HEAT EXCHANGER EXPANSION TANK SIGHT GLASS REPLACEMENT

Many heat exchanger expansion tanks used with Detroit Diesel marine engines are equipped with low coolant level sight glasses.

If a sight glass is damaged and requires replacement, assembly 23507178 can be used to service all three designs.

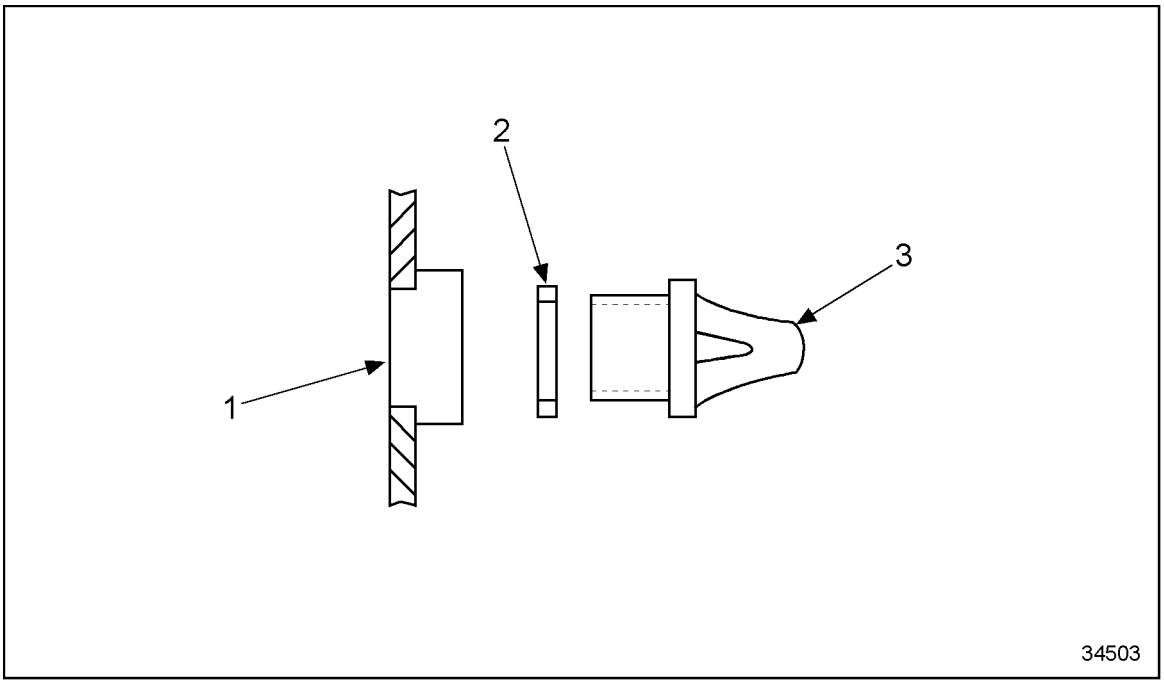
Replacement of Threaded Type Sight Glass

When replacing the threaded glass type sight glasses, reuse the O-ring seal.

1. Install the O-ring seal over the male threads of the sight glass adaptor.

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2. Thread the assembly into the sight glass boss until the assembly bottoms against the adaptor in the top tank. See Figure 4-74.



1. Boss
2. O-ring
3. Glass

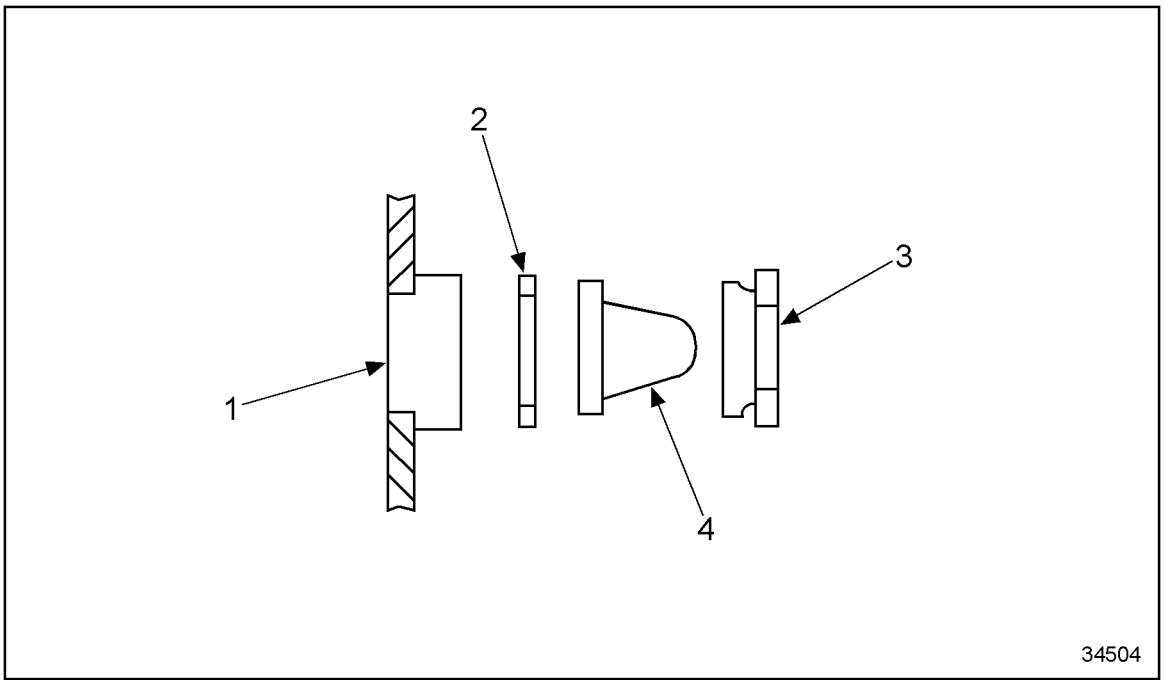
Figure 4-74 Threaded Glass

Replacement of Flange Type Sight Glass

When servicing flange type sight glasses that have been welded or brazed to the top tank, disassemble 23507178. Use only the components needed to make the repair. See Figure 4-75.

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1. Tighten the sight glass retaining nut until the hex bottoms against the adaptor.



1. Boss
2. O-ring
3. Nut
4. Glass

Figure 4-75 Flanged Glass with Adaptor Welded to Tank

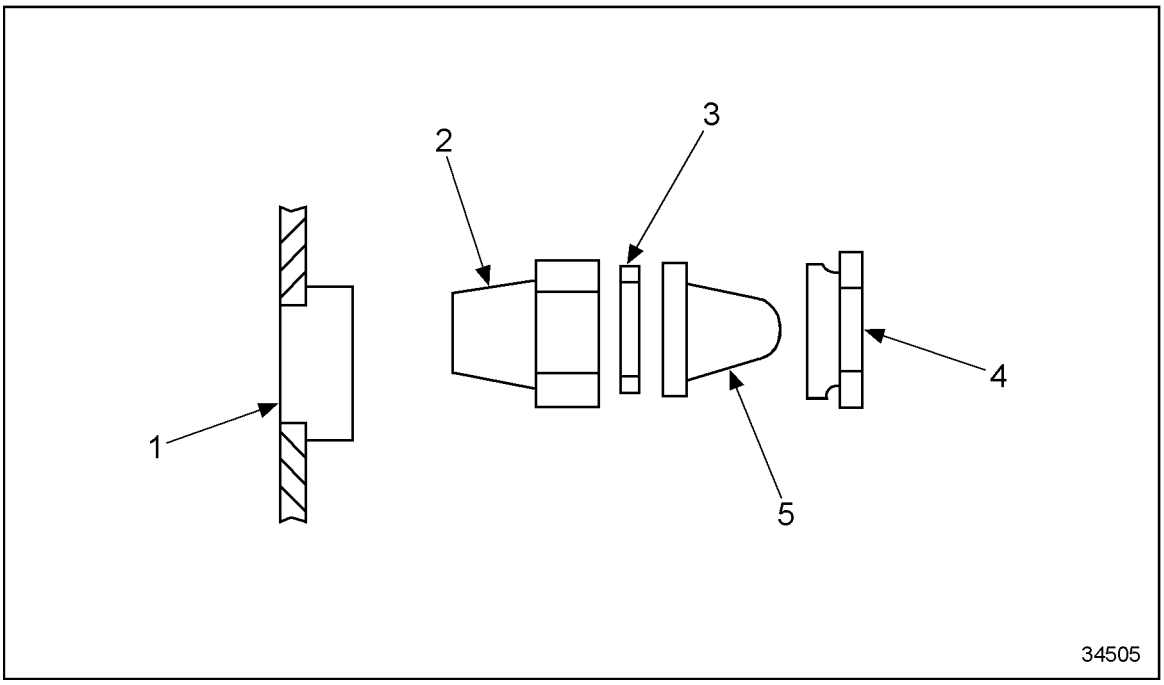
Replacement of Flange Type Sight Glass with Adaptor

Replace the flange type sight glass with the sight glass adaptor as follows:

1. Thread sight glass into a 1/2 in. NPTF boss on the expansion tank.

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2. Remove the old assembly and replace with 23507178. See Figure 4-76.



1. Boss
2. Adaptor
3. O-ring
4. Nut
5. Glass

Figure 4-76 Flanged Glass with 0.50 in. NPTF Boss/Welded to Tank

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

Listed in Table 4-1 are the exceptions to standard bolt and nut torque specifications.

Application	Thread Size	Torque
Water Outlet Cover Plate Bolt	3/8-16	27-34 N·m (20-25 lb·ft)
Water Manifold Nut	3/8-24	27-34 N·m (20-25 lb·ft)
Water Pump Impeller Retaining Nut	7/16-20	47-54 N·m (35-40 lb·ft)

Table 4-1 Exceptions to Standard Bolt and Nut Torque Specifications

STUD TORQUE SPECIFICATIONS

Listed in Table 4-2 are the exceptions to standard bolt and nut torque specifications.

Application	N·m	lb·ft
Water Pump Body (16V)	14-27	10-20
Water Pump Stud (16V)	16-20	12-15

Table 4-2 Stud Torque Specifications

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5 FUEL, LUBRICATING OIL, AND COOLANT

Section		Page
5.1	FUEL	5-3
5.2	LUBRICATING OIL REQUIREMENTS	5-19
5.3	COOLANT	5-28

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5.1 FUEL

Selection of the proper quality of fuel and lubricating oil is important to achieve the long and trouble-free service for which Detroit Diesel engines are designed. Operation with improper fuels and lubricants can cause engine damage. Malfunctions attributable to neglect or failure to follow manufacturer's fuel or lubricating recommendations may not be covered by the warranty.

A Detroit Diesel Corporation extended warranty program (Power Protection Plan) requirement is that the customer use the lubricants, fuels, and filters recommended.

It is Detroit Diesel's policy to build engines which will operate satisfactorily with fuels and lubricants available in the commercial market. However, not all fuels and lubricants are adequate. Product selection should be made based on these recommendations and in consultation with a reliable supplier who understands the equipment and its application.

5.1.1 Quality and Selection

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. 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 provided satisfactory performance. The ASTM D 975 specification, however, does not in itself adequately define the fuel characteristics required for fuel quality assurance.

5.1.1.1 Fuel Lubricity

Some 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.

5.1.1.2 Biodiesel Fuels

Biodiesel fuels may be produced from a wide variety of sources and may be used in all DDC engines provided they are derived from soy methyl ester (SME) and rape methyl ester (RME) and are blended to a maximum of 20% by volume in diesel fuel. The resulting blend must meet the properties listed in Table 5-1.

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General Fuel Classification	ASTM Test Method	No. 1 ASTM 1-D	No. 2 ASTM 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	D 2622	0.5 ‡	0.5 ‡
Cloud Point °F (°C) †	D 2500	Note 1	Note 1
Cetane Number., Minimum	D 613	45	45
Cetane Index, Minimum †	D 4737	40	40
Distillation % Volume Recovery, °F (°C) IBP, Typical * 10% Typical * 50% Typical * 90% Maximum † 95% Maximum * Recovered Volume, % Minimum *	D 86	- 350 (177) 385 (196) 425 (218) 500 (260) 550 (288) 98	- 375 (191) 430 (221) 510 (266) 625 (329) 671 (355) 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
Dupont Pad Test, Rating Maximum *	TM-F21-61 §	7	7
Lubricity, gm, Maximum *	D-6078 ‖	2800	2800

* Not specified ASTM D 975

† Differs from ASTM D 975

‡ Sulfur content of diesel fuel for use in on-road vehicles is limited to 0.5% maximum.

§ Alternate test method for predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

‖ Scuffing Load Ball on Cylinder Wear Test. Higher values indicate less wear and greater lubricity.

No. 2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

1. The cloud point should be 6°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals. When prolonged idling periods or cold weather conditions below 0°C (32°F) are encountered, use of 1-D fuel is recommended.

Table 5-1 Diesel Fuel Specifications

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Although such blends purport to reduce exhaust emission particulates, they increase engine exhaust nitrogen oxides content. They also tend to have poorer thermal stability and may deteriorate engine oil TBN more rapidly than wholly petroleum-based diesel fuels. Use of these fuels may require a reduction in oil drain interval. These fuel blends have not been fully evaluated relative to diesel fuel system durability or engine oil effects.

5.1.1.3 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, @ 60°F	44.3	41.1	45.6	42.3	34.2	38.5
Flash Point, °C	38	62	45	50	74	70
Viscosity, Kin., cSt @ 40°C	-	1.5	1.2	1.69	2.8	3.0
Cloud Point °C	-40	-46	-47	-41	-12	-19
Sulfur, % mass	0.3 Maximum	0.4 Maximum	0.4 Maximum	0.05 Maximum	0.05 Maximum	0.03 Maximum
Cetene Number	-	42	45	44	47	49
Distillation % Vol. Recovered., °C						
IBP	-	180	157	174	190	176
10% Typical	205	191	175	196	222	219
50% Typical	Report	215	200	219	265	365
90% Maximum	Report	242	236	246	313	311
Final Boiling Point, Maximum Temperature	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

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Type	NATO Specification	Mil Specification	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-T-83133	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
DL-1/DL-2	F-54	W-F-800 Conus	Specified Military Use Inside Continental US
DF-2	F-54	W-F-800 Oconus	Specified Military Use Outside Continental US

Table 5-3 Fuel Type Specifications and Applications

Lower density fuels, such as those listed in Table 5-3 and "winter blended" diesel fuels, have a lower volumetric heat content than the standard 2-D fuel listed in Table 5-4, *"Diesel Fuel Specification"*. 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.*

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General Fuel Classification	ASTM Test Method	No. 1 ASTM 1-D	No. 2 ASTM 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	D 2622	0.5 ‡	0.5 ‡
Cloud Point °F (°C) †	D 2500	Note 1	Note 1
Cetane Number., Minimum	D 613	45	45
Cetane Index, Minimum †	D 4737	40	40
Distillation % Volume Recovery, °F (°C) IBP, Typical * IBP, Typical * 10% Typical * 50% Typical * 90% Maximum † 95% Maximum * Recovered Volume, % Minimum *	D 86	 350 (177) 385 (196) 425 (218) 500 (260) 550 (288) 98	 375 (191) 430 (221) 510 (266) 625 (329) 671 (355) 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
Dupont Pad Test, Rating Maximum *	TM-F21-61 §	7	7
Lubricity, gm, Maximum *	D-6078 ‖	2800	2800

* Not specified ASTM D 975

† Differs from ASTM D 975

‡ Sulfur content of diesel fuel for use in on-road vehicles is limited to 0.5% maximum.

§ Alternate test method for predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

‖ Scuffing Load Ball on Cylinder Wear Test. Higher values indicate less wear and greater lubricity.

No.2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

1. The cloud point should be 6°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals. When prolonged idling periods or cold weather conditions below 0°C (32°F) are encountered, use of 1-D fuel is recommended.

Table 5-4 Diesel Fuel Specifications

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Lower density fuels also tend to have lower viscosity and poor lubrication characteristics. Secondary fuel filtration should be changed to Power Guard ™ Plus Filters (recommended for severe duty service) to prevent potential injector seizure from dirt contamination of fuel. Listed in Table 5-5.

Engine	Quantity	Power Guard Primary Fuel Filter	Quantity	Power Guard Secondary Fuel Filter	Power Guard Plus Secondary Fuel Filter
6V-92	1	23518481	1	23518482	23518530
8V-92	1	23518481	1	23518482	23518530
12V-92	1	23518528	1	23518532	23518529
16V-92	1	23518528	1	23518532	23518529

Table 5-5 Spin-On Fuel Filter Elements

5.1.1.4 Heavy Fuels Not Recommended

Heavy fuels intended for use in slow speed diesel engines and as burner fuel are not recommended for use in any Detroit Diesel engine. Marine fuels specified by ASTM D2069 (ISO 8217) are examples of such fuels. These fuels are known to cause combustion deposits and will likely reduce engine durability.

5.1.1.5 Premium Diesel Fuel

Several oil companies market fuels they designate as "premium" diesel fuel. This fuel will typically have a higher cetane number and lower density than ASTM D975 2D fuel. These fuels will also have a performance additive package. Although premium diesel fuels are not covered by any existing industry specification, they may be used in DDC engines. It is recommended that the customer obtain additional information from the fuel marketer and compare properties to those listed in Table 5-6, *"Diesel Fuel Specification"*, before using.

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General Fuel Classification	ASTM Test Method	No. 1 ASTM 1-D	No. 2 ASTM 2-D #
API Gravity, @ 60°F *	D 287	40-44	34-38
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Flash Point, °C, Minimum	D 93	38	52
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Cloud Point °F (°C) †	D 2500	Note 1	Note 1
Cetane Number., Minimum	D 613	45	45
Cetane Index, Minimum †	D 4737	40	40
Distillation % Volume Recovery, °F (°C) IBP, Typical * 10% Typical * 50% Typical * 90% Maximum † 95% Maximum * Recovered Volume, % Minimum *	D 86	 350 (177) 385 (196) 425 (218) 500 (260) 550 (288) 98	 375 (191) 430 (221) 510 (266) 625 (329) 671 (355) 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
Dupont Pad Test, Rating Maximum *	TM-F21-61 §	7	7
Lubricity, gm, Maximum *	D-6078 ‖	2800	2800

* Not specified ASTM D 975

† Differs from ASTM D 975

‡ Sulfur content of diesel fuel for use in on-road vehicles is limited to 0.5% maximum.

§ Alternate test method for predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

‖ Scuffing Load Ball on Cylinder Wear Test. Higher values indicate less wear and greater lubricity.

No.2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

1. The cloud point should be 6°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals. When prolonged idling periods or cold weather conditions below 0°C (32°F) are encountered, use of 1-D fuel is recommended.

Table 5-6 Diesel Fuel Specifications

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5.1.2 Diesel Fuel Selection Criteria

The boiling range indicates the temperature range over which the fuel turns to a vapor, and is a very important property in considering diesel fuel quality. Lower boiling range fuels, such as No. 1D, have a higher volatility, while fuels such as No. 2D fuel are of lower volatility and higher temperature boiling range. Higher volatility fuels are preferred in conditions of prolonged idling, such as city coach applications, or in cold temperatures. The determination of boiling range is made using ASTM Test Method D86 or D2887 (Gas Chromotography Test Method).

5.1.2.1 Distillation

Although many specifications contain only a partial listing of the distillation results (Distillation Temperature at 90% Recovered, for example), this is not enough to determine the quality and suitability of the fuel for use in diesel engines. Diesel fuels are blended products which may contain high boiling temperature constituents that can affect combustion. Only fuels with a minimum 98% recovery by distillation should be used. The full boiling range as shown in previous tables should be used for proper selection.

5.1.2.2 95% Boiling Point

Fuel can be burned in an engine only after it has been completely vaporized. The temperature at which the fuel is completely vaporized is described as the "End Point Temperature" in ASTM D 86 Distillation Test Method. Since this temperature is difficult to measure with good repeatability, the fuel's 90% or 95% distillation point is often used. DDC specifies the 95% temperature because it is closer to the end point than the 90% used by ASTM in D975.

5.1.2.3 Cetane Number

Cetane Number is a relative measure of the time delay between the beginning of fuel injection and the start of combustion. In cold engine starting a low cetane number will cause difficult starting and white exhaust smoke until the engine warms up. In engines with charge air cooling a low cetane number fuel may also cause white exhaust smoke during light load operation.

A minimum cetane number of 45 is specified for best engine performance. However, the cetane number alone should not be considered when selecting a quality fuel. Other properties, such as 95% distillation temperature and carbon residue, should also be considered.

Calculated Cetane Index is sometimes reported instead of Cetane Number. Cetane Index is an empirical property determined mathematically from boiling range temperatures and specific gravity of the fuel, whereas Cetane Number is determined through an engine test. Additives may be used by the fuel marketer to improve the cetane number; however, they have no effect on cetane index. Both properties should be evaluated when selecting diesel fuel.

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5.1.2.4 Fuel Stability

Diesel fuel oxidizes in the presence of air, heat, and water, particularity if the fuel contains cracked products which are relatively unstable. The oxidation of fuel can result in the formation of undesirable gums and black sediment. Such undesirable products can cause filter plugging, combustion chamber deposit formation, and gumming or lacquering of injection system components with resultant reduced engine performance and fuel economy. Two tests are specified for fuel stability, ASTM Test Method D 2274 which measures diesel fuel storage oxidative stability and the DuPont Pad Test which measures in-use stability. The DuPont test should be conducted at 149 C (300 F). The results of the DuPont Pad Test are based on a visual rating of the filter pad in a range from 1 to 20, 1 being clean. ASTM D2274 is a weighed measure of the sediment filtered from the fuel after storage. Although the results of D 2274 may vary with actual field storage, it does measure characteristics which will affect fuel storage stability for periods of up to 12 months.

5.1.2.5 Fuel Sulfur Content

Diesel fuel sulfur content above 0.3% mass causes premature ring and cylinder wear and deposit formation. It has also been identified as a major contributor to exhaust particulates, which became a federal regulated exhaust constituent in 1988. Fuel sulfur was limited to 0.05% for U.S. on-highway engines beginning in October 1993 to reduce particulate emissions.

Diesel fuels with low sulfur content should be selected. If the use of fuels with sulfur contents above 0.5% are unavoidable, lube oil drain intervals and lubricant selection need to be changed. Detroit Diesel recommends that the Total Base Number (TBN D 4739) of the lubricant be monitored and that the oil drain interval be reduced.

The Environmental Protection Agency (EPA) has mandated that all 1994 model year on-highway diesel engines manufactured for use in the United States must meet a new reduced exhaust particulate content of 0.10 gram/horsepower-hour. Refer to section 5.2.1.7 *“Oil Drain Intervals"*.

5.1.2.6 Fuel Operating Temperature and Viscosity

Since diesel fuel provides cooling of the injection system, the temperature of the fuel may vary considerably due to engine operating temperature. As fuel temperature increases, fuel viscosity decreases, along with the lubrication capabilities of the fuel. Maintaining proper fuel temperatures and selecting fuels with the viscosity ranges listed in Table 5-7, *"Diesel Fuel Specification"*, will assure proper injection system functioning.

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General Fuel Classification	ASTM Test Method	No. 1 ASTM 1-D	No. 2 ASTM 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	D 2622	0.5 ‡	0.5 ‡
Cloud Point °F (°C) †	D 2500	Note 1	Note 1
Cetane Number., Minimum	D 613	45	45
Cetane Index, Minimum †	D 4737	40	40
Distillation % Volume Recovery, °F (°C) IBP, Typical *10% Typical *50% Typical *90% Maximum †95% Maximum *Recovered Volume, % Minimum *	D 86	350 (177) 385 (196) 425 (218) 500 (260) 550 (288) 98	375 (191) 430 (221) 510 (266) 625 (329) 671 (355) 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
Dupont Pad Test, Rating Maximum *	TM-F21-61 §	7	7
Lubricity, gm, Maximum *	D-6078 ‖	2800	2800

* Not specified ASTM D 975

† Differs from ASTM D 975

‡ Sulfur content of diesel fuel for use in on-road vehicles is limited to 0.5% maximum.

§ Alternate test method for predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

‖ Scuffing Load Ball on Cylinder Wear Test. Higher values indicate less wear and greater lubricity.

No.2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

1. The cloud point should be 6°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals. When prolonged idling periods or cold weather conditions below 0°C (32°F) are encountered, use of 1-D fuel is recommended.

Table 5-7 Diesel Fuel Specifications

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When operating with reduced fuel viscosity or elevated fuel temperatures the injectors will operate at reduced internal clearances. As a result, dirt and smaller particulate material may cause injector durability concerns. Secondary filters on Detroit Diesel two stroke-cycle engines should be changed to Power Guard Plus Filters (recommended for severe duty service) listed in Table 5-8. Installing a fuel cooler or operating with fuel tanks above half full may also help eliminate the concern.

Engine	Quantity	Power Guard Primary Fuel Filter	Quantity	Power Guard Secondary Fuel Filter	Power Guard Plus Secondary Fuel Filter
6V-92	1	23518481	1	23518482	23518530
8V-92	1	23518481	1	23518482	23518530
12V-92	1	23518528	1	23518532	23518529
16V-92	1	23518528	1	23518532	23518529

Table 5-8 Spin-On Fuel Filter Elements

5.1.2.7 Fuel Additives

Detroit Diesel engines are designed to operate satisfactorily on a wide range of diesel fuels. The regular use of supplemental fuel additives is not required or recommended. Some additives may be beneficial in addressing temporary fuel quality problems but should not replace proper fuel selection and handling.

5.1.2.8 Water Contamination

Some fuel additives provide temporary benefit when fuel is contaminated with water. They are not intended to replace good fuel handling practices. Where water contamination is a concern, the fuel system should be equipped with a fuel/water separator which should be serviced regularly. In marine and other 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.

When small amounts of water are present, supplemental additives containing methyl carbitol or butyl cellusolve are effective. Follow the manufacturer instructions for their use.

NOTE:
The use of isopropyl alcohol is no longer recommended due to its negative effect on fuel lubricity.

5.1.2.9 Prohibited Fuel Additives

The following fuel additives are not allowed:

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 section 5.2.1.6 on *"Waste Oil Disposal and Re-refined 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.

5.1.2.10 Evaluation of Supplemental Fuel Additives

There are many supplements available today which are intended to be added to the fuel by the customer. These include a variety of independently marketed products which claim to be:

- Cetane Improvers
- Emission Control Additives
- Detergents
- Combustion Improvers
- Smoke Suppressants
- Cold Weather Flow Improvers

Should a customer decide that a supplemental additive is to be used, the following is intended to provide guidance to the customer in evaluating potential safety hazards and deleterious engine effects:

NOTE:
Detroit Diesel will not test or verify the performance of any supplemental fuel additives

- A Material Safety Data Sheet (MSDS) should be carefully reviewed for special handling instructions and hazardous material content. Additives containing hazardous materials should not be used due to personal safety risk.
- A detailed compositional analysis should be provided by the supplier. Ash forming metallic elements and corrosive elements must not be present. Additives containing calcium, barium, zinc, phosphorous, sodium, magnesium, iron, copper, and manganese are known to cause combustion ash deposits which can foul fuel injectors and create deposits which may adversely affect cylinder life. Halogenated compounds containing chloride, fluoride, and bromide, are corrosive, as are some sulfur containing compounds. The use of additives with these components should be avoided.
- Many commercial diesel fuels today contain performance additives, particularly those marketed as "premium" diesel fuel. Any supplemental additive being considered must be compatible with the fuel it will be used in.DDC suggests that a mixture containing twice

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the recommended concentration of additive be evaluated for compatibility to represent an overdosage condition, using the tests listed in Table 5-9.

General Fuel Classification	ASTM Test Method	No. 1 ASTM 1-D	No. 2 ASTM 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	D 2622	0.5 ‡	0.5 ‡
Cloud Point °F (°C) †	D 2500	Note 1	Note 1
Cetane Number., Minimum	D 613	45	45
Cetane Index, Minimum †	D 4737	40	40
Distillation % Volume Recovery, °F (°C) IBP, Typical *10% Typical *50% Typical *90% Maximum †95% Maximum *Recovered Volume, % Minimum *	D 86	350 (177) 385 (196) 425 (218) 500 (260) 550 (288) 98	375 (191) 430 (221) 510 (266) 625 (329) 671 (355) 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
Dupont Pad Test, Rating Maximum *	TM-F21-61 §	7	7
Lubricity, gm, Maximum *	D-6078 ‖	2800	2800

* Not specified ASTM D 975

† Differs from ASTM D 975

‡ Sulfur content of diesel fuel for use in on-road vehicles is limited to 0.5% maximum.

§ Alternate test method for predicting fuel stability. The visual rating is related to amount of particulate collected, on a scale of 1 (clean) to 20 (dirty).

‖ Scuffing Load Ball on Cylinder Wear Test. Higher values indicate less wear and greater lubricity.

No.2 diesel fuel may be used in city coach engine models which have been certified to pass Federal and California emission standards.

Note 1: The cloud point should be 6°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

When prolonged idling periods or cold weather conditions below 0°C (32°F) are encountered, use of 1-D fuel is recommended.

Table 5-9 Diesel Fuel Specifications

- Performance evaluation of a fuel supplemental additive should be conducted in customer equipment for a minimum of six months. Testing should be a side-by-side comparison with

and without the additive to verify performance claims. Testimonials are not substantial claims of performance.

NOTICE:
Supplemental fuel additives are not recommended due to potential injector system or engine damage.

Our experience has been that such additives increase operating costs without providing benefit.

NOTE:
The use of supplemental fuel additives does not necessarily void the engine warranty. However, repair expenses which result from fuel system or engine component malfunctions or damage attributed to their use will not be covered.

These products should be accompanied with performance data supporting their merit. It is not the policy of Detroit Diesel Corporation to test, evaluate, approve, or endorse such products.

5.1.3 Diesel Fuel Storage and Cleanliness

Fuel oil should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, and sludge.

NOTICE:
Do not use galvanized steel or sheet metal tanks and galvanized pipes or fittings in any diesel fuel storage, delivery, or fuel system. The fuel oil will react chemically with the zinc coating, forming a compound which can clog fuel filters causing damage to the fuel pump and injectors.

Tanks should be drained and cleaned, if contaminated. Diesel tanks can be made of monel, stainless steel, black iron, welded steel or reinforced (non-reactive) plastic.

5.1.4 Filtration

Filters make up an integral part of fuel and lubricating oil systems. Proper filter selection and maintenance are important to satisfactory engine operation and service life. Filters, however, should be used to maintain a clean system, not to clean up a contaminated system.

5.1.4.1 Specifications

Filter performance and test specifications vary between manufacturers. The filters shown in this section have been qualified to appropriate SAE performance specifications and meet Detroit Diesel requirements. Other brands of filters may be used, provided they have equivalent demonstrated performance.

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5.1.4.2 Spin-On Fuel Filters

Regular duty Power Guard and Severe Duty Power Guard Plus spin-on fuel filters are listed in Table 5-10.

Engine	Quantity	Power Guard Primary Fuel Filter	Quantity	Power Guard Secondary Fuel Filter	Power Guard Plus Secondary Fuel Filter
6V-92	1	23518481	1	23518482	23518530
8V-92	1	23518481	1	23518482	23518530
12V-92	1	23518528	1	23518532	23518529
16V-92	1	23518528	1	23518532	23518529

Table 5-10 Spin-On Fuel Filter Elements

5.1.4.3 Fuel Pro Fuel Filters

Fuel Pro fuel filters are listed in Table 5-11.

Fuel Filter	Part Number
Fuel Pro 230	23519978
Fuel Pro 321	23518481
Fuel Pro 380	23514049
Fuel Pro 40 Mega Filter	23512631

Table 5-11 Fuel Pro® Fuel Filter Elements

5.1.4.4 Sea Pro Fuel Filters

Sea Pro fuel filters are listed in Table 5-12.

Fuel Filter	Part Number
Sea Pro 50/100 (30 Micron Filter)	23519851
Sea Pro 50/100 (5 Micron Filter)	23519852
Sea Pro 150/300 (20 Micron Filter)	23518169
Sea Pro 150/300 (30 Micron Filter)	23518168
Sea Pro 600 (20 Micron Filter)	23519404
Sea Pro 600 (30 Micron Filter)	23519405
Water In-Fuel Sensor Kit	23518182

Table 5-12 Sea Pro® Fuel Filter Elements

5.1.4.5 Cartridge Type Fuel Filters

Cartridge type fuel filters are listed in Table 5-13.

Engine Series	DDC Part Number Primary Fuel Filter	DDC Part Number Secondary Fuel Filter
6V-92	23519151	23519152
8V-92	23519151	23519152
12V-92	23519153	23519154
16V-92	23519153	23519154

Table 5-13 Cartridge Type Fuel Filter Elements

5.1.4.6 Spin-On Lubricating Oil Filters

Spin-on lubricating oil filters are listed in Table 5-14.

Engine	Quantity	Power Guard	Power Guard Plus
6V-92	1	23518671	23518524
8V-92	1	23518671	23518624
12V-92	2 or 4	23518671	23518524
16V-92	2 or 4	23518671	23518524

Table 5-14 Spin-On Lubricating Oil Filters

Finer filtration will generally provide increased engine service life, but may require shorter filter change intervals. Detroit Diesel specifies filter performance based on the optimum combination of filter micron rating, filter capacity, and mechanical requirements (assembly integrity).

5.1.4.7 Aftermarket Filtration

The aftermarket supplemental filtration systems may be used, provided they do not replace the factory-installed system or reduce oil volumes, pressures, or flow rates delivered to the engine. The use of such systems does not address oil degradation from normal use and, therefore, does not permit extension of oil drain intervals. Fuel filters must be properly sized to provide the proper fuel flow to the engine. A fuel/water separator, if used, must be installed between the fuel tank and the inlet side of the engine fuel pump.

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5.2 LUBRICATING OIL REQUIREMENTS

Engine service life depends upon selecting the proper lubricating oil and maintaining proper oil and filter change intervals.

Hundreds of commercial oils are marketed today, but labeling terminology differs among suppliers and can be confusing. Some manufacturers may claim that their lubricant is suitable for all makes of diesel engines and may list engine makes and types, including Detroit Diesel, on their containers. Such claims by themselves are insufficient as a method of lubricant selection for Detroit Diesel engines.

The proper lubricating oil for all Detroit Diesel engines is selected based on SAE Viscosity Grade and API (American Petroleum Institute) Service Designation. Both of these properties are displayed in the API symbol which is illustrated within the specific requirements. See Figure 5-1.

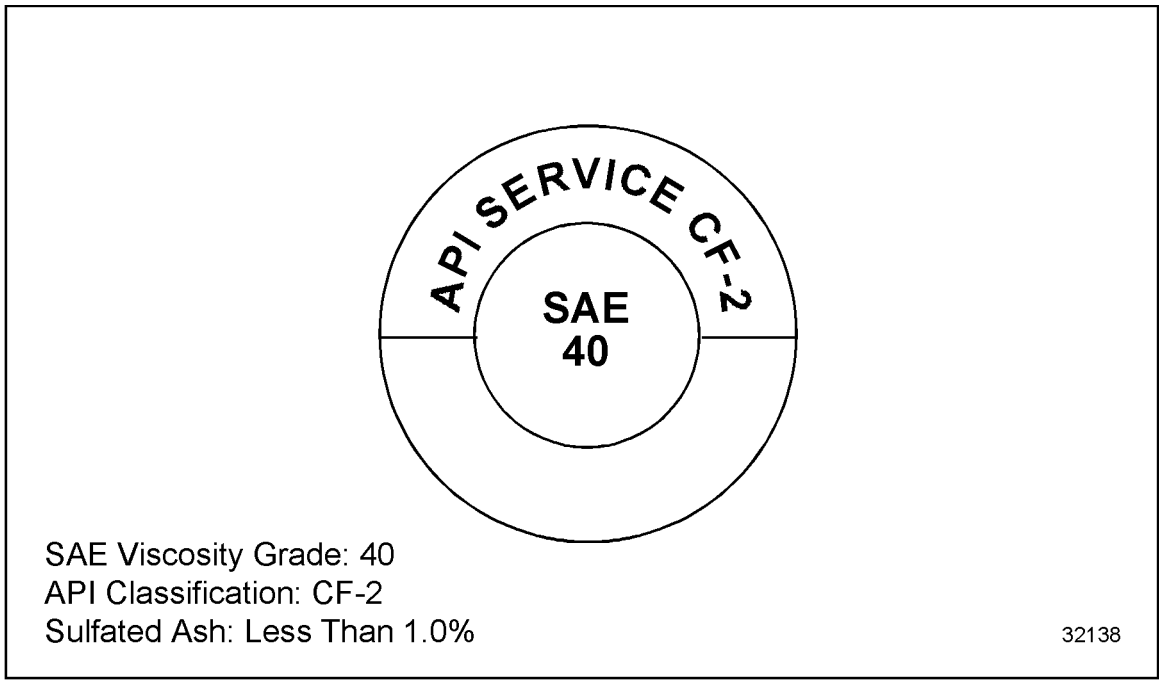


Figure 5-1 API Symbol

5.2.1 Lubricant Requirements

For Detroit Diesel Series 92 engines, the proper lubricant must possess additional requirements.

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The selection of the correct lubricating oil for Series 92 engines is dependent upon the engine application and the fuel sulfur content. The guidelines listed in Table 5-15 should be used to select the proper engine oil type.

Engine Series	Fuel Sulfur Content	Recommended Oil Type Primary	Recommended Oil Type Secondary
53, 71, 92 All Applications	Less Than 0.5%	1, 2	3, 4
53, 71, 92 All Applications	0.5 to 1.0%	1*	4

* The use of oils under these conditions requires a reduction in oil drain interval. For further information, refer to section 5.2.1.9, *"The Use of High Sulfur Fuel"* in this section.

Table 5-15 Oil Type Selection Guidelines

After determining the proper oil type for the application and the anticipated fuel sulfur content, the specifications listed in Table 5-16 should be used to identify the type of lubricant required.

Oil Type	1	2	3	4
API Classification *	CF-2	CF-2	CF-2	CF-2 or LMOA Gen IV/V †
Viscosity Grade ‡	40 §	40 §	50 ††	50 ††
Sulfated Ash ‖	1.0% max	0.8% max	0.8% max	NS
Alkalinity (ASTM D2896)	7.0 min #	7.0 min #	7.0 min #	13.0 min
Calcium, ppm	No Limit	No Limit	500 max	No Limit
Zinc, ppm	* *	* *	* *	100 max
Phosphorous, ppm	* *	* *	* *	100 max

* Only oils which are licensed by the American Petroleum Institute are recommended in Detroit Diesel Series 92 engines. Licensed Oils display the API Symbol: See Figure 5-1.

† LMOA = Locomotive Maintenance Officers' Association.

‡ For continuous high temperature operation over 94°C or (200°F) Coolant Out, the use of an SAE grade 50 lubricant is required for all Series 92 engines.

§ At ambient temperatures below freezing 0°C or (32°F) sufficient starter cranking speed may not be achieved to start the engine with SAE 40 grade oils. Where starting aids are not available or at very cold temperatures 18-32°C or (0-25°F), even if starting aids are available, the use of multigrade SAE 15W-40 or monograde SAE 30 lubricants will improve startability. These lubricants must possess a High Temperature - High Shear Rate Viscosity (measured by ASTM D 4741 or equivalent) of 3.70 cP minimum. **These oils must be replaced with monograde SAE 40 lubricants as soon as ambient conditions permit. Do Not use multigrade or SAE 30 grade lubricants in two-stroke marine engines under any circumstances.**

‖ Sulfated ash to be determined by ASTM D874 and the result rounded to the nearest 0.1%.

Engine oils with alkalinity between 6.5 and 7.0 may be used with demonstration of satisfactory performance and review by Detroit Diesel.

* * Although not specified, zinc and phosphorous are recommended to be above 700 ppm.

†† At lower ambient temperatures where sufficient starter cranking speed may not be achieved to start the engine with SAE 50 grade oils. SAE 40 grade oils may be used.

Table 5-16 Oil Type Specifications

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Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules.

Engine oils meeting military specification Mil-L-2104 are intended for use in military engines. Due to the specific operating and life cycle requirements of military engines, the oils for these engines tend to be specialized toward that application. Military specified oils (Mil-L-2104 suffixes A through F) should not be used in commercial Detroit Diesel two-stroke cycle engines *unless they are API CF-2 licensed.*

5.2.1.1 Sulfated Ash and Total Base Number

Sulfated ash is a lubricant property measured by a laboratory test (ASTM D 874) to determine the potential for formation of metallic ash. The ash residue is related to the additive composition of the oil and is significant in predicting lubricants which may cause valve distress under certain operating conditions. Sulfated ash is related to Total Base Number (TBN), which measures the alkalinity of an oil and its ability to neutralize acid using a laboratory test (ASTM D 2896 or D 4739). As TBN increases, sulfated ash also increases to where lubricants with TBN's above 10 will likely have sulfated ash contents above 1.0% mass.

For Series 92 engines Detroit Diesel recommends lubricants with a sulfated ash content below 1.0% mass and TBN's between 7 and 10 (D 2896) for engines operating on less than 0.5% sulfur fuel.

When the use of a high ash oil is required, such as with high sulfur fuel, the oil selected should have the highest TBN (D 2896) to Ash (D 874) ratio possible. For example, an oil with a TBN of 10 and Ash of 1.2% mass is less desirable than an oil with the same TBN and 1.0% Ash. Refer to section 5.2.1.7 for oil drain intervals.

5.2.1.2 Synthetic Oils

Synthetic oils may be used in Detroit Diesel engines, provided they are API licensed and meet the performance and chemical requirements of non-synthetic oils. However, only synthetic oils that *do not* contain viscosity improver additives may be used in Detroit Diesel two-stroke cycle engines. Their use does not automatically permit extension of recommended oil drain intervals.

Product information about synthetic oils should be reviewed carefully. Synthetic oils offer improved low temperature flow properties and high temperature oxidation resistance.

5.2.1.3 Low Zinc, High TBN Marine Industrial Diesel Lubricants(Type 4 Oil)

Marine and railroad lubricants are recommended for use in Detroit Diesel two-stroke cycle engines where fuel sulfur content exceeds 0.5%. These oils may also be selected for use when one of the following situations exists:

- ☐ Where there is a risk of resulting exhaust valve distress with a conventional high ash oil.
- ☐ They are required in other equipment and only a single engine lubricant can be inventoried.

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Detroit Diesel markets a Type 4 oil branded as Power Guard/Gard ™ Gold. In addition to meeting DDC two-cycle engine requirements, this lubricant offers advantages of improved low and high temperature performance and oil drain extension.

5.2.1.4 The Use of Supplemental Additives

Lubricants meeting the Detroit Diesel specifications outlined in this chapter contain a carefully balanced additive treatment. The use of supplemental additives, such as break-in oils, top oils, graphitizers and friction-reducing compounds, in these fully formulated lubricants are not necessary and can upset the oil's formulation causing a deterioration in performance. These supplemental additives may be marketed as either oil treatments or engine treatments and should not be used in Detroit Diesel engines. Engine damage resulting from the use of such materials is not covered by your Detroit Diesel Corporation warranty. Detroit Diesel will not provide statements relative to their use beyond this manual.

5.2.1.5 Lubricant Selection Outside North America

Although the API Service Classification System is generally utilized worldwide, lubricants meeting Detroit Diesel requirements may not be marketed in all areas of the world. Selection of lubricants in these situations should be made based on viscosity grade first, ash content second, and performance specification third. Oils meeting API CF may be used if they also meet military specification Mil-L-2104 F. Oils which meet European ACEA E2 or E3 may also be used. Modification of oil drain interval may be necessary, depending on fuel quality. Contact Detroit Diesel Corporation for further guidance.

5.2.1.6 Waste Oil Disposal and Re-refined 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. Re-refining waste oils provides an environmentally viable way of handling this material. Several states have established collection and recycling programs.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

A few states have also designated used oil as a hazardous waste requiring special handling and disposal. Detroit Diesel favors the recycling of waste oil and permits the use of re-refined oils in all engine product lines, provided the re-refined oil meets the SAE Viscosity and API specifications previously mentioned. Refer to section 5.2.1.

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5.2.1.7 Oil Drain Intervals

During use, engine lubricating oil undergoes deterioration from combustion by-products and contamination by the engine. Certain components in a lubricant additive package are designed to deplete with use. For this reason, regardless of the oil formulation, regular oil drain intervals are necessary. These intervals may vary in length, depending on engine operation, fuel quality, and lubricant quality. Generally, shorter oil drain intervals extend engine life through prompt replenishment of the protection qualities in the lubricant.

The oil drain intervals listed in Table 5-17 should be considered **maximum** and listed in Table 5-18 should not be exceeded. Always install new engine oil filters when the oil is changed.

Service Application	Oil Drain Interval
Highway Truck & Motor Coach	15,000 Miles (24,000 km)
City Transit Coaches	6,000 Miles (9,600 km) or 3 Months*
Pick-up & Delivery Stop & Go, Short Trip	12,000 Miles (19,000 km)
Industrial, Agricultural and Marine	150 Hours
Stationary Units, Continuous	300 Hours or 3 Months*
Stationary Units, Standby	150 Hours or 1 Year*

* Whichever comes first

Table 5-17 Maximum Allowable Oil Drain Intervals - Normal Operation with *Low Sulfur Fuel*(0.5% or Less)

Service Application	Oil Drain Interval
Highway Truck & Motor Coach	10,000 Miles (16,000 km)
City Transit Coaches	4,000 Miles (6,400 km) or 3 Months Maximum*
Pick-up & Delivery Stop & Go, Short Trip	8,000 Miles (12,500 km)
Industrial, Agricultural and Marine	150 Hours or 1 Year*
Stationary Units, Continuous	200 Hours or 1 Month*
Stationary Units, Standby	100 Hours or 8 Months*

* Whichever comes first

Table 5-18 Maximum Allowable Oil Drain Intervals - Normal Operation with *High Sulfur Fuel* (Above 0.5%) Use Oil Analysis to Determine Optimum Drain Intervals

5.2.1.8 Extended 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.

5.2.1.9 The Use of High Sulfur Fuels

Although diesel fuels containing more than 0.5% sulfur are considered high sulfur fuels, piston ring wear studies have shown that the combustion of fuels containing more than 0.3% sulfur significantly increases ring face wear rates. See Figure 5-2.

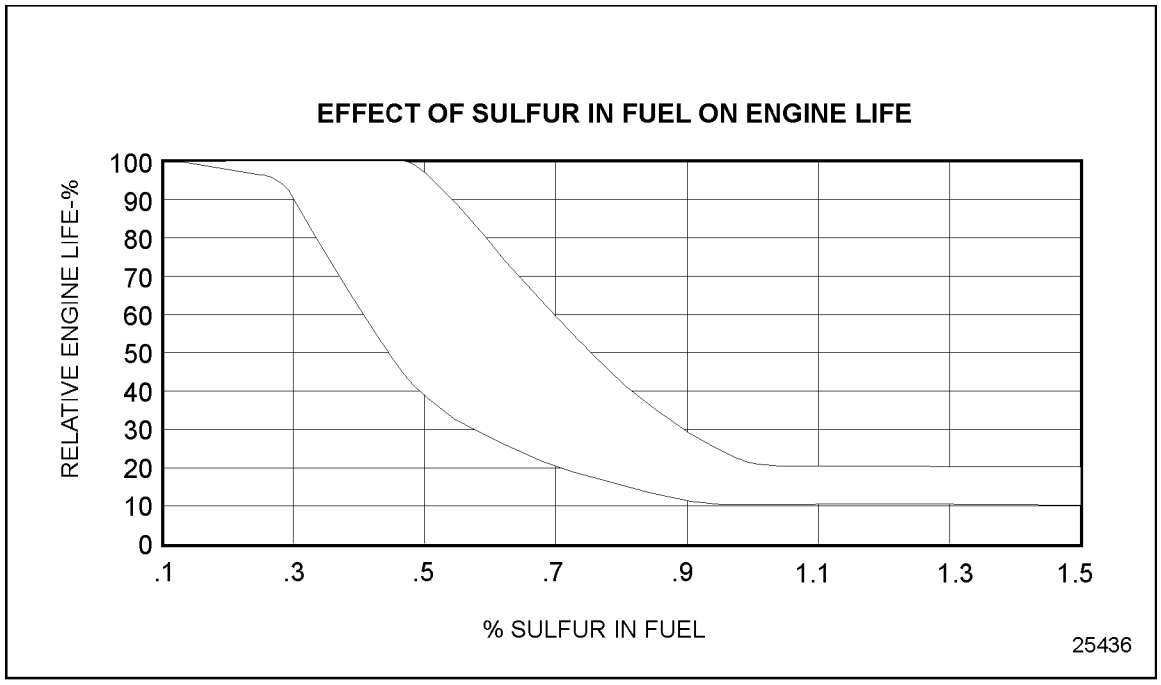


Figure 5-2 Effect of Sulfur in Fuel on Engine Life

High fuel sulfur forms acids during combustion, particularly during idling and low temperature operation. The best defense against the effects of high sulfur fuel is to shorten oil drain intervals. The proper drain interval may be determined by oil analysis or by using the drain intervals listed in Table 5-19.

Service Application	Oil Drain Interval
Highway Truck & Motor Coach	10,000 Miles (16,000 km)
City Transit Coaches	4,000 Miles (6,400 km) or 3 Months Maximum*
Pick-up & Delivery Stop & Go, Short Trip	8,000 Miles (12,500 km)
Industrial, Agricultural and Marine	150 Hours or 1 Year*
Stationary Units, Continuous	200 Hours or 2 Months*
Stationary Units, Standby	100 Hours or 8 Months*

* Whichever comes first

Table 5-19 Maximum Allowable Oil Drain Intervals - Normal Operation with High Sulfur Fuel (Above 0.5%) Use Oil Analysis to Determine Optimum Drain Intervals

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A reduction in TBN (ASTM D 4739) to one-third of the initial value provides a general drain interval guideline. Marine fuels identified as meeting ASTM D2069, Specification for Marine Fuels, should not be used in Detroit Diesel engines due to the high sulfur contents and boiling ranges permitted.

Should it be determined that the oil drain interval is unacceptably short, then the selection of a lubricant with a Total Base Number (TBN per ASTM D 2896) above 10 may be appropriate. Experience has shown, however, that a higher TBN oil with a longer oil change interval is not as effective in protecting the engine from wear. Use the intervals listed in Table 5-19 until the best practical oil drain interval can be established by oil analysis.

Refer to section 5.2.1.3 for type 4 engine oils. These oils have generally demonstrated good performance under these conditions without the exhaust valve guttering (burning) found with conventional higher ash oils.

5.2.1.10 Used Lubricating Oil Analysis

A used oil analysis program such as the Detroit Diesel *Power Trac*® oil analysis program is recommended for monitoring crankcase oil in all engines. Oil analysis consists of a series of laboratory tests conducted on the engine lubricant. Most tests reveal conditions of the engine, while some indicate the condition of the lubricant. The *"Warning Limits*" listed in Table 5-20 show what each test evaluates. Since an oil analysis cannot completely assess the lubricating oil for continued service, it should not be used to extend oil drain intervals. An oil analysis program with regular sampling is recommended, and the oil should be changed immediately if contamination is present in concentrations exceeding the warning limits listed in Table 5-20. If oil contamination is found, refer to section 13.5.5.

Warning Limits	ASTM Designation	Condition Measured	Series 92
Viscosity at 40°C (74°F), cSt % Maximum Increase	D445	Engine and Oil	40.0
Viscosity at 40°C (74°F), cSt % Maximum Decrease	D445	Engine and Oil	15.0
Carbon (Soot) Content, TGA Mass % Maximum	E1131 or LEM℠ †	Engine Combustion	0.8
Pentane Insolubles, % Maximum	D893	Engine Combustion	1.0
Total Base Number (TBN) Minimum	D4739	OIL	1.0
Total Base Number (TBN) Minimum	D2896	OIL	2.0
Water, Volume % Maximum	D1744	Engine	0.30
Fuel, Volume % Maximum	D3524	Engine	2.5
Antifreeze Maximum	D2982	Engine	Negative
Iron, Fe ppm Maximum	D5185	Engine Wear	150 (250*)
Copper, Cu ppm Maximum (Above Baseline)	D5185	Engine Wear	25

* Marine Engines Only

† LEM℠

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 5-20 Single Sample Used Oil Analysis Warning Limits

These limits are provided for guidance for a single sample analysis. It should never be concluded that the engine is worn out based on a single measurement that exceeds the warning level. Imminent engine wearout can only be determined through a continuous oil analysis program wherein the change in data or deviation from baseline data can be used to interpret the condition of engine parts. Confirmation for necessity of engine overhaul should be based upon operational data (for example, increasing oil consumption and crankcase pressure) and physical inspection of parts.

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5.2.1.11 Used Lubricating Oil Analysis Warning Limits

Warning Limits are based on a single oil sample taken by an accepted sampling method. These values indicate the need for an immediate oil change, but do not indicate internal engine malfunctions requiring engine teardown.

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5.3 COOLANT

The following information is provided to guide Detroit Diesel engine users in the selection of a suitable coolant for the cooling system using Detroit Diesel-selected cooling system products. These recommendations are general rules and reflect years of experience, technology research, and product development. Specific concerns not covered here should be addressed to your local Detroit Diesel representative.

The coolant mixture used in Detroit Diesel engines must meet the following basic requirements:

- Provide an adequate heat transfer medium.
- Protect against cavitation damage to both cylinder liners and water pumps.
- Provide a corrosion/erosion-resistant environment within the cooling system.
- Prevent formation of scale or sludge deposits in the cooling system.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze protection.

5.3.1 Initial Fill Coolants

Listed in Table 5-21 are the approved preferred coolants for the Series 92 engine. This section details the proper formulation of these coolants. Once in use, these coolants should be maintained according to procedures. Refer to section 5.3.2(Maintenance).

NOTICE:

Required specifications for water, ethylene glycol, propylene glycol, propylene glycol, inhibitor packages, and inhibitor concentration are included in this coolant section. To avoid possible engine damage from inadequate or over-concentrated coolant, this coolant section should be read thoroughly before replacing coolant.

Coolant Fill Option	Product
Ethylene Glycol and Water + Corrosion Inhibitors *	DDC *Power* Cool®
Commercial Equivalent of DDC *POWER COOL*	Fully Formulated TMC RP-329 Type A Antifreeze and Water
Propylene Glycol and Water + Corrosion Inhibitors	Fully Formulated TMC RP330 Type A Antifreeze and Water
Ethylene Glycol and Water + NOAT Inhibitors	DDC *POWER COOL* Plus
Water Only + Corrosion Inhibitors †	Water + DDC *POWER COOL* 3000
Water Only + NOAT Inhibitors †	Water + DDC *POWER COOL* Plus 6000

* Preferred Coolant

† Water-only coolant systems offer no freeze protection and should not be used where ambient temperatures can fall to 32°F (0°C).

Table 5-21 Initial Fill Coolant Options

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5.3.1.1 Ethylene Glycol/Water + SCA Inhibitor Propylene Glycol/Water + SCA Inhibitor

These products are available as Fully Formulated, Phosphate-Free, Extended Service Interval (ESI) coolants. They are commercially available from Detroit Diesel (recommended) and other manufacturers, as either a concentrated antifreeze or as a premixed antifreeze is ready for use, while the concentrated coolant must be mixed antifreeze is ready for use, while the concentrated coolant must be mixed with water prior to use.

Detroit Diesel *POWER COOL*Engine Coolant (P/N0 23512138) is the preferred ethylene glycol coolant. If other commercial brands of ethylene glycol are used, they must be equivalent to *POWER COOL*. Detroit Diesel does not market a propylene glycol coolant. If a propylene glycol coolant is used, it must also meet the requirements (refer to section 5.3.1.2).

Fully formulated ethylene glycol-based, low silicate antifreeze or coolant must meet TMC RP-329 "Type A" requirements. Fully formulated propylene glycol-based antifreeze does **not** require a dosage of SCA prior to initial use.

5.3.1.2 Mixing EG or PG Antifreeze and Water

If a concentrated Ethylene Glycol (EG) or Propylene Glycol (PG) antifreeze is purchased, mix the antifreeze with water meeting the required quality standards and fill the cooling system. Refer to section 5.3.1.6(Water Requirements). If a prediluted, fully formulated coolant is purchased, simply fill the cooling system. For best overall performance, a coolant consisting of 50% concentration of antifreeze (50% antifreeze, 50% water) is *recommended*. An antifreeze concentration over 67% (67% antifreeze, 33% water) is *not recommended* due to poor heat transfer, reduced freeze protection (IEG only), and possible silicate dropout. An antifreeze concentration below 33% (33% antifreeze, 67% water) offers too little freeze and/or corrosion protection and is *not recommended*.

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See Figure 5-3 for ethylene glycol-based coolant concentration versus freezing and boiling temperatures.

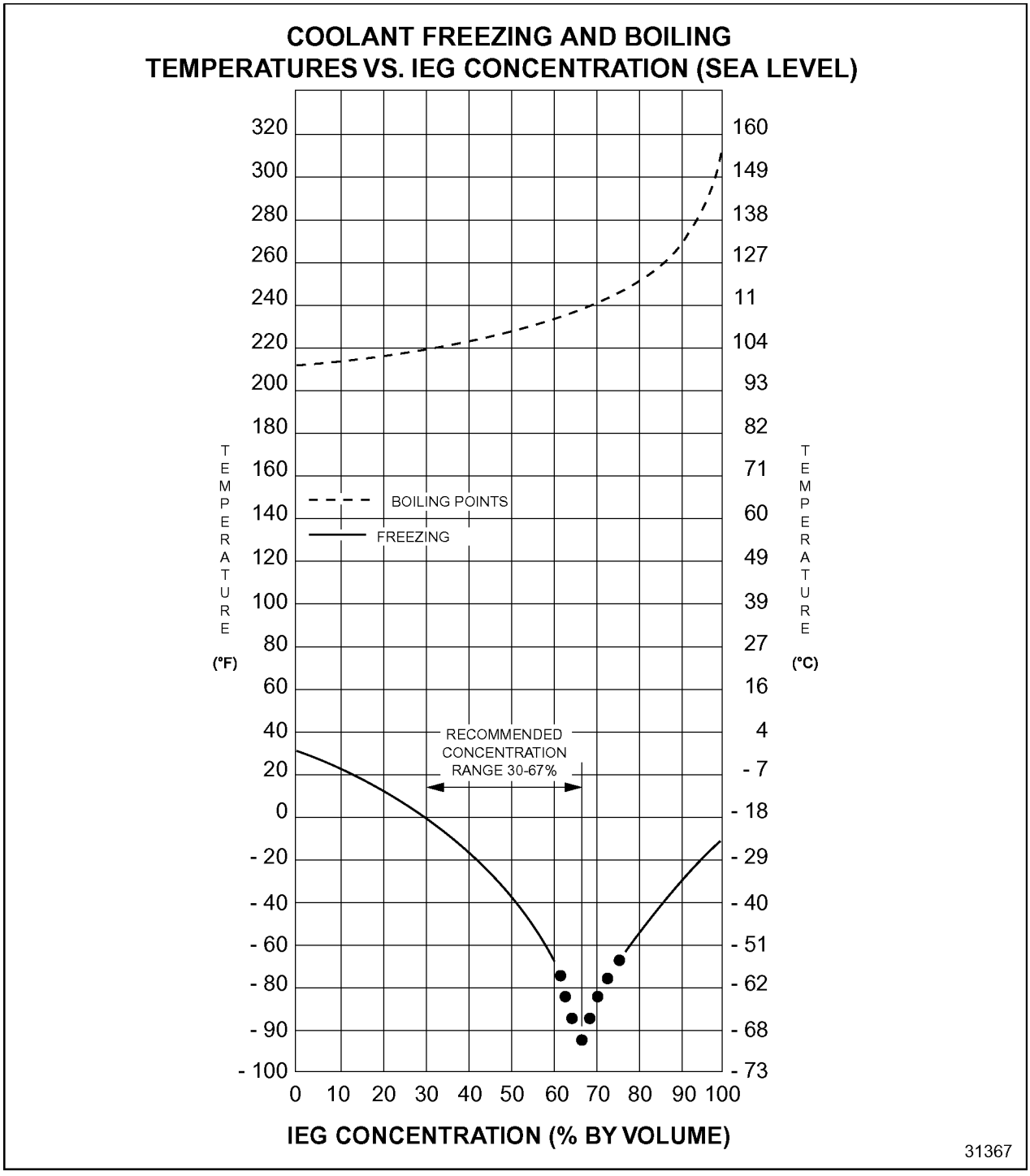


Figure 5-3 Coolant Freezing and Boiling Temperatures vs. Inhibited Ethylene Glycol Concentration (Sea Level)

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See Figure 5-4 for propylene glycol-based coolant concentration versus freezing and boiling temperatures.

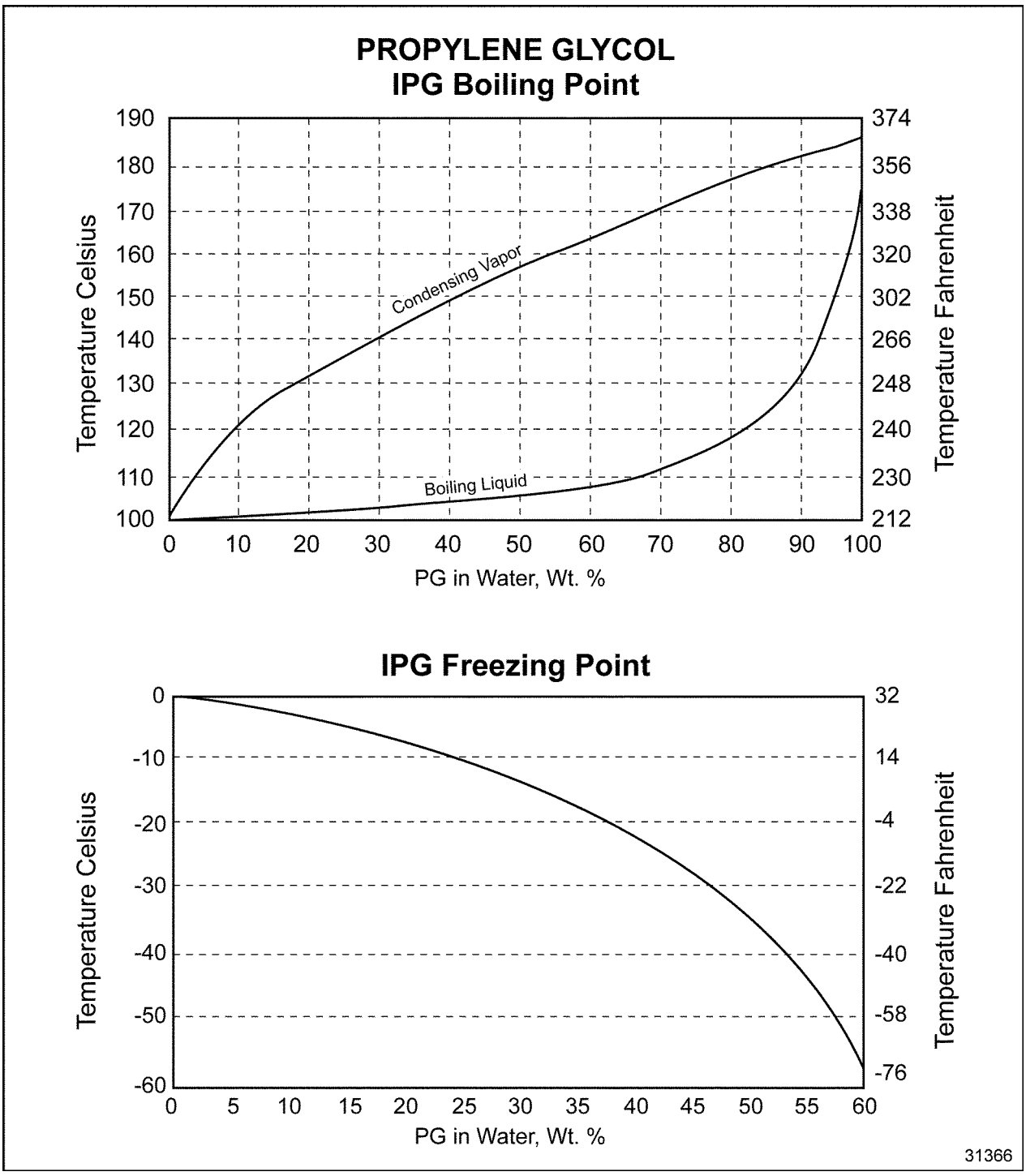


Figure 5-4 Coolant Freezing and Boiling Temperatures vs. Inhibited Propylene Glycol Concentration (Sea Level)

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Always verify that the freeze point and nitrite concentration of the antifreeze/water mix are correct by using a Power Trac 3-Way Test Strip. If chemical analysis is used, elements in the coolant must fall within the limits listed in Table 5-22.

Element	Limits
Boron	125-500 PPM
Nitrite	800-2400 PPM
Nitrate	200-750 PPM
Silicon	50-250 PPM
Phosphate	0 PPM Max.
pH	8.0-11

Table 5-22 Fully Formulated Glycol Coolant Limits with TMC RP-329, RP-330, Chemistry Type A (50/50 Coolant/Water Mixture)

5.3.1.3 Recycled Antifreeze

Antifreeze or coolant recycled by reverse osmosis, distillation, and ion exchange, properly re-inhibited to meet TMC RP-329 "Type A" or RP-330 "Type A" requirements has been demonstrated to provide service equivalent to virgin antifreeze. Recycled antifreeze or coolants of these types are preferred. Other recycled coolants, especially coolants recycled through filtration processes, are not recommended.

5.3.1.4 Ethylene Glycol/Water + NOAT Inhibitor Propylene Glycol/Water + NOAT Inhibitor

Ethylene glycol and propylene glycol are also available with a Nitrite Organic Acid Technology (NOAT) corrosion inhibitor package. These coolants require less maintenance over the useful life of the engine. The cooling system should either be equipped with a "blank" coolant filter or the coolant filter and piping may be omitted from the system.

NOAT fully formulated antifreezes are available as concentrated and premixed. Concentrated antifreezes should be mixed at 50% (50% antifreeze/50% water). NOAT coolants should not be mixed with conventional coolants. If NOAT and conventional coolants are mixed, the coolant should be maintained as a fully formulated ESI coolant, not as a NOAT coolant.

Detroit Diesel markets a NOAT-inhibited ethylene glycol coolant, *DDC POWER COOL* Plus. *POWER COOL* Plus contains all of the required additives. If a non-DDC NOAT antifreeze is used, it must conform to TMC RP 338 specification. *Do not add extender to new NOAT antifreeze or coolant.*

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5.3.1.5 Water Only + SCA (*POWER COOL* 3000) Water Only + NOAT Inhibitor (*POWER COOL* 6000)

In warm climates where freeze protection is not required, water only with corrosion inhibitors is approved for use. Water-only systems need to be treated with the proper dosage of corrosion inhibitors. Detroit Diesel-approved SCAs or NOAT corrosion inhibitors *must* be added to the water to provide required corrosion and cavitation erosion protection. NOAT inhibitors such as *POWER COOL* Plus 6000 are available for water-only systems. Inhibitor should be mixed at 7.5% by volume with water. Traditional SCA (*POWER COOL* 3000) can also be used to protect the engine. Listed in Table 5-23 are the *POWER COOL* 3000 coolant concentration limits.

Element	Limits
Boron	125-500 PPM
Nitrite	800-2400 PPM
Nitrate	0-750 PPM
Silicon	50-400 PPM
Phosphate	0 PPM
pH	8-11.0

Table 5-23 POWER COOL 3000 Concentration Limits, (5% POWER COOL 3000, 95% Water)

POWER COOL 3000 SCA inhibitors should be mixed at 5% by volume with water (1 quart per gallons of water). These additions can be made by adding liquid SCAs available for different cooling system capacities. These filters release the proper amount of SCA at initial fill.

5.3.1.6 Water Requirements

Distilled or de-ionized water which eliminates the adverse effects of minerals in tap water is preferred. High levels of dissolved chlorides, sulfates, magnesium, and calcium in some tap water causes scale deposits, sludge deposits and/or corrosion. These deposits have been shown to result in water pump failures and poor heat transfer, resulting in over-heating. If tap water is used, the mineral content in the water must be below the maximum allowable limits listed in Table 5-24. See Figure 5-5 for evaluating the quality of water.

NOTICE:
Do not add additional SCA to new, fully formulated antifreeze or coolant. This can result in drop-out and/or the formation of deposits.

Element	Parts Per Million	Grains Per Gallon
Chlorides *	40	2.5
Sulfates *	100	5.8
Total Dissolved Solids	340	20
Total Hardness - Magnesium and Calcium	170	10

* Limits currently under review.

Table 5-24 Maximum Allowable Limits

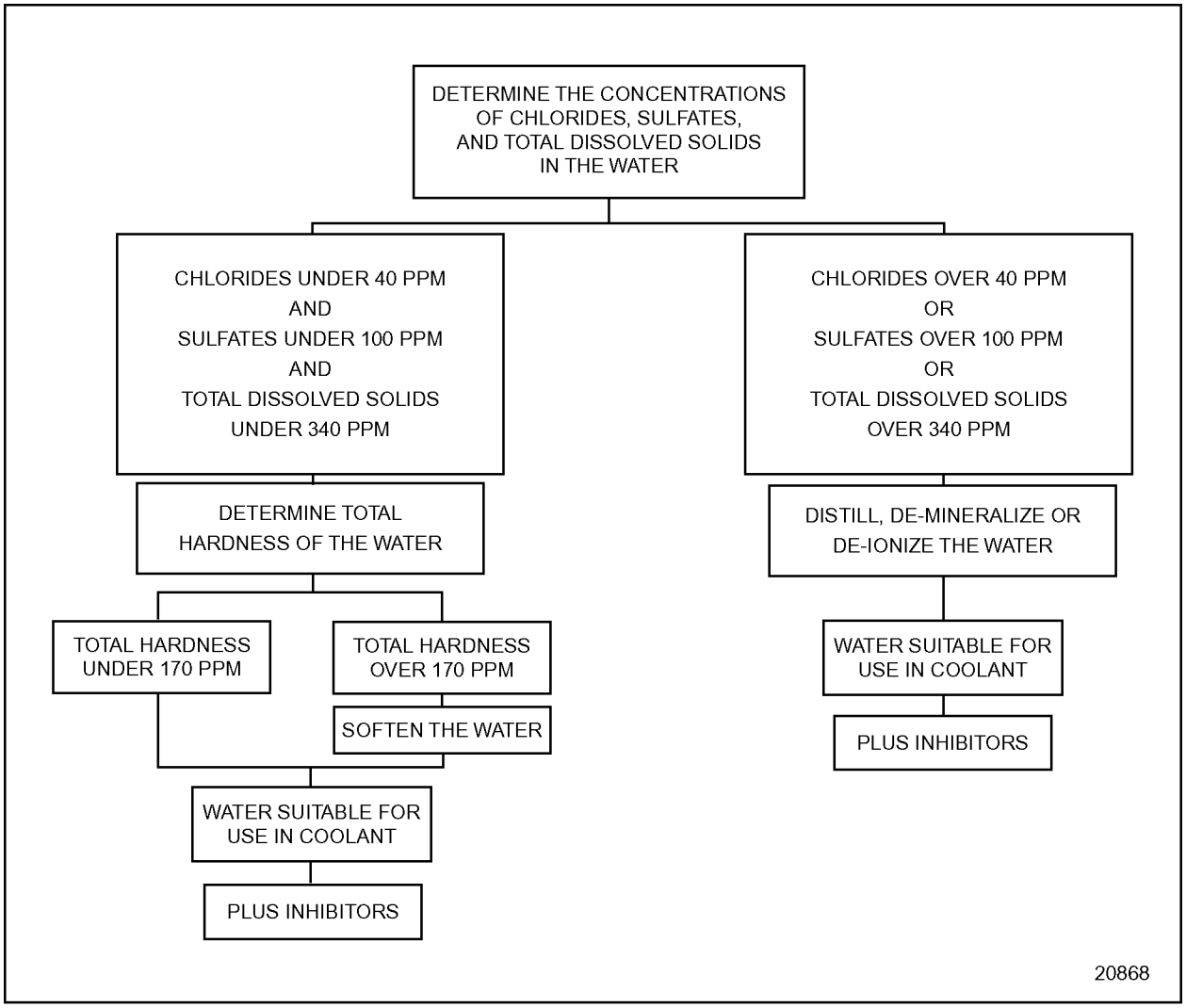


Figure 5-5 Procedure for Evaluating Water

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5.3.1.7 Coolants Not Recommended

The following coolants are not recommended in Detroit Diesel engines.

- **All antifreezes and coolants containing phosphate** should be avoided. Drop-out, overheating, and water pump seal failures can result from use of coolant or inhibitor packages based on phosphate.
- **Automotive type coolants** generally contain high levels of phosphate and silicate, offer no liner pitting protection, and are not suitable for use in Detroit Diesel engines.
- **Methyl alcohol-based antifreeze** must not be used in Detroit Diesel engines because of its effect on the non-metallic components of the cooling system and its low boiling point.
- **Methoxy propanol-based antifreeze** must not be used in Detroit Diesel engines because it is not compatible with fluoroelastomer seals found in the cooling system.
- **Glycol-based coolants formulated for heating/ventilation/air conditioning (HVAC)** should not be used in Detroit Diesel engines. These coolants generally contain high levels of phosphates, which can deposit on hot internal engine surfaces, reduce heat transfer, and cause water pump seal leaks.

5.3.1.8 Additives Not Recommended

The following additives are not recommended in Detroit Diesel engines.

- **Soluble Oil Additives** - are not approved for use in Detroit Diesel engine cooling systems. A small amount of oil adversely affects heat transfer. A small amount of oil adversely affects heat transfer. For example, a 1.25% concentration of soluble oil increases the fire deck temperature 6%. A 2.50% concentration increased the fire deck temperature 15%. The use of soluble oil additives may result in engine overheating and/or failure.
- **Chromate Additives**- are not approved for use in Detroit Diesel engine cooling systems. Chromate additives can form chromium hydroxide, commonly called "green slime." This, in turn, can result in systems operated with chromate-inhibited coolant must be chemically cleaned with *POWER COOL* Twin Pack cooling system cleaner/conditioner (or equivalent sulfamic acid/sodium carbonate cleaner) and flushed.

5.3.2 Maintenance

The following are maintenance procedures.

5.3.2.1 Topping Off Coolant

Coolant level should be checked at each maintenance interval. If topping off is needed, add coolant which is identical to the initial fill coolant.

5.3.2.2 Supplemental Coolant Additives For Fully Formulated Coolant

The concentrations of some inhibitors will gradually deplete during normal engine operation, SCAs replenish the protection for cooling system components. The coolant *must*be maintained with the proper concentration of SCA. Detroit Diesel *POWER COOL* maintenance products are recommended for use in all Detroit Diesel engines.

The proper application of SCA will provide:

- pH control.
- Restored Inhibitor levels to prevent corrosion.
- Water-softening to deter formation of mineral deposits.
- Cavitation protection to protect wet sleeve cylinder liners.Check the nitrite concentration at the regular intervals listed in Table 5-25 with a Power Trac 3-Way Test Strip. Additional SCA *must* be added to the coolant when it becomes depleted, as indicated by a nitrite concentration of 800 PPM or less. *If the nitrite concentration is greater than 800 PPM, do not add additional SCA* .

Service Application	Inhibitor Test Interval
On Highway Trucks and Motor Coaches	20, 000 Miles (32, 000 Kilometers)
City Transit Coaches, Pick-up and Delivery, Short Trip, and Other Applications	6, 000 Miles (9, 000 Kilometers) or Three Months, Whichever Comes First
Industrial, Marine, Generator Set, and All Other Applications	200 Hours or Yearly, Whichever Comes First

This does not apply to organic acid technology-based inhibitor systems.

Table 5-25 Required IEG and IPG Coolant Inhibitor Test Intervals for Traditional Nitrite-based SCA

If the nitrite concentration level listed in Table 5-26 is above 2400 PPM, the system is over-inhibited.

Element	Limits
Boron	125-500 PPM
Nitrite	800-2400 PPM
Nitrate	0-750 PPM
Silicon	50-400 PPM
Phosphate	0 PPM
pH	8-11.0

Table 5-26 POWER COOL 3000 Concentration Limits, (5% POWER COOL 3000, 95% Water)

The system should be partially drained, and filled with a 50/50 nix of water and EG or PG. In this case the EG or PG should contain no inhibitors, and should conform to ASTM D4985 or ASTM D5223. This will dilute the over-concentrated inhibitors.

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5.3.2.3 SCA Test Procedures

Nitrite concentration is an indication of the overall coolant inhibitor concentration. Coolant must be tested for nitrite concentration at the regular intervals listed in Table 5-27.

Coolant	Interval - Whichever Comes First*	Action
DDC *POWER COOL* Antifreeze/Water	32,000 km (20, 000 Miles) 3 Months or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
DDC *POWER COOL* and Need Release ® Filter (ESI)	192,000 km (120,000 Miles) 15 Months or 3,000 Hours	Test the freeze point and nitrite concentration with a Power Trac test strip. Replace the Need Release Filter.
Ethylene Glycol Antifreeze/Water + SCA Inhibitor	32,000 km (20,000 Miles) 3 Months or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
Ethylene Glycol Antifreeze/Water + SCA Inhibitor	480,000 km (300,000 Miles) 2 Years or 4,000 Hours	Drain and clean system, replace w/new coolant.
Propylene Glycol/Water + SCA Inhibitor	32,000 km (20,000 Miles) 3 Months or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
Propylene Glycol/Water + SCA Inhibitor	480,000 km (300,000 Miles) 2 Years or 4,000 Hours	Drain and clean system, replace w/new coolant.
Ethylene Glycol/Water + NOAT Inhibitor	480,000 km (300,000 Miles) 2 Years or 5,000 Hours	Add *POWER COOL* Plus Extender
Ethylene Glycol/Water + NOAT Inhibitor	960,000 km (600,000 Miles) 4 Years or 10,000 Hours	Drain and clean system, replace w/new coolant
Propylene Glycol/Water + NOAT Inhibitor	480,000 km (300,000 Miles) 2 Years or 5,000 Hours	Add *POWER COOL* Plus Extender
Propylene Glycol/Water + NOAT Inhibitor	960,000 km (600,000 Miles) 4 Years or 10,000 Hours	Drain and clean system, replace w/new coolant
Water Only + SCA inhibitor	32,000 km (20,000 Miles) 3 Months or 500 Hours	Test nitrite concentration with test strip. Add SCA or dilute coolant as needed.
Water Only + SCA inhibitor	480,000 km (300,000 Miles) 2 Years or 4,000 Hours	Drain and clean system, replace w/new coolant
Water Only + NOAT inhibitor	480,000 km (300,000 Miles) 2 Years or 5,000 Hours	Add *POWER COOL* Plus Extender
Water Only + NOAT inhibitor	960,000 km (600,000 Miles) 4 Years or 10,000 Hours	Drain and clean system, replace w/new coolant

* The nitrite inhibitor test intervals shown in this table are general recommendations and do not apply in all instances.

Table 5-27 Coolant Maintenance Intervals

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The specific inhibitor test intervals according to engine application are listed in Table 5-28.

Service Application	Inhibitor Test Interval
On Highway Trucks and Motor Coaches	20, 000 Miles (32, 000 Kilometers)
City Transit Coaches, Pick-up and Delivery, Short Trip, and Other Applications	6, 000 Miles (9, 000 Kilometers) or Three Months, Whichever Comes First
Industrial, Marine, Generator Set, and All Other Applications	200 Hours or Yearly, Whichever Comes First

This does not apply to organic acid technology-based inhibitor systems.

Table 5-28 Required IEG and IPG Coolant Inhibitor Test Intervals for Traditional Nitrite-based SCA

Power Trac 3-Way Test Strips (or equivalent) are recommended. Nitrite levels must be within the ranges listed in Table 5-29 and listed in Table 5-30.

Element	Limits
Boron	125-500 PPM
Nitrite	800-2400 PPM
Nitrate	200-750 PPM
Silicon	50-250 PPM
Phosphate	0 PPM
pH	8.0-11

Table 5-29 Fully Formulated Glycol Coolant Limits with TMC RP-329, RP-330, Chemistry Type A (50/50 Coolant/Water Mixture)

Element	Limits
Boron	125-500 PPM
Nitrite	800-2400 PPM
Nitrate	0-750 PPM
Silicon	50-400 PPM
Phosphate	0 PPM
pH	8-11.0

Table 5-30 POWER COOL 3000 Concentration Limits, (5% POWER COOL 3000, 95% Water)

Use Detroit Diesel Power Trac 3-Way Coolant Test Strips to measure nitrite and glycol concentrations. Refer to section 5.3.4 for "*Power Cool* Engine Products". Cavitation/corrosion protection is indicated on the strip by the level of nitrite concentration. Freeze/boil-over protection is determined by glycol concentration.

Use test strips as follows:

1. Dip the strip into coolant for one second. Remove and shake briskly to eliminate excess fluid.

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2. Immediately compare end pad (% Glycol) to the color chart in the container.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad.
4. Color change of additive indicator (middle pad) indicates the presence of inhibitor that is not approved by Detroit Diesel.

For best results make the tests while the coolant is between 10.0°-60°C (50°-140°F). Wait at least 60, but no 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.

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 water pump seal leaks and poor heat transfer, leading to engine damage. Always maintain concentrations at recommended levels. *Do not use traditional SCAs with NOAT coolant.*

A factory coolant analysis program is available through authorized Detroit Diesel service outlets. Refer to section 5.3.4 for "*POWER COOL* Engine Products". To verify coolant acceptability, submit a sample for coolant analysis every three (3) years, 300,000 miles, or 5,000 operating hours, whichever comes first.

5.3.2.4 *POWER COOL* Need Release Coolant Filter

Membranes in the filters release SCAs before the coolant approaches a corrosive condition, protecting the engine from corrosion. The elements release the SCA charge as needed, as opposed to the maintenance SCA elements, which instantaneously release the SCA charge. These elements should be replaced after 15 months, 192,000 km (120,000 miles) or 3000 operating hours, whichever comes first.

A program is available for extending coolant life to 960,000 km (120,000 miles) or four years, whichever comes first. Using these filters will eliminate the need for scheduled coolant changes. With a properly maintained system, the coolant and need-release filters will protect the engine for 960,000 km (120,000 miles) or four years, whichever comes first. Prior approval for extending coolant life to this longer interval *must* be obtained from Detroit Diesel Corporation through one of its Regional Offices. Also, annual coolant analysis under part number 23516921 is required.

5.3.2.5 Drop-Out

Excessive amounts of some inhibitors in the engine coolant can cause a gel or crystalline deposit that reduces heat transfer and coolant flow. The deposit, called drop-out," takes the color of the coolant when wet, but appears as a white or gray 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 using a non-acid (alkali) type heavy-duty cleaner such as Detroit Diesel *POWER COOL* On-Line Cleaner (sodium tetraborate). Refer to section 5.3.4 for "*POWER COOL* Engine Products". If the gel is allowed to dry, it is necessary to disassemble the engine and clean it with a caustic solution or physically clean individual components.

5.3.2.6 Coolant Extender Inhibitor Additive For "NOAT" Coolant

The inhibitors in NOAT must also be maintained, but less often than traditional SCA-type coolants. The concentrations of some inhibitors will gradually deplete during normal engine operation. An organic coolant analysis test is available under part number 23523399. Where this is not used, fleet testing has determined that a NOAT coolant extender package should be added to the coolant at 0.6% by volume at 480,000 km (300,00 miles), 2 years, or 5,000 hours, whichever comes first. A properly maintained NOAT-inhibited coolant will last 4 years 960,000 km (6000,000 miles) or 10,000 hours, whichever comes first, at which time the coolant should be drained. This is the only maintenance needed for the NOAT coolants. This dosage should be added to the water-only and the glycol systems at the same interval.

NOTE:
Do not use traditional SCAs in NOAT coolant, and do not use NOAT extender in traditional coolants.

5.3.2.7 Coolant Filter Elements

Replaceable coolant filter elements (spin-on canisters) are available in various sizes suitable for cooling systems of varying capacity. Selection of the proper element size is vital when pro-charging non-fully formulated coolant (i.e. water) at initial fill, and at maintenance intervals. *A fully formulated antifreeze must NOT have SCA added at initial fill. Do not use SCA-containing filters with NOAT antifreeze or coolant.*The need for maintenance elements is determined by the results of the nitrite concentration test performed at each cooling system service interval. *Do not automatically install maintenance elements at maintenance intervals unless the nitrite concentration level falls below 800 ppm.*

5.3.3 Summary of Coolant Recommendations

The following is a summery of coolant recommendations:

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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).

- Always maintain the engine coolant to meet Detroit Diesel specifications.
- Only use water that meets Detroit Diesel specifications listed in Table 5-31. Distilled, de-mineralized (reverse osmosis) or de-ionized water is preferred.

NOTICE:

Do not add additional SCA to new, fully formulated antifreeze or coolant. This can result in drop-out and/or the formation of deposits.

Element	Parts Per Million	Grains Per Gallon
Chlorides *	40	2.5
Sulfates *	100	5.8
Total Dissolved Solids	340	20
Total Hardness	-	-
Magnesium and Calcium	170	10

* Limits currently under review.

Table 5-31 Maximum Allowable Limits

- The proper dosage of inhibitors *must* be included in the coolant at initial fill for all Detroit Diesel engines. This dosage id usually included in the fully formulated antifreeze used, or it may need to be added if water alone or if less than 50% antifreeze is used. The user is urged to refer to the full text of this section to determine the proper dosage. Mixing of different manufacturers' technologies (brands) could cause cooling system problems.
- Maintain the inhibitor at the prescribed concentration. Test the nitrite concentration by using a titration kit or Detroit Diesel Power Trac 3-Way Coolant Strips. Add SCA only if the nitrite concentration is below 800 PPM. Do not use Power Trac 3-Way Test Strips or SCA in NOAT coolant.
- Do not use another manufacturer's test kit to measure the SCA concentration of Detroit Diesel Maintenance Products.
- Pre-mix coolant makeup solutions to the proper concentration before adding to the cooling system.
- Do not mix NOAT and other coolants in the same engine.
- Do not use automotive coolants or coolants with phosphates.
- Where freeze/boil over protection is required, use only antifreeze that meets TMC RP-329 (EG) "Type A"or TMC RP-330 (PG) "Type A" specifications.
- Always maintain coolant at the proper level.

- Coolant Life:
  - A properly maintained cooling system, filled with phosphate-free coolant consisting of a 50/50 mix of antifreeze and water per TMC RP-329 "Type A" or TMC RP-330 "Type A" can be operated until overhaul. The proper maintenance involves periodic evaluation using Power Trac 3-Way Test Strips and addition of SCA as needed, as indicated by the strip test. To verify coolant acceptability, submit a sample for coolant analysis every three (3) years, 480,000 km (300,000 miles), 5,000 operating hours, whichever comes first. Submit the sample in DDC Power Trac Coolant Test Bottle. Refer to section 5.3.4 for *"POWER COOL* Engine Products."
  - NOAT Coolant: A properly maintained NOAT coolant may be operated 4 years, 960,000 km (600,000 miles) or 10,000 operating hours, whichever comes first. At this time, the system *must* be completely drained and refilled.
  - NOAT Coolants require the addition of an extender at 480,000 km (300,000 miles) 5,000 hours, or two years, whichever comes first. Use one pint of extender for every 20 gallons of coolant (1:60 ratio).
- Do not use the following in Detroit Diesel engine cooling systems:
  - Soluble Oil
  - High Silicate, Automotive Type Antifreeze
  - Chromate SCA
  - Methoxy Propanol-Base Coolant
  - Methyl Alcohol-Base Coolant
  - Sealer Additives or Coolant Containing Sealer Additives
  - HVAC Coolant
  - Phosphated Coolants

5.3.4 *POWER COOL* Engine Products

Listed in Table 5-32 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
Concentrated	235122138 235122139 235122140	One Gallon Jug - 6 Per Case 55 Gallon Drum Bulk Delivery - 1,000 Gallon Minimum
Pre-Blended 50:50	23518918 23513503	55 Gallon Drum Bulk Delivery - 1,000 Gallon Minimum

Table 5-32 POWER COOL Fully Formulated IEG Coolant

Listed in Table 5-33 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
For *POWER COOL* IEG Coolant	23507858 23507859 23507860 23507861	Pint Bottle - 12 Per Case Half Gallon Jug - 6 Per Case 5 Gallon Pail 55 Gallon Drum

Table 5-33 POWER COOL 2000 Supplemental Coolant Additive

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Listed in Table 5-34 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
For *POWER COOL* IEG Coolant	23507854	Pint Bottle - 12 Per Case
	23507855	Half Gallon Jug - 6 Per Case
	23507856	5 Gallon Pail
	23507857	55 Gallon Drum

Table 5-34 POWER COOL 3000 Supplemental Coolant Additive

Listed in Table 5-35 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
For *POWER COOL* IEG Coolant	23507545	4 Ounce (1 Pint Equivalent)
	23508425	8 Ounce (2 Pint Equivalent)
	23508426	12 Ounce (3 Pint Equivalent)
	23507189	16 Ounce (4 Pint Equivalent)
	23508427	32 Ounce (8 Pint Equivalent)
	23508428	53 Ounce (13 Pint Equivalent)

Table 5-35 POWER COOL 3000 Supplemental Additive Coolant Filters

Listed in Table 5-36 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
For *POWER COOL* IEG Coolant	23516488	For 0-8 Gallon Systems
	23516489	For 8-20 Gallon Systems

Table 5-36 POWER COOL Supplemental Additive Need Release Coolant Filters

Listed in Table 5-37 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
Concentrated	23519397	One Gallon Jug - 6 Per Case
	23519394	55 Gallon Drum
	23519395	Bulk Delivery - 2,000 Gallon Minimum
Pre-Blended 50:50	23519396	One Gallon Jug - 6 Per Case
	23519398	55 Gallon Drum
	23519399	Bulk Delivery - 2,000 Gallon Minimum

Table 5-37 POWER COOL Plus Extended Life NOAT Coolant

Listed in Table 5-38 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
For *POWER COOL* Plus	23519400	One Quart Bottle - 6 Per Case

Table 5-38 POWER COOL Plus Extender for use with POWER COOL Plus NOAT Coolant

Listed in Table 5-39 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
Water Only	23522127 23522128	One Gallon Jug - 6 Per Case 5 Gallon Pail

Table 5-39 POWER COOL Plus 6000 NOAT Inhibitor for Water-Only Systems

Listed in Table 5-40 is the *POWER COOL* coolant type and description:

Coolant Type	Part Number	Description
On-Line Cleaner	23507862 223507863 23507864	One - Half Gallon Jug - 6 Per Case 5 Gallon Pail 55 Gallon Drum
Twin Pack	23507867	Twin Pack -2 Per Case

Table 5-40 POWER COOL Cooling System Cleaners

Listed in Table 5-41 is the Power Trac coolant type and description:

Coolant Type	Part Number	Description
Indicates Nitrite, Molybdate, and Glycol Levels	23519401	3-Way Coolant Test Strips (Single Foil Packs)
Indicates Nitrite, Molybdate, and Glycol Levels	23519402	3-Way Coolant Test Strips (Bottle of 50)
Indicates Nitrite, Molybdate, and Glycol Levels	23522774	3-Way Coolant Test Strips (Bottle of 10)
Complete Coolant Analysis	23516921	Coolant Analysis Bottle (Carton of 6)
Organic Coolant Analysis	23523398	Laboratory Coolant Analysis
Organic Coolant Analysis	23523399	Field Test Coolant Analysis

Table 5-41 Power Trac Coolant Testing and Analysis Products

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Listed in Table 5-42 are the coolant inhibitor element size requirements:

Cooling System Capacity (Gallons)	Filter Quantity	Part Number	Liquid Number of Pints
1-4	1	23507545	1/4 - 1
5-8	1	23508425	1 1/4 - 2
9-12	1	23508426	2 1/4 - 3
13-16	1	23507189	3 1/4 - 4
24-32	1	23508427	6 - 8
47-52	1	23508428	11 3/4 - 13
50-75	2	23508427	12 1/2 - 18 3/4
75-100	2	23508428	18 3/4 - 25
100-125	2	23508428	25 - 31 1/4
125-150	2	23508428	31 1/4 - 37 1/2

Not necessary if *POWER COOL*coolant is used (already pro-charged).

Table 5-42 Coolant Inhibitor Element Size Requirements - Initial Fill Dosage for IEG or IPG Plus Water Coolant Mixtures

Listed in Table 5-43 are the coolant inhibitor element size requirements:

Cooling System Capacity (Gallons)	Filter Quantity	Part Number	Additional SCA Required	Number of Pints or Quarts Needed
3	1	23507545	None	2 Pints
4	2	23507545	None	2 Pints
5	1	23508425	None	3 Pints
7	1	23508426	None	4 Pints
10	1	23507189	None	5 Pints
15	2	23508426	None	8 Pints
20	1	23508427	None	10 Pints
25	1	23508427	None	13 Pints
-	1	23507545	-	-
30	1	23508427	None	15 Pints
-	1	23508426	-	-
35	1	23508427	None	18 Pints
-	1	23507189	-	-
40	2	23508427	None	2 1/2 Quarts
50	2	23508427	None	3 1/8 Quarts
60	1	23508428	None	3 3/4 Quarts
-	1	23508427	-	-
70	2	23508428	None	4 3/8 Quarts
85	2	23508428	1 Gallon **	5 3/8 Quarts
100	2	23508428	2 Gallons **	6 1/4 Quarts
125	2	23508428	3 1/4 Gallons **	7 7/8 Quarts
150	2	23508428	5 Gallons **	9 3/8 Quarts

* * Use *POWER COOL*2000 and 3000 liquid SCA, or equivalent.

Table 5-43 Coolant Inhibitor Element Size Requirements - Initial Dosage for Water-Only Systems

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Listed in Table 5-44 are the coolant inhibitor element size requirements:

Cooling System Capacity (Gallons)	Filter Quantity	Part Number	Number of Pints
1-4	1	23507545	1/4
5-8	1	23507545	1/4 - 1/2
9-12	1	23507545	1/2 - 3/4
13-16	1	23507545	3/4 - 1
24-32	1	23508425	1 1/2 - 2
47-52	1	23508426	3 - 3 1/4
50-75	2	23508426	3 1/4 - 4 3/4
75-100	2	23507189	4 3/4 - 6 1/4
100-125	2	23507189	6 1/4 - 7 3/4
125-150	2	23508427	7 3/4 - 9 1/4

Table 5-44 Coolant Inhibitor Element Size Requirements - Maintenance Dosage for IEG, IPG, Precharged, and Water-Only Coolant Mixtures

Listed in Table 5-45 are the need release filters:

Cooling System Capacity (Gallons)	Filter Quantity	Part Number	Number of Pints
0-8	1	23516488	N/A
8-20	1	23516489	N/A

Table 5-45 Need Release Filters

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6 AIR INTAKE SYSTEM

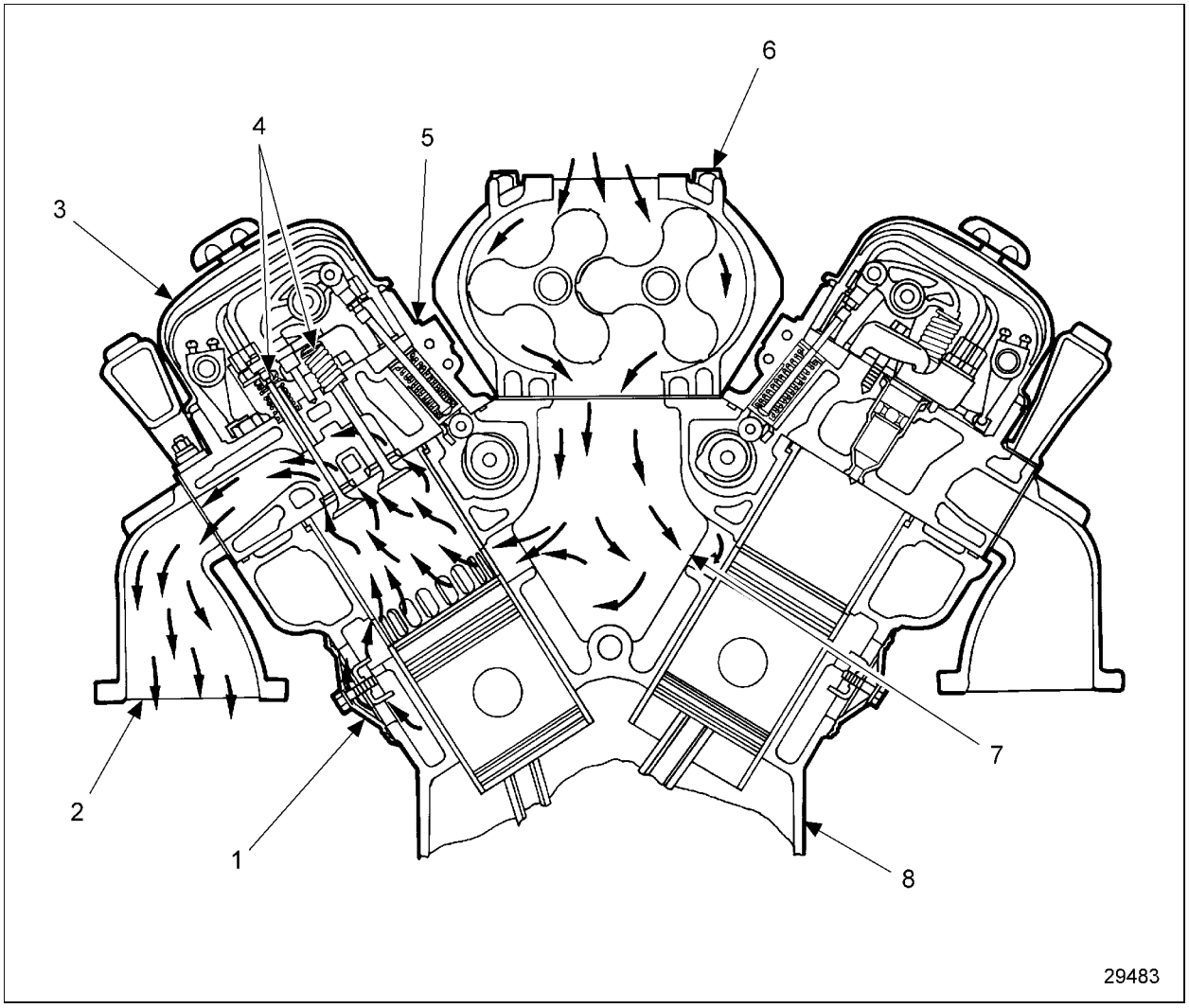
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6.1 AIR INTAKE SYSTEM

The blower, which sweeps out all burned gases through the exhaust valve ports, forces a charge of air into the cylinders. This air also cools the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, each cylinder is filled with fresh, clean air for efficient combustion.

The air entering the blower from the air cleaner is picked up by the blower rotor lobes and carried to the discharge side of the blower. See Figure 6-1. The continuous discharge of fresh air from the blower enters the cylinder block air box and sweeps through the intake ports of the cylinder liners.



1. Air Box Covers
2. Exhaust Manifold
3. Rocker Covers
4. Exhaust Valves and Spring Assemblies
5. Cylinder Head Assembly
6. Blower
7. Air Box
8. Cylinder Block

Figure 6-1 Typical Air Intake System through Blower and Engine

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The angle of the cylinder liner ports creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

The system consists of the following components:

- Air Intake System
- Air Cleaner
- Air Separator
- Air Shutdown Housing
- Blower
- Turbocharger
- Turbocharger Intercooler
- Turbocharger Aftercooler

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6.2 AIR CLEANER

Clean air is essential to satisfactory engine operation and longevity. The air cleaner must be able to remove fine and coarse materials, such as, dust, blown sand, chaff, sawdust, or lint from the air. It must also have a reservoir capacity large enough to retain the material separated from the air, permitting operation for a reasonable period before cleaning and service are required.

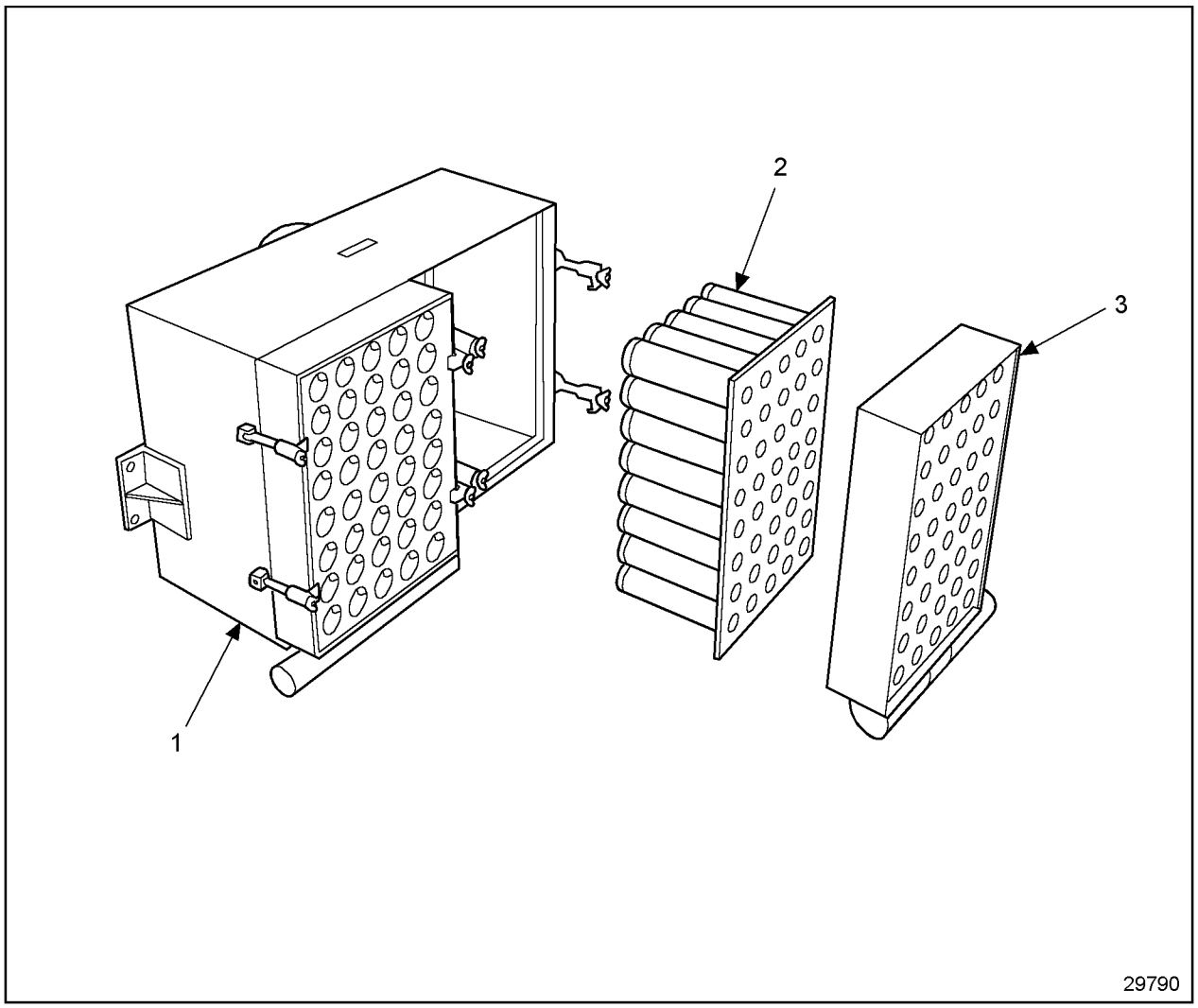
Dust and dirt entering an engine will cause rapid piston ring, cylinder liner, piston, and exhaust valve mechanism wear, resulting in power loss and high lubricating oil consumption. Dust and dirt allowed to build-up in the air cleaner passages will eventually restrict the air supply to the engine and result in heavy carbon deposits on pistons and valves.

Dry paper element type air cleaners are factory installed or OEM installed on Detroit Diesel engines.

NOTE:
Detroit Diesel does not recommend certain foam type air cleaner elements. They produce gummy or varnish-like deposits that may affect engine operation.

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The ***dry type air cleaner***is designed to provide highly efficient air filtration under all operating conditions and is not affected by engine speed. See Figure 6-2. The cleaner assembly consists of a centrifugal air cleaner in series with a replaceable paper filter element. Connecting the dust bin to an exhaust gas aspirator will expel the dust collected in the centrifugal cleaner. The centrifugal cleaner and replaceable filter element are held together in a steel housing. Rubber gaskets positively seal between the two elements and the housing. The steel housing incorporates filter fasteners, mounting flanges, and an outlet for the filtered air.

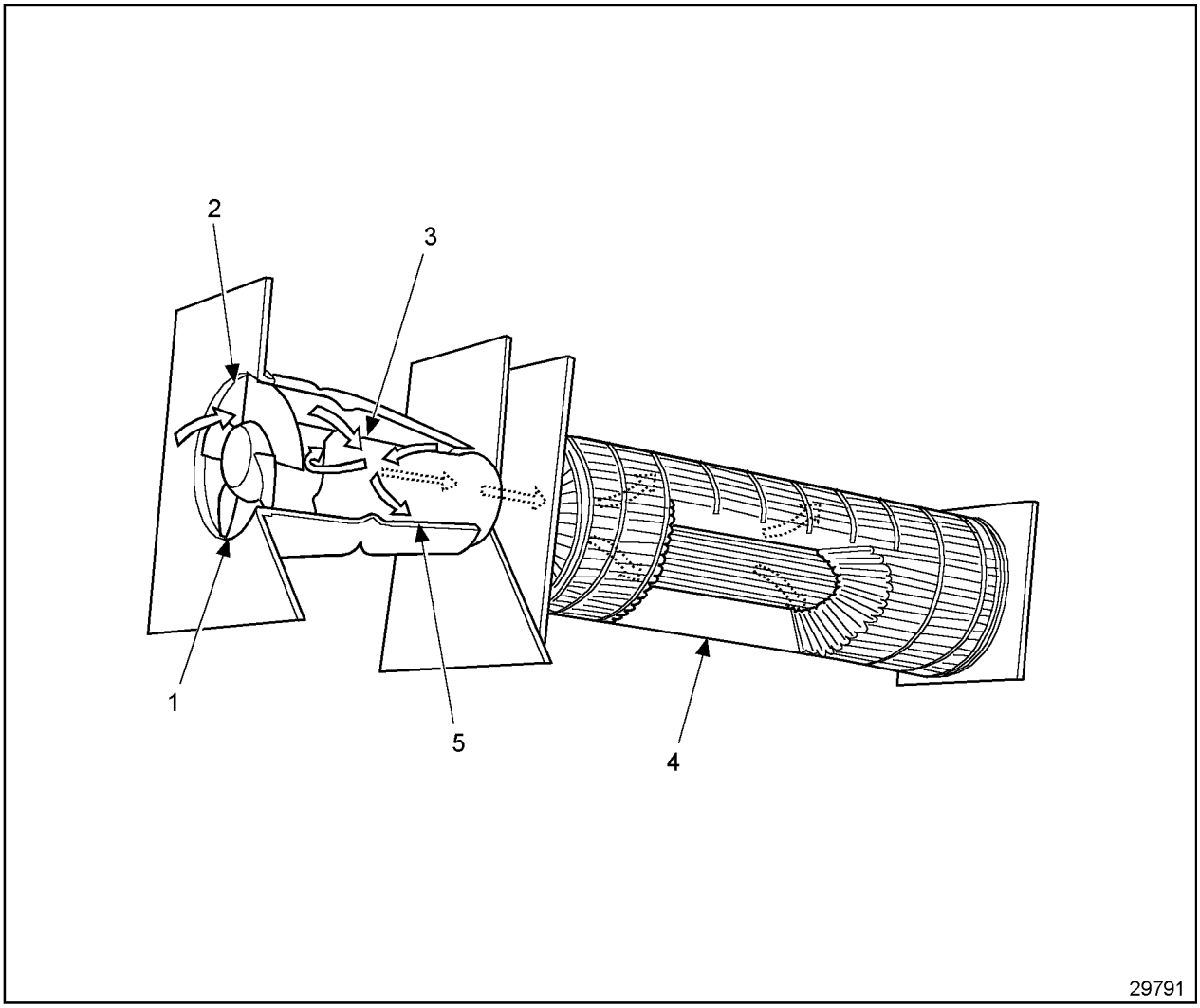


1. Dust Bin
2. Replaceable Filter Element
3. Centrifugal Air Cleaner

Figure 6-2 Dry Type Air Cleaner

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The deflector vanes centrifugal motion separates the air entering the dry type air cleaner from the dust. The dust particles are carried to the dust bin at the bottom of the cleaner by approximately 10% bleed-off air and are finally discharged into the atmosphere through an exhaust gas aspirator. See Figure 6-3.

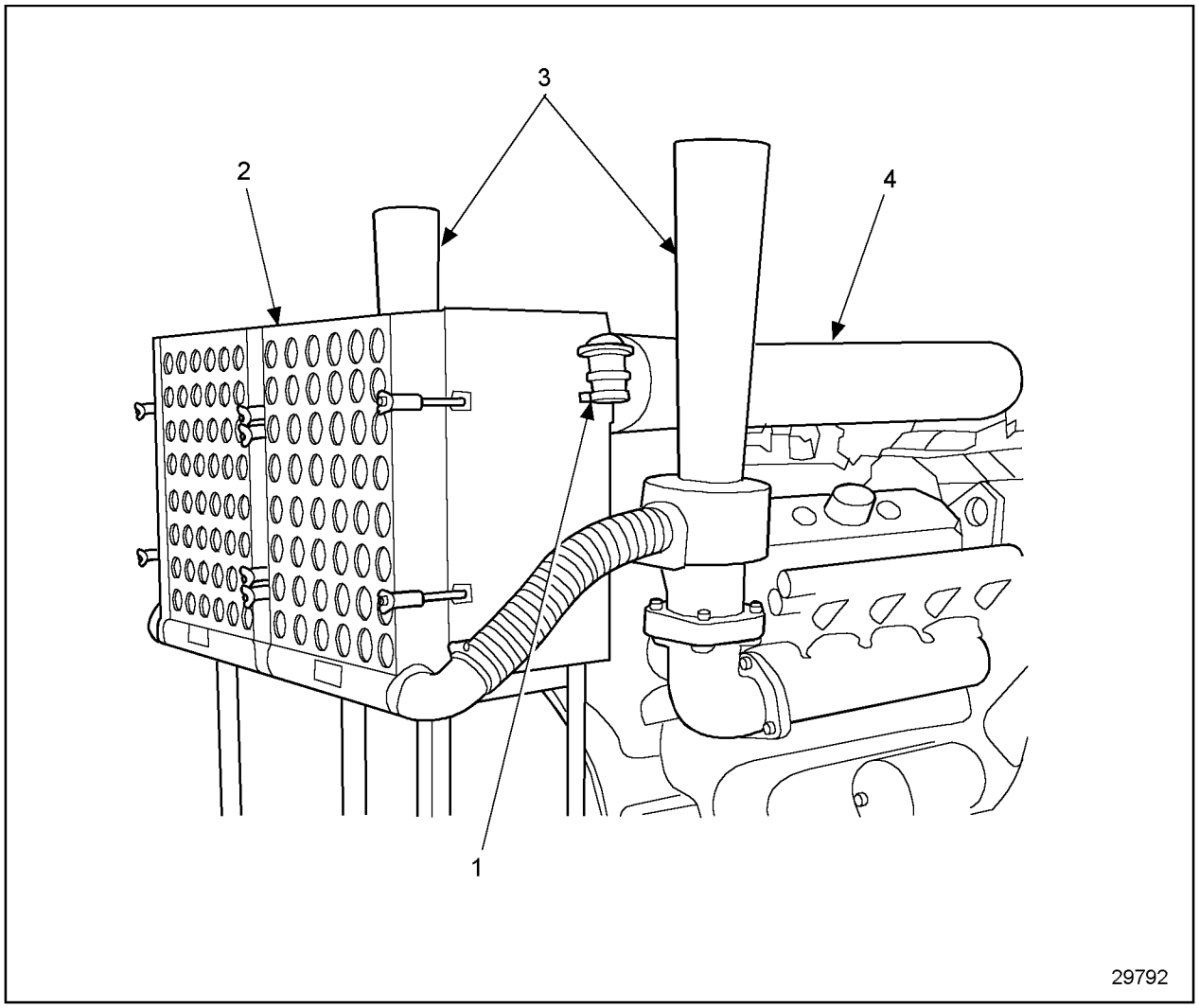


1. Deflector Vanes
2. Inlet Tube
3. Primary Chamber
4. Filter
5. Discharge Tube

Figure 6-3 Flow of Air Through Dry Type Air Cleaner

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The exhaust gas aspirator is connected into the engine exhaust system. See Figure 6-4. A flexible hose carries the dust particles from the cleaner dust bin to the aspirator, where the exhaust gas waste energy draws the dust-laden bleed-off air out and discharges it into the atmosphere with the engine exhaust gas. Approximately 90% of the total dust load is disposed of this way. The centrifugal air cleaner is fully effective at both high and low velocities.



1. Restriction Indicator
2. Air Cleaner
3. Exhaust Gas Aspirators
4. Air Inlet Housing

Figure 6-4 Typical Dry Type Air Cleaner Mounting

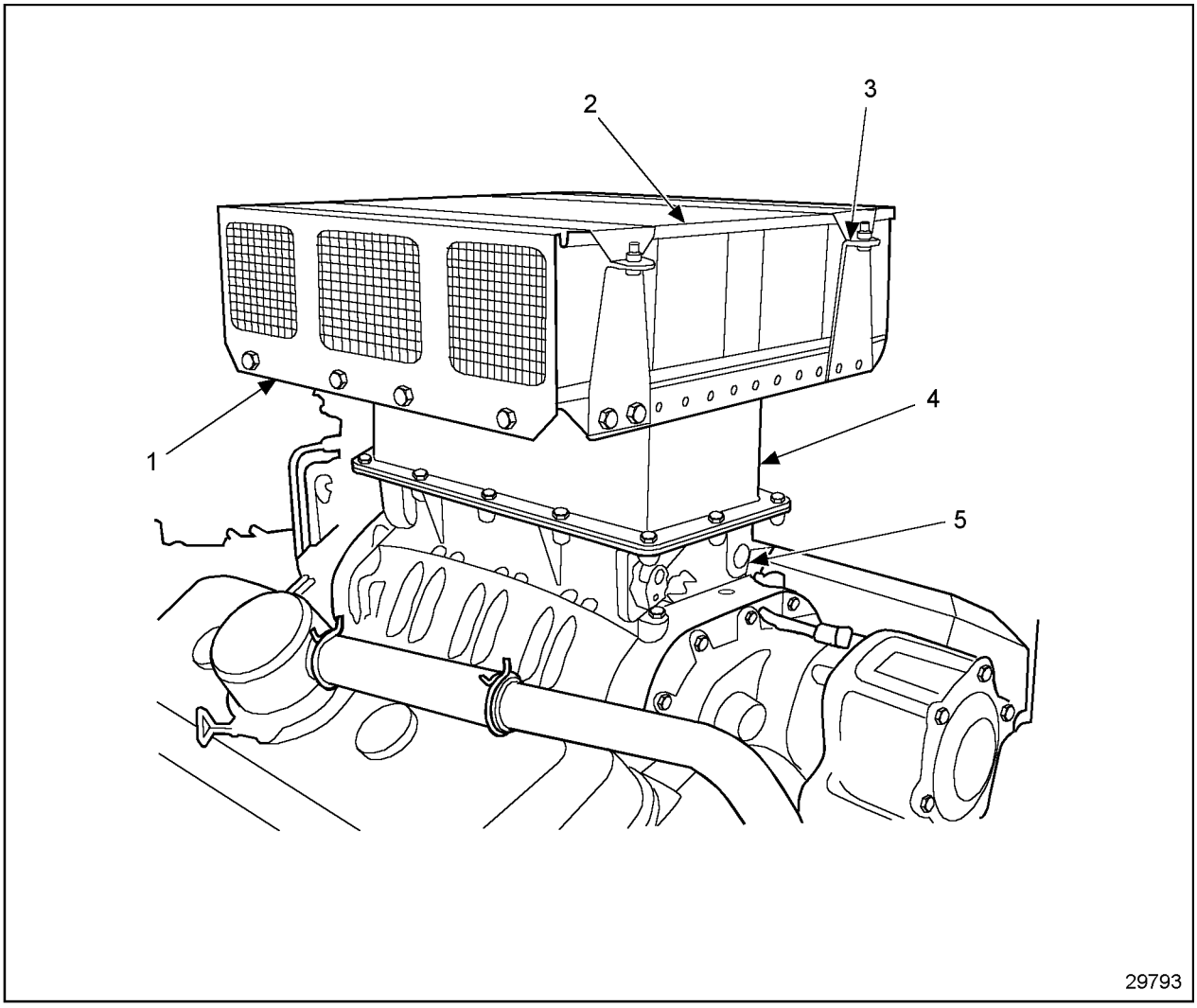
The remaining air in the cleaner reverses direction and spirals back along the discharge tubes, centrifuging the air. The filtered air reverses direction and enters the replaceable filter element through the center portion of the discharge tubes. The air is filtered once more as it passes through the paper element pleats before leaving the cleaner housing outlet port.

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An air cleaner restriction indicator may be attached near the outlet side of the cleaner. As the cleaner restriction increases, suction will pull the indicator plunger upward. A brightly colored card, attached to the plunger and visible through a small window in the indicator, will indicate the relative air restriction amount in the cleaner. When the card is fully visible, the air cleaner should be cleaned, and the indicator should be reset. Push the plunger all the way up, and release it.

The air cleaner restriction indicator is equipped with a safety fitting. The fitting incorporates an internal filter in one end and does not require any service. When replacing the safety fitting, thread the open end of the fitting in the indicator and the screen end in the air cleaner.

The ***Farr dry type air cleaner*** is specially designed to provide highly efficient air filtration under all operating conditions. See Figure 6-5.

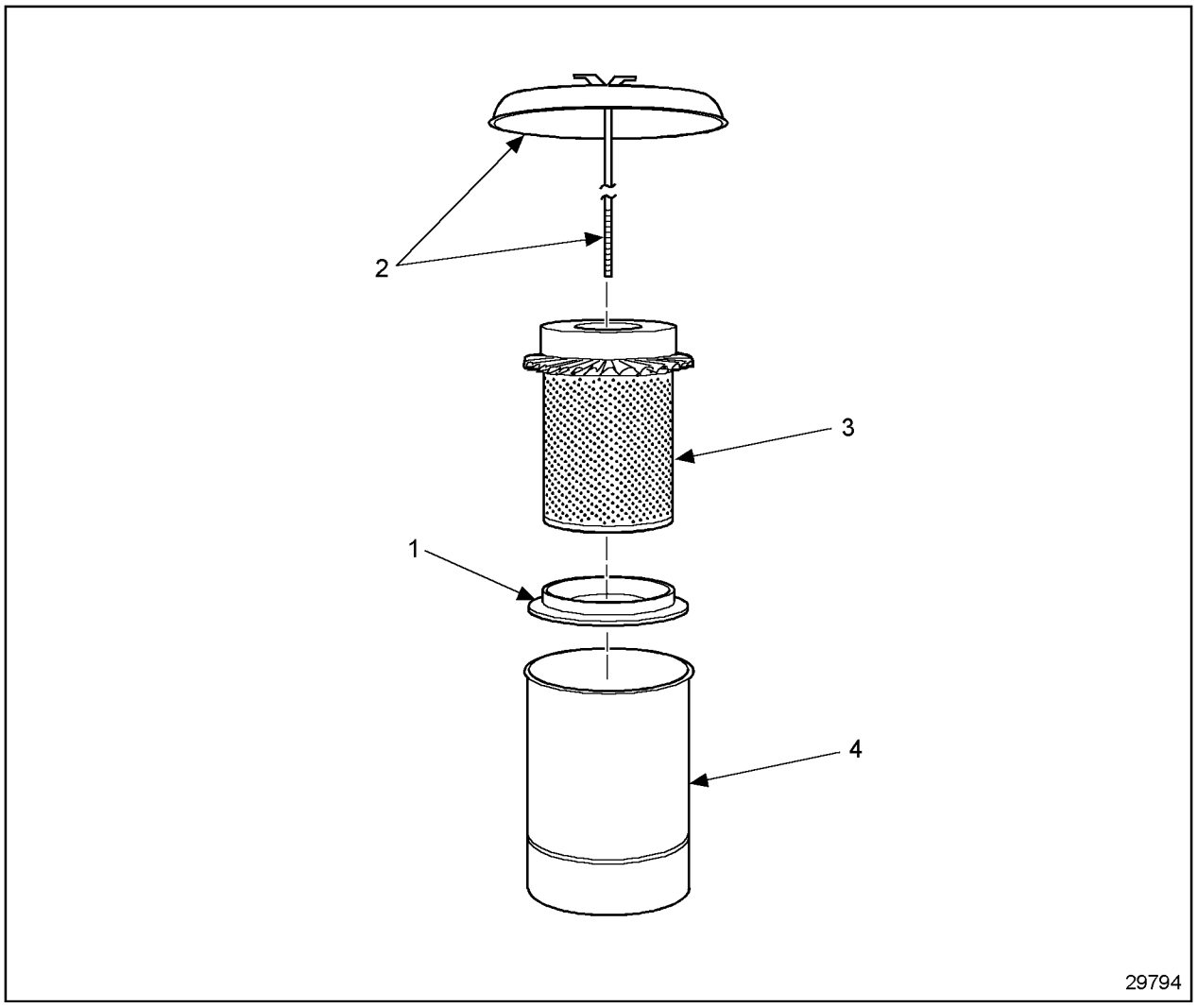


1. Inlet Screen
2. Element Filter
3. Filter Strap
4. Plenum Chamber
5. Shutdown Assembly

Figure 6-5 Farr Dry Type Air Cleaner

The air cleaner assembly consists of a plenum chamber, a replaceable Dynacell air filter element, holding straps, and an inlet screen. The air cleaner mounts on a pan type air inlet manifold shutdown assembly.

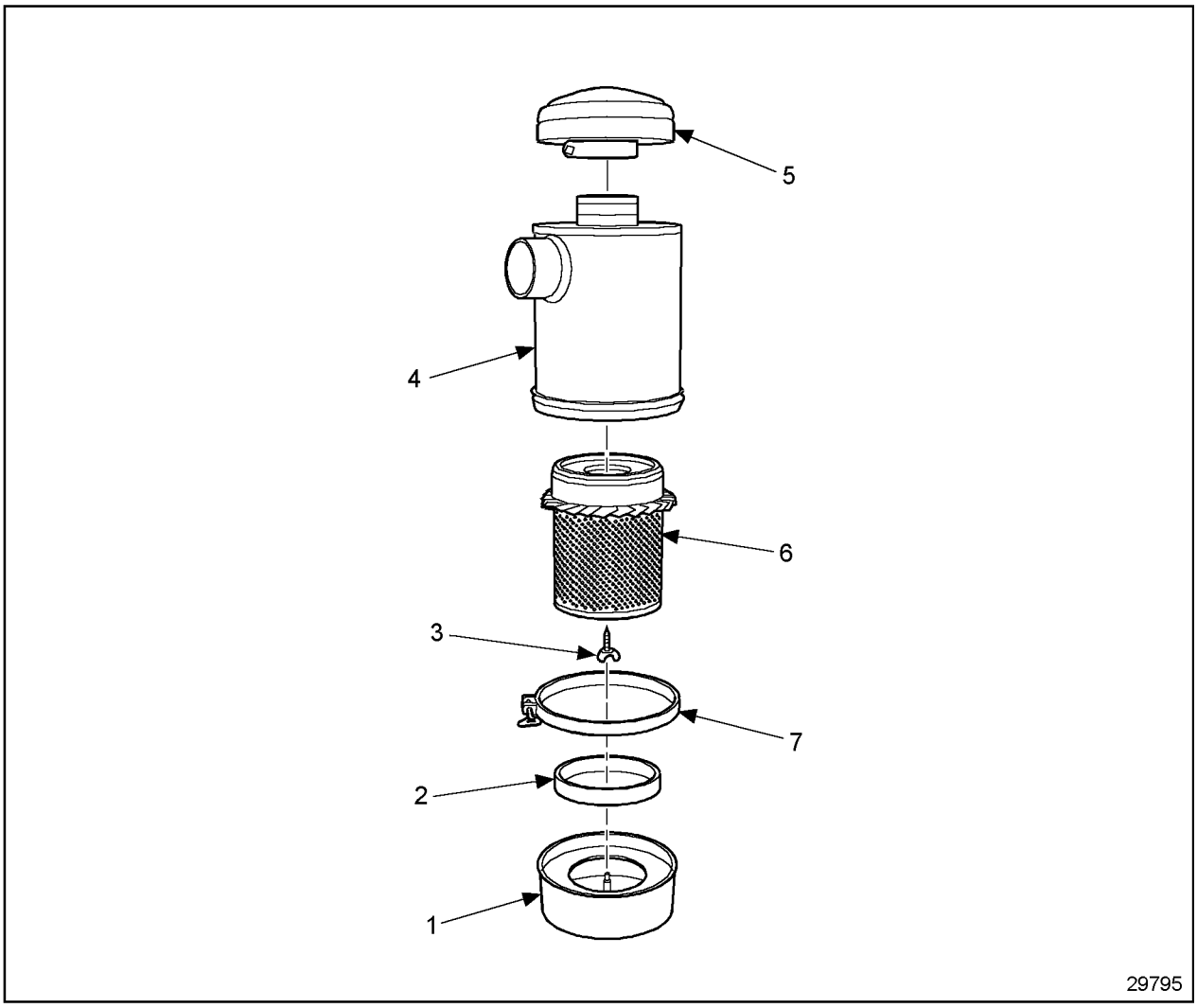
The ***Donaldson dry type air cleaners*** are designed to provide highly efficient air filtration under all operating conditions. See Figure 6-6 and see Figure 6-7. The cleaners have a replaceable paper filter element that can be cleaned.



1. Baffle
2. Cover Assembly
3. Element Assembly
4. Body

Figure 6-6 Dry Type Air Cleaner

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1. Dust Cup
2. Baffle
3. Wing Bolt
4. Body
5. Cap
6. Element
7. Clamp

Figure 6-7 Dry Type Air Cleaner (Heavy Duty)

The fins on the element give high speed rotation to the intake air, that separates a large portion of the dust from the air by centrifugal motion. The plastic fins, the element, and the gasket make up a single, replaceable element assembly.

The dust is swept through a space in the side of the baffle and collects in the lower portion of the body or dust cup. The dust remaining in the precleaned air is removed by the element.

The dry type heavy duty air cleaner cannot be used where the atmosphere contains oil vapors, or where fumes from the breather can be picked up by the air cleaner.

The air cleaner should be serviced as operating conditions warrant. Refer to section 13.47 for element change intervals.

Under no operating conditions should the maximum allowable air intake restriction be exceeded. Refer to section 11.5. Check restriction with a water manometer. Refer to section 11.6.9 *"Final Run-In"*. A clogged air cleaner element will cause excessive intake restriction, reduce air supply to the engine, and cause poor performance and higher valve and cylinder temperatures.

The recommended product life (shelf life plus service life) of Donaldson dry type air cleaner elements is three years. Donaldson elements should be put into service no later than two years from the manufacture date.

Farr air cleaner elements should be put into service within one year from the manufacture date.

6.2.1 Repair or Replacement of Air Cleaner

For specific repair or replacement procedures, refer to OEM guidelines. For proper maintenance intervals, refer to section 13.47. For general removal and installation procedures, refer to section 6.2.2, and refer to section 6.2.3.

6.2.2 Removal of Air Cleaner

Remove the air cleaner as follows:

1. Disconnect the flexible aspirator hose at the dust bin of the air cleaner.
2. Loosen the wing nuts on the filter fasteners, and swing the retaining bolts away from the cleaner.
3. Lift the cleaner away from the housing, and inspect it. Clean out any accumulated foreign material.
4. Withdraw the paper filter element, and discard it.

6.2.3 Installation of Air Cleaner

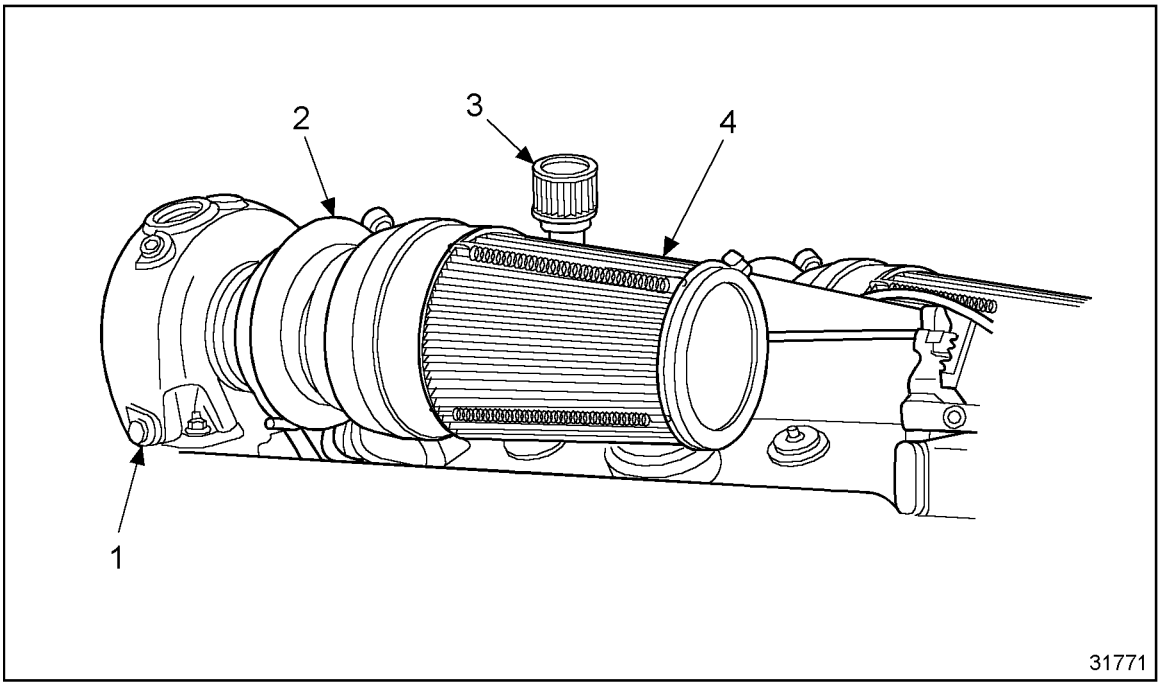
Install the air cleaner as follows:

1. Install a new filter element. New sealing gaskets are provided with the element to ensure a positive air seal.
2. Install the cleaner, and secure it in place with the fasteners.
3. Connect the aspirator hose to the dust bin. Ensure the connection is airtight.

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6.3 AIR SEPARATOR FILTER ELEMENT

The breather system consists of an air separator assembly mounted to the inlet side of each turbocharger along with an oil drain tube(s), check valve(s), required breather piping and mounting hardware. See Figure 6-8.



1. Turbine Housing
2. Compressor Housing
3. Vacuum Limiter
4. Air Separator Assembly

Figure 6-8 Typical Air Separator System

The system performs three functions:

- Collects the crankcase vapors normally emitted to atmosphere particles of oil from the vapors. Any oil collected in this manner drains back to the crankcase, while the remaining fumes are mixed with the turbocharger air flow. This system virtually eliminates crankcase fumes from the engine room.
- Filters the outside air entering the turbocharger. The oil-coated cotton filter element removes dirt and salt particles from the incoming air.
- Serves as an air silencer to reduce air induction noise.
- In some marine applications an air separator is used to prevent crankcase breather fumes from discharging into the engine room.

6.3.1 Repair or Replacement of Air Separator Filter Element

Refer to OEM for repair or replacement procedures.

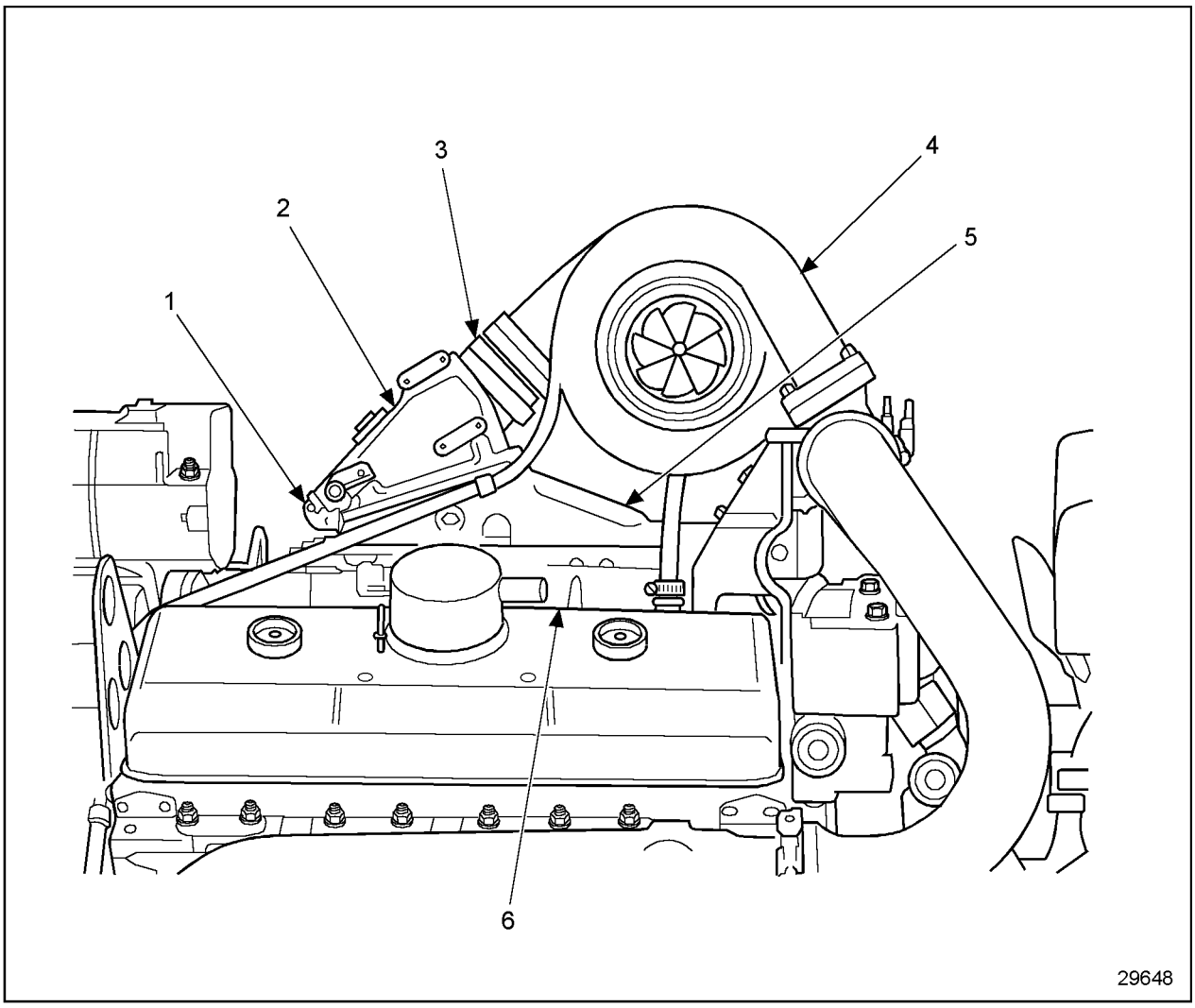
NOTICE:
Failure to clean the air separator filter and the vacuum regulator/limiter will affect the operation of the air separator and may cause reduced engine performance and/or engine damage caused by engine overheating.

Refer to section 13.49, preventive maintenance for change intervals and cleaning procedures.

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6.4 AIR SHUTDOWN HOUSING

The air shutdown housing is mounted on the blower. A valve mounted inside the housing may be closed to shut off the air supply and stop the engine when abnormal operating conditions require an emergency shutdown. See Figure 6-9.



1. Latch
2. Air Shutdown Housing
3. Hose
4. Turbocharger
5. Housing Adaptor
6. Blower

Figure 6-9 Typical Air Shutdown Housing Mounting (Turbocharged Engines)

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6.4.1 Repair or Replacement of Air Shutdown Housing

To determine if replacement is necessary, perform the following procedure. See Figure 6-10.

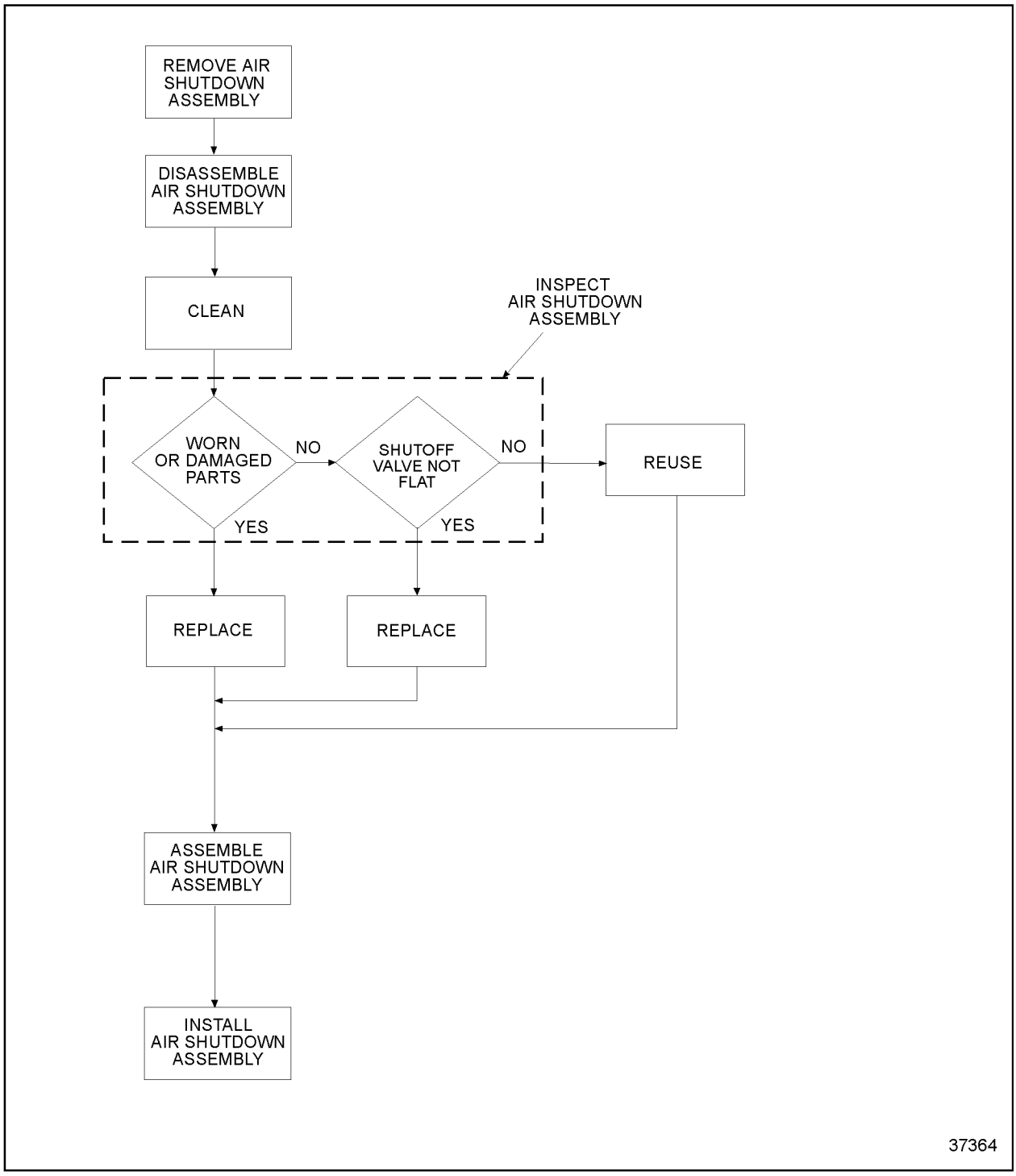


Figure 6-10 Flowchart for Repair or Replacement of Air Shutdown Housing

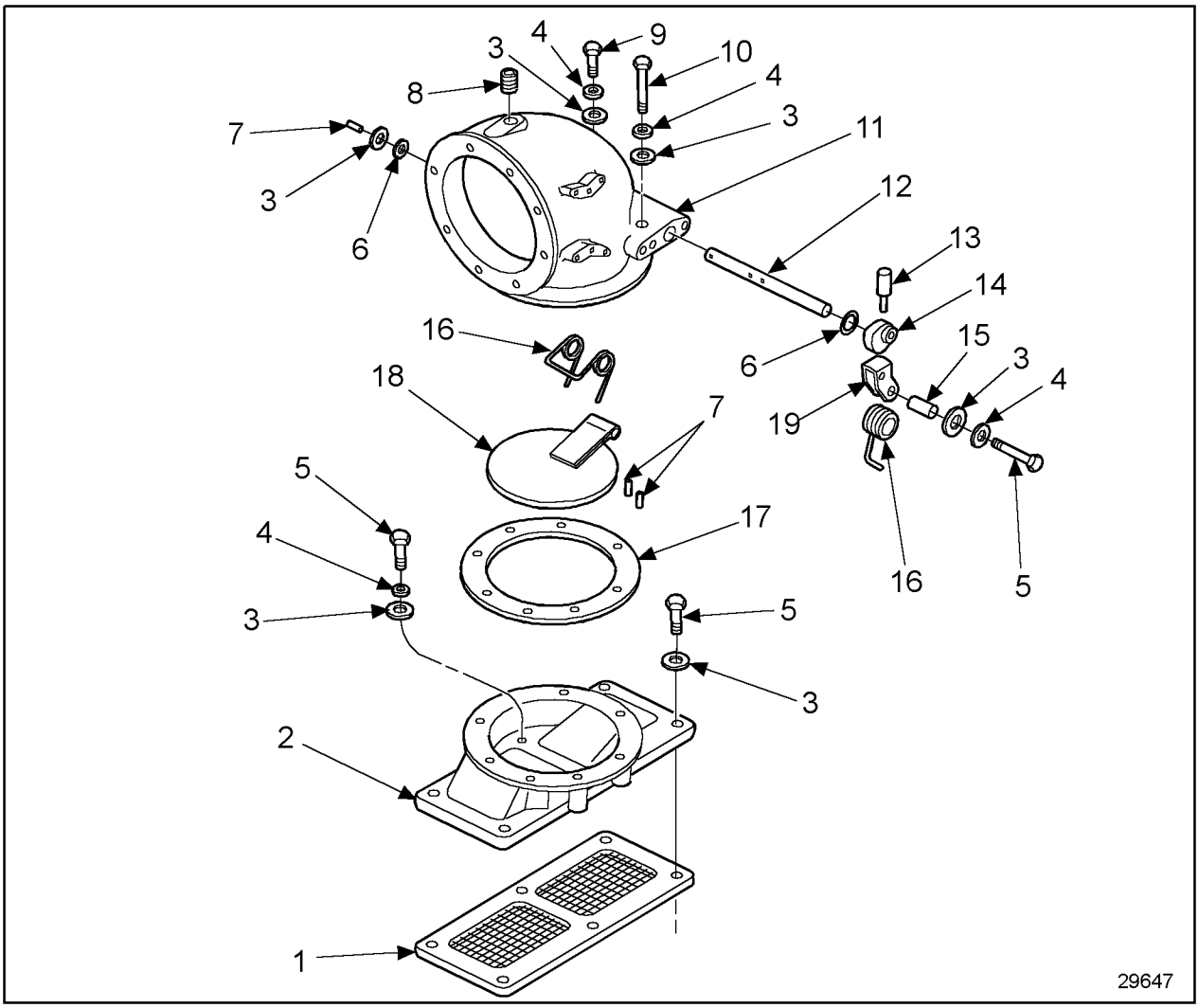
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6.4.2 Removal of Air Shutdown Housing

Remove the air shutdown housing as follows:

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1. On naturally aspirated engines, disconnect and remove the air inlet housing between the air cleaner(s) and the air shutdown housing. See Figure 6-11.

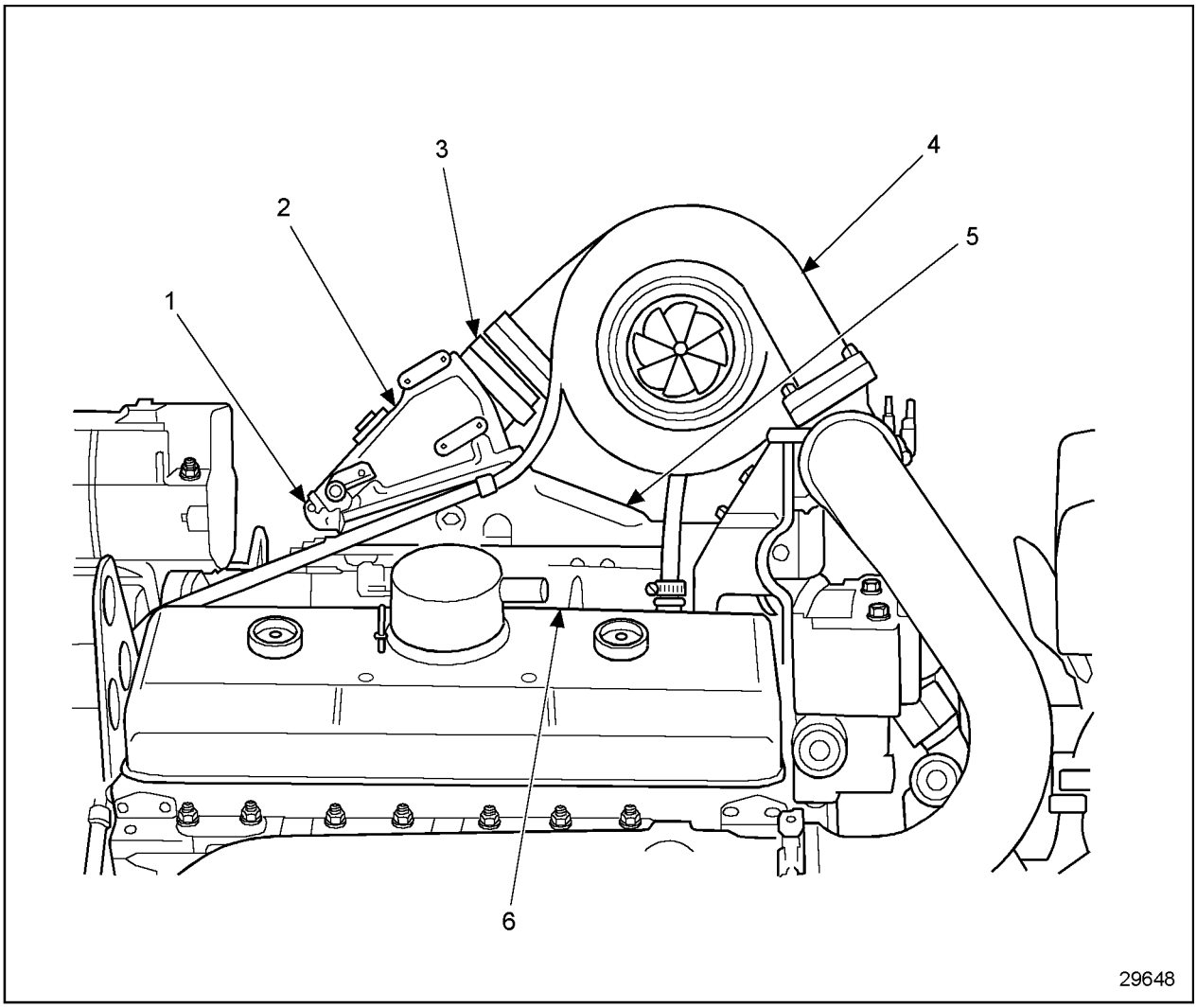


1. Blower Screen
2. Air Shutdown Adaptor
3. Washer
4. Lock Washer
5. Bolt
6. Seal Ring
7. Pin
8. Pipe Plug
9. Short Bolt
10. Long Bolt
11. Air Shutdown Housing
12. Shaft
13. Cam Pin Handle
14. Cam
15. Spacer
16. Spring
17. Gasket
18. Air Shutoff Valve
19. Latch

Figure 6-11 Air Shutdown Housing (Non-Turbocharged Engines)

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2. On turbocharged engines, loosen the hose clamp. See Figure 6-12. Slide the hose between the air shutdown housing and the turbocharger back.



1. Latch
2. Air Shutdown Housing
3. Hose
4. Turbocharger
5. Housing Adaptor
6. Blower

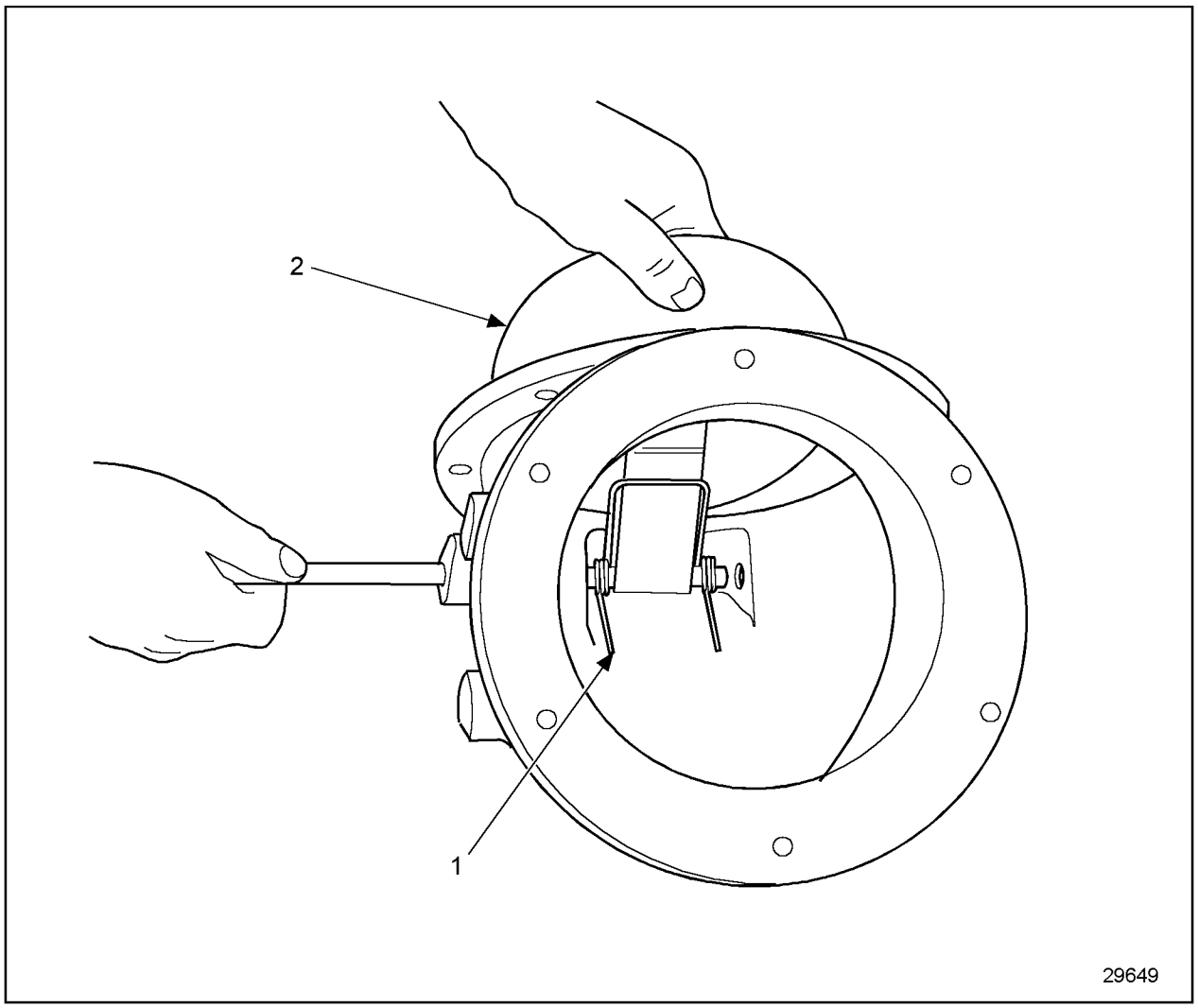
Figure 6-12 Typical Air Shutdown Housing Mounting (Turbocharged Engines)

3. Disconnect the control wire from the air shutoff cam pin handle.
4. Remove the bolts and lock washers attaching the air shutdown housing to the adaptor.
5. Remove the housing and gasket.
6. Remove the bolts and washers attaching the housing adaptor to the blower.
7. Remove the adaptor and the blower screen.

6.4.3 Disassembly of Air Shutdown Housing

Disassemble the air shutdown housing as follows:

1. Remove the pin from the end of the shutdown shaft.
2. Remove the spacer from the shaft and the seal ring from the housing.
3. Remove the two pins securing the shutdown valve to the shaft.
4. Remove the bolt, lock washer, and plain washer attaching the latch to the housing.
5. Remove the latch, latch spring, and spacer.
6. Observe the position of the air shutdown valve spring and valve. See Figure 6-13.



1. Spring
2. Air Shutoff Valve

Figure 6-13 Air Shutdown Valve Spring and Valve Position

7. Withdraw the shaft from the housing to release the valve and spring.

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8. Remove the valve and spring and the seal ring from the housing.
9. Remove the cam pin handle, and withdraw the cam from the shaft.

6.4.3.1 Cleaning of Air Shutdown Housing

Clean the air shutdown housing as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Clean all parts, including the blower screen, 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 parts with compressed air.

6.4.3.2 Inspection of Air Shutdown Housing

Inspect the air shutdown housing as follows:

1. Visually Inspect the face of the shutdown valve for flatness.

NOTE:
The face of the shutdown valve must be perfectly flat to assure a tight seal when it is in the shutdown position.

[a] If the shutdown valve is not flat, replace the shutdown valve. Refer to section 6.4.4.

[b] If the shutdown valve is flat, proceed with inspection.

2. On 8V and 16V engines, visually inspect the nylon bushing at each end of the valve shaft for wear.

   [a] If the nylon bushing is worn, replace the bushing. Refer to section 6.4.4.

   [b] Reuse If the nylon bushing is not worn.

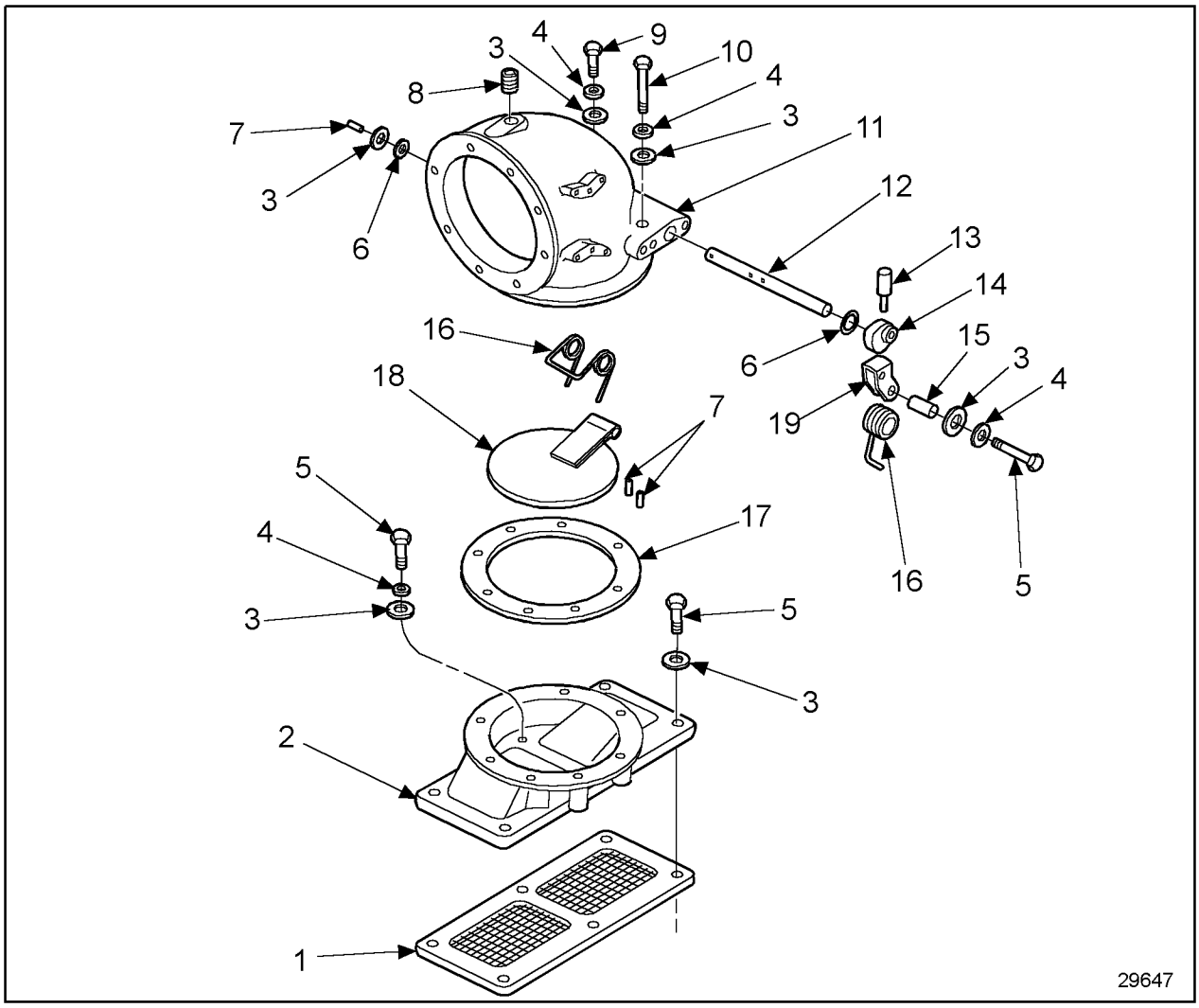
6.4.4 Assembly of Air Shutdown Housing

Assemble the air shutdown housing as follows:

NOTE:
The holes for the cam pin handle and the retaining pins must be drilled, using a 1/8 in. diameter drill, when a new service shaft or shutdown valve(s) is assembled. Refer to section ADDITIONAL INFORMATION *Shop Notes*. The valve(s) must be in the same plane within 0.76 mm (0.030 in.) when in the stop position (flush with the housing face). Proceed as follows:

1. Place the valve(s) and spring in position in the housing, and slip the shaft in place. The shaft must extend 17.78 mm (0.700 in.) from the side of the housing where the shutdown latch is assembled. See Figure 6-14.

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1. Blower Screen
2. Air Shutdown Adaptor
3. Washer
4. Lock Washer
5. Bolt
6. Seal Ring
7. Pin
8. Pipe Plug
9. Short Bolt
10. Long Bolt
11. Air Shutdown Housing
12. Shaft
13. Cam Pin Handle
14. Cam
15. Spacer
16. Spring
17. Gasket
18. Air Shutoff Valve
19. Latch

Figure 6-14 Air Shutdown Housing (Non-Turbocharged Engines)

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate with engine oil and install a new seal ring at each end of the shaft.

NOTE:
Ensure that the seal is seated in the housing counterbore.

3. Install the cam and cam pin handle on the shaft. Install the pin that retains the cam to the shaft.
4. Install a washer or spacer and retaining pin at the other end of the shaft.
5. Align the notch on the cam with the notch on the latch, and lock the cam in this position.
6. Install the pins in the valve(s) to retain them to the shaft with the cam release latch set and the valve(s) in the run position.
7. Level the valve(s) in the shutdown position.
8. Adjust the cam so the valve(s) contact the housing when the cam release latch is set.

6.4.5 Installation of Air Shutdown Housing

Install the air shutdown housing as follows:

1. Place the blower screen and gasket assembly, if used, in position. Install the shutdown housing adaptor on the blower.
2. Tighten the 3/8 in.-16 attaching bolts to 22-27 N·m (16-20 lb·ft) torque.

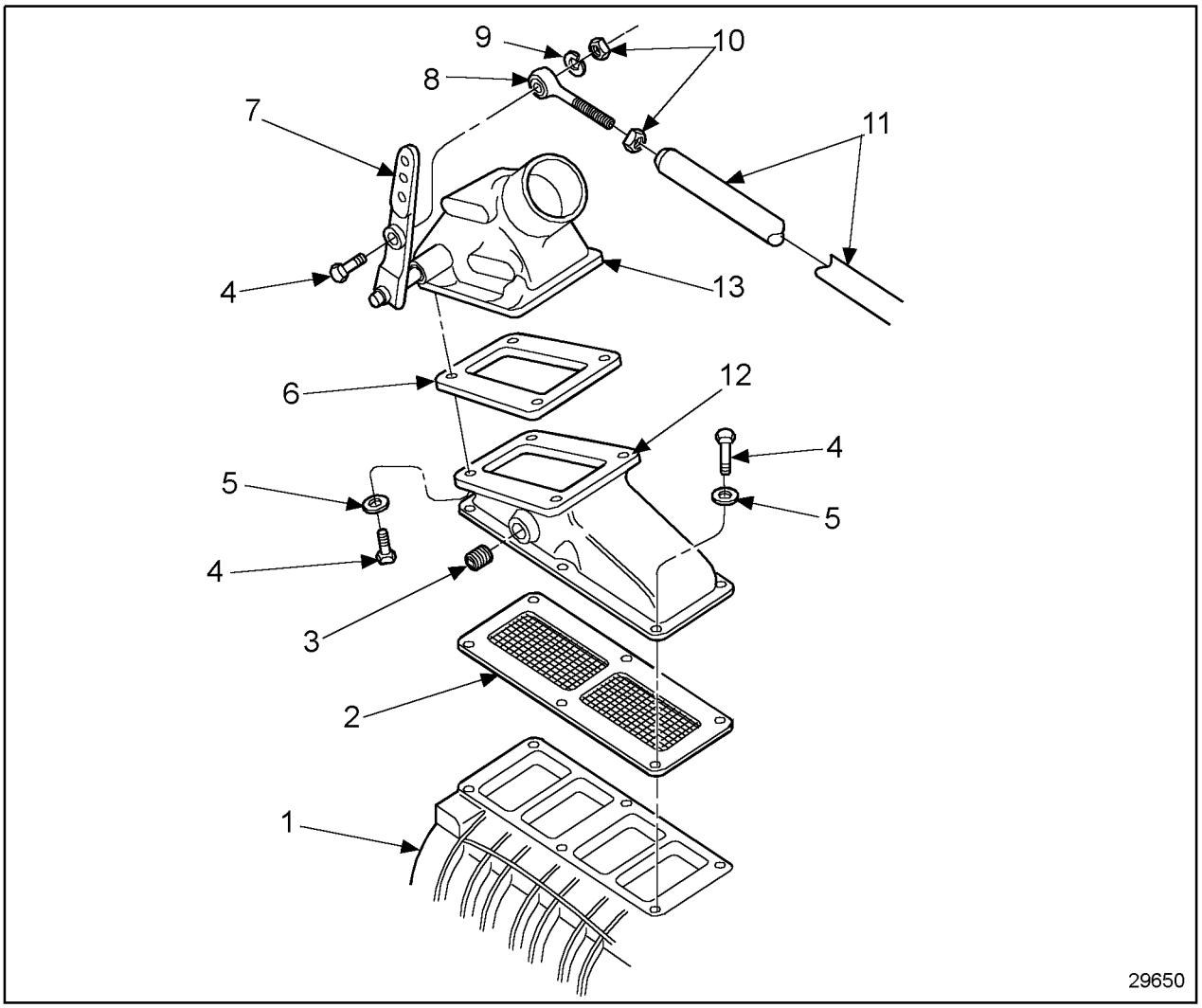
NOTE:
The current blower screen gasket consists of wire mesh secured between two sheets of gasket material. The former screen was imbedded in one sheet of gasket material and was installed with the screen side toward the blower.

NOTE:
When a striker plate and gasket are used, install them between the blower screen and gasket assembly and the air shutdown housing.

3. Place a new gasket on the adaptor. Mount the air shutdown housing on the adaptor. Secure it with 3/8 in.-16 bolts and lock washers. Tighten the bolts to 22-27 N m (16-20 lb·ft) torque.
4. On naturally aspirated engines, install the air ducts from the air cleaner to the air shutdown housing. Use a new gasket at the housing. Ensure that all connections are airtight.
5. On turbocharged engines, slide the hose between the shutdown housing and the turbocharger. Tighten the clamps.

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6. When dual air shutdown housings have been installed, position the crossover rod between the shutdown housings at the reset lever and the shutdown lever. See Figure 6-15.



1. Blower
2. Blower Screen
3. Pipe Plug
4. Bolt
5. Washer
6. Gasket
7. Reset Lever
8. Rod End Bearing
9. Lock Washer
10. Nut
11. Cross-Over Rod
12. Inlet Housing Adaptor
13. Shut Down Housing

Figure 6-15 Air Shutdown Housing (Rear of Dual Mounting - Turbocharged Engines)

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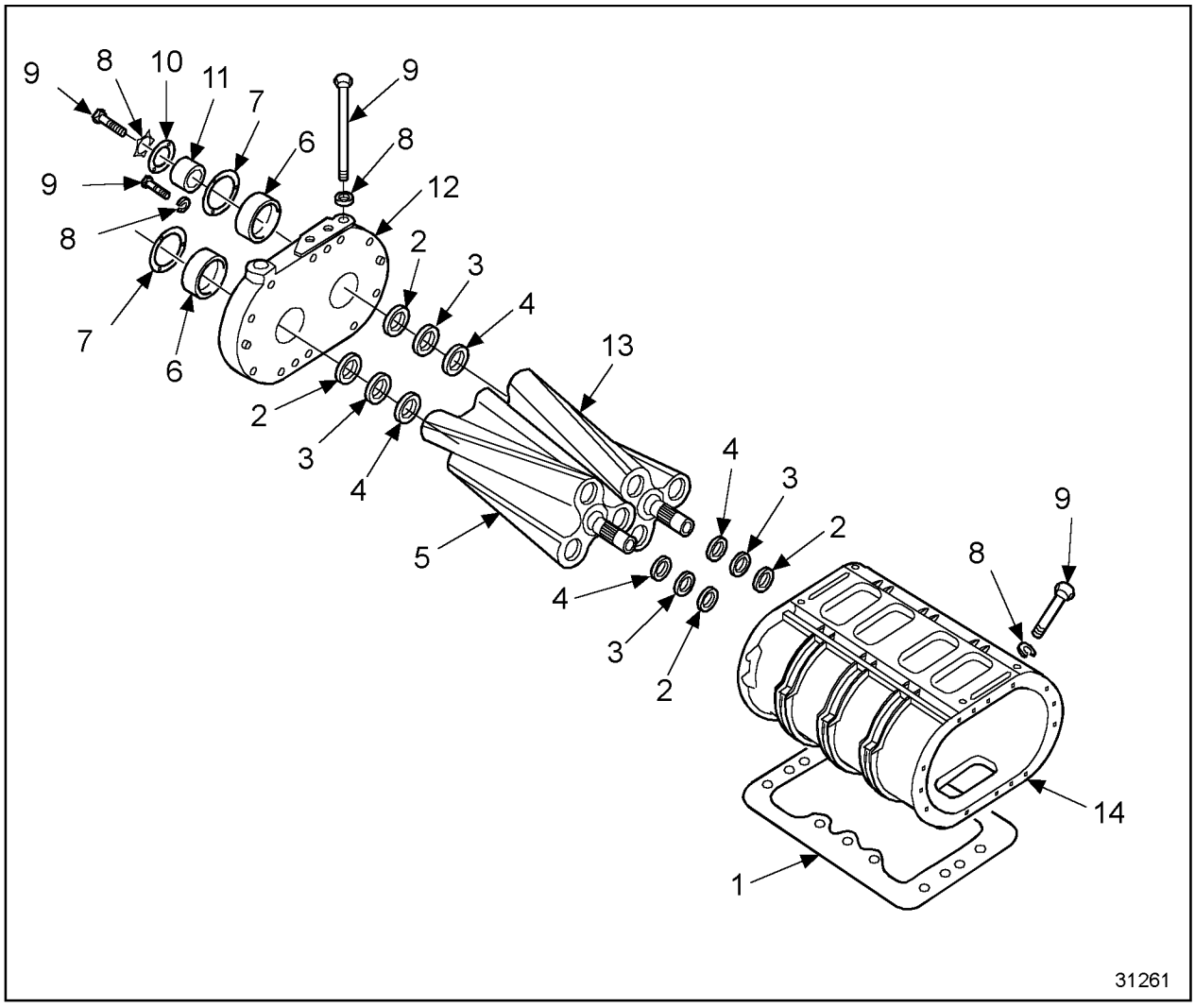
NOTE:
Before securing the couplings (non-turbocharged engines), close the valves in both of the shutdown housings. Center the couplings on the housing shafts with the aid of new roll pins. On turbocharged engines, secure the rod end bearings at the levers with 5/16 in.-24 x 1-1/8 in. bolts. Tighten the bolts to 20-26 N·m (15-19 lb·ft) torque.

7. Reset the air shutdown latch to the run position.
8. Start and run the engine at idle speed and no load. Trip the air shutdown latch.
9. If the engine does not stop, check it for air leakage between the valves and the air inlet housing adaptor. If necessary, reposition the valves.
10. After this test has been satisfactorily performed, drill and pin the couplings (non-turbocharged engines) to the shafts with a roll pin for each coupling, using a 1/8 in. diameter drill.

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6.5 BLOWER

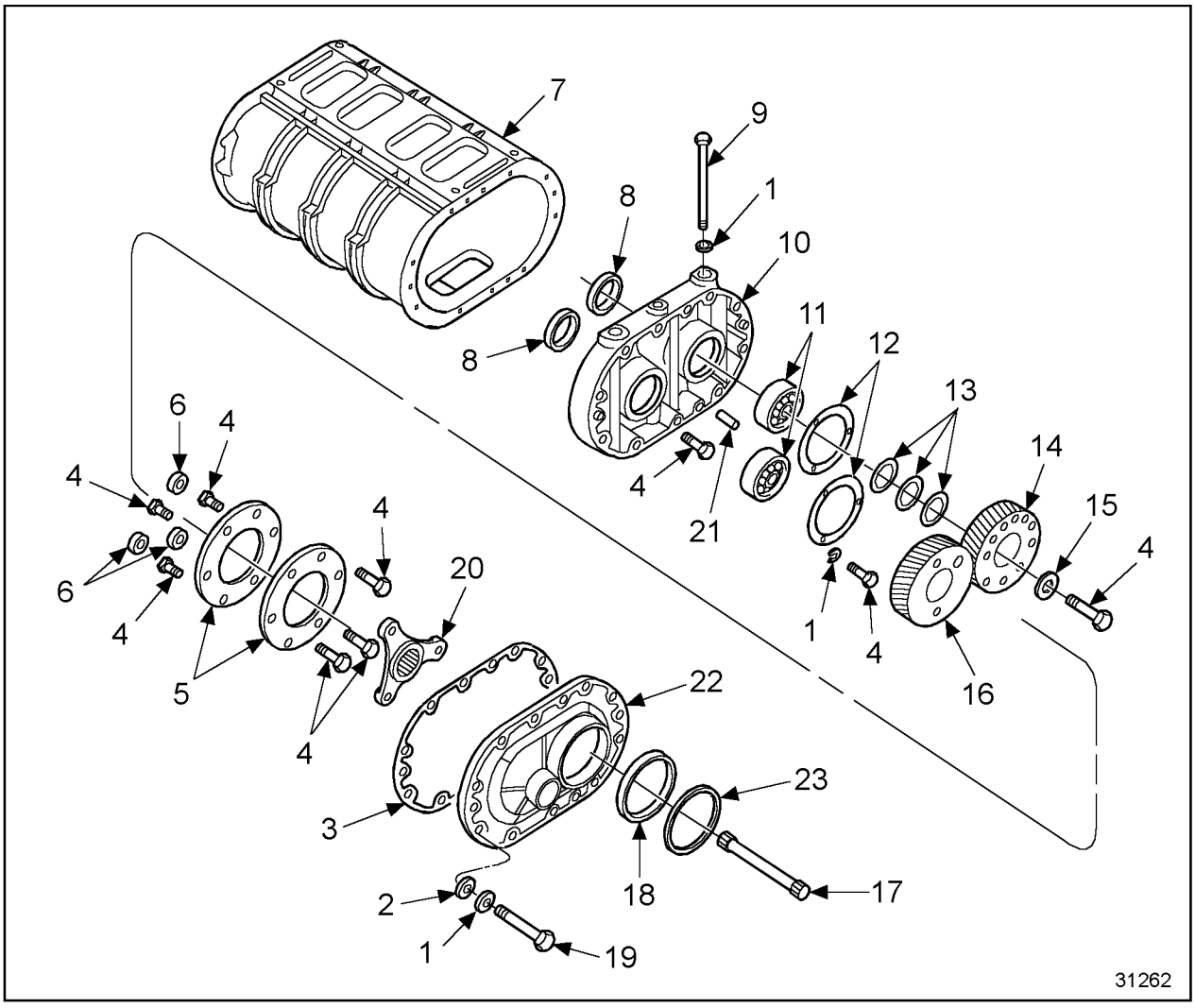
The large bearing blower, designed especially for efficient diesel operation, supplies the fresh air needed for combustion and scavenging. Its operation is similar to a gear-type oil pump. Two hollow three-lobe rotors revolve with very close clearances in a housing bolted to the top deck of the cylinder block, between the two banks of cylinders. To provide continuous and uniform air displacement, the rotor lobes are made with a helical (spiral) form. See Figure 6-16 and see Figure 6-17.



1. Gasket
2. Blower End Plate Cooler
3. Seal Ring (Piston Type)
4. Seal Ring Carrier
5. LH Helix Rotor Assembly
6. Blower Rotor Bearing
7. Blower Bearing Retainer
8. Lock Washer
9. Bolt
10. Fuel Pump Drive Disc
11. Fuel Pump Drive Disc Spacer
12. Blower Front End Plate
13. RH Helix Rotor Assembly
14. Blower Housing

Figure 6-16 Blower Assembly (1 of 2)

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1. Lock Washer (3)
2. Special Flat Washer
3. Gasket Cover
4. Bolt (8)
5. Flexible Plate
6. Spacer (30
7. Blower Housing
8. Oil Seal (2)
9. Blower Mounting Bolt
10. Blower Rear End Plate
11. Blower Rotor Rear Ball Bearing
12. Blower Bearing Retainer
13. Shims
14. RH Helix Rotor
15. Washer
16. L.H. Helix Rotor
17. Blower Drive Shaft
18. Hose Clamp
19. Cover Bolt
20. Drive Hub
21. Oil Passage Orifice
22. Rear End Plate Cover
23. Blower Drive Hose Cover

Figure 6-17 Blower Assembly (2 of 2)

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Two basic types of large bearing blowers are used. The regular type blower has six mounting holes in the top of the blower housing and has regular end plates. The Optional Turbocharger Mounting (OTM) type blower has additional outboard holes for mounting the turbocharger adaptor (6 and 8V blowers). One end plate includes two oil drain holes with seal rings for the turbocharger return oil drain back. Refer to section 6.5.

The blower used on naturally aspirated engines has a 2.60:1 ratio blower-to-engine speed. The blower used on turbocharged engines has a 2.05:1 ratio blower-to-engine speed. Certain 6V turbocharged aftercooled, 12V turbocharged and 16V turbocharged aftercooled engines have a 1.95:1 ratio blower-to-engine speed.

Two timing gears, located on the drive end of the rotor shafts, space the rotor lobes with a close tolerance. Since the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip-type oil seals are installed in the blower end plates on the naturally aspirated engines. Metal ring-type oil seals were formerly used in the blowers on turbocharged engines. Each ring-type oil seal consisted of a carrier pressed on the rotor shaft, a collar pressed into the end plate, and a seal ring contained in a carrier groove. The outside diameter of the seal ring rode against the collar to prevent air or oil leakage.

These 3-piece seals were replaced by double lip Teflon oil seals in 1986.

A roller bearing at the front end and a double-row radial and thrust ball bearing at the gear end supports each rotor.

The blower drive shaft drives the blower right-hand helix rotor. The blower drive shaft is splined at one end to a drive hub attached to the blower drive gear and at the other end to a drive hub attached to the right-hand helix blower timing gear. The mating left-hand helix timing gear drives the left-hand helix rotor.

The basic blower parts for the 6V and 8V cylinder engines are identical and interchangeable with the exception of the housing and rotors that differ in length. Two 6V blowers are mounted on the top deck of the 12V cylinder engines, while two 8V blowers are mounted on the top deck of the 16 cylinder engines. The gear trains at each end of the engine drives both 12V and 16V blowers.

The two rotor gears at the rear end of the rotor time the blower rotors. Timing must be correct, otherwise the required clearance between the rotor lobes will not be maintained. Shims used between the gears and the bearings change rotor timing.

Normal gear wear causes a rotor-to-rotor clearance decrease between the leading edge of the right-hand helix (drive) rotor and the trailing edge of the left-hand helix (driven) rotor. Clearance between the opposite sides of the rotor lobes is increased correspondingly.

While adjustments can correct the rotor lobe clearance, gear backlash cannot be corrected. When gears have worn to the point where the backlash exceeds 0.10 mm (0.004 in.), replace the gears. Refer to section 6.5.4.

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A coarse spline, 29-tooth blower drive system has replaced the 48-tooth system. The shafts are carbon-nitride hardened and the spline length of the front hub and turbo rear hub has been increased. The new 29 and 29/48 drive shafts are drilled to accept a 0.24 in. diameter spring. This spring is pressed into the front of the blower drive shaft and limits the axial drive shaft movement to reduce spline wear. New blower drive supports with a 1/32 in. oil passage for additional lubrication are being used on turbocharged engines only. The former 48-tooth and the new 29-tooth blower drive shafts, hubs, couplings and supports, and the former and new snap rings are not interchangeable.

Two special 29/48-tooth blower drive shaft assemblies have been released to service large bearing blower engines having the former 48-tooth blower drive systems. The new shafts have 29 coarse splines on the blower drive support (rear) end and 48 splines on the blower timing gear (front) end. The new shaft assemblies are to be used only when the 48-tooth shaft and rear hub require replacement. If the blower assembly or front hub requires replacement, or during major engine overhaul, a complete 29-tooth blower drive system should be installed.

A blower drive coupling spring pack is used in 6V-92TA coach engines to prevent the transfer of torque fluctuations to the blower and reduce blower drive shaft spline wear. The spring pack is installed with the retainer groove in the cam facing the gear.

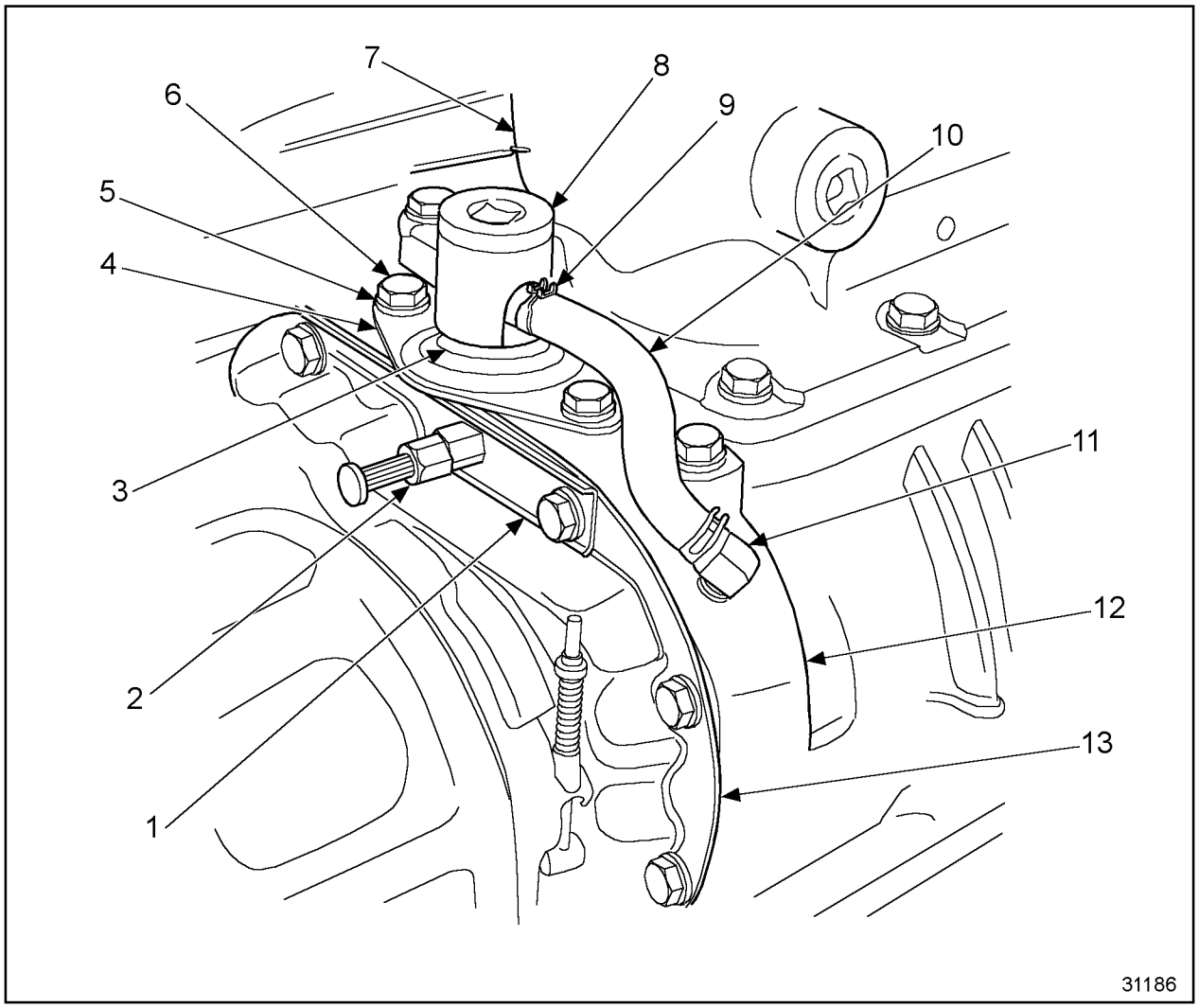
NOTE:
The former blower drive shaft bore supports installed in pre-1979 production engines cannot be rebored to the increased diameter of the current blower drive supports. On engines built before 1979, new blower drive supports must be used when converting from a 48-tooth to a complete 29-tooth blower drive system.

Effective with engine serial numbers 6VF-096295 and 8VF-079550, mini-bypass blowers have been released for 6V and 8V Federal-certified and 8V California-certified automotive engines equipped with front blower-mounted and rear bracket-mounted turbochargers. Coach engines are not included in this change.

The mini-bypass blower was developed to reduce the amount of engine power required to operate the blower, increasing fuel efficiency.

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A spring-loaded bypass relief valve is positioned in a passage in the rear blower end plate of the turbocharged 6V and 8V automotive engines indicated. See Figure 6-18. This valve is closed at start-up and during low RPM. light load operation. As engine speed and load increase, turbocharger speed also increases until the turbocharger provides sufficient boost pressure for scavenging and charging the engine cylinders.



1. Reinforcing Plate
2. Oil Transfer Tube Assembly
3. Seal Ring
4. Clamp
5. Lock Washer
6. Bolt
7. Air Inlet Housing
8. Valve Assembly
9. Clamp
10. Hose
11. Elbow 90 Degrees
12. Blower End Plate
13. Blower End Plate Cover Gasket

Figure 6-18 Typical Mini-Bypass Blower (6V-92)

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At 41 kPa (12 in. Hg), the air box pressure causes the valve in the passage to open. See Figure 6-19. With the valve in the open position, incoming air is allowed to flow through the blower lobes and through the rear end plate to the air box. The blower continues to operate with the valve open, but requires less engine power because the pressure rise across the blower is greatly reduced. This results in decreased brake specific fuel consumption and increased fuel economy.

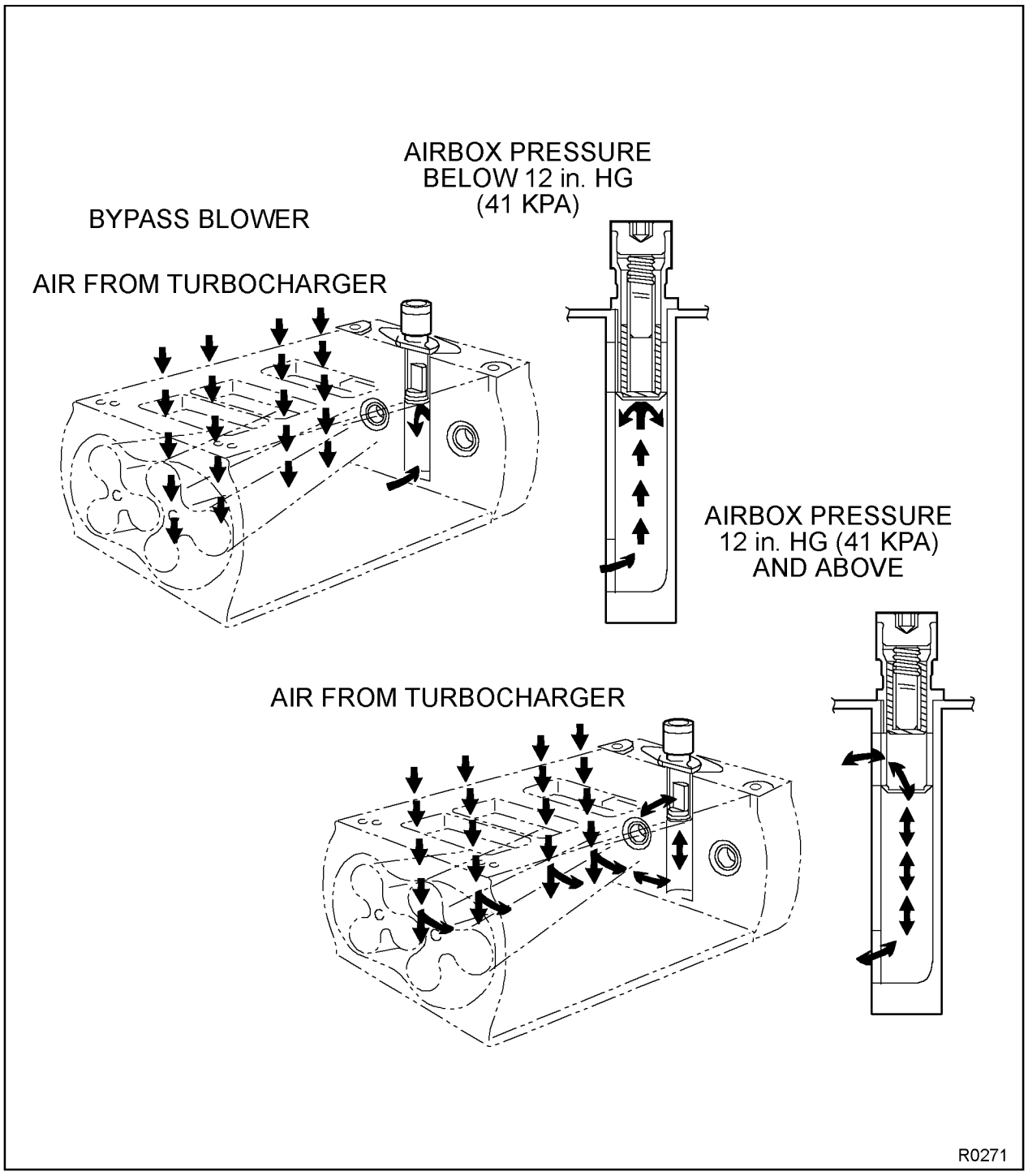


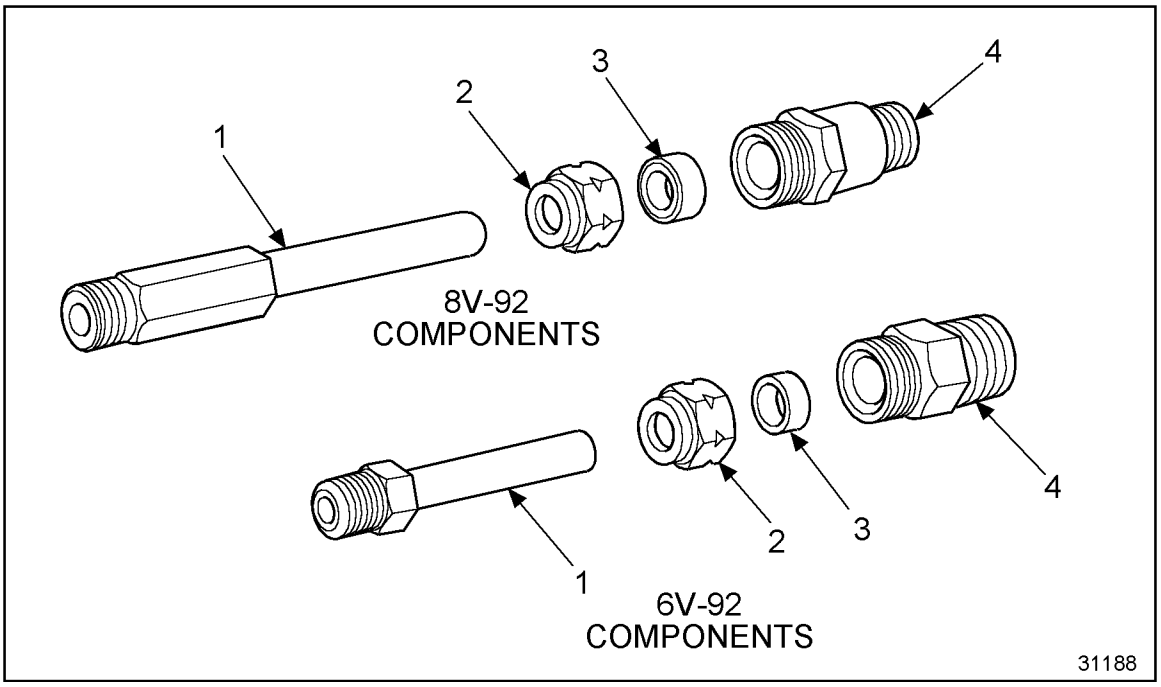
Figure 6-19 Mini-Bypass Blower Air Flow Diagram

A small vent hose and tube through the rear blower end plate externally vents the mini-bypass into the crankcase. A small amount of air bleeds past the valve and passes through the hose to help keep the valve clean and functioning properly. This has no effect on crankcase pressure.

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With the advent of the mini-bypass blower end plate and valve, one blower end plate cover bolt is eliminated and a new end plate cover reinforcing plate has been released. A new composition gasket is also being used to ensure a proper blower-to-end plate cover joint seal. An end plate cover reinforcing plate is used on 6V and 12V mini-bypass blowers, effective with units manufactured March, 1986.

Due to the size and location of the mini-bypass valve, new oil supply fittings are being used between the blower and the blower drive support, and new air inlet housings have been released. See Figure 6-20. The blower assemblies formerly used on 6V and 8V automotive engines equipped with front blower-mounted turbochargers or rear bracket-mounted turbochargers are serviced.

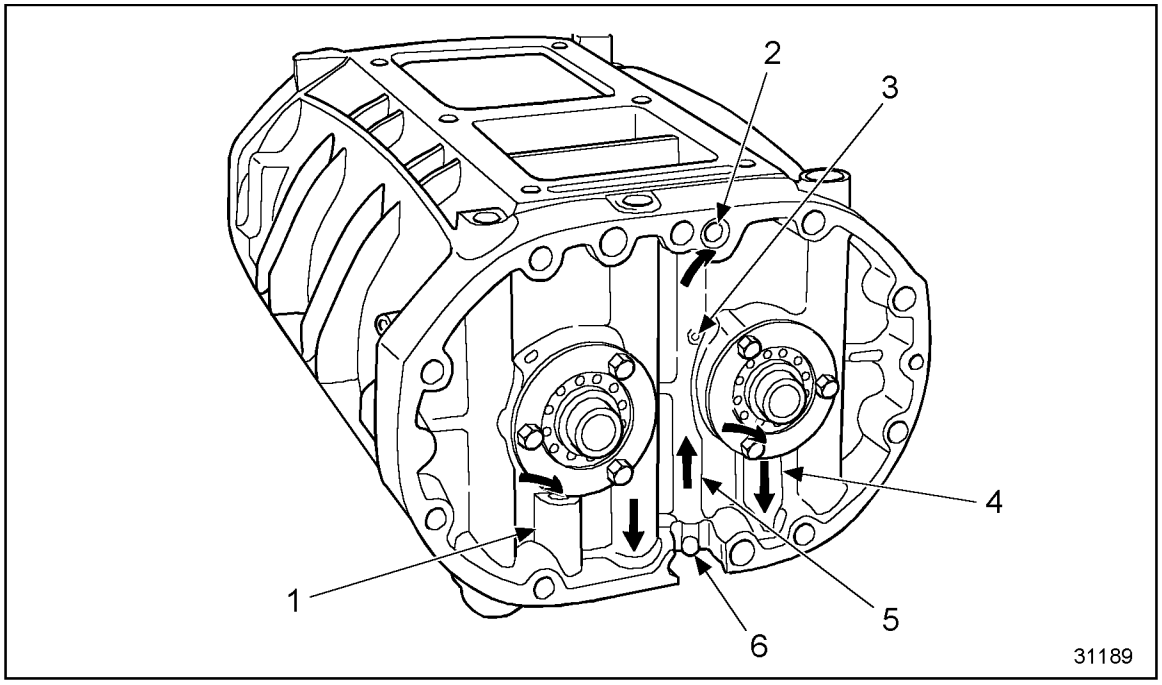


1. Adaptor
2. Coupling Nut
3. Seal Ring
4. Connector (to Blower End Plate)

Figure 6-20 Mini-Bypass Oil Transfer Assembly Components

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Oil passages in the top deck of the cylinder block, leading from the main oil galleries to an oil passage in each blower end plate pressure, lubricate the blower bearings, timing gears, governor drive, and fuel pump drive. See Figure 6-21.



1. Overflow Oil Return Passage
2. Oil Outlet-to-Blower Drive Support Bearings (From Rear End Plate Only)
3. Orifice
4. Overflow Oil Return Passage
5. Oil Inlet Passage From Cylinder Block
6. Oil Strainer

Figure 6-21 Blower Lubrication (Except OTM Blower)

A cup shaped oil strainer has been incorporated in the vertical oil passage at the bottom side of each blower end plate to remove any foreign material in the lubricating oil.

The oil flows upward in the end plate and leaves through a small orifice just above the center line of the end plate. The oil is ejected from this orifice against the timing gears at the rear and the governor weights at the front of the blower and is splashed on the bearings. Oil collecting at the bottom of each end plate overflows into two drain passages leading back to the crankcase via oil passages in the cylinder block.

NOTE:
The OTM type blower does not include an oil orifice in the end plate since the drain oil from the turbocharger lubricates the blower bearings.

The blower drive support bearings receive oil under pressure from a tube connecting the oil passage in the rear end plate to blower drive support passages. Excess oil drains back to the crankcase through the gear train.

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6.5.1 Repair or Replacement of Blower

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 6-22.

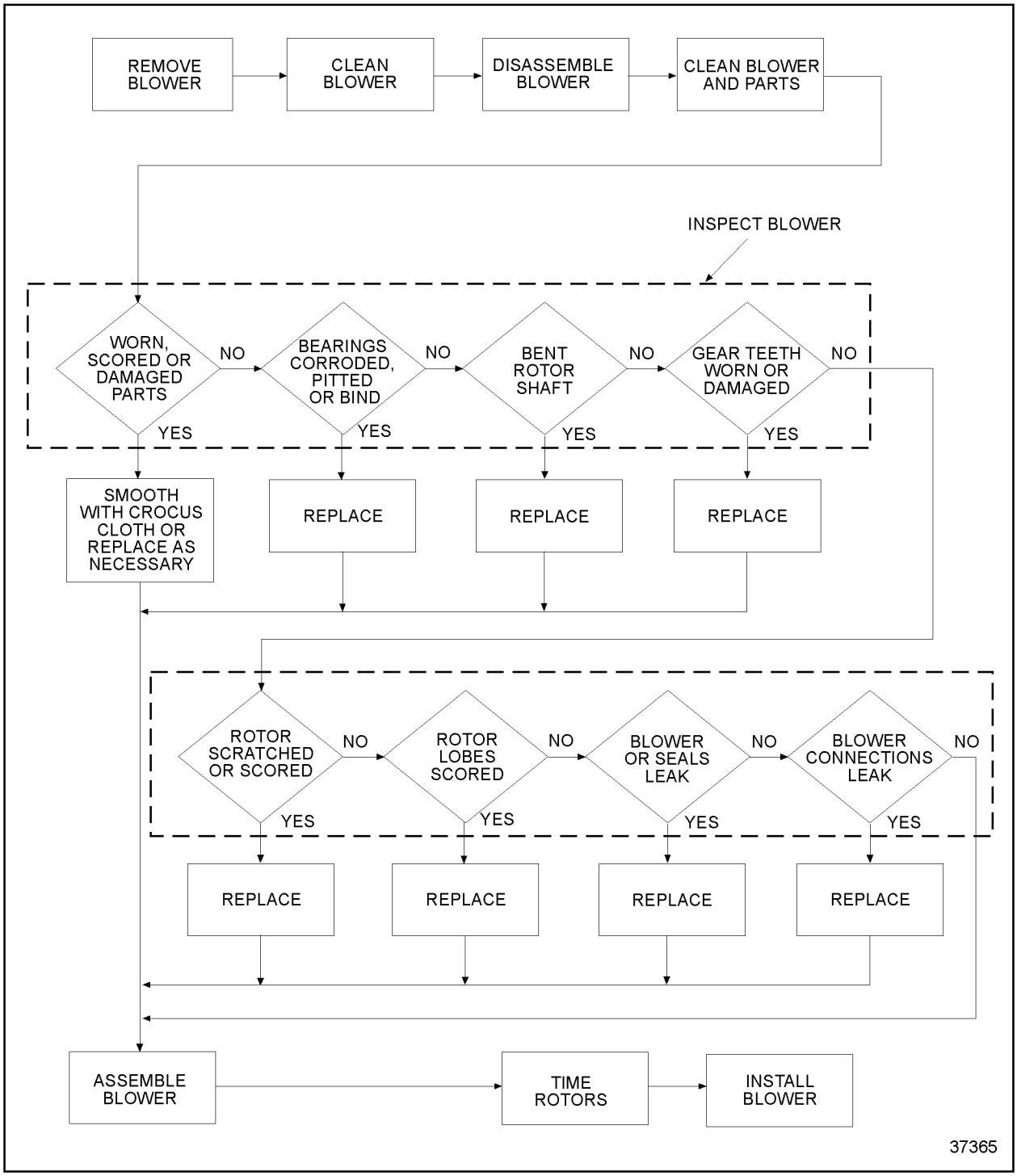
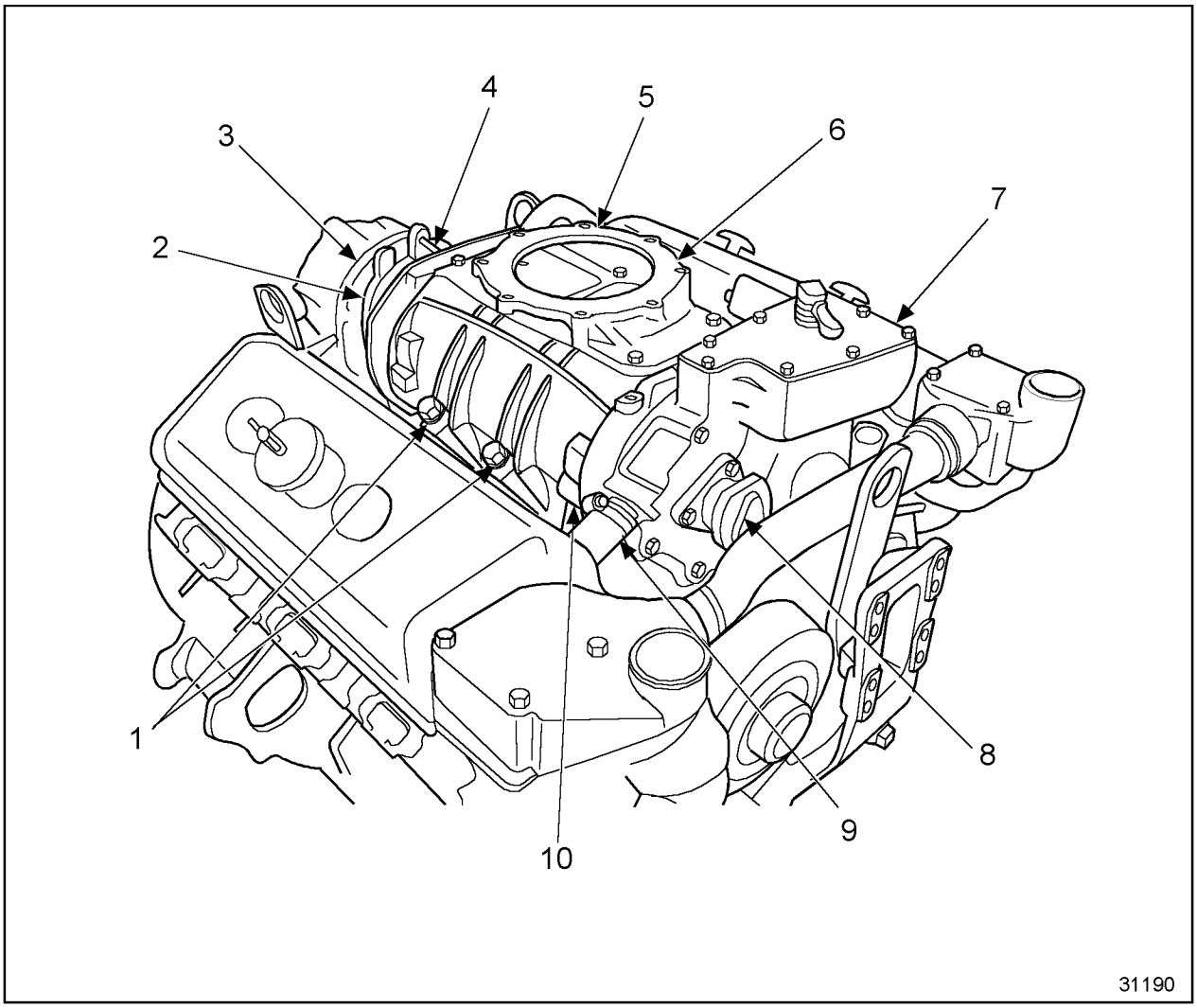


Figure 6-22 Flowchart for Repair or Replacement of Blower

6.5.2 Removal of Blower

Remove the blower as follows:

NOTE:
The mechanical engine governor components are assembled in a combination governor housing and blower front end plate cover. The fuel pump is attached to the front end of the blower. When removing the blower assembly from the engine, remove the governor and fuel pump at the same time. See Figure 6-23.



1. Mounting Bolts and Lugs
2. Seal and Clamp
3. Blower Drive Support
4. Lubrication Tube
5. Breather Tube
6. Air Shutdown Adaptor
7. Governor
8. Fuel Pump
9. Fuel Rod Cover
10. Blower

Figure 6-23 Typical Blower Mounting (Single Blower)

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1. Disconnect the air cleaner-to-air shutdown housing.
2. Disconnect the turbocharger tubing. Refer to section 6.6.2.
3. Remove the turbocharger, if used, and attaching parts. Refer to section 6.6.2.
4. Disconnect the shutdown wire assembly from the air shutoff cam pin handle.
5. Remove the air shutdown housing assembly and gasket. Refer to section 6.4.2.
6. Remove the bolts and washers securing the air shutdown housing to the blower.
7. Remove the adaptor and the blower screen (if used).
8. Loosen the oil pressure line fitting from the rear of the blower to the blower drive support.
9. Slide the fitting back on the tube.
10. Loosen the hose clamp on the blower drive support-to-blower seal.
11. Disconnect the tachometer drive cable from the adaptor at the rear of the blower.
12. Remove the flywheel housing cover at the blower drive support.
13. Remove the snap ring and withdraw the blower drive shaft from the blower.
14. Open the drain cocks and drain the engine cooling system.
15. Loosen the hose clamps and slide the hoses back on the bypass tube between the thermostat housings. Remove the bypass tube.
16. Remove the fuel inlet and outlet lines to the fuel pump. Remove the fuel return crossover tube between the cylinder heads.
17. Remove or disconnect the breather pipe at the top of the cylinder block.
18. Remove the front engine lifter bracket, if necessary.
19. Disconnect the throttle control rods from the governor.
20. Clean and remove the rocker cover from each cylinder head.
21. Remove the governor cover screws and lock washers. Remove the governor cover.
22. Disconnect the fuel rods from both the injector control tube levers and the governor. Remove the fuel rods.
23. Loosen the hose clamps on the fuel rod cover tube hoses next to each cylinder head. Slide each hose and clamp on the tube in the governor housing.
24. Remove the two bolts and washers through the top of each end plate securing the blower to the cylinder block.
25. Remove the blower-to-block bolts and retaining washers on each side of the blower.
26. Disconnect and remove any tubing or accessories that may interfere with blower removal.
27. On 12V and 16V engines, disconnect the governor linkage. Refer to section 2.24.11.
28. Remove the governor from the engine. Either blower may be removed without disturbing the other blower. Remove the governor to blower gasket.

CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the lifting sling before removing from engine. Blower damage may result if the blower falls from the lifting device.

29. Thread eyebolts in the diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.
30. Lift the blower slightly, and move it forward to detach the blower from the seal at the drive end.
31. Lift the blower up and away from the engine. Remove the blower gasket.
32. With the blower, fuel pump, and governor assembly removed from the engine, cover the air inlet and outlet openings of the blower housing, and install the governor cover.

6.5.2.1 Cleaning of Blower

Clean the blower as follows:

CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- **Keep those people who are not directly involved in servicing away from the engine.**
- **Stop the engine immediately if a fuel leak is detected.**
- **Do not allow open flames or smoke when working on an operating engine.**
- **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash the exterior of the blower and governor housing with clean fuel oil.

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CAUTION:

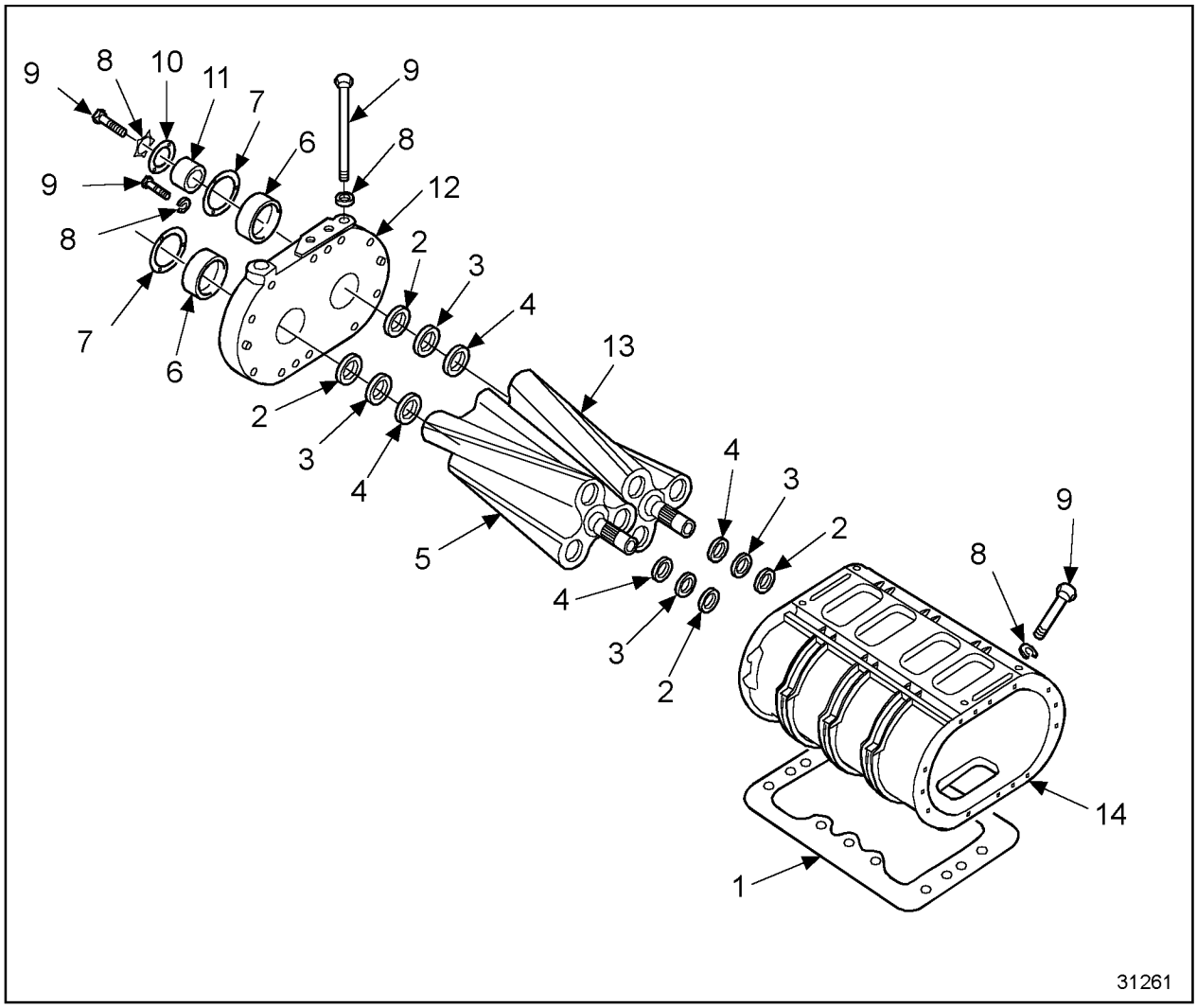
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

2. Dry parts with compressed air.

6.5.3 Disassembly of Blower

Remove the blower rear end plate cover, governor, and fuel pump assembly from the blower as follows:

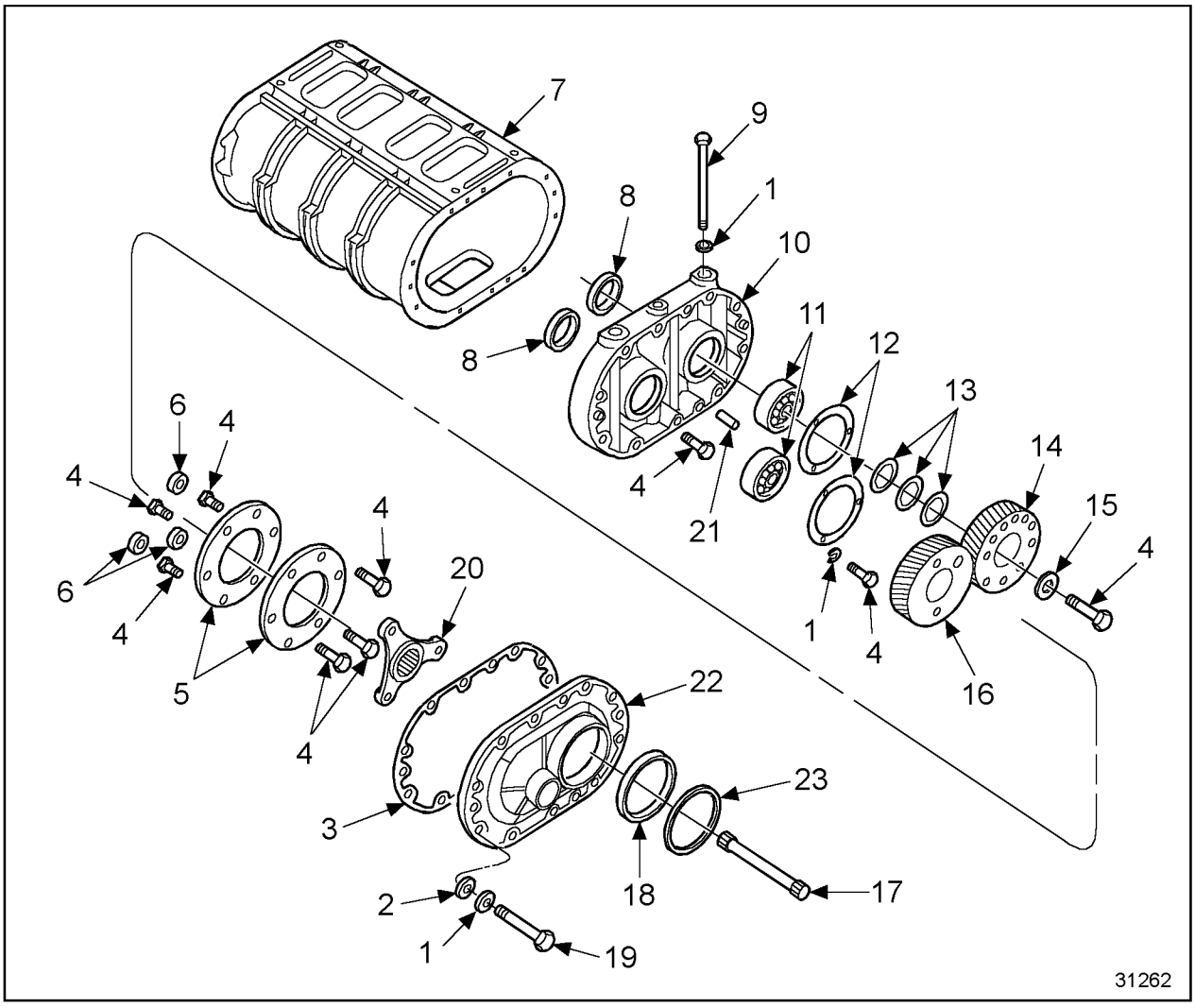
1. Remove the remaining bolts, lock washers, and special washers securing the rear end plate cover to the end plate. Remove the cover and gasket from the end plate. See Figure 6-24 and see Figure 6-25.



1. Gasket
2. Blower End Plate Cooler
3. Seal Ring (Piston Type)
4. Seal Ring Carrier
5. LH Helix Rotor Assembly
6. Blower Rotor Bearing
7. Blower Bearing Retainer
8. Lock Washer
9. Bolt
10. Fuel Pump Drive Disc
11. Fuel Pump Drive Disc Spacer
12. Blower Front End Plate
13. RH Helix Rotor Assembly
14. Blower Housing

Figure 6-24 Blower Assembly (1 of 2)

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1. Lock Washer
2. Special Flat Washer
3. Cover Gasket
4. Bolt
5. Flexible Plate
6. Spacer
7. Blower Housing
8. Oil Seal
9. Blower Mounting Bolt
10. Blower Rear End Plate
11. Blower Rotor Rear Ball Bearing
12. Blower Bearing Retainer
13. Shims
14. RH Helix Rotor
15. Washer
16. L.H. Helix Rotor
17. Blower Drive Shaft
18. Hose Clamp
19. Cover Bolt
20. Drive Hub
21. Oil Passage Orifice
22. Rear End Plate Cover
23. Blower Drive Hose Cover

Figure 6-25 Blower Assembly (2 of 2)

2. Remove the three bolts and washers or lock bolts securing the flex plates to the right-hand blower rotor gear. Remove the drive coupling from the gear.

NOTE:
Some former engines are equipped with thin hub spacers. They are not readily accessible, being they are behind the flex plate. When working on the blower hub assemblies, remove the flex plate attaching bolts carefully to avoid dropping the thin hub spacers into the gear train. If spacers are inadvertently dropped into the gear train, remove the engine flywheel housing and/or oil pan to retrieve them.

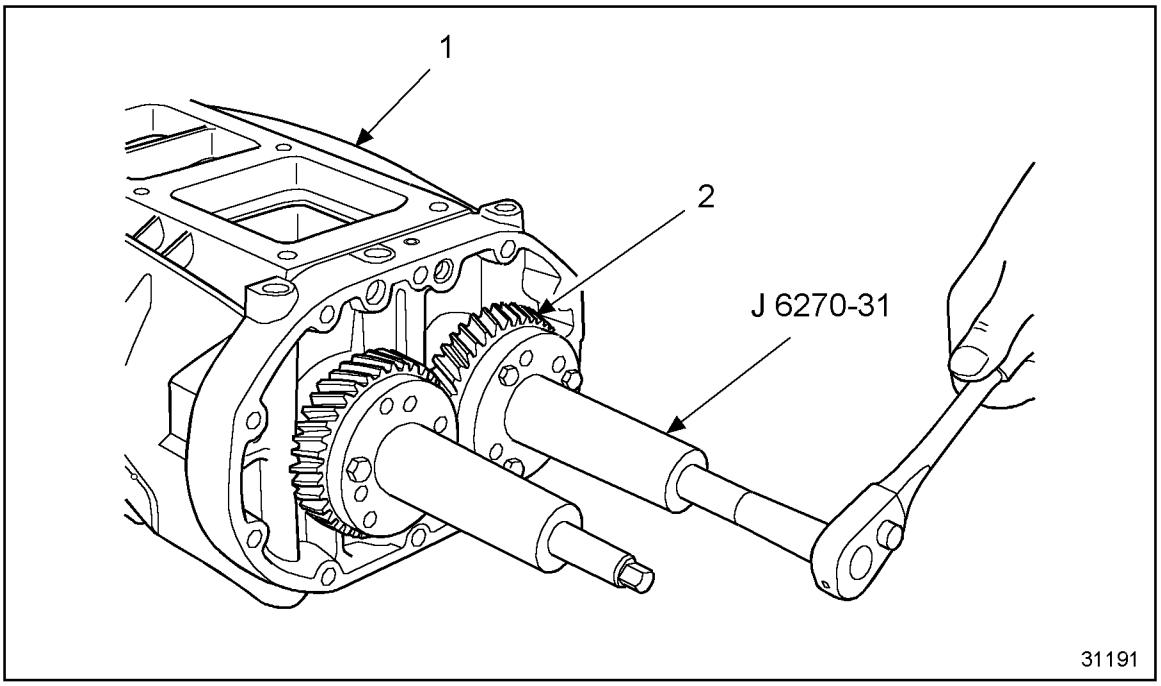
3. Observe the location of the two copper washers, one plain washer, and eight lock washers on the governor-to-blower bolts before removing them.
4. Remove the ten bolts and washers (two inside and eight outside) securing the governor and fuel pump assembly to the blower.
5. Tap the sides of the governor housing slightly with a plastic hammer to loosen the governor from the blower.
6. Pull the governor and fuel pump assembly from the dowels in the blower end plate.
7. Remove the fuel pump drive coupling fork and the governor housing gasket.

Disassemble the blower as follows:

1. Place a clean folded cloth between the rotors, and remove the lock bolts and thick washers securing the timing gears to the blower rotor shaft.

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2. Remove the timing gears with pullers J 6270-31 (from set J 6270-G). See Figure 6-26. Both gears must be pulled at the same time as follows:



1. Blower Assembly
2. Blower Drive Gears

Figure 6-26 Removing Blower Gears with Tool J 6270-31 (from Set J 6270-G)

[a] Back out the center screws of both pullers.

[b] Place the flanges against the gear faces, aligning the flange holes with the tapped holes in the gears.

[c] Secure the pullers to the gears with 5/16 in.-24 x 1-1/2 in. bolts (two bolts on the LH helix gear and three bolts on the RH helix gear).

[d] Turn the two puller screws uniformly clockwise and withdraw the gears from the rotor shafts.

3. After the gears have been removed, remove the shims from the rotor shafts, and note the number and thickness of shims on each rotor shaft to ensure identical replacement when reassembling the blower.
4. Remove the self-locking screws securing the rotor shaft bearing retainers to the front and rear end plates. Remove the retainers.

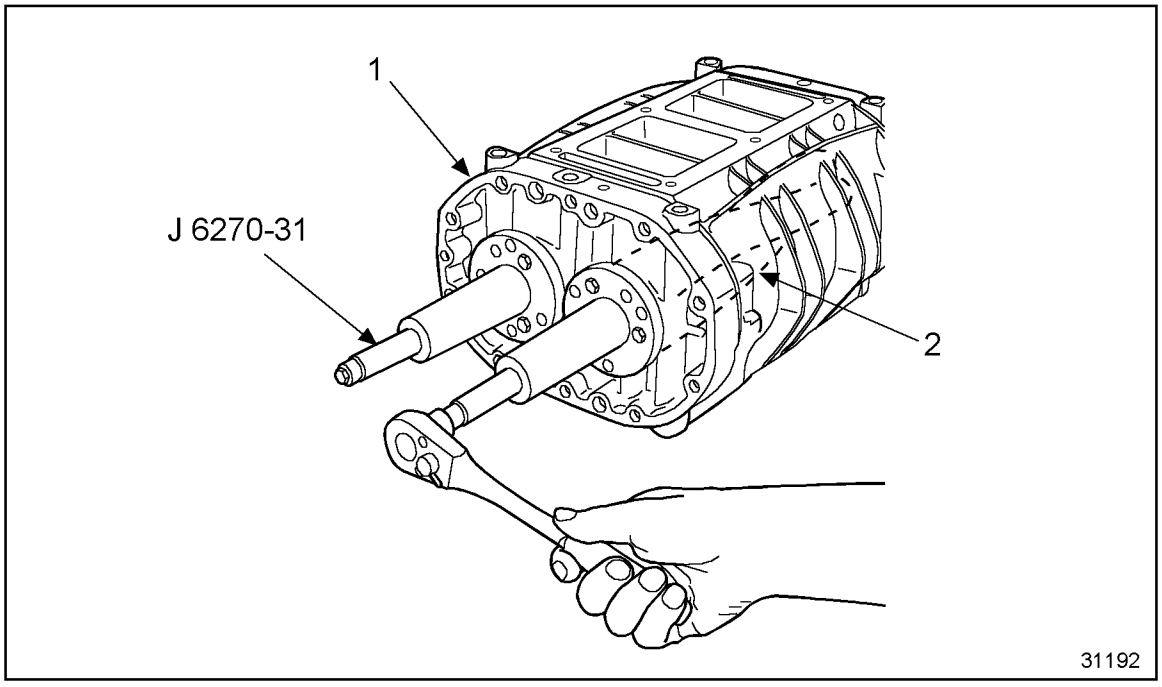
Remove the blower rear end plate and ball bearing assembly from the blower housing and rotors with the two pullers J 6270-31 (from set J 6270-G) as follows:

1. Remove the two fillister head screws securing the rear end plate to the blower housing.
2. Loosen the two fillister head screws securing the front end plate to the housing approximately three turns.

3. Back out the puller center screws far enough to permit each puller flange to lay flat on the end plate face.

NOTICE:
Ensure that the 1/4 in.-20 bolts are threaded all the way into the tapped holes in the end plate to provide maximum anchorage for the pullers and to eliminate possible damage to the end plate.

4. Align the holes in each puller flange with the tapped holes in the end plate. Secure the pullers to the end plate with six 1/4 in.-20 x 1-1/4 in. or longer bolts.
5. Turn the two puller screws uniformly clockwise, and withdraw the end plate and bearings from the blower housing and rotors. See Figure 6-27.



1. Blower Assembly
2. Rotors

Figure 6-27 Removing Blower End Plate and Bearings From Housing and Rotors with Tool J 6270-31 (from Set J 6270-G)

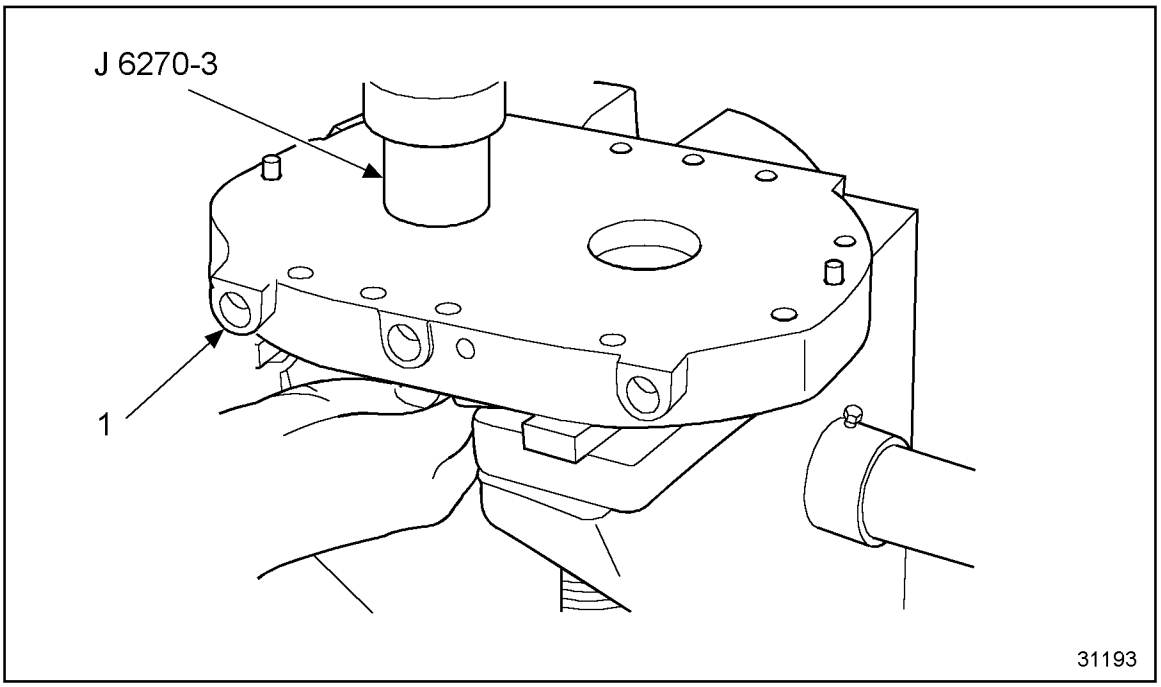
Remove the blower front end plate and roller bearing assembly from the blower housing and rotors as follows:

1. Remove the fuel pump drive bolt, washer, and spacer.
2. Remove the two fillister head screws securing the front end plate to the blower housing.
3. Remove the front end plate and roller bearings from the housing and rotors.
4. Withdraw the blower rotors from the housing.

Remove the bearings and lip-type oil seals from the blower end plates as follows:

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1. Support the outer face of the end plate on wood blocks on an arbor press bed.
2. Place the long end of the oil seal remover J 6270-3 (from set J 6270-G) and installer J 6270-4 (from set J 6270-G) through the oil seal and into the bearing, with the opposite end of the remover under the press ram. See Figure 6-28.



1. Blower End Plate

Figure 6-28 Removing Oil Seal (or Oil Seal Ring Collar) and Bearing from End Plate with Tool J 6270-3 (from Set J 6270-G)

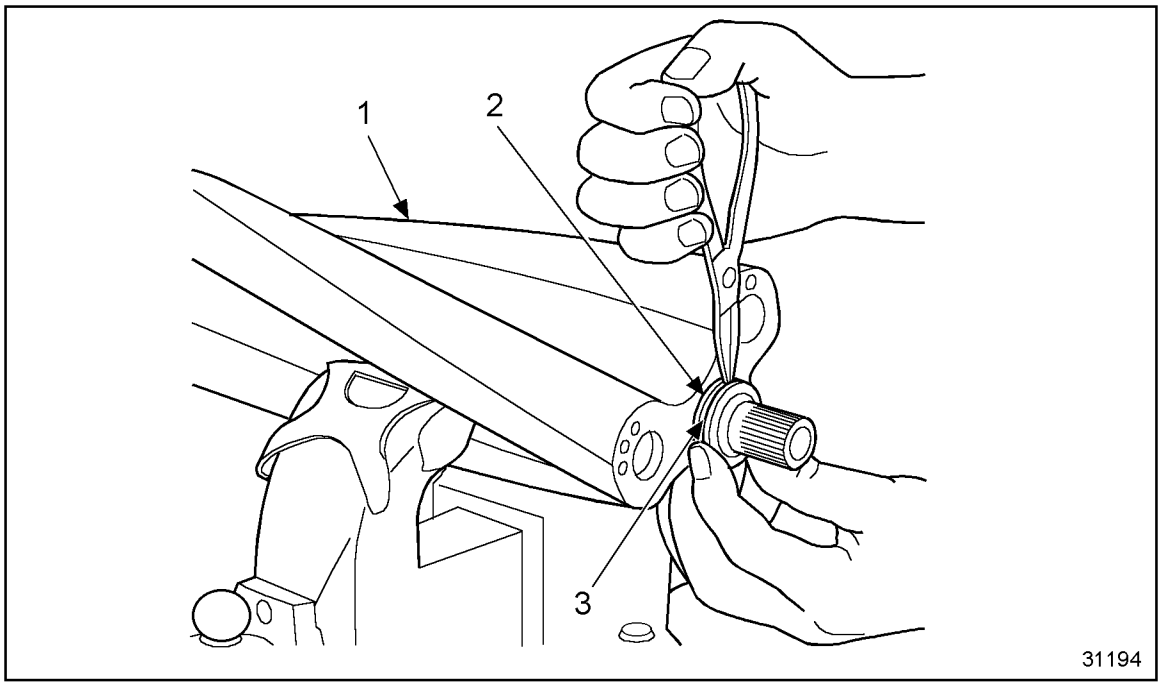
3. Press the bearing and oil seal out of the end plate. Discard the oil seal.
4. Remove the remaining bearings and oil seals from the end plates. Support the outer face of the end plate on wood blocks on an arbor press bed.
5. Place the long end of the oil seal remover J 6270-3 and installer J 6270-4 (from set J 6270-G), through the oil seal and into the bearing, with the opposite end of the remover under the press ram.
6. Press the bearing and oil seal out of the end plate. Discard the oil seal.

Remove the bearings and ring-type oil seals, carriers, roller bearing inner races, and collars from the turbocharged engine blower rotor shafts and end plates as follows:

1. Clamp one rotor lobe in a soft jawed bench vise. Tighten the vise just enough to hold the rotor stationary.

NOTICE:
To avoid breakage or distortion, do not spread or twist the ring any more than necessary to remove it.

2. Remove the oil seal ring from the seal ring carrier on each blower rotor shaft with a pair of snap ring pliers. See Figure 6-29.

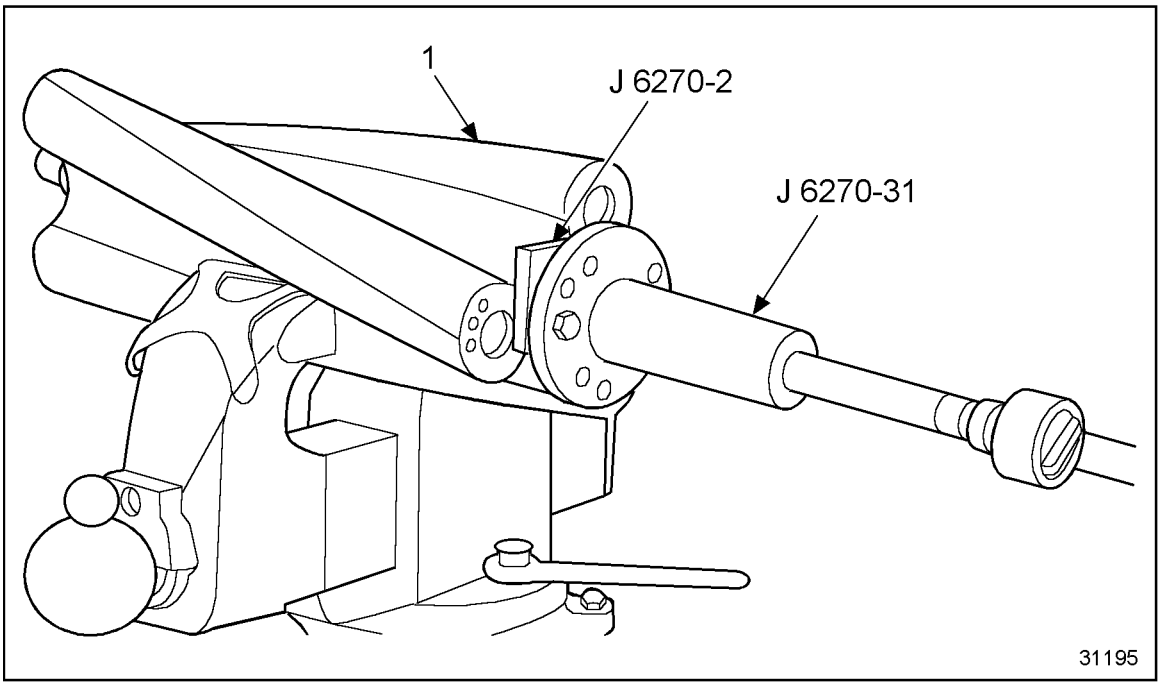


1. Rotor
2. Seal Ring Carrier
3. Oil Seal Ring

Figure 6-29 Removing Oil Seal Ring from Carrier (Turbocharged Engine Blowers)

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3. Place the seal ring carrier remover adaptor J 6270-2 (from set J 6270-G) over the carrier. Ensure that the adaptor is seated in the carrier groove. See Figure 6-30.



1. Rotor

Figure 6-30 Removing Oil Seal Ring Carrier from Blower Rotor Shaft (Turbocharged Engine Blowers)

4. Back out puller J 6270-31 (from set J 6270-G) center screw far enough to permit the puller flange to lay flat against the adaptor J 6270-2.
5. Place the puller over the end of the rotor shaft and against the adaptor on the oil seal ring carrier. Align the holes in the puller flange with the tapped holes in the adaptor.
6. Secure the puller to the adaptor with two bolts.
7. Turn the puller screw clockwise, and pull the oil seal ring carrier and roller bearing inner race (front end of blower rotors only) from the rotor shaft.
8. Remove the remaining oil seal ring carriers from the rotor shafts.
9. Support the outer face of the blower end plate on wood blocks on an arbor press bed.
10. Place the long end of the oil seal remover and installer J 6270-3 (from set J 6270-G) through the oil seal ring collar and into the bearing, with the opposite end of the remover under the press ram.
11. Press the bearing and oil seal ring collar out of the end plate.
12. Remove the remaining bearings and oil seal ring collars from the end plates.

The oil seal ring collar can be removed from the blower end plate with the bearing in place as follows:

1. Insert J 6270-14 bushing remover (from set J 6270-G), with the O-ring in the collar and the lip of the remover on the inside edge of the collar.
2. Support the inner face of the blower end plate on wood blocks.
3. Insert the small end of the driver handle J 6270-17 (from set J 6270-G) through the bearing and into the collar remover, spreading it tightly in the collar.
4. Press or tap on the driver handle to remove the collar.

6.5.3.1 Cleaning of Blower and Parts

Clean the blower and parts as follows:

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

1. Wash blower 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 with compressed air.
3. Clean the oil strainer in the vertical oil passage at the bottom side of each blower end plate.

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⚠ 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 out all oil passages with compressed air.

6.5.3.2 Inspection of Blower

Inspect the blower 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.

⚠ 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 blower may be inspected without being removed from the engine. However, the air separator and adaptor, or the air inlet housing, air shutdown housing, and adaptor must first be removed.

- ☐ Air separator and adaptor removal, refer to section 13.49.
- ☐ Air inlet housing removal, refer to section 6.4.2.
- ☐ Air shutdown housing and adaptor removal, refer to section 6.4.2.

NOTE:
The turbocharger and adaptor must be removed on engines equipped with the OTM blower. Refer to section 6.6.2. To correct any problems, the blower must be removed from the engine. Refer to section 6.5.2.

1. Inspect the rotor for scratches, scores, and burrs.
   [a] If excessively scratched or scored, replace the rotors. Refer to section 6.5.4.
   [b] If burrs cause interference between the rotors or between the rotors and the housing, remove the blower from the engine, and "dress" the parts to eliminate interference. Refer to section 6.5.2.

[c] If no scratches, scores, or burrs are present, continue with inspection.

2. Inspect the oil seals for oil on the blower rotors and inside housing surface.

   [a] Run the engine at low speed and shine a light into the rotor compartment at the end plates and the oil seals.

   [b] If a thin film of oil radiates away from the seals toward the blower inlet, the seals are leaking. Replace the seals. Refer to section 6.5.4.

   [c] If no leaks are detected, continue inspection.

3. Inspect the rotor lobe crowns, mating rotor roots, rotors, end plates, and housing for scoring.

   [a] If scored, tighten rotor shafts and replace damaged bearings. Refer to section 6.5.4.

   [b] If scoring is not detected, continue inspection.

4. Inspect for worn or damaged bearings, this will cause rubbing between mating rotor lobes at some point or perhaps allow the rotor assemblies to rub the blower housing end plate.

   [a] If rubbing is detected, replace the rotor lobe and damaged bearings. Refer to section 6.5.4.

   [b] If scoring is not detected, continue inspection.

5. Inspect the blower rotor lobes, especially the sealing ribs, for burrs or scoring. Rotors must be smooth for satisfactory blower operation.

   [a] If the rotors are excessively scored, replace them. Refer to section 6.5.4.

   [b] If the rotors are slightly scored or burred, clean with emery cloth, and continue inspection.

6. Inspect the blower inlet screen for accumulated dirt or broken wires. Refer to section 13.35.

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⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:

- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

[a] Thoroughly wash the screen in fuel oil, and clean with a stiff brush until it is free of all dirt.

[b] If broken wires are found in the blower screen, replace the screen. Refer to section 6.5.4.

[c] If no damage is detected, continue inspection.

7. Check the lubricating oil connection between the blower and the blower drive support for excessive oil leaks.

   [a] If oil leaks exist, tighten or replace the fittings or seal rings. Refer to section 6.5.4.

   [b] If no oil leaks are detected, continue inspection.

NOTE:
To correct any of the conditions cited in step 1 through step 7, the blower must be removed from the engine and either repaired or replaced.

8. Check the rubber seal ring used between the blower end plate cover and the blower drive support for oil leaks.

   [a] If oil leaks exist, retighten the seal clamp or replace the seal ring. Refer to section 6.5.4.

   [b] If no oil leaks exist, continue inspection.

NOTE:
Some engines use a seal ring (18.796 mm or 0.740 in. wide) that incorporates two raised edges, which provide a groove to retain the clamp. To replace a seal ring without removing the blower, refer to section ADDITIONAL INFORMATION.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

9. Lubricate each ball bearing with light engine oil to examine the bearings for corrosion or pitting. While keeping the bearing inner race from turning, revolve the outer race slowly by hand, and check for rough spots.

NOTE:
The double-row ball bearings are preloaded and have no end play. A new bearing will have considerable resistance when revolved by hand.

[a] If the bearing does not turn freely, it must be replaced. Refer to section 6.5.4.

[b] If the bearing turns freely, continue inspection.

10. Check the oil seal rings, carriers, and collars for wear or scoring.

[a] If excessively scored or worn, replace the oil seal rings, carriers, and collars. Refer to section 6.5.4.

[b] If not excessively worn or scored, continue inspection.

NOTE:
The current oil seal rings are chrome flashed, and the carriers are liquid nitrided. When oil seal ring or carrier replacement is necessary, both parts must be replaced together.

11. Examine the rotor shaft serrations for wear, burrs, or peening. Inspect the bearing and oil seal contact shaft surfaces for wear or scoring.

[a] If worn, burred, peened, or scored, replace the rotor shaft. Refer to section 6.5.4.

[b] If not burred, peened, or scored, continue inspection.

12. Inspect the inside face of each end plate for smoothness, flatness, and freedom from scoring and burrs.

NOTICE:

Do not remove metal at the joint face between the end plates and the housing. Air or oil leaks could develop after assembly.

[a] If the finished face is slightly scored or burred, clean with emery cloth.

[b] If the finished face is warped, replace it. Refer to section 6.5.4.

[c] If neither scored, burred, or warped, continue inspection.

13. Examine the blower timing gear serrations for wear or peening.

[a] If worn or peened, replace the blower timing gear. Refer to section 6.5.4.

[b] If neither worn nor peened, continue inspection.

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14. Check the blower timing gear teeth for wear, chipping, or other damage.
    [a] If the gears are worn so that backlash between the gears exceeds 0.10 mm (0.004 in.), or damaged sufficiently to require replacement, both gears must be replaced as a set. Refer to section 6.5.4.
    [b] If no wear, chipping, or damage are detected, continue inspection.
15. Inspect the blower drive shaft serrations for wear or peening.
    [a] If excessively worn or peened, replace the drive shaft. Refer to section 6.5.4.
    [b] If neither worn nor peened, continue inspection.
16. Inspect the drive shaft for bending, cracks, or wear.
    [a] If bent, cracked, or worn, replace the shaft. Refer to section 6.5.4.
    [b] If not bent, cracked, or worn, continue inspection.

NOTE:
Before installing a 29/48-tooth blower drive shaft, check the splines on the front hub for wear. During engine operation, the splines on the front hub and the front hub end of the blower drive shaft normally wear at a slower rate than the rear hub splines. Before replacing the drive shaft and rear hub, install the new shaft and rotate it back and forth to determine the amount of front hub spline wear. If perceptible lash (wear) is felt, the front hub is badly worn, and a complete 29-tooth blower drive system should be installed.

17. Inspect the corresponding splines on the used blower drive shaft to determine the amount of front hub wear.
    [a] If the shaft spline is worn, the front hub spline is worn. In this event the 48-tooth system should be replaced immediately with the 29-tooth system. Refer to section 6.5.4.

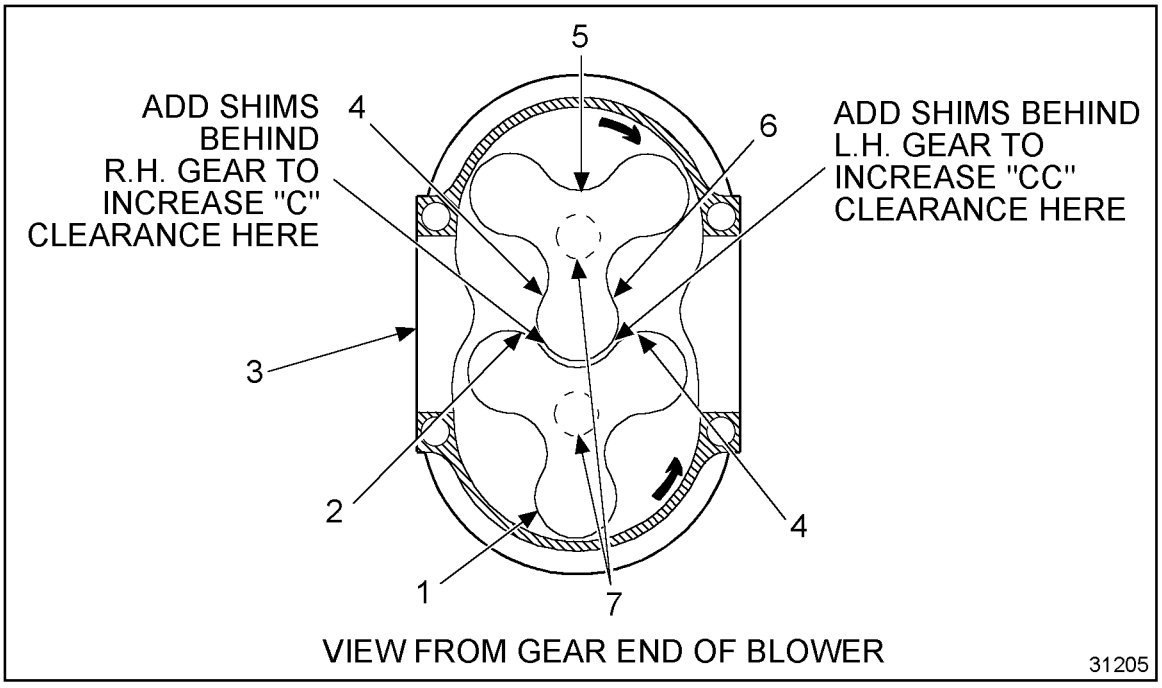
NOTE:
Minimal shaft spline wear indicates minimal hub spline wear, and the new 29-48-tooth drive shaft should provide satisfactory service until engine overhaul and complete system replacement.

    [b] If the shaft spline is not worn, continue inspection.
18. Inspect the inside surface of the blower housing for burrs or scoring. The inside surface must be smooth for efficient blower operation.
    [a] If excessively scored or burred, replace the housing. Refer to section 6.5.4.
    [b] If the inside surface of the housing is slightly scored or burred, clean with emery cloth.
19. Check the finished ends of the blower housing for flatness or burrs. The end plates must rest flat against the blower housing.
    [a] If warped or burred, replace the housing. Refer to section 6.5.4.
    [b] If neither warped nor burred, reuse the blower housing.

6.5.4 Assembly of Blower

Several precautions are given below to assure proper assembly of the rotors and gears for correct blower timing:

1. The driving blower rotor lobes and the gear teeth form a right-hand helix, while the driven rotor lobes and gear teeth form a left-hand helix. A rotor with right-hand helix lobes must be used with a gear having right-hand helix teeth and vice versa.
2. One serration is omitted on each blower rotor shaft drive end, and a corresponding serration is omitted in each gear. Assemble the gears on the rotor shafts with the serrations aligned.
3. The rotors must be assembled in the blower housing with the omitted serrations in the rotor shafts aligned. See Figure 6-31.



1. LH Helix Rotor
2. Trailing Side
3. Air Inlet Side
4. Leading Side (2)
5. RH Helix Rotor
6. Trailing Side
7. Omitted Serrations

Figure 6-31 Diagram Showing Proper Location of Shims for Correct Rotor Lobe Clearance

Install new lip type oil seals as follows:

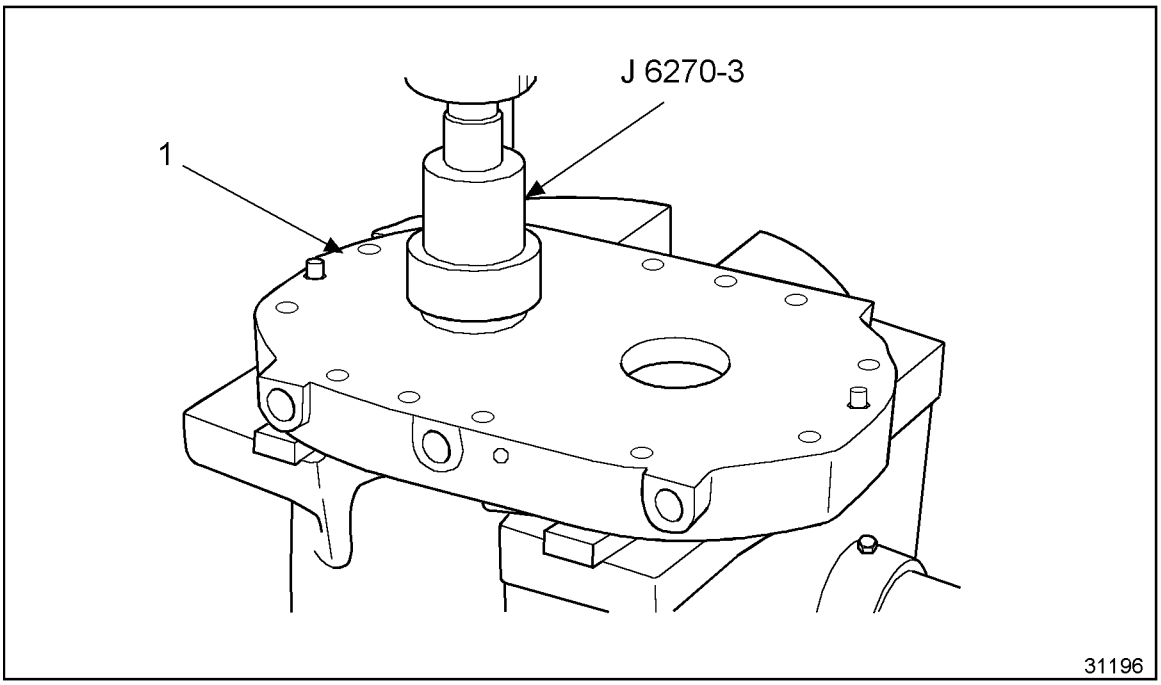
1. Support the blower end plate, finished surface facing up, on wood blocks on an arbor press bed.

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2. Start the oil seal straight into the bore in the end plate with the sealing edge facing down (toward the bearing bore).

NOTE:
If oversized oil seals are being used in the blower end plates, use installer J 6270-28 (from set J 6270-G) to install the oversized oil seal spacers on the rotor shafts.

3. Place the short end of oil seal remover J 6270-3 and installer J 6270-4 (from set J 6270-G) in the oil seal, and press the oil seal into the end plate until the shoulder on the installer contacts the end plate. See Figure 6-32.



1. Blower End Plate

Figure 6-32 Installing Oil Seal (or Oil Seal Ring Collar) in End Plate using Tool J 6270-4 (from Set J 6270-G)

NOTE:
A step under the installer shoulder will position the oil seal approximately 0.13 mm (0.005 in.) below the finished face of the end plate. This is within the 0.0508–0.2032 mm (0.002–0.008 in.) specified.

4. Install the remaining oil seals in the end plates.

Install double-lip Teflon oil seals as follows:

1. Press the oversized oil seal spacer onto the rotor shaft with installer J 35787-A (from set J 6270-G) until either the shoulder of the tool or the spacer contacts the rotor.

NOTE:
Do not lubricate the seals, spacers, or blower rotor shafts prior to seal installation. Teflon lip seals must be installed dry. This allows the Teflon to transfer to the spacer surface for proper sealing.

2. Support the blower end plate, finished surface up, on wood blocks on an arbor press bed.
3. With the part number on the seal facing the rotor, start the oil seal straight into the end plate bore.

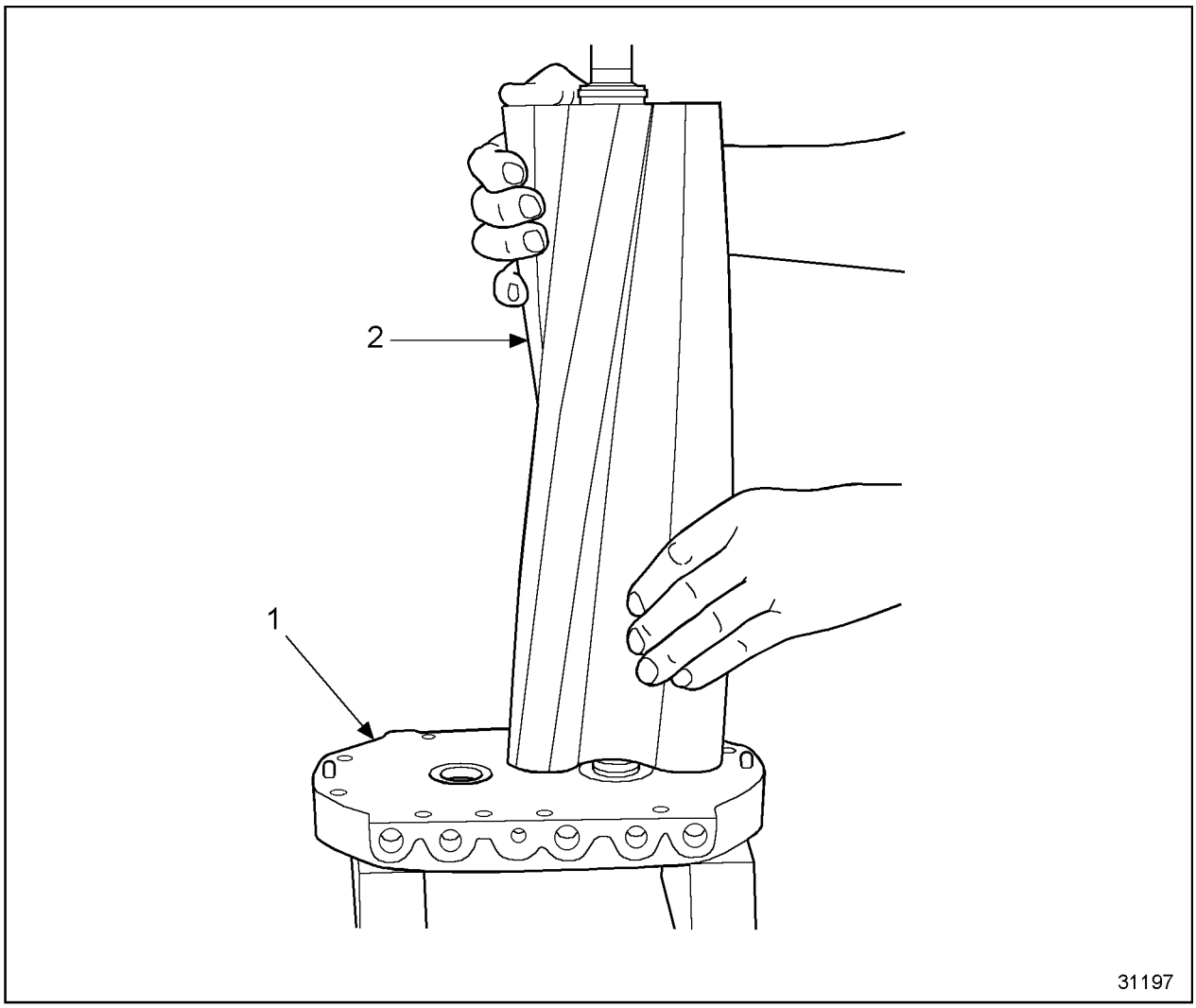
NOTE:
Double-lip Teflon seals are packaged around a special plastic sleeve that should not be removed prior to seal installation. The sleeve protects the seal lips during shipment and acts as a seal lip expander during blower assembly.

4. Using installer J 35787-A (from set J 6270-G), press the double-lip oil seal below the end plate surface until the installer shoulder contacts the end plate.
5. Install the remaining oil seals in the end plates.

Install the ring-type oil seal carriers, collars, seal rings, and roller bearing inner races (front end of blower rotors only) on the rotor shafts and in the end plates as follows:

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1. Support one rotor assembly on wood blocks on an arbor press bed. See Figure 6-33.



1. Front End Plate
2. Right-Hand Helix Rotor

Figure 6-33 Installing Blower Rotor in Front End Plate (V-92T Blowers)

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Lubricate the inside diameter of the oil seal ring carrier with engine oil. Start the carrier straight over the end of the rotor shaft with the chamfered inside diameter end facing the rotor.
3. Place the oil seal ring carrier installer J 6270-2 (from set J 6270-G) over the end of the rotor shaft and against the carrier, with the rotor shaft end against the carrier and the installer end under the ram of the press. Press the carrier tightly against the rotor.

4. Install the remaining oil seal ring carriers on the rotor shafts.

NOTICE:
To avoid breaking the oil seal rings, do not spread them any more than necessary to place them over the end of the carrier. Do not twist the rings. Possible distortion may result in loss of side contact area.

5. Install an oil seal ring in the carrier ring groove with a pair of snap ring pliers.
6. Support one of the blower end plates, inner face up, on wood blocks on an arbor press bed.

CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

7. Lubricate the outside diameter of a seal ring collar with engine oil. Start the chamfered outside diameter collar end straight into the end plate bore.
8. Place the oil seal ring collar installer J 6270-3 (from set J 6270-G) on top of the seal ring collar and under the press ram.
9. Press the collar into the end plate until the shoulder on the installer contacts the end plate.

NOTE:
A step under the shoulder of the installer will position the collar approximately 0.127 mm (0.005 in.) below the finished face of the end plate. This is within the 0.0508–0.2032 mm (0.002–0.008 in.) specified.

10. Install the remaining oil seal ring collars in the end plates.

Assemble rotors and end plates on blowers with lip type oil seals as follows:

NOTE:
The top of the end plate is readily identified by the two bolt holes and *one* oil hole. The bottom side of the end plate has two bolt holes and *three* oil holes. The front end plate is thinner than the rear end plate.

NOTE:
The horizontal oil passage in the top front face of the front end plate that intersects the vertical oil passage is plugged. Do not install this end plate on the rear end of the blower housing.

Attach the front end plate to the blower housing as follows:

1. If removed, press a new oil strainer into the vertical oil passage at the bottom side of the end plate 3.81 mm (0.150 in.) below the bottom surface. Install the pipe plug in the vertical oil passage at the top of the end plate.

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2. Check the dowel pins. The dowel pins must project 8.128 mm (0.320 in.) from the flat inner front end plate face to assure proper end plate alignment with the housing.
3. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate.
4. Install the sleeve, with the three notches on the sleeve, to the bottom side of the end plate and the center notch to the outside of the end plate.

NOTE:
When installed, the inside sleeve flats will be parallel to the center line of the housing. The notch should be flush to 0.13 mm (0.005 in.) below the end plate surface.

5. Place the blower housing on a bench with the top side of the housing up and the front end of the housing facing the outside of the bench.

NOTICE:
A blower end plate sealant kit is required (available from an authorized Detroit Diesel distributor) when assembling blower end plates. Failure to use the kit may result in air leakage between the blower housing and blower housing end plates, and may affect engine performance.

6. Apply a thin, even coating of Teflon sealant over the entire end surfaces for both ends of the blower housing. Wipe off any excess sealant from housing bores.

NOTE:
Ensure that no sealant protrudes into the housing. The sealant must not prevent the end plate from laying flat against the housing.

NOTE:
Allow sealant to dry before assembling end plates.

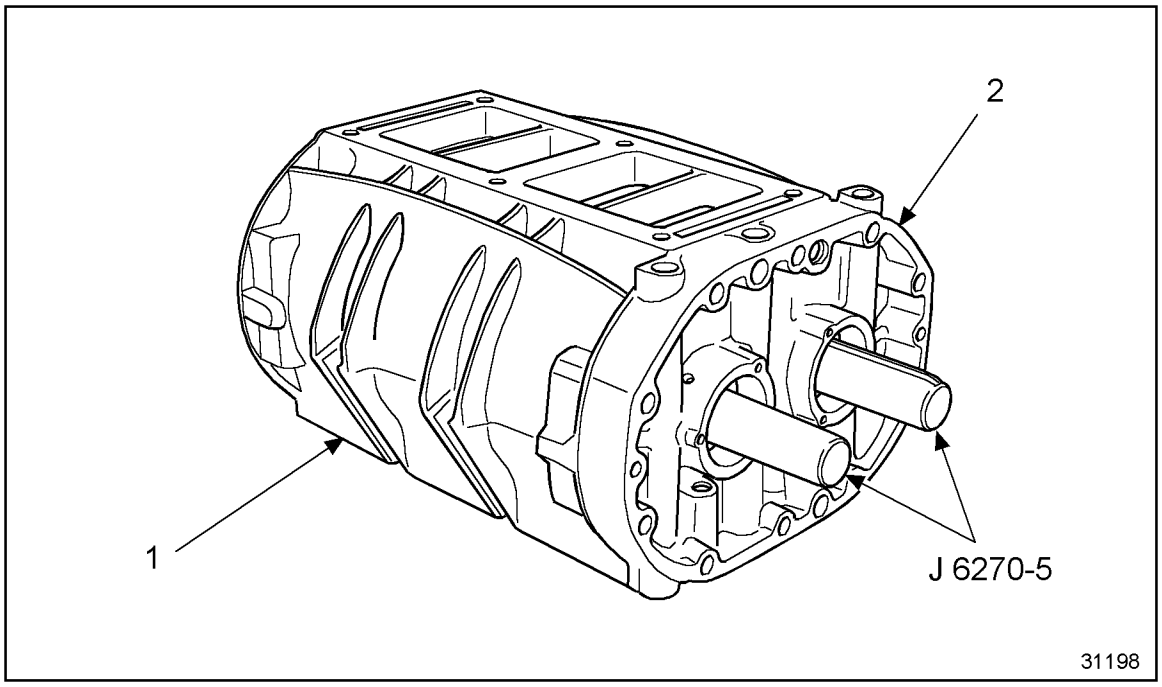
7. Position the end plate in front of the blower housing, with the top side of the end plate facing up. Start the dowel pins straight into the dowel pin holes in the housing.
8. Push or tap the end plate against the housing.

NOTE:
No gaskets are used between the end plates and the housing. The mating surfaces should be perfectly flat and smooth.

9. Insert the two fillister head screws through the end plate, and thread them into the housing. Tighten the screws to 7-14 N·m (5-10 lb·ft) torque. Do not use lock washers on these screws.

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See Figure 6-34. Install the blower rotors in the blower housing and end plate as follows:



1. Blower Housing
2. Front End Plate

Figure 6-34 Assembling Blower Rotors in Housing and Front End Plate with Oil Seal Pilots using Tool J 6270-5 (from Set J 6270-G)

1. Reverse the blower housing on the bench (open end of housing facing the outside of the bench).
2. Mesh the rotors horizontally and facing to the left (viewed from the gear end, with the omitted serrations in the rotor shafts).

NOTE:
The right-hand helix rotor is marked "GEAR END" on one end. The gear end of the left-hand rotor is the end with the serrated shaft

3. Install an oil seal pilot J 6270-5 (from set J 6270-G) over the opposite end of each rotor shaft.

NOTE:
When oversized oil seals are used in the blower end plate, use oil seal spacer installer J 6270-28 for the oil seal pilots in place of J 6270-5 (from set J 6270-G).

NOTE:
When double-lip Teflon oil seals are installed, use oil seal pilot J 6270-5 (from set J 6270-G) over each rotor shaft. Insert the plastic sleeves that came with the seals, tapered edges facing outboard. When end plates are lowered into position over the

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shafts, the ends of the spacers will push out the plastic sleeves, permitting seals to seat squarely on the spacers without damage.

4. Insert the rotors straight into the housing and through the front blower end plate.
5. Remove the oil seal pilots from the rotor shafts.

Install the blower rear end plate as follows:

1. If removed, press a new oil strainer into the vertical oil passage at the bottom side of the end plate 3.81 mm (0.150 in.) below the bottom surface.
2. Install the pipe plug in the vertical oil passage at the top of the end plate.
3. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate.
4. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to 1.27 mm (0.05 in.) below the surface of the end plate.

NOTE:
When installed, the inside flats of the sleeve will be parallel to the center line of the housing.

5. Install an oil seal pilot J 6270-5 (from set J 6270-G) over the serrated end of each rotor shaft.

NOTE:
When oversized oil seals are used in the blower end plate, use oil seal spacer installers J 6270-28 for the oil seal pilots in place of J 6270-5 (from set J 6270-G).

NOTE:
When double-lip Teflon oil seals are installed, use oil seal pilot J 6270-5 (from set J 6270-G) over each rotor shaft. Reinsert the plastic sleeves that came with the seals, tapered edges facing outboard. When end plates are lowered into position over the shafts, the ends of the spacers will push out the plastic sleeves, permitting seals to seat squarely on the spacers without damage.

6. Check the dowel pins. The dowel pins must project 8.128 mm (0.320 in.) from the flat inner face of the rear end plate to assure proper end plate alignment with the housing.
7. Slide the end plate straight over the oil seal pilots.
8. Start the dowel pins straight into the dowel pin holes in the housing. Push or tap the end plate against the housing.
9. Insert the two fillister head screws through the end plate, and thread them into the housing. Tighten the screws to 7-14 N m (5-10 lb ft) torque. Do not use lock washers on these screws.
10. Remove the oil seal pilots from the rotor shafts.

NOTICE:
Excessive housing protrusion could distort the housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

11. Check the relationship of the blower end plates to the housing at the cylinder block side of the blower assembly. The protrusion of the housing with respect to the end plates should not be more than 0.0127 mm (0.0005 in.) above to 0.1651 mm (0.0065 in.) below the end plate.

Assemble the rotors and end plates on blowers with ring-type oil seals (regular and OTM blowers) as follows:

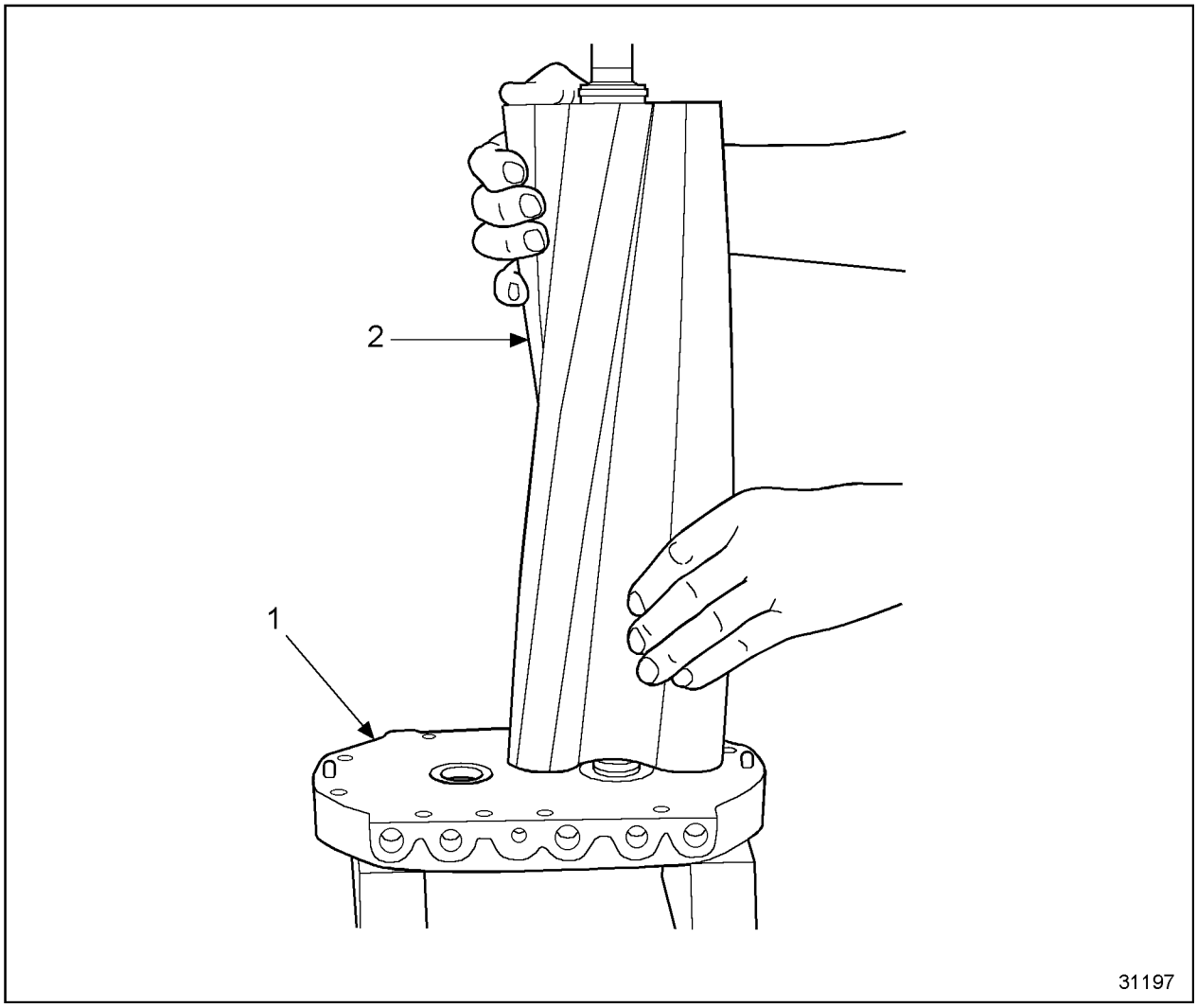
Install the blower rotors in the blower front end plate as follows:

1. Check the dowel pins. The dowel pins must project 8.128 mm (0.320 in.) from the flat inner face of the front end plate to assure end plate alignment with the housing.
2. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate.
3. Install the sleeve, with the three notches on the sleeve to the bottom side of the end plate and the center notch to the outside of the end plate, flush to 0.13 mm (0.005 in.) below the surface of the end plate.

NOTE:
When installed, the inside sleeve flats will be parallel to the center line of the housing.

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4. Support the front end plate on two wood blocks approximately 4 in. high, with the inner face of the end plate facing up and the TOP side of the plate facing your right. See Figure 6-35.



1. Front End Plate
2. Right-Hand Helix Rotor

Figure 6-35 Installing Blower Rotor in Front End Plate (V-92T Blowers)

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

5. Lubricate the oil seal ring in the carrier on the front end of the right-hand helix rotor shaft with engine oil.
6. Hold the right-hand helix rotor vertically (gear end up). Position the seal ring in the carrier so the ring protrudes evenly from its groove on each side and the gap is facing away from you.
7. With the omitted shaft spline serration facing toward the top side of the end plate, start the end of the rotor shaft into the right-hand end plate shaft opening so that the gap portion of the seal ring is started into the ring collar.
8. Continue to lower the rotor, and apply pressure to the seal ring approximately 180 degrees from the gap, while gently working the seal ring into the collar until the rotor contacts the end plate.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

9. Lubricate the oil seal ring in the carrier on the front end of the left-hand helix rotor shaft with engine oil.
10. Hold the left-hand helix rotor vertically (gear end up). Position the seal ring in the carrier so the ring protrudes evenly from its groove on each side and the gap is facing away from you.
11. Mesh the lobes or the rotors, and face the omitted spline serration face toward the top side of the end plate.
12. With the omitted shaft spline serration facing toward the top side of the end plate, start the end of the rotor shaft into the left-hand end plate shaft opening so that the gap portion of the seal ring is started into the ring collar.
13. Continue to lower the rotor, and apply pressure to the seal ring approximately 180 degrees from the gap, while gently working the seal ring into the collar until the rotor contacts the end plate.

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

14. Lubricate the oil seal ring in the carrier on the front end of the right-hand helix rotor shaft with engine oil.
15. Hold the right-hand helix rotor vertically (gear end up). Position the seal ring in the carrier so the ring protrudes evenly from its groove on each side and the gap is facing away from you.
16. Mesh the rotors lobes and face the omitted spline serration face toward the top side of the end plate.
17. With the omitted shaft spline serration facing toward the top side of the end plate, start the end of the rotor shaft into the right-hand end plate shaft opening so that the gap portion of the seal ring is started into the ring collar.
18. Continue to lower the rotor, and apply pressure to the seal ring approximately 180 degrees from the gap, while gently working the seal ring into the collar until the rotor contacts the end plate.

Install the blower housing over the rotors, and attach it to the front end plate as follows:

NOTE:
When assembling an OTM 6V blower, determine what end is the front of the housing. For front mounted OTM vehicle engines, the housing must be installed with the stamped triangle end toward the front of the engine. With the rear mounted OTM vehicles engines, the housing is installed with the stamped triangle end toward the rear. On the 8V OTM vehicle engines, either end of the housing can face toward the front of the engine.

NOTICE:

A blower end plate sealant kit (available from an authorized Detroit Diesel distributor) is required when assembling blower end plates. Failure to use the kit may result in air leakage between the blower housing and the blower housing end plates, and may affect engine performance.

1. Apply a thin, even coating of Teflon sealant over the entire end surfaces of both ends of the blower housing. Wipe off excess sealant from housing bores.
2. Position the blower housing over the top of the rotors so the bottom face of the housing faces the bottom side of the front end plate.

NOTE:
Allow sealant to dry to touch before assembling end plates.

3. Lower the housing over the rotors until it contacts the dowel pins in the end plate.

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4. Align the dowel pin holes in the housing with the dowel pins in the end plate.
5. Push the housing tightly against the end plate. If necessary, tap the housing lightly with a plastic hammer.

NOTE:
Caution must be used so that no sealant protrudes into the housing. The sealant must not prevent the end plate from laying flat against the housing or blower.

NOTE:
No gaskets are used between the end plates and the housing. Therefore, the mating surfaces should be perfectly flat and smooth.

6. Insert the two fillister head screws through the front end plate, and thread them into the housing. Tighten the screws to 7-14 N m (5-10 lb ft) torque. Do not use lock washers on these screws.

Install the blower rear end plate on the rotor shafts and housing as follows:

1. Check the dowel pins. The dowel pins must project 8.128 mm (0.320 in.) from the flat inner face of the rear end plate to assure proper end plate alignment with the housing.
2. If removed, press a new bolt guide sleeve (bushing) into one bolt hole in the bottom side of the end plate.
3. Install the sleeve with the three notches to the bottom side of the end plate, and the center notch to the outside of the end plate, flush to 0.13 mm (0.005 in.) below the surface of the end plate.

NOTE:
When installed, the inside sleeve flats will be parallel to the center line of the housing.

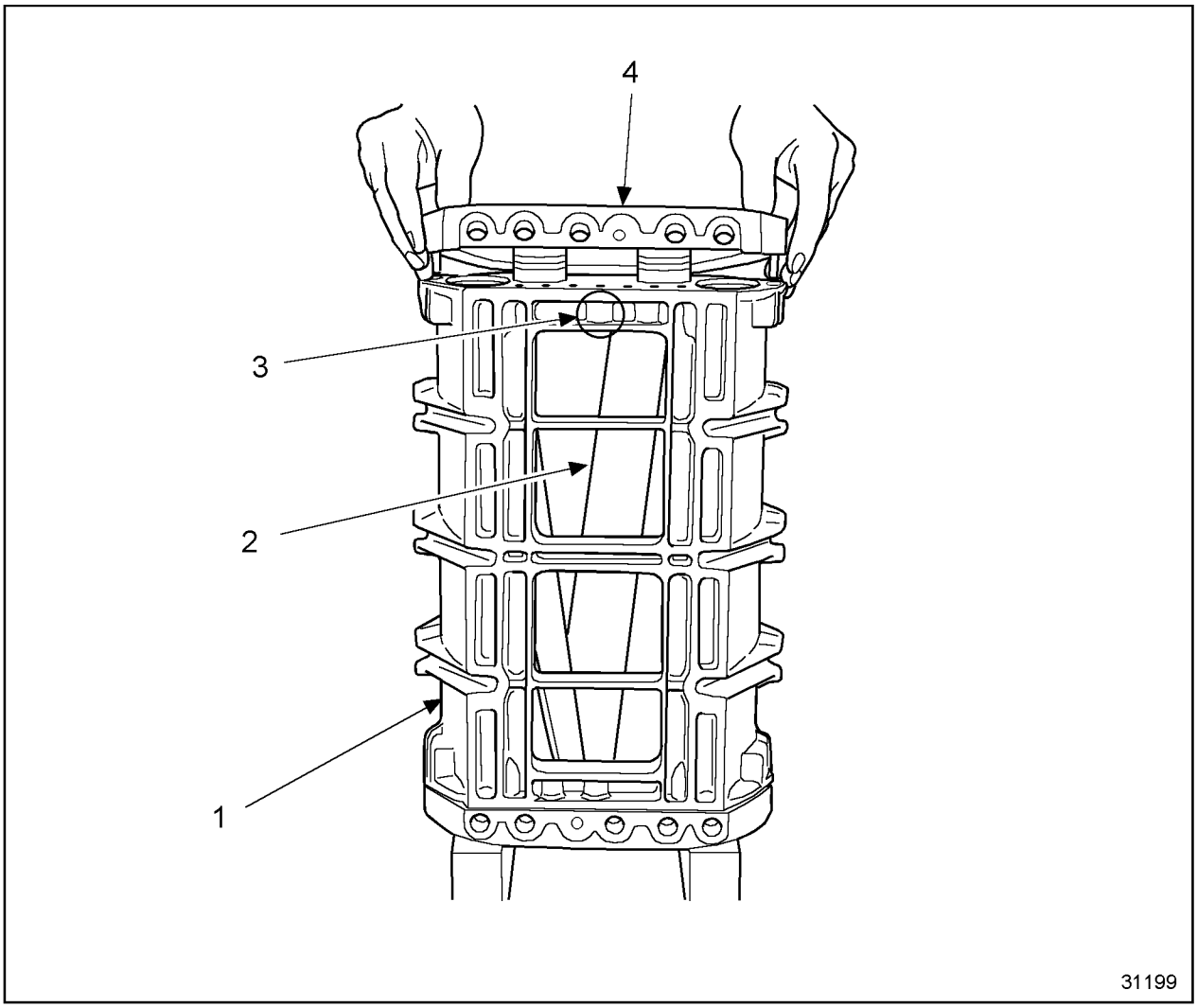
⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the oil seal rings in the carriers on the rotor shaft with engine oil.
5. Position the oil seal rings in the carriers so the ring protrudes from its groove equally on each side.
6. Position the rear end plate over the top of the rotor shafts, with the end plate inner face facing the rotors, and the TOP of the end plate facing the top of the blower housing.

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7. Lower the end plate straight over the rotor shafts until the dowel pins in the end plate contact the blower housing. See Figure 6-36.



1. Blower Housing Assembly
2. Rotors
3. Cast Triangle on OTM 6V Blower
4. Rear End Plate

Figure 6-36 Installing Rear End Plate on Blower Rotors and Housing

8. Carefully work the dowel pins into the dowel pin holes in the housing and the oil seal rings into the collars.
9. Push the end plate tightly against the housing. If necessary, tap the end plate lightly with a plastic hammer.

NOTE:
The housing protrusion should not be more than 0.0127 mm (0.0005 in.) above to 0.1651 mm (0.0065 in.) below the end plate. Excessive protrusion could distort the

housing when the end plate to cylinder block bolts are tightened and cause rotor to housing interference.

10. Insert the two fillister head screws through the rear end plate, and thread them into the housing. Tighten the screws to 7-14 N m (5-10 lb ft) torque. Do not use lock washers on these screws.

With the blower housing, rotors, and end plates still supported in a vertical position on the two wood blocks, install the ball bearings on the rotor shafts and in the rear end plate as follows:

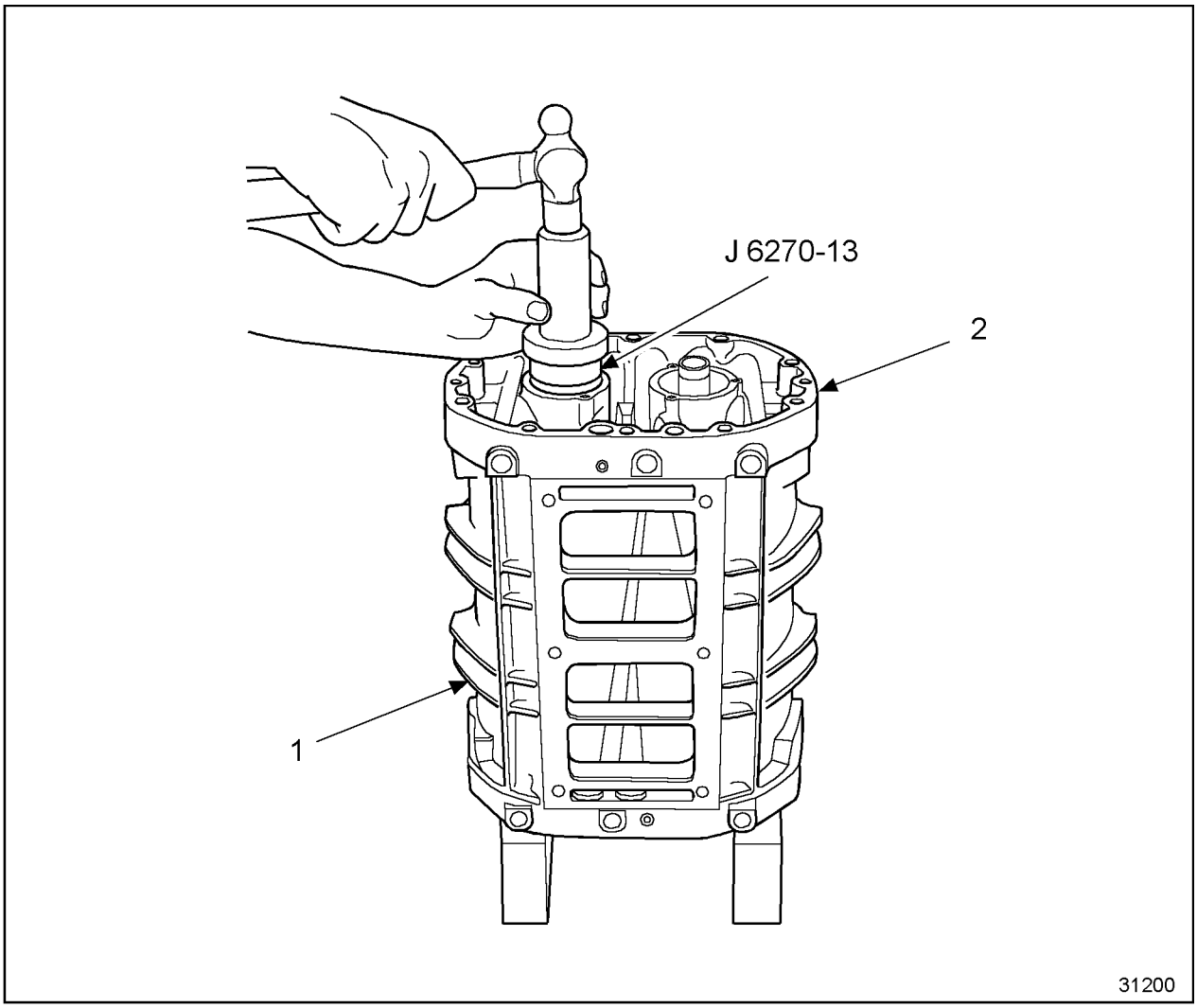
CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate one of the ball bearings with light engine oil. Start the bearing, numbered end up, straight on one of the rotor shafts.

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2. Place installer J 6270-13 (from set J 6270-G) on top of the bearing. Tap the bearing straight on the shaft and into the rear end plate. See Figure 6-37.



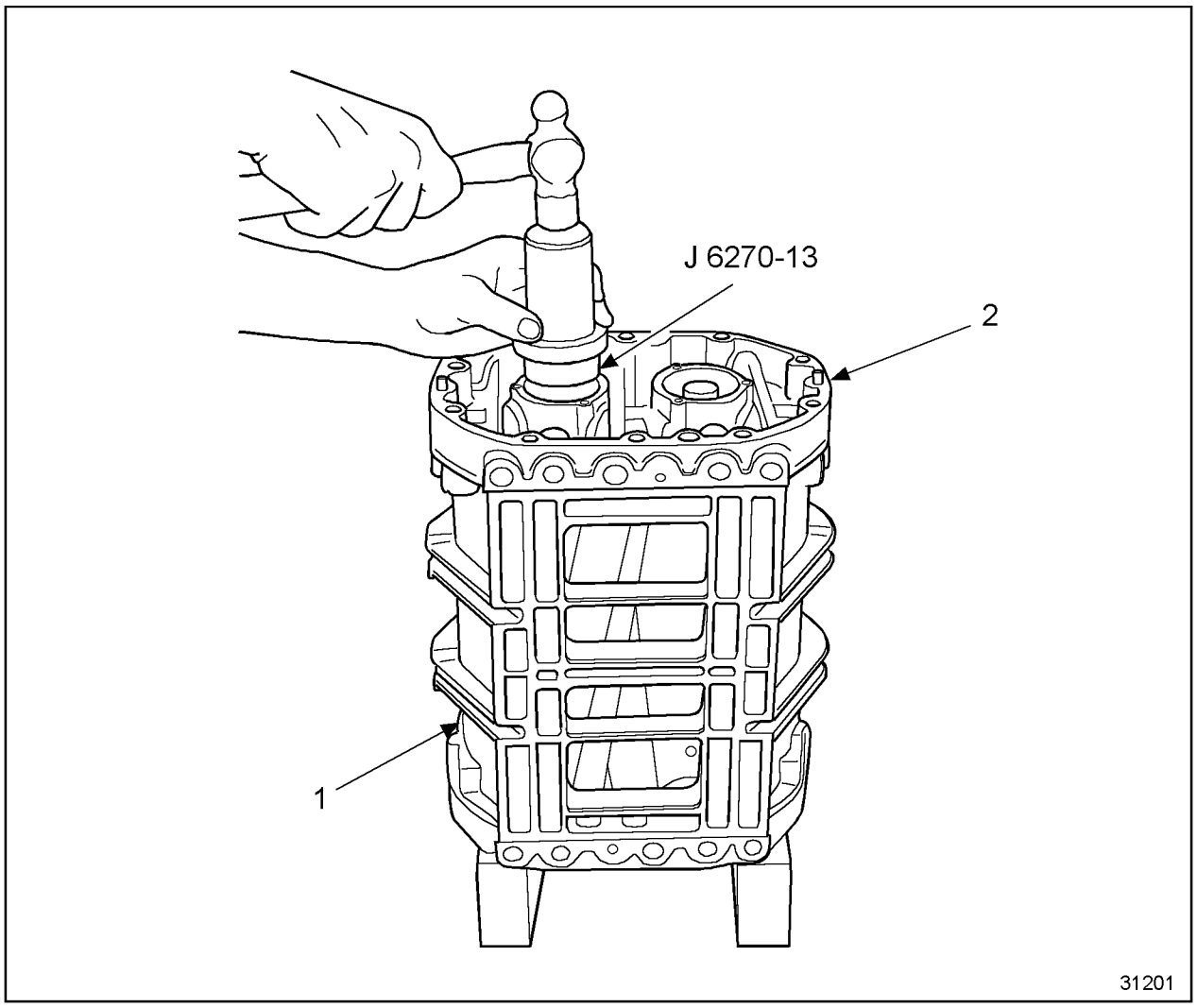
1. Blower Housing Assembly
2. Rear End Plate

Figure 6-37 Installing Ball Bearings on Rotor Shaft and in Rear End Plate with Tool J 6270-13 (from Set J 6270-G)

3. Install the second ball bearing on the remaining rotor shaft.
4. Place the bearing retainers on top of the bearings and the end plate.
5. Install the self-locking screws. Tighten the screws to 9-12 N·m (7-9 lb·ft) torque.

Install the roller bearing inner races on the rotor shafts at the front end plate as follows:

1. Reverse the position of the blower housing on the two wood blocks. See Figure 6-38.



1. Blower Housing Assembly
2. Front End Plate

Figure 6-38 Installing Roller Bearings on Rotor Shafts and in Front End Plate with Tool J 6270-1 (from Set J 6270-G)

2. Position the roller bearing inner race over the front end of the rotor shaft. Press the race on the shaft with tool J 6270-13 (from set J 6270-G) until the bearing contacts the shaft shoulder.
3. Install the bearing inner race on the front end of the other rotor.

Install the roller bearing outer race assemblies in the front end plate as follows:

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

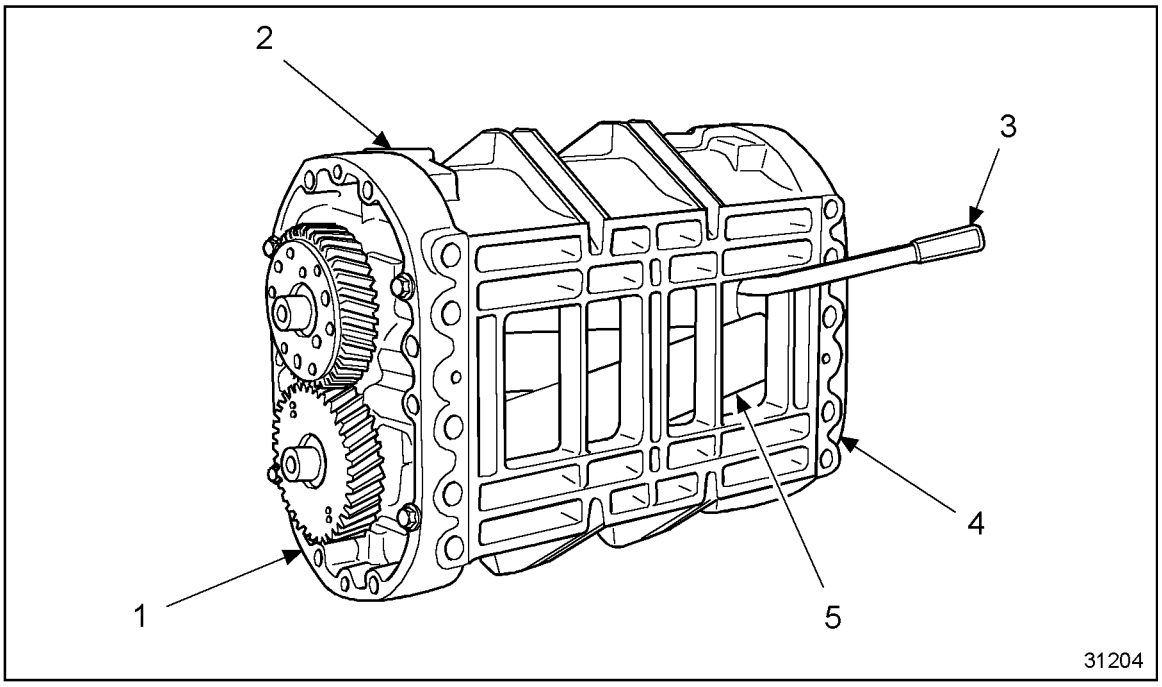
1. Lubricate one roller bearing with light engine oil. Start the bearing, shoulder side up, over the rotor shaft and bearing inner race and into the end plate.
2. Place installer J 6270-13 (from set J 6270-G) on top of the bearing. Tap the bearing straight on the inner race and into the front end plate.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Install the second roller bearing on the remaining rotor shaft. Lubricate one roller bearing with light engine oil. Start the bearing, shoulder side up, over the rotor shaft and bearing inner race and into the end plate.
4. Place installer J 6270-13 (from set J 6270-G) on top of the bearing. Tap the bearing straight on the inner race and into the front end plate.
5. Place the bearing retainers on top of the bearings and the end plate.
6. Install three self-locking retainer screws in each retainer. Tighten the screws to 9-12 N·m (7-9 lb·ft) torque.
7. Make a preliminary check of the rotor-to-end plate and rotor-to-housing clearances at this time with a feeler gage. See Figure 6-39. Minimum blower clearances are listed in Table 6-1.

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1. Front End Plate
2. Blower Housing Assembly
3. Feeler Gage
4. Rear End Plate
5. Rotors

Figure 6-39 Measuring End Clearance Between Blower Rotors and End Plate

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Blower Part No.	Engine	A	B	C	CC	D	E
5101528	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.005
5103854	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.005
5104936	6V-92T	0.007	0.012	0.010	0.006	0.015	0.005
5104937	8V-92	0.007	0.019	0.010	0.006	0.015	0.005
5144787	8V-92	0.007	0.014	0.010	0.006	0.015	0.005
5144893	8V-92	0.007	0.014	0.010	0.006	0.015	0.005
5146912	6V, 12V-92	0.007	0.012	0.010	0.006	0.015	0.005
5147252	6V, 12V-92	0.007	0.012	0.010	0.006	0.015	0.005
8921938	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.009
8923474	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.007
8923475	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.007
8923476	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.007
8923495	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.007
8923496	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.007
8923497	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.007
8926407	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.005
8926408	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.005
8926615	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.005
8926616	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.005
8927037	8V-92	0.007	0.019	0.010	0.006	0.015	0.007
8927039	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.005
8927041	8V-92TA	0.007	0.019	0.013	0.013	0.015	0.009
8927043	8V-92	0.007	0.019	0.010	0.006	0.015	0.007
8927156	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.005
8927468	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.009
23501076	6V-92	0.007	0.012	0.010	0.010	0.015	0.007
23501261	8V-92TA	0.007	0.019	0.010	0.006	0.015	0.009
23502057	12V-92TA	0.010	0.012	0.020	0.013	0.015	0.009
23502485	6V-92TA	0.007	0.012	0.010	0.007	0.015	0.007
23502734	6V-92TA	0.007	0.012	0.010	0.006	0.015	0.004
23503027	8V, 16V-92TA	0.010	0.019	0.025	0.013	0.015	0.009
23503651	8V-92TA	0.007	0.019	0.013	0.013	0.015	0.009

Table 6-1 Minimum Blower Clearances

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See Figure 6-40, and install the blower timing gears as follows:

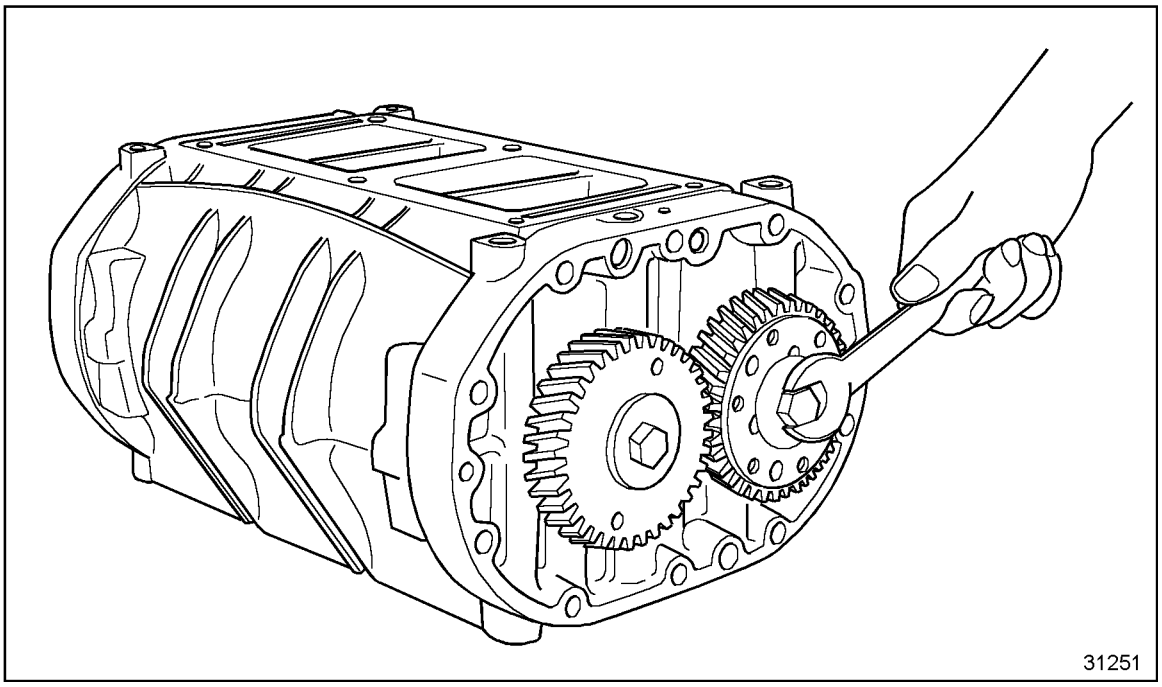


Figure 6-40 Installing Blower Rotor Timing Gears

NOTE:
The center punch mark in the end of each rotor shaft at the omitted serration assists in aligning the gears on the shafts.

NOTE:
If shims were removed from the back side of the gears (between the inner race of the bearing and the gear), they should be replaced in their original positions before installing the gears on their respective shafts.

1. Place the blower assembly on the bench, with the top of the housing up and the rear end (serrated end of rotor shafts) of the blower facing the outside of the bench
2. Rotate the rotors to align the omitted serrations on the shafts and face to the left.
3. Install a 3.556 mm (0.140 in.) thick gear spacer and the same number and thickness shims on each rotor shaft that was removed at the time of disassembly.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Lubricate the rotor shaft serrations with light weight engine oil.
5. Mesh the rotor gear teeth so that the omitted serrations inside the gears are aligned and facing the same direction as the shaft serrations.
6. Start both rotor gears straight on the rotor shafts, with the right-hand helix gear on the right-hand helix rotor and the left-hand helix gear on the left-hand helix rotor and the omitted serrations in the gears in line with the omitted serrations on the rotor shafts.
7. Thread a 1/2 in.-20 x 1-1/4 in. bolt with a thick washer into the end of each rotor shaft. Place a clean folded cloth between the rotor lobes to prevent the gears from turning.
8. Draw the gears into position against the spacers and shims and the bearing inner races.
9. Remove the two bolts and washers that were used to draw the gears into position on the rotor shafts.

CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

10. Lubricate the threads of the 1/2 in.-20 x 1-1/2 in. gear retaining bolts with engine oil.
11. Place a spacer (0.340 in. thick) on each bolt, and thread the bolts into the rotor shafts. Tighten the bolts to 136-150 N m (100-110 lb ft) torque. Remove the cloth from the blower rotors.

Time the blower rotors as follows:

NOTE:
After the blower rotors and timing gears are assembled, the blower rotors must be timed

1. Prior to timing the rotor, install four 5/16 in.-18 x 1-7/8 in. bolts with flat washers through four bolt holes in each end plate (top and bottom), and thread them into the blower housing. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque. This will hold the end plates against the blower housing so the proper clearance between the rotors and the end plate can be obtained.
2. Move the helical gears in or out on the shaft relative to the other gears to vary the clearance between the lobes.

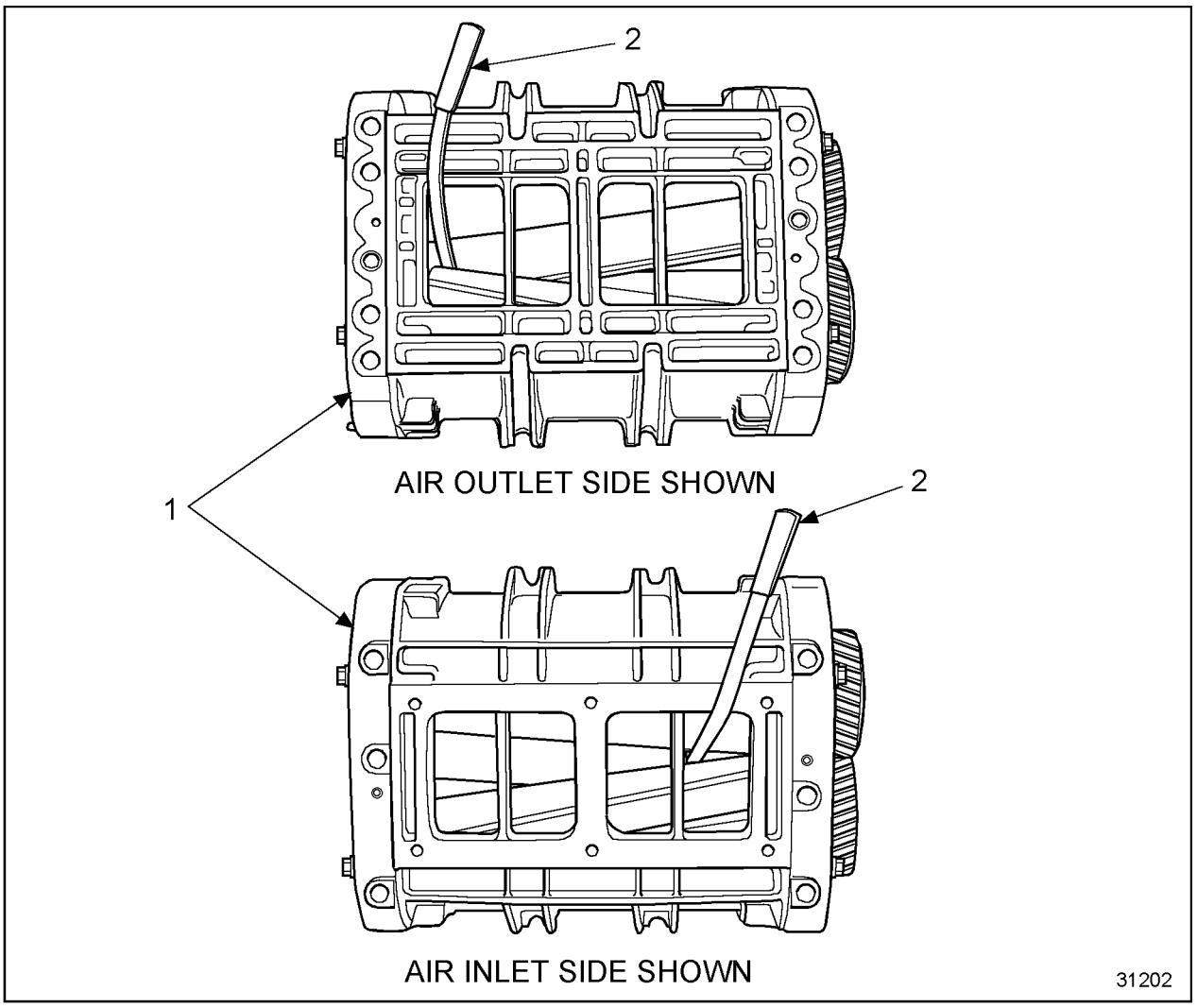
NOTE:
If the right-hand helix gear is moved out, the right-hand helix rotor will turn counterclockwise when viewed from the gear end. If the left-hand helix gear is moved

out, the left-hand helix rotor will turn clockwise when viewed from the gear end. Positioning the gears to obtain the proper clearance between the rotor lobes is known as blower timing.

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3. Add or remove shims between the gears and the bearings to move the gears in or out on the rotor shafts.

NOTE:
The clearance between the rotor lobes may be checked with 1/2 in. wide feeler gages. See Figure 6-41.



1. Blower Assembly
2. Feeler Gage

Figure 6-41 Measuring "CC" and "C" Clearance Between Blower Rotor Lobes

NOTE:
Clearances should be measured from both the inlet and outlet sides of the blower.

NOTE:
When measuring clearances of more than 0.005 in., laminated feeler gages that are made up of 0.002 in., 0.003 in., or 0.005 in., feeler stock are more practical and suitable than a single feeler gage. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available.

Time the Rotors as Follows:

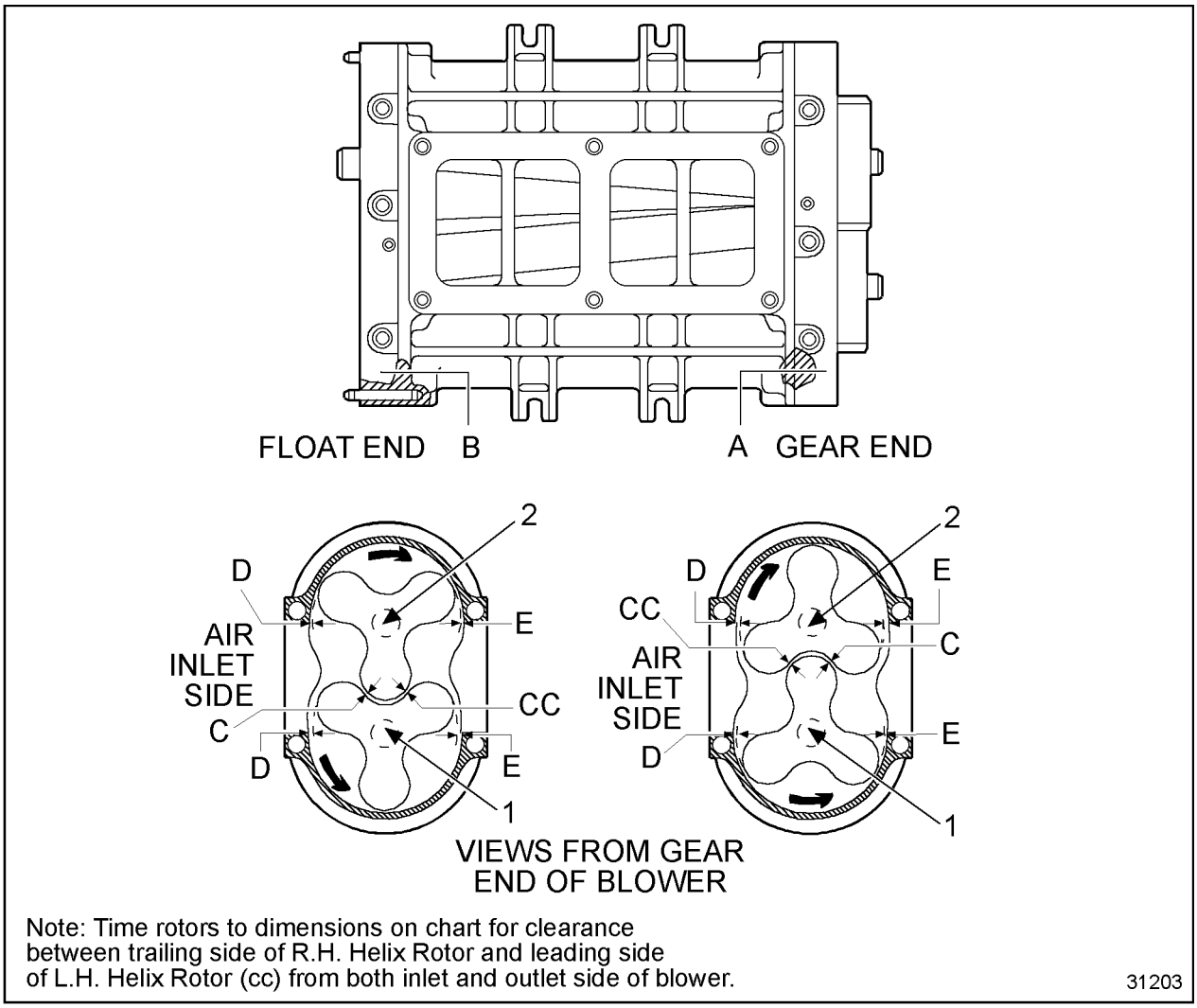
4. Time the rotors to the specified clearance between the trailing edge of the right-hand helix rotor and the leading edge of the left-hand helix rotor ("CC" clearance), measured from both the inlet and outlet sides.
5. Check the clearance between the leading edge of the right-hand helix rotor and the trailing edge of the left-hand helix rotor ("C" clearance) for the minimum clearance.

NOTE:
Rotor-to-rotor measurements should be taken 25.4 mm (1 in.) from each end and at the center of the blower.

6. After determining the amount one rotor must be revolved to obtain the proper clearance, add shims behind the proper gear to produce the desired result. When more or fewer shims are required, both gears must be removed from the rotors. Placing a 0.0762 mm (0.003 in.) shim behind a rotor gear will revolve the rotor 0.03 mm (0.001 in.).
7. Install the required thickness shim behind the proper gear and next to the 3.556 mm (0.140 in.) thick gear spacer that is against the bearing inner race.
8. Install both gears. Check the clearances between the rotor lobes.
9. Determine the minimum clearances at points "A" and "B".
10. Insert the feeler gages between the end plates and the ends of the rotors. Perform this operation at the ends of each lobe. Make a total of 12 measurements.

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11. Check the clearance between each rotor lobe and the blower housing at both the inlet and outlet side. Make a total of 12 measurements. See Figure 6-42.



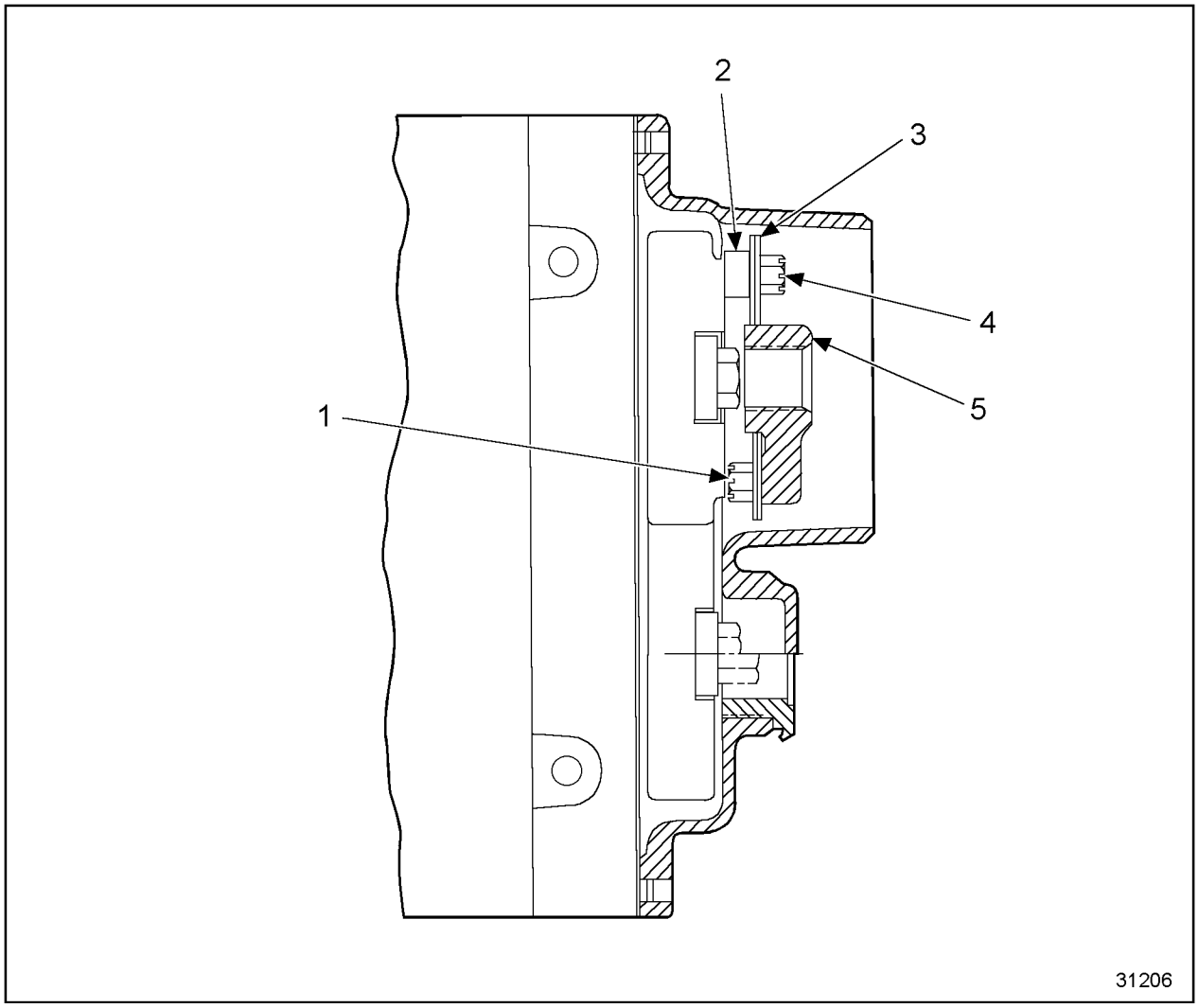
1. LH Helix Rotor
2. RH Helix Rotor

Figure 6-42 End View of Blower Rotor Clearance

After the blower rotors are timed, complete blower assembly as follows:

1. Place the fuel pump drive disc spacer over the forward end of the right-hand helix rotor shaft. Place the special lock washer and the drive disc on the retaining bolt.
2. Thread the bolt into the rotor shaft against the spacer. Tighten the bolt to 75-88 N·m (55-65 lb·ft) torque. Bend one lock washer tang into the slot in the drive disc and two tangs against the flat sides of the bolt head.

3. Attach the two flex plates and spacers to the drive hub with three new type B hex lock bolts. See Figure 6-43. Do not attempt to reuse patch bolts. Tighten the 5/16 in.-24 x 0.750 in. bolts to 34-41 N·m (25-30 lb·ft) torque.



1. Type B Hex Lock Bolt
2. Spacer
3. Flex Plate
4. Type B Hex Lock Bolt
5. Hub

Figure 6-43 Front Hub Assembly - Large Bearing Blowers

NOTE:
Only the new flex plates and type B hex lock bolts should be used to service engines with large bearing blowers.

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4. Attach the drive hub and spring plate assembly to the right-hand helix blower rotor timing gear with three spacers and three type B hex lock bolts. Tighten the 5/16 in.-24 x 1 in. bolts to 34-41 N·m (25-30 lb·ft) torque.

NOTE:
When replacing a blower drive hub, use the new drive hub and the new blower drive shaft flex plates, type B hex lock bolts, and hub spacers.

5. Affix a new gasket to the blower rear end plate cover. Place the cover over the gears and against the end plate, with the opening in the cover over the blower drive hub attached to the right-hand helix gear.
6. Install the rear cover using ten 5/16 in.-18 x 2-1/2 in. bolts and lock washers. Tighten the bolts to 18-23 N m (13-17 lb ft) torque.

NOTE:
The tab on the gasket is to assure the gasket is in place.

7. On 6V and 12V engines, attach the adaptor and dry seal connector to the rear blower end plate when installing the blower on an engine.
8. On all 8V and 16V engines, attach the lubricating oil tube and dry seal connector to the rear blower end plate when installing the blower on the engine.

Attach the governor and fuel pump assembly to the blower as follows:

1. Affix a new gasket to the forward face of the blower end plate.
2. Place the fuel pump drive fork on the fuel pump shaft.
3. Position the governor and fuel pump assembly in front of the blower. Rotate the fuel pump fork until the fork prongs align with the drive disc slots.
4. Rotate the weight shaft, and align the shaft splines with the blower rotor splines.
5. Push the governor straight on the dowel pins in the blower end plate and against the gasket.
6. Refer to section 2.24.2 for the location. Install the bolts, lock washers, copper washers, and plain washer that secure the governor to the blower. Tighten the bolts to 18-23 N·m (13-17 lb·ft) torque.

6.5.5 Installation of Blower

Install the blower as follows:

NOTE:
On 12V and 16V engines, if both blowers were removed, install the rear blower first.

1. Affix a new blower housing gasket to the cylinder block with Scotch Grip rubber adhesive No. 1300, or equivalent, to prevent the gasket from shifting when the blower is positioned.
2. If removed, place a fuel rod cover tube hose and clamp on each fuel rod cover tube at each side of the governor housing. Tighten the clamps.

3. Place the blower end plate cover seal ring and clamp on the end of the blower drive support.

CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure blower is securely attached to the engine before releasing the lifting sling. Blower damage may result if the blower falls from the engine.

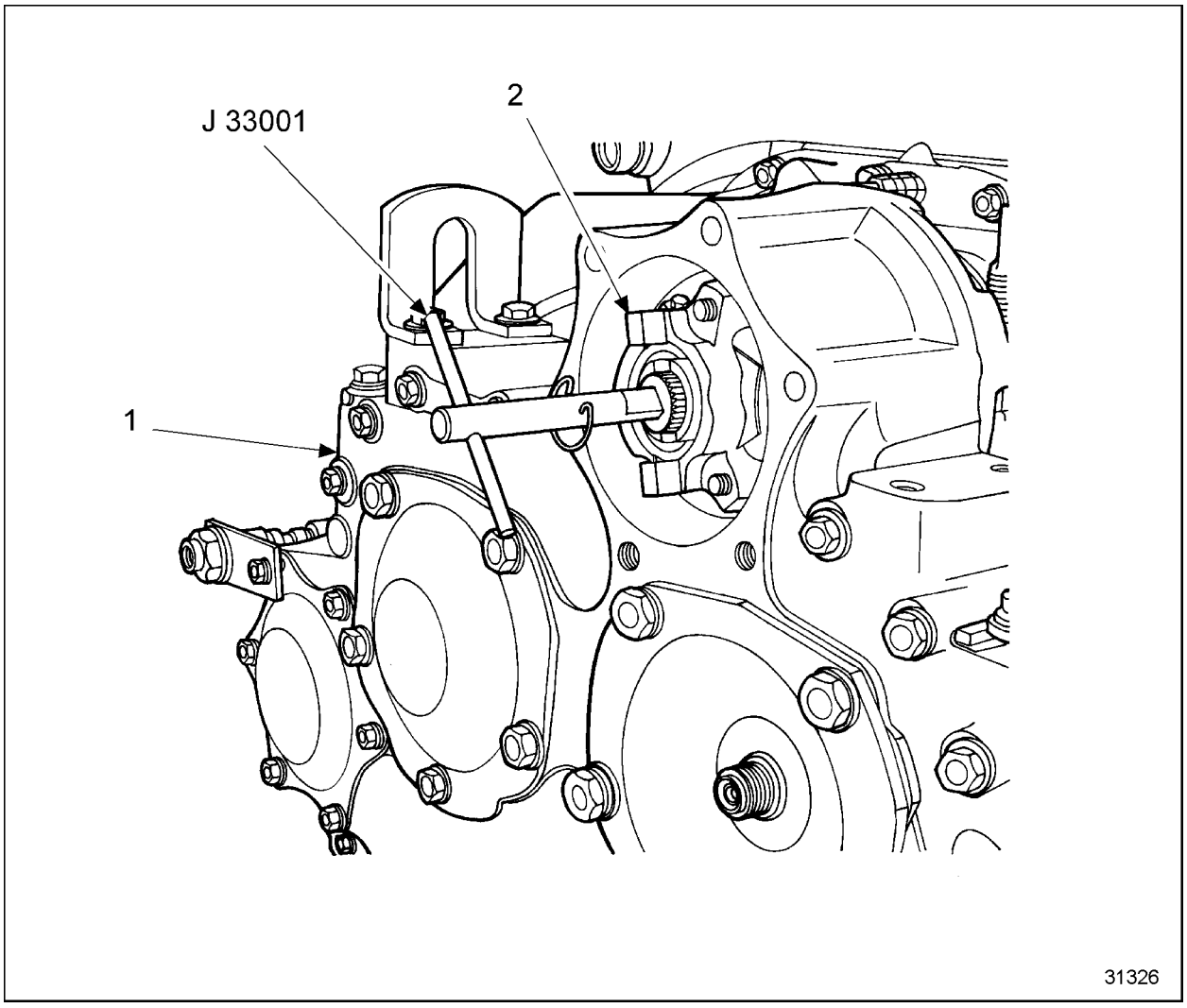
4. Thread eyebolts in diagonally opposite tapped holes in the top of the blower housing. Attach a rope sling and chain hoist to the eyebolts.
5. Lift the blower assembly at a slight angle, and position it on top of the cylinder block, with the rear end plate cover flange inside the seal ring or hose.
6. Loosely install the 7/16 in.-14 x 8-1/4 in. blower end plate bolts and special washers. Loosely install the 3/8 in-16 x 5-1/2 in. side angle bolts and retaining washers at each side of the blower housing.

NOTE:
The lip at the beveled end of the bolt retaining washer goes in the small recess in the blower housing just above the bolt slot.

7. Slip the snap ring over the notched end of the alignment tool J 33001, and thread the blower drive shaft onto the end.

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8. Install the alignment tool, and position the blower so that the shaft can be removed and installed easily without drag. See Figure 6-44.



1. Flywheel Housing
2. Blower Drive Shaft Assembly

Figure 6-44 Installing Blower Alignment Tool J 33001

9. Remove the shaft with the tool, and rotate the blower lobes in 90 degree increments, reinserting the alignment tool and repositioning the blower, as necessary. Check the alignment at 90 degree increments through the full 360 degree blower rotation.
10. If it is not possible to position the blower so that the tool can be removed and installed without drag in all positions, remove the shaft with the tool, and rotate the blower lobes in 90 degree increments, reinserting the alignment tool and repositioning the blower, as

necessary. Check the alignment at 90 degree increments through the full 360 degree blower rotation.

NOTE:
Try to achieve a condition in which the shaft can be removed with minimum drag in the two worst positions.

With the shaft in place and the blower properly aligned, tighten the bolts, as follows:

1. Tighten the blower-to-block end plate bolts to 54-61 N·m (40-45 lb·ft) torque.
2. Tighten the blower housing-to-block side angle bolts uniformly to 41-47 N·m (30-35 lb·ft) torque in 7 N·m (5 lb·ft) increments.
3. Check the blower-to-block end plate bolts.

Continue blower installation as follows:

1. Install the snap ring. The notch in the tool provides sufficient clearance for installing the snap ring with needle-nose pliers. Installing the snap ring with the alignment tool in place will prevent it from dropping into the engine gear train.
2. Remove the alignment tool from the blower drive shaft.
3. Position the blower rear end plate cover seal ring and hose clamp, and tighten the clamp. The former rubber seal ring 18.796 mm (0.740 in. wide) incorporates two raised edges that provide a groove to retain the clamp.

NOTE:
To retain seal load on the molded blower drive seal rings, a new 123.698 mm (4.87 in.) diameter spring loaded T-bolt style clamp is used.

4. After installing the new T-bolt style clamp on the blower drive seal, tighten the clamp nut on the bolt until the spring in the clamp is completely compressed.
5. Connect the lubricating oil tube to the fitting in the blower drive support.
6. Attach the flywheel housing cover to the flywheel housing.

NOTE:
If the spring has been removed in error, compress the spring and force it into the drilled hole opposite the tach drive square hole. This operation must be done on a press. To check for proper assembly, hold the spring and shaft assembly vertically by the spring. Shaft weight cannot allow the spring to come out of the drilled hole. A simple installation tool can be made from a 1/2 in. diameter piece of steel stock.

7. Attach the tachometer drive adaptor, if used, to the blower. Connect the tachometer drive cable to the drive adaptor.
8. Slide each fuel rod cover tube hose down on the cover tubes attached to the cylinder heads. Tighten the hose clamps.

Install the fuel rods between the cylinder heads and governor as follows:

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1. Insert the end of the left-bank fuel rod through the hole in the cylinder head and through the fuel rod cover tube to the control link operating lever.
2. Raise the connecting pin in the connecting link lever. Insert the end of the fuel rod between the two bosses on the lever, and insert the connecting pin through the fuel rod and into the lower boss.
3. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.
4. Insert the end of the right-bank fuel rod through the hole in the cylinder head and through the fuel rod cover tube to the control link operating lever.
5. Remove the short screw pin from the control link operating lever.
6. Insert the end of the fuel rod between the two bosses on the lever and install the screw pin. Tighten the pin securely.
7. Connect the opposite end of the fuel rod to the injector control tube lever with a clevis pin and cotter pin.

Continue blower installation as follows:

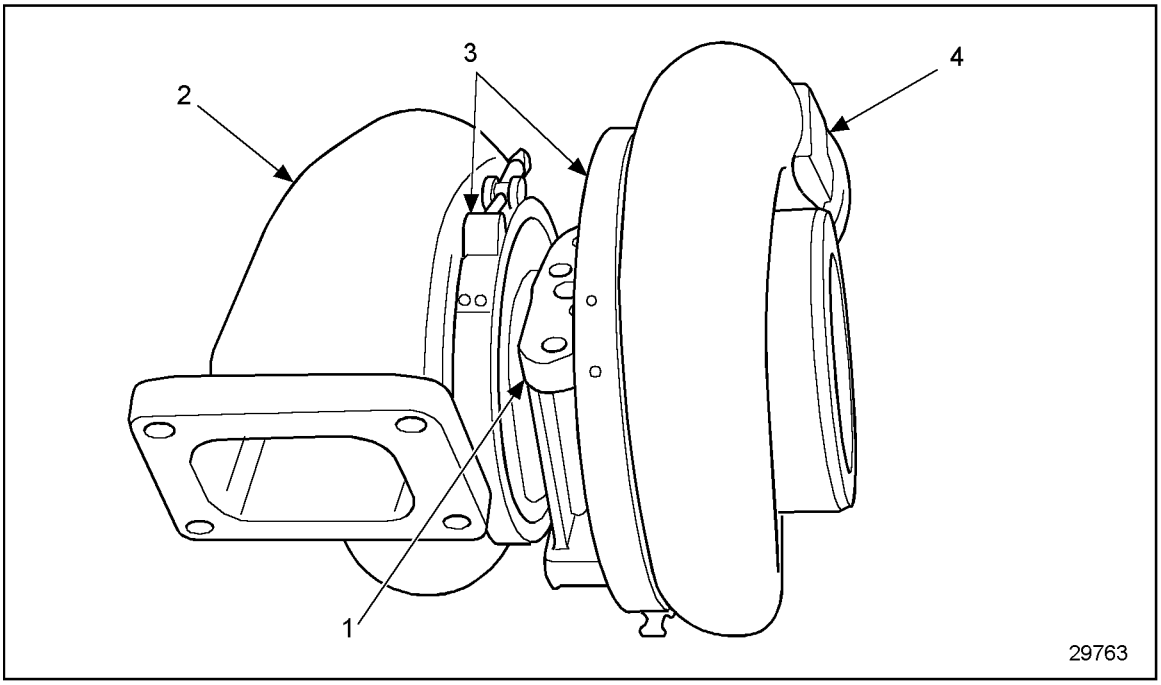
1. Affix a new gasket to the top of the governor housing. Place the governor cover assembly on the governor housing with the pin in the speed control or stop lever shaft assembly in the differential lever slot and the housing dowel pins in the cover dowel pin holes.
2. Install the eight cover attaching screws and lock washers. Securely tighten the screws.
3. If the engine is equipped with a variable speed governor, attach the governor booster spring to the speed control lever.
4. If the engine is equipped with a battery-charging alternator, attach the alternator and support bracket to the cylinder head. Connect the wires to the alternator.
5. Install and connect the crossover fuel oil line to each cylinder head. Connect the fuel oil lines to the fuel pump.
6. If removed, install the front engine lifter bracket.
7. Place the water bypass tube between the two thermostat housings, and slide the hoses part way on the thermostat housings.
8. Position the bypass tube so it clears the governor, fuel pump and fuel oil lines. Tighten the hose clamps.
9. Attach the air shutdown adaptor to the blower and the air shutdown housing assembly to the adaptor. Refer to section 6.4.4.
10. Connect the shutdown wire assembly to the air shutoff cam pin handle at the side of the air shutdown housing.
11. Install the turbocharger and attaching parts, if used. Refer to section 6.6.5.
12. Connect the air cleaner to shutdown housing or turbocharger tubing as required. Refer to section 6.6.5.
13. Connect the throttle control rods to the speed control and stop levers on the governor.

14. Attach any other accessories that were removed to the engine.
15. Close the drain cocks, and fill the engine cooling system. Refer to section 13.12.
16. Perform the governor and injector rack control adjustment. Refer to section 12.10.
17. Check for and correct any coolant or oil leaks.

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6.6 TURBOCHARGER (AIRESEARCH)

The turbocharger is designed to increase the over-all engine efficiency. See Figure 6-45. Power to drive the turbocharger is extracted from the waste energy in the engine exhaust gas.

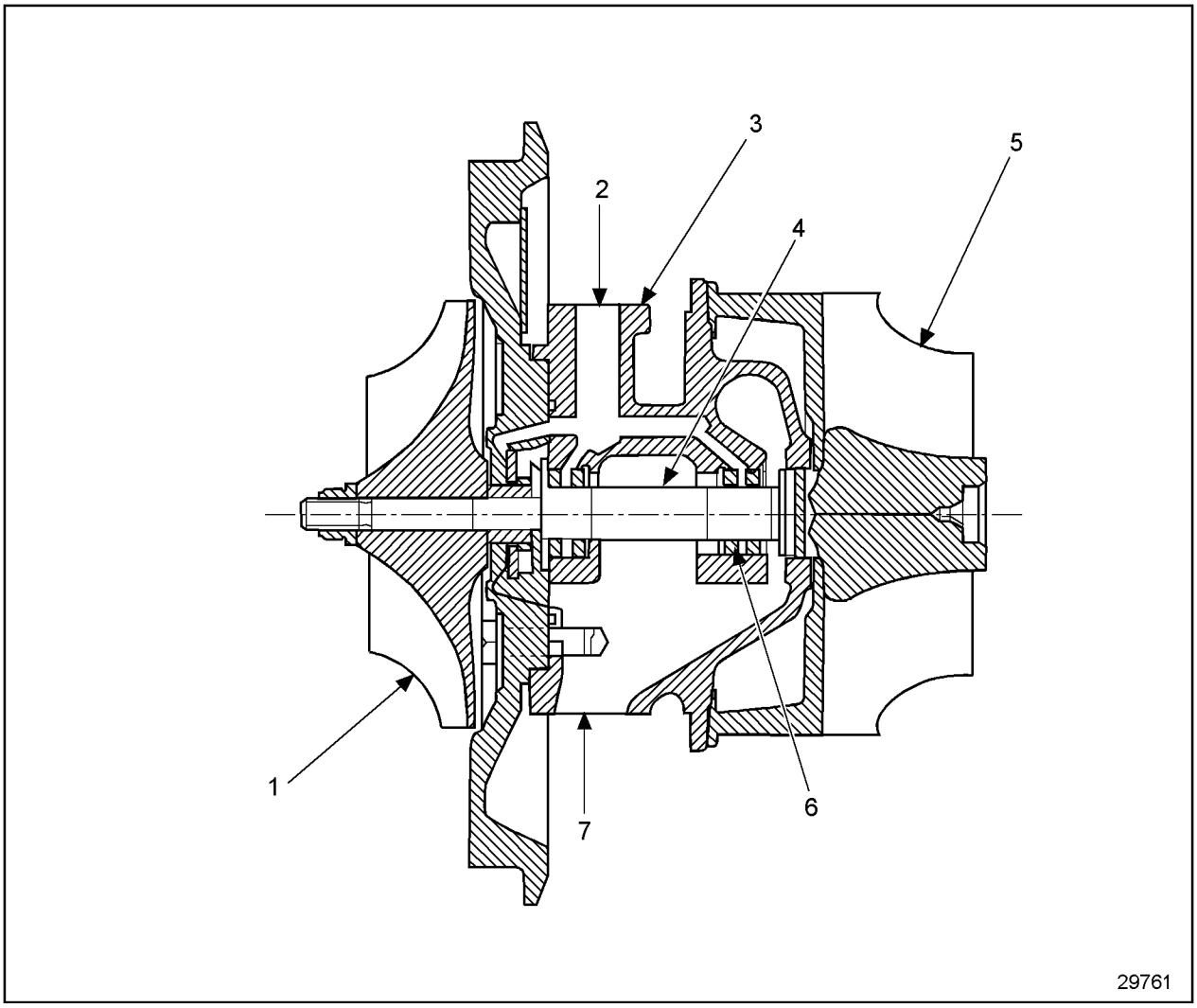


1. Center Housing
2. Turbine Housing
3. "V" Band Coupling
4. Compressor Housing

Figure 6-45 Typical Turbocharger Assembly

The turbocharger consists of a radial inward flow turbine wheel and shaft, a centrifugal compressor wheel, and a center housing that serves to support the rotating assembly, bearings, seals, turbine housing, and compressor housing. The center housing has connections for oil inlet and oil outlet fittings.

The turbine wheel is inside the turbine housing and mounted on one end of the turbine shaft. The compressor wheel is in the compressor housing and mounted on the opposite end of the turbine wheel shaft to form an integral rotating assembly. See Figure 6-46.



1. Compressor Wheel
2. Oil Inlet
3. Center Housing
4. Shaft
5. Turbine Wheel
6. Shaft Bearings, Thrust Bearings,Retainers, and Washer
7. Oil Outlet

Figure 6-46 Typical Turbocharger

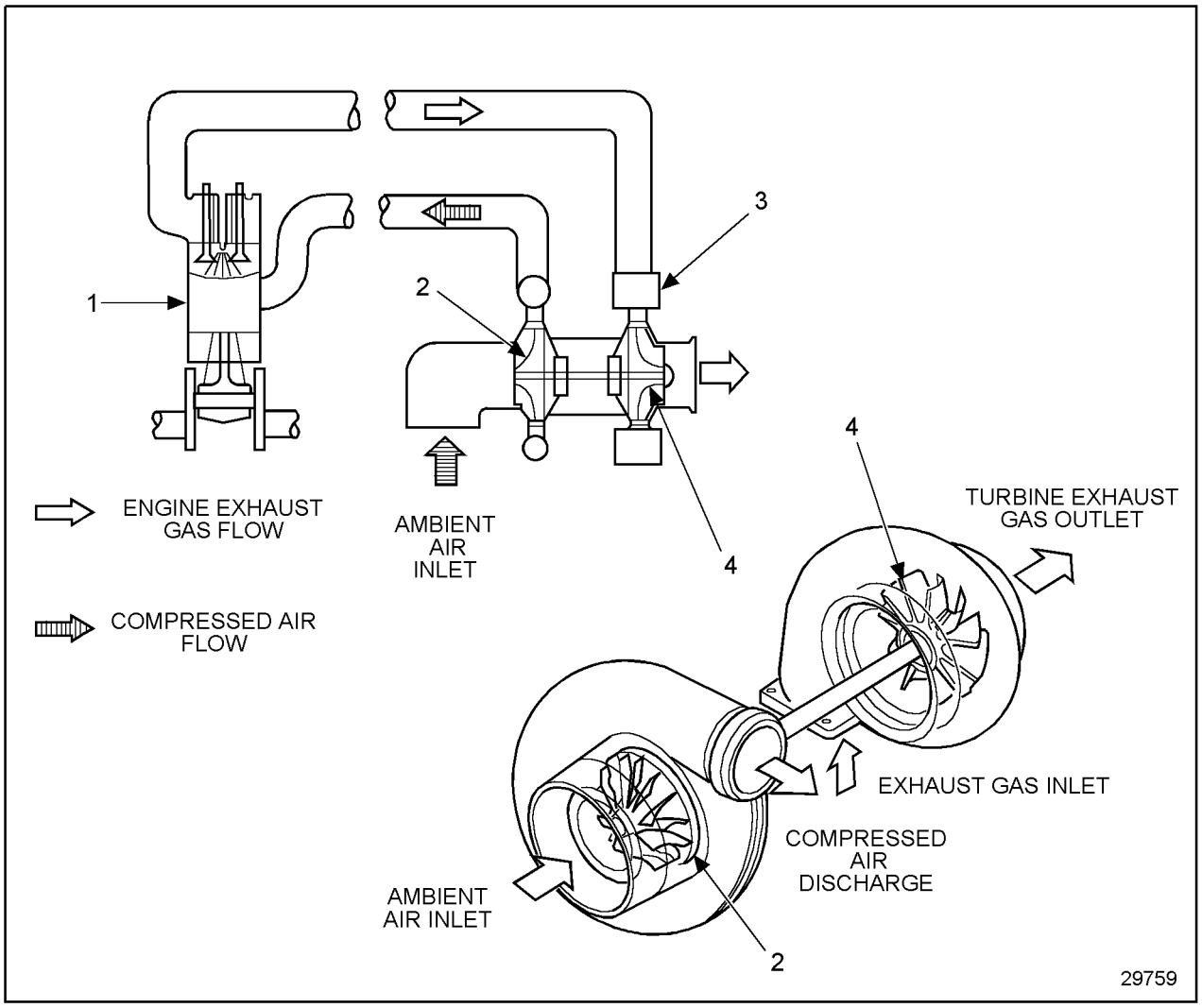
The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer or thrust collar, compressor wheel and wheel retaining nut. The rotating assembly is supported on two pressure lubricated bearings retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings and the thrust bearing.

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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 T18A40 and T18A90 turbine housings are bolted to the turbine end of the center housing. The TV71 and TV81 turbine housings are secured to the turbine end of the center housing with a "V" band coupling, providing a compact and vibration free assembly.

The compressor housing enclosing the compressor wheel provides an ambient air inlet and a compressed air discharge outlet. The T18A40, T18A90, TV71, and TV81 compressor housings are secured to the back plate assembly with a "V" band coupling.

The turbocharger is mounted on the engine exhaust outlet flange. After the engine is started, the exhaust gases flowing from the engine and through the turbine housing cause the turbine wheel and shaft to rotate. See Figure 6-47. The gases are discharged into the atmosphere after passing through the turbine housing.



1. Piston and Cylinder
2. Compressor Wheel
3. Exhaust Gas Discharge
4. Turbine Wheel

Figure 6-47 Turbocharger Schematic Air Flow Diagram

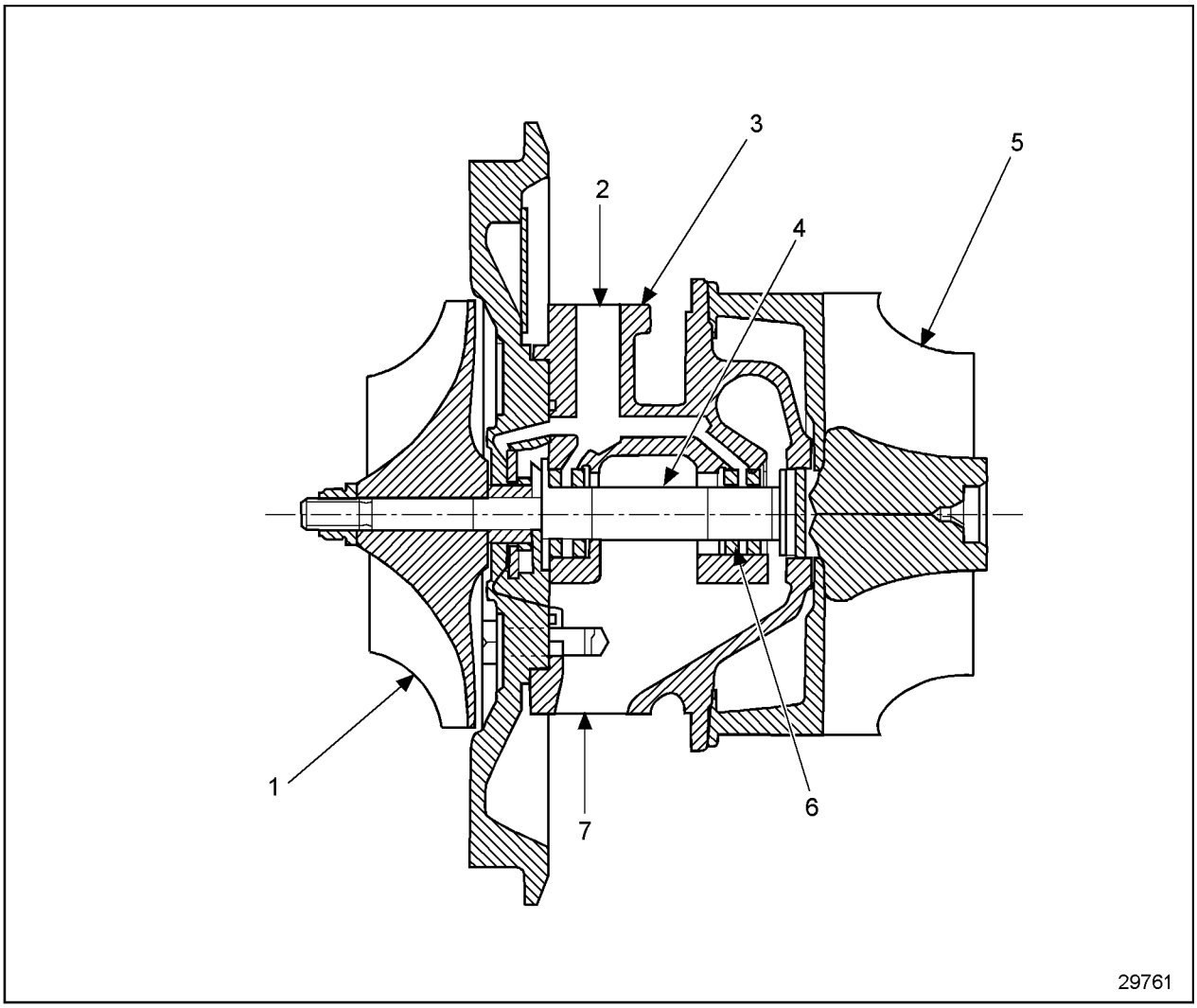
The compressor wheel, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in fresh air, compresses it, and delivers high pressure air through the engine blower to the engine cylinders.

During operation, the turbocharger reacts to the engine exhaust gas flow, responding to the engine load. As the engine power output increases or decreases, the turbocharger delivers the required amount of air under all conditions.

Some engines are equipped with an aftercooler to cool the air going into the engine after it passes through the turbocharger and the engine blower. Refer to section 6.8. Some marine engines are equipped with an intercooler to cool the air going into the engine after it passes through the turbocharger and engine blower. Refer to section 6.7.

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Lubricating oil for the turbocharger is supplied under pressure through an external oil line extending from the engine cylinder block to the top of the center housing. From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings and thrust bearings. See Figure 6-48. The oil returns to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block.

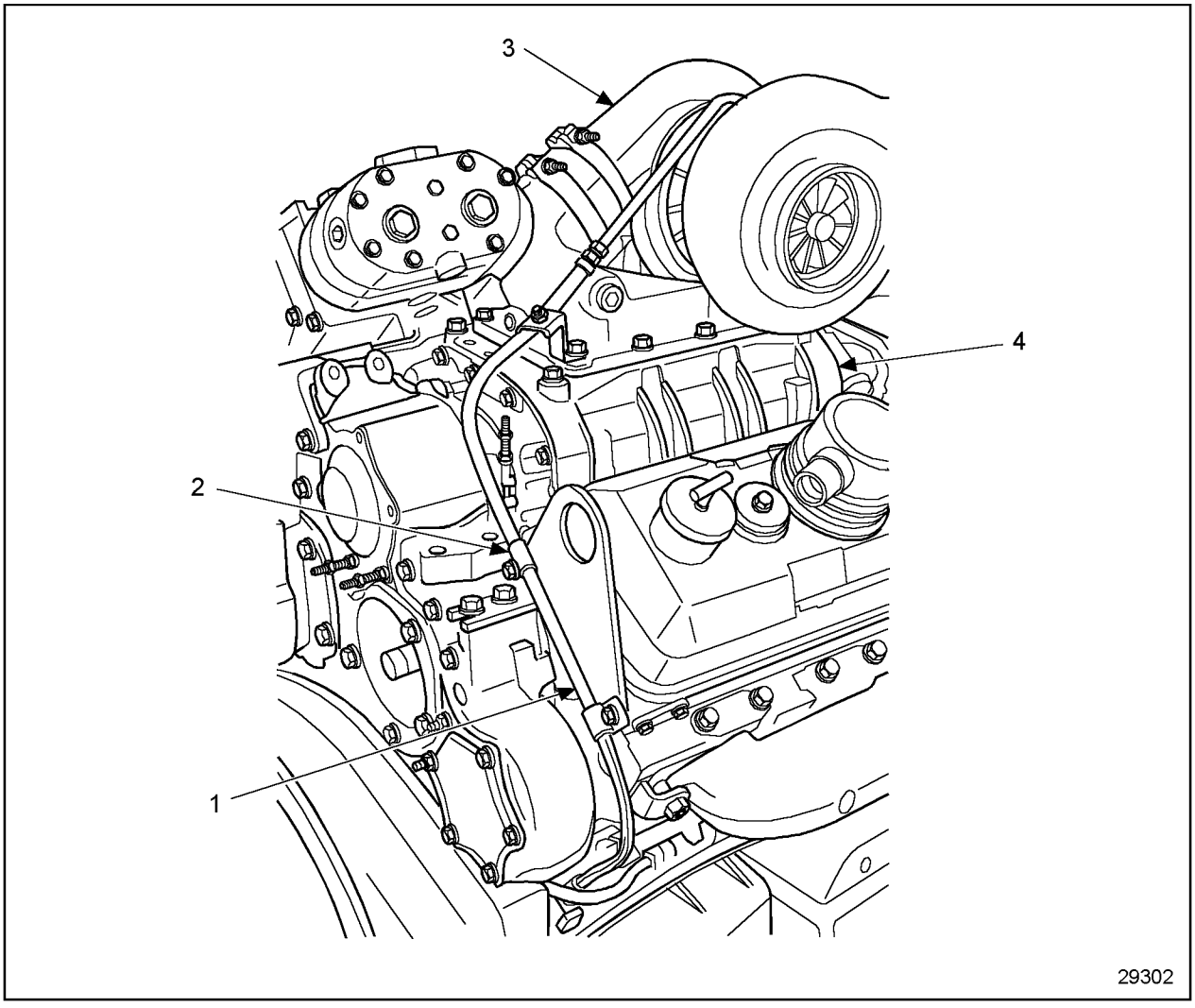


1. Compressor Wheel
2. Oil Inlet
3. Center Housing
4. Shaft
5. Turbine Wheel
6. Shaft Bearings, Thrust Bearings,Retainers, and Washer
7. Oil Outlet

Figure 6-48 Typical Turbocharger

On optional turbocharger mounting (OTM) vehicle engines, the oil returns directly from the turbocharger through two drain holes in the blower end plate (front end plate for front mounted turbocharger or rear plate for rear mounted turbocharger) to lubricate the blower bearings and either the timing gears or the governor drive and fuel pump drive. Refer to section 6.5.4.

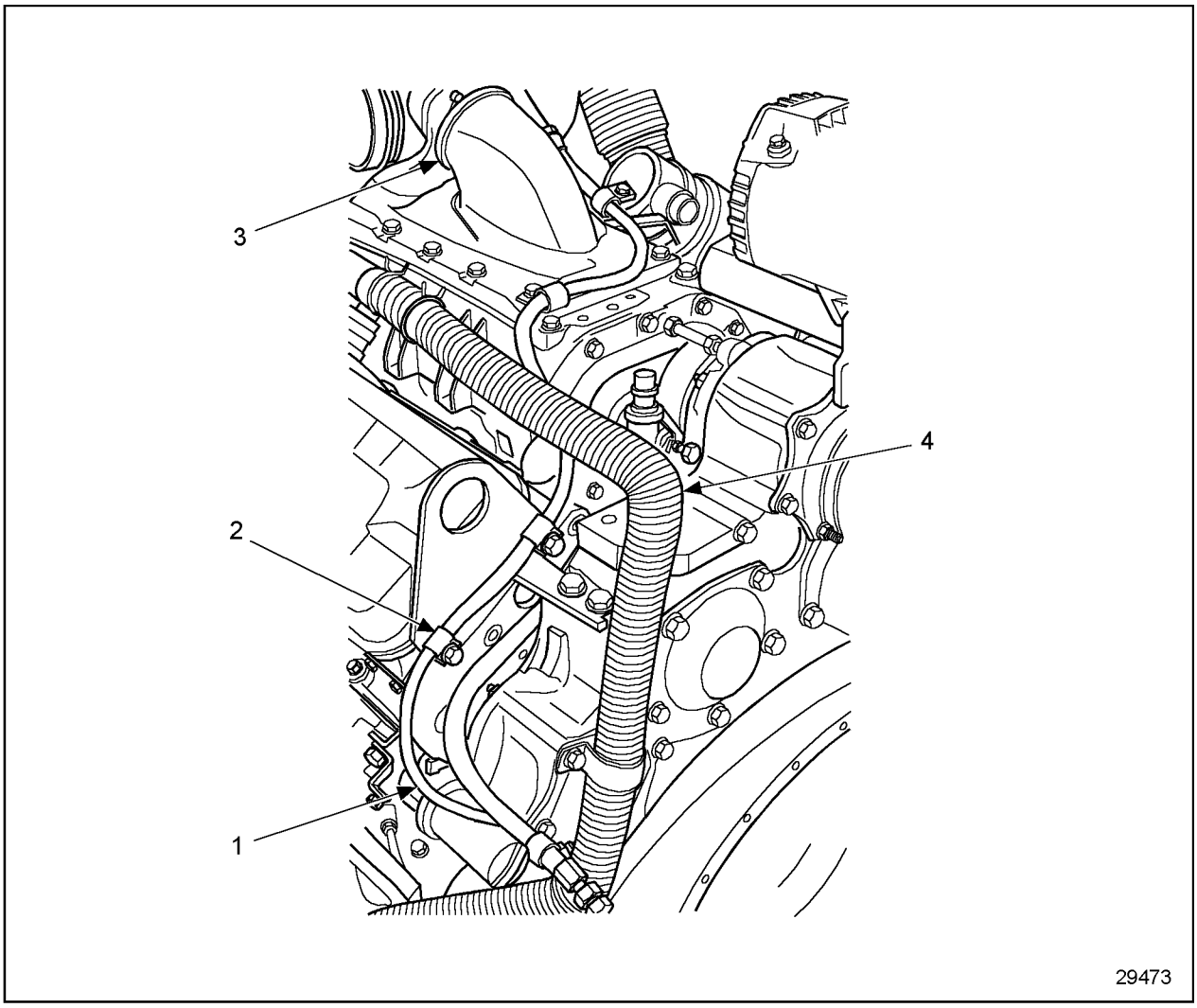
NOTE:
New service kits have been released to provide more durable rear lube oil supply lines for blower mounted turbochargers used on 6V and 8V engines. Each line must be positioned to prevent the braided stainless steel hose cover from rubbing or chafing against other hoses and/or engine components. The hose bracket-to-air inlet housing must support the hose and tube assembly at the air inlet housing. See Figure 6-49 and see Figure 6-50.



1. Oil Supply Line
2. Clamp
3. Turbocharger
4. Blower

Figure 6-49 Typical 6V-92 Right-Bank Turbo Oil Supply Hose Routing

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1. Oil Supply Line
2. Clamp
3. Air Inlet Housing
4. Breather Tube

Figure 6-50 Typical 8V-92 Left-Bank Turbo Oil Supply Hose Routing

Front-mounted turbocharger lube oil supply line kits are now available to service 6V and 8V engines equipped with blower mounted turbochargers. Marine engines are not included in this change. The new front-mounted turbocharger lines provide a shorter, more direct path for the turbocharger lube oil supply. Two tapped holes have been added to the front of current 6V and 8V cylinder blocks. Refer to section ADDITIONAL INFORMATION for former cylinder block modifications. The right-bank hole is used for the turbocharger oil supply line. The left-bank hole may be used for an additional oil feed location, if desired.

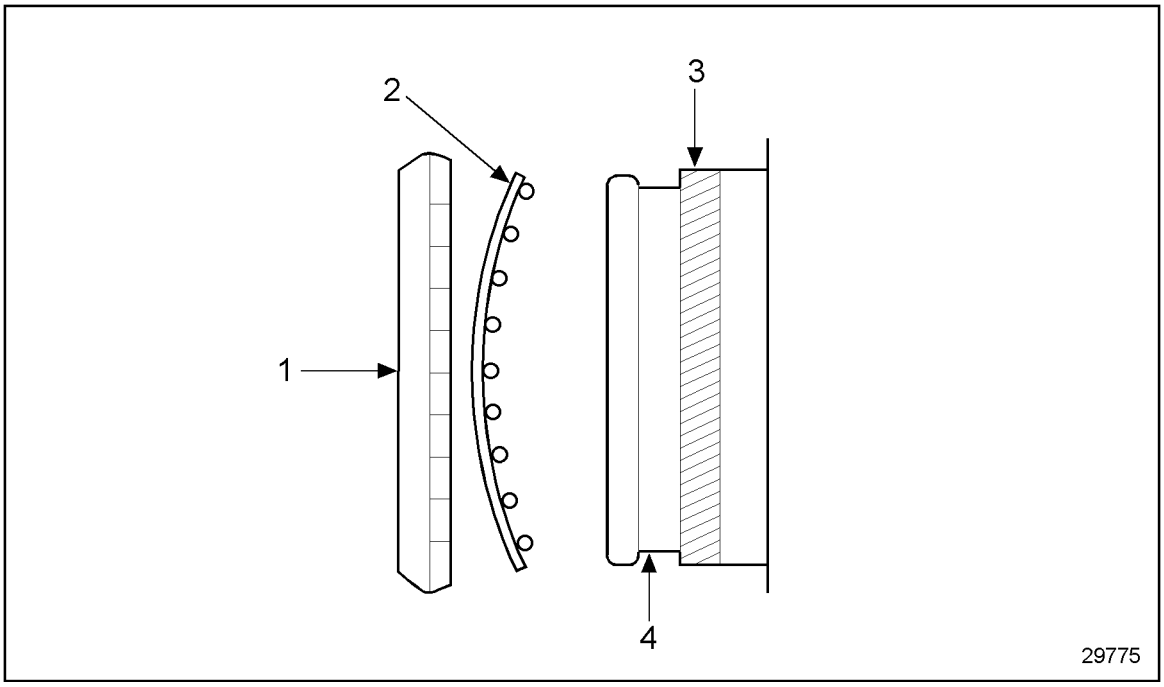
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NOTICE:
On engines using a governor high idle cylinder, sufficient clearance must be provided between the turbo oil supply line and the high idle cylinder to avoid damaging the supply line.

NOTICE:
Failure to perform the prelubrication procedure may result in premature bearing failure due to "oil lag" or lack of lubrication.

Before the initial start, when a new or overhauled turbocharger is installed, the turbocharger must be prelubricated.

For increased safety, a guard assembly is installed over the compressor inlets of all blower-mounted and front center-mounted Airesearch turbochargers. The two-piece assembly protects the service technician from the exposed turbocharger compressor wheel when the engine is operated with the air inlet piping removed from the compressor housing. See Figure 6-51. The guard assembly also prevents the turbocharger from ingesting foreign objects and causing damage.



1. Retainer
2. Screen
3. Strip Seal
4. Compressor Inlet

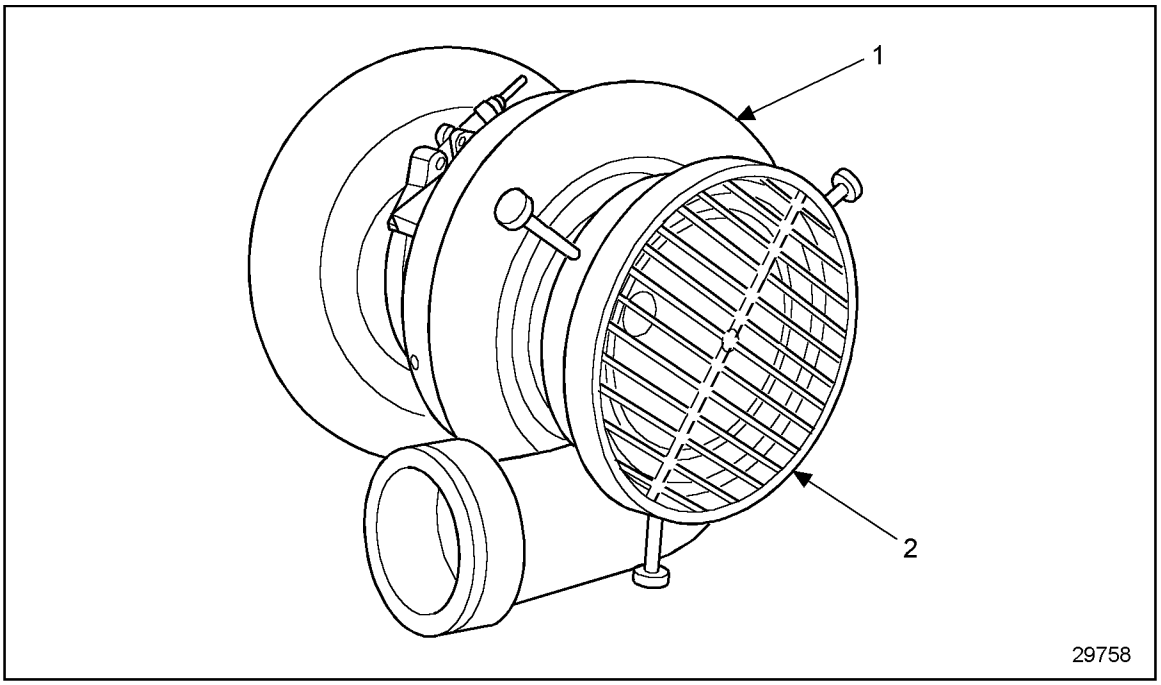
Figure 6-51 Compressor Inlet Screen Assembly and Strip Seal

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NOTICE:
DO NOT remove the guard assembly. Attempting to remove the guard will result in damage to the guard and the housing. A damaged guard or housing cannot be reused.

⚠ 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.

NOTE:
Because the inlet guard assembly provides added safety, DDC recommends having the guard installed on early blower-mounted and front center-mounted turbochargers when the air inlet piping is removed for any reason. See Figure 6-52.

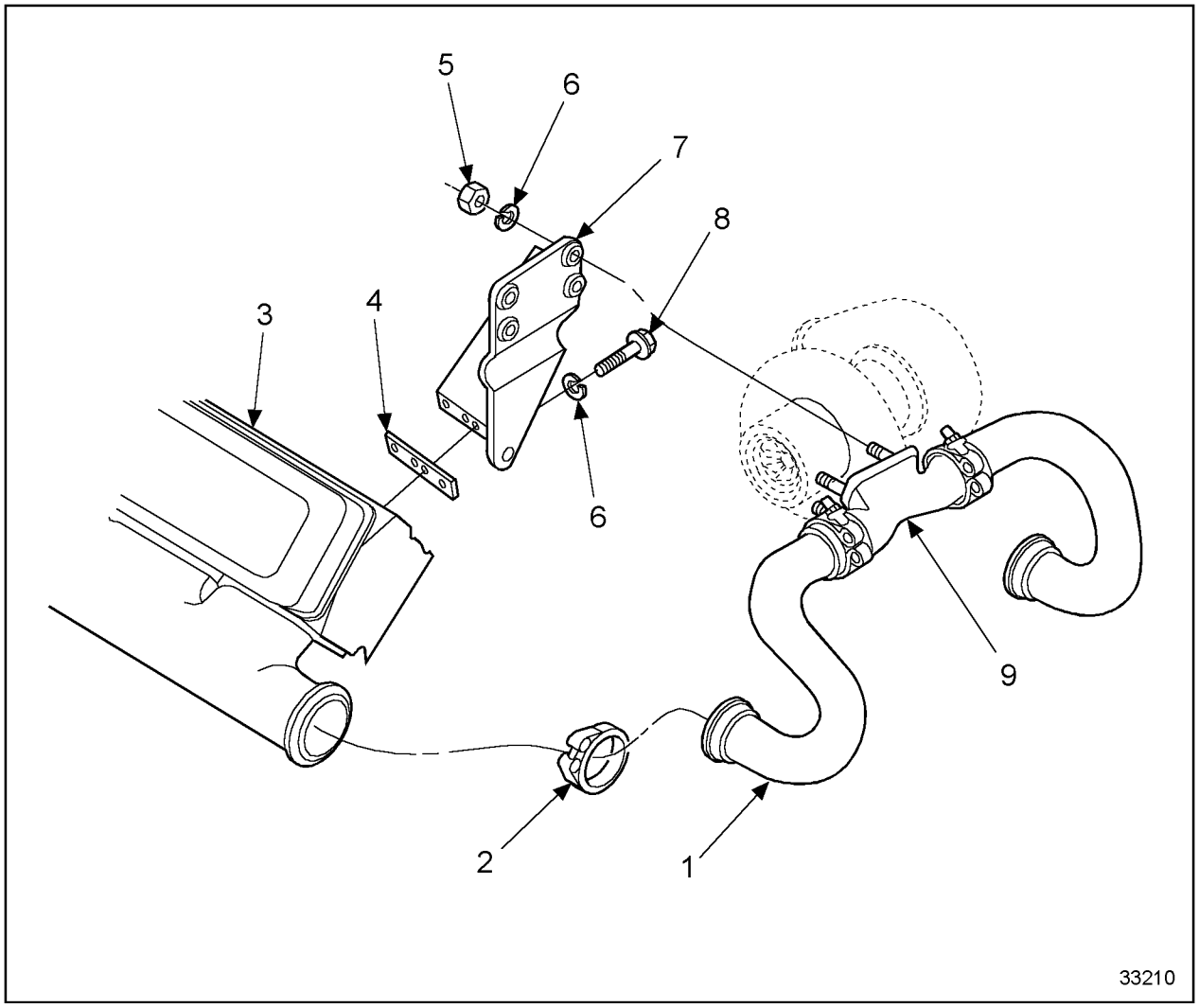


1. Turbocharger Assembly
2. Inlet Shield

Figure 6-52 Turbocharger Inlet Shield

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Detroit Diesel has released turbocharger mounting bracket gaskets with self-adhesive backing for the methanol-fueled engines. These gaskets are installed between the cylinder head and the turbocharger mounting bracket. See Figure 6-53.



1. Exhaust Tube Assembly
2. Exhaust Clamp
3. Cylinder Head
4. Bracket Gasket
5. Nut
6. Lock Washer
7. Turbocharger Mounting Bracket
8. Bolt
9. Turbocharger Mounting Tee

Figure 6-53 Placement of Turbocharger Mounting Gaskets

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NOTICE:
To avoid serious engine damage, remove the paper backing from the gasket before installation.

A pressure sensitive adhesive coating has been has been added to the gasket. A paper backing protects the adhesive film.

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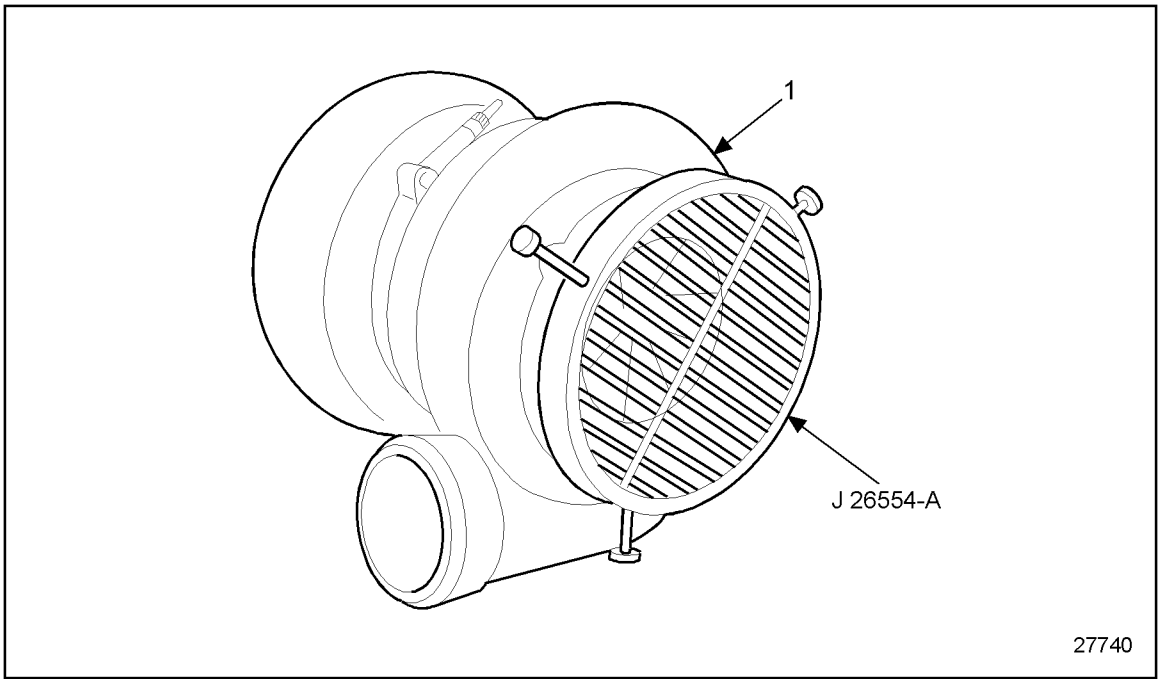
NOTICE:

DO NOT remove the guard assembly. Attempting to remove the guard will result in damage to the guard and the housing. A damaged guard or housing cannot be reused.

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.

A new screen assembly with a special strip seal is currently installed over the 5 in. diameter blower-mounted and front center-mounted Garrett turbocharger compressor inlets, see Figure 6-54. The current screen assembly replaces the former assembly. Former and current screen assemblies are similar, except the bezel on the new assembly has an inboard tapered face. The screen assembly with strip seal is standard on Garrett turbochargers.



1. Turbocharger

Figure 6-54 Installed on Air InletJ 26554-A

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The current screen assembly protects the service technician from the exposed turbocharger compressor wheel when the engine is operated with the air inlet piping removed from the compressor housing. The screen assembly prevents large foreign objects from damaging the turbocharger. The rubber strip seal keeps unfiltered air from seeping around the air inlet hose and entering the turbocharger.

A bead machined on the end of the compressor housing permanently retains the guard assembly. Compressor housings for all blower-mounted and front center-mounted turbochargers are serviced with the inlet guard installed.

Tests show that the following three conditions contribute to oil seal leakage at the internal turbocharger oil seal:

- A worn or defective oil seal, that must be replaced.
- High air inlet restriction (above specified limits) will cause oil to be pulled past the oil seal.
- Long periods of operation where the engine is being motored (using the engine as a braking device while going down a long hill), causing oil to pass the oil seal.

For oil leak testing procedure, refer to section ADDITIONAL INFORMATION.

6.6.1 Repair or Replacement of Turbocharger (Airesearch)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 6-55.

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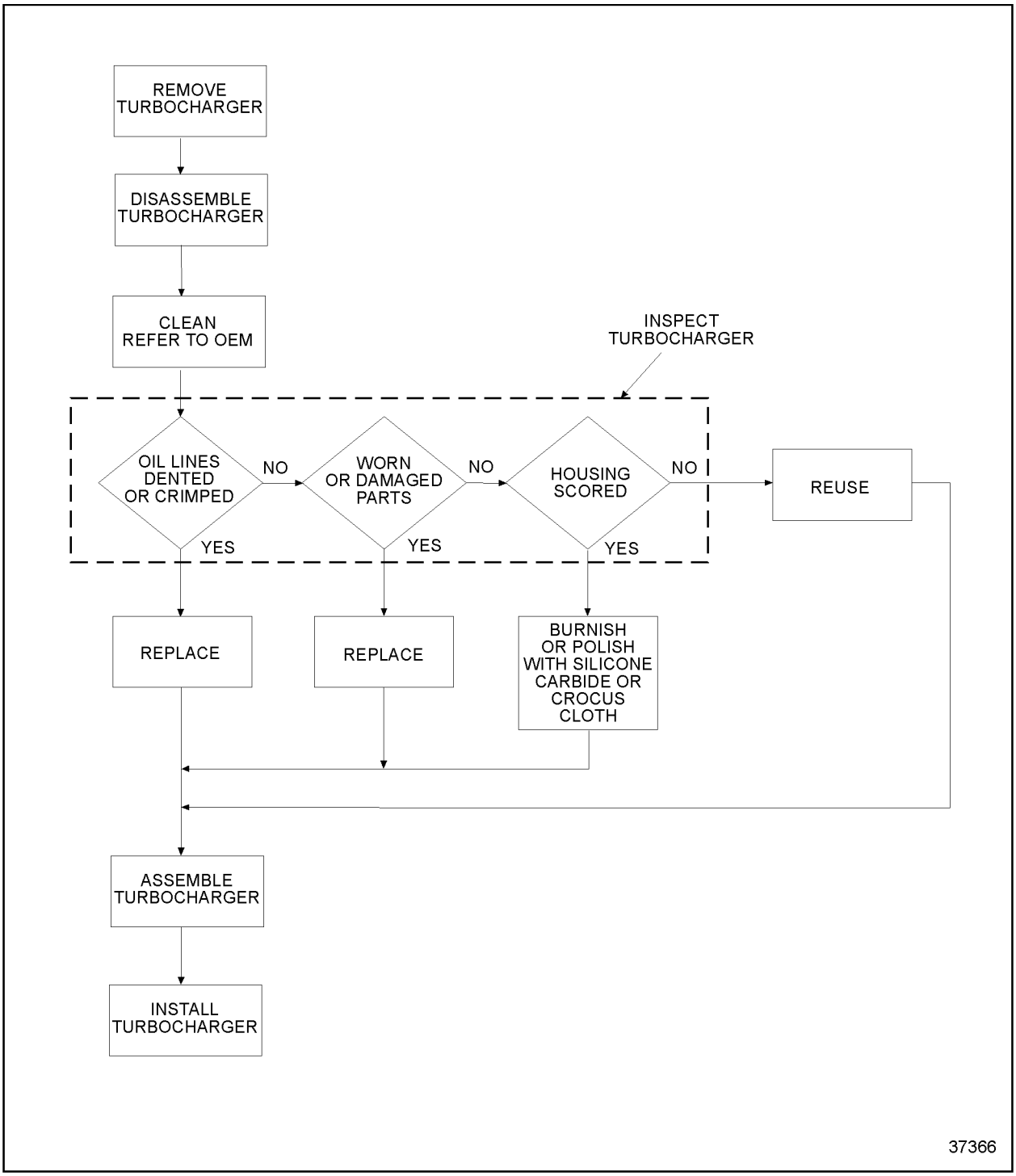


Figure 6-55 Flowchart for Repair or Replacement of Turbocharger (Airesearch)

6.6.2 Removal of Turbocharger

Remove the turbocharger as follows:

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1. Drain the cooling system. Refer to section 13.5.2.
2. Disconnect the exhaust manifold adaptor attached to the turbine housing.

NOTE:
When removing the left-bank exhaust manifold to turbocharger tube on the blower mounted turbochargers, matchmark one end of the tube for easy identification when installing the tube.

3. Disconnect the air inlet hose attached to the compressor housing.
4. Remove the oil inlet line from the top of the center housing.
5. Remove the oil outlet line from the bottom to the center housing.
6. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
7. Remove the nuts and lock washers securing the turbocharger assembly to the mounting bracket.

⚠ CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure turbocharger is securely attached to the lifting sling before removing from the engine. Turbocharger damage may result if the turbocharger breaks away from the lifting device and falls.

8. Lift the turbocharger assembly away from the engine, and place it on a bench.
9. Cover the end of each oil inlet and outlet line and the air inlet and exhaust outlet openings on the engine to prevent foreign material entry.

6.6.3 Disassembly of Turbocharger

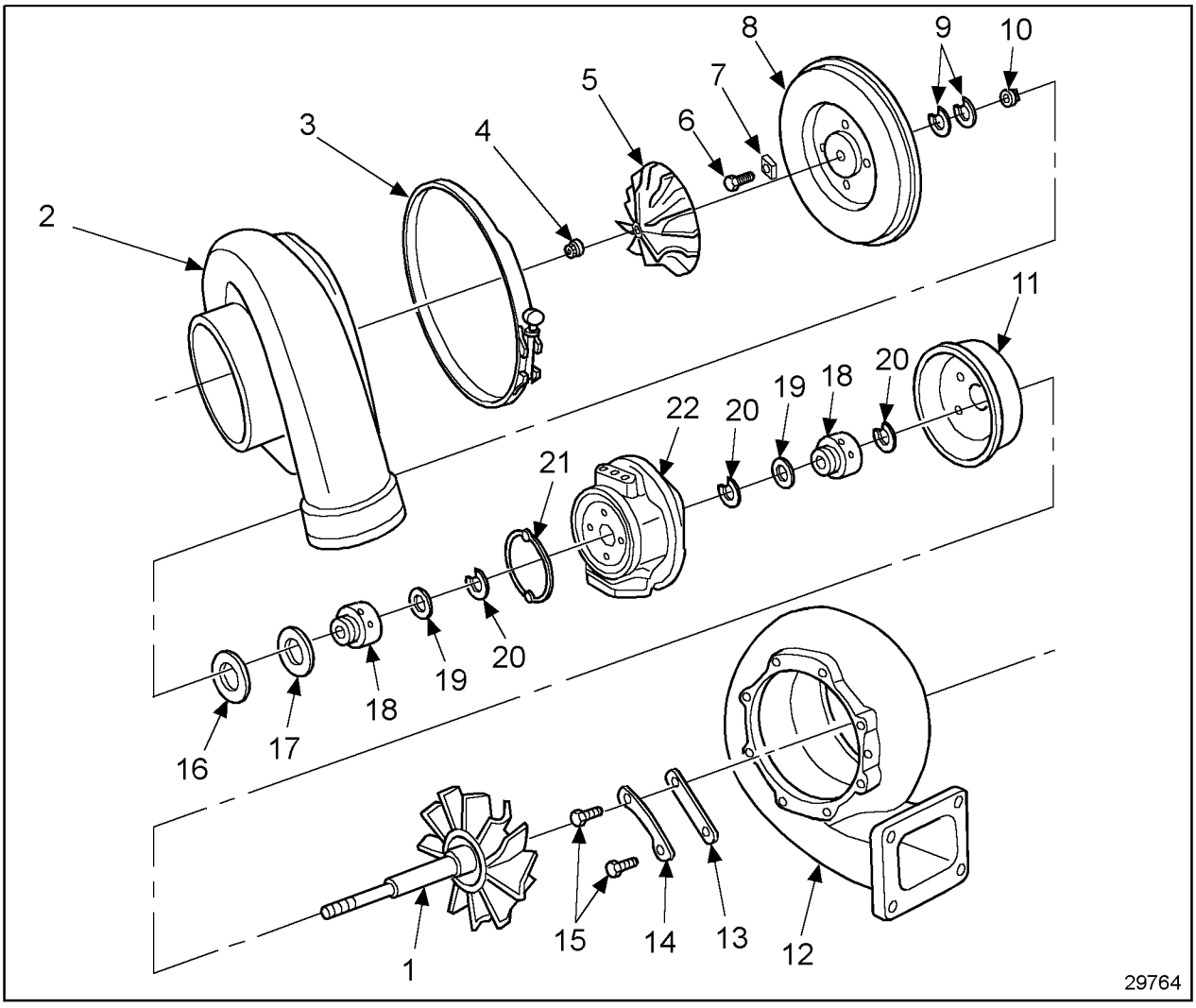
Disassemble the turbocharger as follows:

1. Clean the exterior of the turbocharger with a non-caustic cleaning solvent.

NOTE:
Mark the compressor housing, center housing and turbine housing positions with a punch or scribe prior to disassembly to ensure that it is assembled in the same position.

2. See Figure 6-56. Loosen the "V" band coupling securing the compressor housing to the back plate assembly.

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1. Turbine Wheel Assembly Shaft
2. Compressor Housing
3. "V" Band Coupling
4. Self-Locking Nut
5. Compressor Wheel
6. Bolt
7. Lock Plate
8. Back Plate Assembly
9. Piston Ring (Two for 18A90)
10. Thrust Spacer
11. Turbine Wheel Shroud
12. Turbine Housing
13. Turbine Housing Clamp
14. Lock Plate
15. Bolt
16. Thrust Collar
17. Inboard Thrust Bearing
18. Bearing
19. Bearing Washer
20. Snap Ring
21. Seal Ring
22. Center Housing

Figure 6-56 T18A40 and T18A90 Turbocharger

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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.

3. Remove the compressor housing and "V" band.

NOTICE:

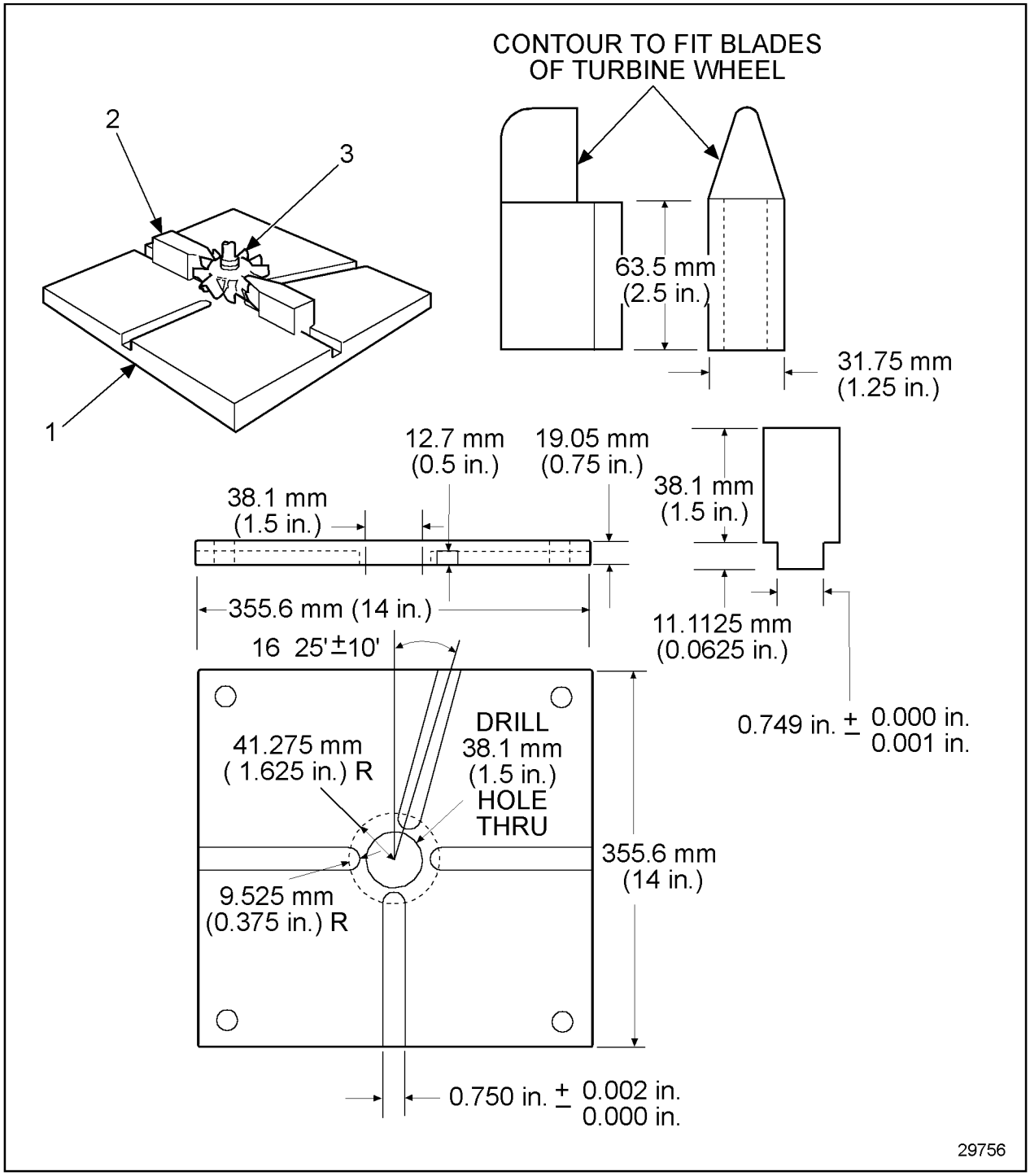
Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

4. With the T18A40 and T18A90 turbochargers, bend the ends of the lock plates, and remove the eight bolts securing the four lock plates and turbine housing clamps to the center housing and turbine housing.
5. With the TV71 and TV81 turbochargers, loosen the "V" band coupling securing the turbine housing to the center housing.
6. Remove the turbine housing from the center housing.

NOTE:
Tap the housing with a soft hammer, if necessary.

7. Place the center housing assembly turbine wheel in a suitable holding fixture. See Figure 6-57.

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1. Base
2. Fingers
3. Turbine Wheel

Figure 6-57 Turbocharger Holding Fixture

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NOTICE:
To prevent bending the turbine wheel shaft, remove the compressor wheel nut from the shaft with a double universal socket and tee handle.

8. Remove the wheel nut from the shaft.

NOTE:
If a holding fixture is not available, clamp a suitable socket or box end wrench in a vise, and place the extended hub on the shaft in the socket or wrench. Hold the center housing upright, and remove the wheel nut from the shaft.

9. Lift or press the compressor wheel from the wheel shaft assembly.
10. Withdraw the wheel shaft assembly from the center housing. The wheel shroud, which is not retained, will fall free when the wheel shaft is removed.
11. With TV71 and TV81 turbochargers, remove and discard the turbine piston ring from the wheel shaft.
12. Bend down the lock tabs, and remove the four bolts and lock plates securing the back plate assembly to the center housing.
13. Tap the back plate lightly to remove it from the center housing recess.

NOTE:
Do not disassemble the back plate assembly. Unless it is necessary to replace the pins, do not remove them from the center housing.

14. Remove and discard the seal ring from the groove in the center housing.
15. Remove the thrust spacer and piston ring(s) from the back plate assembly. Discard the piston ring(s).
16. Remove the thrust collar, inboard thrust bearing (if used), bearing, bearing washer (if used), and snap ring from the center housing. Discard the thrust bearing, bearing washer, and snap ring.
17. Remove the snap ring, bearing, bearing washer (if used), and snap ring from the opposite end of the center housing. Discard the snap rings, bearing, and washer.

6.6.3.1 Cleaning of Turbocharger

Refer to OEM

6.6.3.2 Inspection of Turbocharger

Inspect the turbocharger as follows:

1. Visually inspect the oil inlet and outlet lines for dents or crimping or oil leaks.

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[a] If dented or crimped, replace the oil inlet and outlet lines. Refer to section 6.6.4.

[b] Oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that will require turbocharger overhaul. Refer to section ADDITIONAL INFORMATION.

[c] If not dented or crimped, continue with inspection.

2. Visually inspect the turbine wheel shroud and turbine wheel for rubbing.

[a] If rubbing has occurred, replace the turbine wheel, shroud and air compressor. Refer to section 6.6.4.

[b] If no rubbing has occurred, continue with inspection.

3. Check shaft bearing journal dimensions and wear limits. Refer to section ADDITIONAL INFORMATION.

[a] If dimensions are not within wear limits, replace the shaft bearing journal. Refer to section 6.6.4.

[b] If dimensions fall within specified wear limits, proceed with inspection.

4. Inspect the shaft for scoring, scratches or bearing seizure.

[a] If scored or scratched, burnish or polish using a silicone carbide cloth for aluminum parts or a crocus cloth for steel parts.

[b] If excessively scored or scratched or if bearings have seized, replace the shaft. Refer to section 6.6.4.

[c] If no scoring or scratches are evident and if bearings have not seized, proceed with inspection.

5. Inspect the seal parts for rubbing or scoring on the running faces.

[a] If rubbed or scored, burnish or polish using a Silicone Carbide cloth for aluminum parts or a crocus cloth for steel parts.

[b] If excessively rubbed or scored, replace the seal. Refer to section 6.6.4.

[c] If no rubbing or scoring is evident, proceed with inspection.

6. Visually inspect the back plate assembly for wear or damage.

[a] If worn or damaged, replace the back plate. Refer to section 6.6.4.

[b] If the back plate is not worn or damaged, proceed with inspection.

7. Visually inspect the housing for contact with the rotating parts.

[a] If housing is contacting the rotating parts, replace the turbocharger. Refer to section 6.6.4.

[b] If no contact with rotating parts is evident, proceed with inspection.

8. Visually inspect the oil and air passages for obstructions.

[a] If obstructed, remove the foreign material.

[b] If no obstructions are visible, proceed with inspection.

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9. Inspect the exhaust outlet elbow seal ring for wear or damage.
   [a] If worn or damaged, replace the exhaust outlet elbow seal ring. Refer to section 6.6.4.
   [b] If not worn or damaged, proceed with inspection.

NOTE:
DDC recommends that the seal ring, piston rings, thrust bearings, bearing washers, snap rings, lock plates, and bolts be replaced at time of disassembly. If the thrust bearing is excessively worn, the back plate must be replaced.

10. Check for dirt or carbon buildup on the impeller or in the housing. Excessive accumulations indicate either a leak in the ducting or a faulty air filtering system.
    [a] Remove all dirt and carbon. Determine and correct the cause.
    [b] If no dirt or carbon has accumulated, proceed with inspection.
11. Check for leaking oil from the turbocharger housings.
    [a] If oil is leaking excessively, replace. Refer to section 6.6.5.
    [b] If no excessive leaks are present, continue with inspection.

NOTE:
Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. After the turbocharger has been operated for a time under load conditions and with the inlet restriction at normal, however, oil in these sections should disappear.

12. Inspect the turbocharger rotating assembly for free rotation. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.
    [a] If the turbine wheel does not spin freely, replace. Refer to section 6.6.5.
    [b] If the turbine wheel spins freely, proceed with inspection.
13. Inspect the compressor and turbine wheels for nicks.
    [a] If nicked, replace the compressor and turbine wheel.
    [b] If no nicks are evident, proceed with inspection.
14. Visually inspect the compressor and turbine wheel blades for damage.

NOTE:
Both wheels are precision balanced. A broken or bent blade can throw the rotating assembly out of balance and shorten the life of the turbocharger.

    [a] If the blades are damaged, replace the rotating assembly. Refer to section 6.6.4.
    [b] If the blades are not damaged, proceed with inspection.
15. Visually inspect the wheel bore for galling.
    [a] If galled, replace the turbocharger. Refer to section 6.6.4.

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[b] If not galled, proceed with inspection.

16. Inspect the wheel for dirt and other foreign material.

NOTICE:
Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. The blades on the wheels must be thoroughly cleaned. If chunks of carbon are left on the blades, the wheels will become unbalanced and cause bearing failure.

NOTE:
It is not necessary to disassemble the turbocharger to remove dirt and dust buildup.

[a] If contaminated, clean the wheel.

[b] If not contaminated, reuse the parts.

6.6.4 Assembly of Turbocharger

Assemble the turbocharger as follows:

NOTE:
Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent dirt or other foreign material from entering the engine.

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

1. Lubricate the new bearings with clean engine oil.
2. Install a new snap ring, bearing washer, bearing, and snap ring in the turbine end of the center housing.
3. Install a new snap ring, bearing washer, and bearing in the compressor end of the center housing.
4. Install a new piston ring(s) on the thrust spacer, and gently insert the spacer into the back plate assembly.

NOTE:
The current thrust spacer has two grooves. When replacing the former one groove spacer with the two groove spacer, ensure that the two piston rings are included.

5. Ensure that the compressor bearing is in place, and position the new inboard thrust washer flat against the center housing with the thrust washer hole and cutout aligned with the center housing pins.

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6. Install the thrust collar snugly against the thrust washer.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

7. Lubricate the thrust collar and thrust washer with clean engine oil.
8. Install a new seal ring in the groove at the compressor end of the center housing.
9. Align the oil feed holes in the center housing and the back plate assembly, and attach the back plate to the center housing with four bolts and new lock plates.
10. Tighten the T18A bolts to 10-12 N·m (90-110 lb·ft) torque or the TV71 and TV81 bolts to 9-11 N·m (80-100 lb·ft) torque. Bend the lock plate tangs against the side of the bolt heads.

NOTICE:

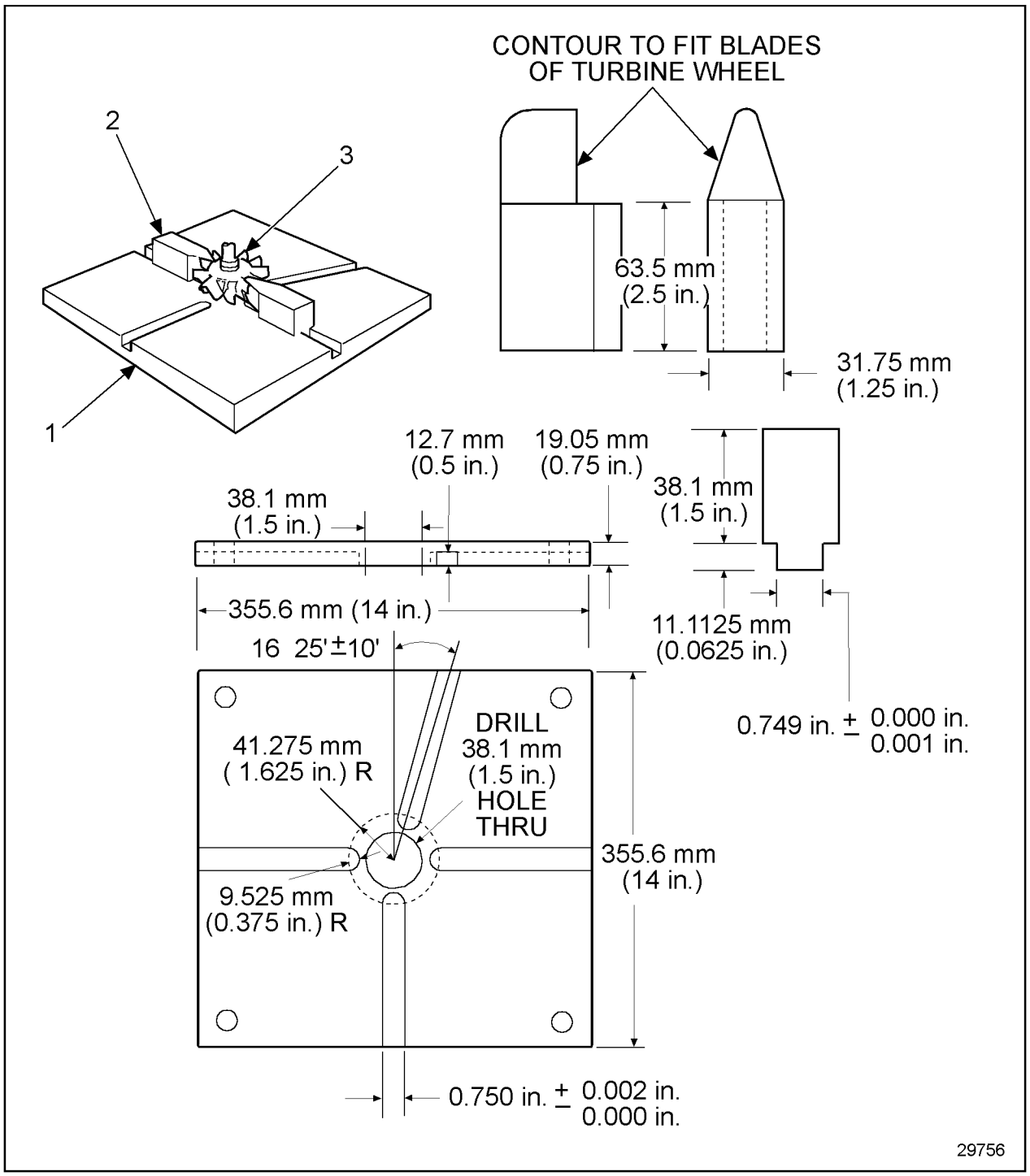
If a new back plate with a warning plate is installed, the warning plate must be removed and the three drive screw holes plugged to prevent air leaks. Failure to observe this notice will result in engine damage.

NOTE:
A steel lock plate and high strength bolts are now used in the T18A Series turbocharger. The high strength bolts and lock plates must be used together. The bolts must be tightened to 18-20 N·m (160-180 lb·ft) torque. Bend the lock plate tangs against the side of the bolt heads after tightening the bolts. Only the current steel lock plate and high strength bolts are serviced.

11. Before installing the piston ring, fill the piston ring groove with Dow Corning High Vacuum Silicone grease, or equivalent.
12. On TV71 and TV81 and turbochargers, install a new turbine piston ring on the wheel shaft assembly.
13. Position the wheel shroud against the center housing.
14. Lubricate the wheel shaft assembly journal.
15. Insert the wheel shaft assembly through the wheel shroud and into the center housing.

NOTE:
Ensure that the bearings do not become scuffed or scratched when installing the shaft.

16. Place the turbine wheel shaft assembly, shroud, center housing, and back plate upright in a suitable holding fixture. See Figure 6-58.



1. Base
2. Fingers
3. Turbine Wheels

Figure 6-58 Turbocharger Holding Fixture

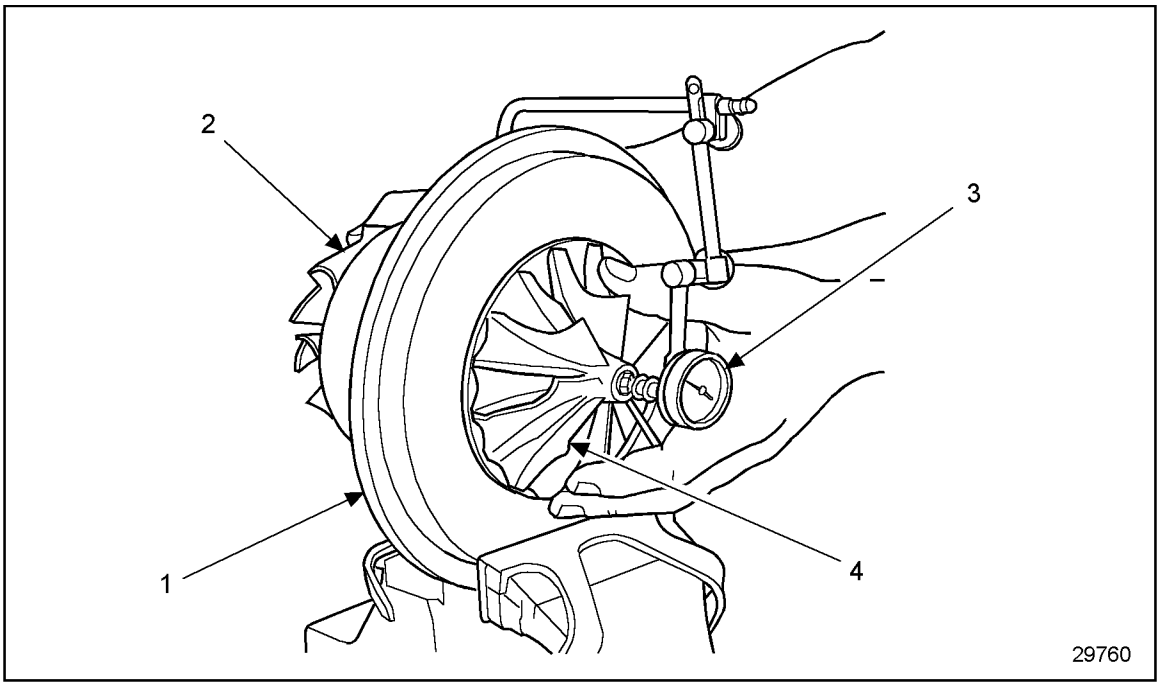
NOTE:
If a holding fixture is not available, clamp a suitable socket or box wrench in a vise, and place the extended hub on the socket or wrench shaft.

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17. At room temperature, position the compressor wheel over the shaft.
18. Lightly lubricate the shaft threads and wheel face with engine oil.
19. Install the retaining nut. Tighten the nut to 14-17 N·m (125-150 lb·in.) torque to seat the compressor wheel against the thrust spacer.
20. Loosen the nut, and inspect the nut face and the front face of the compressor wheel.

NOTE:
Ensure that the nut face and compressor wheel face are smooth and clean.

21. Tighten the nut to 4-6 N·m (35-55 lb·in.) torque.
22. Tighten the retaining nut until the shaft increases 0.1778–0.2032 mm (0.007–0.008 in.) in length (T18A40) or 0.2286–0.254 mm (0.009–0.010 in.) in length (T18A90, TV71 and TV81). Tighten the retaining nut without imposing bending load on the shaft.
23. If equipment is not available to measure the shaft stretch, tighten the wheel retaining nut to 4-6 N·m (35-55 lb·in.) torque. Continue to tighten the nut through an angle of 100 to 110 degrees turn for the T18A40 or 120 to 130 degrees turn for the T18A90, TV71 and TV81.Check the bearing axial end play as follows:
24. Clamp the center housing assembly in a soft jawed bench vise. See Figure 6-59.



1. Center Housing
2. Turbine Wheel
3. Magnetic Base Dial Indicator
4. Compressor Wheel

Figure 6-59 Checking Bearing Axial End Play

25. Fasten the dial indicator and magnetic base J 7872-2 (from set J 7872) to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side.
26. Move the shaft back and forth by hand. The total indicator reading (thrust float) should be 0.1016–0.2286 mm (0.004–0.009 in.) on T18A40 and T18A90 or 0.0762–0.254 mm (0.003–0.010 in.) on TV71 and TV81.
27. If the total dial indicator readings do not fall within the specified limits, repair or replace the rotating assembly.Continue turbocharger assembly as follows:
28. Position the turbine housing (as marked at disassembly) against the center housing.
29. Secure the T18A40 and T18A90 turbine with four clamps, four new lock plates, and eight bolts. Tighten the bolts to 11-15 N·m (100-130 lb-in) torque. Bend the lock plate tabs against the bolts.

NOTICE:
Ensure that the "T" bolt is position properly. Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak and/or turbine wheel damage.

30. On TV71 and TV81 turbochargers, 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.
31. Tighten the "V" band coupling nut, as follows:
    [a] Lubricate the toggle bolt threads with a high temperature anti-seize compound, such as Jet Lube (Mil Spec A-907D), or equivalent.

NOTE:
Do not pull a misaligned turbine housing into alignment with the "V" band coupling. The parts must be aligned and seated first.

    [b] Tighten the nut on the "V" band toggle bolt to 18 N·m (160 lb·in.) torque.

NOTE:
Ensure that the extension rod does not make contact with the sides of the center housing. Otherwise it will be impossible to obtain an accurate reading.

    [c] Loosen the "V" band coupling nut to approximately 6 N·m (50 lb·in.) torque. Tighten the nut to 17-19 N·m (152-168 lb·in.) torque.
32. Position the compressor housing as marked at disassembly against the back plate assembly. Secure it with the "V" band coupling.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

33. Lightly lubricate the toggle bolt threads with engine oil, and tighten the nut to 12-15 N·m (110-130 lb·in.) torque.Check the shaft radial movement as follows:
34. Position the magnetic base J 7872-2 with the swivel adaptor J 7872-3 (from set J 7872) on the flat surface of the turbine housing inlet flange.
35. Fasten the dial indicator extension rod J 7872-1 to the dial indicator J 8001-3 (from set J 7872). Attach the dial indicator to the swivel adaptor.
36. Insert the extension rod J 7872-1 (from set J 7872) into the oil drain tube mounting pad opening so that the rod is against the wheel shaft and perpendicular to the shaft.

NOTE:
Ensure that the extension rod does not make contact with the sides of the center housing. It will be impossible to obtain an accurate reading.

37. Grasp each end of the rotating assembly and, apply equal pressure at each end.
38. Move the rotating shaft toward and away from the dial indicator, creating a transverse movement in the shaft.
39. Refer to section ADDITIONAL INFORMATION for dial indicator displacement. If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly. Refer to section 6.6.3.Complete assembly as follows:
40. If the unit will be stored, lubricate it internally, and install protective covers on all openings.
41. Stamp the letter "R" in the lower left-hand corner of the name plate to indicate that the turbocharger has been reworked.

6.6.5 Installation of Turbocharger

Install the turbocharger as follows:

CAUTION:

To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:

Ensure turbocharger is securely attached to the lifting sling before removing from the engine. Turbocharger damage may result if the turbocharger breaks away from the lifting device and falls.

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove the covers from the air inlet and exhaust outlet openings.
3. On TV71 and TV81 turbochargers, install gaskets at the three mounting bracket to flywheel housing attaching bolts.
4. Place the turbocharger assembly into position on the mounting bracket. Use a new gasket between the exhaust manifold adaptor and the turbine housing flange.

NOTE:
When attaching the exhaust flange or adaptor to the turbine housing, ensure that the inner diameter of the flange or adaptor is the same as the turbine housing inner diameter. The turbine opening in the T18A40 turbocharger is 97.79 mm (3.850 in.), the T18A90 turbocharger is 107.95 mm (4.250 in.), the TV71 turbocharger is 88.392 mm (3.480 in.), the TV81 turbocharger is 98.8568 mm (3.892 in.).

5. Secure the turbocharger to the mounting bracket with bolts, lock washers, and nuts. Tighten the nuts enough to hold the turbocharger tightly against the bracket.

NOTE:
When self-locking nuts are used to secure the turbocharger to the mounting bracket, ensure that the thread fully engages the bolts.

6. Slide the blower air inlet hose over the compressor housing outlet opening. Center the hose between the turbocharger and the blower air inlet housing.
7. Secure the clamps with the "T" section positioned away from the parting line on the air inlet housing.

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NOTICE:
When installing the left-bank exhaust manifold-to-turbocharger tube on a blower mounted turbocharger, it is important to install the tube correctly. If the tube is installed incorrectly, the flange area can crack and adversely affect performance.

NOTE:
Ensure the exhaust manifold remains seated on the locating pads on the cylinder head.

NOTE:
The solid left-bank tube is almost symmetrical. Thus, it is difficult to identify which end goes where. Position the tube between the exhaust manifold and the turbocharger and determine that the conical seat at each end of the tube is a flush fit with the openings. If not, reverse the tube and check to ensure that each end of the tube fits flush with the openings.

NOTE:
To help in tube installation, loosen the exhaust manifold mounting bolts and tighten them alternately while tightening the tube clamps.

8. Tighten the turbocharger to exhaust manifold adaptor bolts securely.

⚠ CAUTION:
To avoid injury from a falling component while using a lifting device, never stand beneath a suspended load.

NOTICE:
Ensure turbocharger is securely attached to the engine before releasing the lifting sling. Turbocharger damage may result if the turbocharger breaks away from the engine and falls.

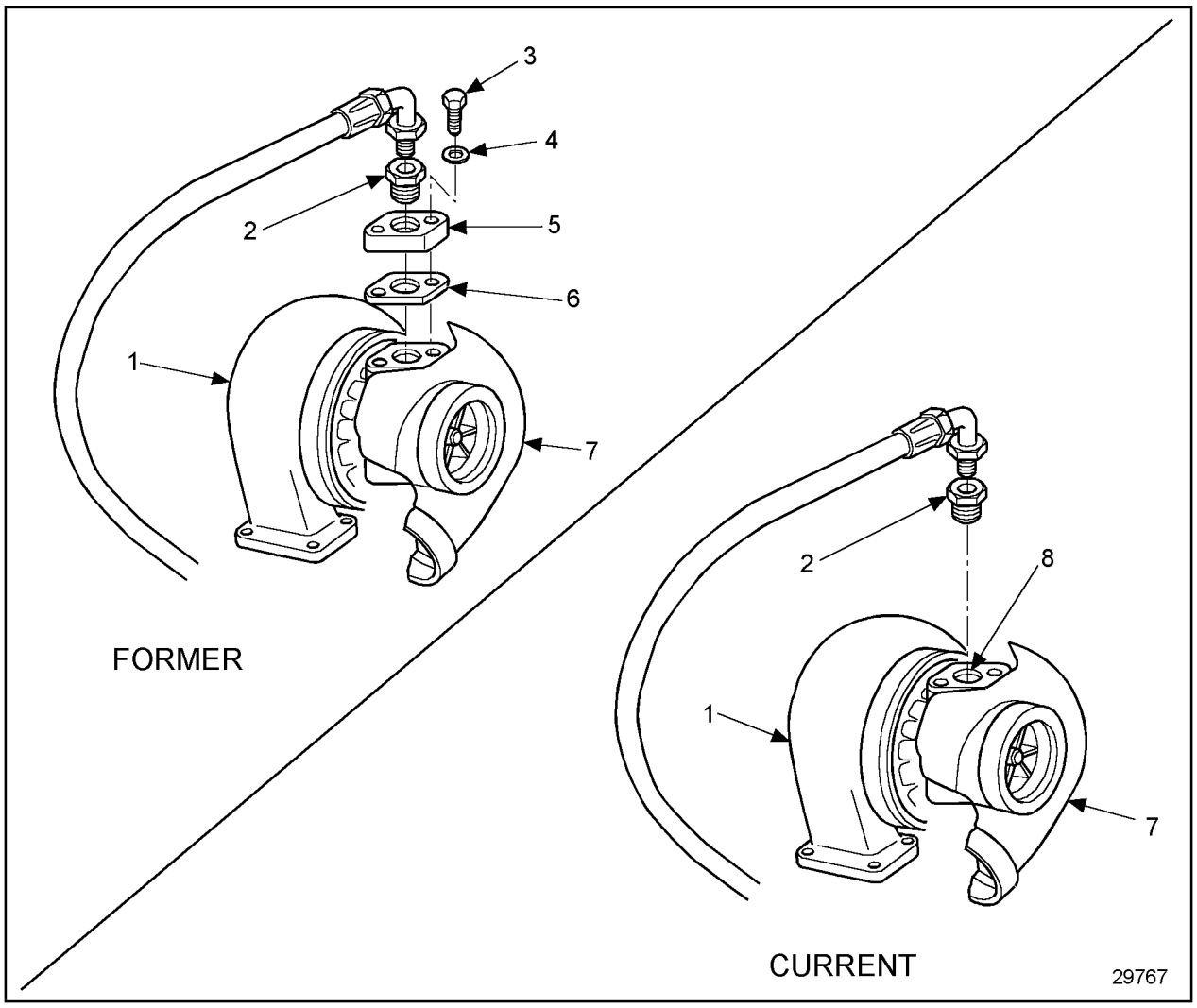
9. Remove the chain hoist and lifting sling from the turbocharger.
10. Install the oil drain line between the opening in the bottom side of the center housing and the cylinder block.
11. Attach the oil inlet line to the cylinder block.

After installing a rebuilt or new turbocharger, lubricate all moving turbocharger center housing parts as follows:

1. Clean the area and disconnect the oil inlet line at the bearing housing.
2. Fill the bearing housing cavity with clean engine oil.
3. Install the oil line.

4. Clean any spilled oil.

NOTE:
The lube oil supply connector formerly installed in the plate is assembled directly to the turbocharger center housing. The current TV turbocharger oil inlet is threaded by the manufacturer. See Figure 6-60.



1. Turbine Outlet
2. Connector
3. Bolt
4. Washer
5. Cover Threaded
6. Gasket
7. Compressor Inlet
8. Oil Inlet Now Threaded

Figure 6-60 Former and Current Lube Oil Supply Connections

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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:

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. Use of lubricant can cause the hose to blow off when the turbocharger builds boost pressure.

NOTICE:

The free floating bearings in the turbocharger center housing require positive lubrication. 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.

5. Run the engine at idle until oil reaches all moving parts. An oil pressure gage pressure of 69 kPa (10 lb/in.^{2}) at idle speed indicates that all moving parts are being lubricated.

Complete turbocharger installation as follows:

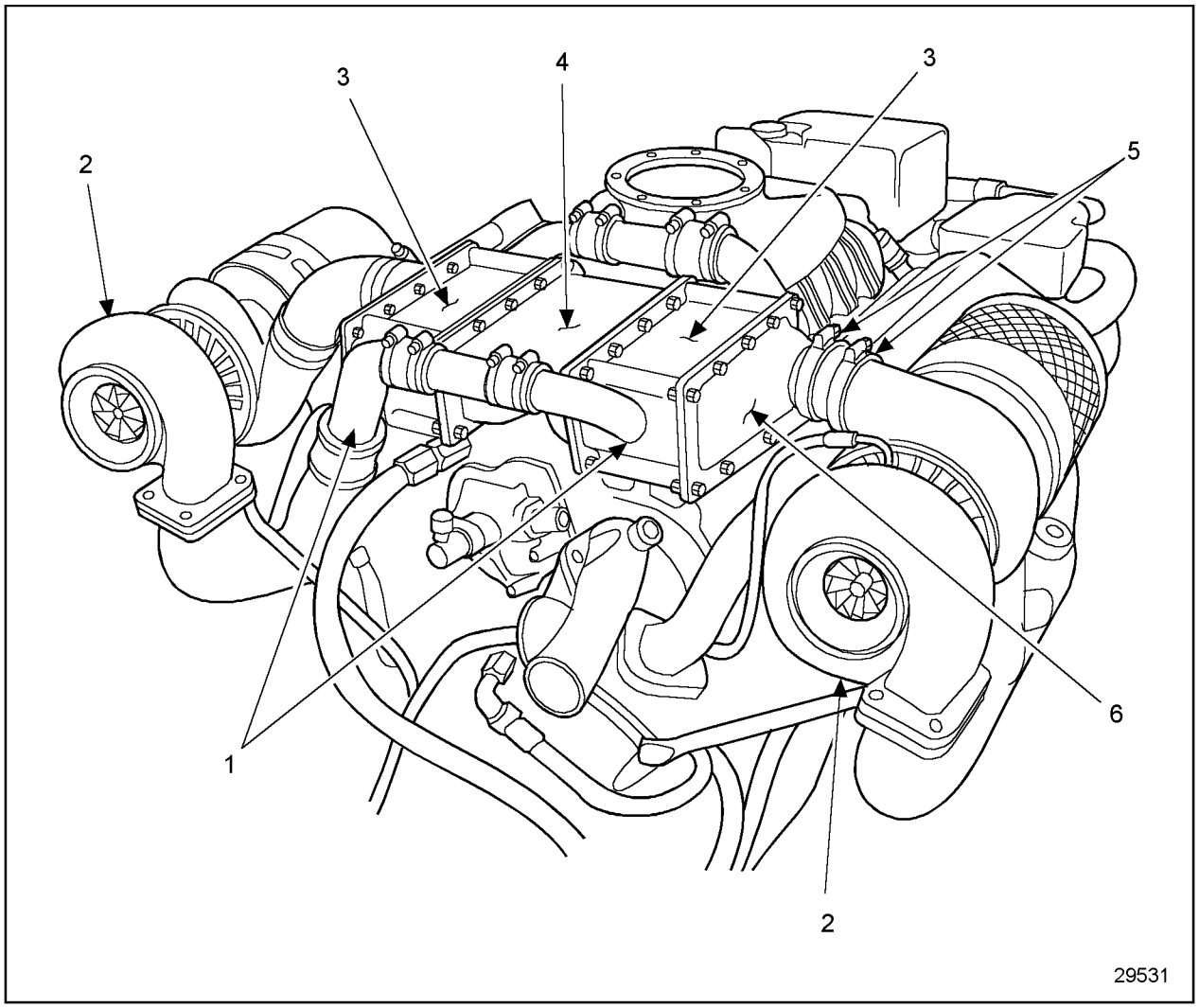
1. Check all connections, ducts, and gaskets for leaks after starting the engine.
2. Operate the engine at rated output, and listen for metallic contact sounds from the turbocharger.
3. If any such noise is heard, stop the engine immediately. Identify and correct the cause.

NOTE:
After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should freely coast to a stop after the engine has stopped. If the rotating assembly jerks to a sudden stop, immediately determine and eliminate the cause.

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6.7 TURBOCHARGER INTERCOOLER

An intercooler is placed between the air discharge side of each turbocharger and the air inlet side of the engine blower. See Figure 6-61. The intercooler is used to reduce the temperature of compressed air leaving the turbocharger before it reaches the blower, allowing a denser air charge to be delivered to the engine.



1. Water Connections
2. Turbocharger
3. Intercooler Cores
4. Air Outlet Housing
5. Hose and Clamp Assemblies
6. Air Inlet Housing

Figure 6-61 Turbocharger Intercooler Mounting

A raw water pump driven off the rear end of the engine supplies water to the intercooler. The water makes six passes through the core and is discharged from the connection diagonally opposite the inlet. The air from the turbocharger enters the finned side of the intercooler face opposite the water inlet, and flows counter to the water flow through the core.

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A cone-shaped 20 mesh water filter protects the coolant circulated through the intercoolers. The filter is located at the water connection in the water pump-to-engine oil cooler tube.

6.7.1 Repair or Replacement of Turbocharger Intercooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 6-62.

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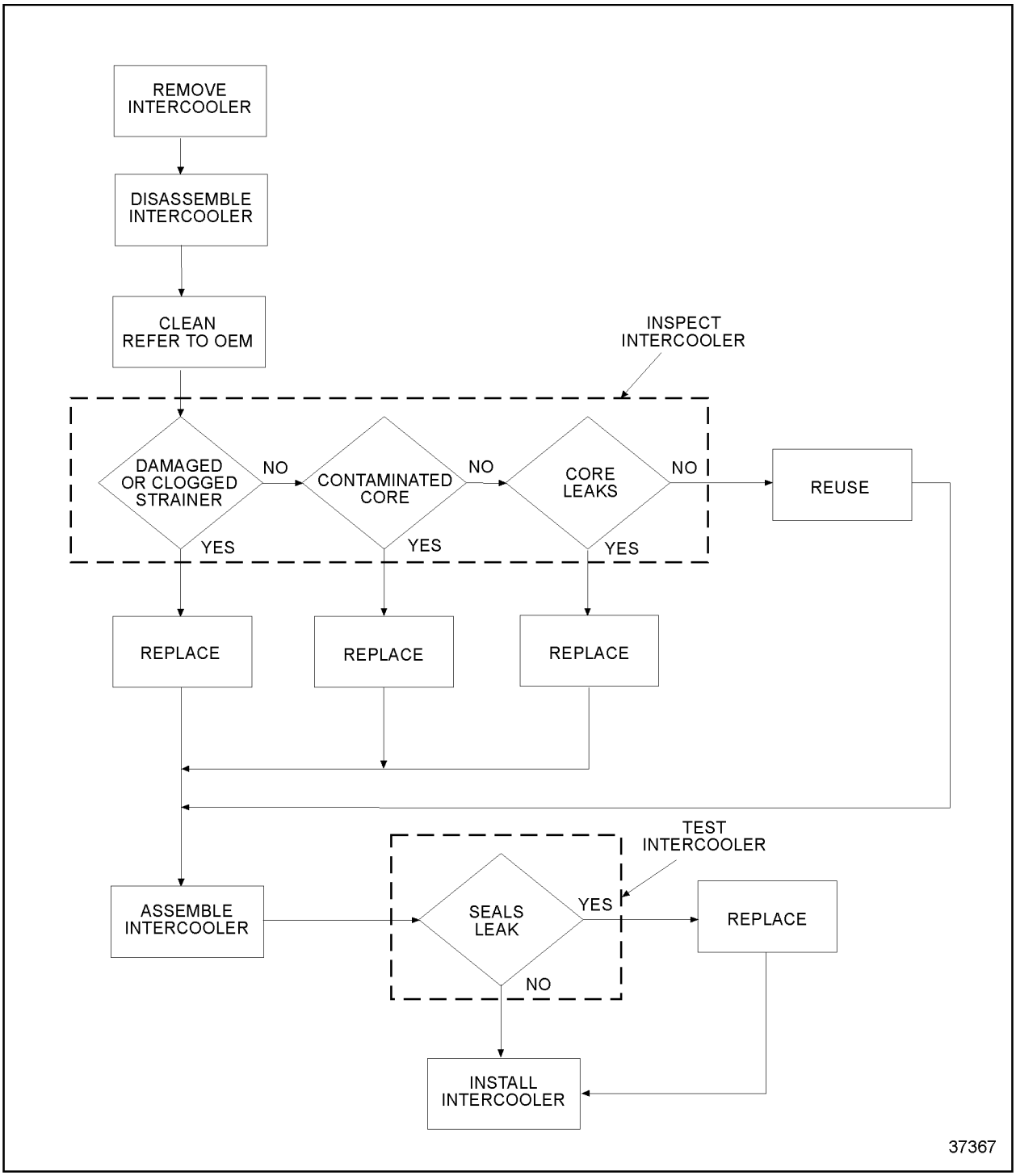


Figure 6-62 Flowchart for Repair or Replacement of Turbocharger Intercooler

6.7.2 Removal of Turbocharger Intercooler

Remove the turbocharger intercooler as follows:

1. Drain the raw water system. Refer to section 13.54.

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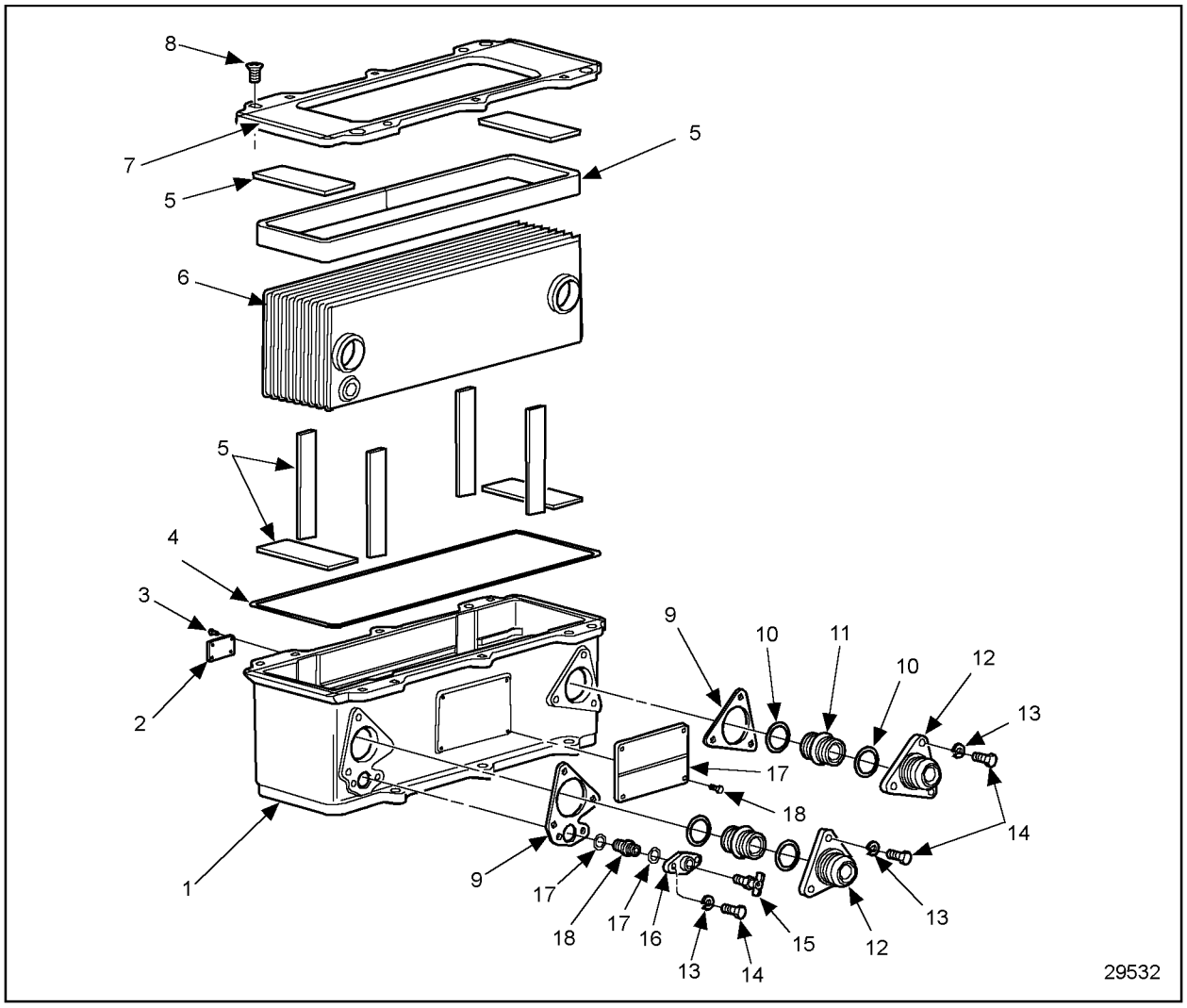
2. Disconnect the air and water inlet hose connections at the air shutdown housing.
3. Remove the intercooler air inlet housing.
4. Remove the intercooler from the air outlet housing.
5. Discard the gaskets.

6.7.3 Disassembly of Turbocharger Intercooler

Disassemble the intercooler as follows:

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1. Remove the two bolts and lock washers, and withdraw the drain adaptor, with the drain cock, from the drain hole below the intercooler outlet connector. See Figure 6-63.



1. Housing
2. Name Plate
3. Screw
4. Housing Seal Ring
5. Felt Pads
6. Intercooler Core
7. Adaptor Plate
8. Adaptor Plate Screw
9. Gasket
10. Seal Ring
11. Tube
12. Connector
13. Lock Washer
14. Bolt
15. Drain Cock
16. Adaptor
17. Small Seal Rings
18. Smaller Tube

Figure 6-63 Exploded View Assembly of Intercooler and Related Parts

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2. Remove three bolts and lock washers from each connector, and withdraw the inlet and outlet connectors straight out from the intercooler. Remove and discard the gaskets.
3. Remove the drain, inlet and outlet tubes, and seal rings from the water openings in the intercooler.
4. Remove and discard the two seal rings on each tube.
5. Remove the four cross-head screws from the intercooler adaptor plate.
6. Remove the plate, and discard the seal ring.
7. Remove the top one-piece felt pad.
8. Lift the intercooler core straight up and out of the housing.
9. If necessary, remove the eight upright felt pads for cleaning.

6.7.3.1 Inspection of Turbocharger Intercooler

Inspect the intercooler as follows:

1. Inspect the intercooler for marine growth and debris plugging the intercooler tubes.
   [a] Clear the intercooler tubes of debris, and thoroughly clean the intercooler. Refer to section 6.7.3.2.
   [b] If no growth or debris are evident, continue inspection.

Pressure check the intercooler as follows:

1. Make a suitable adaptor that an air hose can be attached, and fasten it to the inner cooler core inlet pipe. Use a piece of hose, a plug, and clamp to seal the outlet pipe.

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⚠ 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.

⚠ CAUTION:

To avoid injury from flying debris, wear a face shield or goggles when pressurizing the charge cooler system.

2. Attach an air hose, and apply approximately 138 kPa (20 lb/in.^{2}) air pressure. Submerge the cooler core in a tank of water. Any leaks will be indicated by air bubbles in the water.
3. Remove the air hose, clamp, plug, hose, and adaptor.

⚠ 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 cooler core with compressed air.
   [a] If any leaks are disclosed, replace the cooler core. Refer to section 6.7.4
   [b] If no leaks are disclosed, reuse the cooler core.

6.7.3.2 Cleaning of Turbocharger Intercooler

Refer to OEM

6.7.4 Assembly of Turbocharger Intercooler

Assemble the intercooler as follows:

1. If removed, affix the eight upright felt pads in the intercooler housing using Silastic 732 RTV, or equivalent.
2. Place the intercooler core straight into the housing.
3. Fix the one-piece felt pad around the top side of the housing.

NOTE:
The felt pad should meet at the center of the housing, and must not overlap.

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4. Lubricate a new seal ring and the adaptor plate groove with vegetable shortening, and install the seal ring in the plate.
5. Place the adaptor plate on the intercooler housing, and thread the four 3/8 in.-16 x 0.75 in. screws into the housing. Tighten the screws to 5.65 N·m (50 lb·in) torque.
6. Lubricate new seal rings and the two grooves on each drain, inlet, and outlet tube with vegetable shortening, and place the seal rings on the tubes. Place the drain, inlet, and outlet tubes in the housing water openings.
7. Use new gaskets, and install the water inlet and outlet connectors on the housing with three 3/8 in.-16 x 1 in. bolts and lock washers. Tighten the bolts to 27.12 N·m (240 lb·in.) torque.

NOTE:
The gasket with the drain hole is used at the outlet opening.

8. Install the drain adaptor and drain cock with two 5/16 in.-18 x 0.88 in. bolts and lock washers. Tighten the bolts to 13.56 N·m (120 lb·in.) torque.

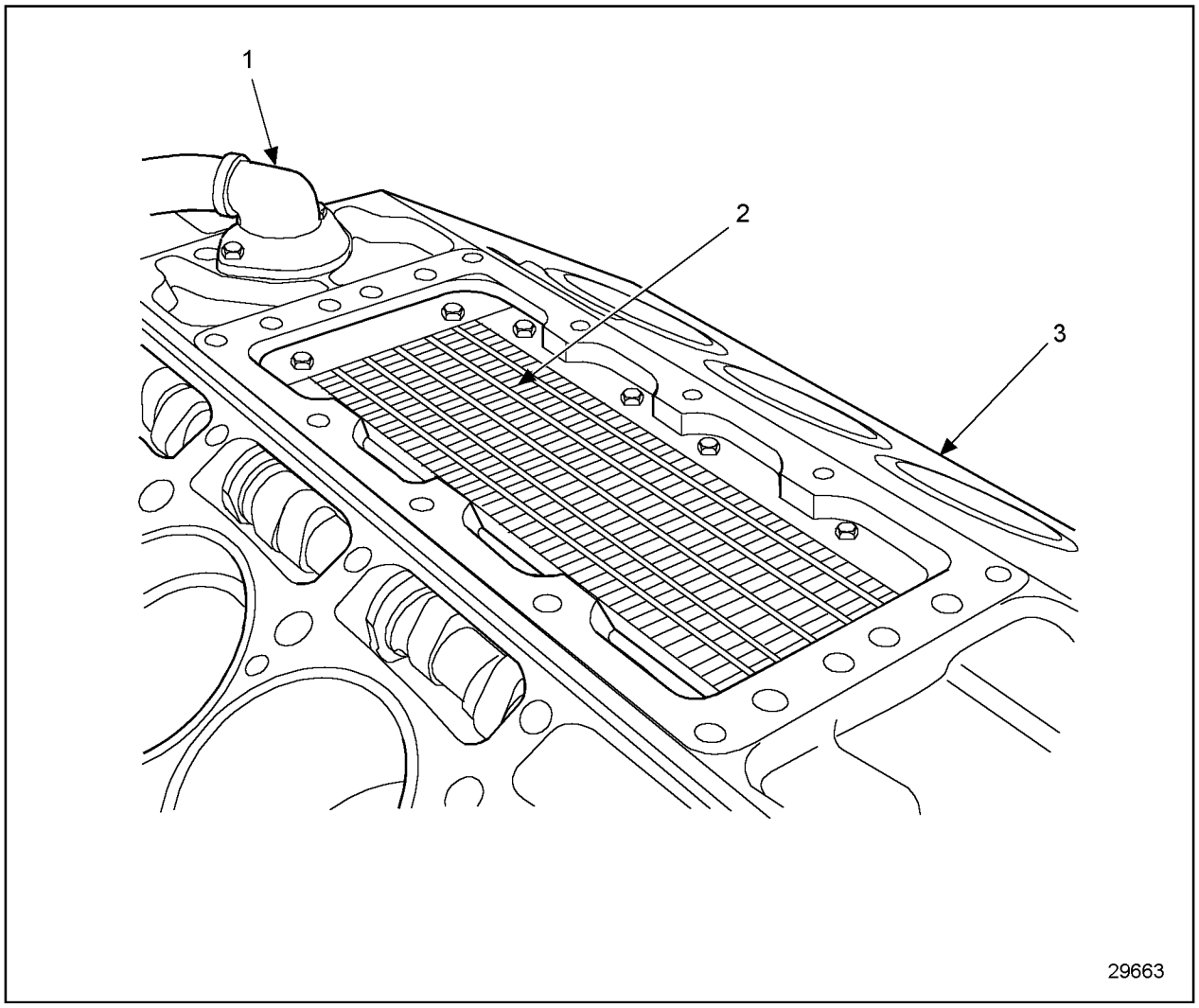
6.7.5 Installation of Turbocharger Intercooler

Install the intercooler as follows:

1. Use new gaskets, and install the intercooler on the air outlet housing with twenty 3/8 in.-16 x 1 in. bolts with lock washers and nuts. Tighten the nuts.
2. Use new gaskets, and attach the inlet housing to the intercooler with twenty 3/8 in.-16 x 1-1/8 in. bolts with lock washers and nuts. Tighten the nuts.
3. Connect the air and water inlet and outlet hoses at the air shutdown housing, turbocharger, and intercooler. Tighten the hose clamps.
4. Fill the raw water system. Refer to section 13.54.
5. Start the engine, and check for any air or water leaks.

6.8 TURBOCHARGER AFTERCOOLER

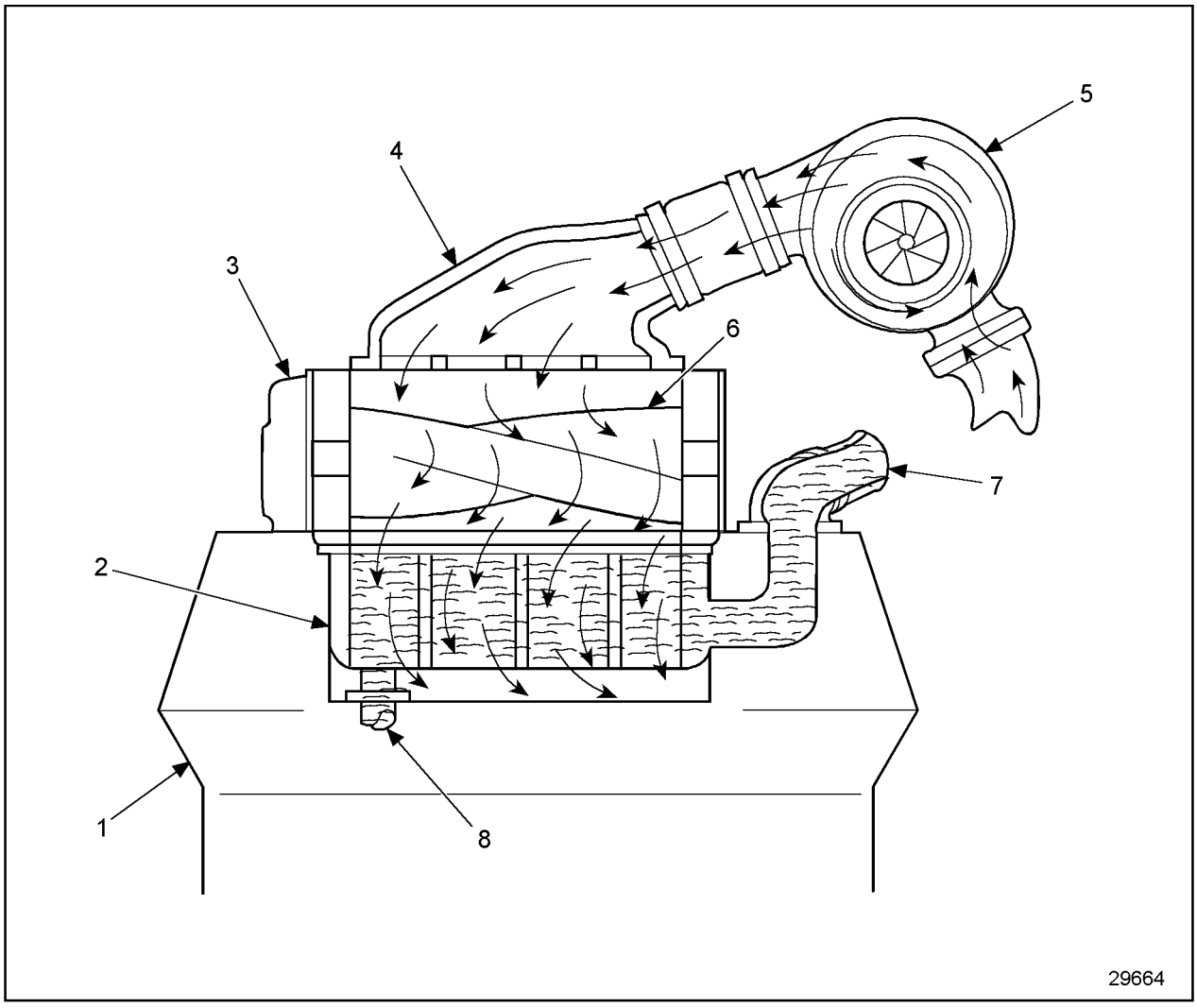
The aftercooler mounts in the cylinder block opening between the cylinders and beneath the blower assembly. See Figure 6-64. The aftercooler cools the air going into the engine after it passes through the turbocharger and the blower. See Figure 6-65. The air flows through the aftercooler, and the coolant flows from rear to front through the aftercooler and returns through the left-bank thermostat housing (6 and 8V engines) and to the water manifold (12 and 16V engines).



1. Water Outlet Tube
2. Aftercooler
3. Cylinder Block

Figure 6-64 Aftercooler Mounted in Cylinder Block

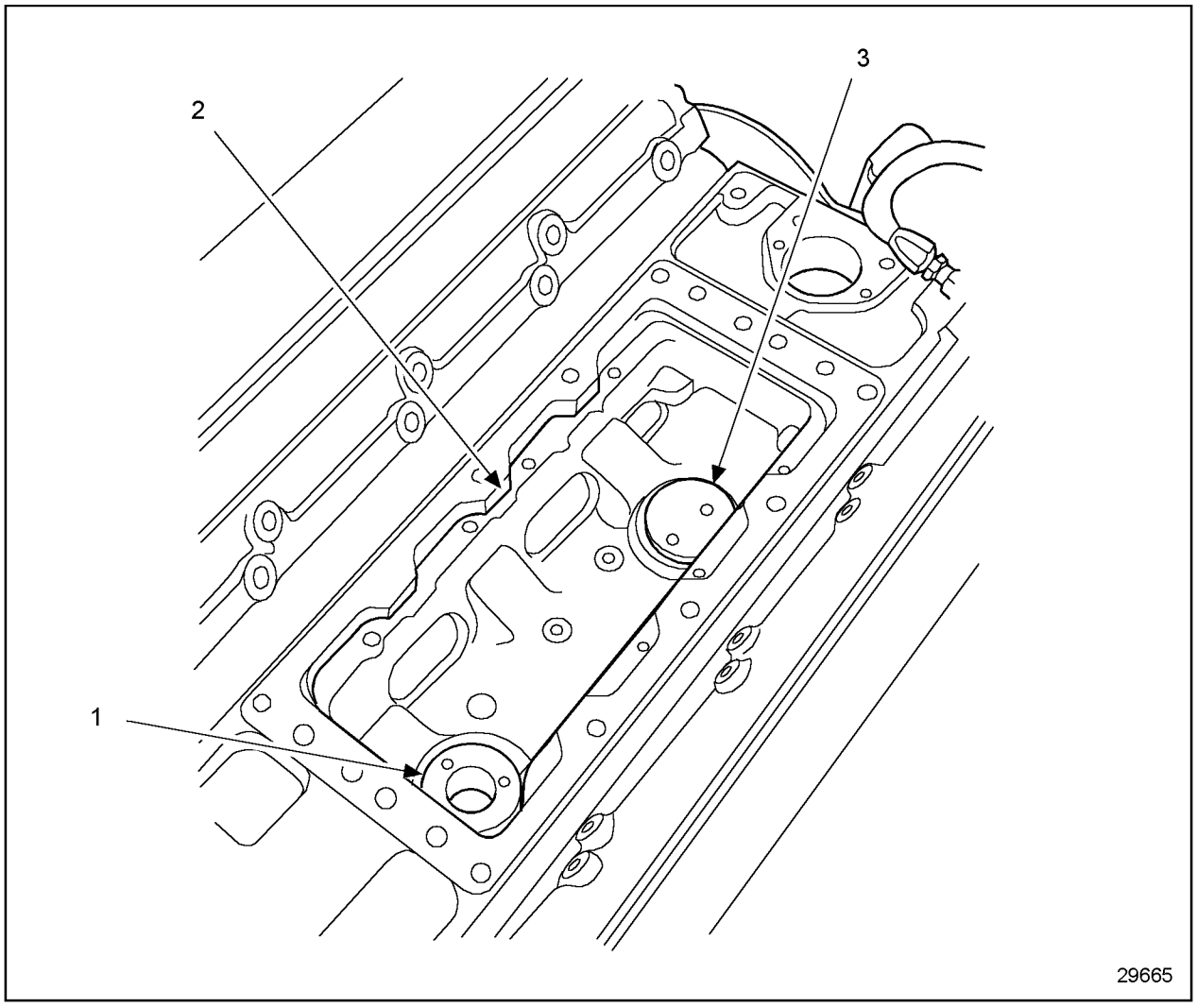
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1. Cylinder Block
2. Aftercooler
3. Blower Assembly
4. Air Inlet Housing
5. Turbocharger
6. Blower Rotors
7. Water Outlet
8. Water Inlet

Figure 6-65 Cutaway of Aftercooler Assembly Showing Air Flow

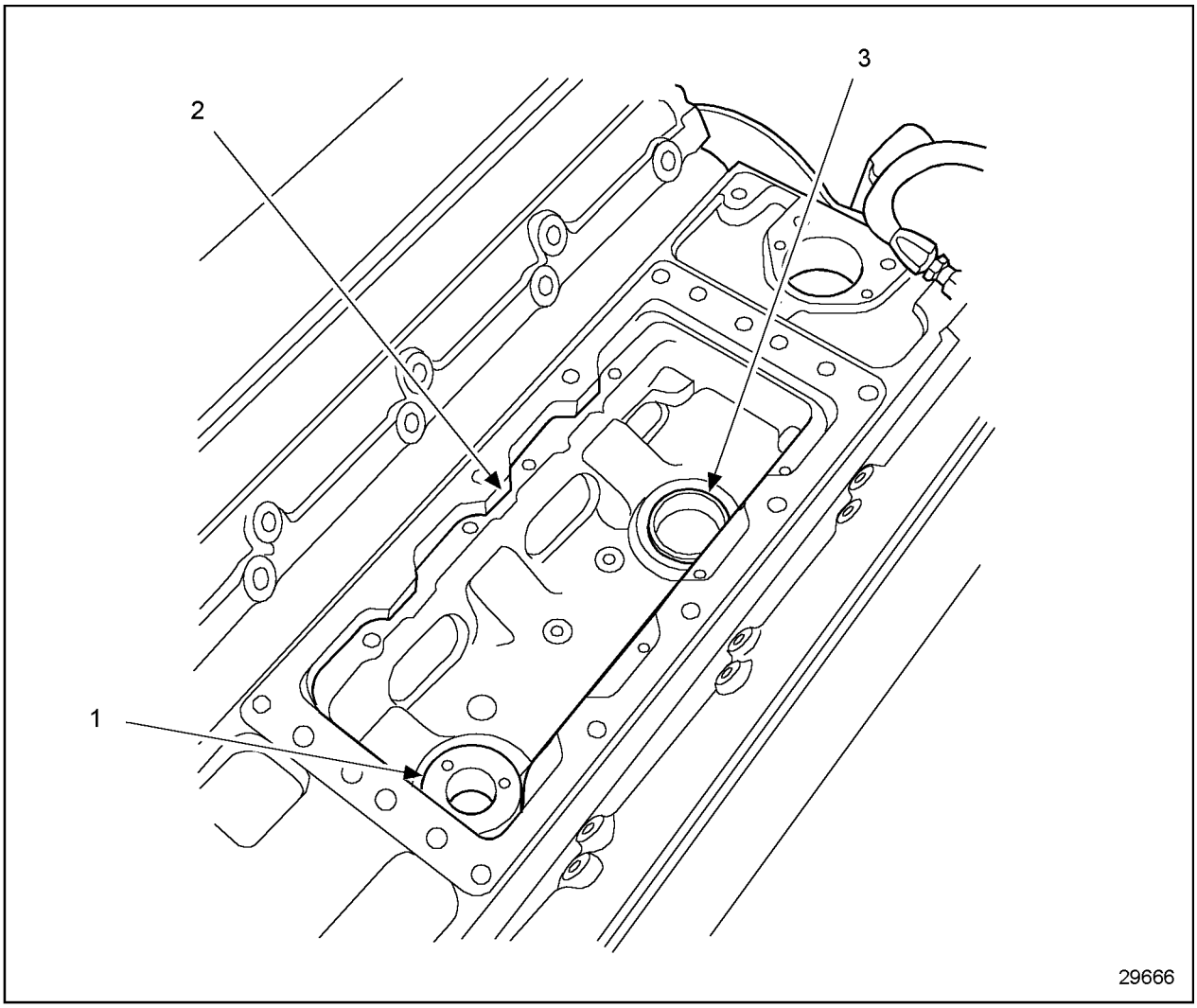
The top deck of the cylinder block has been revised to accept the aftercooler. A water inlet adaptor plug or cup plug replaces the rear 2-1/2 in. core plug in the bottom of the cylinder block opening to supply water to the aftercooler. See Figure 6-66. Tool J 25275 should be used to install or remove this adaptor plug and tool J 33420 is used to install the cup plug. See Figure 6-67.



1. Water Inlet Adaptor
2. Air Box Cavity
3. Plug 1-1/2 in.

Figure 6-66 Location of Water Inlet Adaptor Plug in Cylinder Block

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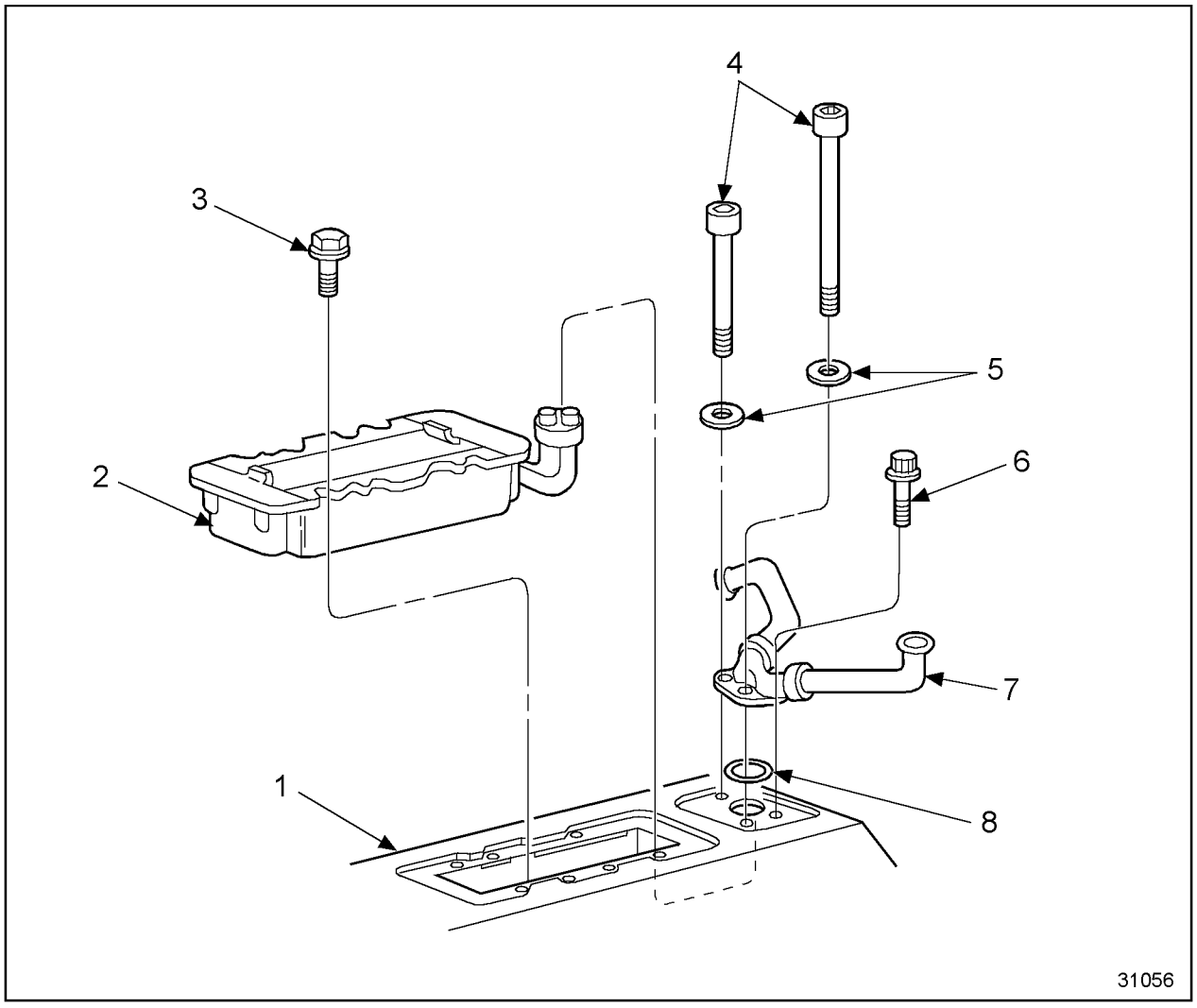


1. Water Inlet Adaptor
2. Air Box Cavity
3. Plug 1-1/2 in.

Figure 6-67 Installing Aftercooler Water Plug

A limited number of 6, 8 and 16V blocks use the stainless steel cup plugs and aftercooler inlet adaptor to seal the water holes in the air box floor of the cylinder blocks. The 2-1/2 in. cup plug and the solid aftercooler inlet adaptor will remain available to service the blocks.

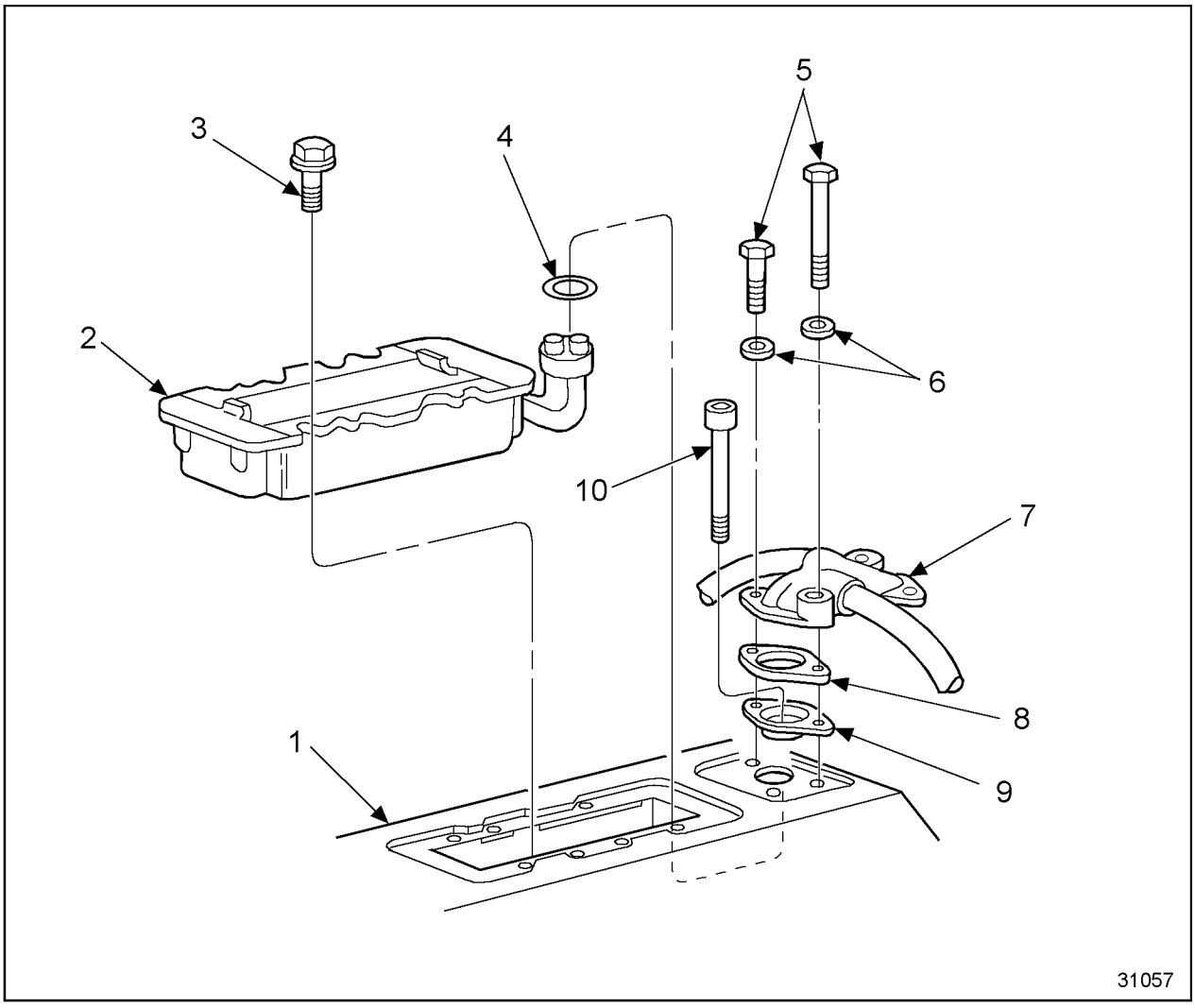
To improve seal and provide a consistent clamp load between seal and adaptor on marine aftercoolers, Detroit Diesel Corporation has released fasteners coated with a thread locking compound. See Figure 6-68. When removing bolts securing aftercooler assembly and adaptor, replace uncoated bolts with coated thread bolts. See Figure 6-69. Whenever coated thread bolts are removed and replaced, coat the threads with Loctite Dri-Loc No. 203 or equivalent.



1. Cylinder Block
2. Aftercooler
3. Bolt
4. Allen Screws
5. Plain Washers
6. 12 Pt. Bolt
7. Hose Connector Adaptor
8. O-ring Seal

Figure 6-68 Typical Marine Aftercooler (6V and 8V-92)

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1. Cylinder Block
2. Aftercooler
3. Bolt
4. O-ring Seal
5. Hose Adaptor Bolts
6. Plain Washers
7. Hose Connector Adaptor
8. Gasket
9. Adaptor
10. Allen Screw

Figure 6-69 Typical Marine Aftercooler (12V and 16V-92)

6.8.1 Repair or Replacement of Turbocharger Aftercooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 6-70.

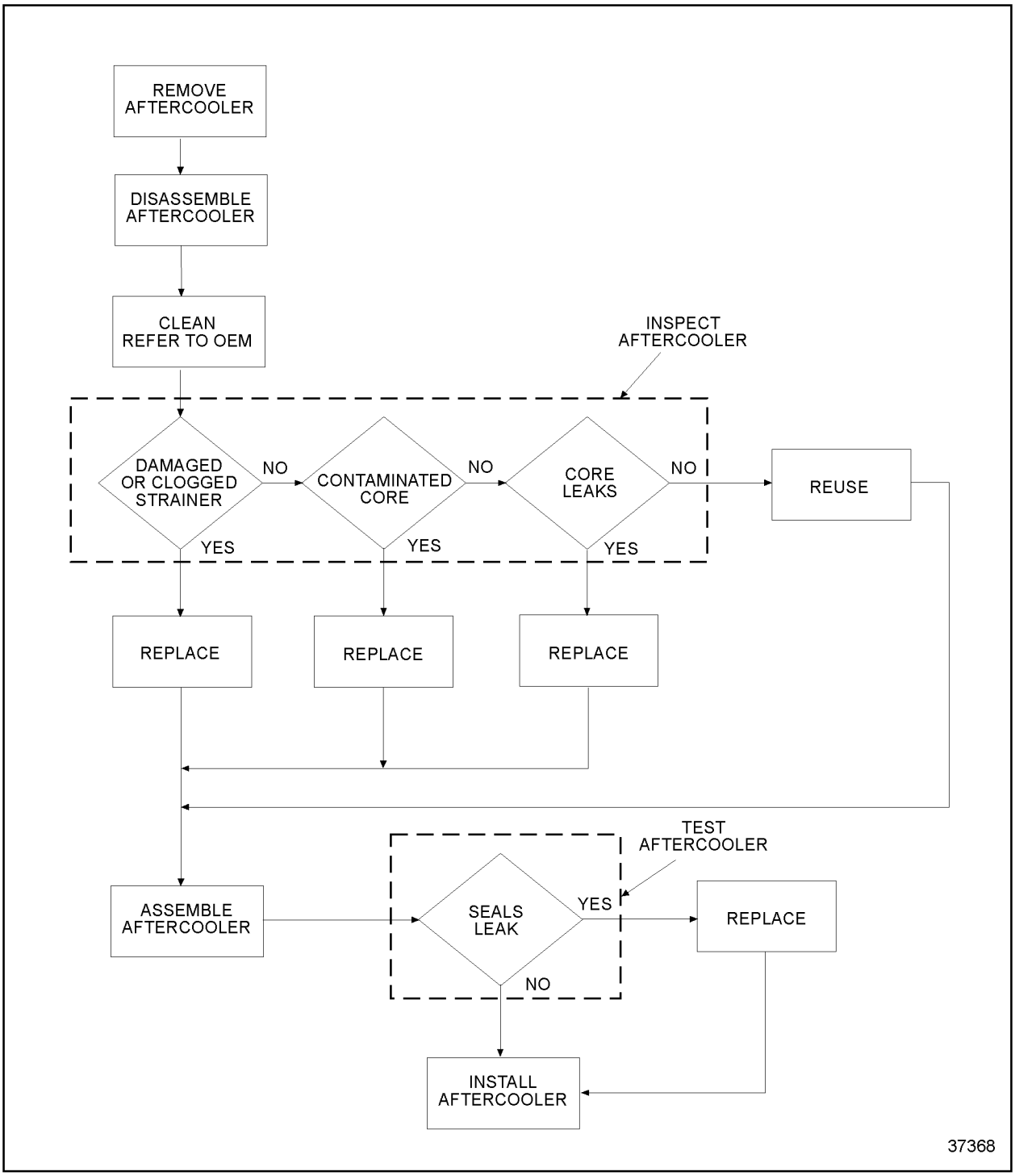


Figure 6-70 Flowchart for Repair or Replacement of Turbocharger Aftercooler

6.8.2 Removal of Turbocharger Aftercooler

Remove the aftercooler as follows:

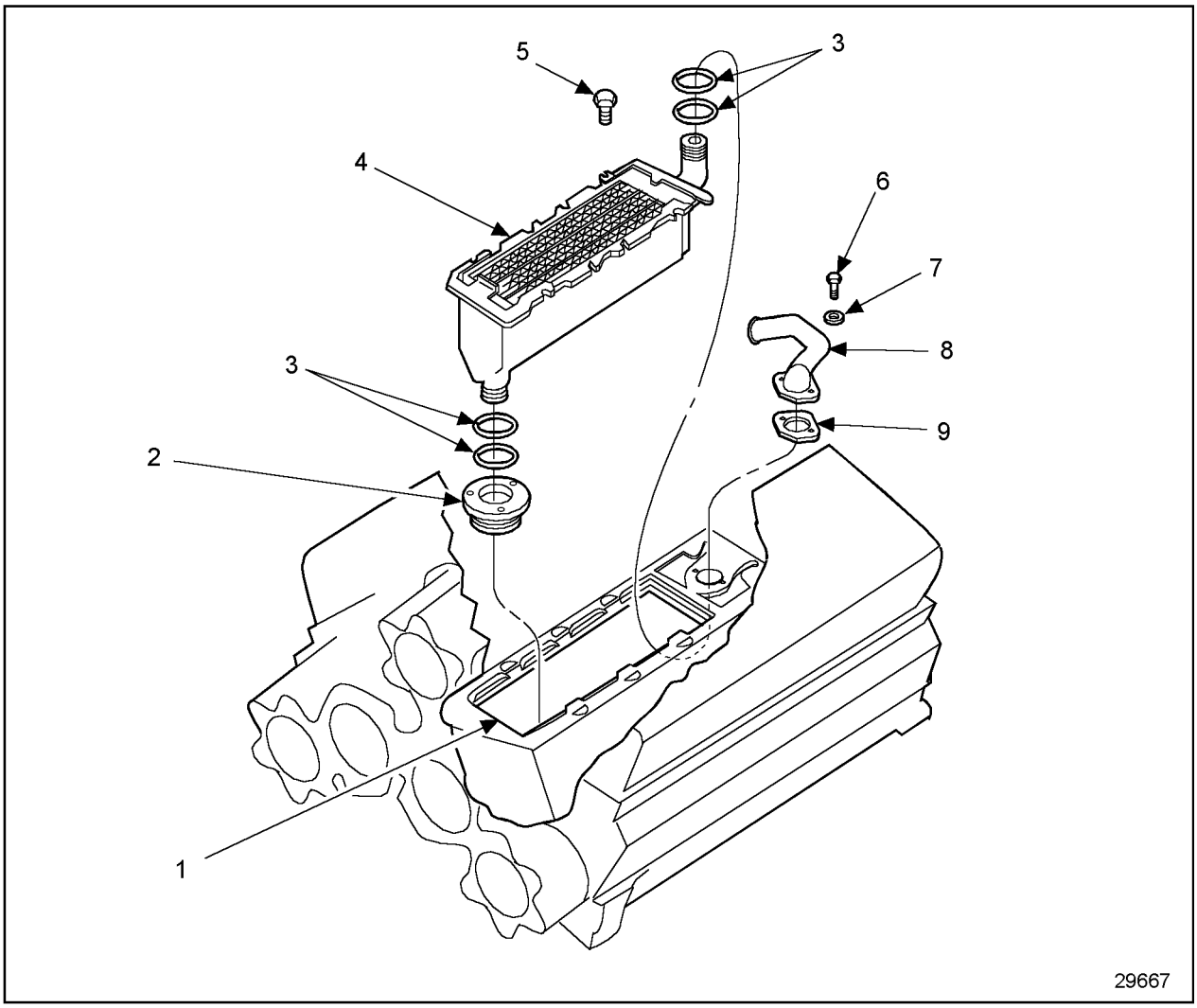
1. Drain the cooling system. Refer to section 13.12.3.

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2. Drain the block.

NOTE:
Some coolant may remain in the cooler if only the radiator is drained.

3. Loosen the two 7/16 in.-14 x 5-1/4 in. attaching bolts, and lift the turbocharger from the air inlet adaptor. See Figure 6-71.



1. Air Box Cavity
2. Water Inlet Adaptor
3. O-ring Seals
4. Aftercooler
5. Aftercooler Mounting Bolt
6. Bolt
7. Lock Washer
8. Water Outlet Tube
9. Gasket

Figure 6-71 Removal and Installation of Aftercooler

4. Remove the air inlet adaptor from the blower.

5. Remove the blower and any accessories attached to the blower from the cylinder block. Refer to section 6.5.2.
6. Loosen the hose clamps, and slide the cylinder block water outlet tube hose against the thermostat housing (6 and 8V engines) or water manifold (12 and 16V engines).
7. Remove the water outlet tube from the front of the cylinder block. Discard the gasket.
8. Remove and discard the 5/16 in.-18 x 9/16 in. attaching bolts with nylon patch.

NOTICE:
Remove the aftercooler with care. The cylinder fins may be damaged when the aftercooler is lifted from the cylinder block.

9. Lift the aftercooler from the cylinder block. Do not remove the four bolts in the top face of the aftercooler.
10. Remove and discard the seal rings from the grooves in the water inlet and outlet tube ends of the aftercooler.

6.8.2.1 Cleaning of Turbocharger Aftercooler

Refer to OEM.

6.8.2.2 Inspection of Turbocharger Aftercooler

Inspect the aftercooler as follows:

1. Check all cooler fins and air and water passages for plugging.
   [a] Remove dirt or any other obstructions with a small brush.
   [b] If fins and water passages are clear, proceed with inspection.
2. Determine whether the aftercooler core is clogged with oil, dirt, or carbon.
   [a] If the aftercooler core is clogged, perform a comprehensive cleaning. Refer to section 6.8.2.1.
   [b] If the aftercooler is not clogged, it may be installed. Refer to section 6.8.3.

6.8.3 Installation of Turbocharger Aftercooler

Install the aftercooler as follows:

1. Install new seal rings in the two grooves on the water inlet and outlet tube ends of the aftercooler.

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⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Coat the seal rings lightly with engine oil or vegetable shortening.

NOTE:
Take care not to scratch or nick the sealing edge of the seal rings.

3. Place the aftercooler, water outlet end first, into the cylinder block opening between the cylinders. The water inlet end of the cooler seats in the water inlet adaptor plug.
4. Install new 5/16 in.-18 x 9/16 in. attaching bolts with nylon locking patch (six bolts - 6 and 12V or eight bolts - 8 and 16V).

NOTE:
Do not tighten the bolts until the water outlet tube-to-thermostat housing (6 or 8V engines) or water manifold (12 and 16V engine) hose and clamps are aligned and tightened.

5. Use a new gasket and attach the water outlet tube with two 5/16 in. bolts and lock washers to the cylinder block. Do not tighten the attaching bolts.
6. Align the water outlet tube to the thermostat housing (6 or 8V engines) or water manifold (12 and 16V engine) with the hose and clamps. Tighten the clamps.

NOTE:
The aftercooler water outlet hose used on 16V turbocharged-aftercooled engines has been replaced by a longer hose (2.26-2.75 in.). This eliminates coolant leak possibilities. Aftercooler water outlet tube and water outlet elbow misalignment contributes to these leaks. The extra hose length ensures that properly installed hoses do not leak during engine operation.

NOTE:
When tightening coated bolts, torque to 11-14 N·m (96-120 lb-in) to ensure proper seal.

7. Tighten the two 5/16 in. water outlet tube bolts. Tighten the aftercooler attaching bolts.
8. Use a new blower to cylinder block gasket, and install the blower and any accessories attached to the blower. Refer to section 6.5.5.
9. Attach the air inlet adaptor to the blower with the 7/16 in.-14 x 1-1/2 in. attaching bolts and lock washers (eight bolts - 6 and 12V, ten bolt - 8 and 16V). Tighten the bolts to 62-68 N·m (46-50 lb·ft) torque.
10. Install the turbocharger. Refer to section 6.7.5.
11. Tighten the two 7/16 in.-14 x 5-1/4 in. bolts to 62-68 N·m (46-50 lb·ft) torque.

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6.A ADDITIONAL INFORMATION

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SHOP NOTES

The following are shop note procedures:

TEST COMPRESSOR HOUSING FOR OIL LEAK

Perform the oil leak test as follows:

1. Remove the compressor housing, and inspect the back plate.
   [a] If the surface is wet with oil, perform the following leak test.
   [b] If the back plate is not wet with oil, reuse the turbocharger.
2. Determine that air inlet restriction is within the maximum limit. Refer to section 11.5.
3. Ensure that the turbocharger oil drain line is unrestricted.
4. Remove the air intake ducting.
5. Inspect the inside of the ducting for oil.
   [a] If oil is found in the intake system, determine the source before proceeding with the compressor seal test.
   [b] If no oil is found in the intake system, proceed with the test.
6. Thoroughly remove oil from the intake.

NOTE:
Air compressor line, or a leak near an oil source such as an engine breather, are all potential external oil sources.

7. Remove the compressor housing from the turbocharger.
8. Thoroughly clean the internal surfaces of the compressor housing, impeller cavity behind the impeller, and the back plate annulus with suitable solvent spray.

⚠ 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.

9. Dry completely with shop air.
10. Spray the back plate annulus with a light coating of Spot-Check developer type SKD-MF, or equivalent.
11. Install the compressor housing on the turbocharger, and reconnect the inlet and outlet connections.
12. Warm the engine to normal operating temperature.
13. Operate the engine at no load at the governor limited high speed for approximately five minutes.
14. Return the engine to low idle.
15. Stop the engine.
16. Remove the intake duct and outlet hose.
17. Remove the compressor housing.

[a] Oil streaks in the Spot-Check developer on the back plate annulus indicate oil leaks. This surface should be completely free of oil streaks after the test.

NOTICE:

Do not operate the engine if leaks are found in the turbocharger ducting or if the air cleaner is not filtering efficiently. Dust leaking into the air ducting can damage the turbocharger and the engine.

[b] If leaks are detected, and oil is not entering through the intake duct, the turbocharger may be removed from the engine and inspected for damaged components. Refer to section 6.6.2.

NOTE:
Inadequate air filtering and excessive restrictions to air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed the specified limits. Refer to section 11.5.

[c] If this test does not show leaks, the oil seal assembly is suitable for normal operation.

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BLOWER DRIVE SEAL RING

The rubber seal ring used between the blower end plate and the blower drive support can be replaced without removing the blower, as follows:

1. Remove the clamp.
2. Cut and remove the old seal ring.
3. After thoroughly cleaning the blower drive groove area, make a square cut on a new seal ring, and install the seal ring around the groove, with the cut at the top.

Attach the two ends of the seal ring with Loctite No. 06, or equivalent, as follows:

1. The cutting blade must be clean and free of contaminants.

NOTE:
If a razor is used, remove the protective oil film by wiping with solvent.

NOTE:
The cut ends must remain clean to achieve a satisfactory bond.

2. Make a square cut in the replacement seal.

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

3. Apply a thin film of Loctite Super Bonder Adhesive to one of the cut ends. Shake off excess adhesive.

NOTE:
Use adhesive sparingly and avoid contact with skin.

4. Position the seal in the blower drive groove, locating the adhesive treated end first.
5. Place the other end of the seal in the groove, and slide it into the adhesive end to make the joint.
6. Lightly apply pressure to the joint, and hold firmly for 30 seconds.
7. To remove excess adhesive around the joint, apply a chlorinated solvent (Acetone, MEK or Methylene Chloride) to a cloth and wipe the joint.

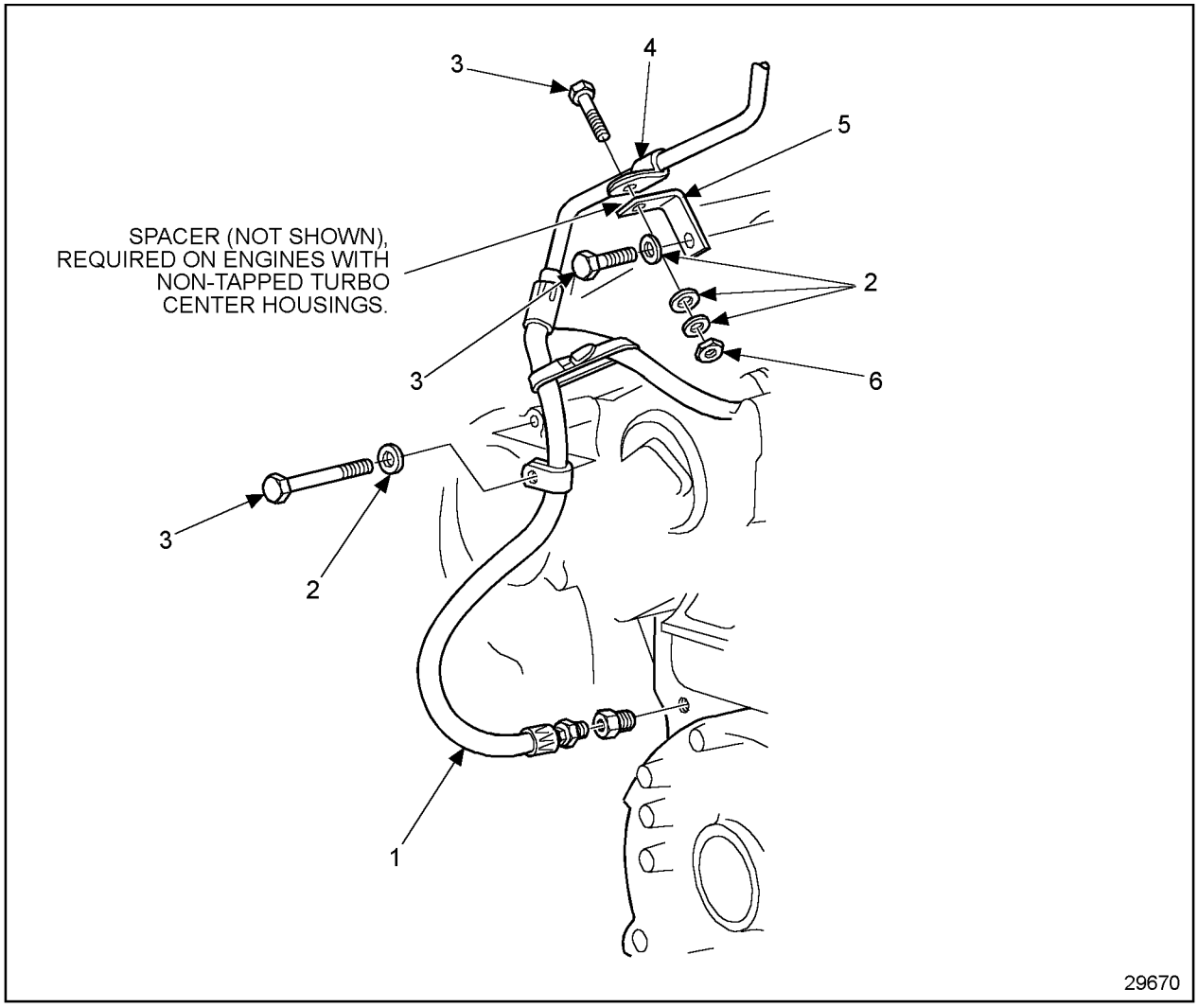
Continue blower seal ring installation as follows:

1. Install the plain clamp between the raised edges of the seal ring and tighten.

NOTE:
If a former seal ring (without groove) is used, it should be replaced with the current molded (two raised edges) type seal ring.

BLOCK MODIFICATION FOR FRONT-MOUNTED TURBOCHARGER LUBE OIL SUPPLY LINE

At the time of an out-of-frame overhaul, 6V and 8V cylinder blocks may be modified to accept a front-mounted turbo lube oil supply line. See Figure 6-72, and proceed as follows:



1. Oil Supply Line
2. Washer
3. Bolt
4. Clip
5. Bracket
6. Nut

Figure 6-72 Turbocharger Lube Oil Supply Line Routing (6V and 8V Engines)

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1. Fabricate the locating template. See Figure 6-73.

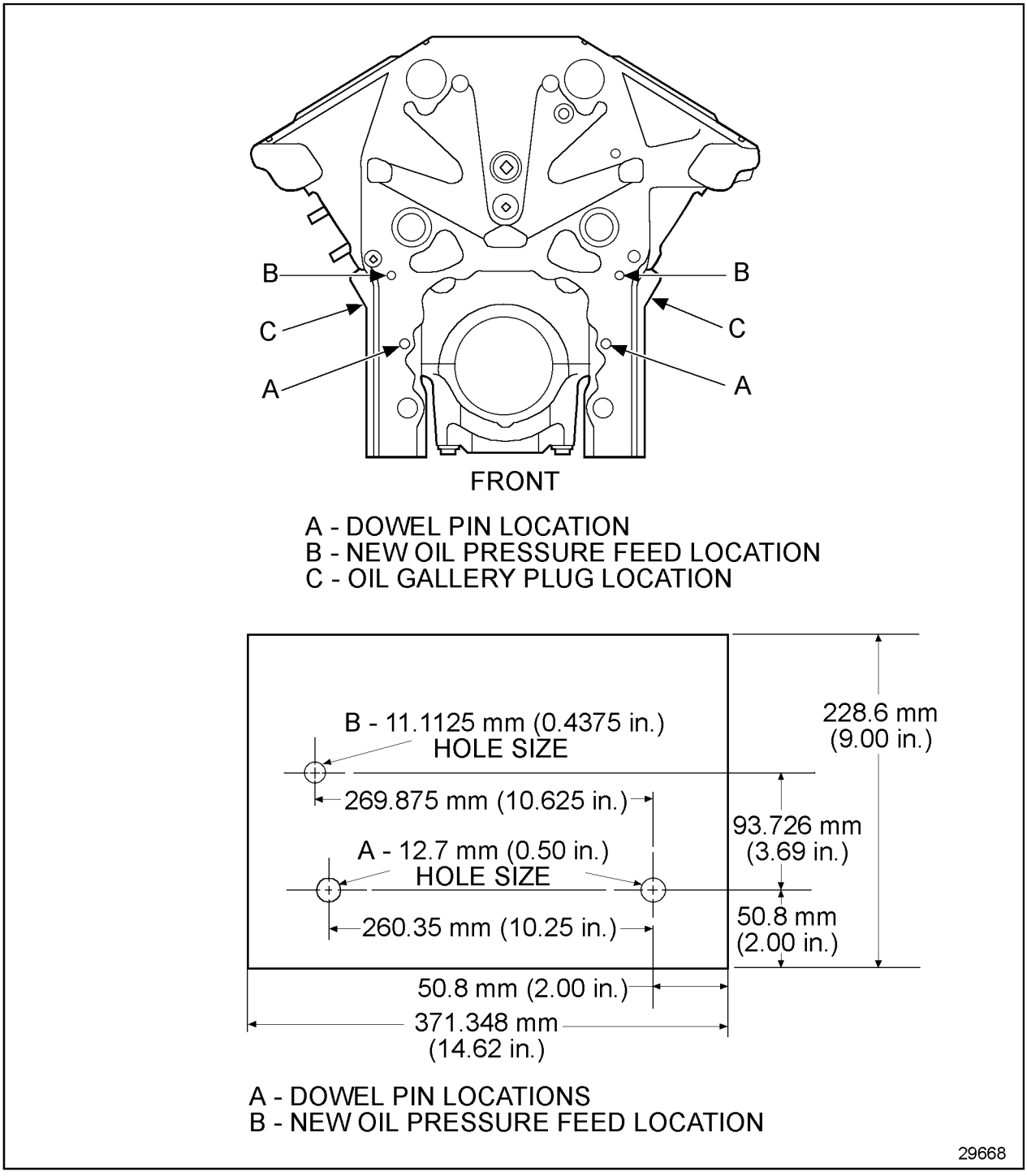


Figure 6-73 Locating Template

2. With the cylinder block completely stripped, mount the locating template on the block dowel pins.

3. Drill a 7/16 in. hole 1-1/2 in. deep into the oil gallery at the "B" location.
4. Thread the hole with a 1/4 in. NPTF tap.

NOTE:
If an additional oil feed location is required on the opposite bank, flip the template, and repeat the modification 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.

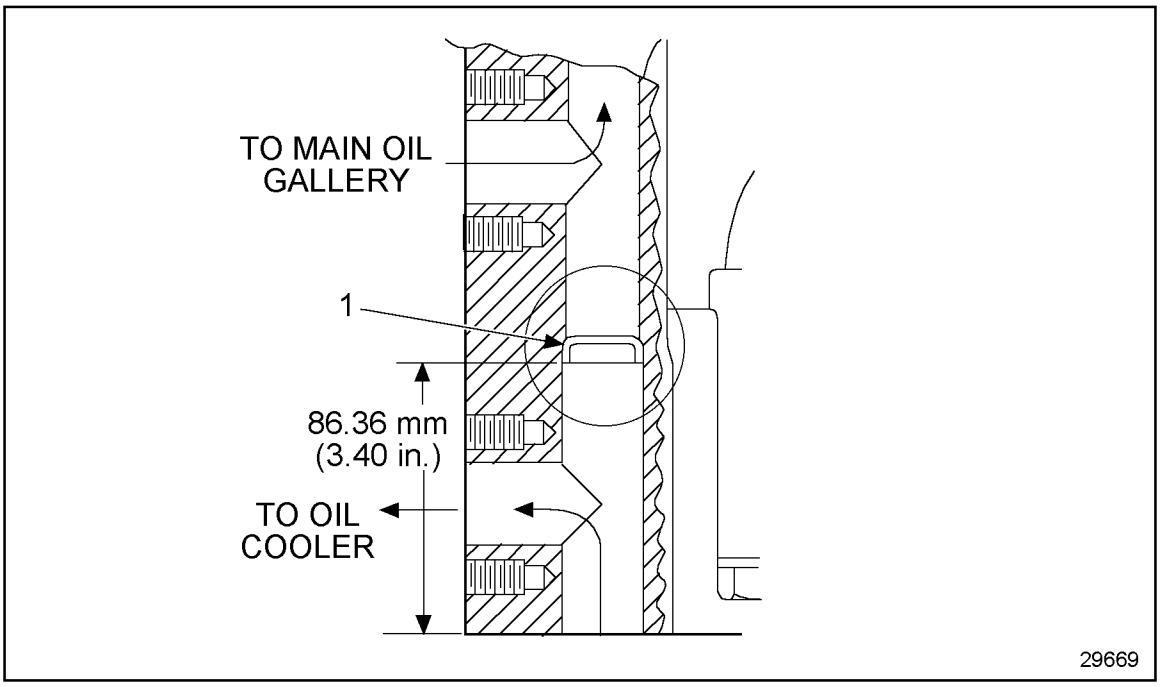
NOTICE:
To avoid damage to the oil gallery do not exceed 138 kPa (20 lb/in.^{2})

5. Remove the oil gallery plug, and blow out all metal chips using an air hose and suitable nozzle.

NOTE:
If the oil cooler side of the block is drilled for the turbo oil supply, pay special attention to the area around the 1 in. cup plug that divides the vertical oil gallery between the oil cooler inlet and outlet passages. See Figure 6-74. Remove the cup plug, and flush the

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oil gallery with the air hose and a cleaning solvent in combination to ensure the removal of all metal chips.



1. Cup Plug

Figure 6-74 Location of Cup Plug in Oil Gallery

NOTICE:
Neglecting to install the cup plug allows lube oil to completely bypass both the filter and the oil cooler. This unfiltered and improperly cooled oil can seriously damage the engine.

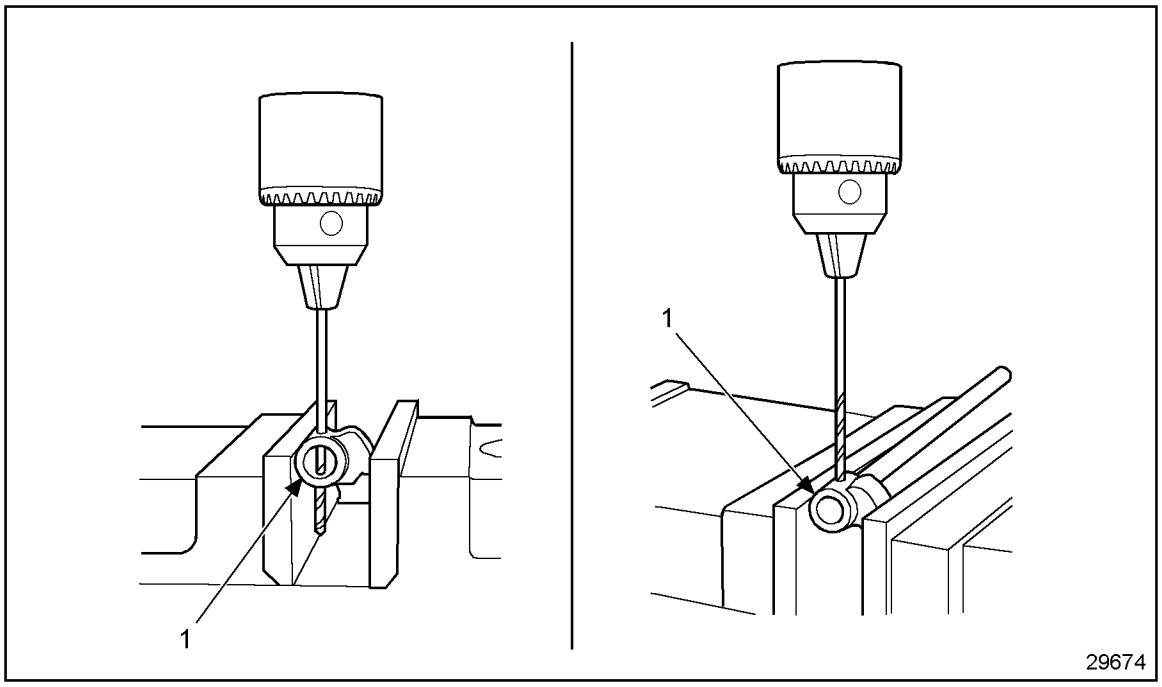
6. After cleaning the block thoroughly, apply Loctite 567 pipe sealant with Teflon (or equivalent) to the oil gallery plug and the cup plug and install. Torque the oil gallery plug to 105-115 N·m (78-85 lb·ft). Install the cup plug to a depth of 86.6 mm (3.40 in.) with tool J 33420.

DRILLING PROCEDURE FOR AIR SHUTDOWN REPLACEMENT SHAFT

Whenever a replacement air shutdown valve shaft is installed, the shaft must be match-drilled to the cam and the flapper valve in order to ensure positive air shutdown operation. Failure to properly index the shaft can result in improper flapper valve operation and engine run-on at shutdown. Use the following procedure to drill the air shutdown valve shaft:

1. Install a 1/8 in. drill bit in the chuck of a drill press.

2. Locate and align the bit through the existing hole in the shutdown cam. See Figure 6-75.



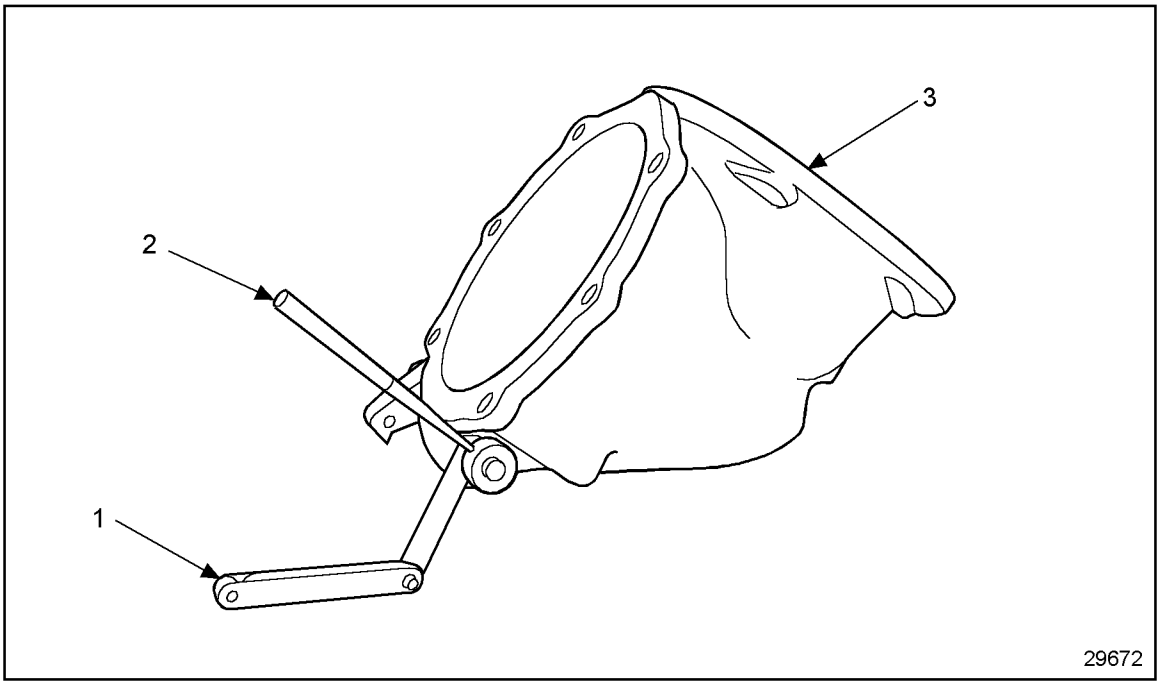
1. Cam

Figure 6-75 Aligning Drill Bit and Drilling Shaft

3. Lock the cam in the holding fixture on the drill press, and withdraw the bit.
4. Insert the replacement shaft into the cam until the end of the shaft is recessed 1/8 in. from the end of the cam.
5. Start the drill, and bore a hole through the shaft.
6. Withdraw the drill bit, install the pin handle through the hole, and remove the shaft from the drill press.
7. Insert the shaft into the shutdown housing bore, and install the spacer on the end of the shaft.

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8. Place a 0.015 in. feeler gage between the housing and spacer, and mark the shaft with a center punch inserted into the existing hole in the spacer. See Figure 6-76.

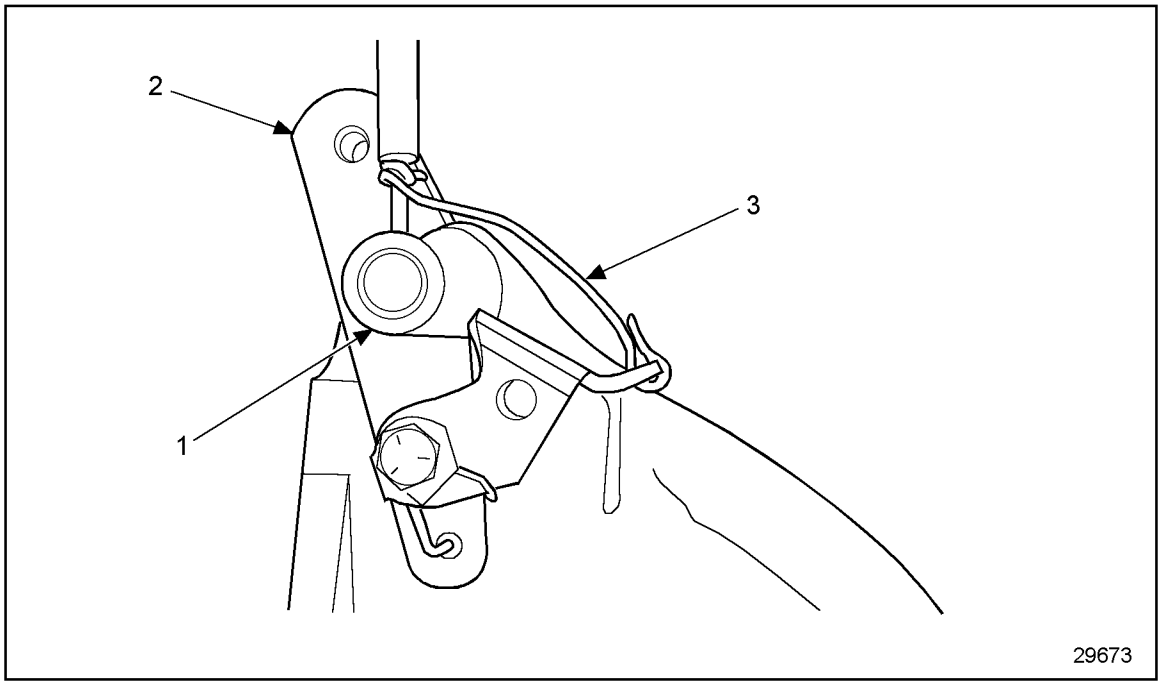


1. Feeler Gage
2. Punch
3. Air Shutdown Housing

Figure 6-76 Center Punch Shaft though Spacer Hole

9. Remove the shaft from the housing.
10. Locate and align the 1/8 in. drill bit through the hole in the spacer, and lock the spacer in the holding fixture on the drill press. Withdraw the drill bit.
11. Insert the shaft through the spacer, locate the center punched mark, and drill a hole through the shaft.
12. Remove the shaft and spacer from the drill press.
13. Assemble the shaft, seal ring spring, flapper valve, and spacer in the housing. Refer to section 6.4.4.
14. If using a new valve, center punch four holes in approximately the same position as on the old valve. If reusing the old valve, center punch four holes just inside the existing holes.

15. Align the notch on the cam with the latch, and hold in this position with a piece of stiff wire. See Figure 6-77.



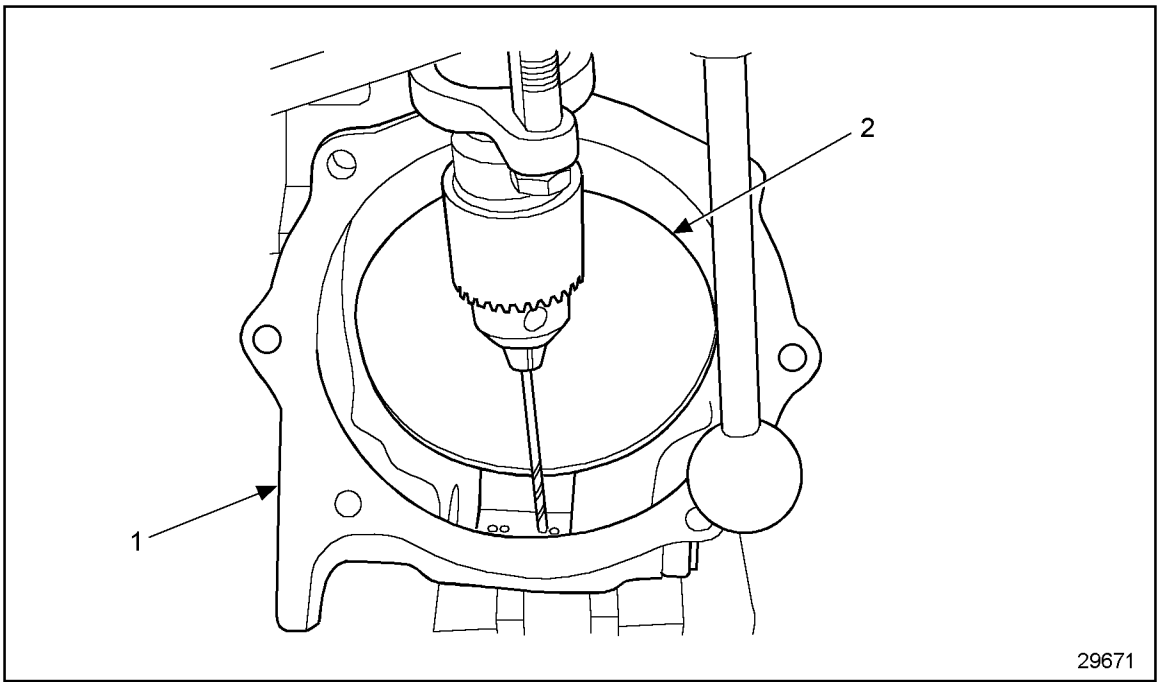
1. Cam
2. Latch
3. Wire

Figure 6-77 Cam and Latch Wired to Prevent Movement

16. Place the housing on the drill press.
17. With the valve held in the wide open run position, align the 1/8 in. drill bit with the marks center punched on the valve.

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18. Drill through the valve and shaft. See Figure 6-78.



1. Air Shutdown Housing
2. Cover Plate

Figure 6-78 Drilling Valve-to-Shaft Holes

19. Install the retaining pins to hold the valve to the shaft.
20. Clean the air shutdown assembly thoroughly, and check for proper operation before installing it on the engine.

SPECIFICATIONS

Listed in Table 6-2 are the specifications.

Engine Parts (Standard Size, New)	Minimum	Maximum	Limits
Blower			
Backlash (Timing Gears)	0.0127 mm (0.0005 in.)	0.0635 mm (0.0025 in.)	0.1016 mm (0.0040 in.)
Oil Seal (Below End Plate Surface)	0.0508 mm (0.0020 in.)	0.2032 mm (0.0080 in.)	-
Oil Strainer (Below End Plate Surface)	-	0.381 mm (0.0150 in.)	-
Dowel Pin (Projection Beyond Inside Face of Front End Plate)	8.128 mm (0.3200 in.)	-	-
Dowel Pin (Projection Beyond Inside Face of Rear End Plate)	8.128 mm (0.3200 in.)	-	-

Engine Parts (Standard Size, New)	Minimum	Maximum	Limits
Clearances:			
Rotor-to-End Plate (Gear End)	0.1778 mm (0.0070 in.)	-	-
Rotor-to-End Plate (Front End - 6V-92)	0.3048 mm (0.0120 in.)	-	-
Rotor-to-End Plate (Front End - 8V-92 and 16V-92)	0.3556 mm (0.0140 in.)	-	-
Rotor-to-Housing (Inlet Side)	0.381 mm (0.0150 in.)	-	-
Rotor-to-Housing (Outlet Side)	0.1016 mm (0.0040 in.)	-	-
Trailing Edge of RH Helix Rotor to Leading Edge of LH Helix Rotor	0.1016 mm (0.0040 in.)	0.2032 mm (0.0080 in.)	0.2032 mm (0.0080 in.)
Leading Edge of RH Helix Rotor to Leading Edge ofLH Helix Rotor	0.254 mm (0.0100 in.)	-	-
T18A40 and T18A90 Turbochargers (Airesearch)			
End Play - Rotating Shaft	0.1016 mm (0.0040 in.)	0.2286 mm (0.0090 in.)	-
Radial Movement - Rotating Shaft	0.0762 mm (0.0030 in.)	0.1778 mm (0.0070 in.)	-
Turbine Wheel Shaft Journal Bearing:			
Inside Diameter	-	24.7728 mm (0.6272 in.)	-
Outside Diameter	24.8412 mm (0.9780 in.)	-	-
Journal Diameter - Turbine Wheel Shaft	15.8674mm (0.6247 in.)	-	-
Bearing Bore - (Center Housing) Inside Diameter	-	24.9809 mm (0.9835 in.)	-
Back Plate Seal Bore Inside Diameter	-	17.4879 mm (0.6885 in.)	-
Thrust Collar:			
Thickness	7.5946 mm (0.2990 in.)	-	-
Bore - Inside Diameter (18A40)	-	9.5453 mm (0.3758 in.)	-
Bore - Inside Diameter (18A90)	-	11.1506 mm (0.4390 in.)	-
Thrust Spacer:			
Outside Diameter (18A40)	26.0715 mm (0.6715 in.)	-	-
Outside Diameter (18A90)	21.844 mm (0.8600 in.)	-	-
Ring Groove Width	-	1.7653 mm (0.0695 in.)	-

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Engine Parts (Standard Size, New)	Minimum	Maximum	Limits
Thrust Washer, Inboard Thickness	2.286 mm (0.0900 in.)	-	-
Compressor Wheel Bore:			
Inside Diameter (18A40)	-	9.4971 mm (0.3739 in.)	-
Inside Diameter (18A90)	-	11.1201 mm (0.4378 in.)	-
TV81 Turbocharger (Airesearch)			
End Play - Rotating Shaft	0.0762 mm (0.0030 in.)	0.254 mm (0.0100 in.)	-
Radial Movement - Rotating Shaft	0.0762 mm (0.0030 in.)	0.1778 mm (0.0070 in.)	-
Turbine Wheel Shaft Journal Bearing:			
Inside Diameter	15.9207 mm (0.6268 in.)	15.9309 mm (0.6272 in.)	-
Outside Diameter	24.8463 mm (0.9782 in.)	24.8589 mm (0.9787 in.)	-
Journal Diameter - Turbine Wheel Shaft	15.875 mm (0.6250 in.)	15.885 mm (0.6254 in.)	-
Bearing Bore - (Center Housing) Inside Diameter	24.9606 mm (0.9827 in.)	24.9733 mm (0.9832 in.)	24.9987 mm (0.9842 in.)
Back Plate Seal Bore Inside Diameter	17.4625 mm (0.6875 in.)	17.4879 mm (0.6885 in.)	17.5133 mm (0.6895 in.)
Thrust Collar:			
Thickness	7.5946 mm (0.2990 in.)	7.62 mm (0.3000 in.)	7.5438 mm (0.2970 in.)
Bore - Inside Diameter	9.5352 mm (0.3754 in.)	9.5453 mm (0.3758 in.)	9.5961 mm (0.3778 in.)
Thrust Spacer:			
Outside Diameter	26.0715 mm (0.06715 in.)	17.0815 mm (0.6725 in.)	17.0307 mm (0.6705 in.)
Ring Groove Width	1.7399 mm (0.0685 in.)	1.7653 mm (0.0695 in.)	1.8161 mm (0.0715 in.)
Thrust Washer, Inboard Thickness	2.86 mm (0.0900 in.)	2.3368 mm (0.0920 in.)	-
Compressor Wheel Bore Inside Diameter	9.4894 mm (0.3736 in.)	9.4971 mm (0.3739 in.)	9.5225 mm (0.3749 in.)

These limits also apply to oversize and undersize parts.

Table 6-2 Clearances and Wear Limits

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

Listed in Table 6-3 are the exceptions to standard bolt and nut torque specifications.

Application	Thread Size	Torque
Air Inlet Housing Adaptor-to-Blower Housing Bolt	3/8-16	22-27 N·m (16-20 lb·ft)
Air Inlet Housing-to-Adaptor Bolt	3/8-16	22-27 N·m (16-20 lb·ft)
Blower Side Angle Bolt	3/8-16	41-47 N·m (30-35 lb·ft)
Blower End Plate-to-Cylinder Block Bolt	7/16-14	54-61 N·m (40-45 lb·ft)
Blower Rotor Gear Retainer Bolt (Large Bearing Blower)	1/2-20	136-150 N·m (100-110 lb·ft)
Fuel Pump Drive Disc Bolt	1/2-20	75-88 N·m (55-65 lb·ft)

Table 6-3 Exceptions to Standard Bolt and Nut Torque Specifications

TURBOCHARGER

Listed in Table 6-4 are the turbocharger specifications.

Application	Thread Size	Torque
"V" Band Coupling Locknut (Compressor)	1/4-28	12-15 N·m (110-130 lb·ft)
"V" Band Coupling Locknut (Turbocharger TV71-TV81)	1/4-28	17-19 N·m (152-168 lb·ft)
Back Plate-to-Center Housing Bolts	5/16-18	10-12 N·m (90-110 lb·ft)
Turbine Housing-to-Center Housing Bolts	5/16-18	11-15 N·m (100-130 lb·ft)
Turbine Housing-to-Center Housing Bolts (TH08A)	5/16-18	18-21 N·m (160-190 lb·ft)
Compressor Wheel Locknut (18A40)	3/8-24	14-17 N·m (125-150 lb·ft)
Compressor Wheel Locknut (18A90)	7/16-20	14-17 N·m (125-150 lb·ft)

Table 6-4 Turbocharger Specifications

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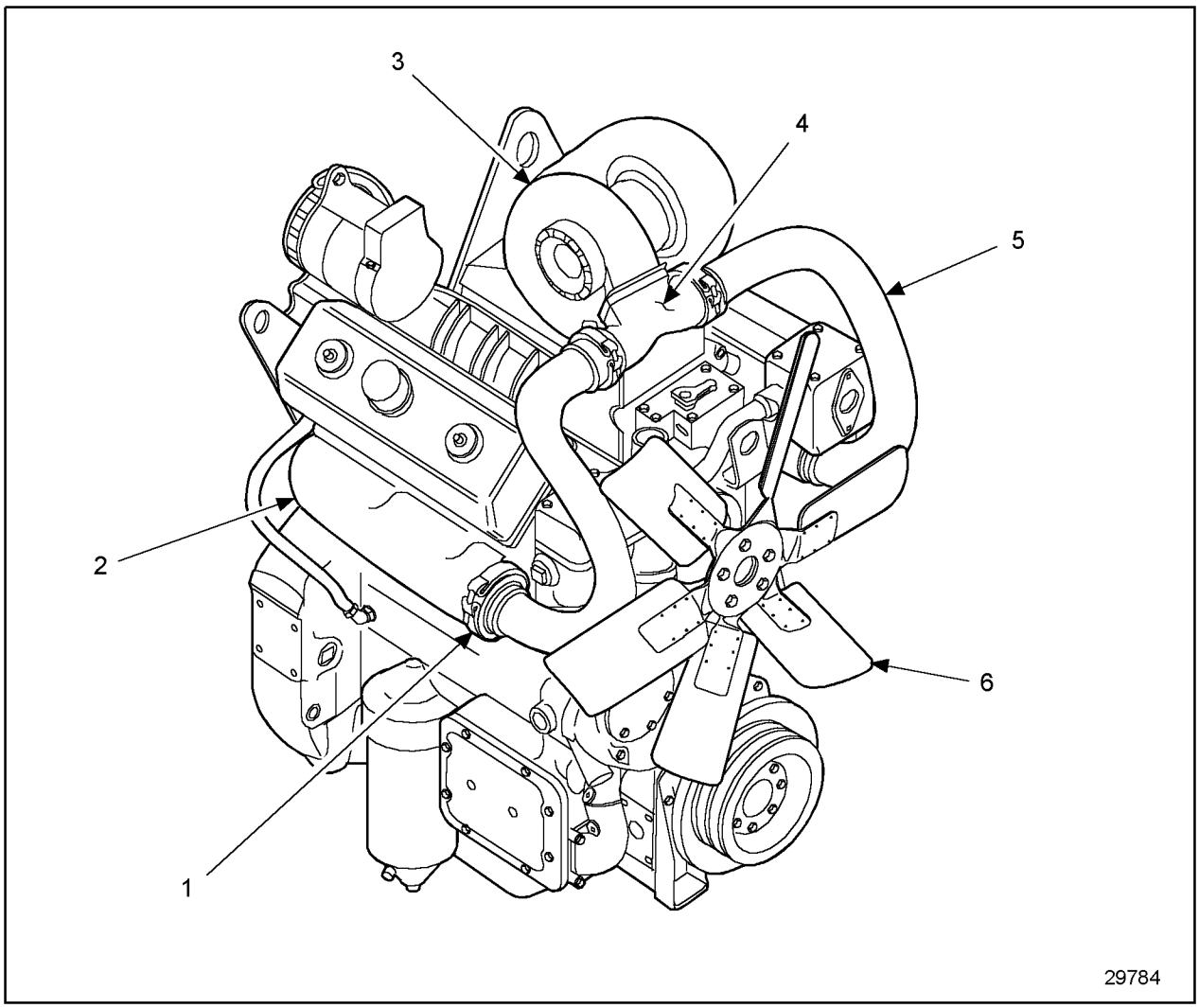
7 EXHAUST SYSTEM

Section		Page
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7.3	EXHAUST MANIFOLD (WATER-COOLED)	7-11

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7.1 EXHAUST SYSTEM

Fan and radiator cooled engines are equipped with an air-cooled exhaust manifold. See Figure 7-1. A water-cooled exhaust manifold is provided for engines incorporating a heat exchanger or keel cooling system.



1. Outlet Flanges
2. Exhaust Manifold
3. Turbocharger
4. Tee Adaptor
5. Exhaust Tube
6. Fan

Figure 7-1 Typical 6V or 8V Turbocharged Engine

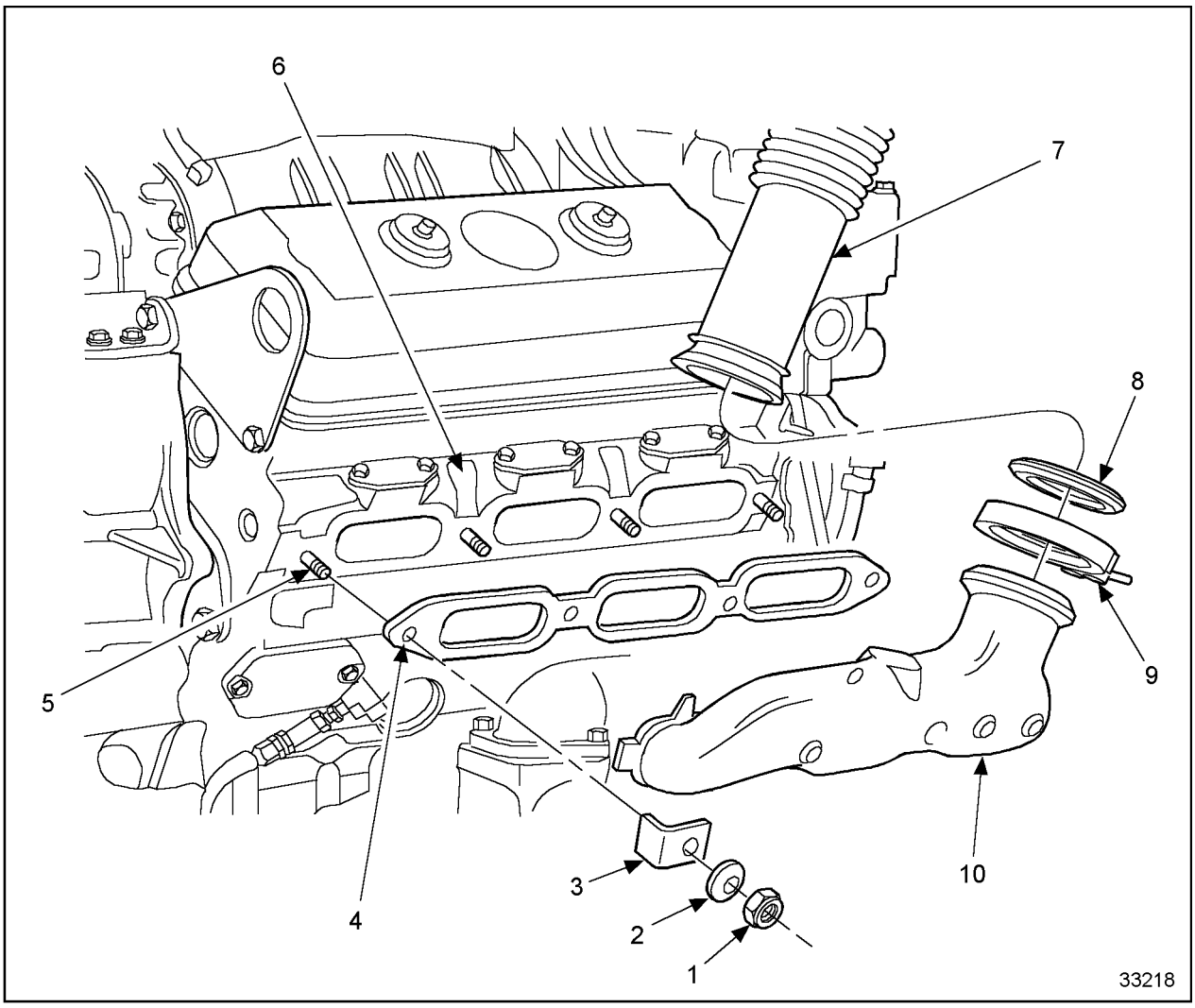
The outlet flange may be located at the end or at the mid-section of the exhaust manifold, depending upon the installation requirements. A flexible exhaust connection or a muffler may be attached to the outlet flange.

The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

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7.2 EXHAUST MANIFOLD

The cast iron air-cooled manifold has changes in cross-section and blends from each end toward the center flange to balance exhaust flow. The exhaust tubes attach to the flange leading to a turbocharger or muffler. See Figure 7-2.



1. Nut
2. Bevel Washer
3. Mounting Bracket
4. Gasket
5. Stud
6. Cylinder Head
7. Exhaust Tubes
8. Flange Seal
9. Clamp
10. Exhaust Manifold

Figure 7-2 Typical Cast Exhaust Manifold Mounting

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The current hold-down crab is made of hardened steel and is larger than the former hold-down crab. This minimizes wear and gouging of the manifold, crab, and cylinder head mating surfaces. The former and the current hold-down crab are interchangeable on an engine. Only the current crab is serviced.

The current special washer is used at the center portions of the exhaust manifolds. The current washer accurately controls the seating area for the 7/16 in. nut or bolt. Only the current special washer is serviced.

7.2.1 Repair or Replacement of Exhaust Manifold

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 7-3.

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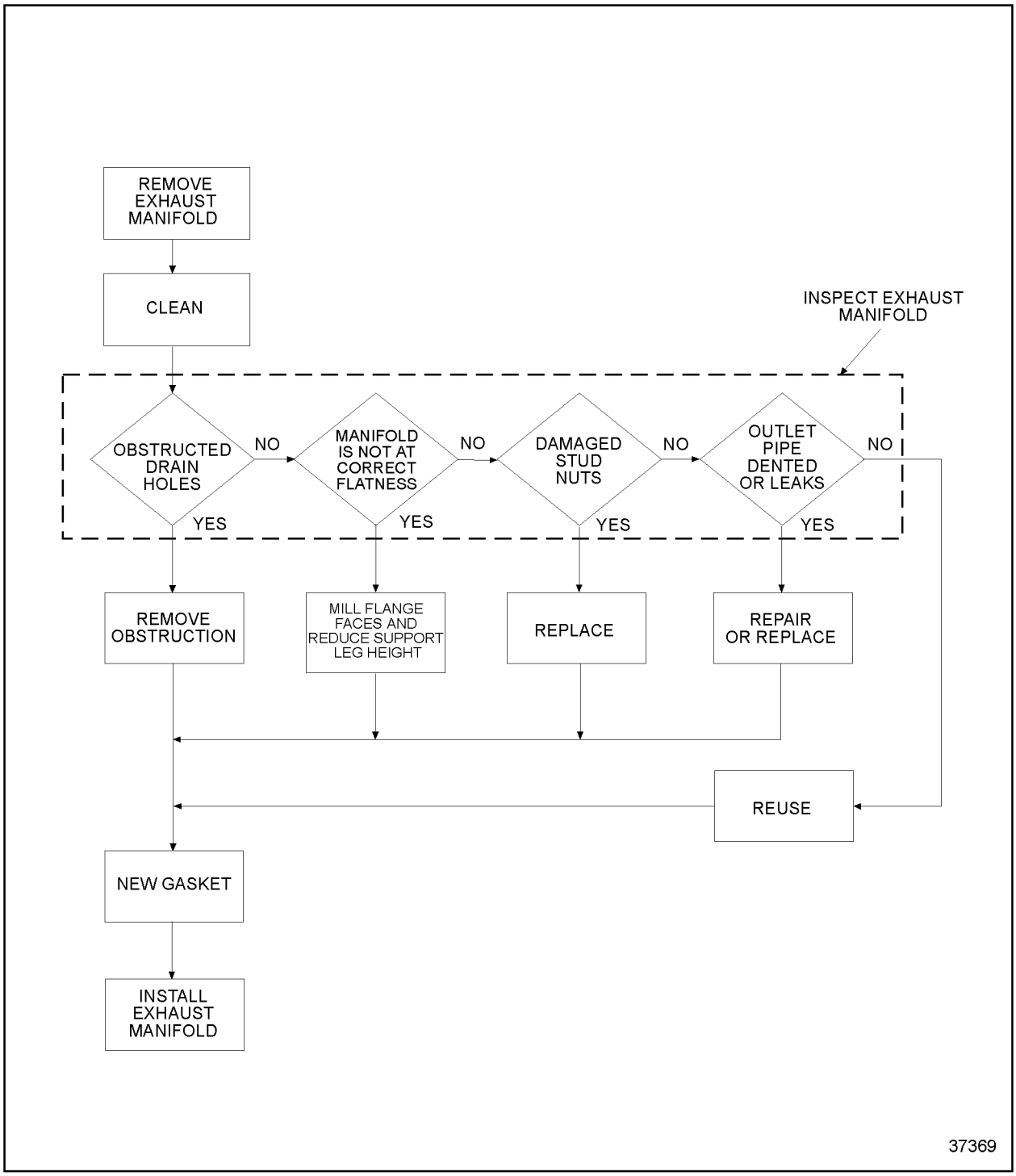


Figure 7-3 Flowchart for Repair or Replacement of Exhaust Manifold

7.2.2 Removal of Exhaust Manifold

Usually, the exhaust manifold is removed with the cylinder head. However, when the exhaust manifold gaskets only need replacing, the manifold may be removed without removing the cylinder head as follows:

1. Loosen the flange clamp and disconnect the exhaust tube from the exhaust manifold flange.
2. Loosen and remove the nuts and bevel washers which secure the exhaust manifold to the cylinder head.

NOTE:
One nut and washer should be loosened and left on one center stud until all other nuts and washers have been removed.

3. Support the manifold, and remove the nut and washer from the center stud.
4. Lift the manifold away from cylinder head.
5. Remove the manifold gaskets.

7.2.2.1 Cleaning of Exhaust Manifold

Prior to inspection, clean the exhaust manifold as follows:

1. Remove the loose scale and carbon from the exhaust manifold internal walls.
2. Remove old gasket material from the cylinder head and exhaust manifold bolting flanges.

7.2.2.2 Inspection of Exhaust Manifold

Inspect the exhaust manifold as follows:

1. Visually inspect the exhaust manifold studs for damage.
   [a] If damaged, replace the studs.

NOTE:
New studs should be torqued to 34-54 N·m (25-40 lb·ft).

   [b] If not damaged, continue inspection.
2. Inspect the exhaust outlet piping for dents, holes, and loose clamps or deteriorated seals.
   [a] Repair or replace, if necessary.
   [b] If not in need or repair or replacement, reuse the parts.

7.2.3 Installation of Exhaust Manifold

Install the exhaust manifold as follows:

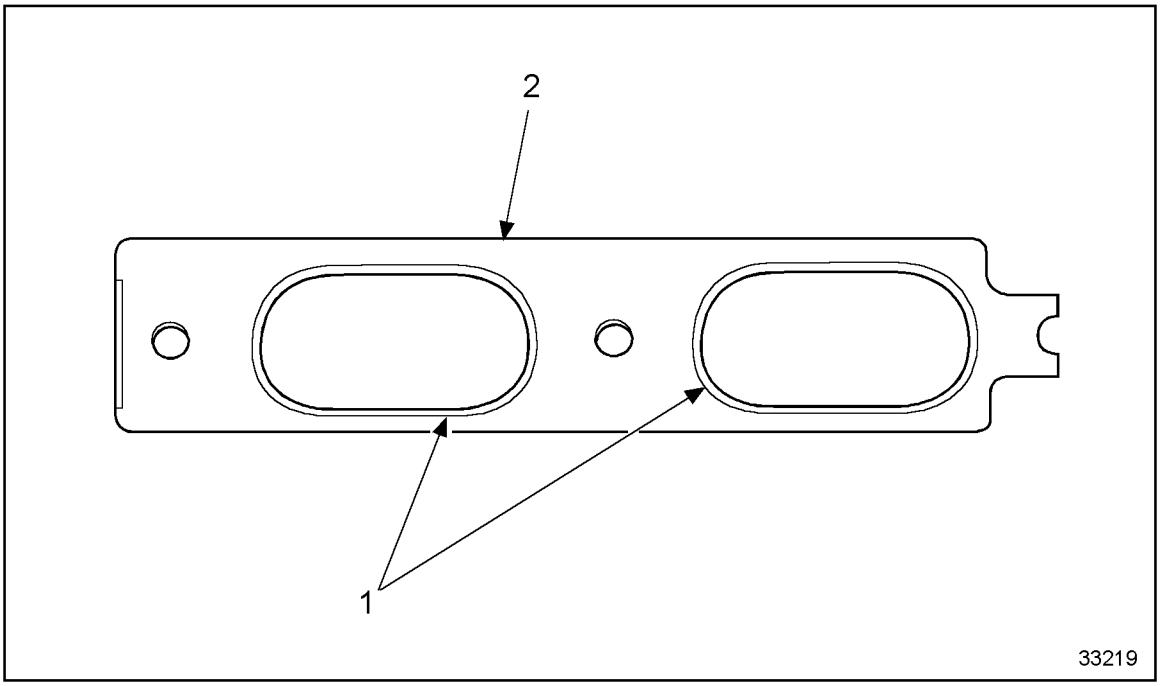
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NOTICE:
Ensure the internal manifold walls are clean to eliminate possible turbocharger damage.

1. Place new gaskets over the studs and against the cylinder head.

NOTE:
Do not reuse metal-clad gaskets.

NOTE:
When installing the metal clad exhaust manifold gasket(s) be sure the crimped side of the gasket faces the cylinder head. See Figure 7-4.



1. Crimp
2. Gasket

Figure 7-4 Metal Clad Exhaust Manifold Gasket

2. Position the exhaust manifold over the studs and against the gasket.

NOTE:
Ensure the locating pads on the exhaust manifold rest on the cylinder block locating pads.

3. Install the bevel washers and nuts on the studs, and draw the exhaust manifold up against the gasket.
4. Position the bevel washers so that the outer diameter rests on the manifold, and the center crown is next to the nut.

5. Tighten the exhaust manifold stud nuts from the center of the exhaust manifold outward, alternating toward either end. Torque the nuts to 41-47 N·m (30-35 lb·ft).
6. Connect the exhaust tube to the exhaust manifold flange, ensuring the seal is properly located.
7. Tighten the flange clamp connecting the exhaust manifold to the outlet tube.

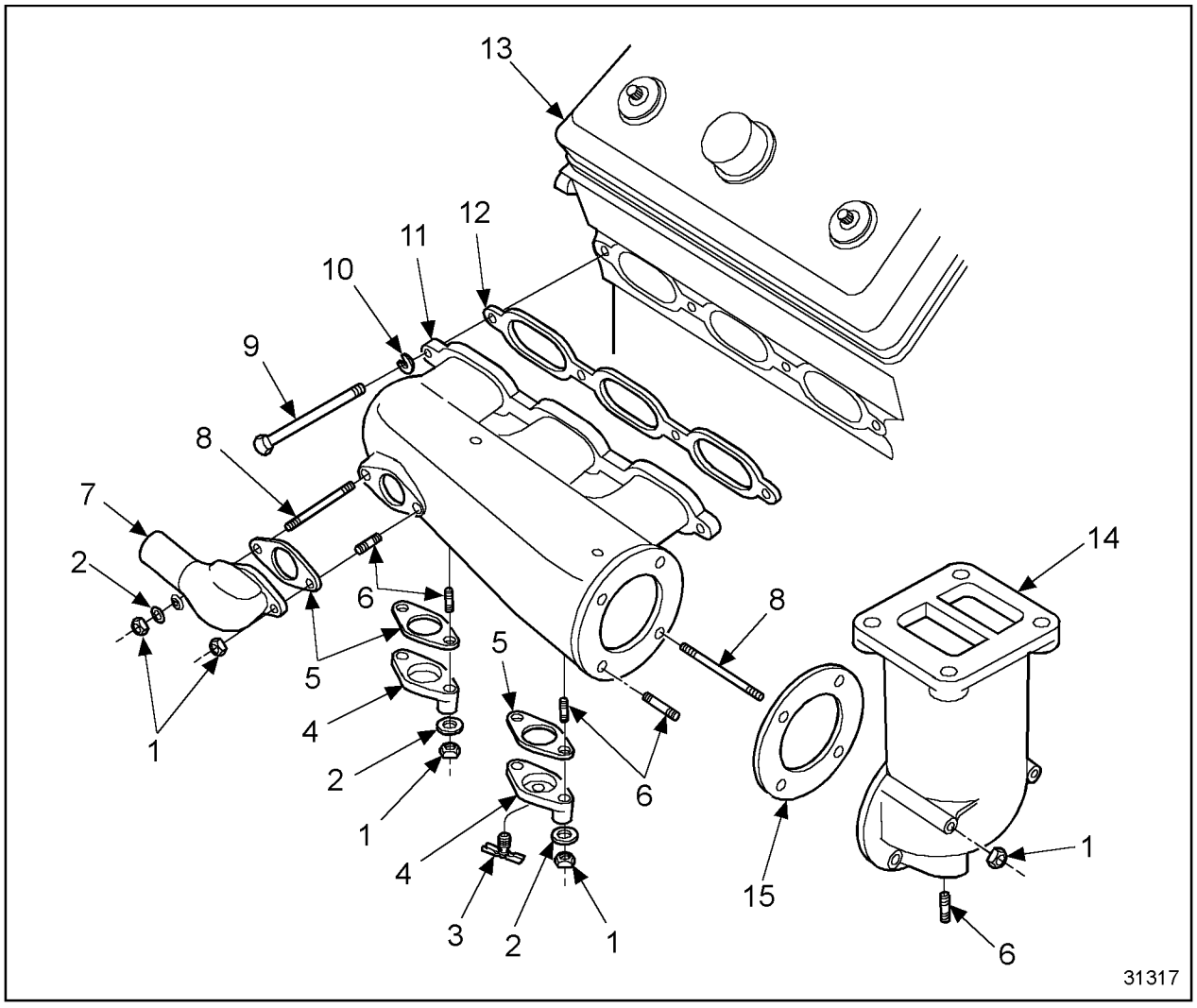
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7.3 EXHAUST MANIFOLD (WATER-COOLED)

The one-piece water-cooled manifold is cast with an integral water jacket surrounding the exhaust chamber. The exhaust chamber diameter increases uniformly from one end to the other where it terminates into a flange where an elbow and flexible exhaust connection is attached.

A portion of the engine coolant is bypassed from the rear of the cylinder block into the rear end of the jacket surrounding the exhaust manifold. It is discharged from the forward end through a tube and into the thermostat housing. A drain cock is installed in the bottom of the manifold for draining the water jacket. A plug is provided in the bottom of the exhaust manifold elbow for draining moisture condensed from the exhaust gases. See Figure 7-5.

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1. Nut (4)
2. Plain Washer (3)
3. Drain Cock
4. Cover Plate (2)
5. Gasket (3)
6. Short Stud (5)
7. Water Tube Elbow
8. Long Stud (2)
9. Manifold Bolt
10. Lock Washer
11. Water Cooled Exhaust Manifold
12. Manifold Gasket
13. Rocker Cover
14. Exhaust Elbow
15. Flange Gasket

View shown in illustration, front of engine.

Figure 7-5 Typical Water Cooled Exhaust Manifold Assembly

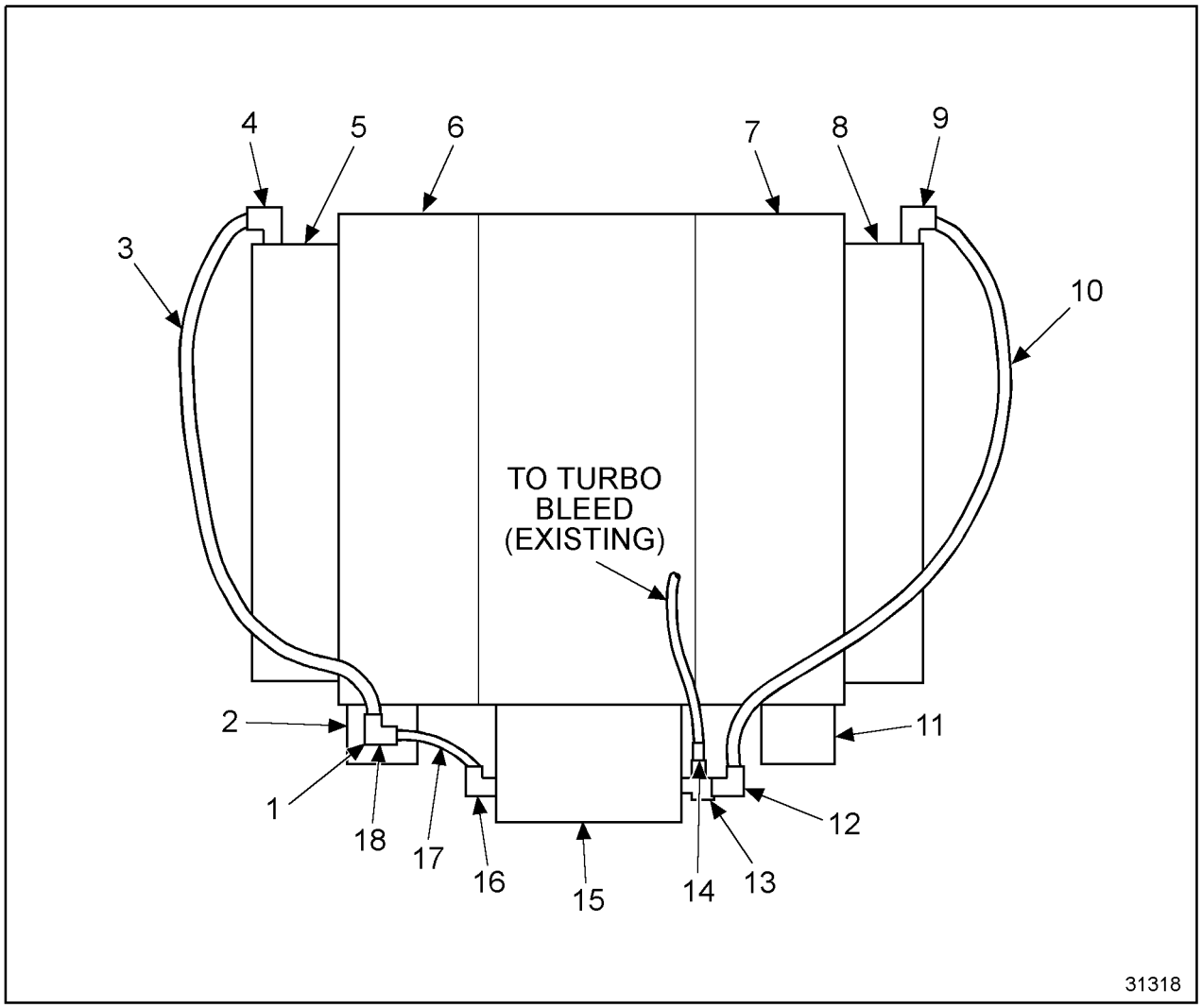
Former model 8122-7400 marine engines were built with four-bolt design exhaust manifolds, covers, connectors, gaskets, and turbo exhaust inlet elbows. This design was replaced with the current six-bolt design components. The six bolt design is standard on all 12V-TA marine engines.

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To improve water-cooled exhaust manifold sealing, a new manifold gasket was released. This change went into effect in September, 1993. The current gasket is gray graphite colored. *Only current gaskets are serviced.* The current gaskets do not mix with the former flanges. If necessary, replace the center connector or exhaust riser with the current flange, connector, and riser. Because the current gasket does not have the beaded area around the water transfer slots, do not use this gasket on double-block engines which have the former small diameter 165.10 mm (6.5 in.) manifold flange, connector, and risers. The Manifold flange and gasket outside diameters increased from 165.1–174.752 mm (6.5–6.88 in.). The flange size change to these components took place with engines built in January of 1989.

Only the six-bolt design parts and the four-bolt design connector, cover, and gasket are serviced. When a former manifold or turbo exhaust inlet elbow requires replacement, all four-bolt design parts must be replaced with six-bolt design parts.

New air bleed lines are used to improve deaeration of 6V forward plan marine engine cooling systems. The new lines permit faster entrained air removal from the coolant. This results in more uniform temperature gradients in the water-cooled exhaust manifolds, helping extend component life. Because of the improved deaeration that results from this change, DDC recommends retrofitting all existing 6V marine models with the new system any time engines are in for major service. See Figure 7-6 and see Figure 7-7.

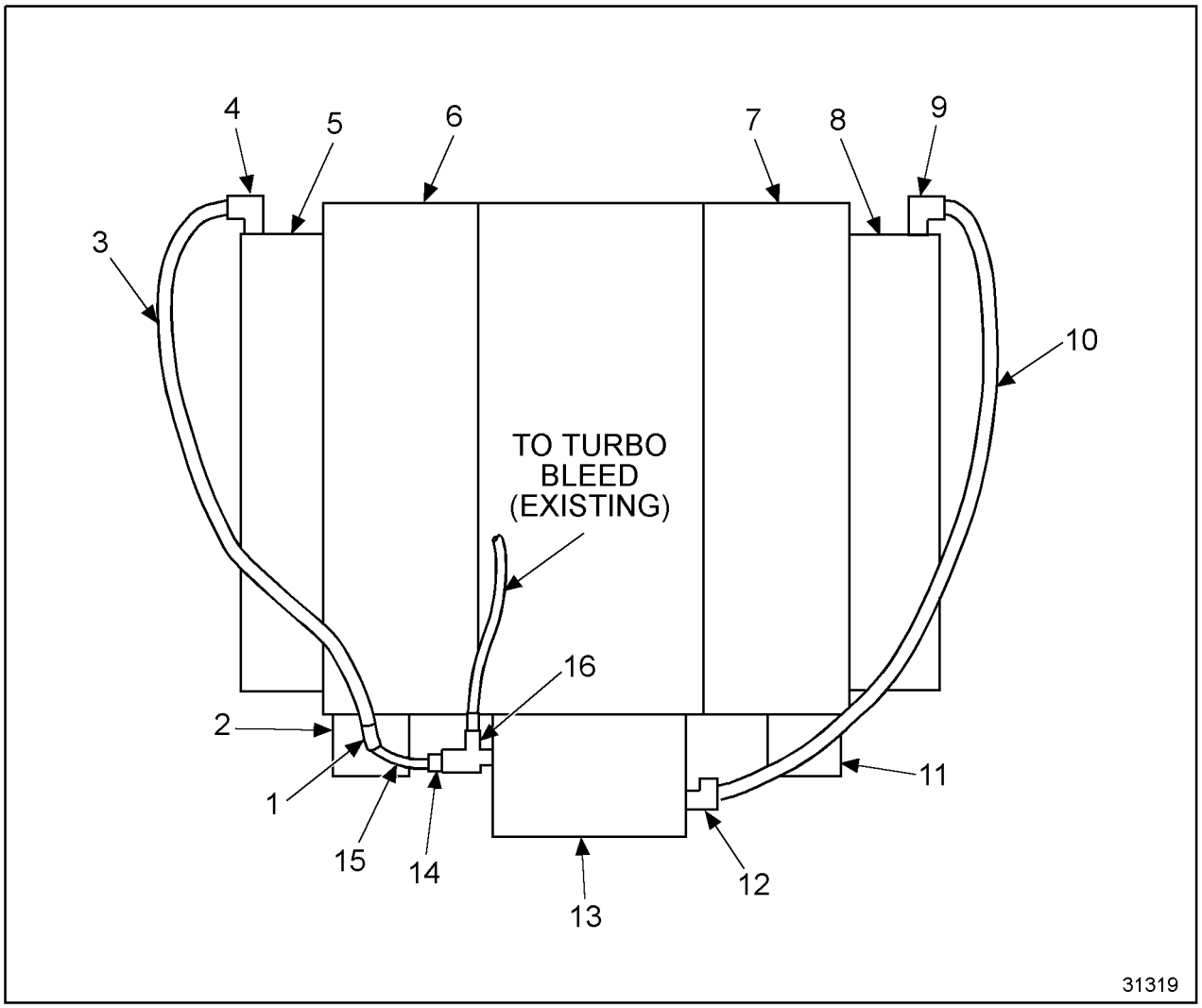


1. Adaptor 8926232 (Under Tee)
2. RB Thermostat HSG
3. Hose Assembly 5136052
4. Elbow 8924149
5. RB Exhaust Manifold
6. RB Cylinder Head
7. LB Cylinder Head
8. LB Exhaust Manifold
9. Elbow 8924149
10. Hose Assembly 5116929
11. LB Thermostat HSG
12. Elbow 8924146
13. Tee 8924178
14. Connector 8924145
15. Heat Exchanger Tank
16. 8924146 Elbow
17. Existing Hose 5131604
18. Tee 8925003

View shown in illustration, front of engine.

Figure 7-6 Dearation Line Routing 6V-92TA Port Engine

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1. Tee 178996
2. RB Thermostat HSG
3. Hose Assembly 5136052
4. Elbow 8924149
5. RB Exhaust Manifold
6. RB Cylinder Head
7. LB Cylinder Head
8. LB Exhaust Manifold
9. Elbow 8924149
10. Hose Assembly 5116929
11. LB Thermostat HSG
12. Connector 8924145
13. Heat Exhaust Tank
14. Connector 8924145
15. Hose Assembly 5109271

Figure 7-7 Dearation Line Routing 6V-92TA Starboard Engine

7.3.1 Repair or Replacement of Exhaust Manifold (Water-Cooled)

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 7-8.

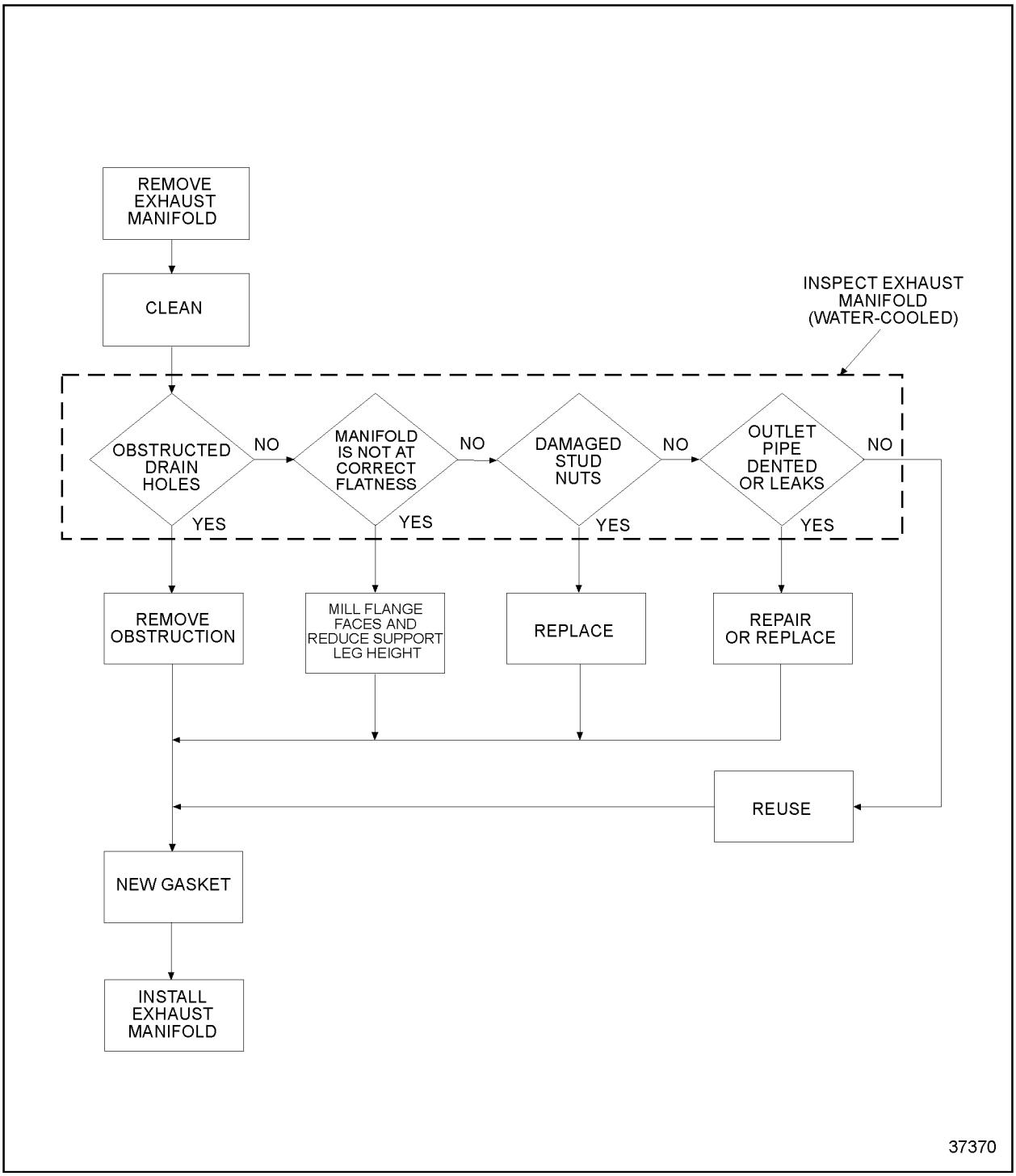


Figure 7-8 Flowchart for Repair or Replacement of Exhaust Manifold (Water-Cooled)

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7.3.2 Removal of Exhaust Manifold (Water-Cooled) Former Design using Studs

Usually, the exhaust manifold is removed with the cylinder head. However, when the exhaust manifold gasket only needs replacing, the manifold may be removed without removing the cylinder head as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Disconnect the water inlet and the water outlet tubes from the exhaust manifold.
3. Disconnect the exhaust pipe from the flange.
4. Loosen and remove the nuts and bevel washers which secure the exhaust manifold to the cylinder head.

NOTE:
One nut and washer should be loosened and left on one of the center until all other nuts and washers have been removed.

5. Support the manifold, and remove the nut and washer from the center stud.
6. Lift the manifold off the studs and away from the cylinder head.
7. Remove the manifold gasket.

7.3.2.1 Cleaning of Exhaust Manifold (Water-Cooled)

Prior to inspection, clean the exhaust manifold as follows:

1. Remove the loose scale and carbon from the exhaust manifold internal walls with a wire brush.
2. Remove old gasket material from the cylinder head and exhaust manifold bolting flange.

7.3.2.2 Inspection of Exhaust Manifold Water-Cooled (Former Design using Studs)

Inspect the exhaust manifold follows:

1. Visually inspect the exhaust manifold studs for damage.
   [a] If damage to the studs is found, replace the studs.

NOTE:
Torque studs in to 34-54 N·m (25-40 lb·ft).

   [b] If not damaged, continue inspection.
2. Inspect the exhaust outlet piping for dents, holes, and loose clamps or deteriorated seals.
   [a] If dents, holes, loose claps or deteriorated seals are found, replace parts as necessary.
   [b] If no dents, holes, loose claps or deteriorated seals are found, reuse the parts.

7.3.3 Installation of Exhaust Manifold Water-Cooled (Former Design using Studs)

Install the exhaust manifold as follows:

1. Place a gasket over the studs and against the cylinder head.

NOTE:
Ensure the locating pads on the exhaust manifold rests on the cylinder block locating pads.

2. Position the exhaust manifold over the studs and against the gasket.
3. Install the bevel washers and nuts on the studs, and draw the exhaust manifold against the gasket.
4. Position the bevel washers so the outer diameter rests on the manifold and the crown center is next to the nut.
5. Tighten the exhaust manifold stud nuts from the center of the exhaust manifold outward, alternating towards either end. Torque the nuts to 41-47 N·m (30-35 lb·ft).

7.3.4 Installation of Exhaust Manifold Water-Cooled (Current Design using Bolts, 6V and 8V)

Install the 6V and 8V exhaust manifold as follows:

1. Position new exhaust manifold on locator pads of the cylinder block, and start the bolts.
2. With new gaskets, assemble manifold to head, and tighten bolts to 14-20 N·m (10-15 lb·ft) initial torque.

NOTE:
When using the new gasket, ensure the connector and riser size are the larger 174.88 mm (6.88 in.) diameter. The new gaskets cannot be mixed with the old flanges.

3. Using a star pattern, tighten manifold-to-riser joint nuts to 88-95 N·m (65-70 lb·ft) torque.
4. Repeat torque to ensure proper fastening

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5. Tighten manifold-to-head bolts to 62-68 N·m (46-50 lb·ft) final torque. See Figure 7-9 and see Figure 7-10.

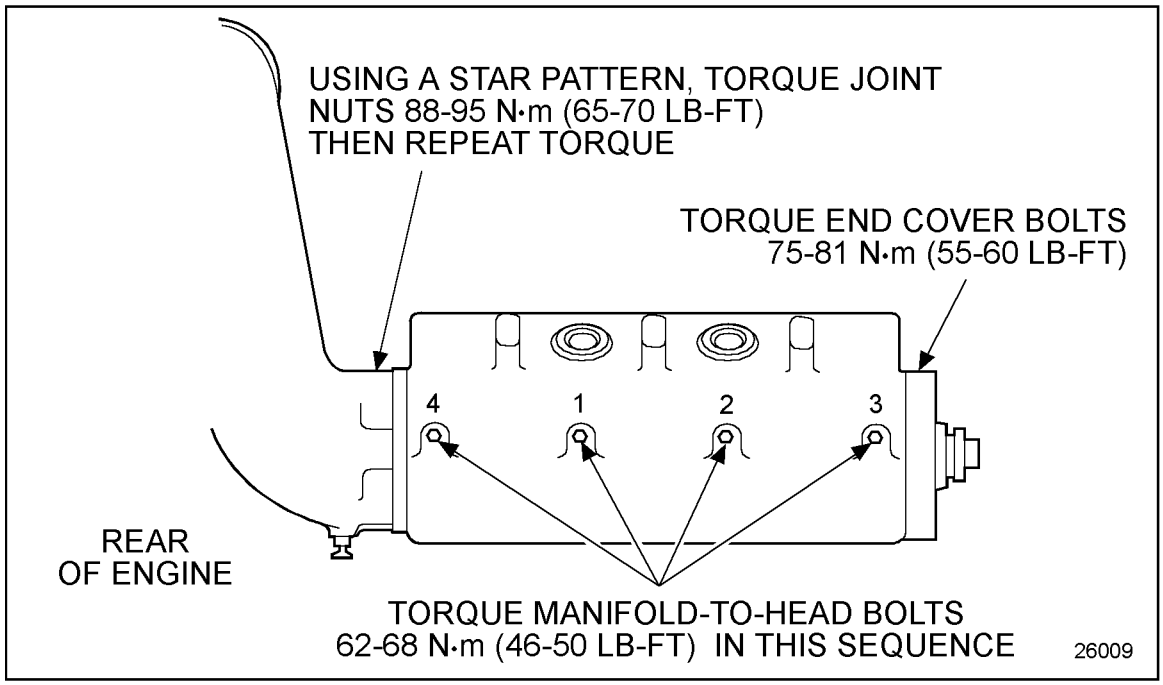


Figure 7-9 Torque Sequence for 3-Cylinder Manifold

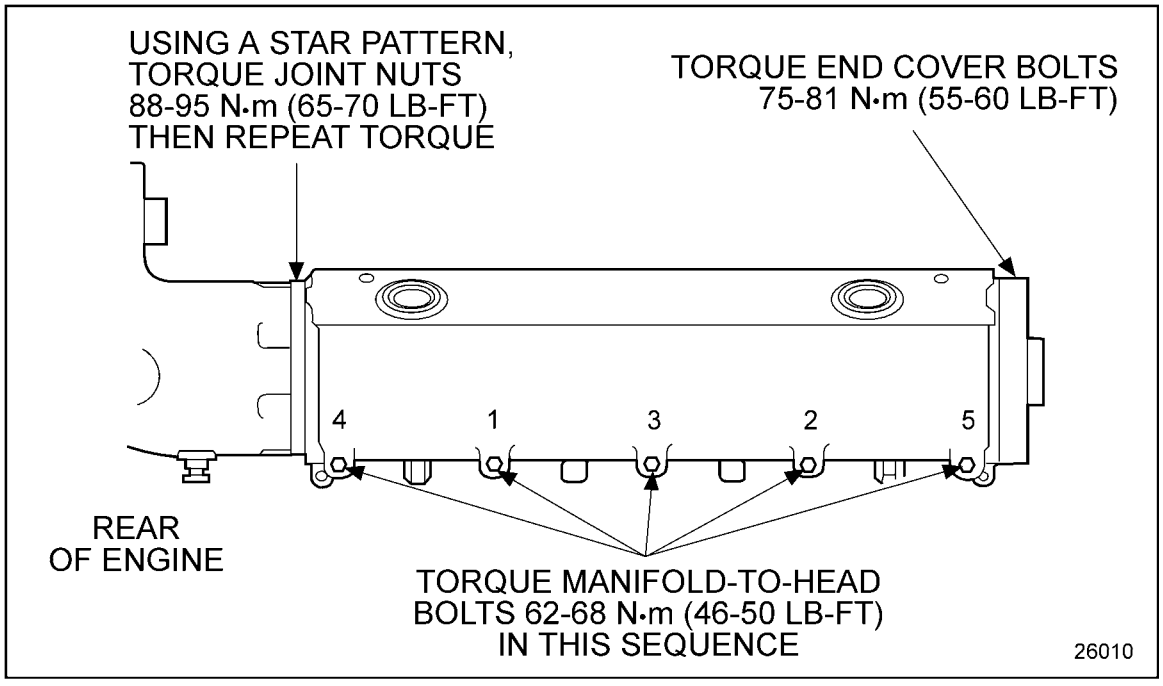


Figure 7-10 Torque Sequence for 4-Cylinder Manifold

6. Tighten the crossover, if used, followed by any supporting brackets.

7.3.5 Installation of Exhaust Manifold Water-Cooled (Current Design 12V and 16V Engines)

Install the 12V and 16V manifold as follows:

NOTE:
Assemble manifolds before installing on the engine.

1. Install new studs in manifold joint face.
2. With a new flange gasket, assemble manifold halves.
3. Using a star pattern, tighten nuts to 88-95 N·m (65-70 lb·ft) torque.

NOTE:
Joint faces (manifold-to-head and machined surface on bottom of manifold) must be held in alignment while torquing.

4. Repeat torque to insure proper fastening.
5. Install manifold assembly to head, install bolts, and tighten to 14-20 N·m (10-15 lb·ft) initial torque.
6. Install new manifold end gasket over studs, install riser, and thread bolts into brackets.
7. Install manifold-to-riser nuts.
8. Tighten bracket bolts to 14-20 N·m (10-15 lb·ft) torque.
9. Using a star pattern, tighten manifold-to-riser joint nuts to 88-95 N·m (65-70 lb·ft) torque. Repeat torque.

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10. Tighten manifold-to-head bolts to 62-68 N·m (46-50 lb·ft) final torque. See Figure 7-11 and see Figure 7-12.

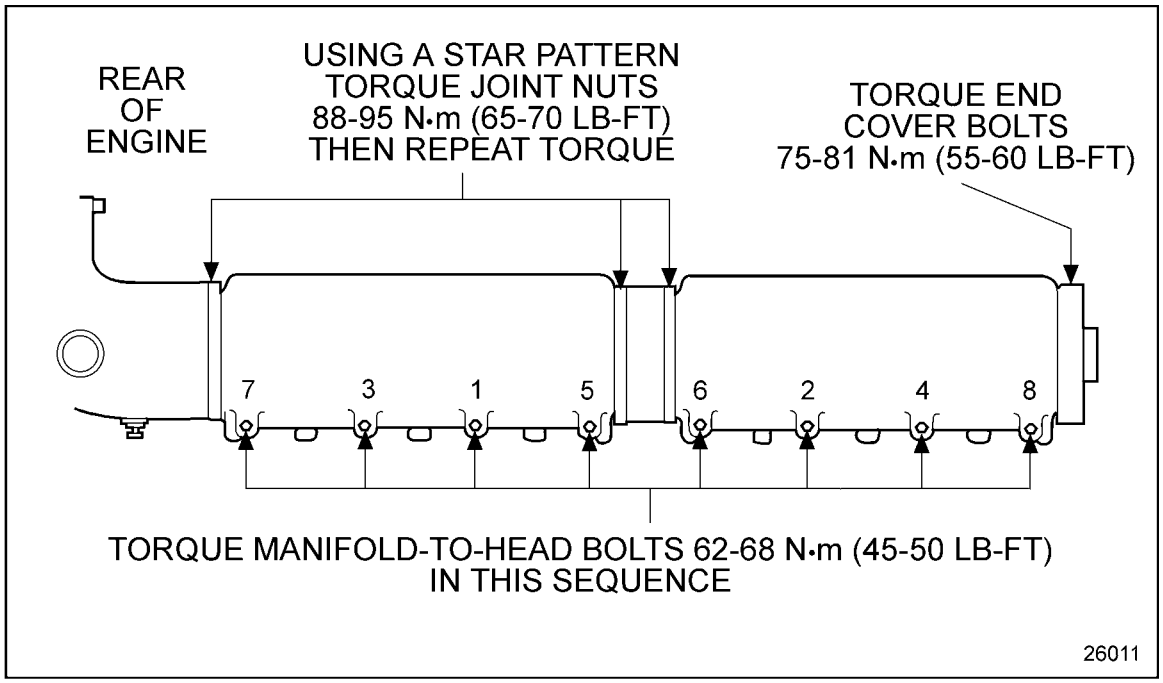


Figure 7-11 Torque Sequence for Two 3-Cylinder Manifolds with Connector SIB3-D-91 Figure 5

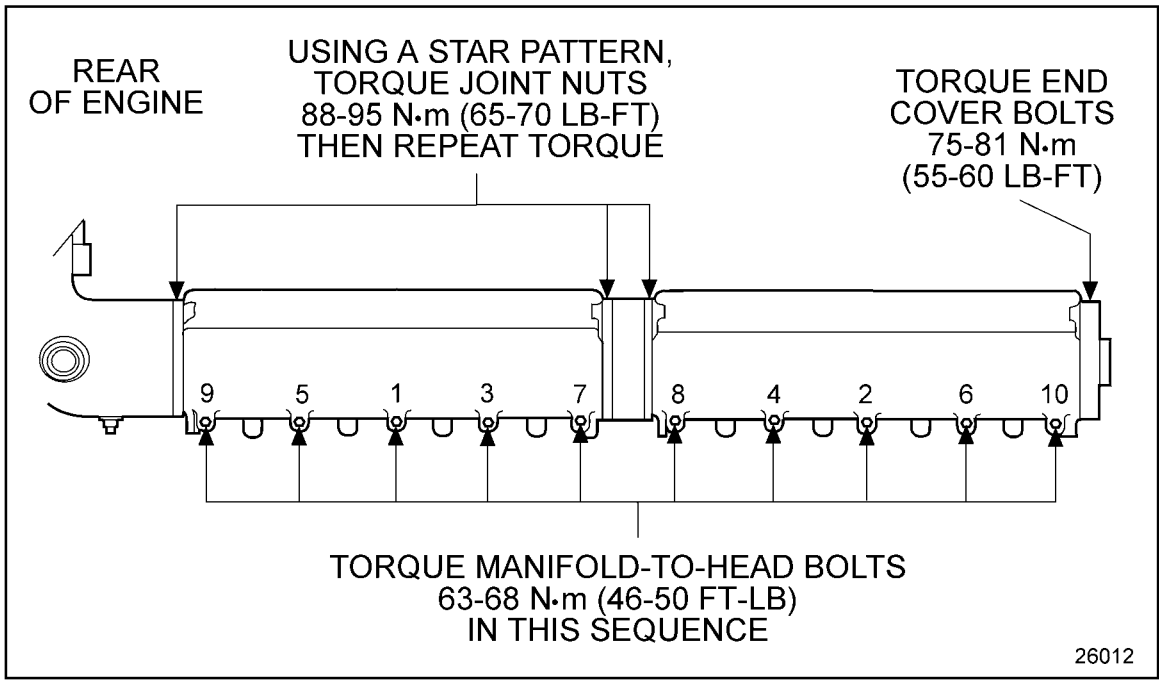


Figure 7-12 Torque Sequence for Two 4-Cylinder Manifolds with Connector SIB3-D-91 Figure 6

11. Tighten end cover bolts (where used) to 75-81 N·m (55-60 lb·ft) torque.
12. Torque remaining bracket bolts.If it is not possible to install the dual manifolds as a complete assembly, parts can be assembled on the engine. Proceed as follows:
13. Tighten the manifold-to-head bolts to 14-20 N·m (10-15 lb·ft) initial torque.
14. Using a star pattern, tighten the connector flange and riser stud nuts to the specified torque.
15. Repeat torque to insure proper fastening.
16. Torque the manifold-to-head bolts.Complete installation as follows:
17. If removed from the manifold, install the exhaust flange using a new gasket.

NOTICE:
Do not allow exhaust piping to impose excessive loads on the turbocharger.

18. Connect the exhaust pipe to the flange.
19. Connect the water inlet and outlet tubes to the manifold.
20. Fill the cooling system, and check for leaks. Refer to section 13.12.

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8 ELECTRICAL EQUIPMENT

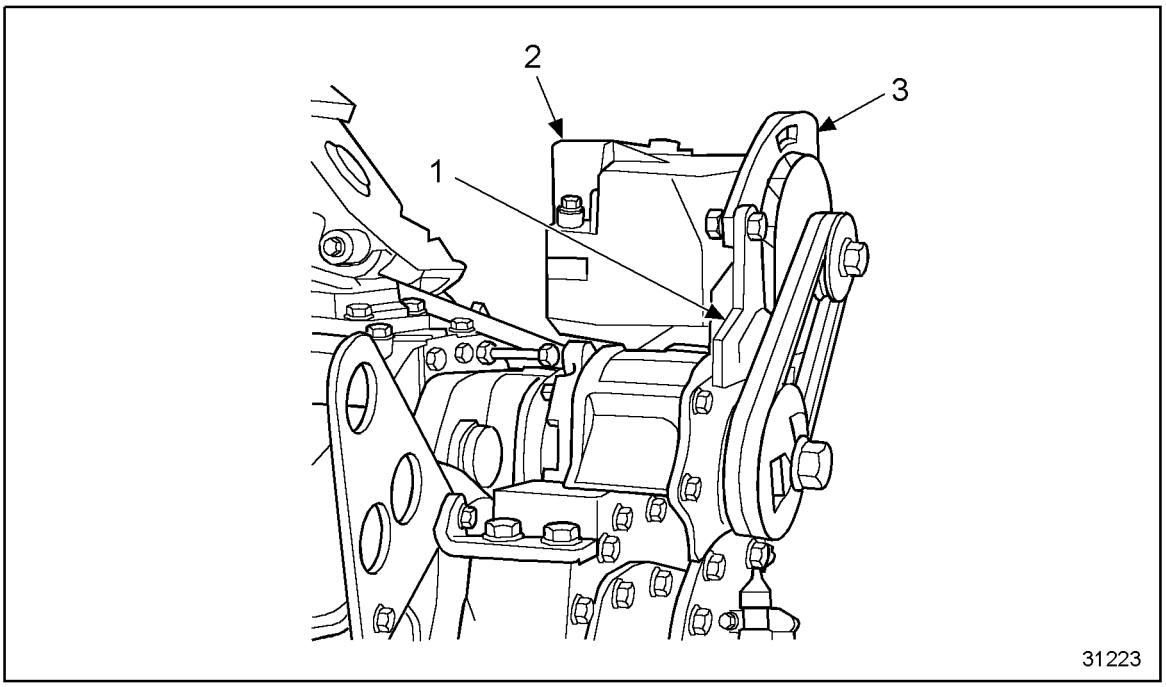
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8.1 BATTERY-CHARGING ALTERNATOR

The battery-charging circuit consists of an alternator, battery, and wiring. The battery-charging alternator provides electrical current for maintaining the battery in a charged condition and supplies sufficient current to carry normal electrical load requirements up to the rated alternator capacity.

The hinge-mounted alternating current self-rectifying alternator, mounted at the rear of the engine, is belt-driven. See Figure 8-1. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.



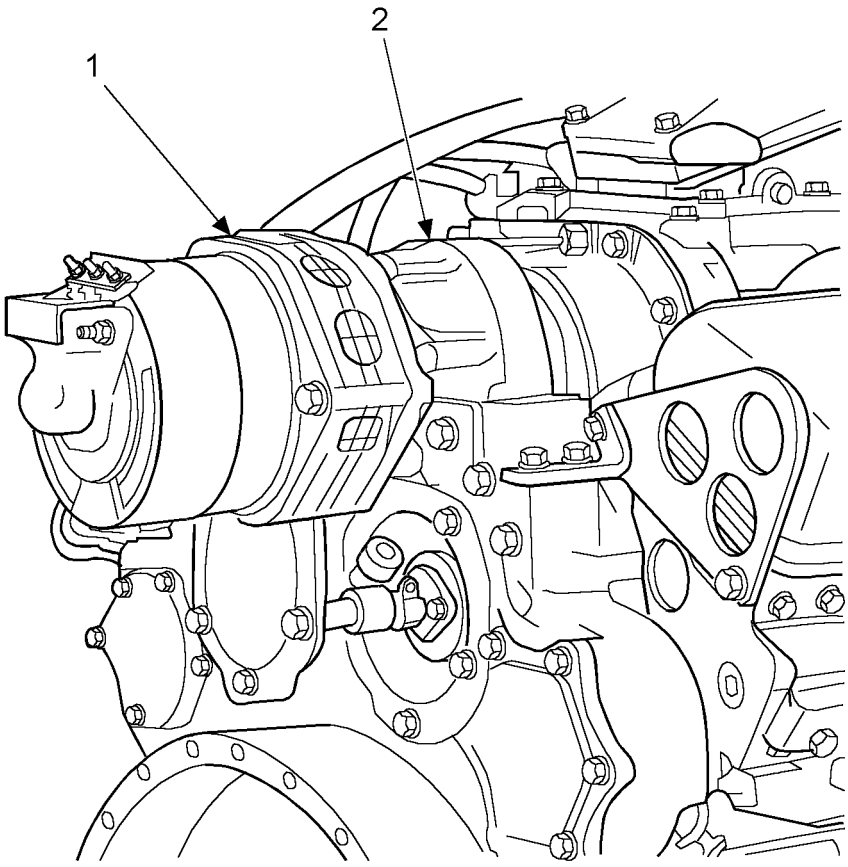
1. Bracket
2. Alternator
3. Adjusting Strap

Figure 8-1 Typical Hinge-Mounted Alternator (Belt-Driven)

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and operates for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase AC voltage to provide DC voltage at the alternator battery terminal, eliminating the need for an external rectifier. The alternator is also available in various sizes and types, depending upon the specific application.

The access hole permitting the external voltage regulator adjustment has been eliminated on current alternators. To adjust the voltage setting on the current alternators, refer to the manufacturers' service information for complete adjustment procedure.

The flange-mounted alternator is coupling-driven through a drive hub attached to the blower drive gear. It is a self load limiting alternator with a fully adjustable, solid state integral regulator. It is designed with slow speed characteristics, which allow lower rotational alternator speed without sacrificing amperage output at idle or top speed. The alternator shaft may be rotated in either direction without affecting the output or unit cooling. Six silicon diodes, mounted in heat sinks, convert alternating current from the *delta wound stator* into direct current. See Figure 8-2.



1. Alternator
2. Flywheel Housing

Figure 8-2 Typical Flange-Mounted Alternator (Beltless)

The brushes and integral voltage regulator are encased in a waterproof housing that may be removed for replacement or inspection.

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Maintain proper drive belt tension. Refer to section 13.18. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the alternator drive.

NOTE:
When installing or adjusting an alternator drive belt, ensure that the bolt at the alternator pivot point is properly tightened, as well as the bolt in the adjusting slot.

Alternator bearings are permanently lubricated. There are no external oil fittings.

As of June 3, 1991 a new camshaft gear bolt locking plate, attaching bolts, and washer are used on all 6V and 8V coach engines equipped with Delco Remy 50DN alternators. The locking plate and attaching parts virtually eliminate the possibility of the camshaft gear retaining bolt losing torque after installation. Refer to section ADDITIONAL INFORMATION for further details.

New sealing components are provided in flange-mounted Leece-Neville® alternators used in marine applications. Refer to section ADDITIONAL INFORMATION for further details.

Avoid reversing the battery connections.

⚠ CAUTION:

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

⚠ 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 from accidental engine startup while servicing the engine, disconnect/disable the starting system.

⚠ CAUTION:

To avoid injury from electrical shock, use care when connecting battery cables. The magnetic switch studs are at battery voltage.

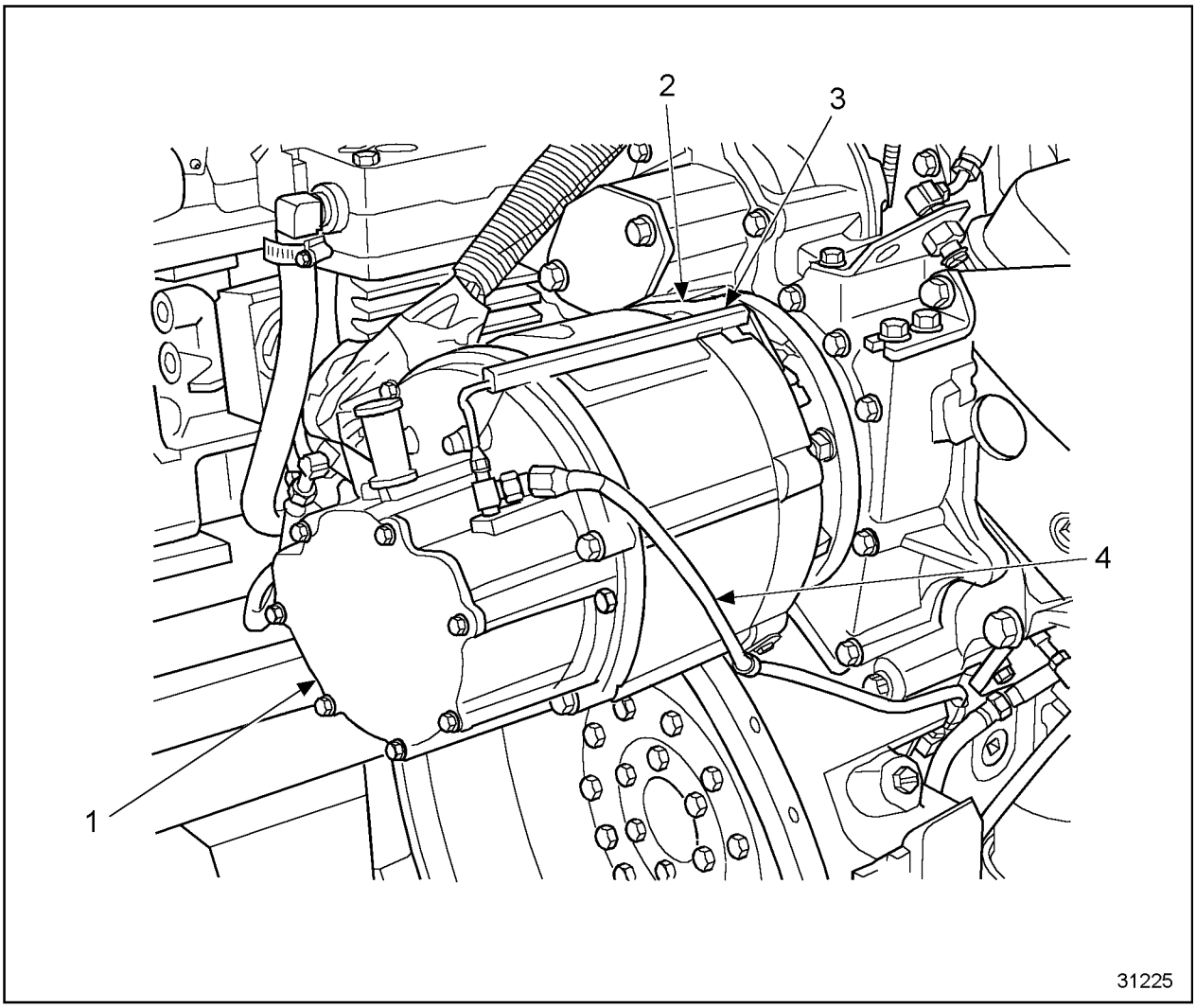
NOTICE:

Precautions must be taken when working around alternators. The diodes and transistors in the alternator circuit are sensitive and can easily be destroyed. Take the following precautions when handling the alternator:

- ☐ Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.
- ☐ Grounding an alternator's output or wire terminals, (which are always "hot" regardless of whether or not the engine is running), or accidental reversing of the battery polarity will destroy the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme care be used.
- ☐ Never disconnect the battery while an alternator is in operation. The magnetic field collapse will momentarily generate high voltage and current, damaging the diodes.
- ☐ On marine applications, do not switch from one set of batteries to the other while the engine is in operation. This will momentarily disconnect the batteries, and result in damage to the alternator diodes.
- ☐ If a booster battery is used, correctly connect the batteries (negative to negative and positive to positive). Failure to connect batteries correctly will cause damage to the alternator.
- ☐ Never use a fast charger with the battery connected or as a booster for battery output. Never attempt to polarize the alternator.
- ☐ The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.
- ☐ If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to ensure that a ground strap is present and is correctly installed.

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A dual internal gear driven high output alternator is available for some applications. See Figure 8-3.



1. High Output Alternator
2. Adaptor Plate
3. Oil Supply Line
4. Supply Spill Line

Figure 8-3 Dual Internal Gear Driven High Output Alternator

8.1.1 Repair or Replacement of Battery-Charging Alternator

Refer repairs and overhaul work to a manufacturer authorized repair station. Order replacement parts through the manufacturer outlets. Repair service and parts are available for alternators manufactured by Delco-Remy Division through AC Delco branches and repair stations.

8.1.2 Removal of Battery-Charging Alternator

Remove the battery-charging alternator as follows:

⚠ CAUTION:

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

1. Disconnect the cables at the battery supply.
2. If the alternator has a separately mounted regulator and field relay, disconnect all other leads from the alternator, and tag each one to ensure correct installation.
3. Loosen the mounting bolts and the adjusting strap bolt. Remove the drive belts.
4. While supporting the alternator, remove the adjusting strap bolt, hardened washer, and lock washer.
5. Remove the mounting bolts, hardened washer, lock washer, and nuts.

NOTICE:

The fan guard, which includes an oil seal, should not be separated from the beltless alternator until the alternator half of the coupling is removed. Any attempt to separate the fan guard from the alternator could damage the oil seal.

NOTICE:

While lifting the alternator use care to protect the alternator and fan guard assembly from damage.

6. On beltless alternators, lift the alternator and fan guard from the mounting adaptor as a unit.
7. On belt-driven alternators, carefully remove the alternator only.
8. On beltless alternators, loosen the retaining nut, and remove the coupling hub keyed to the alternator shaft.
9. If replacing the belt-driven alternator, remove the pulley assembly. If replacing the beltless alternator, separate the alternator from the flange mounting.
10. Remove the alternator flange mounting adaptor from the flywheel housing, if necessary.

8.1.2.1 Inspection of Battery-Charging Alternator

Inspect the alternator as follows:

1. Inspect the drive coupling and hub for wear at the seal surface and the drive tangs.
   [a] If excessively worn, replace the drive coupling and hub. Refer to section 8.1.3.
   [b] If not worn, continue inspection.
2. Inspect the drive coupling and hub for oil leaks.

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[a] If oil leaks are found, replace the oil seal in the fan guard. Refer to section 8.1.3.

[b] If oil seals are worn or damaged, replace the oil seal in the fan guard. Refer to section 8.1.3.

[c] If no oil leaks or damage is found, proceed with inspection.

3. Inspect the alternator housing and flange adaptor at the mounting bolt holes for cracks.

   [a] If cracked, replace the housing and flange adaptor. Refer to section 8.1.3.

   [b] If not cracked, proceed with inspection.

4. Inspect the pilot diameter for damage, cracks, or distortion.

   [a] If damaged, cracked, or distorted, replace the pilot. Refer to section 8.1.3.

   [b] If not damaged, cracked, or distorted, refer to section 8.1.3.

8.1.3 Installation of Battery-Charging Alternator

Install the battery-charging alternator as follows:

1. Install the drive pulley, if removed. Tighten the pulley retaining nut to 68-81 N·m (50-60 lb·ft) torque.

NOTE:
If the pulley was not removed, check the retaining nut for proper torque.

NOTICE:
To avoid gear damage, ensure the alternator is properly fitted to the adaptor before bolting it in place.

2. Position the alternator on the mounting brackets, with lock washers and hardened washers in place, start the bolts through the bolt holes in the alternator end frames.

NOTE:
Special hardened, plain washers seat in the six adaptor counterbored bolt holes, and the current gasket has a position identification tab.

3. If nuts are used, insert the bolts through the bolt holes in the mounting bracket and alternator end frame.

NOTE:
Check the lock washers, hardened washers and nuts to ensure they are in their proper locations.

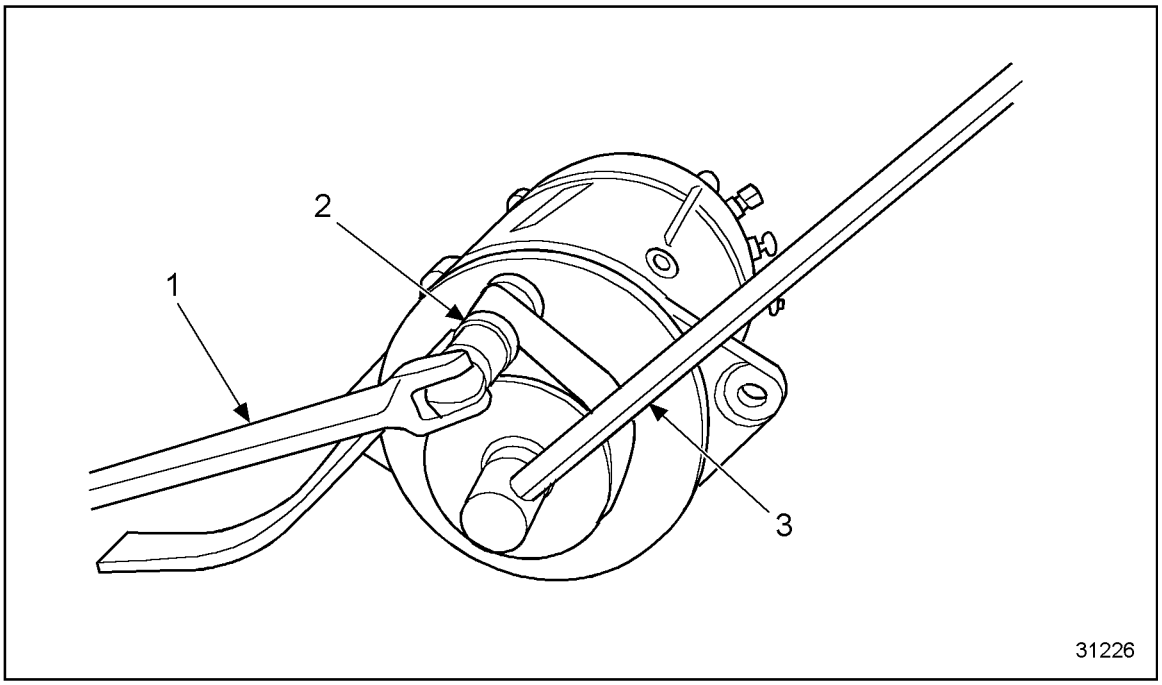
4. If the fan guard and hub were removed from a beltless alternator, engage the mating pilot diameters to locate the fan guard on the alternator.
5. Lubricate the seal diameter on the coupling hub and the seal lip.

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6. Install the coupling hub on the shaft. Tighten to 95-108 N·m (70-80 lb·ft) torque.

NOTE:
If the fan guard and hub were not removed, check the retaining nut for proper torque.

7. Align the threaded hole in the drive end frame adjusting lug with the adjusting strap slot.
8. Start the bolt with the lock washer and hardened washer, through the adjustithng strap slot, and into the threaded hole in the alternator end frame.
9. On beltless alternators, align the bolt holes in the fan guard with the mounting holes in the alternator housing.
10. Support the alternator assembly against the mounting flange adaptor. Use a new gasket.
11. Install the three 3/8 in.-16 x 3-1/2 in. bolts, lock washers, and hardened washers through the alternator housing and fan guard mounting holes in the mounting adaptor. Tighten the bolts to 40-47 N·m (30-35 lb·ft) torque.
12. Place the drive belts in the pulley grooves.
13. On belt driven alternators, adjust the alternator belt tension. Refer to section 13.20.
14. Tighten the bolts. See Figure 8-4.



1. Flex Handle
2. Strap Wrench
3. Torque Wrench

Figure 8-4 Tightening Alternator Pulley Retaining Nut

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15. Attach the wires and cables.

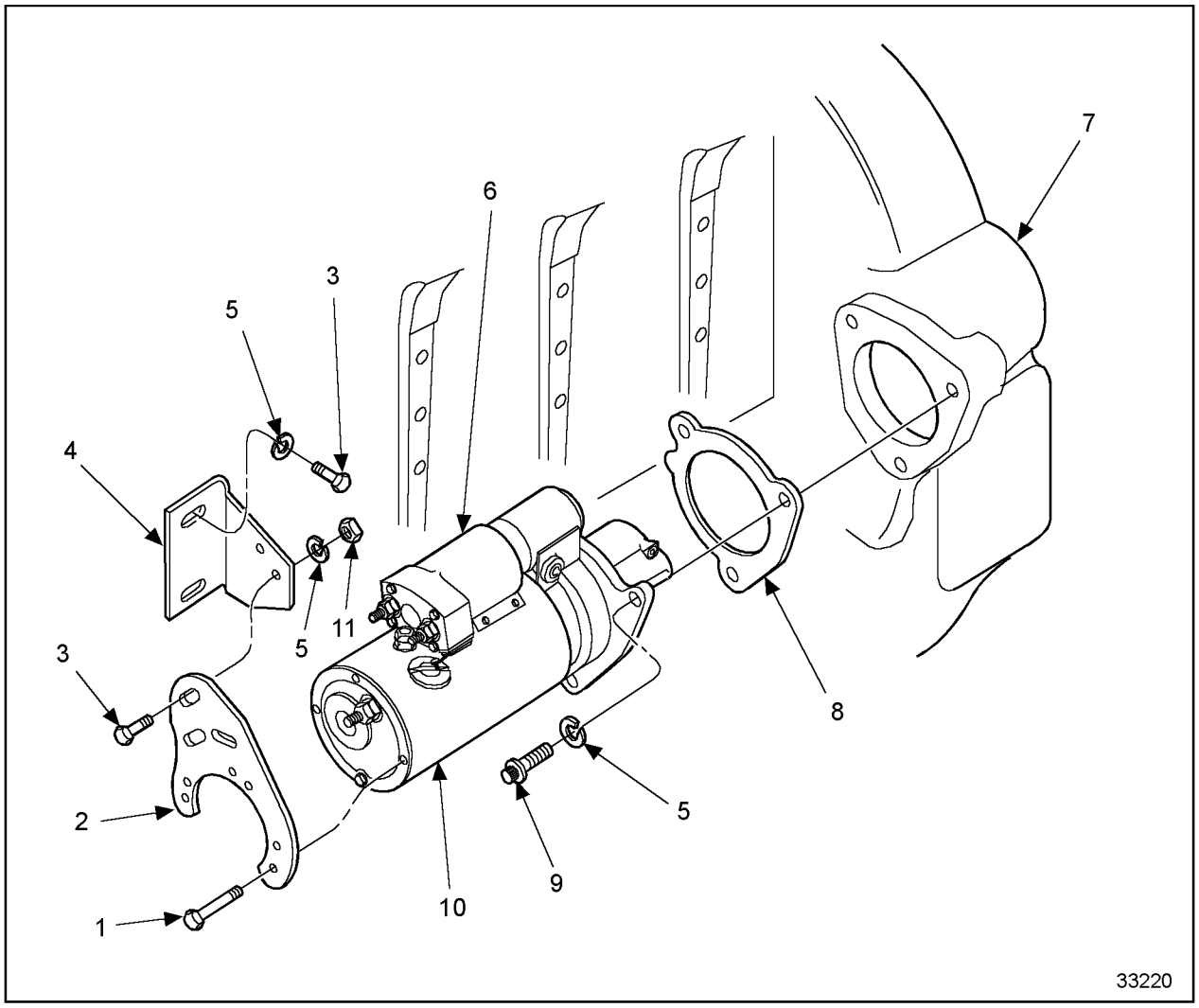
NOTE:
Ensure each one is correctly installed in its previous location on the alternator. Keep all connections clean and tight.

16. Connect the oil feed line, if used, to the alternator.

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8.2 STARTING MOTOR

The starting motor is mounted on the flywheel housing. See Figure 8-5. When the starting circuit is closed, a small drive pinion on the armature shaft engages the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, the drive pinion is disengaged preventing the armature from overspeeding and damaging the starting motor.



1. Long Bolt
2. Support Bracket
3. Short Bolt
4. Cylinder Block Support Bracket
5. Lock Washer
6. Solenoid
7. Flywheel Housing
8. Gasket
9. Starter Mounting Bolts
10. Starter Motor Assembly
11. Nut

Figure 8-5 Typical Starter Assembly

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For information on the mounting of a starter auxiliary magnetic switch, refer to section ADDITIONAL INFORMATION.

8.2.1 Repair or Replacement of Starting Motor

The starting motor is not a serviceable item. Refer to OEM guidelines or an authorized Detroit Diesel distributor for service recommendations.

8.2.2 Removal of Starting Motor

Remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting motor solenoid.
2. Tape the cable end to prevent battery discharge from a direct short.
3. Disconnect the starting motor cables and solenoid wiring.

NOTE:
Tag each lead to ensure correct connections when the starting motor is installed.

4. Support the motor, and remove the three bolts and lock washers that secure it to the flywheel housing.
5. Pull the motor forward to remove it from the flywheel housing.

8.2.2.1 Inspection of Starting Motor

Inspect the starting motor as follows:

Check the starting motor in accordance with the Delco-Remy *"Cranking Circuit*" maintenance handbook. Refer to OEM for details.

8.2.2.2 Repositioning Solenoid

When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

1. If a twelve hole starter mounting flange is used, remove the six socket head screws and six neoprene plugs.

NOTICE:
The solenoid must never be located below the centerline of the starter. Dust, oil, moisture, and foreign material can collect and cause solenoid failures.

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 starter mounting flange is used.
4. Tighten the screws to 18-23 N·m (13-17 lb·ft) torque.

8.2.3 Installation of Starting Motor

Install the starting motor as follows:

1. Position the motor to the flywheel housing.
2. Install the three 5/8 in.-11 bolts and lock washers. Tighten to 186-200 N·m (137-147 lb·ft) torque with a cast iron flywheel housing and to 129-143 N·m (95-105 lb·ft) with an aluminum flywheel housing.
3. Keep all electrical connections clean and tight. Install the wiring terminal leads to the starting motor and the solenoid switch.
4. Tighten the No. 10-32 connections to 2-3 N·m (16-30 lb·in) torque and the 1/2 in.-13 connections to 27-34 N·m (20-25 lb·ft) torque.
5. Remove the tape from the cable end.
6. Attach the ground strap or cable to the battery, or attach the cable to the starting motor solenoid.

After installing the motor and repositioning the solenoid as necessary, proceed as follows:

1. If a twelve hole starter mounting flange is used, remove the six socket head screws and six neoprene plugs.

NOTICE:
The solenoid must never be located below the centerline of the starter. Dust, oil, moisture, and foreign material can collect and cause solenoid failures.

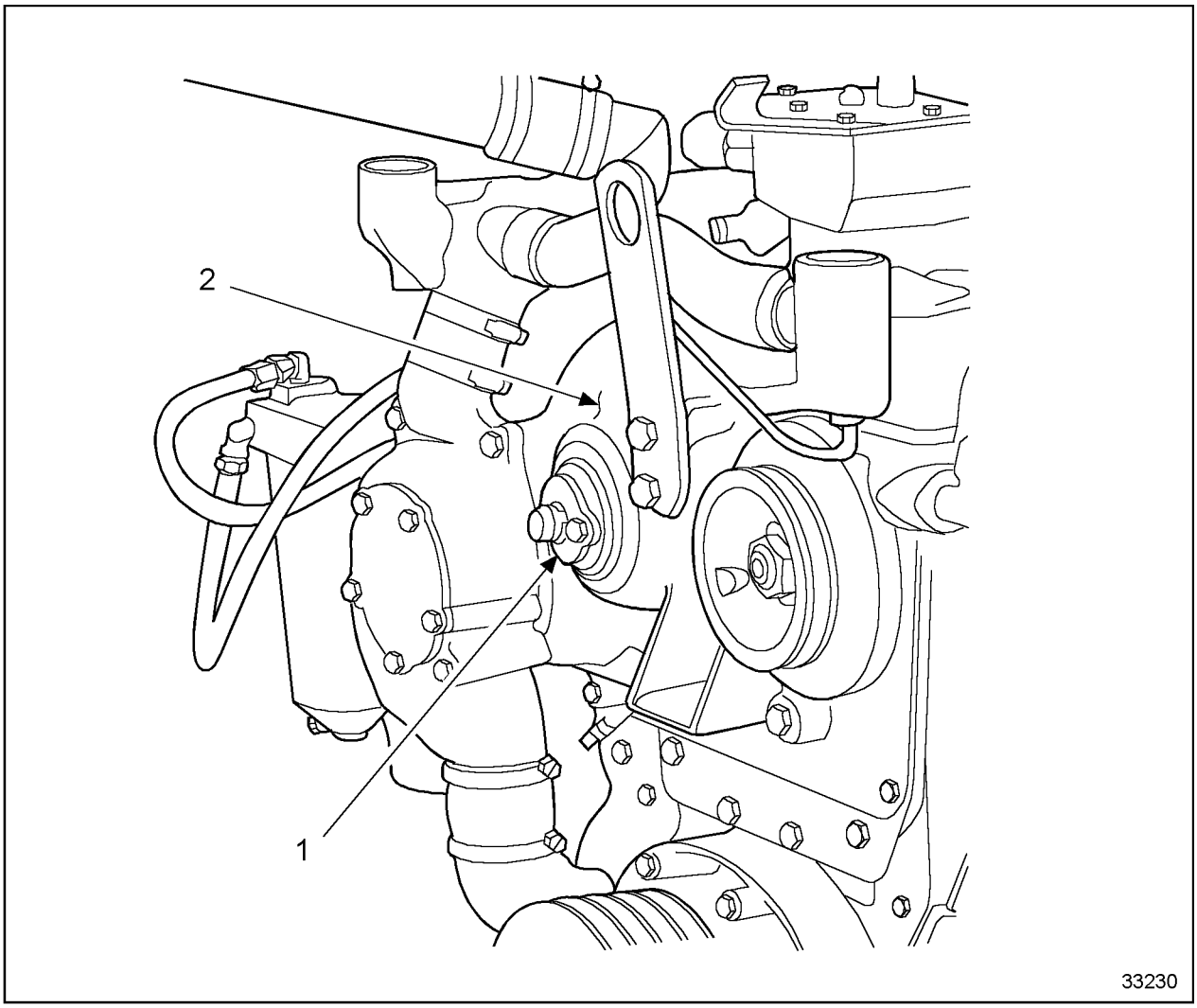
2. Turn the nose housing to the required position.
3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs if a twelve hole starter mounting flange is used.
4. Tighten the screws to 18-23 N·m (13-17 lb·ft) torque.

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8.3 TACHOMETER DRIVE

A tachometer drive shaft may be installed in several locations on the engine.

At the front end of the engine, the tachometer drive shaft is pressed into the end of the right bank camshaft and extends through an adaptor attached to the balance weight cover. See Figure 8-6.

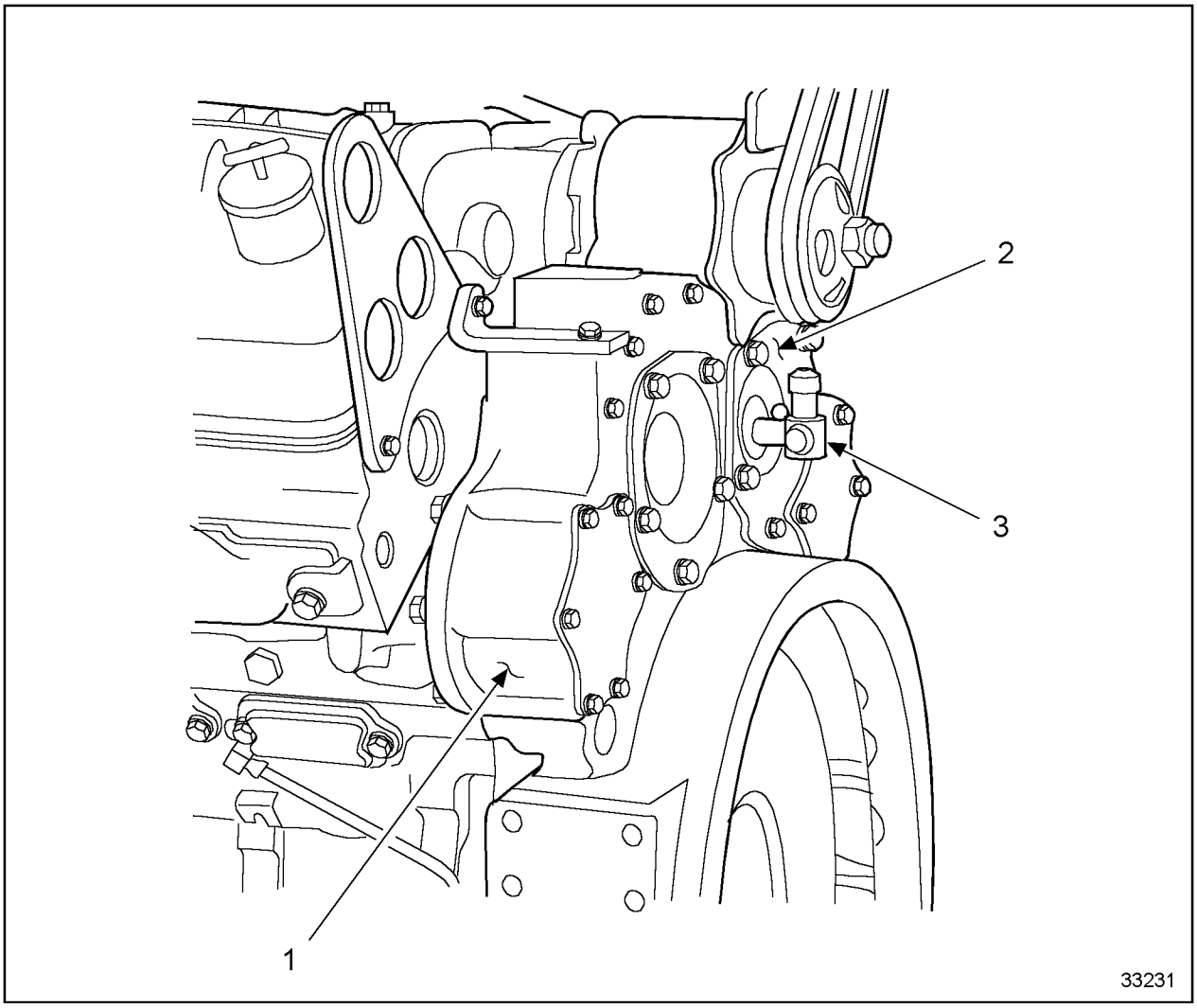


1. Tachometer Drive Shaft Adaptor
2. Engine Upper Front Cover

Figure 8-6 Front Mounted Tachometer Drive

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At the rear of the engine, the tachometer drive shaft may be installed in either the camshaft end, the blower drive shaft, or the left hand helix blower rotor shaft. See Figure 8-7. A tachometer drive shaft adaptor is attached to the flywheel housing cover or the blower rear end plate cover.



1. Flywheel Housing
2. Tachometer Camshaft Rear End Cover
3. Tachometer Drive

Figure 8-7 Rear Mounted Tachometer Drive

When required, a tachometer drive cable adaptor changes speed or rotational direction, depending upon the tachometer drive location. A special key connects the drive shaft to the tachometer drive cable adaptor.

The cable connection on the current tachometer head is a 5/8 in. threaded connection in place of the former 7/8 in. connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output shaft key size has been increased from 5/32 in. to SAE 3/16 in. Current flexible drive cables are required with the current tachometers and angle drives.

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8.3.1 Repair or Replacement of Tachometer Drive

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 8-8.

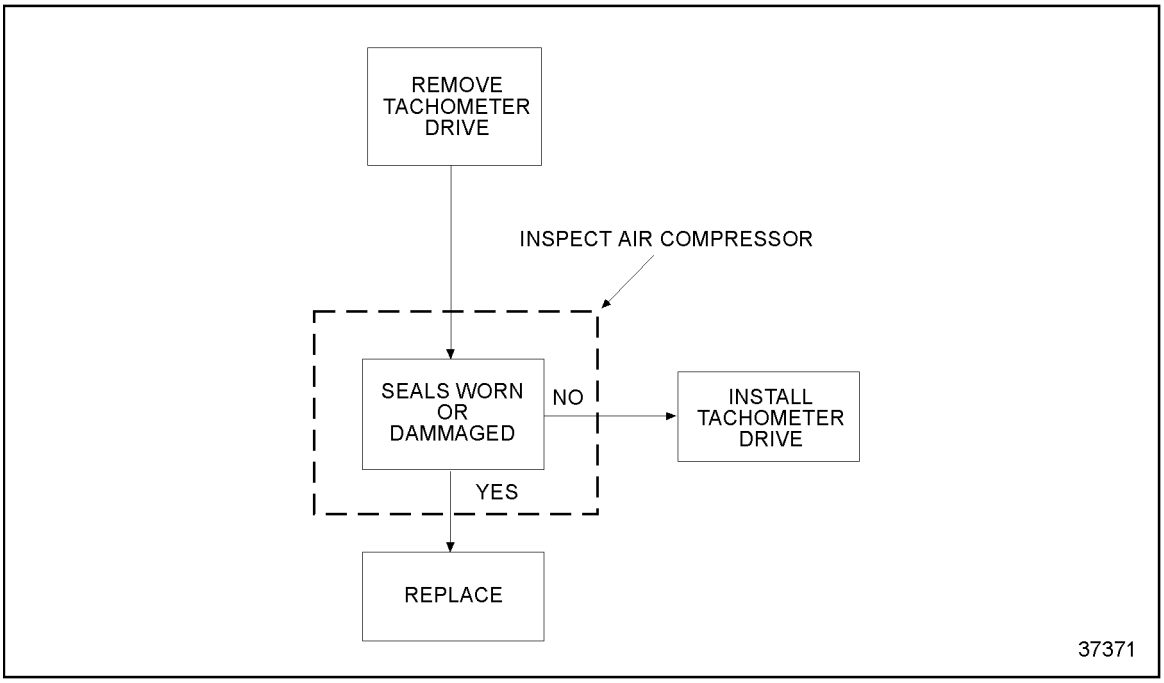


Figure 8-8 Flowchart for Repair or Replacement of Tachometer Drive

8.3.2 Removal of Tachometer Drive (Camshaft or Blower Drive Shaft Driven)

Remove the camshaft or blower drive shaft driven tachometer drive as follows:

1. Disconnect the tachometer drive cable from the tachometer drive cable adaptor.
2. If used, remove the tachometer drive cable adaptor and key. Remove the key and seal assembly if the tachometer drive shaft is driven by the blower drive shaft.
3. If the tachometer drive is located at the front of the engine, remove the tachometer drive shaft adaptor and gasket from the balance weight cover. For a rear mounted tachometer drive, remove the flywheel housing cover and adaptor assembly and gasket.
4. If the tachometer drive shaft is driven by the blower drive shaft, remove the blower drive shaft.
5. Remove a tachometer drive shaft that is pressed into the camshaft as follows:

   [a] If the tachometer drive shaft is pressed into the end of the camshaft, it cannot be turned since the end is either square or knurled. If threads (5/16 in.-24 or 3/8 in.-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3 from set J 5901-01 on the shaft.

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[b] Attach slide hammer J 23907-1 to the remover. A few sharp blows against the slide hammer rod will remove the tachometer drive shaft.

[c] If threads are not provided on the outer end of the tachometer drive shaft or the end of the shaft is broken off, drill and tap the shaft.

NOTICE:
To avoid potential engine damage, prevent metal particles from falling into the gear train and oil pan.

[d] Thread a stud into the shaft, and remove the shaft with the remover and slide hammer.

8.3.3 Removal of Tachometer Drive (Blower Rotor Shaft Driven)

Remove the blower rotor shaft driven tachometer drive shaft as follows:

1. Disconnect the tachometer drive cable from the tachometer drive cable adaptor.
2. Remove the tachometer drive cable adaptor and key.
3. Remove the blower from the engine. Refer to section 6.5.2.
4. Remove the blower rear end plate cover.
5. Remove the tachometer drive shaft, which also functions as the left hand blower rotor gear retaining bolt, with a 3/4 in. wrench.

8.3.3.1 Inspection of Tachometer Drive

Inspect the oil seals as follows:

1. Visually inspect the oil seal(s) for wear or damage.
   [a] If worn or damaged, replace the oil seal (camshaft drive) or oil seal unit (blower drive shaft drive).
   [b] If not worn or damaged, reuse the seal(s).

8.3.4 Installation of Tachometer Drive (Camshaft or Blower Drive Shaft Driven)

Install the camshaft or blower drive shaft driven tachometer drive as follows:

NOTE:
When installing a tachometer drive cover assembly or a drive adaptor, ensure they are aligned properly with the tachometer drive shaft. Refer to section ADDITIONAL INFORMATION.

1. Start the tachometer drive shaft in the end of the camshaft or blower drive shaft.
2. Using a suitable sleeve, tap or press against the shoulder on the tachometer drive shaft until the shoulder contacts the camshaft or blower drive shaft.

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3. Install the blower drive shaft.
4. Use a new gasket, and install the tachometer drive cover and adaptor on the balance weight cover or flywheel housing.
5. Check the tachometer drive shaft alignment. Refer to section ADDITIONAL INFORMATION.
6. Install the oil seal and key assembly (blower drive shaft driven tachometer drive).
7. Install the tachometer drive cable adaptor and key, if used. Lubricate the tachometer drive cable adaptor with grease through the fitting provided.
8. Attach the tachometer drive cable.

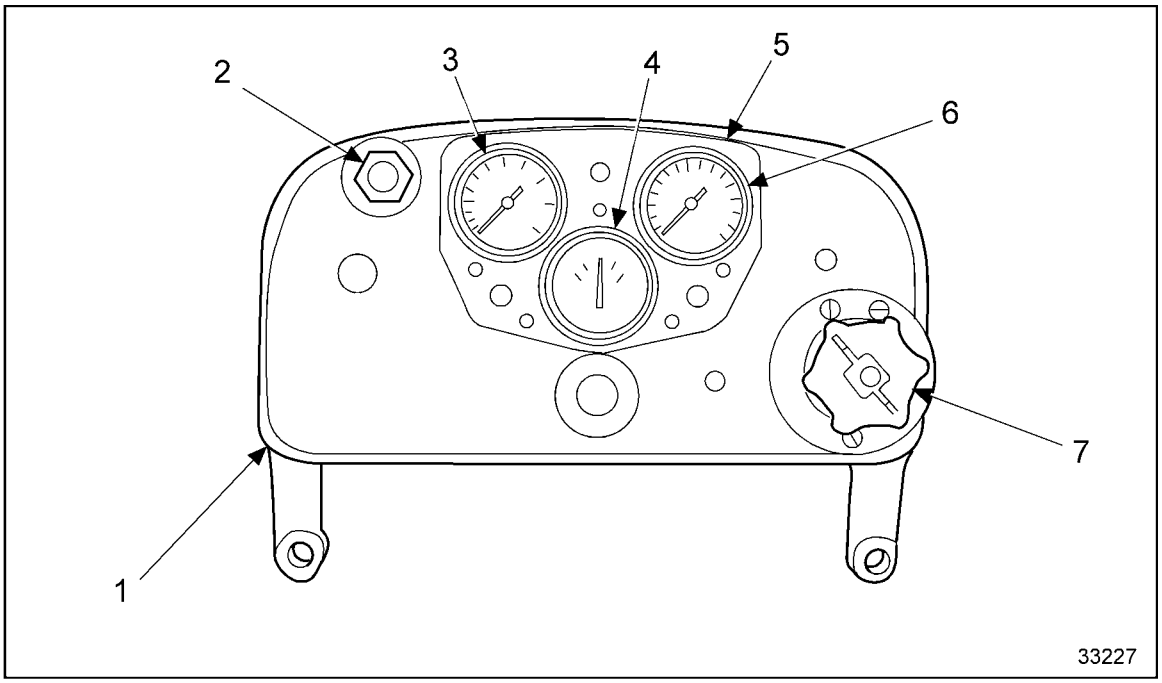
8.3.5 Installation of Tachometer Drive (Driven by Blower Rotor Shaft)

Install the blower rotor shaft driven tachometer drive as follows:

1. Lubricate the threads with engine oil, and install the combination blower rotor retaining bolt and tachometer drive shaft. Tighten to 75-88 N·m (55-65 lb·ft) torque.
2. Install the blower rear end plate cover.
3. Align the blower rear end plate cover with the tachometer drive shaft. Check the drive shaft alignment. Refer to section ADDITIONAL INFORMATION.
4. Install the blower on the engine. Refer to section 6.5.5.
5. Install the tachometer drive cable adaptor and key.
6. Attach the tachometer drive cable.

8.4 INSTRUMENTS

The instruments generally required in diesel engine operation consist of an oil pressure gage, a water temperature gage, an ammeter, and a mechanical tachometer. An engine starting switch, engine stop knob, and an emergency stop knob are closely related and are usually installed near the other instruments. See Figure 8-9.



1. Instrument Panel
2. Starting Switch
3. Water Temperature Gage
4. Ammeter
5. Cluster Panel
6. Oil Pressure Gage
7. Throttle Knob

Figure 8-9 Typical Instrument Panel

All Torqmatic converters are equipped with an oil pressure gage and, in some instances, with an oil temperature gage. These instruments are mounted on a separate panel.

Instruments, throttle control, and engine starting and stopping controls are mounted in various locations depending upon the engine use.

Marine propulsion engine instrument panels usually include an engine oil pressure gage, reverse gear oil pressure gage, water temperature gage, ammeter, and a tachometer. The instrument panels are mounted some distance from the engine. Illuminated instrument panels are provided for marine applications which require night operations.

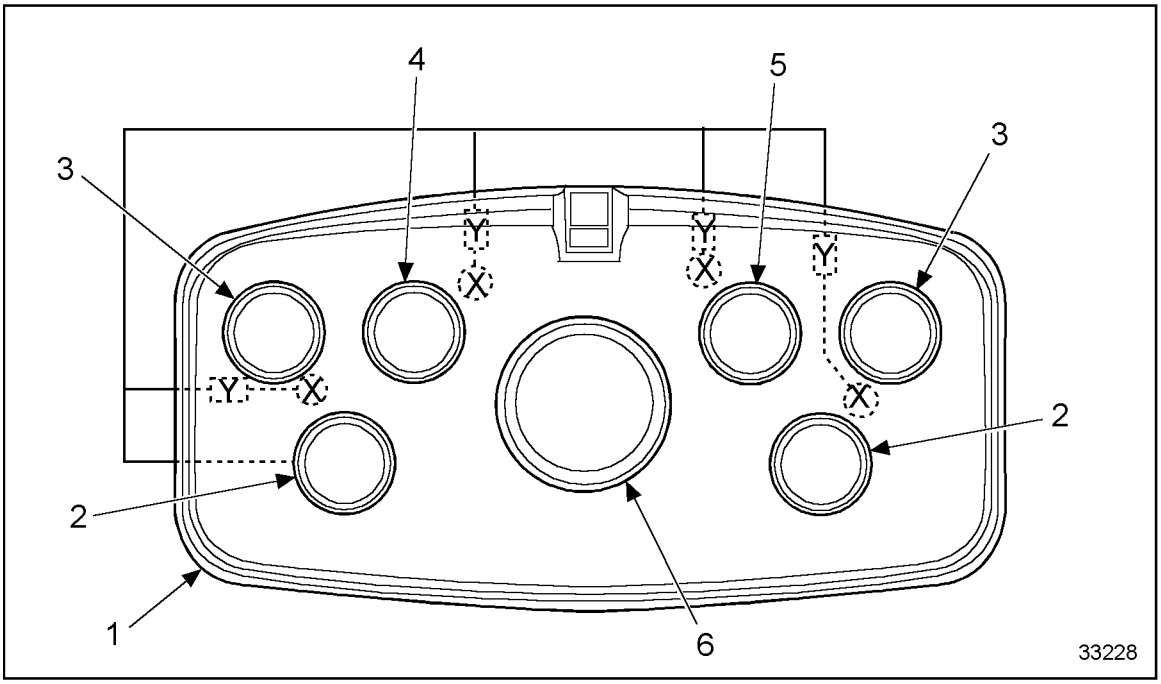
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All illuminated instrument panels are wired for a 12 volt lighting circuit. When marine propulsion units incorporate either a 24 or 32 volt electrical system, a 12 volt tap-off from the battery may be made, or resistors may be installed in the circuit to protect the instrument panel bulbs. Resistor specifications are listed in Table 8-1. One resistor is used in the lead for each instrument panel bulb. See Figure 8-10.

Volts	Ohms	Watts
24	50	10
32	100	10

Table 8-1 Resistor Specifications

NOTE:
X=Panel Lights Y=Resistors. See Figure 8-10.



1. Instrument Panel
2. Amps
3. Water Temperature Gage
4. Oil Pressure Gage
5. Reverse Gear Pressure
5. Tachometer

Figure 8-10 Installation of Resistors in Illuminated Instrument Panel

8.4.1 Anti-Vibration Instrument Mountings

Anti-vibration mountings are used in many places to absorb engine vibration in the mounting of instruments, drop relays, tachometers, etc. When servicing a rubber mount secured part, exercise care during removal and installation to avoid twist imposed into the rubber mount diaphragm. The mounts should be inspected for damage and replaced, if necessary.

The attaching screw, through the center of the mount, must be held from turning during final nut tightening. Support the screw, and tighten the nut only. If this screw turns, it will preload the rubber diaphragm in torsion and considerably shorten the life of the mount.

8.4.2 Oil Pressure Gage

The oil pressure gage registers the lubricating oil pressure in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure, stop the engine. Determine the cause, and correct it before the engine is started again. Refer to section 11.5.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, use a new mounting clamp and connector.

8.4.3 Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent vibration damage to the gage assembly, the full length of the capillary tube must be securely fastened to the engine with suitable clips at intervals of ten inches or less. Avoid sharp bends in the tube, particularly at the gage or bulb connection areas. The bend must not be less than one inch radius where the tube must be bent around any object.

Coil any extra length with a diameter no less than two inches. The coils must be located so that they may be securely fastened to prevent vibration.

8.4.4 Ammeter

The ammeter is wired into the electrical circuit to show the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in the charge rate to the battery. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. The small current registered prevents rapid brush wear in the battery-charging alternator. If lights or other electrical equipment are connected into the circuit, the ammeter will show discharge when these items are operating and the engine speed is reduced.

8.4.5 Throttle Control

The engine throttle is connected to the governor speed control shaft through linkage. Speed control shaft movement changes the governor speed setting and the engine speed.

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8.4.6 Engine Starting Switch

A switch energizes the starting motor to start the engine. Starting switches may vary in design, and their contacts must be rated sufficiently to carry the starter solenoid current. Tighten the starting switch mounting nut to 4-5.5 N·m (36-48 lb·in.) torque.

8.4.7 Engine Stop Knob (MUI Engine)

Use the stop knob to shut the engine down. When stopping an engine, reduce the engine speed to idle, and operate the engine at idle for a few minutes to permit the coolant to reduce the temperature of moving engine parts. Pull the stop knob, and hold it until the engine stops. Pulling on the stop knob manually places the injector racks in the no-fuel position. Return the stop knob to its original position after the engine stops.

NOTICE:
When an emergency shut down is necessary on a MUI engine with the spring loaded fuel injector control tubes, the stop knob should be pulled immediately, and held until the engine stops.

8.4.8 Air Shutdown-Valve

Solenoid-activated air shutdown valves are used on many Detroit Diesel engines. To ensure positive valve closure, the latch bracket on the solenoid plunger must be adjusted to permit the cam to rotate downward without interference from the latch.

NOTICE:
If not adjusted properly, the valve may not close completely when activated. It will not cut off air flow to the engine and shut it down during abnormal operating conditions. This can cause engine damage.

Refer to section ADDITIONAL INFORMATION for adjusting procedures.

8.4.9 Emergency Stop Knob (Engine Equipped with Air Shutoff-Valve)

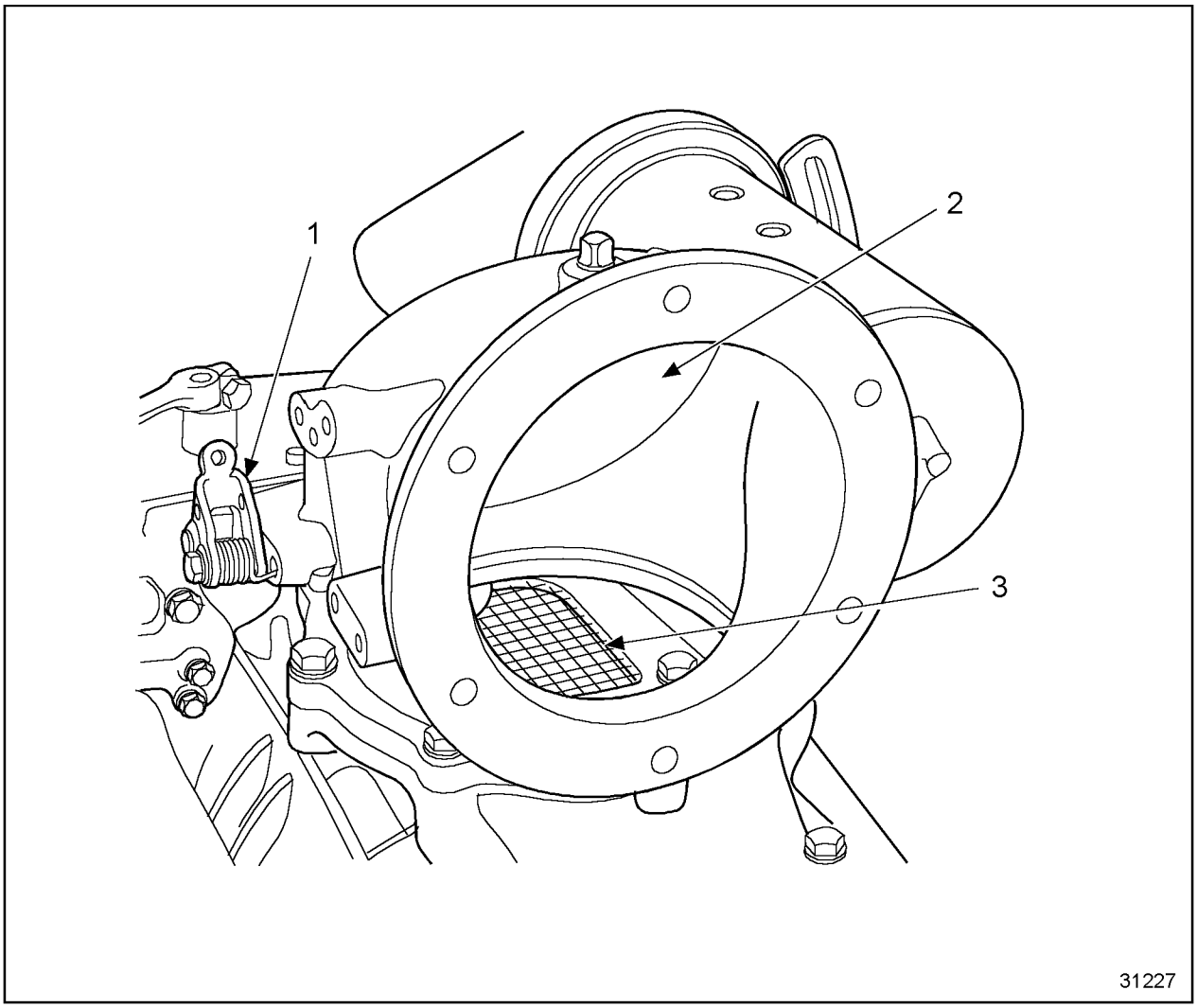
In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air shutoff valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further fuel combustion, stopping the engine.

The emergency stop knob must be pushed back in and the air shutoff valve must be reset manually after the engine is stopped. Determine the cause for malfunction before starting the engine again.

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8.5 ENGINE PROTECTIVE SYSTEMS

A manually-operated emergency engine shutdown device, mounted in the air shutdown housing, enables the engine operator to stop the engine if an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the no-fuel position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing engine overspeed, the shutdown device will cut off the air supply to stop the engine and prevent damage. The device consists of a shutdown valve mounted in the air shutdown housing and a suitable operating mechanism. See Figure 8-11.



1. Shutdown Latch Assembly
2. Air Shutdown Valve
3. Blower Screen

Figure 8-11 Manually Operated Emergency Engine Shutdown Valve Mounting

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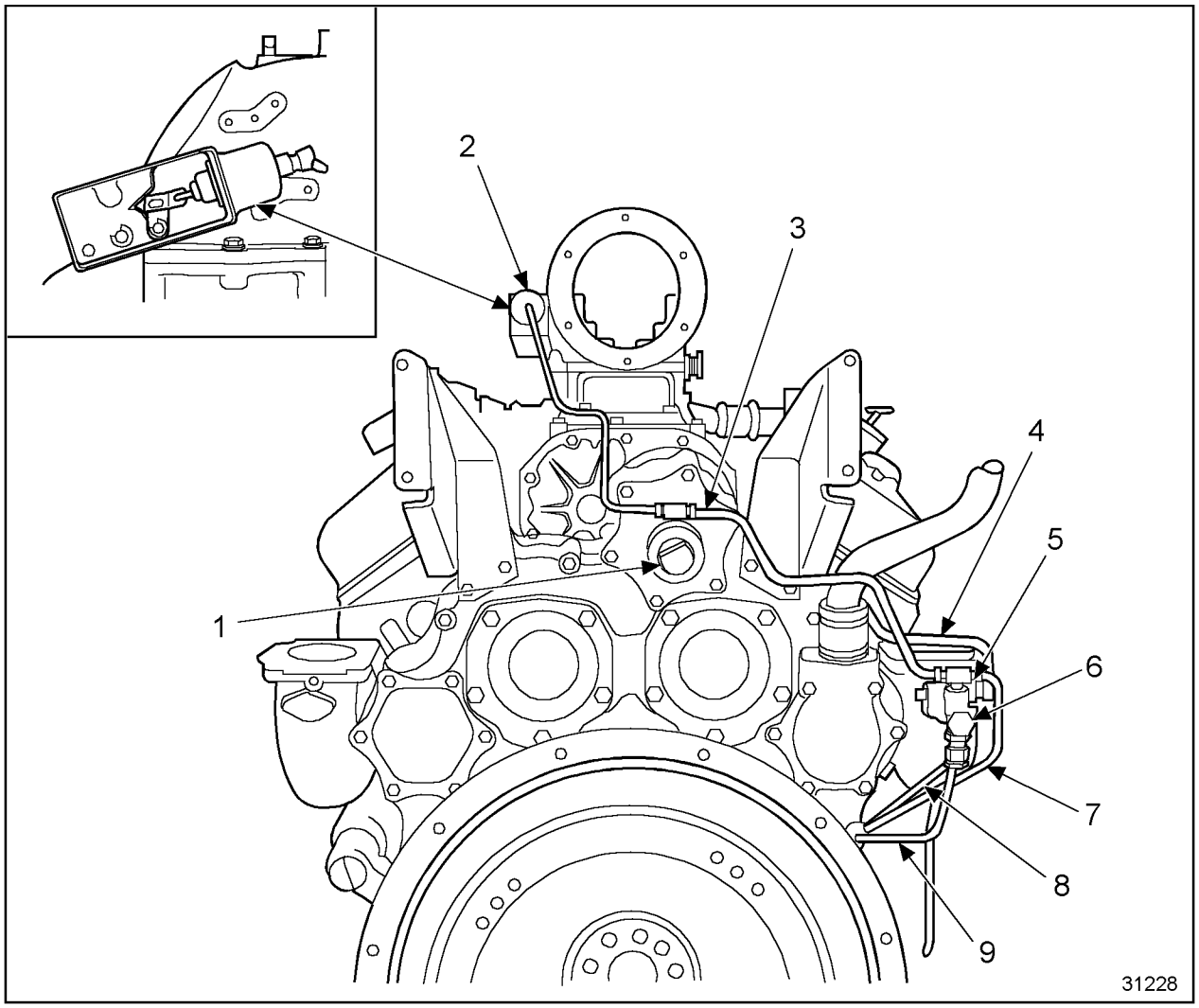
A latch retains the air shutdown valve in the open position. A bowden wire or cable assembly is used to trip the latch. Pulling the emergency shutdown knob all the way out will stop the engine. After the engine stops, push the emergency shutdown knob all the way in, and manually reset the air shutdown valve before the engine is restarted.

For manual shutdown device removal and installation or disassembly and assembly, refer to section 6.4.

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8.5.1 Automatic Mechanical Shutdown System

The automatic mechanical shutdown system stops the engine if oil pressure loss, engine coolant loss, engine coolant overheating, or engine overspeeding occurs. However, this will not guarantee protection in all circumstances. See Figure 8-12. Engine oil pressure is utilized to activate the system components.



1. Overspeed Governor
2. Oil Pressure Bellows
3. Oil Line
4. Tube-to-Water Pump
5. Plug and Adaptor
6. Temperature Sensing Valve
7. Oil Supply
8. Water Tube-to-Oil Cooler
9. Oil Return

Figure 8-12 Typical Automatic Mechanical Shutdown System Mounting

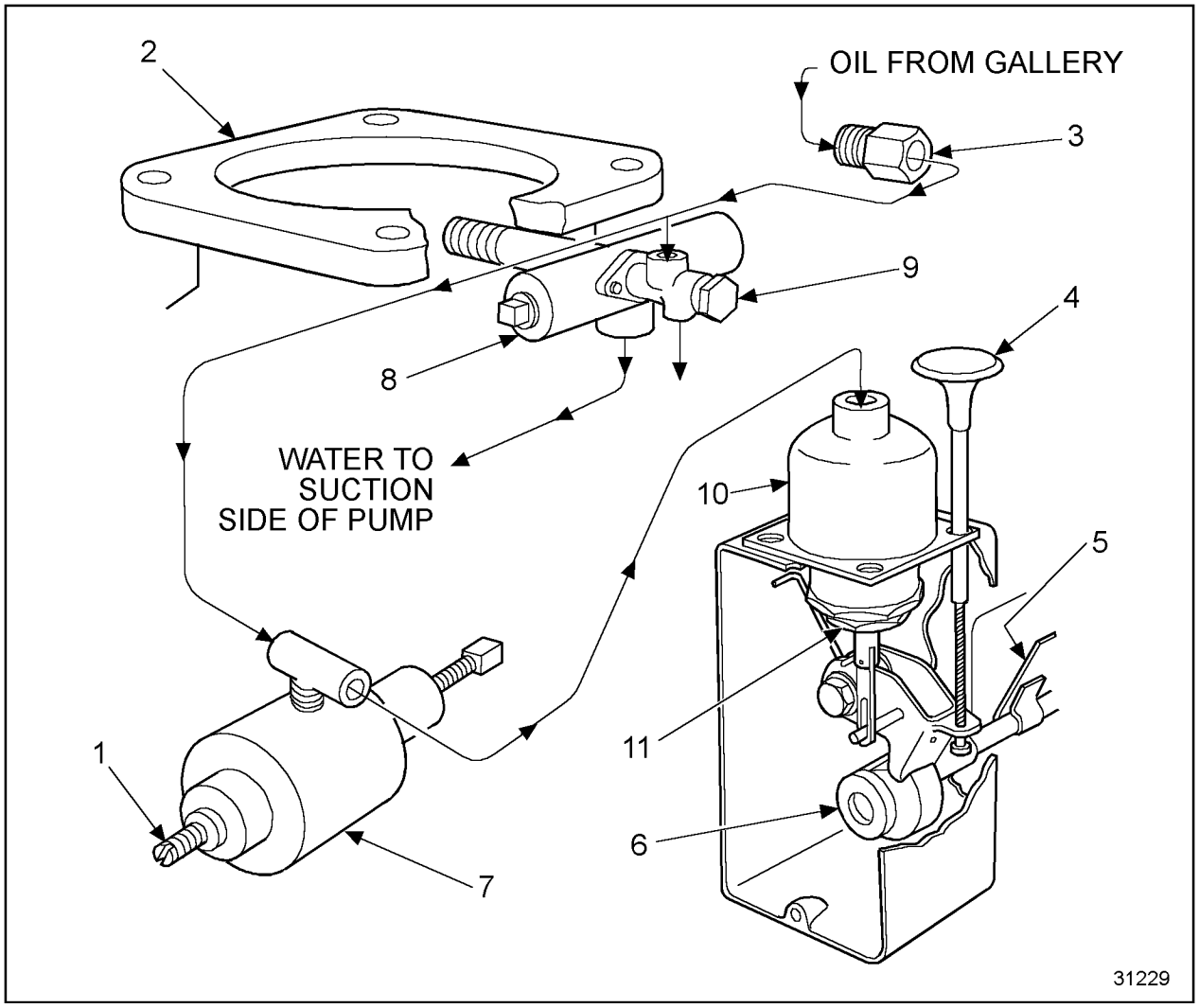
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A coolant temperature-sensing valve, an adaptor, and copper plug assembly are mounted on the exhaust manifold outlet. The temperature-sensing valve power element is placed against one end of the copper plug, and the other end of the plug extends into the exhaust manifold. Engine coolant is directed through the adaptor and passes over the valve power element. Engine oil, under pressure, is directed through a restricted fitting, to the temperature-sensing valve, and to an oil pressure actuated bellow located on the air inlet housing.

The pressure of the oil entering the bellows overcomes the bellows spring tension and permits the latch to retain the air shutdown valve in the open position. If the oil pressure drops below a predetermined value, the bellows spring will release the latch and permit the air shutdown valve to close, stopping the engine.

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A set of spring-loaded weights actuates the overspeed governor valve. See Figure 8-13. Engine oil is supplied to the valve through a connection in the oil line between the bellows and the temperature-sensing valve. An outlet in the governor valve is connected to the engine oil sump. Whenever the engine speed exceeds the overspeed governor setting, the valve moves from its seat and permits the oil to flow to the engine sump. This decreases the oil pressure to the bellows which actuates the shutdown mechanism and stops the engine.



1. Adjusting Screw
2. Exhaust Manifold
3. Restricted Fitting
4. Emergency Shutdown Cable
5. Air Shutdown Valve
6. Cam and Latch Mechanism
7. Overspeed Governor
8. Copper Plug and Adaptor
9. Temperature Sensing Valve
10. Oil Bellows
11. Low Oil Pressure Adjusting Screw

Figure 8-13 Schematic Drawing of Automatic Mechanical Shutdown System with Overspeed Governor

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8.5.1.1 Operation of Automatic Mechanical Shutdown System

To start an engine equipped with a mechanical shutdown system, manually open the air shutdown valve, and press the engine starting switch. As soon as the engine starts, the starting switch may be released, but the air shutdown valve must be held in the open position until the engine oil pressure increases sufficiently for the bellows to retain the latch in the open position.

During operation, if the engine oil pressure drops below the setting of the pressure sensitive bellows, the spring within the bellows will release the latch and permit the air shutdown valve to close, stopping the engine.

If the engine coolant overheats, the temperature-sensing valve will open and permit the oil in the protective system to flow to the engine crankcase. The resulting decrease in oil pressure will actuate the shutdown mechanism and stop the engine. If the engine loses its coolant, passing hot exhaust gases will overheat the plug and cause the temperature-sensing valve to open, actuating the shutdown mechanism.

Whenever the engine speed exceeds the overspeed governor setting, the oil in the line flows to the sump, resulting in an oil pressure decrease. The oil pressure bellows release the latch and permit the air shutdown valve to close.

When an engine is stopped by the action of the shutdown system, the engine cannot be started again until the particular device which actuated the shutdown mechanism has returned to its normal position. The abnormal condition which caused the engine to stop must be corrected before attempting to start it again.

8.5.1.2 Adjustment of Automatic Mechanical Shutdown System

The only adjustments necessary in the mechanical shutdown system are the bellows low oil pressure setting and the overspeed governor overspeed setting. Replace the temperature-sensing valve when operation is unsatisfactory.

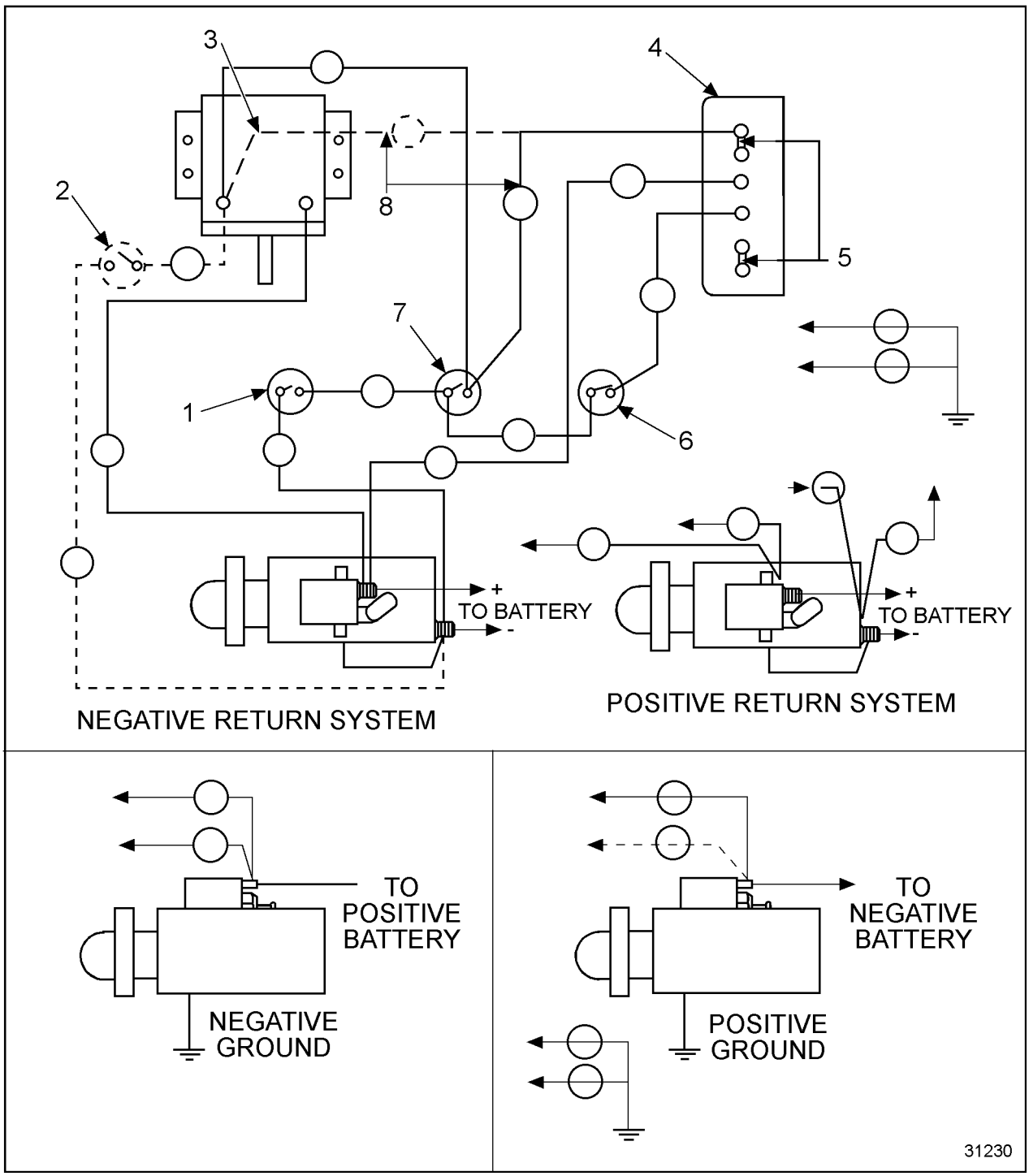
To adjust the low oil pressure setting of the bellows, run the engine until normal operating temperature (71-85°C or 160-185°F) has been reached and the oil pressure has stabilized. Reduce the engine speed slowly until the bellows disengage the latch on the air shutdown valve and stop the engine. Note the oil pressure at which the shutdown occurred. The oil pressure at disengagement should be 34-69 kPa (5-10 lb/in.^{2}) at 45-600 RPM; 69-103 kPa (10-15 lb/in.^{2}) at 601-140 RPM; or 103-138 kPa (15-20 lb/in.^{2}) at 1401 and above RPM. If adjustment is necessary, loosen the locknut on the bellows, and turn the adjusting screw, and tighten the locknut when the proper setting has been obtained.

NOTE:
Set the bellows disengagement pressure as near as possible to the high end of the pressure range for the low engine speed specified for the engine.

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8.5.2 Automatic Electrical Shutdown System

The automatic electrical shutdown system protects the engine against coolant loss, coolant overheating, oil pressure loss, or overspeeding. See Figure 8-14. If one of these conditions arises, a switch will close the electrical circuit and energize the solenoid switch, causing the shutdown solenoid to release the air shutdown latch and stop the engine.



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1. Fuel Oil Pressure Switch
2. Optional Overspeed Governor
3. Shutdown Solenoid
4. Time Relay Switch
5. Shorting Jumpers
6. Lube Oil Pressure Switch
7. Water Temperature Switch
8. Optional Connection

Figure 8-14 Automatic Electrical Shutdown System Diagram

8.5.2.1 Operation of Automatic Electrical Shutdown System

The electrical circuit is de-energized under normal operating conditions. When the engine is started, one oil pressure switch opens when the oil pressure reaches approximately 69 kPa (10 lb/in.^{2}) and the fuel oil pressure switch closes at approximately 138 kPa (20 lb/in.^{2}) fuel pressure.

If the oil pressure drops below 69 kPa (10 lb/in.^{2}), the oil pressure switch will close the circuit and energize the shutdown solenoid. This will activate the shutdown mechanism and stop the engine.

A coolant loss or a coolant temperature increase in the cylinder block to approximately 95°C (203°F) will close the contacts in the water temperature switch, closing the electrical circuit and activating the shutdown mechanism.

The water temperature switch consists of a temperature-sensing element and a micro-switch. The element contacts a copper plug (heat probe), which extends into the exhaust manifold outlet. Engine coolant is directed over the temperature-sensing element in the switch. Should the coolant temperature in the cylinder block exceed approximately 95°C (203°F), the element will close the contacts in the micro-switch and energize the shutdown circuit. If coolant loss occurs, the exhaust gas heat will transmit through the copper plug to the temperature-sensing element. The shutdown circuit will stop the engine.

In the event of an automatic shutdown, determine the problem, and correct it before starting the engine. Manually reset the air shutdown valve in the open position before restarting the engine.

When the engine is shutdown, the decrease in oil and fuel pressure will close the oil pressure switches and open the fuel pressure switch, de-energizing the circuit.

Some engines are equipped with an electrically operated automatic shutdown system which incorporates a time delay switch.

Since the fuel pressure builds up rapidly, the fuel oil pressure switch could close before the lubricating oil pressure switch opens, causing an engine shutdown. The time delay switch delays solenoid operation for 3 to 10 seconds, enabling the lubricating oil pressure to build up and open the oil pressure switch contacts.

When the lubricating oil pressure falls below 69 ± 7 kPa (10 ± 2 lb/in.^{2}), the contacts in the oil pressure switch will close, and current will flow to the time delay switch.

The few seconds required to heat the time delay switch provides sufficient delay to avoid an engine shutdown when low oil pressure is caused by a temporary condition such as an air bubble or a temporary overlap in the operation of the oil pressure switch and the fuel oil pressure switch when starting or stopping the engine.

8.5.3 Shutdown System for Direct Mounted Turbocharged Engines

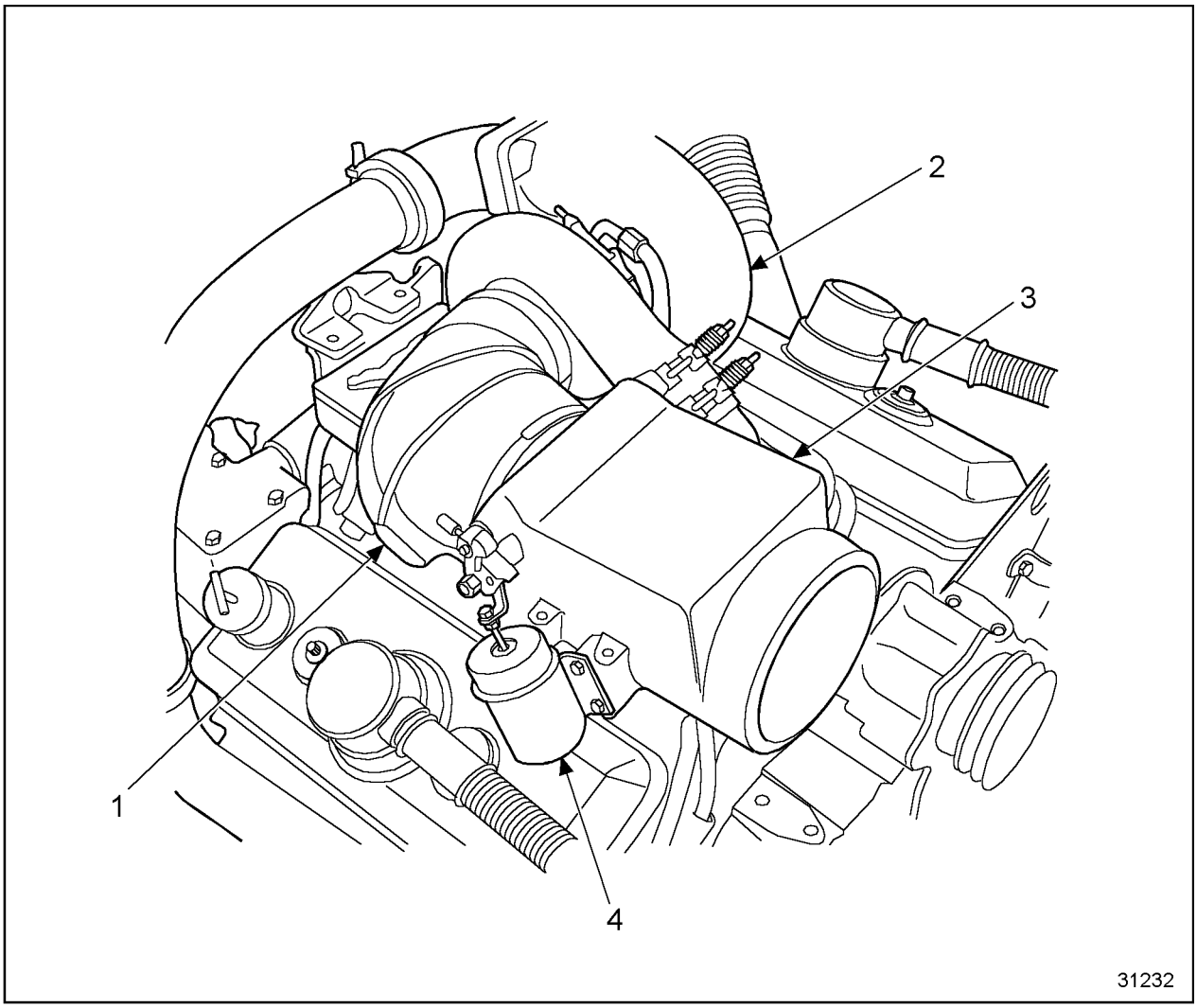
With a direct mounted turbocharger and spring loaded MUI fuel injector control racks, the air shutoff valve was eliminated from the air inlet housing. The spring loaded injector control racks enable the engine to come out of any advanced fuel position when an emergency situation arises.

When an engine is operating in an atmosphere subject to volatile fuel and is equipped with an air inlet housing without the air shutdown valve, an external or remote mounted emergency air shutdown assembly can be added.

The remote mounted emergency air shutdown assembly that is equipped with the air shutdown valve can be installed upstream of the turbocharger air inlet side.

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Care should be taken when installing the emergency air shutdown assembly between the turbocharger and the air cleaner. See Figure 8-15.



1. Rubber Elbow
2. Turbocharger
3. Shutdown Assembly
4. Solenoid

Figure 8-15 Emergency Shutdown Assembly (Direct Mounted Turbocharger)

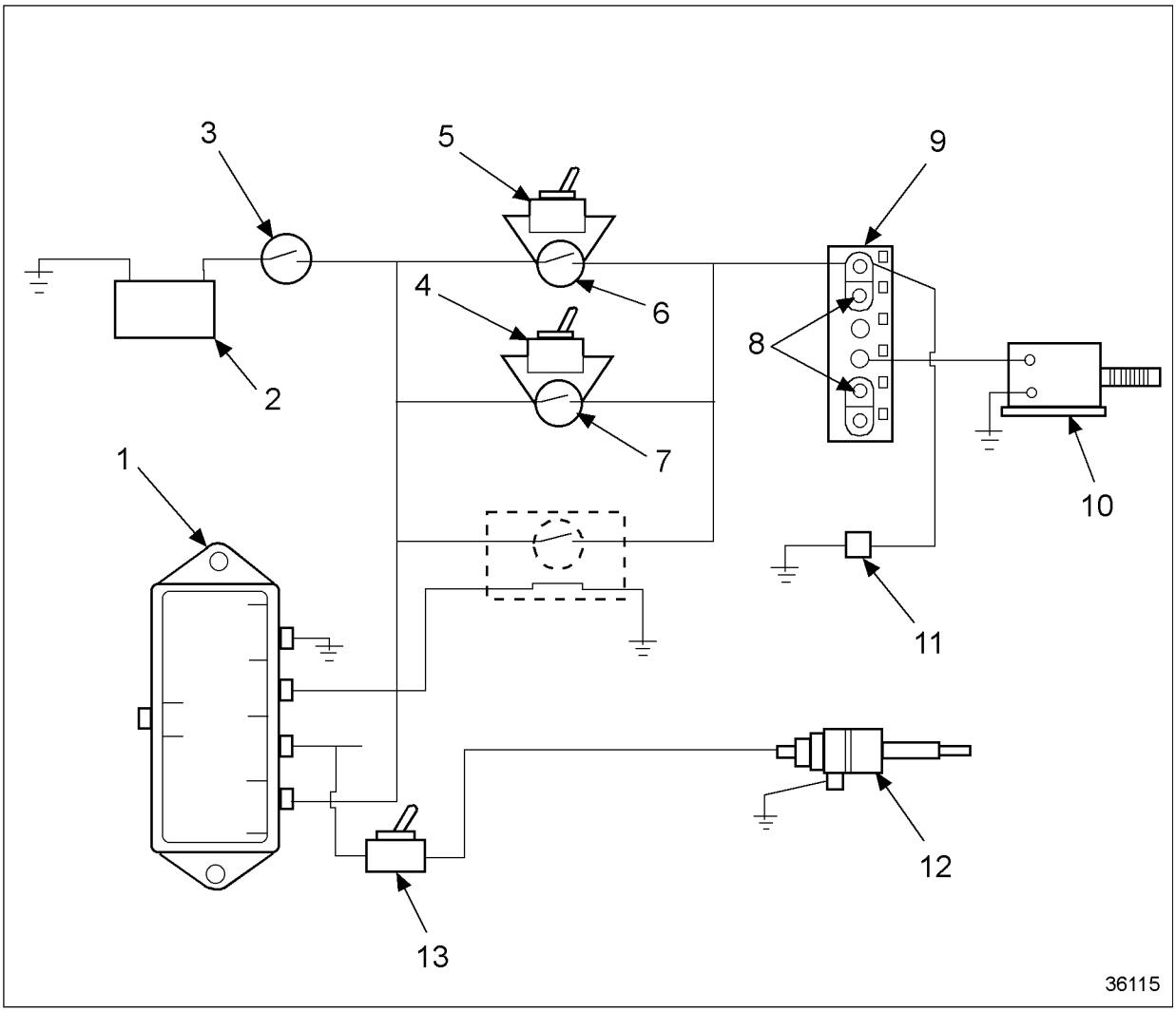
A 7 to 5 inch diameter reducing 90 degree rubber hose or a 7 to 5 inch diameter hump hose reducer can be used to adapt the shutdown to the turbocharger.

The emergency air shutdown assembly is typically manually operated. Install a solenoid to make it automatic.

To ensure positive emergency engine shutdown, a dual-solenoid shutdown system has replaced the former single-solenoid/latch lever connecting rod shutdown system on all 16V-TA marine engines, effective February 1, 1996. Refer to section ADDITIONAL INFORMATION.

An automatic electric shutdown system with solid state low coolant protection is used on some industrial and off-highway engine applications. This system incorporates many of the same components as the automatic electrical shutdown systems. This system protects the engine against low coolant level, coolant overheating, and oil pressure loss. See Figure 8-16 and see Figure 8-17.

NOTE:
Diagram represents the switch positions during normal engine operation.

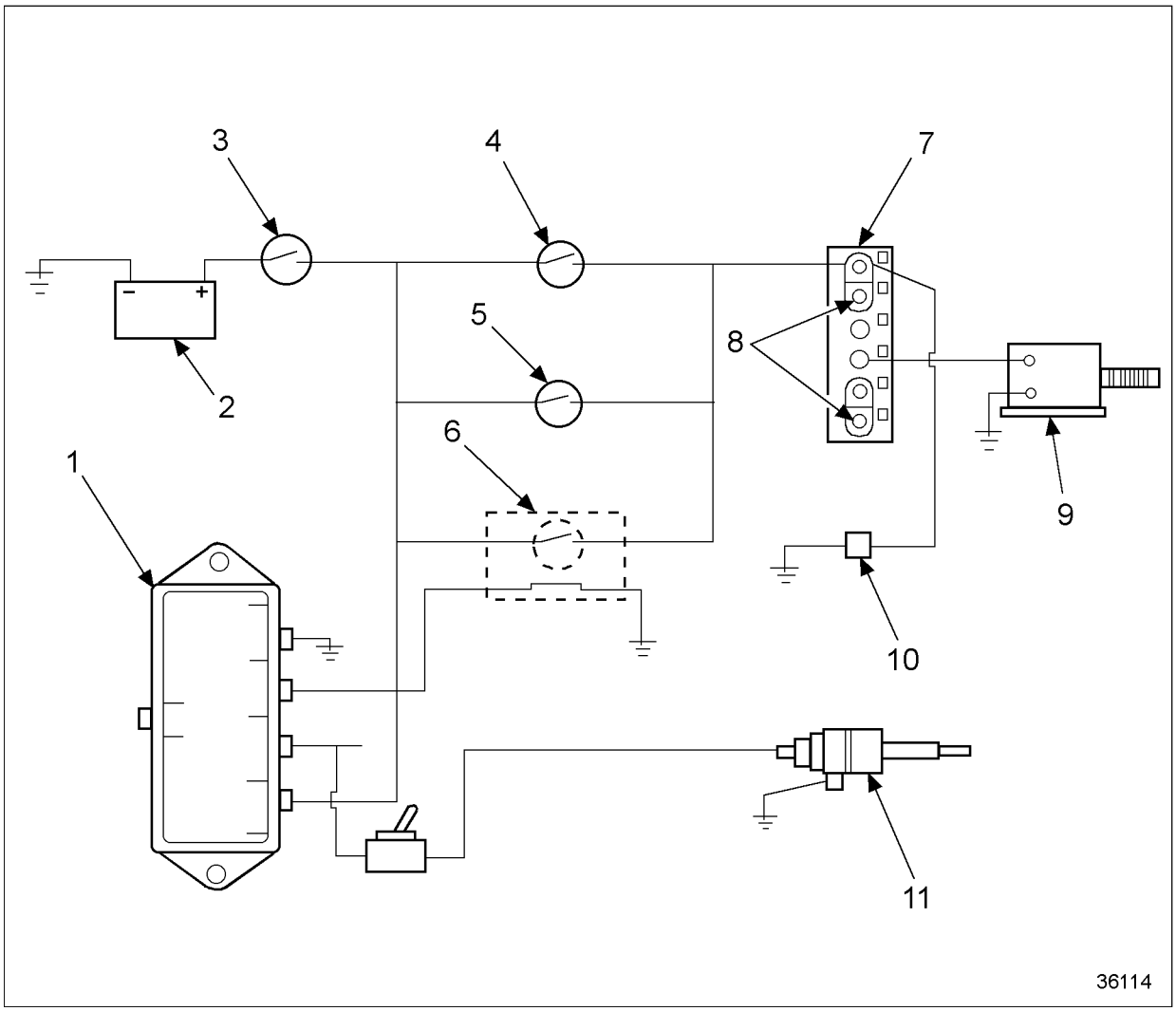


1. Coolant Level Module
2. Battery 12VDG
3. Fuel Pressure Switch
4. SPST Switch Installed
5. SPST Switch Installed
6. Oil Pressure Switch
7. Coolant Temperature Switch
8. Jumpers
9. Time Delay Switch
10. Shutdown Solenoid
11. Optional Warning Buzzer/Light 24 Max
12. Coolant Level Probe
13. SPST Switch Installed

Figure 8-16 Electrical Diagram (1 of 2)

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NOTE:
Diagram represents the switch positions during normal engine operation.



1. Coolant Level Module
2. Battery 12VDG
3. Fuel Pressure Switch
4. Oil Pressure Switch
5. Coolant Temperature Switch
6. Coolant Level Relay
7. Time Delay Switch
8. Jumpers
9. Shutdown Solenoid
10. Optional Warning Buzzer/Light 24 Max
11. Coolant Level Probe

Figure 8-17 Electrical Diagram (2 of 2)

If one of the preceding conditions occur, a switch will close the electrical circuit and energize the time delay switch, shutting the solenoid down to release the air shutdown latch and stop the engine.

There are no failure mode diagnostics associated with the shutdown systems used on mechanically governed engines. Systems must be periodically tested to ensure proper operation. Perform preventive maintenance every 20,000 miles or 700 hours, whichever occurs first. Refer to section 13.50.

The automatic electrical shutdown system with solid state low coolant protection is comprised of three shutdown switches wired in parallel to a solid state time delay switch (TDS). If one or more of the switches closes, the TDS starts an 8-10 second clock before energizing the shutdown solenoid. A fuel pressure switch, wired in series with battery voltage and the shutdown circuit, enables the system.

8.5.3.1 Check Engine Coolant Temperature Sensing Valve Operation on Mechanical Shutdown Systems

Perform the following to check the operating of the engine coolant temperature sensing valve on mechanical shutdown systems as follows:

NOTICE:
If the temperature-sensing valve is removed, examine the temperature shutdown valve plunger in the copper probe. If it is not free in the probe and adaptor, install a new plunger, spring, and adaptor. Deposits from the engine coolant building up between the plunger spring and plug can cause the plunger to stick in the probe.

1. Place a cover over the radiator while the engine is operating at part load.
2. Observe the coolant outlet temperature at which the bellows disengage the air shutdown latch.

NOTE:
The air shutdown valve should close and stop the engine within 92-99°C (200 -210°F).

[a] If the engine does not shut down in this range, replace the temperature-sensing valve.

[b] If the engine shuts down below 93°C (200°F), check the coolant flow through the plug and adaptor assembly.

[c] If circulation is satisfactory, replace the temperature-sensing valve.

[d] If the engine shuts down in the specified range, continue inspection.

8.5.3.2 Bench Test the Temperature-Sensing Valve on Mechanical Shutdown Systems

Bench test the temperature-sensing valve as follows:

1. Attach an air hose to the oil inlet side, and install a tube from the outlet side to a can of water.

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2. Immerse the valve power element in a container of water that is heated, and agitate the container.
3. Check the water temperature with a thermometer.

> **⚠ 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. Apply air to the valve.

NOTE:
Air flow at a 91-96°C (195-206°F) water temperature indicates that the valve is open.

[a] If air does not flow at the specified temperature, replace the valve.

[b] If air flows at the specified temperature, continue inspection.

To adjust the overspeed governor, run the engine until normal operating temperature is reached. Increase the engine speed to the desired overspeed shutdown speed. At this speed, the bellows should disengage the air shutdown latch and stop the engine. If necessary, adjust the overspeed governor setting by loosening the locknut on the adjusting screw at the rear of the governor, and turn the screw clockwise to increase the shutdown speed or counterclockwise to decrease the shutdown speed. After the proper setting is obtained, tighten the locknut while holding the adjusting screw.

8.5.3.3 Inspection of Engine Protective System

Inspect the engine protective system as follows:

1. If the temperature-sensing valve is removed, examine the temperature shutdown valve plunger in the copper probe.

   [a] If it is not free in the probe and adaptor, install a new plunger, spring and adaptor.

   [b] If it is free in the probe and adaptor, continue inspection.

NOTE:
Deposits from the engine coolant building up between the plunger, spring, and plug can cause the plunger to stick in the probe.

2. Visually inspect all electrical components and wiring for any deterioration.

   [a] If deteriorated, replace.

   [b] If not deteriorated, proceed with inspection.

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8.5.3.4 Inspection of Engine Coolant Temperature Sensing Valve

Inspect the engine coolant temperature sensing valve as follows:

1. Place a cover over the radiator while the engine is operating at part load.
2. Observe the coolant outlet temperature at which the bellows disengages the air shutdown latch.

NOTE:
The air shutdown valve should close and stop the engine within 92-99°C (200-210°F).

[a] If the engine does not shut down in this range, replace the temperature-sensing valve.

[b] If the engine shuts down below 93°C (200°F), check the coolant flow through the plug and adaptor assembly.

[c] If circulation is satisfactory, replace the temperature-sensing valve.

[d] If the engine shuts down in the specified range, continue inspection.

8.5.3.5 Temperature Sensing Valve Bench Test

Bench test the temperature-sensing valve as follows:

1. Attach an air hose to the oil inlet side, and install a tube from the outlet side to a can of water.
2. Immerse the valve power element in a container of water that is heated, and agitate the container.
3. Check the water temperature with a thermometer.

⚠ 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. Apply air to the valve.

NOTE:
Air flow at a 91-96°C (195-206°F) water temperature indicates that the valve is open.

[a] If air does not flow at the specified temperature, replace the valve.

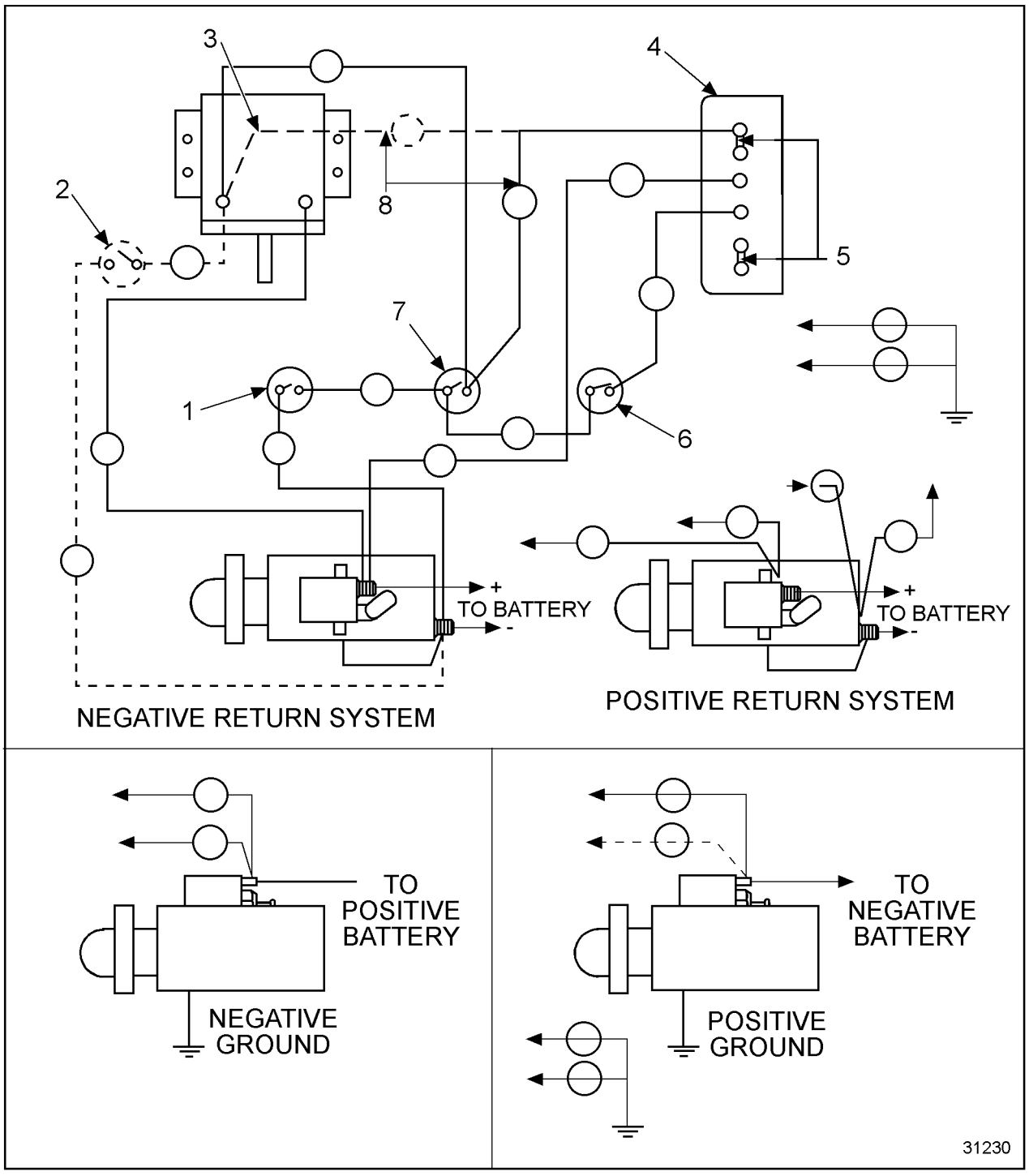
[b] If air flows at the specified temperature, continue inspection.

8.5.3.6 Solid State Time Delay Switch Bench Test

Bench test the solid state time delay switch as follows:

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1. Remove the time delay switch from the engine. See Figure 8-18.

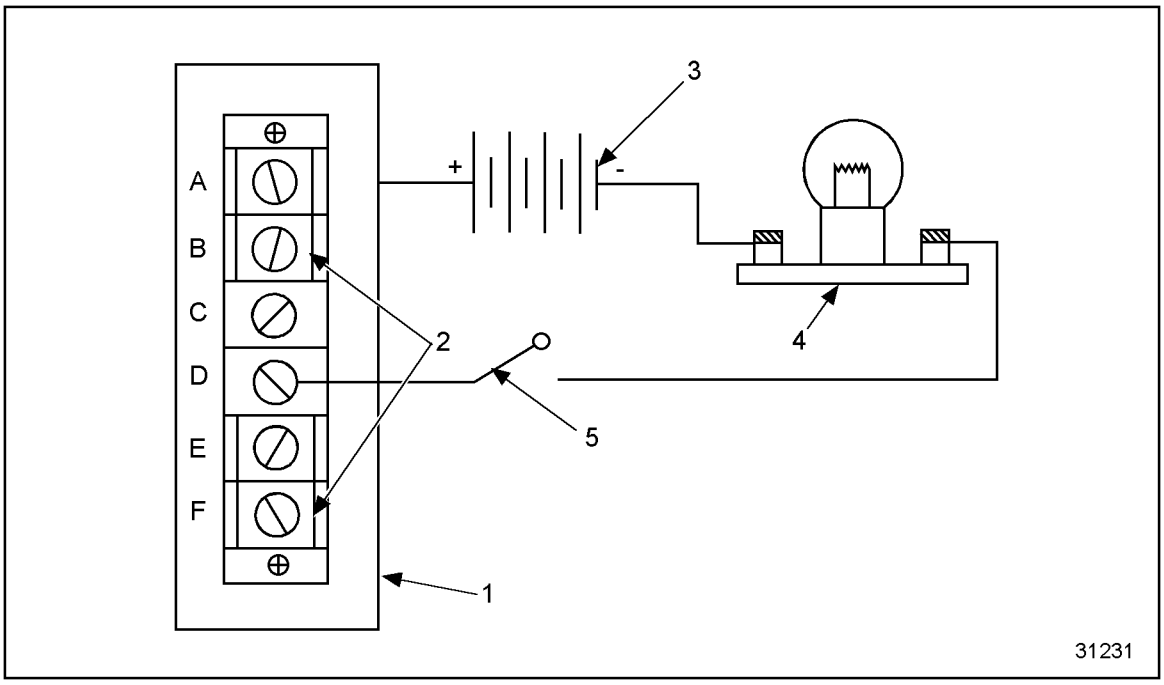


1. Fuel Oil Pressure Switch
2. Optional Overspeed Governor
5. Shorting Jumpers
6. Lube Oil Pressure Switch

3. Shutdown Solenoid
4. Time Delay Switch
7. Water Temperature Switch
8. Optional Connection

Figure 8-18 Automatic Electrical Shutdown System Diagram

2. Install the jumper straps on terminals A to B and E to F. See Figure 8-19.



1. Time Delay Switch
2. Jumper Straps
3. 12 Volt Battery
4. 12 Volt Light
5. Switch

Figure 8-19 Solid State Time Delay Switch Testing Diagram

3. Install a positive battery lead to terminal A.
4. Install a negative battery lead to one side of a 12 volt light.
5. Install a lead from the opposite side of the light to terminal D. A switch may be used in this lead, if desired.
6. After the negative lead is connected to terminal D or the switch is closed, the lamp should light in 8 to 10 seconds.
   [a] If the lamp does not light up, replace the time delay switch.
   [b] If the lamp lights, continue inspection.

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8.5.3.7 Automatic Electrical Shutdown System with Solid State Low Coolant Protection Test

To test the shutdown system, simulate abnormal engine operating conditions as follows:

1. Connect a 10 amp single pole single throw (SPST) switch and two jumper leads (No. 14 gage wire minimum) with clips across each engine shutdown switch.
2. Toggle the switch with the engine running, simulating an abnormal engine operating condition.
   [a] If the shutdown solenoid does not energize between 8-10 seconds and the engine does not stop after a few seconds, reset the air shutdown latch and proceed to the next test.
   [b] If the engine does not stop within a few additional seconds, stop the engine with the mechanical shutdown.
   [c] If the solenoid energizes between 8-10 seconds and the engine stops after a few seconds, reuse the parts.

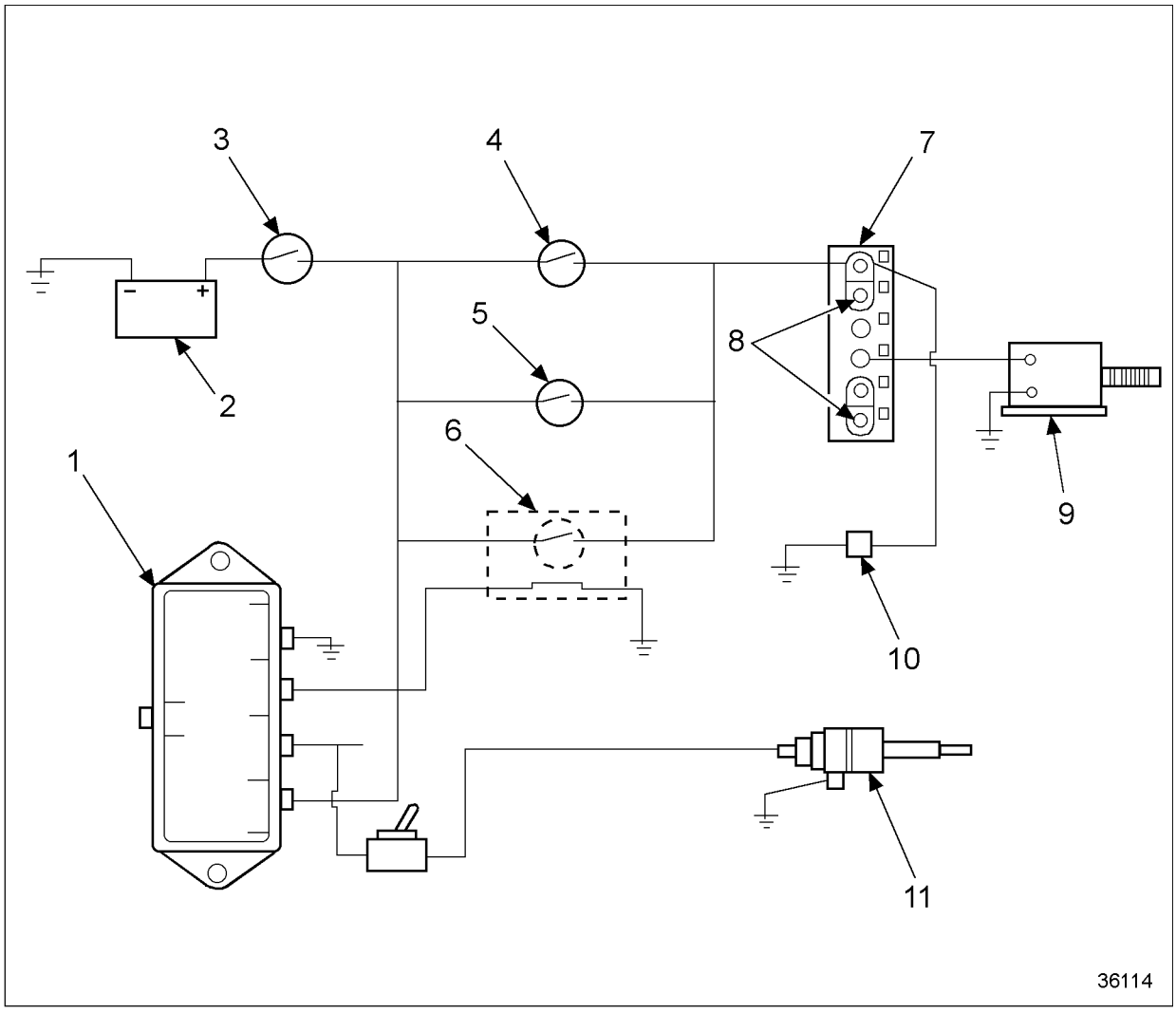
Perform the second test as follows:

1. With the engine not running, install the SPST switch and jumper leads across the oil pressure switch. See Figure 8-20.

NOTE:
Ensure the SPST switch is in the "OFF" position before conducting the test.

NOTE:
Diagram represents the switch positions during normal engine operation.

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1. Coolant Level Module
2. Battery 12VDG
3. Fuel Pressure Switch
4. Oil Pressure Switch
5. Coolant Temperature Switch
6. Coolant Level Relay
7. Time Delay Switch
8. Jumpers
9. Shutdown Solenoid
10. Optional Warning Buzzer/Light 24 Max
11. Coolant Level Probe

Figure 8-20 Electrical Diagram

2. Start the engine and allow it to run at idle speed. Let the engine run for a few moments.
3. Toggle the SPST switch to the "ON" position.
   [a] If the engine stops, proceed to step 3[b].
   [b] If the engine does not stop, shut down the engine, determine and correct the cause.

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4. Remove the SPST switch assembly from the oil pressure switch, and install it across the coolant temperature switch terminals.

NOTE:
Ensure SPST switch is in the "OFF" position.

5. Start the engine, and allow it to run at idle speed.
6. After the engine has been running for a few minutes, toggle the SPST switch to the "ON" position.
   [a] If the engine stops, continue to step 6[b].
   [b] If the engine does not stop, shut down the engine, determine and correct the cause.
7. Remove the SPST switch assembly from the coolant temperature switch.
8. Disconnect the wire which terminates at the No. 2 terminal of the coolant level module.
9. Install the SPST switch between this wire and the No. 2 terminal of the coolant level module.

NOTE:
Ensure SPST switch in the "ON" position.

10. Start the engine, and allow it to run at idle speed.
11. After the engine has run for a few moments, toggle the SPST switch to the "OFF" position.
    [a] If the engine stops, proceed to step 11[b].
    [b] If the engine does not stop, shutdown the engine, determine and correct the cause.
12. Remove the SPST switch assembly from the circuit, and connect the wire removed from the number 2 terminal of the coolant level module.

8.5.3.8 Inspection of Automatic Electrical Shutdown System with Solid State Low Coolant Protection

Inspect the automatic electrical shutdown system with solid state low coolant protection as follows:

NOTE:
Clean and inspect the coolant level probe at service intervals.

1. Clean contaminants from the probe center.
2. Inspect the nylon bushing between the probe center and probe base for cracks.
   [a] If cracked, replace the probe.
   [b] If not cracked, continue inspection.
3. Using a volt-ohm meter, check for continuity between the probe center and probe base.
   [a] If there is incontinuity, replace the probe.

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[b] If there is continuity, continue inspection.

4. Inspect nylon bushing for cracks.

[a] If cracked, replace the probe.

[b] If not cracked, reuse the probe.

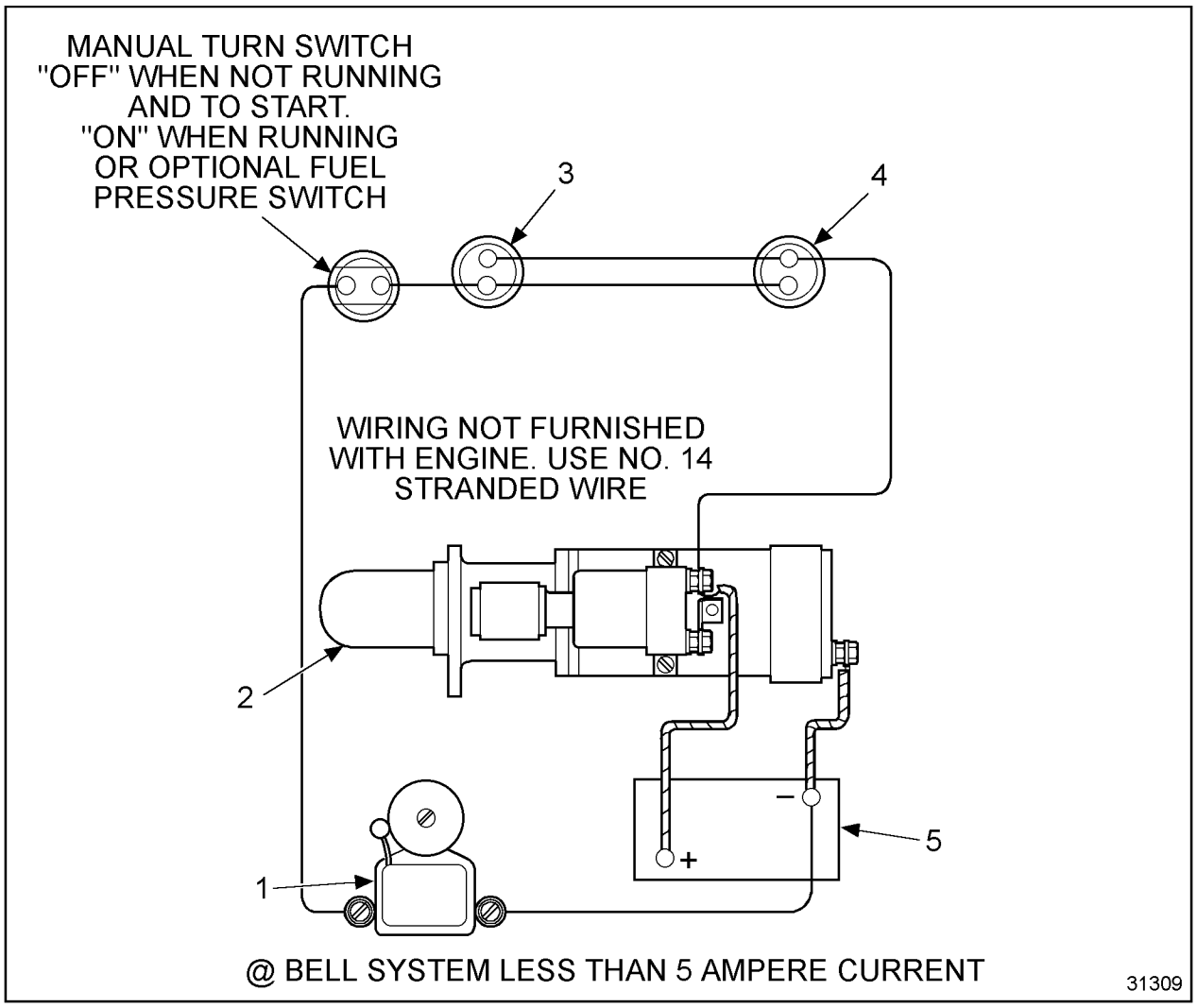
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8.6 ALARM SYSTEM

The alarm system is similar to the automatic electrical shutdown system, but uses a warning bell in place of the air shutdown valve solenoid. The bell warns the engine operator if the engine coolant overheats or the oil pressure drops below the oil pressure switch setting.

When the engine is started and the oil pressure is sufficient to open the oil pressure switch contacts (opening pressure is stamped on the switch cover), the alarm switch must be turned on manually to put the system in operation. The water temperature switch is normally open. Should the engine coolant exceed 102 ± 3°C (215 ± 5°F), the water temperature switch will close the electrical circuit and sound the alarm bell. If the oil pressure drops below the oil pressure switch setting, the switch will close and cause the bell to ring. The bell will continue to ring until the engine operator turns the alarm switch off. The alarm switch must be turned off before a routine stop, since the decreasing oil pressure will close the oil pressure switch and cause the bell to ring.

The current Bell System requires less than 5 amperes to ring the bell. See Figure 8-21.

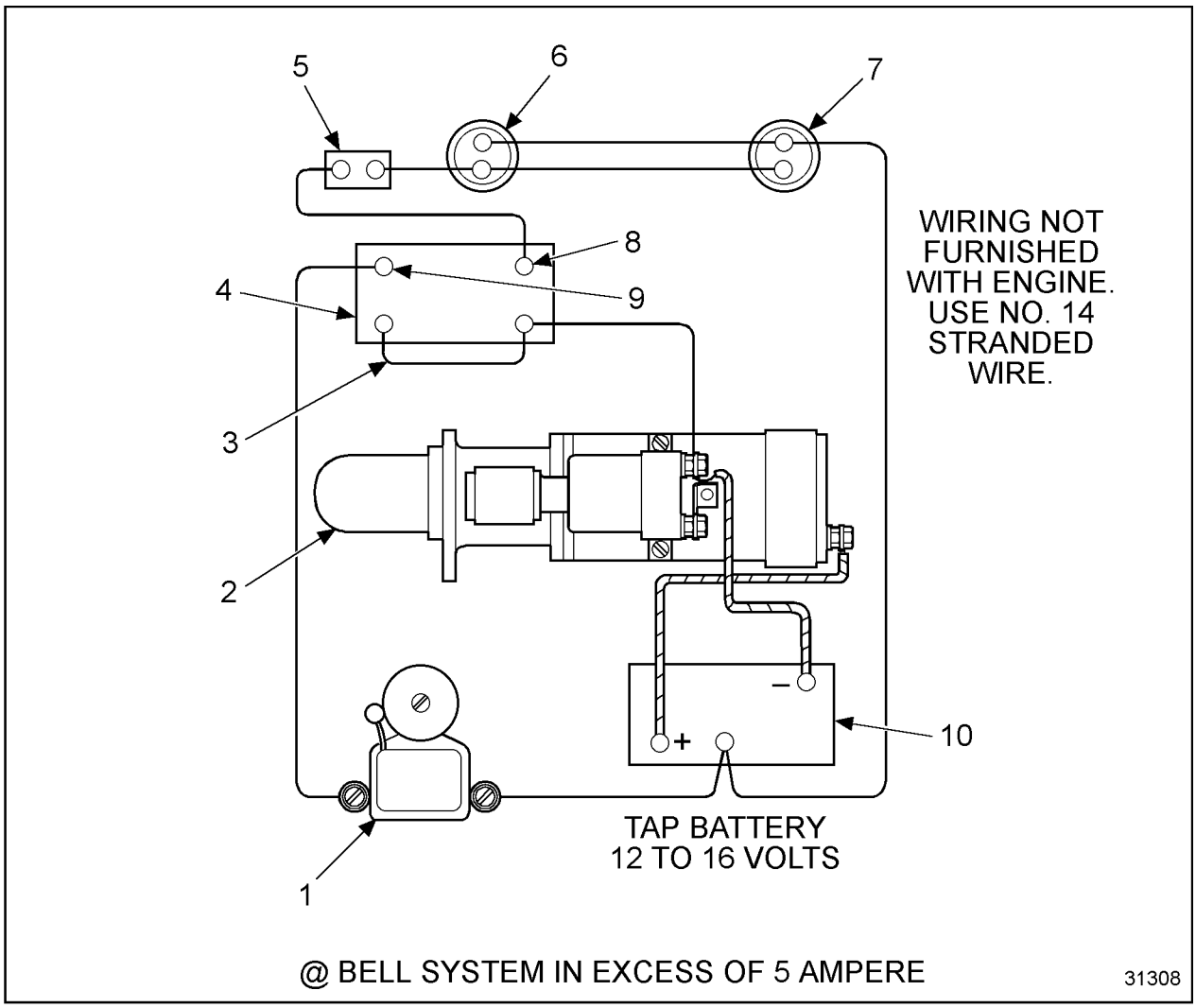


1. Alarm Bell
2. Starting Motor
3. Lube Oil Pressure Switch
4. Water Temperature Switch
5. Battery (12-16 Volt Only)

Figure 8-21 Current Alarm System Wiring Diagram

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The former Bell System requires more than 5 amperes to ring the bell. See Figure 8-22.

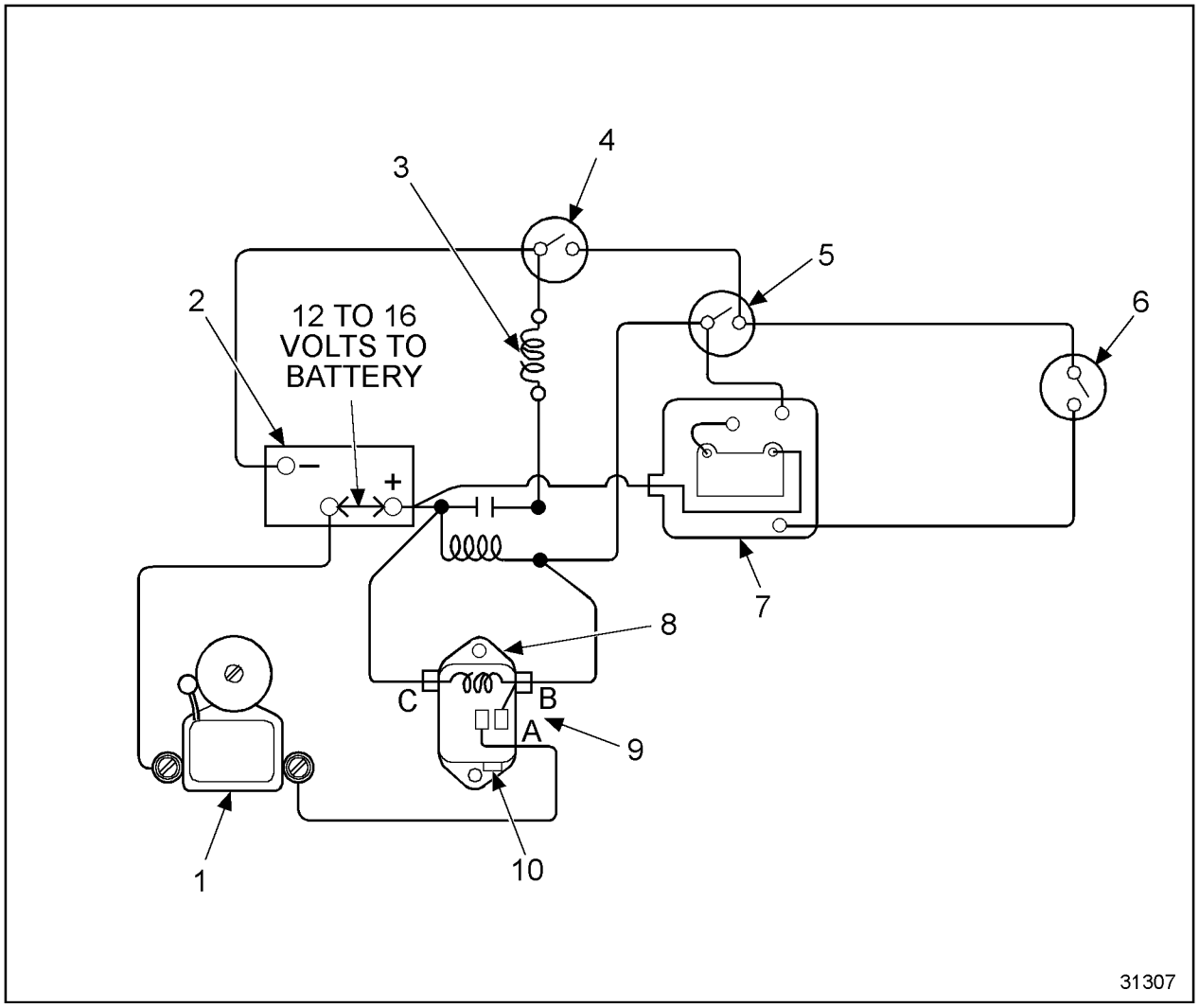


1. Alarm
2. Starting Motor
3. External Jumper
4. Relay
5. Alarm Switch
6. Oil Pressure
7. Water Temperature Switch
8. Coil
9. Contacts
10. Battery

Figure 8-22 Former Alarm System Wiring Diagram

If the alarm bell rings during engine operation, stop the engine immediately and determine the cause. Make the necessary corrections before restarting the engine.

An alarm bell may be connected to the electrical shutdown system. See Figure 8-23. If an abnormal condition occurs, the engine will stop and the alarm bell will ring. The bell will continue to ring until the operator pushes the reset button on the drop relay.

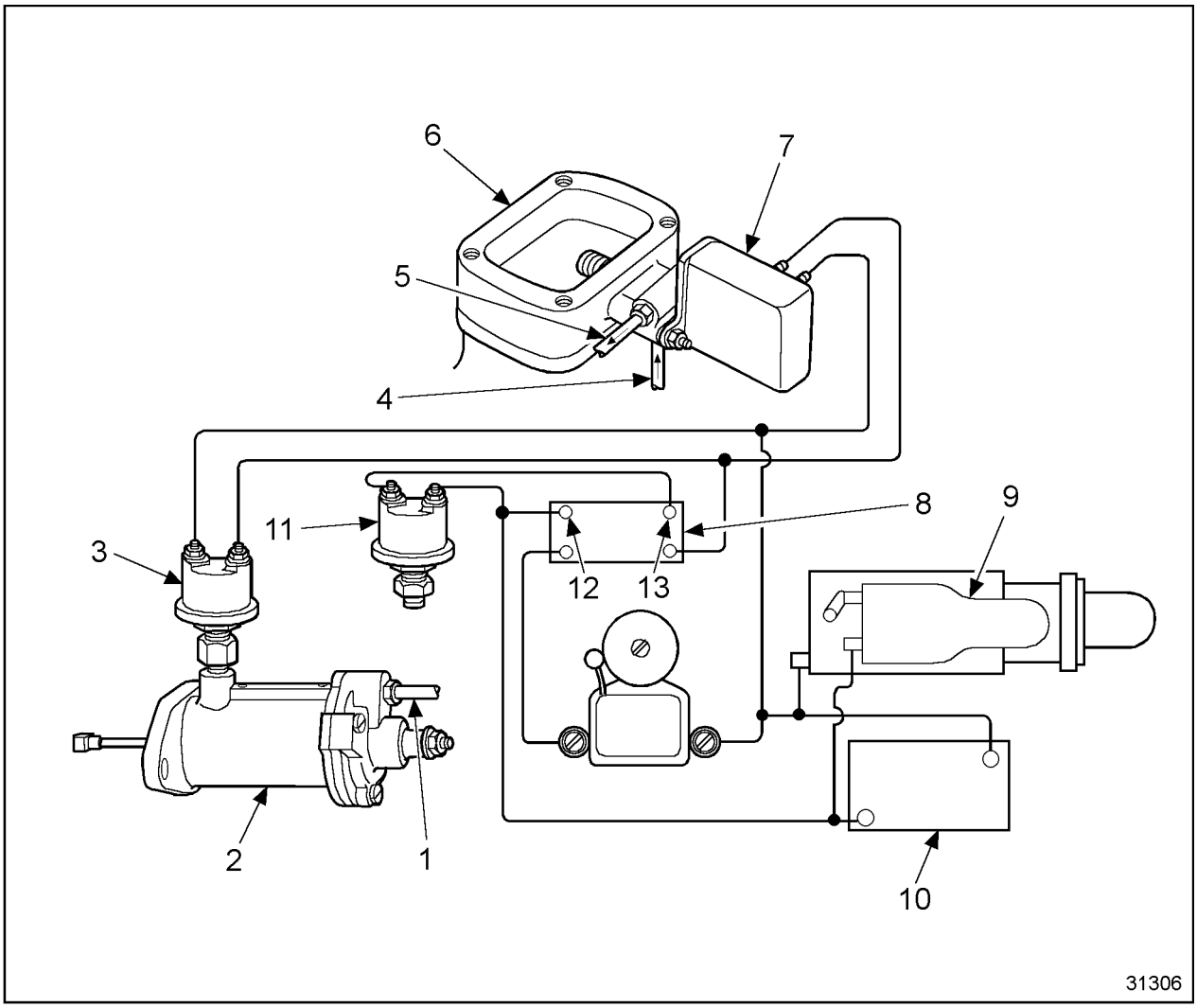


1. Bell
2. Battery
3. Shutdown Solenoid
4. Fuel Oil Pressure Switch
5. Water Temperature Switch
6. Low Oil Pressure Switch
7. Hot Wire Relay
8. Solenoid Switch
9. Drop Relay
10. Manual Reset Button

Figure 8-23 Alarm Bell Connected to Electrical Shutdown

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The alarm system utilizes the temperature-sensing switch and the low oil pressure valve. See Figure 8-24.



1. Oil Line Gallery
2. Oil Pressure Valve
3. Oil Pressure Switch
4. Water From Cylinder Block
5. Water Return to Suction Side of Pump
6. Exhaust Manifold Flange
7. Water Temperature Switch
8. Relay
9. Starter
10. Battery
11. Fuel Oil Pressure Switch
12. Contacts
13. Coil

Figure 8-24 Alarm System with Mechanical Sensing Units

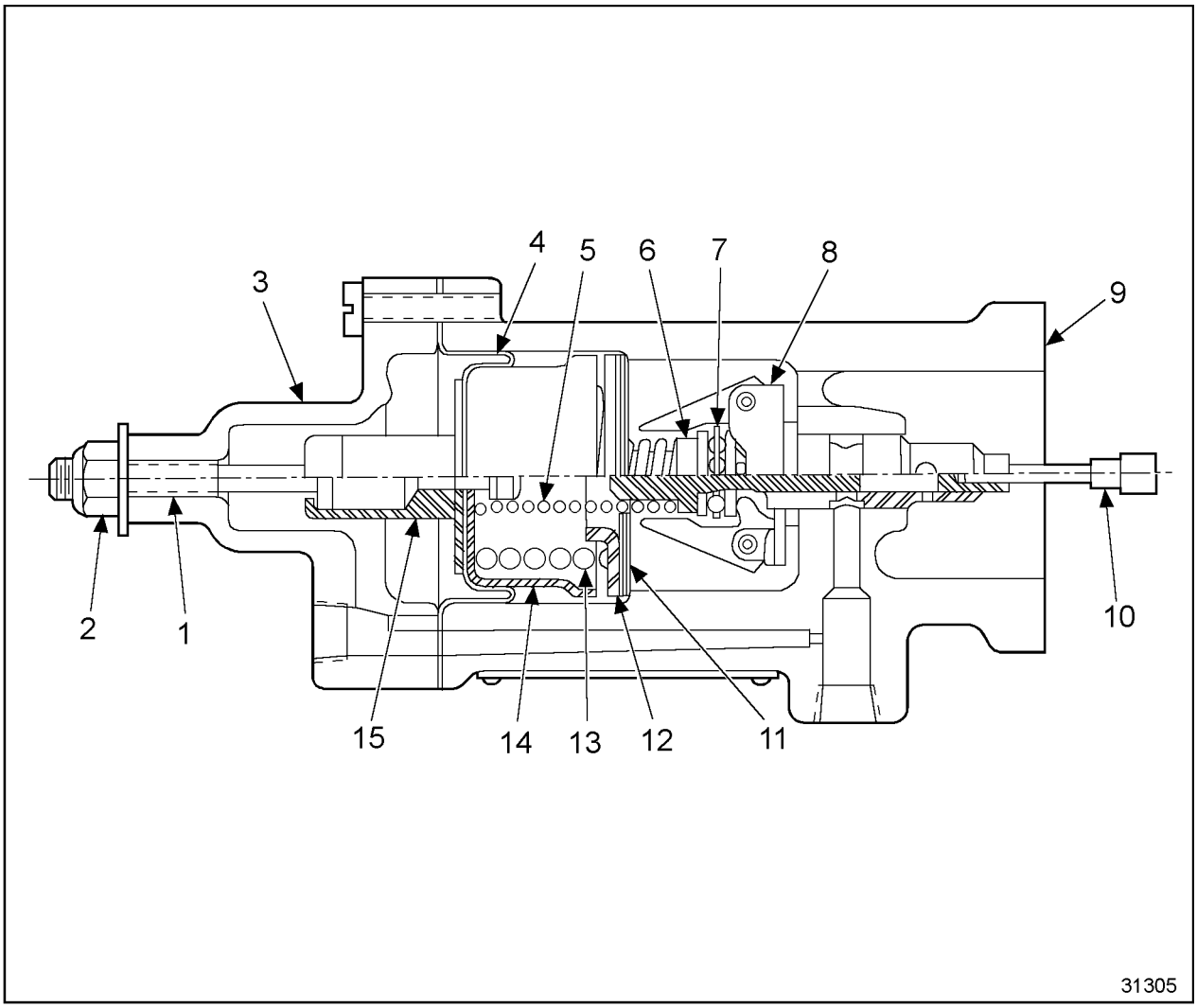
When the engine is started, the oil pressure switch will open when the oil pressure reaches 34.5 kPa (5 lb/in.^{2}), and the fuel oil pressure switch will close when the fuel pressure reaches 138 kPa (20 lb/in.^{2}). If overheating or engine coolant loss occurs, the temperature-sensing switch will close and complete the electrical circuit to the alarm bell. Engine oil pressure loss will cause the oil pressure valve to open, activating the alarm system. Once the alarm system is activated, the bell will continue to ring until the engine operator stops the engine.

During a routine engine shut down, the decreasing fuel pressure causes the fuel pressure switch to open the electrical circuit before the decreasing oil pressure can activate the alarm system.

Coolant protection is obtained through an exhaust probe and adaptor assembly and a temperature switch. The engine coolant circulates around the switch power element to prevent the heat transfer to the exhaust probe which will activate the switch. An alarm will sound if coolant flow through the adaptor is interrupted for any reason. The switch will operate when the engine coolant discharge temperature exceeds 96-102°C (205-215°F).

The oil pressure switch, mounted in the low oil pressure valve, will sound the alarm when the engine oil pressure drops below the safe operating pressure. See Figure 8-25. The switch will detect an engine overspeed. Engine oil is supplied to the valve. Should the engine oil pressure drop below a safe operating value, above 1200 RPM, the valve will operate, dropping the oil pressure at the switch which completes the circuit and sounds the alarm. Below 1200 RPM, the oil pressure switch will close whenever the oil pressure is less than the oil pressure switch setting.

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1. Adjusting Screw
2. Nut
3. Cover
4. Seal
5. Inner Spring
6. Valve
7. Bearing
8. Weight
9. Housing
10. Drive Shaft
11. Shims
12. Retainer
13. Outer Spring
14. Piston
15. Guide Assembly

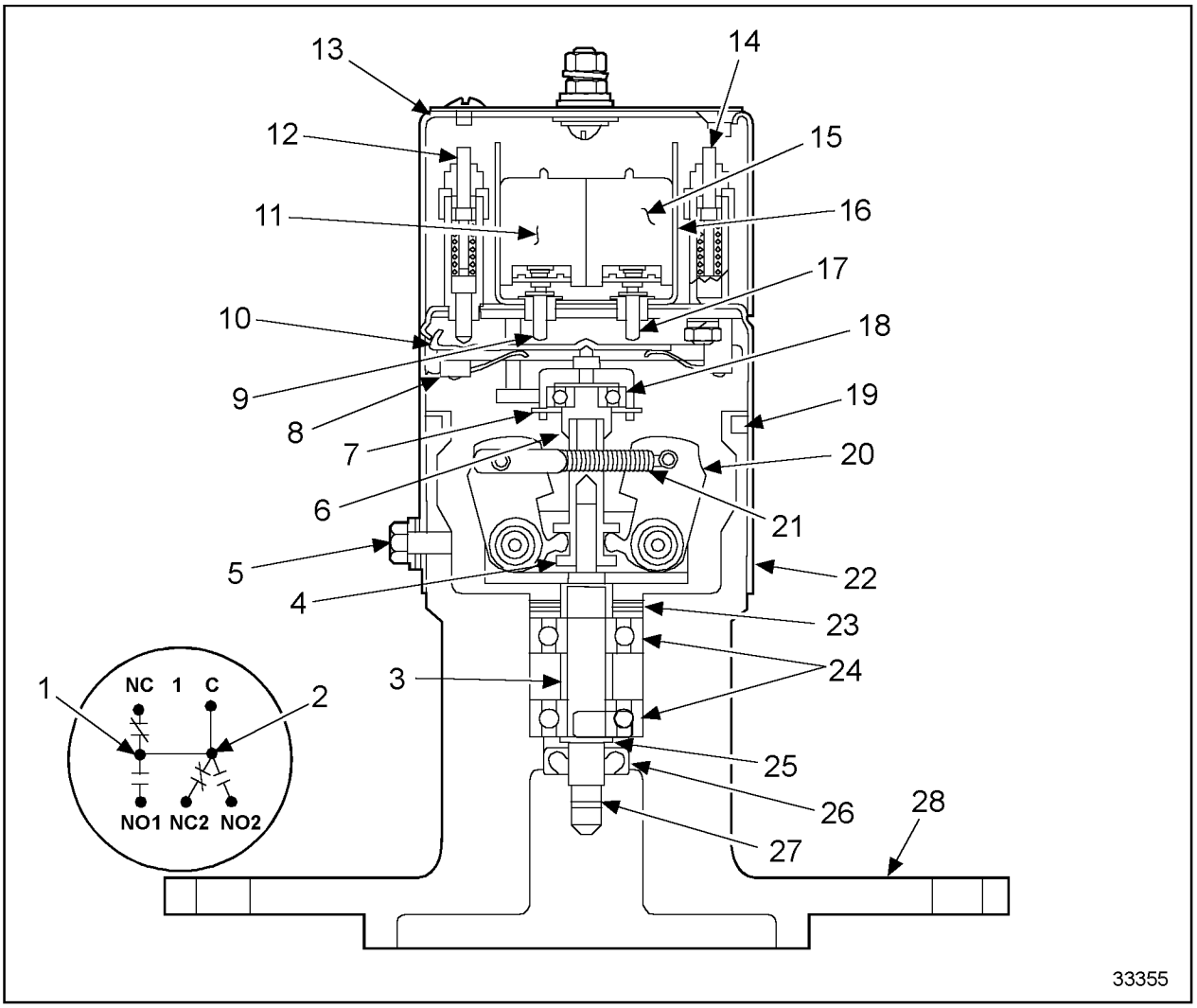
Figure 8-25 Typical Low Oil Pressure Valve

A relay prevents damage to the pressure and temperature switches should the current to operate the alarm device be too high.

Should the alarm be activated for any reason, the engine should be stopped immediately. The cause must be corrected before the engine is restarted.

8.7 OVERSPEED GOVERNOR

The series GW-2 Synchro-Start overspeed governor contains two separate snap action switches with single-pole double-throw contacts which operate at two different speeds. See Figure 8-26. The governor trips at the speeds indicated on the name plate. Unless otherwise specified, the name plate indicates trip points on increasing speed. The contacts will return to normal when the speed is decreased approximately 100 RPM below the trip speed, except on the high speed switch of those models having a manual reset button. The letter "M" after any model number indicates the high speed switch must be reset manually.



1. Low Speed Switch
2. High Speed Switch
3. Bearing Spacer
4. Plunger
5. Cap Holding Screw
6. Plunger Cap
15. High Speed Switch
16. Switch Bracket
17. High Speed Switch Lifter
18. Bearing
19. Seal Ring
20. Flyweight

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7. Snap Ring
8. Spring
9. Low Speed Switch Lifter
10. Channel Lever
11. Low Speed Switch
12. Low Speed Adjusting Screw
13. Governor Cover
14. High Speed Adjusting Screw
21. Flyweight Spring
22. Governor Cap
23. Retaining Ring
24. Bearing
25. Snap Ring
26. Oil Seal
27. Shaft
28. Governor Body

Figure 8-26 Cross-Section of Overspeed Governor

The hydraulic governor, which contains a set of spring loaded weights, prevents excessive engine speeds.

The overspeed governor is mounted in an adaptor on the rear of the flywheel housing. A seal ring in the adaptor end of the governor housing prevents oil seeping from the flywheel housing. A flexible drive assembly from the blower drive shaft drives the governor. A tube, which is connected to the oil gallery in the cylinder block, supplies the governor with pressurized oil.

When the engine speed reaches the value for which the overspeed governor is set, the centrifugal force of the weights in the overspeed governor overcomes the spring tension and opens a pilot valve in the governor. The pilot valve dumps oil from the oil tube, lowering the pressure at the engine oil pressure switch. This closes the switch, energizes the shutdown solenoid, and closes the shutdown valve.

The overspeed governor is lubricated by oil from the engine crankcase.

The position of the adjusting screw in the overspeed governor cover determines the engine shutdown speed. To change the setting, loosen the locknut, and turn the adjusting screw in to increase the speed and out to decrease the speed. When the proper setting is obtained, tighten the adjusting screw locknut.

8.7.1 Service of Overspeed Governor

Perform the following procedures to service the overspeed governor.

8.7.2 Removal of Snap Action Switches

Remove the snap action switches as follows:

1. Mark the position of the dust cover, and remove both hold-down screws.
2. Observe the position of the switches. Usually they are positioned with 1/64 in. clearance between the switch button and the lifters. If the lifters are replaced, ensure that the long lifter is placed beneath the low speed switch, and the short lifter is placed beneath the high speed switch.

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8.7.3 Removal of Governor Cap

Remove the governor cap as follows:

1. Observe the marking on the cap and the body then remove the three holding screws.
2. Remove the cap assembly, ensuring not to damage the seal ring.

8.7.4 Removal of Adjusting Springs

Remove the adjusting springs as follows:

1. Hold the speed adjusting stud with a 5/16 in. open end wrench, and loosen the adjusting stud nut with a 3/8 in. open end wrench.
2. Remove the adjusting spring and related parts.

8.7.5 Removal of Flexible Drive Shaft

Remove the flexible drive shaft as follows:

1. Insert a sharp pointed instrument in the loop of the spring clip and pull it from the shaft as far as possible and remove the shaft assembly.

8.7.6 Installation of Snap Action Switches

Install the snap action switches as follows:

1. Install the switches.
2. Tighten the hold-down screws.

NOTICE:
When replacing the dust cover on a governor with a manual reset, ensure that the switch wiring does not interfere with the reset mechanism.

3. Replace the dust cover.

8.7.7 Installation of Governor Cap

Install the governor cap as follows:

1. Lightly coat the seal ring and body with grease.

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NOTICE:
The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1000 RPM and the trip point of the high speed switch is above 2100 RPM. These governors use elongated loop flyweight springs. If, after assembly, the No. 1 switch trips at a far higher point than normal, lower the cap position slightly. If the No. 2 switch trips at a very low speed, raise the cap position slightly. If difficulty arises, refer to section 8.7.10.

2. Install the cap. Do not damage the seal ring.
3. Install and tighten the holding screws.

8.7.8 Installation of Speed Adjusting Springs

Install the speed adjusting springs as follows:

NOTE:
Prevent dirt from accumulating on the parts.

1. Hold the speed adjusting stud with a 5/16 in. open end wrench, and tighten the adjusting stud nut with a 3/8 in. open end wrench.

8.7.9 Installation of Flexible Drive Shaft

Install the flexible drive shaft as follows:

1. Install the spring clip in the fitting groove on the end of the governor shaft.
2. Push the shaft assembly into the square end of the governor shaft. The spring clip will snap in place.

NOTE:
Check the position of the spring clip. If the clip has sprung out of position, use a small screwdriver and push it into place.

8.7.10 Adjustment of Governor Cap

Adjust the governor cap (with the dust cover in place) as follows:

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NOTICE:
The position of the cap is very critical on governors in which the difference in trip points between the two switches is more than 1000 RPM and the trip point of the high speed switch is above 2100 RPM. These governors use elongated loop flyweight springs. If after assembly, the No. 1 switch trips at a far higher point than normal, lower the cap position slightly. If the No. 2 switch trips at a very low speed, raise the cap position slightly.

1. Turn the low speed adjusting screw out for minimum speed adjustment. The top of the adjusting screw should be approximately 1/8 in. from the top of the dust cover.
2. Turn the high speed adjusting screw in for almost maximum speed adjustment. The top of the adjusting screw should be approximately 5/16 in. from the top of the dust cover.
3. With partial tension on the cap holding screws, turn the governor cap to the maximum extended position.
4. Operate the governor at 200 RPM above the low speed switch trip point.
5. Slowly rotate the cap clockwise until the low speed switch trips.
6. Mark the cap position and stop the governor.
7. Turn the cap another 1/16 in. and lock the holding screws securely.

8.7.11 Adjustment of Speed

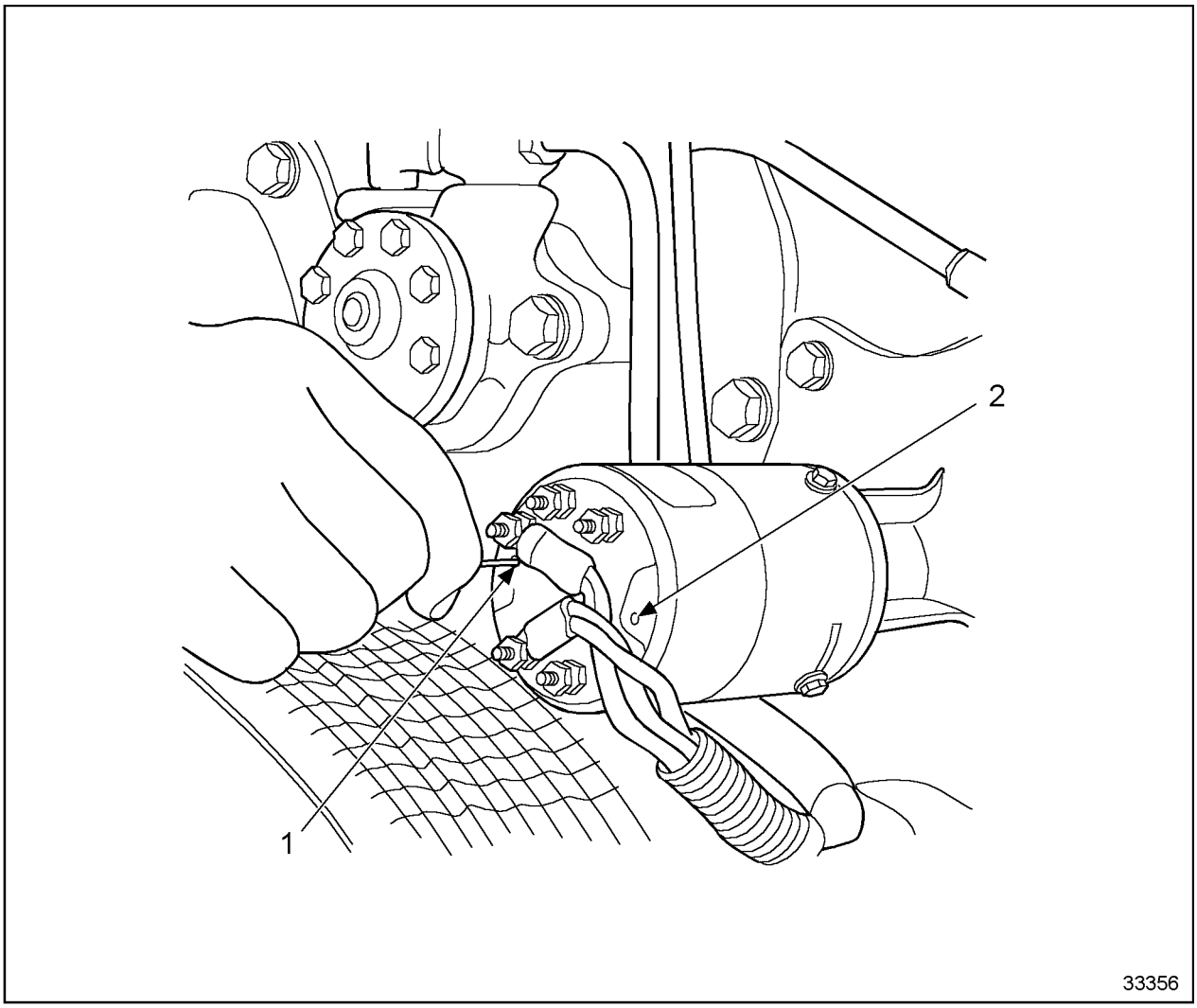
Adjust the speed as follows:

1. Remove the appropriate dust cover screw.

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2. Insert a 1/16 in. allen wrench into the adjusting screw. See Figure 8-27.

NOTE:
Both switches may be individually adjusted. Dust cover screw marked "I" covers the low speed adjuster and screw marked "2" covers the high speed adjuster.



1. High Speed Adjustment
2. Low Speed Adjustment

Figure 8-27 Adjusting Trip Speed of Overspeed Governor

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NOTICE:
If the adjusting screws are turned in too far, the switch will no longer operate. Do not attempt to use the slots in the cap for normal speed adjustments. This position is set and marked by the manufacturer for operation in the speed range required.

3. Turn the screw clockwise to increase the trip speed, or counterclockwise to decrease the trip speed.

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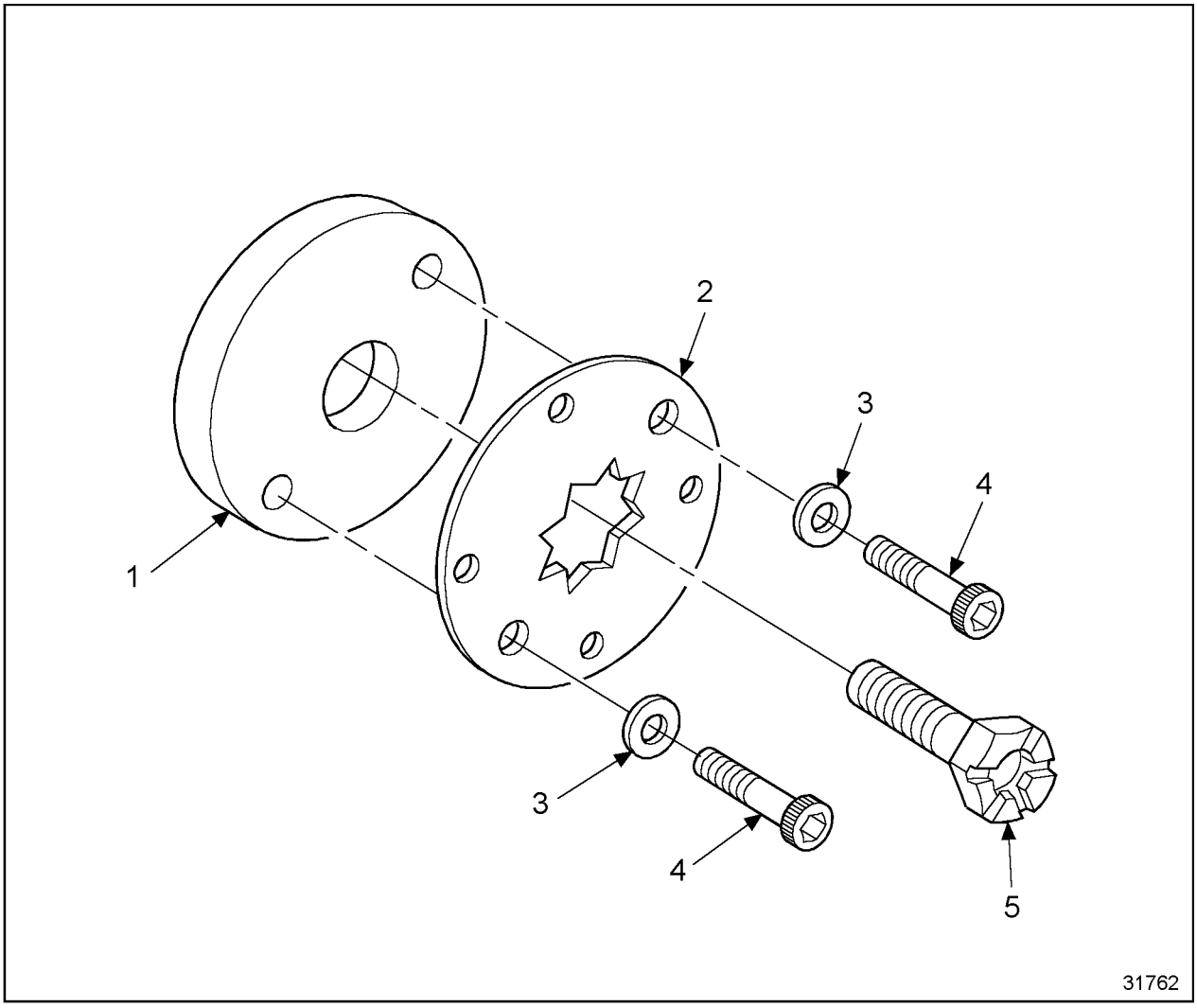
SHOP NOTES

The following are shop notes for electrical equipment:

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CAMSHAFT GEAR RETAINING BOLT LOCKING PLATE (COACH ENGINES WITH 50DN ALTERNATORS)

Because of the positive torque retention provided by this kit. Detroit Diesel recommends installing it on these units whenever the alternator is removed for any reason. See Figure 8-28.



1. Locking Washer
2. Locking Plate
3. Washer
4. Bolts
5. Camshaft Gear Bolt

Figure 8-28 Camshaft Gear Retaining Bolt Locking Plate (Coach Engines)

Removal of Camshaft Gear Bolt Locking Plate

Install the camshaft gear bolt locking plate as follows:

1. Remove the alternator, camshaft gear retaining bolt, and washer from the engine.
2. Discard the camshaft gear bolt and washer.

Installation of Camshaft Gear Bolt Locking Plate

Install the camshaft gear bolt locking plate as follows:

1. Apply a light coating of International Compound #2 to the threads under the head of the new camshaft gear retaining bolt. Wipe off any excess compound.
2. Install the camshaft gear retaining bolt and new two-hole washer, aligning the mounting holes of washer with those on the cam gear.
3. To maintain alignment of the mounting holes with the cam gear, install the two 5/16 in.-24 socket-head bolts finger tight.
4. Torque the remaining bolt to 244-258 N·m (180-190 lb·ft).
5. Remove the two socket-head bolts.

Alignment of Camshaft Gear Mounting Bolts

Perform the following to align camshaft gear mounting bolts:

1. Place the locking plate over the cam gear retaining bolt head with the 5/16 in. mounting holes also aligned with those in the cam.

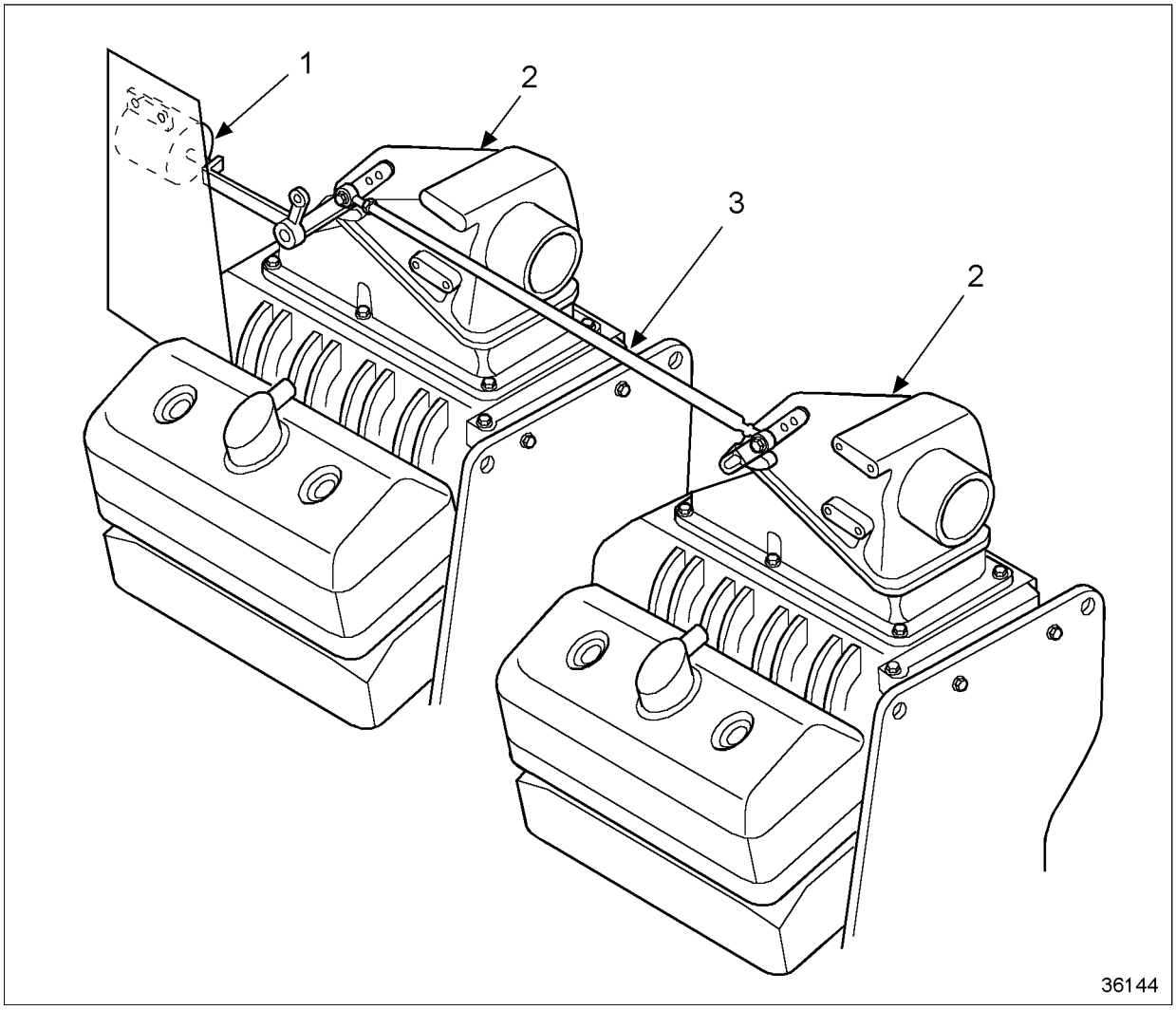
NOTICE:
The locking plate is designed with unique index between the double-hex center hole and the three pairs of mounting bolt holes. This provides six index positions between the bolt hex head and the mounting bolts. Turning the plate over provides another six unique positions. If all positions are tried without alignment choose the locking plate orientation which most closely aligns the mounting bolt holes, then increase the torque on the cam gear retaining bolt until alignment is achieved. DO NOT DECREASE TORQUE TO ACHIEVE ALIGNMENT.

2. Install the two 5/16 in.-24 socket head bolts and torque to 31-37 N·m (23-27 lb·ft).
3. Install the alternator. Refer to section 8.1.

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DUAL-SOLENOID EMERGENCY SHUTDOWN SYSTEM ON 16V-92TA MARINE ENGINES

Detroit Diesel has found that the former single-solenoid/latch lever connecting rod shutdown system used on 16V-92TA marine units may not shut down an engine completely if the rod connecting the shut down latch levers are not adjusted properly. See Figure 8-29.



1. Solenoid
2. Air Shutdown Assembly
3. Latch Lever Connecting Rod

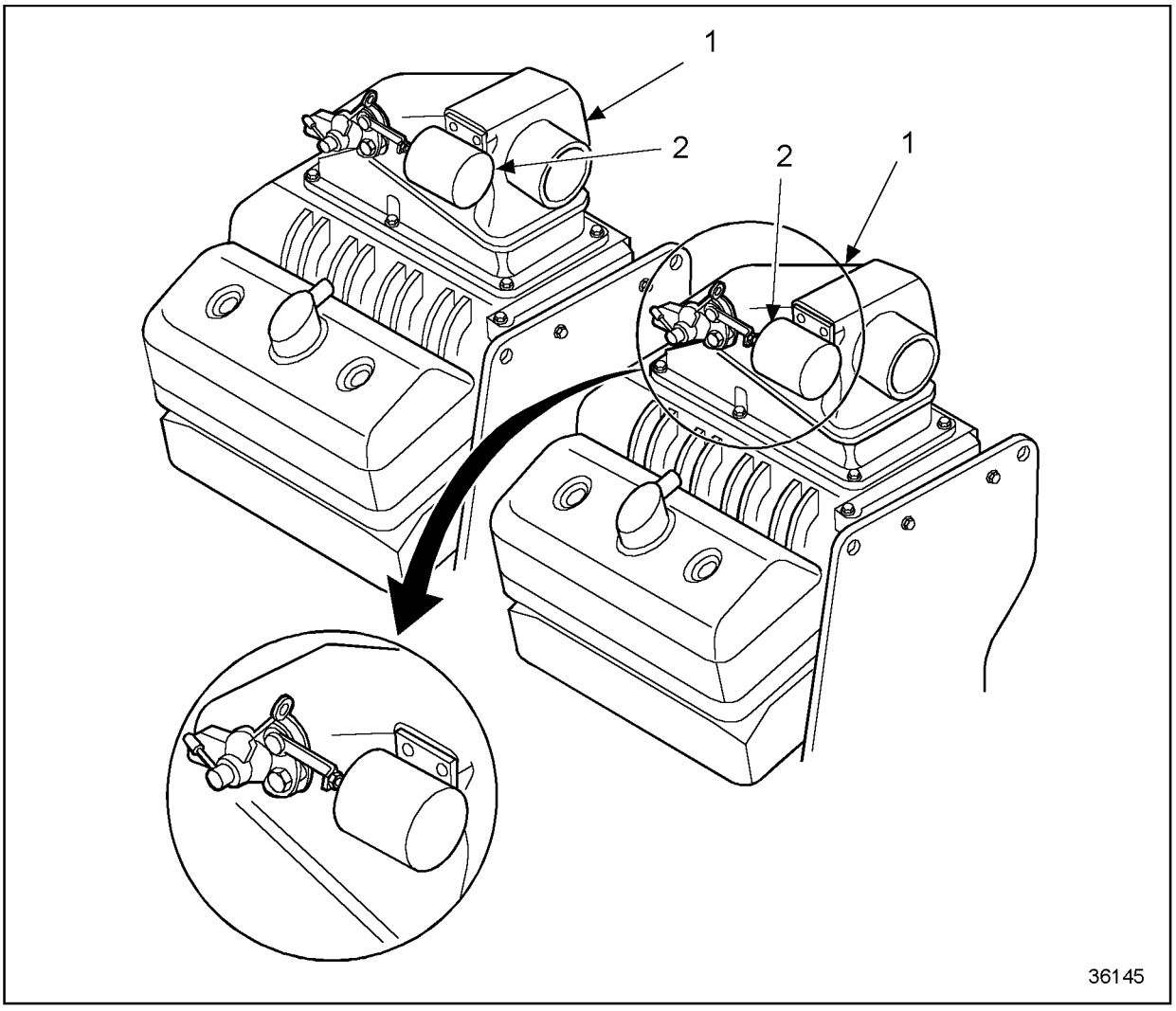
Figure 8-29 Former Single Solenoid/Latch Lever Connecting Rod Shutdown System

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

To eliminate the potential for engine run-on caused by a mis-adjusted latch lever connecting rod, a dual-solenoid shutdown system has replaced the former single-solenoid/latch lever connecting rod shutdown system on all 16V-92 TA marine engines.

In the dual-solenoid system, each shutdown assembly is activated by its own solenoid, thereby eliminating the need for a connecting rod between the shutdown latch levers. See Figure 8-30.



1. Air Shutdown Assembly
2. Solenoid

Figure 8-30 Dual Solenoid Shutdown System

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The dual-solenoid system provides positive engine shutdown without the need for periodic latch lever connecting rod adjustment. Detroit Diesel recommends replacing the former system with the dual solenoid system whenever convenient.

Replacement of Former Shutdown System with the Dual-Solenoid System on 16V-92TA Marine Engines

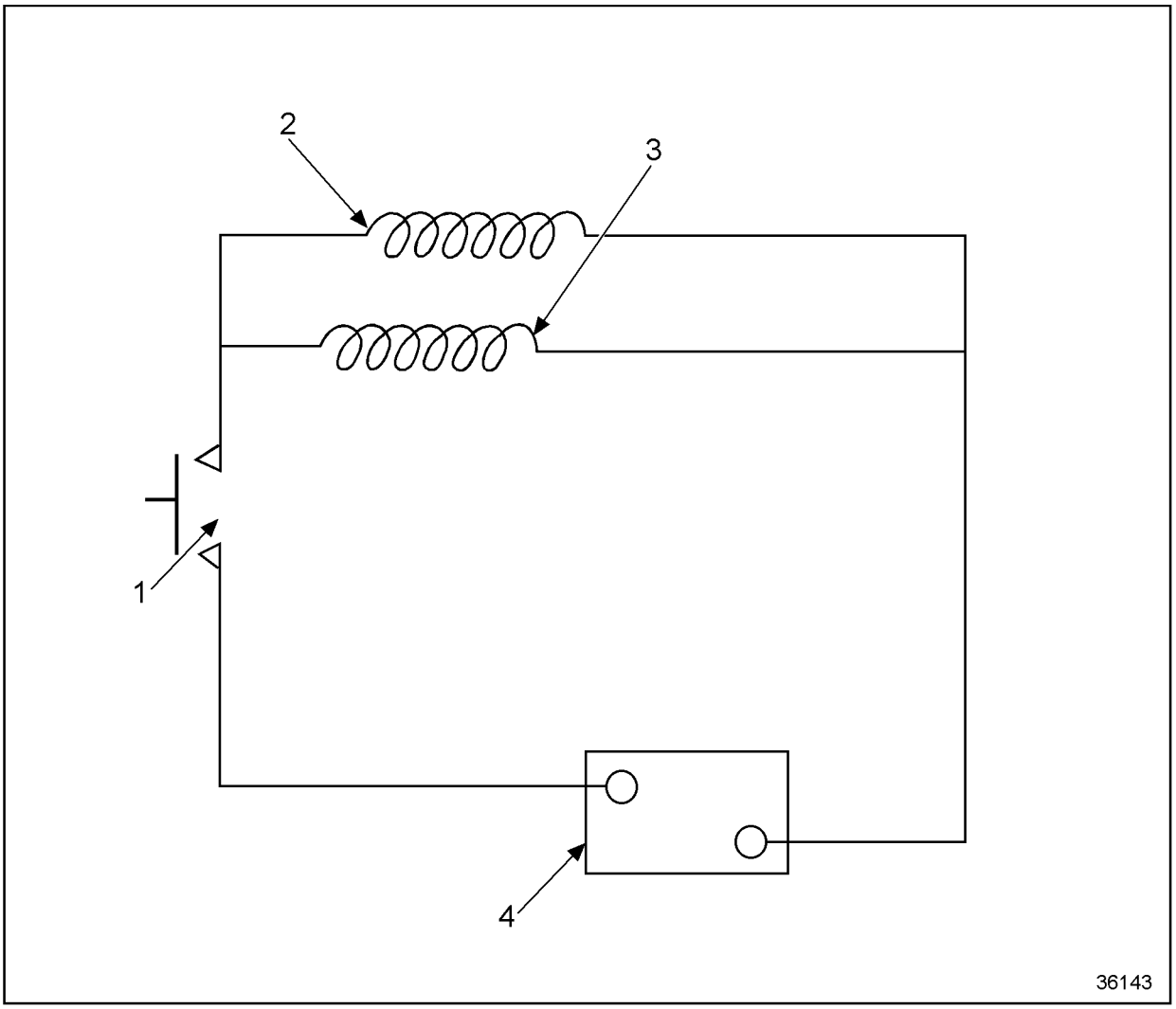
Replace the former shutdown system with the dual-solenoid system on a 16V-92 marine engine as follows:

1. Remove the adjustable rod connecting the two shutdown latch levers.
2. If installed, remove the solenoid and solenoid mounting bracket.
3. Disconnect the air inlet piping from the shutdown air inlet housings.
4. Remove the former shutdown assemblies.

NOTE:
The air shutdown assemblies used in the dual solenoid system are completely assembled and adjusted at the factory before being shipped. No further adjustments should be required.

5. With the dual solenoid shutdown assemblies latched in the *open* position and using fresh gaskets, install the shutdowns onto the air inlet adaptors.
6. Reconnect the air inlet piping to the shutdown air inlet housings.

7. See Figure 8-31, and wire the shutdown solenoids to the electrical system of the engine as shown. Provide a push button type switch to complete the circuit.



1. Customer-Furnished Shutdown Switch Snap Acting 10 AMP Minute Rating
2. Front Air Shutdown Solenoid 24 Volt
3. Rear Air Shutdown Solenoid 24 Volt
4. Battery 24 Volt

Figure 8-31 Dual-Solenoid Shutdown System Wiring Schematic

8. With the engine not running, energize the solenoids and check to ensure that both air shutdown valves close at the same time.
9. Reset the air shutdown valves to the open position and start the engine.

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NOTICE:
To avoid possible engine damage, perform the following step with the engine at idle. Activating the shutdown system with the engine running at high RPM may result in blower seal damage and may also cause turbocharger damage.

10. With the engine at idle, activate the engine shutdown system.

NOTE:
Both shutdowns should close immediately and the engine should stop. If both shutdowns do not close, check the wiring for proper connections.

NOTE:
Engines equipped with electrical shutdown systems *must* also have a back-up mechanical shutdown system that will allow the operator to manually shut down the engine in the event of electrical system failure.

11. After checking shutdown assemblies for proper operation, install a bowden onto each shutdown latch lever and connect the wires to a single handle.
12. Adjust wires so that one pull of the handle will close both shutdowns at the same moment.

NOTICE:
To ensure efficient electrical shutdown deployment and avoid possible interference which may lead to shutdown failure, engine run-on, and possible engine damage, install the bowden wires so that they do not interfere with latch lever or solenoid operation.

⚠ CAUTION:
To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

NOTE:
The air shutdown valves located in the housings must be reset to the open position by hand and the emergency stop knob pushed on before the engine is ready to start again.

PROPER OPERATION OF THE SWITCHES OR ALARM SYSTEM FOR TESTING THE ELECTRICAL SHUTDOWN

The protective system is activated whenever low lubricating oil pressure, high coolant temperature, engine overspeed, or any other abnormal condition develops that could damage the engine.

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In a properly maintained installation, the shutdown system seldom has cause to function. Check the system periodically to ensure that it will function when needed.

Check each component of the shutdown system as outlined below:

NOTE:
Thoroughly warm-up the engine before any component of the shutdown system is checked.

Overspeed Governor

Check the overspeed governor as follows:

1. Remove the valve rocker cover. Discard the gasket.
2. Start the engine, and move the speed control lever to the full-speed position.
3. While watching a tachometer, manually move the control tube slowly toward the increased fuel position until the air shutoff valve closes and stops the engine.

NOTE:
Do not exceed the engine no-load operating speed by more than 10%.

4. Observe the speed at which the engine stops, and adjust the overspeed governor if necessary.
5. Using new gaskets, install the valve rocker cover.

Water Temperature Switch

Check the water temperature switch as follows:

NOTE:
The terminals of the water temperature switch are connected into the shutdown system. When the engine water temperature reaches 99°C (210°F), the switch closes and completes the circuit in the shutdown or alarm system.

1. Cover the radiator with a sheet of cardboard to prevent circulation of air.

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⚠ 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. With the engine cooled down, remove the radiator cap, if the engine is operating near sea level, and insert a steel jacketed thermometer.

NOTE:
The boiling point of water lowers approximately -16.67°C (2°F) for each 1000 foot rise in altitude. For example, water boils at approximately 95°C (203°F) at 5000 feet and at 90°C (195°F) at 9000 feet altitude. Keep the radiator pressure cap on engines operating at higher than 1000 feet to prevent the coolant from boiling while performing this test. An accurate engine temperature gage must be used when performing this test.

NOTE:
Do not exceed 99°C (210°F) when performing this test.

3. Start and run the engine at rated speed and with enough load to raise the water temperature gradually until the air shutoff valve closes. The water temperature switch will usually be set at 99°C (210°F).
4. Observe the temperature at which the air shutoff valve closed.
5. Remove the radiator cover, and start the engine without load immediately after the engine stops. This will permit the engine to cool to normal operating temperature.

Fuel Oil Pressure Switch

The fuel oil pressure switch is set to make contact at an increasing fuel pressure of 138 kPa (20 lb/in.^{2}). The phrase "20-MAKE" is stamped on the switch cover.

As the fuel pressure increases, a diaphragm in the switch body expands, forcing the plunger upward. See Figure 8-32. Since the bottom of the adjusting screw bears against this plunger, the adjusting screw and the lower breaker point are also forced upward. When the fuel pressure reaches 138 kPa (20 lb/in.^{2}), the breaker points close, and current flows to the terminals of the lubricating oil pressure switch and the water temperature switch.

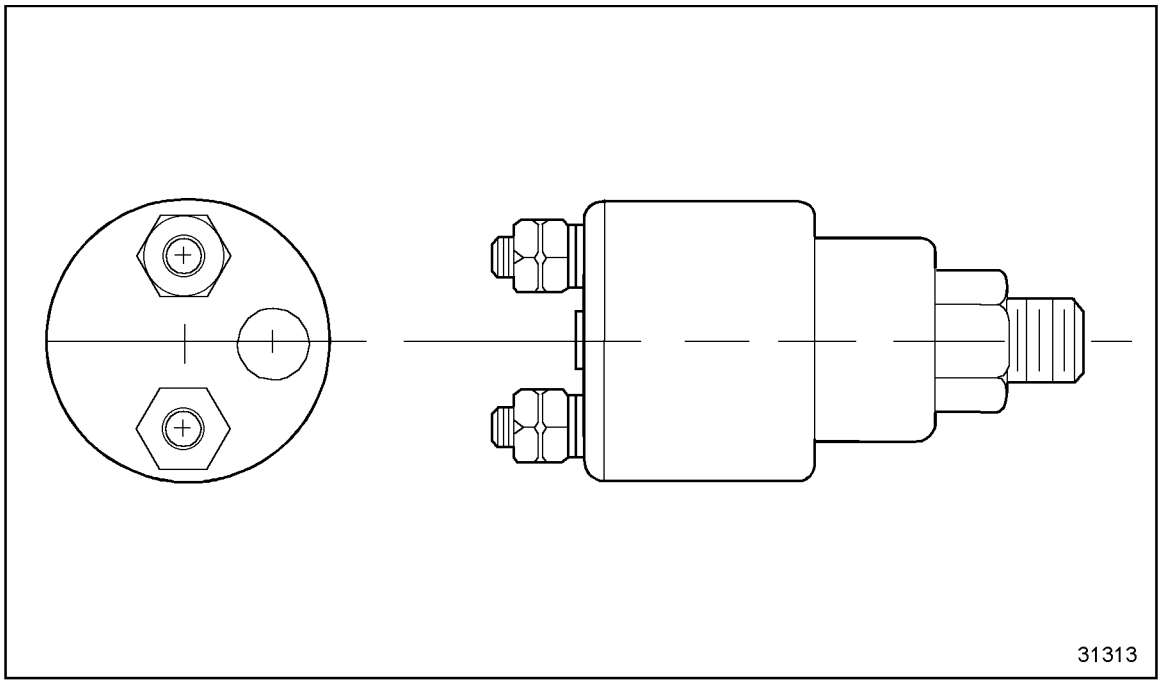


Figure 8-32 Fuel Oil Pressure Switch

With the engine stopped, the fuel pressure decreases, and the diaphragm in the switch body contracts. This causes the plunger to lower and, when the fuel pressure decreases to 138 kPa (20 lb/in.^{2}), permits the lower breaker point arm to lower and break the electrical circuit. The bracket to which the lower breaker point arm and the adjusting screw are attached is spring-loaded, which provides for positive breaking of the connection when the fuel pressure decreases sufficiently.

Check the fuel oil pressure switch as follows:

1. Insert a pressure gage on the discharge side of the fuel strainer.
2. While performing this test, remove one of the leads from the lubricating oil pressure switch. This will prevent engine shutdown.
3. Start and run the engine at idle speed.
4. Slow the engine by moving the speed control lever toward the no-fuel position until the fuel pressure is approximately 103 kPa (15 lb/in.^{2}) with the engine barely turning over.
5. Place a jumper wire across the water temperature switch terminals.
6. Raise the engine speed slowly, and watch the fuel oil pressure gage until the air shutoff valve closes.

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7. Observe the fuel pressure at which the air shutoff valve closed, and if necessary, replace the switch.
8. Remove the jumper wire from the water temperature switch, and reconnect the lubricating oil pressure switch.

Lubricating Oil Pressure Switch

The lubricating oil pressure switch is similar to the fuel oil pressure switch, except that the lubricating oil pressure switch is calibrated to break contact when the lubricating oil pressure increases to 69 kPa (10 lb/in.^{2}). The phrase "10 BREAK" is stamped on the switch cover.

A 138 kPa (20 lb/in.^{2}) break switch is used on some engines that predominantly operate at constant speed.

As the lubricating oil pressure increases, the diaphragm in the switch body expands, forcing the plunger upward. See Figure 8-33.

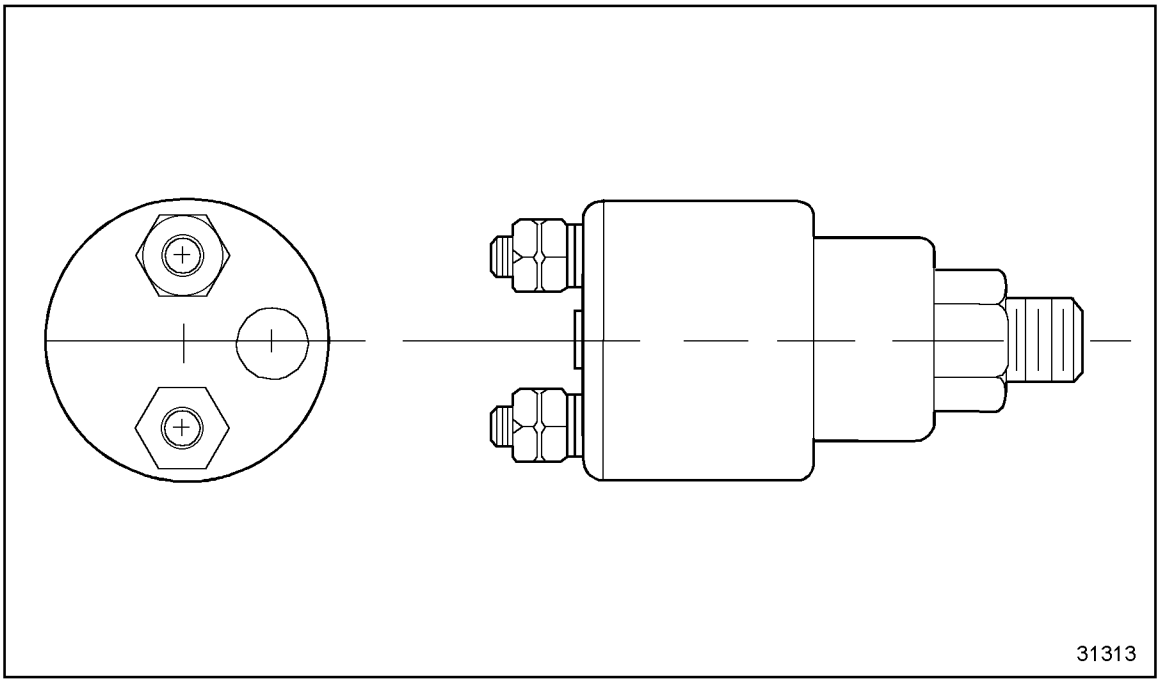


Figure 8-33 Lubricating Oil Pressure Switch

Since the bottom of the adjusting screw bears against the plunger, and the adjusting screw is attached to the bracket which controls the upper breaker point arm, the arm is also forced upward. When the lubricating oil pressure increases to 69 kPa (10 lb/in.^{2}), the points separate. Current flows to the lubricating oil pressure switch only after the fuel oil pressure switch closes, while the points of the lubricating oil switch are open. If the lubricating oil pressure decreases to 69 kPa (10 lb/in.^{2}) during operation, the breaker point will close and either the alarm bell or shutdown solenoid will be energized.

Check the lubricating oil pressure switch as follows:

1. Start and run the engine at idle speed.
2. Place a jumper wire on the hot wire relay between the "1" and "S" terminals.
3. Place a jumper wire across the fuel oil pressure switch terminals.
4. Reduce the engine speed by moving the control lever towards the no-fuel position while watching the lubricating oil pressure gage.
5. Observe the oil pressure at which the switch stops the engine and, if necessary, replace the switch.
6. Remove the jumper wire.

Adjust Bellows

Perform the following procedure to adjust bellows:

1. To adjust the bellows low oil pressure setting, run the engine until normal operating temperature (160-185°F or 71-85°C) has been reached, and the oil pressure has stabilized.
2. Reduce the engine speed slowly until the bellows disengage the latch on the air shutdown valve, stopping the engine.
3. Observe the oil pressure at which the shutdown occurred. The oil pressure at disengagement should be 34-69 kPa (5-10 lb/in.^{2}) at 450-600 RPM, 69-103 kPa (10-15 lb/in.^{2}) at 601-1400 RPM, or 103-138 kPa (15-20 lb/in.^{2}) at 1401 RPM and above.

NOTICE:
Set the bellows disengagement pressure near the high end of the pressure range for the specified low engine speed.

4. If adjustment is necessary, loosen the locknut on the bellows, and turn the adjusting screw clockwise to increase the oil pressure setting or counterclockwise to decrease the setting.
5. Hold the adjusting screw, and tighten the locknut when the proper setting has been obtained.

Adjust the Latch Bracket on the Air Shutdown Valve

Adjust the latch bracket as follows:

1. Push the solenoid plunger all the way in until it bottoms.
2. Hold this position while adjusting the bracket. This will ensure maximum pull force when the solenoid is activated.
3. Loosen the locknuts on the solenoid plunger shaft.
4. Turn the inboard nut clockwise to move the bracket and latch toward the solenoid, counterclockwise to move them away from the solenoid.

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NOTICE:
If not adjusted properly, the valve may not close completely when activated, and the engine will not shut off during abnormal operating conditions. This could cause severe engine damage.

5. Adjust the bracket position so when the latch is tripped, the high point of the rotating cam clears the latch end by 0.79375-2.38125 mm (0.03125-0.09375 in.).

NOTE:
Excess latch-to-cam clearance greatly reduces solenoid pull force.

6. Tighten the locknuts to retain adjustment.

Test Air Shutdown Operation

Test air shutdown operation as follows:

NOTICE:
To avoid possible engine damage from shutdown failure, test air shutdown assemblies, whether electrical or manual, at least once a year or after 700 hours engine operation, whichever comes first.

1. Start the engine and allow it to idle.
2. Using the required DC voltage, activate the shutdown solenoid.
3. The shutdown-valve should close, stopping the engine.
   [a] If the valve does not close, determine and correct the cause. Refer to section 6.4.

Hot Wire Relay

Perform the hot wire relay as follows:

1. Start and operate the engine at idle speed.
2. Place the jumper wire across the terminals of the lubricating oil pressure switch while watching the second hand of a clock.
3. Not more than 3 to 10 seconds should elapse between the time the jumper wire is placed across the lubricating oil pressure switch terminals and the air shutoff valve closes.

NOTE:
The above procedures completely test the normally open electrical shutdown system on an engine.

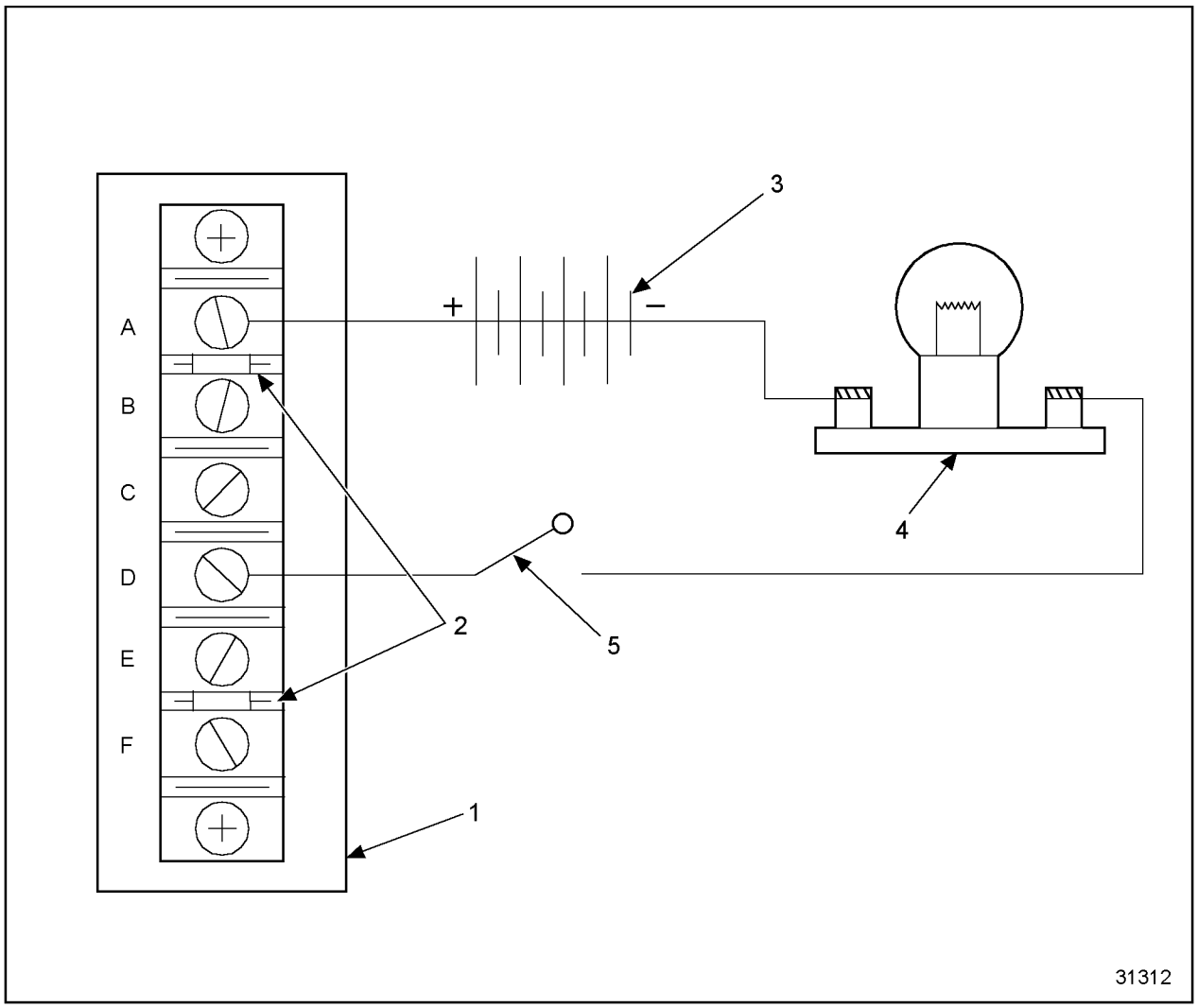
NOTE:
When the engine is operating at idle speed or above, the air shutoff valve will completely cut off air from the engine, causing it to stop. However, when the engine is operating at

the low speeds required to test the fuel shutdown and lubricating oil shutdown switches, the air damper solenoid will close the air shutoff valve, but the engine may continue to run very slowly. This is because the low air flow on the back of the shutoff valve may be insufficient to close it completely.

Solid State Time Delay Switch 12, 24, or 32 Volts-Direct Current

A solid state time delay switch is used on current engines in place of the former hot wire relay.

See Figure 8-34, and bench test the solid state time delay switch as follows:



1. Time Delay Switch
2. Jumper Straps
3. Battery (12 Volt)
4. Light (12 Volt)
5. Switch

Figure 8-34 Time Delay Switch Testing Diagram

1. Remove the time delay switch from the engine.

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2. Install the jumper straps on terminals "A" to "B" and "E" to "F," if they have been removed. Normally, the jumper straps are on the time delay switches as supplied.
3. Install a positive battery lead to terminal "A."
4. Install a negative battery lead to one side of a 12 volt light which is a known good test lamp.
5. Install a lead from the opposite side of the light to terminal "D". A switch may be used in this lead, if desired.
6. The negative lead is connected to "D" or the switch is closed, the lamp should light in 8 to 10 seconds. If not, the time delay switch must be relapsed.

CHECK ENGINE STARTING SWITCH

If experiencing starting difficulty in a vehicle powered by a diesel engine, check whether the vehicle has a key-type or push button starting switch.

Key-type starting switches are usually unable to carry sufficient current for heavy-duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and prevents the starter from engaging and cranking.

Install a push button starting switch capable of making, breaking and carrying the required solenoid current. Refer to section 8.4.6. Otherwise, a heavy-duty magnetic switch should be used along with the key-type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12 volt system. The key switch will then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adaptor is installed, the cover assembly or adaptor must be properly aligned with the tachometer drive shaft.

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NOTICE:
Tachometer drive shaft misalignment can impose a side load on a tachometer drive cable adaptor, leading to gear seizure and damage to other related components.

To ensure proper alignment, use one of three tools in set J 23068 to establish the proper alignment. See Figure 8-35.

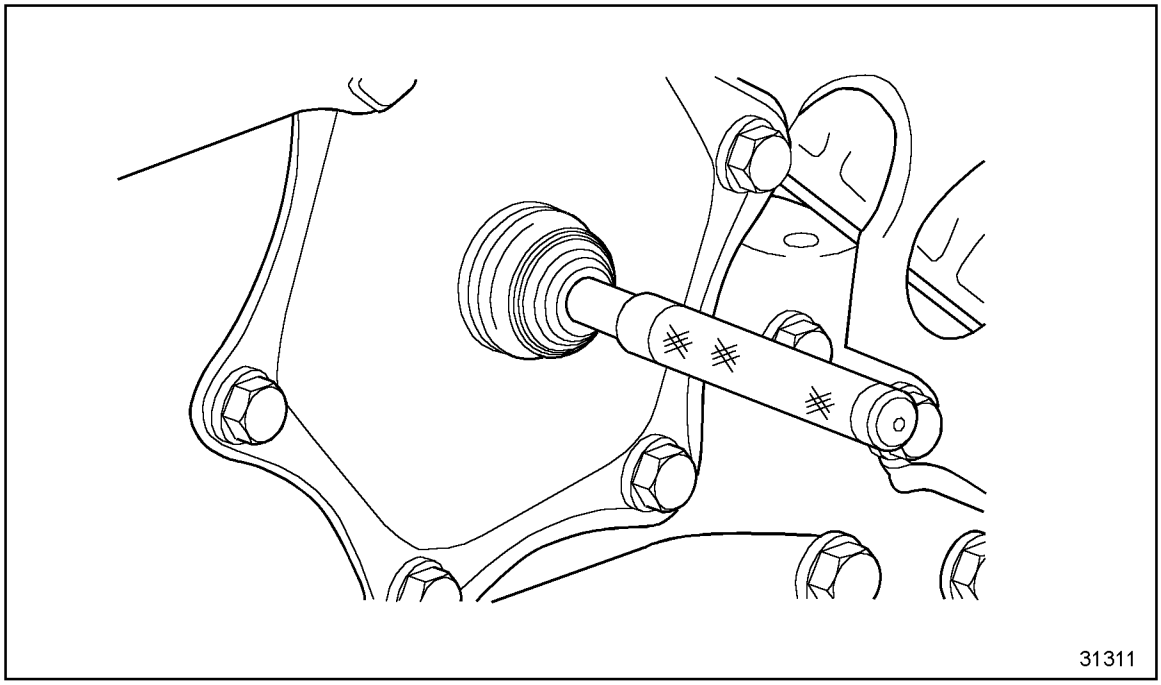


Figure 8-35 Checking Tachometer Drive Shaft Alignment

NOTE:
Because of the many different combinations of tachometer drive shafts, covers and adaptors, specific uses for each tool can not be itemized. When performing an alignment, test fit each tool to determine which provides the best fit, and make the alignment with that tool.

Components are aligned when the tachometer drive shaft does not bind on the inside diameter of the tool while a complete hand rotation of the engine is made.

MOUNTING THE STARTER AUXILIARY MAGNETIC SWITCH

On certain railcar and highway units equipped with Detroit Diesel engines and Delco-Remy starter auxiliary magnetic switches, a no-start condition may result from vibration damage to the starter auxiliary magnetic switch. Vibration may result from improper auxiliary magnetic switch mounting.

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When mounting a Delco-Remy starter auxiliary magnetic switch, observe the following guidelines. See Figure 8-36.

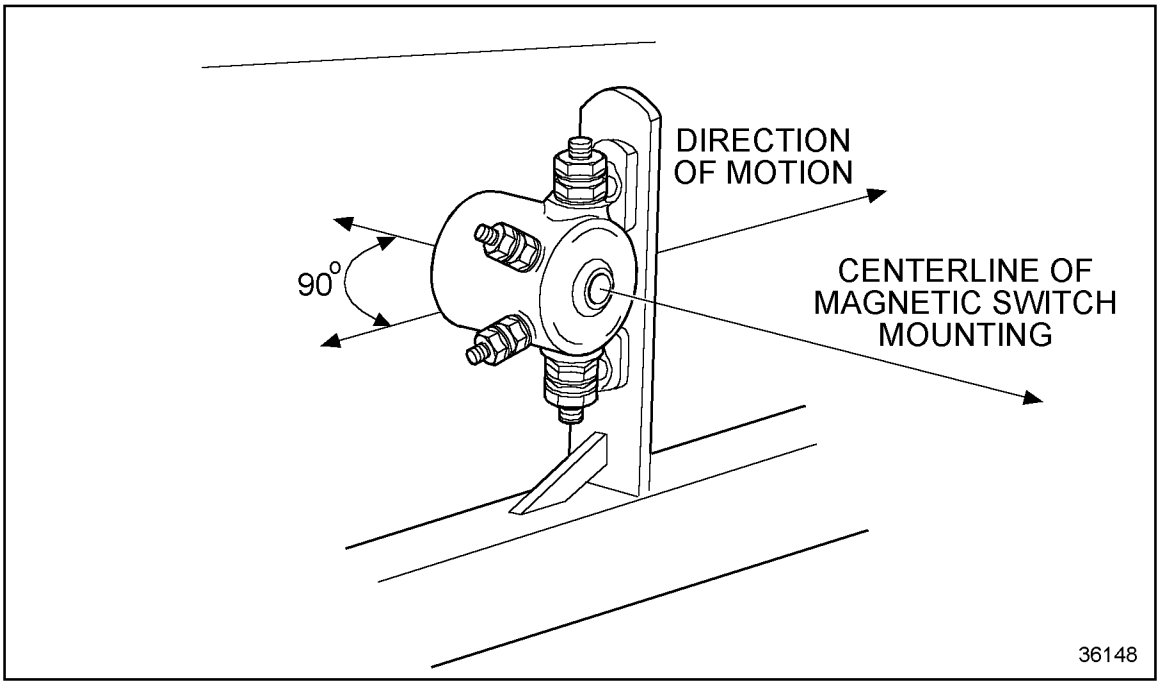


Figure 8-36 Starter Auxiliary Magnetic Switch Mounting

NOTE:
Do not mount the switch on the engine.

1. Position the mounting pads on the switch vertically (one above the other).
2. Mount the switch on a rigid bracket, base rail, or fire wall.
3. Mount the switch on a surface perpendicular (90 degrees) to the forward motion of the vehicle so that contact disc movement is not in line with gravity or vehicle movement.

NEW SEALING COMPONENTS IN FLANGE-MOUNTED LEECE-NEVILLE ALTERNATORS USED IN MARINE APPLICATIONS

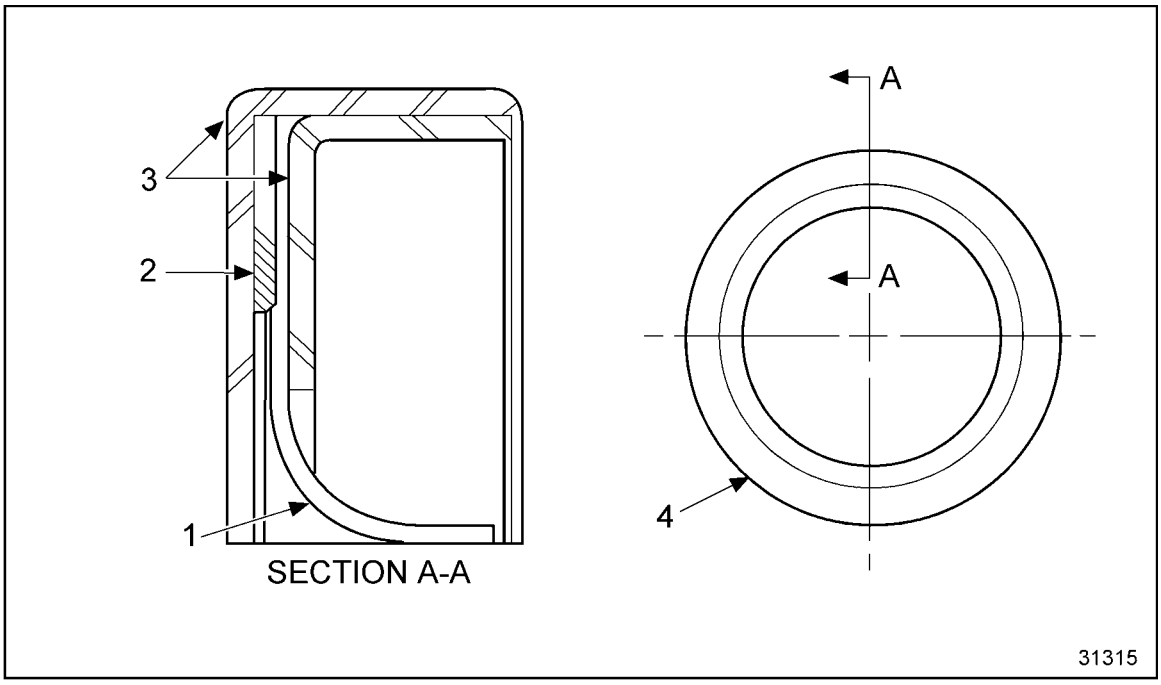
To reduce the possibility of oil leaks between the engine flywheel housing and alternator, new sealing components have been released for flange-mounted Leece-Neville alternators used in marine applications.

New Components For Flange-Mounted Leece-Neville Alternators

A new alternator fan guard assembly with Teflon-lip seal, new beaded guard-to-adaptor gasket, and new bolt seal washers (stat-o-seals) now form part of the production-only alternator assemblies:

NOTE:
These production-only assemblies are not serviced separately.

The lay down design of the bi-directional Teflon-lip seal provides greater surface contact with the alternator hub. See Figure 8-37.

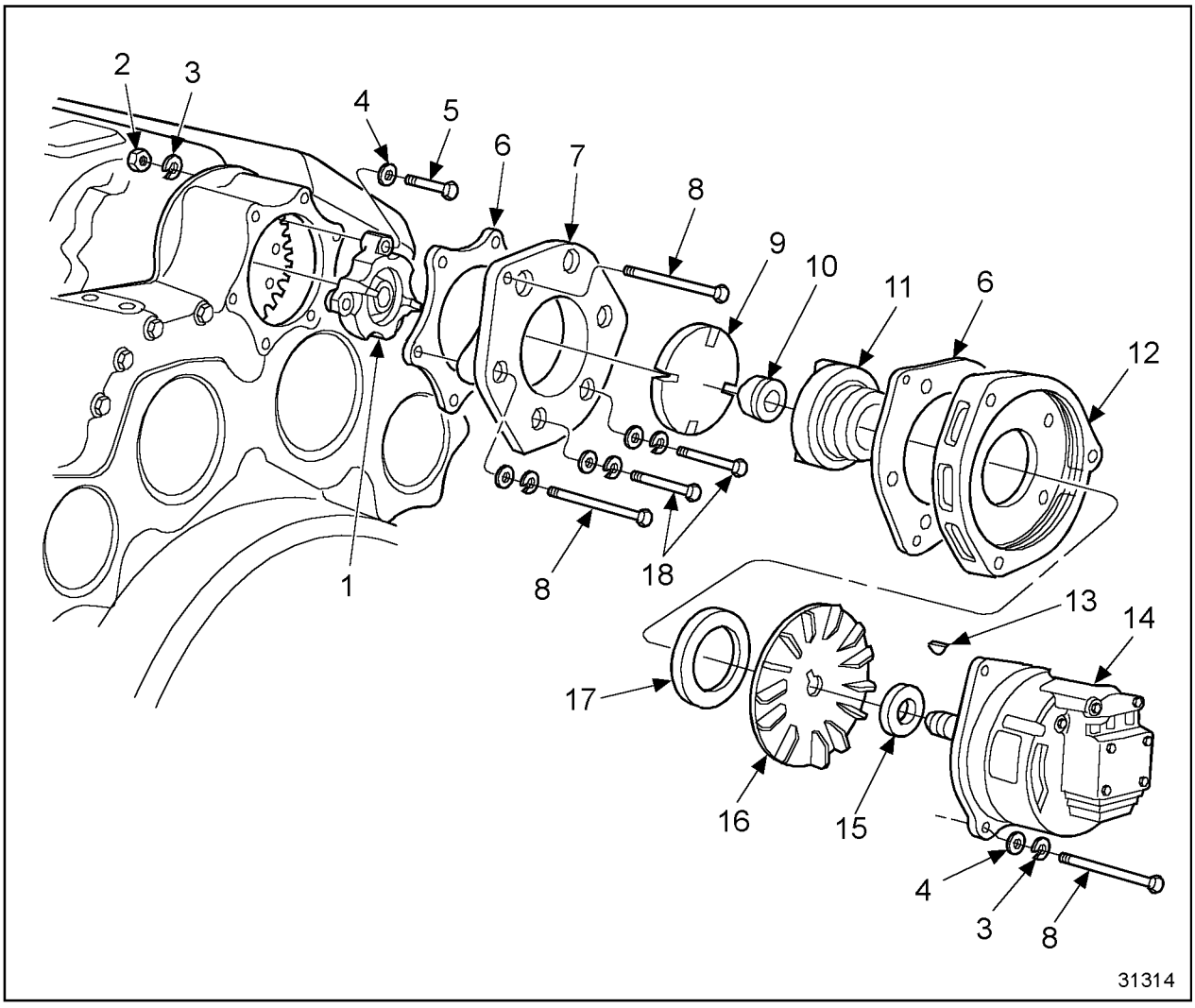


1. Teflon-Lip Sealing Element
2. Gasket
3. Metal Cases
4. Seal Face

Figure 8-37 Teflon-Lip Oil Seal

This virtually eliminates the possibility of oil leaks at this point. The sealant bead around the center hole of the guard-to-adaptor gasket and the alternator mounting bolt seal washers further reduce the chance of leaks. See Figure 8-38.

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1. Drive Coupling
2. Nut
3. Lock Washer
4. Plain Washer
5. Bolt (2)
6. Gasket (2)
7. Adaptor Plate
8. Long Bolt
9. Coupling Block
10. Bearing
11. Hub
12. Guard Seal Assembly
13. Woodruff Key
14. Alternator Assembly
15. Spacer
16. Cooling Fan
17. Seal
18. Short Bolt

Figure 8-38 Typical Alternator, Fan Guard, Hub Installation

NEW SERVICE KITS FOR FLANGE-MOUNTED LEECE-NEVILLE ALTERNATORS

To conform with this change, two new seal and hub service kits have been released for use on marine engines. The kits include a new fan guard assembly (with seal installed), new beaded gasket, new bolt seal washers, a replacement drive hub, and adaptor-to-flywheel housing mounting gasket(s).

Because of the improved sealing these components provide, DDC recommends using a new kit whenever one of the flange-mounted Leece-Neville alternators are replaced on a marine unit. Kit parts are also available separately for units already having the new fan guard assembly installed.

Prior to installation, inspect the components as follows:

NOTE:
The alternator must be removed from the engine before the fan guard/seal assembly can be replaced.

1. Inspect the fan guard/seal assembly to ensure the Teflon-lip seal face is flush with the dry side of the guard housing and square within the bore.
2. Remove the cardboard insert from the seal, and inspect the seal for cuts, nicks, folds, or any other material damage.
   [a] If cut, nicked, folded, or damaged, replace the seal.
   [b] If not cut, nicked, folded, or damaged, continue inspection.
3. Check for metal chips or slivers in both the seal O.D. and lip areas.

⚠ 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 chips or slivers are present, remove with air, if possible.

NOTE:
Wiping may scratch the seal or embed the chip.

4. Inspect the seal contact surface of the alternator drive hub for nicks, pits, or rust.
   [a] Replace if nicked, pitted, or rusted.
   [b] If not nicked, pitted, or rusted, continue inspection.
5. Inspect for the proper lead chamfer.

NOTE:
The lead chamfer must be free of cuts, nicks, scratches which could damage the seal.

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[a] If cut, nicked, or scratched, replace.

[b] If not cut, nicked, or scratched, replace.

NOTICE:
Do not lubricate the seal or hub before installation. Teflon-lip seals must be installed dry. This allows transfer of the Teflon-to-hub surface for proper sealing. Failure to observe this precaution can result in seal leaks.

6. Wipe the hub sealing surface dry.

Installation of Kit For Flange-Mounted Leece-Neville Alternators

Install the service kit as follows:

1. Place the guard/hub assembly onto the alternator as one piece, ensuring it is properly aligned. Press down until the hub is seated.
2. Apply thread sealant to the flange nut threads.
3. Start the flange nut on the alternator drive shaft by hand, and tighten to 95-108 N·m (70-80 lb·ft) torque.
4. Check to ensure the fan is tight. Hold the fan guard against the alternator, and using a screwdriver, pry up gently on the fan.

NOTE:
The fan should not move.

5. Position the beaded gasket on the alternator/fan guard assembly so that the narrow (cut) side of the gasket lines up with the flat on the guard casting and the bead faces the guard.
6. Place the drive coupling on the hub.
7. Remove the alternator-to-flywheel housing adaptor, and replace the small hole gasket.

NOTE:
The kit contains two gaskets for this location. Ensure that the correct gasket is used in conjunction with the pilot diameter of this adaptor.

8. Apply thread sealant to the bolts, and assemble the coupling on the hub using the six seal washers between the plain washers and adaptor. Tighten to 47-53 N·m (35-39 lb·ft) torque.
9. Fit the coupling onto the hub and assemble the alternator/fan guard/hub assembly to the adaptor using three 3/8 in.-16 bolts with lock washers and plain washers. Tighten to 41-47 N·m (30-35 lb·ft) torque.

ALTERNATOR MOUNTING ADAPTOR AND FLYWHEEL HOUSING

The improved alternating mounting adaptor used along with the improved housings provide a greater resistance to cracking at the alternator mounting studs.

Interchangeability of the Alternator Mounting Adaptor

If an adaptor-mounted alternator is installed on an improved flywheel housing, the improved adaptor *must* be used to ensure interchangeability. The improved adaptor also can be used on former flywheel housings. The former adaptor cannot be used on the improved flywheel housings.

Refer to section 1.19.3 for the flywheel housing installation procedure. Refer to section 8.1.2 for camshaft-driven alternator and mounting adaptor (flange) installation procedure.
Refer to section 1.31.19 for the alternator mounting adaptor/step-up gear alignment procedure which is required when installing a camshaft gear-driven alternator.

NOTICE:
Failure to properly align the alternator mounting adaptor with the step-up gear may result in gear train damage at start-up.

When installing the improved adaptor on an improved flywheel housing, use hole set "J" to adjust the adaptor to the alternator step-up gear. When installing the improved adaptor on a former flywheel housing, use hole set "H" for adjustment. See Figure 8-39.

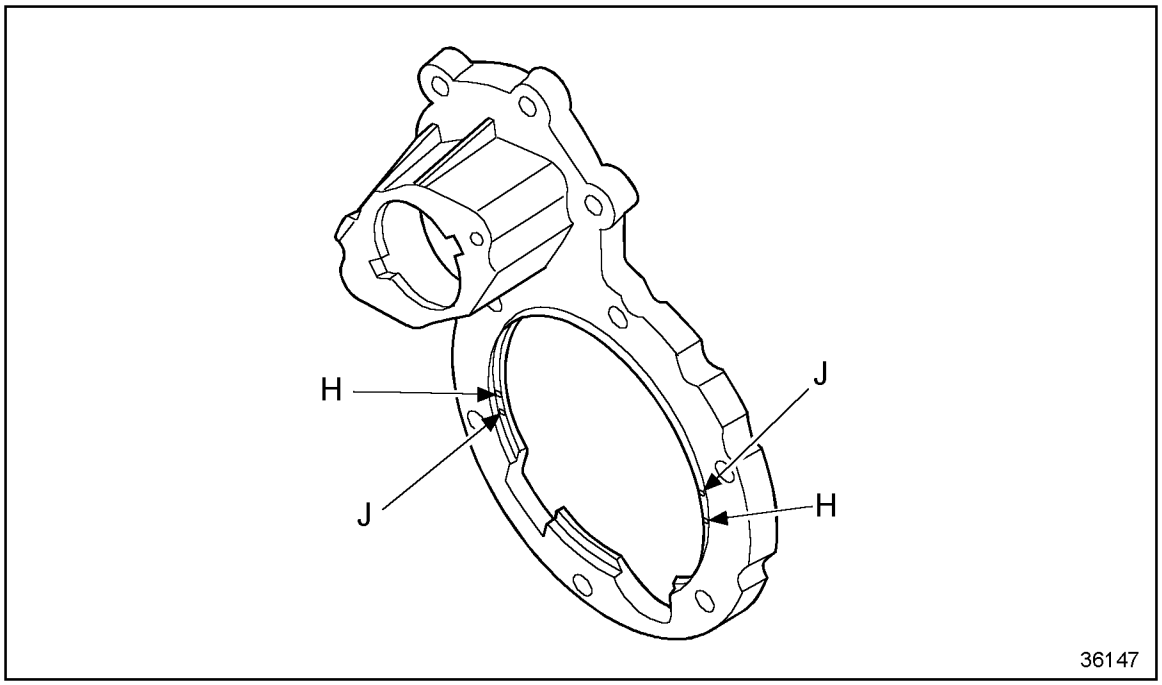


Figure 8-39 Alternator Adaptor Showing Location of "H" and "J" Adjusting Holes

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EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

Listed in Table 8-2 are the exceptions to standard bolt and nut torque specifications.

Application	Thread	lb·ft	N·m
Flange Mounted Alternator Adaptor Nut	3/8-24	15-20	20-27
Tachometer Drive Cover Bolt	7/16-14	30-35	41-47
Tachometer Drive Cover Bolt	1/2-13	30-35	41-47
Tachometer Drive Shaft (Blower)	1/2-20	55-65	75-88
Starting Motor Switch Mounting Nut	5/8-32	36-48	45-65
Starting Motor Attaching Bolts (Aluminum Flywheel Housing)	5/8-11	95-105	129-143
50 DN Alternator Mounting Nut	1/2-13	53-56	72-76
50 DN Alternator Mounting Nut	3/8-16	30-35	41-47
50 DN Alternator Mounting Stud	1/2-13	20-25	27-34
50 DN Alternator Mounting Stud	3/8-16	20-25	27-34

Table 8-2 Exceptions to Standard Bolt and Nut Torque Specifications

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9 POWER TAKE-OFF

Section **Page**

9.1 POWER TAKE-OFF TORQMATIC CONVERTER 9-3

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9.1 POWER TAKE-OFF TORQMATIC CONVERTER

DDC does not service the power take-off torqmatic converter. Refer to OEM guidelines for service information.

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10 SPECIAL EQUIPMENT

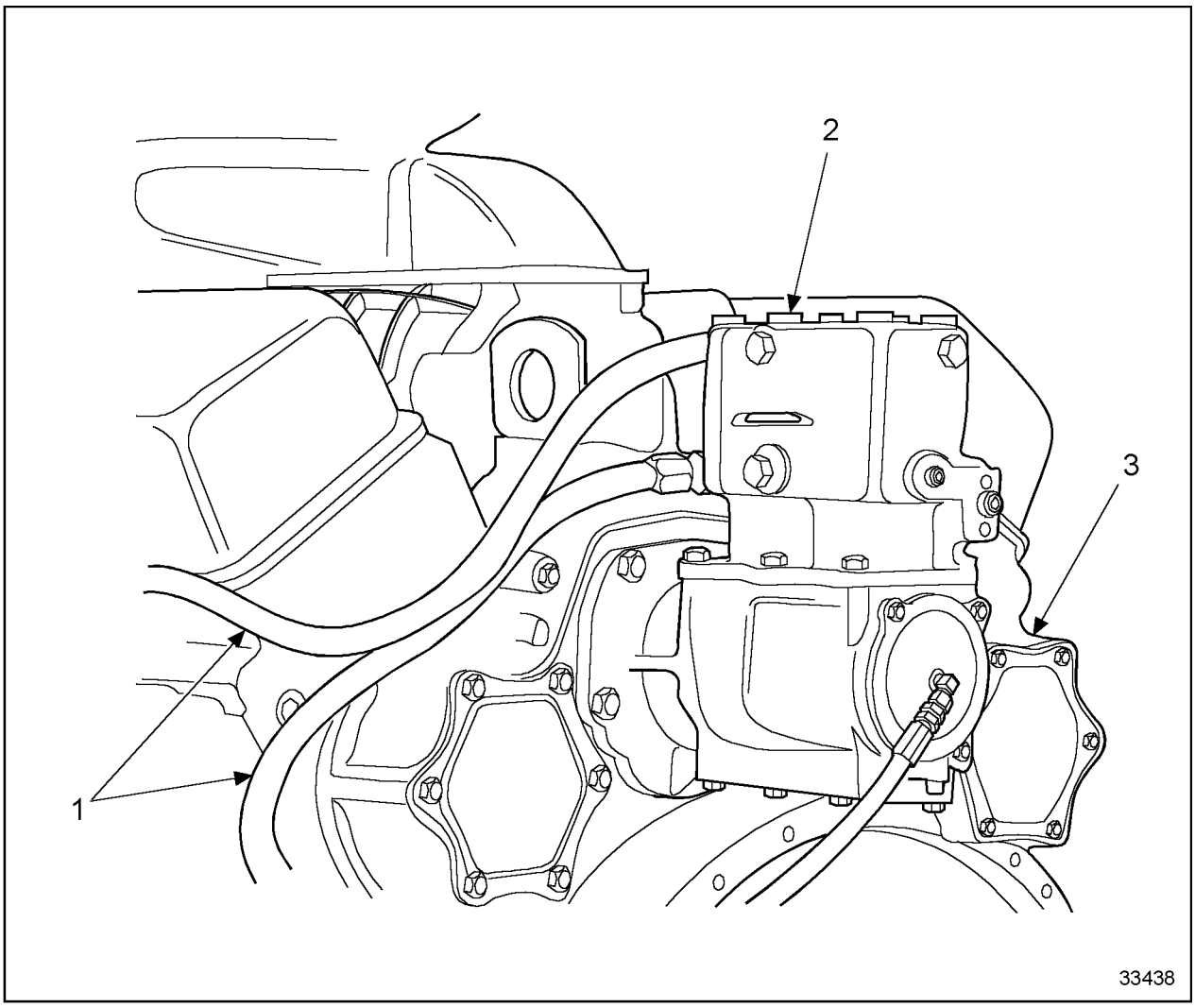
Section **Page**

10.1 AIR COMPRESSOR 10-3
10.2 ENGINE BLOCK HEATER 10-9
10.3 TRANSMISSIONS 10-10

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10.1 AIR COMPRESSOR

The air compressor can be mounted on a bracket attached to the engine cylinder block and belt-driven from the crankshaft pulley, or it can be flange-mounted to the flywheel housing and gear driven by an accessory drive attached to a camshaft gear. See Figure 10-1.



1. Air Compressor Lines
2. Air Compressor Assembly
3. Flywheel Housing

Figure 10-1 Air Compressor Mounting (Flange Mounted)

A six bolt design air compressor mounting base, mounting bracket, and gasket are used on engines equipped with a belt-driven air compressor.

The air compressor runs continuously while the engine is running. With the compressor running, the compressor governor, which acts in conjunction with the unloading mechanism in the compressor cylinder block, controls the actual air compression. The governor starts and stops the air compression. The governor loads or unloads the compressor when the air pressure in the system reaches the desired minimum or maximum pressure.

During each piston down stroke, a partial vacuum is created above the piston, which unseats the inlet valve and allows air drawn from the airbox or through an intake strainer to enter the cylinder above the piston. As the piston starts the upward stroke, the air pressure on top of the inlet valves and the inlet valve return spring force closed the inlet valve. The air above the piston is compressed until the pressure lifts the discharge valve. The compressed air is discharged through the discharge line into the reservoir.

As each piston starts its down stroke, the discharge valve above it returns to its seat, preventing the compressed air from returning to the cylinder. The cycle repeats.

When the air pressure in the reservoir reaches the maximum governor setting, compressed air from the reservoir passes through the governor into the cavity below the unloading piston in the compressor cylinder block. The air pressure lifts the unloading pistons, which lifts the inlet valves off their seats.

With the inlet valves held off their seats, the air during each piston upstroke is passed back through the air inlet cavity and to the other cylinder, where the piston is on the down stroke. When the air pressure in the reservoir drops to the minimum governor setting, the governor releases the air pressure beneath the unloading pistons. The unloading piston return spring forces the piston down, and the inlet valve springs return the inlet valves to their seats. Compression resumes.

⚠ CAUTION:

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

The Midland air compressor oil test card is used to test engine-mounted air compressors for excessive oil leaks.

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Air compressor oil test card DD5524 is available from authorized Detroit Diesel service outlets. See Figure 10-2.

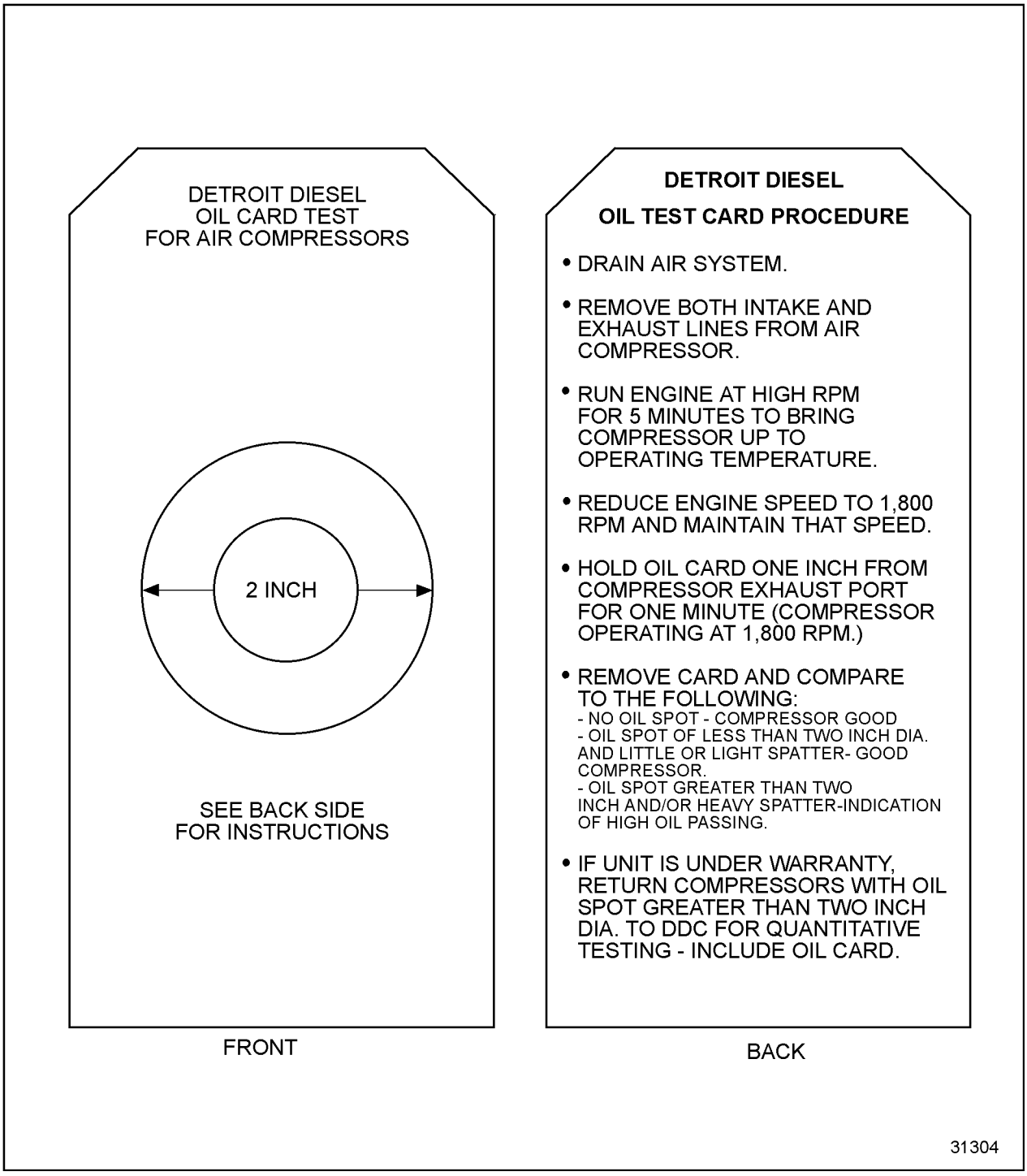


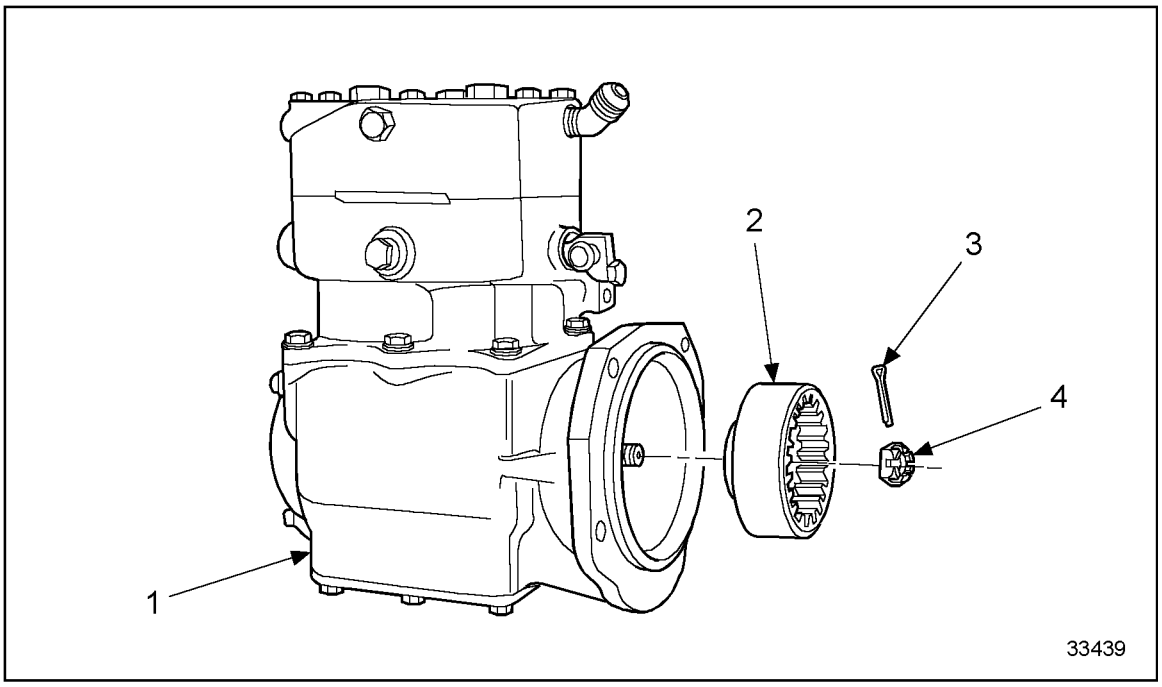
Figure 10-2 Midland Air Compressor Oil Test Card

⚠ CAUTION:

To avoid injury from oil spray, wear adequate eye protection (face shield or safety goggles) when performing the oil test procedure.

Follow the instructions printed on both sides of the card for optimum test results. If compressor is under warranty, return to Detroit Diesel for testing with the oil card.

NOTE:
When installing a pulley or a drive hub on a flange mounted air compressor, the 3/4 in.-16 drive shaft slotted nut must be tightened to 136 N·m (100 lb·ft) torque minimum before installing the 3/32 in. x 1-1/4 in. cotter pin. See Figure 10-3.



1. Air Compressor Assembly
2. Drive Hub
3. Cotter Pin
4. Slotted Nut

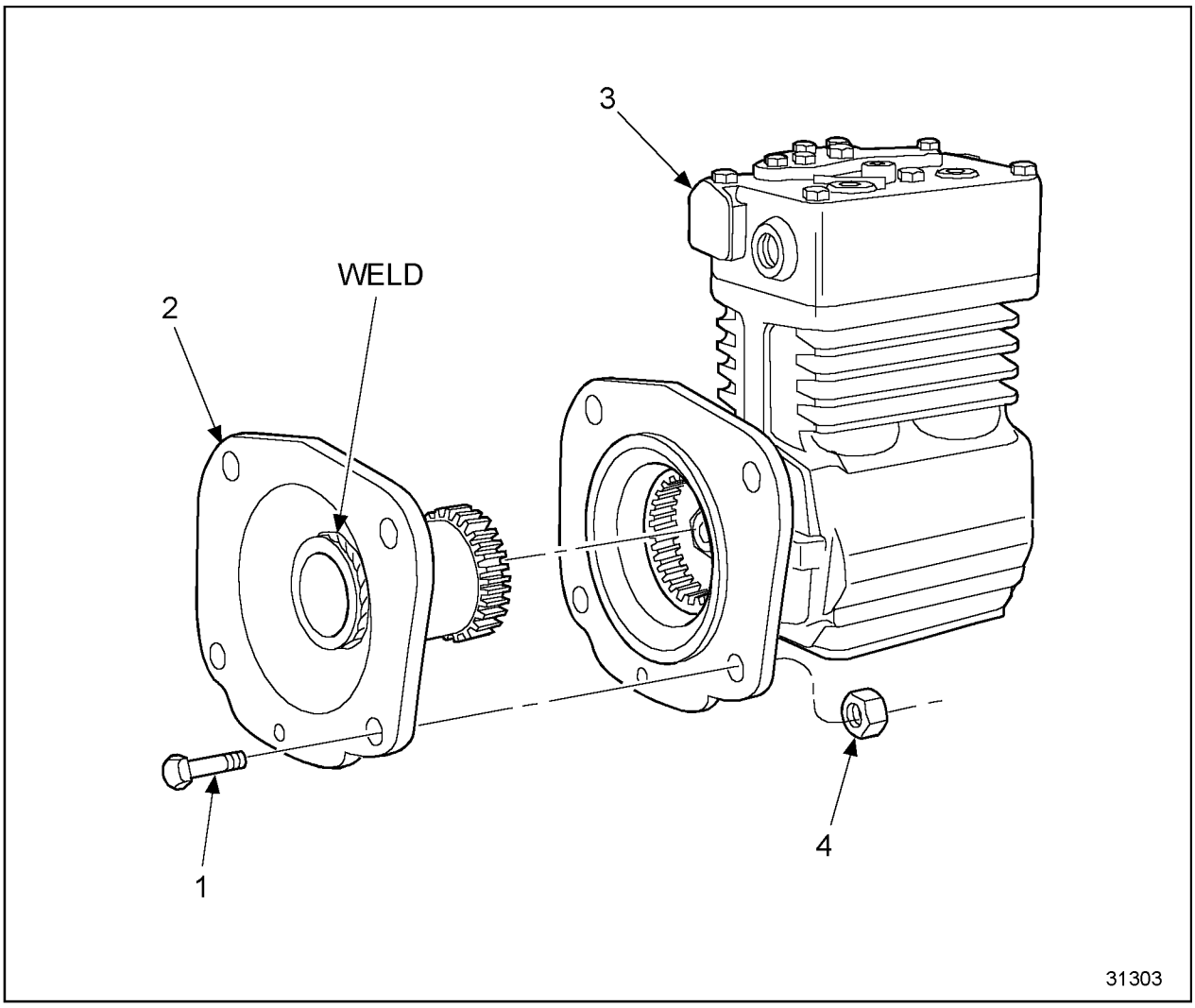
Figure 10-3 Typical Air Compressor with Drive Hub

Perform the procedure as follows:

NOTE:
The air compressor drive shaft will turn during the torquing operation unless some provision is made to hold it.

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1. Weld a modified drive coupling to a support or base. See Figure 10-4.



1. Bolt
2. Holding Fixture
3. Air Compressor Assembly
4. Nut

Figure 10-4 Fixture for Holding Drive While Installing or Removing Slotted Nut

2. Anchor the base to the compressor mounting flange.

NOTE:
An old flywheel housing cover that matches the compressor flange makes an ideal base for the modified coupling.

3. Mesh the coupling exterior splines with the drive hub internal splines.

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4. Secure the entire assembly to the compressor housing.

NOTE:
The hub and shaft will not rotate when torque is applied.

5. Remove the part of the base within the coupling inner diameter to permit wrench socket placement on the nut.
6. Secure the base to the compressor during the torquing operation with two bolts.

10.1.1 Repair or Replacement of Air Compressor

The air compressor is not a serviceable item. Refer to OEM guidelines or an authorized Detroit Diesel distributor for service recommendations.

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10.2 ENGINE BLOCK HEATER

To improve engine block heater maintenance, adhere to the following procedure:

Any time the engine cooling system is drained, the electrical connections to the engine block heater must first be disconnected. Failure to follow this procedure will result in damage to the engine block heater.

The label is available under part number 23515818 and should be placed in a prominent location on any engine with a block heater. See Figure 10-5.

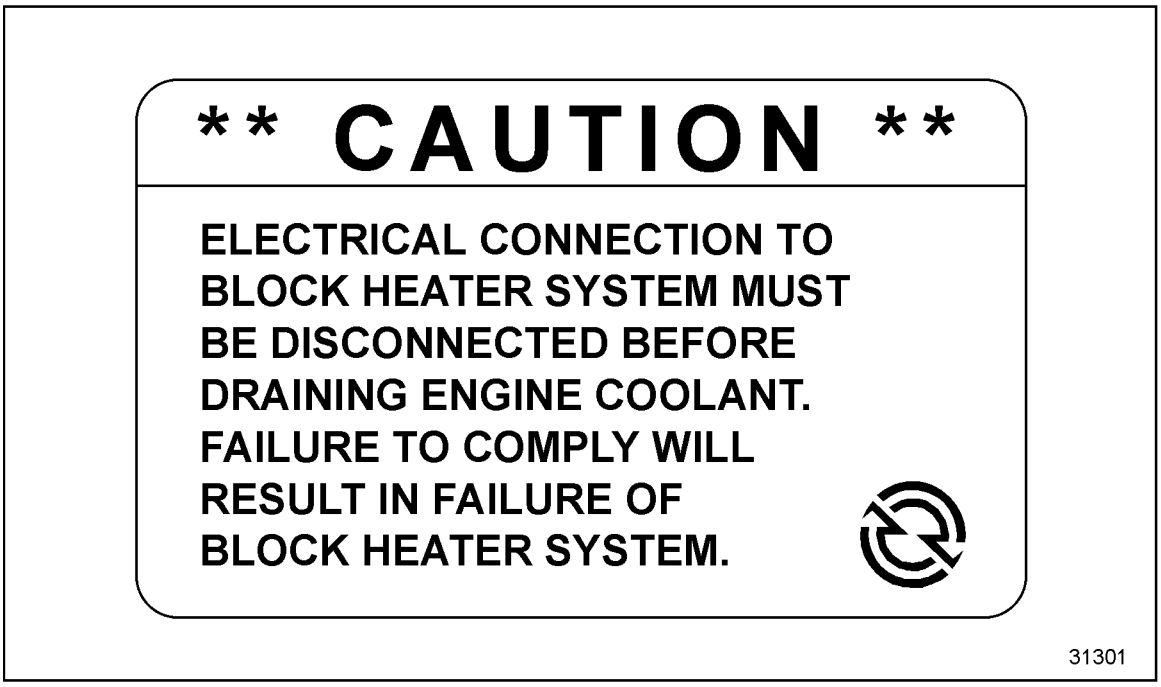


Figure 10-5 Block Heater Caution Label

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10.3 TRANSMISSIONS

DDC does not service the transmission. Refer to OEM Guidelines for service information.

For service and overhaul procedures for Allison products, refer to the manufacturer:

Allison Transmission Division

General Motors Corporation

P.O. Box 894

Indianapolis, IN 46206-0894

For service and overhaul procedures for the Twin Disc Marine Gear assembly, refer to the manufacturer:

Twin Disc, Inc.

1328 Racine Street

Racine, Wisc. 53403

10.3.1 Marine Transmission Trolling Valve Operation

When the troll mode is used for extended periods of time (over two hours), marine gear oil temperature alarms should be installed and set for 90.8°C (195°F).

If the alarm sounds while the troll mode is in use, perform one of the following steps:

1. Once every hour, put the gear in neutral and run the engine at a higher RPM. This will cool the gear oil to an acceptable temperature.
2. Determine whether the desired prop shaft speed can be achieved while running at a higher engine speed and moving the troll lever to a higher slip position.

NOTE:
At higher engine RPM's, vibration or "chatter" may become evident near clutch lock-up. This is an audible indication that the output speed is more than 75% of lock-up. This is not an approved operating range.

To eliminate vibration, perform one or both of the following steps:

1. Reduce trolling lever position, and increase engine speed within allowable control limits.
2. Decrease engine speed, and shift out of troll to lock-up position.

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11 OPERATION AND VERIFICATION

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11.1 PREPARATION FOR A FIRST TIME START

Before starting an engine for the first time, carefully read and follow the instructions contained in this chapter and refer to section 12.

NOTICE:
Attempting to run the engine before studying these instructions may result in serious engine damage.

NOTICE:
Failure to perform the required prestart operations will result in engine damage.

When preparing to start a new or overhauled engine, or an engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), refer to section 13.2.1 for *"Daily Interval Maintenance"*.

11.1.1 Installation of Drain Cocks or Plugs in Cooling System

Install all drain cocks or plugs in the cooling system as follows:

1. Open the cooling system vents, if used.
2. Remove the filler cap, and fill the cooling system with a specified coolant. Refer to section 5.3 and refer to section 13.12.2.

NOTE:
Keep the liquid level about two inches below the filler neck to allow fluid expansion.

3. Close the vents, if used, after filling the cooling system.

NOTICE:
Failure to prime the raw water pump may result in damage to the pump impeller.

4. On marine installations, prime the raw water cooling system, and open any sea cocks in the raw water pump intake line. Refer to section 13.54.
5. Remove the pipe plug or electrode provided in the pump outlet elbow, and pour water in the pump.

11.1.2 Pre-Lubricate Lubrication System

To ensure an immediate oil flow to all bearing surfaces at initial engine start-up, DDC recommends that the engine lubrication system be charged with a commercially available pressure prelubricator.

Pre-lubricate as follows:

1. Remove the pipe plug from the engine main oil gallery, and attach the prelubricator hose.
2. Remove the valve rocker cover(s) and, using a positive displacement pump set at 172-241 kPa (25-35 lb/in.^{2}), pump the recommended grade engine lubricating oil until it flows from the rocker arms.
3. If the engine is turbocharged, disconnect the oil supply lines at the turbo bearing (center) housings, and fill the bearing housing cavities with approximately 1/2 liter (one pint) of the recommended grade clean engine oil.
4. Turn the rotating assemblies by hand to coat all internal surfaces with oil.
5. Install the turbo oil supply lines. Refer to secton 6.6.5.
6. After 20 minutes, check the crankcase oil level. Add enough oil to bring the level to the "full" mark on the dipstick.

NOTE:
Do not overfill crankcase.

7. Disconnect the prelubricator hose, and plug the main oil gallery hole.
8. Replace all components previously removed.
9. Before initial engine start-up, DDC recommends cranking the engine with the governor in the no-fuel position until oil pressure registers on the gage.For engine lubricating oil recommendations, refer to section 13.5.

NOTE:
If a pressure prelubricator is not available, fill the crankcase to the proper level with the specified heavy-duty lubricating oil. Refer to section 13.5.1. Remove the valve rocker covers, and pour lubricating oil (the same grade and viscosity as that used in the crankcase) over the rocker arms.

11.1.3 Turbocharger Run-In

Perform turbocharger run-in as follows:

1. Clean the area, and disconnect the oil inlet line at the bearing housing.
2. Fill the bearing housing cavity with clean engine oil.
3. Install the oil line.
4. Clean any spilled oil.

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⚠ 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:

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.

5. Start and run the engine at idle until oil pressure and supply has reached all turbocharger moving parts.

NOTE:
When the oil pressure gage registers 69 kPa (10 lb/in.^{2}) pressure at idle speed, all moving parts are lubricated.

NOTE:
The free floating bearings in the turbocharger center housing require positive lubrication. Before the turbocharger reaches its maximum operating speed which is produced by high engine speeds, run it at idle.

11.1.4 Transmission

Check the oil level and, if necessary, fill the transmission case, marine gear, or torque converter supply tank to the proper lever with the specified lubricant. Refer to section 13.5.1.

11.1.5 Fuel System

Fill the fuel system as follows:

1. Fill the fuel tank with the specified fuel. Refer to section 5.1.
2. Open the fuel valve (if the unit is equipped with one).
3. Fill the fuel system between the pump and the fuel return manifold with fuel to ensure prompt starting.

NOTE:
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.

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4. Remove the plug in the top of the fuel filter cover, and slowly fill the filter with fuel.

NOTE:
On an engine equipped with a hydrostarter, use a priming pump to ensure the fuel lines and the injectors are filled with fuel before attempting to start the engine.

NOTE:
The fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

11.1.6 Lubrication Fittings

Prepare the lubrication fittings as follows:

1. Fill all grease cups, and lubricate at all fittings with an all purpose grease (except for fan hub pulley fitting) Refer to section 13.33.
2. Apply lubricating oil to the throttle linkage and other moving parts, and fill the hinged cap oilers with a hand oiler.

11.1.7 Drive Belts

Adjust all drive belts. Refer to section 13.18.

11.1.8 Battery

Examine the battery. The top should be clean and dry. The terminals should be tight and protected with a petroleum jelly. The electrolyte must be at the proper level.

NOTE:
When necessary, check the battery with a hydrometer. The reading should be 1.265 or higher. Hydrometer readings should always be corrected for the temperature of the electrolyte.

11.1.9 Generator Set

Where applicable, fill the generator end bearing housing with the same lubricating oil as used in the engine.

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NOTICE:
A generator set should be connected and grounded in accordance with the applicable local electrical codes. Failure to observe this notice may result in electrical shortage to generator set.

11.1.10 Clutch

Disengage the clutch, if equipped.

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11.2 STARTING

Before starting the engine for the first time, perform the operations listed under Preparation For Starting Engine First Time. Refer to section 11.1.

Before a routine start, refer to section 13.1 *"Daily Operations"*.

NOTICE:
If a manual or an automatic shutdown system is incorporated in the unit, the control must be set in the open position before starting the engine. The blower will be seriously damaged if operated with the air shutoff valve in the closed position.

NOTE:
On engines with dual air shutdown housings, both air shutoff valves must be in the open position before starting the engine.

NOTE:
Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid.

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⚠ 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.**

The instructions for cold weather fluid starting aid use will vary depending on the type used. Reference should be made to these instructions before attempting a cold weather start.

11.2.1 Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows:

1. Set the speed control lever at part throttle.
2. Bring it back to the desired no-load speed.
3. On mechanical governors, ensure stop lever on the governor cover is in the run position. On hydraulic governors, make sure the stop knob is pushed all the way in.
4. Press the starting motor switch firmly.

NOTICE:
To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

5. If the engine fails to start within 30 seconds, release the starting switch, and allow the starting motor to cool a few minutes before trying again.
6. If the engine fails to start after four attempts, an inspection for the cause.

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11.2.2 Initial Engine Start (Air Starter)

Because of the limited storage tank volume and the relatively short cranking cycle, ensure engine is ready to start before activating the air starter.

Start an engine equipped with an air starter as follows:

1. Set the speed control lever at part throttle.
2. Bring it back to the desired no-load speed.
3. Ensure stop lever on the mechanical governor cover is in the "run" position. On hydraulic governors, ensure stop knob is pushed all the way in.
4. Check the pressure in the air storage tank.
5. If necessary, add air to bring the pressure up to the recommended minimum for starting.
6. Press the starter button firmly, and hold until the engine starts.

11.2.3 Initial Engine Start (Hydrostarter)

Start an engine equipped with a hydrostarter as follows:

1. Use the priming pump to ensure fuel filter, fuel lines, and injectors are filled with fuel before attempting to start the engine.
2. Raise the hydrostarter accumulator pressure with the hand pump until the gage reads as listed in Table 11-1.

Ambient Temperature	kPa	psi
Above 4.4°C (40°F)	10342	1500
4.4 to -18°C (40-0°F)	17237	2500
Below -18°C (0°F)	22753	3300

Table 11-1 Pressure Gage Reading

3. Set the engine controls for starting with the throttle at least half open.

NOTICE:
During cold weather, add starting fluid at the same time the hydrostarter motor lever is moved. Do not wait to add the fluid after the engine is turning over. Failure to observe this notice may result in hydrostarter failure.

4. Push the hydrostarter control lever to simultaneously engage the starter pinion with the flywheel ring gear and to open the control valve.
5. Close the valve as soon as the engine starts to conserve the accumulator pressure and to avoid excessive starter drive clutch assembly over-run.

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11.3 RUNNING

The following procedures 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, stop the engine, and check the lubricating oil system. Refer to section 13.5.

11.3.2 Warm-Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm-up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows to supply ample air for the engine.

11.3.3 Inspection of Cooling, Fuel and Lubrication System

While the engine is running at operating temperature, check for coolant refer to section 13.12, fuel refer to section 13.11, fuel lines and flexible hoses, or lubricating oil leaks refer to section 13.5.3, leak check lubrication system. Tighten the line connections where necessary.

11.3.4 Engine Temperature

Refer to section 11.5 for normal engine coolant temperature.

Listed in Table 11-2 are the ambient temperature readings.

Marine Gear	Posi-tion	†Test RPM	Test Pressure kPa/psi	Marine Gear	Position	†Test RPM	Test Pressure kPa/psi
MG-506 (Except 1.5:1 and 2:1 Ratio)	Neutral and Engaged	600	1930-2170 kPa (280-315 lb/in.^{2})	MG-514 (Less Than 4:1 Ratio) (Shallow Case)	Neutral Neutral	600 1800	138-448 kPa (20-65 lb/in.^{2}) 310-634 kPa (40-92 lb/in.^{2})
MG-506 (Except 1.5:1 and 2:1 Ratio)	Neutral and Engaged	1800	2067-2205 kPa (300-320 lb/in.^{2})	MG-514 (Less Than 4:1 Ratio) (Shallow Case)	Engaged Engaged	600 1800	1447-1619 kPa (210-235 lb/in.^{2}) 1571-1633 kPa (228-237 lb/in.^{2})
MG-506 (Except 1.5:1 and 2:1 Ratio)	Cruising	Mini-mum	1861 kPa (270 lb/in.^{2})	MG-514 (Less Than 4:1 Ratio) (Shallow Case)	Cruising	Mini-mum	1481 kPa (215 lb/in.^{2})

Marine Gear	Posi-tion	†Test RPM	Test Pressure kPa/psi	Marine Gear	Position	†Test RPM	Test Pressure kPa/psi
MG-506 (Only 1.5:1 and 2:1 ratios)	Neutral and Engaged	600	2274-2515 kPa (330-365 lb/in.^{2})	MG-514 (4:1 and Greater Ratio) (Deep Case)	Neutral Neutral	600 1800	241-448 kPa (35-65 lb/in.^{2}) 379-586 kPa (50-85 lb/in.^{2})
MG-506 (Only 1.5:1 and 2:1 ratios)	Neutral and Engaged	1800	2412-2550 kPa (350-370 lb/in.^{2})	MG-514 (4:1 and Greater Ratio) (Deep Case)	Engaged Engaged	600 1800	241-448 kPa (35-65 lb/in.^{2}) 379-586 kPa (50-85 lb/in.^{2})
MG-506 (Only 1.5:1 and 2:1 ratios)	Cruising	Mini-mum	2308 kPa (335 lb/in.^{2})	MG-514 (4:1 and Greater Ratio) (Deep Case)	Cruising	Mini-mum	1275 kPa (185 lb/in.^{2})
MG-509	Neutral	600	241-483 kPa (35-70 lb/in.^{2})	MG-521	Neutral	600	310-586 kPa (45-85 lb/in.^{2})
MG-509	Neutral	1800	345-586 kPa (50-85 lb/in.^{2})	MG-521	Neutral	1800	517-689 kPa (475-100 lb/in.^{2})
MG-509	Engaged	600	1289-1481 kPa (187-215 lb/in.^{2})	MG-521	Engaged	600	1241-1481 kPa (180-215 lb/in.^{2})
MG-509	Engaged	1800	1330-1516 kPa (193-220 lb/in.^{2})	MG-521	Engaged	1800	1296-1516 kPa (188-220 lb/in.^{2})
MG-509	Cruising	Mini-mum	1137 kPa (165 lb/in.^{2})	MG-521	Cruising	Mini-mum	1137 kPa (165 lb/in.^{2})
MG-512	Neutral	600	310-483 kPa (45-70 lb/in.^{2})	MG-527	Neutral	600	310-586 kPa (45-85 lb/in.^{2})
MG-512	Neutral	1800	414-621 kPa (60-90 lb/in.^{2})	MG-527	Neutral	1800	448-689 kPa (65-100 lb/in.^{2})
MG-512	Engaged	600	1275-1481 kPa (185-215 lb/in.^{2})	MG-527	Engaged	600	1241-1481 kPa (180-215 lb/in.^{2})
MG-512	Engaged	1800	1344-1516 kPa (195-220 lb/in.^{2})	MG-527	Engaged	1800	1296-1516 kPa (188-220 lb/in.^{2})
MG-512	Cruising	Mini-mum	1275 kPa (185 lb/in.^{2})	MG-527	Cruising	Mini-mum	1137 kPa (165 lb/in.^{2})
MG-513	Neutral	600	483-758 kPa (70-110 lb/in.^{2})	-	-	-	-
MG-513	Neutral	1800	621-896 kPa (90-130 lb/in.^{2})	-	-	-	-
MG-513	Engaged	600	1585-1861 kPa (230-270 lb/in.^{2})	-	-	-	-
MG-513	Engaged	1800	1654-1930 kPa (240-280 lb/in.^{2})	-	-	-	-
MG-513	Cruising	Mini-mum	1612 kPa (234 lb/in.^{2})	-	-	-	-

* Sump or heat exchanger inlet 99°C (210°F) maximum. Normal operating range desired 60-82°C (140-180°F) minimum continuous duty.

† Sump or heat exchanger inlet 107°C (225°F) maximum intermittent permissible in pleasure craft.

Table 11-2 Twin Disc Marine Gear Operating Conditions

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11.3.5 Crankcase

Prepare the crankcase as follows:

1. If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached.
2. Allow the oil to drain (approximately 20 minutes) back into the crankcase.
3. Check the oil level.
4. Add oil, if necessary, to the proper level on the dipstick. Refer to section 13.5.1.

11.3.6 Clutch

Do not engage a clutch with a sintered iron clutch plate at engine speeds over 850 RPM. A clutch with an asbestos or vegetable fiber material clutch plate must not be engaged at speeds over 1000 RPM.

11.3.7 Cooling System

Remove the radiator or heat exchanger tank cap slowly after the engine has reached normal operating temperature, and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean soft water or an ethylene glycol base antifreeze.

11.3.8 Transmission

Check the marine gear oil pressure. The operating oil pressure range at operating speed is 621-1034 kPa (90-150 lb/in.^{2}) (Allison gear). The operating oil pressure varies with the different Twin Disc® gears as listed in Table 11-3. Check, and if necessary, replenish the oil supply in the transmission.

Marine Gear	Posi-tion	†Test RPM	Test Pressure kPa/psi	Marine Gear	Position	†Test RPM	Test Pressure kPa/psi
MG-506 (Except 1.5:1 and 2:1 Ratio)	Neutral and Engaged	600	1930-2170 kPa (280-315 lb/in.^{2})	MG-514 (Less Than 4:1 Ratio) (Shallow Case)	Neutral Neutral	600 1800	138-448 kPa (20-65 lb/in.^{2}) 310-634 kPa (40-92 lb/in.^{2})
MG-506 (Except 1.5:1 and 2:1 Ratio)	Neutral and Engaged	1800	2067-2205 kPa (300-320 lb/in.^{2})	MG-514 (Less Than 4:1 Ratio) (Shallow Case)	Engaged Engaged	600 1800	1447-1619 kPa (210-235 lb/in.^{2}) 1571-1633 kPa (228-237 lb/in.^{2})
MG-506 (Except 1.5:1 and 2:1 Ratio)	Cruising	Mini-mum	1861 kPa (270 lb/in.^{2})	MG-514 (Less Than 4:1 Ratio) (Shallow Case)	Cruising	Mini-mum	1481 kPa (215 lb/in.^{2})

Marine Gear	Posi-tion	†Test RPM	Test Pressure kPa/psi	Marine Gear	Position	†Test RPM	Test Pressure kPa/psi
MG-506 (Only 1.5:1 and 2:1 ratios)	Neutral and Engaged	600	2274-2515 kPa (330-365 lb/in.^{2})	MG-514 (4:1 and Greater Ratio) (Deep Case)	Neutral Neutral	600 1800	241-448 kPa (35-65 lb/in.^{2}) 379-586 kPa (50-85 lb/in.^{2})
MG-506 (Only 1.5:1 and 2:1 ratios)	Neutral and Engaged	1800	2412-2550 kPa (350-370 lb/in.^{2})	MG-514 (4:1 and Greater Ratio) (Deep Case)	Engaged Engaged	600 1800	241-448 kPa (35-65 lb/in.^{2}) 379-586 kPa (50-85 lb/in.^{2})
MG-506 (Only 1.5:1 and 2:1 ratios)	Cruising	Mini-mum	2308 kPa (335 lb/in.^{2})	MG-514 (4:1 and Greater Ratio) (Deep Case)	Cruising	Mini-mum	1275 kPa (185 lb/in.^{2})
MG-509	Neutral	600	241-483 kPa (35-70 lb/in.^{2})	MG-521	Neutral	600	310-586 kPa (45-85 lb/in.^{2})
MG-509	Neutral	1800	345-586 kPa (50-85 lb/in.^{2})	MG-521	Neutral	1800	517-689 kPa (475-100 lb/in.^{2})
MG-509	Engaged	600	1289-1481 kPa (187-215 lb/in.^{2})	MG-521	Engaged	600	1241-1481 kPa (180-215 lb/in.^{2})
MG-509	Engaged	1800	1330-1516 kPa (193-220 lb/in.^{2})	MG-521	Engaged	1800	1296-1516 kPa (188-220 lb/in.^{2})
MG-509	Cruising	Mini-mum	1137 kPa (165 lb/in.^{2})	MG-521	Cruising	Mini-mum	1137 kPa (165 lb/in.^{2})
MG-512	Neutral	600	310-483 kPa (45-70 lb/in.^{2})	MG-527	Neutral	600	310-586 kPa (45-85 lb/in.^{2})
MG-512	Neutral	1800	414-621 kPa (60-90 lb/in.^{2})	MG-527	Neutral	1800	448-689 kPa (65-100 lb/in.^{2})
MG-512	Engaged	600	1275-1481 kPa (185-215 lb/in.^{2})	MG-527	Engaged	600	1241-1481 kPa (180-215 lb/in.^{2})
MG-512	Engaged	1800	1344-1516 kPa (195-220 lb/in.^{2})	MG-527	Engaged	1800	1296-1516 kPa (188-220 lb/in.^{2})
MG-512	Cruising	Mini-mum	1275 kPa (185 lb/in.^{2})	MG-527	Cruising	Mini-mum	1137 kPa (165 lb/in.^{2})
MG-513	Neutral	600	483-758 kPa (70-110 lb/in.^{2})	-	-	-	-
MG-513	Neutral	1800	621-896 kPa (90-130 lb/in.^{2})	-	-	-	-
MG-513	Engaged	600	1585-1861 kPa (230-270 lb/in.^{2})	-	-	-	-
MG-513	Engaged	1800	1654-1930 kPa (240-280 lb/in.^{2})	-	-	-	-
MG-513	Cruising	Mini-mum	1612 kPa (234 lb/in.^{2})	-	-	-	-

* Sump or heat exchanger inlet 99°C (210°F) maximum. Normal operating range desired 60-82°C (140-180°F) minimum continuous duty.

† Sump or heat exchanger inlet 107°C (225°F) maximum intermittent permissible in pleasure craft.

Table 11-3 Twin Disc Marine Gear Operating Conditions

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11.3.9 Turbocharger

Inspect the turbocharger for leaks and excessive vibration, refer to section 13.17. Stop the engine immediately if there is an unusual noise in the turbocharger.

11.3.10 Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete fuel combustion in a cold engine will cause crankcase dilution, lacquer or formation, gummy deposits on the valves, pistons, and rings, and rapid sludge accumulation in the engine.

NOTICE:
When prolonged engine idling is necessary, maintain at least 800 RPM. Failure to follow this notice may result in reduced engine life.

11.4 STOPPING

Perform the following procedure for stopping the engine.

11.4.1 Normal Stopping

Perform the following for normal stopping:

1. Release the load, and decrease the engine speed.
2. Put all shift levers in the neutral position.
3. Allow the engine to run at half speed or slower with no load for four or five minutes.
4. Move the stop lever to the stop position to stop the engine.

11.4.2 Emergency Stopping

To stop an engine (normal or emergency) equipped with the ***spring-loaded one-screw design*** injector control tube, perform the following procedure:

1. Pull the governor stop lever to the stop position.If engine is equipped with the ***non-spring loaded two-screw design*** injector control tube, and does not stop after using the normal stopping procedure, perform the following procedure.
2. Pull the Emergency Stop knob all the way out. This control cuts off the air to the engine.

NOTICE:
The emergency shutdown system should never be used except in an emergency. Emergency shutdown use can cause oil to be sucked past the oil seals and into the blower housing.

The air shutoff valve, located on the blower air inlet housing, must be reset by hand. The Emergency Stop knob must be pushed in before the engine can be started again.

NOTE:
Do not try to restart until the cause for the malfunction has been found and corrected.

11.4.3 Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank. A full tank minimizes condensation.

11.4.4 Exhaust System

Drain the condensation from the exhaust line or silencer.

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11.4.5 Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Refer to section 13.12.3. Leave the drains open. Open the heat exchanger cooling system raw water drains.

11.4.6 Crankcase

Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.

11.4.7 Transmission

Check and, if necessary, add sufficient oil to bring it to the proper level.

11.4.8 Inspection

Inspect for leaks in the fuel refer to section 13.11, lubricating refer to section 13.5.3, and cooling systems refer to section 13.12. Tighten the line connections where necessary.

11.4.9 Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run. Refer to section 13.42 and steam clean engine.

Refer to section 13.1 for information on all daily maintenance operations. Perform the operations required for the number of hours or miles the engine has been in operation.

Make any adjustments and minor repairs necessary to correct problems encountered by operators during the previous run.

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11.5 OPERATING CONDITIONS

The following charts are included as an aid to troubleshooting. Variations from the conditions as listed may be indicative of an abnormal situation demanding correction. Ensure that readings represent true values and that instruments are accurate, before attempting to make corrections to the engine.

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See Figure 11-1 for chart of the operating conditions on all engines (except turbocharged).

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–47	50–70	50–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	1.1	3.8	5.0
At max. full–load exhaust back pressure	2.3	6.4	8.2
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – oil bath or dry type	12.4	25.0	25.0
Clean air cleaner:			
Oil bath type	8.7	13.4	15.9
Dry type with precleaner	8.7	13.4	15.9
Dry type less precleaner	5.2	9.1	11.5
Crankcase pressure (inches water) – max.	1.0	2.2	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	1.5	3.3	4.0
No load	1.0	2.1	2.6
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting (6, 8V)	45–70	45–70	45–70
Normal with .070" restriction fitting (12, 16V)	30–65	30–65	30–65
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
6 and 8V engines	0.8	0.9	0.9
12 and 16V engines	1.2	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	550		
Minimum – at 600 rpm	500		

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-1 All Engines (Except Turbocharged)

See Figure 11-2 for chart of the operating conditions on 6V-T engines with TI8A40 turbocharger.

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	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50–70	50–70	50–70
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9280 injector	21.0	25.5	28.0
9285 injector	22.5	27.0	29.5
9290 injector	24.0	29.0	31.5
9295 injector	25.5		
At max. full–load exhaust back pressure (clean ports):			
9280 injector	19.5	23.7	26.0
9285 injector	20.9	25.1	27.4
9290 injector	22.3	27.0	29.3
9295 injector	23.4		
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	14.5	18.0	20.0
Clean air cleaner:			
Dry type with precleaner	8.7	10.8	12.0
Dry type less precleaner	5.8	7.2	8.0
Crankcase pressure (inches water) – max.	2.2	2.7	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	1.8	2.2	2.5
No load	1.3	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
.080" restriction fitting	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.

When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-2 6V-T Engines with TI8A40 Turbocharger and 1.14 A/R* Turbine Housing

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See Figure 11-3 for chart of the operating conditions on 6V-T (OTM) engines.

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	12.5	25.9	33.9
At max. exhaust back pressure (clean ports)	11.8	24.4	32.0
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.4	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.7	2.0	2.5
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-3 6V-T (OTM) Engines with TVI802 Turbocharger and 1.23 A/R* Turbine Housing — 9290 Injectors

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See Figure 11-4 for chart of the operating conditions on 6V-TA and 6V-TAC engines with TV7101 turbocharger and 1.23 A/R* turbine housing — California coach

	1900 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9E65 injector – No. 1 Fuel	35.3	38.4	41.5
9E70 injector – No. 1 Fuel	37.3	40.5	43.7
9E65 injector – No. 2 Fuel	34.6	41.1	44.3
9E70 injector – No. 2 Fuel	37.0	43.7	47.0
At max. exhaust back pressure (clean ports):			
9E65 injector – No. 1 Fuel	33.0	36.1	39.2
9E70 injector – No. 1 Fuel	35.0	38.2	41.4
9E65 injector – No. 2 Fuel	32.3	38.8	42.0
9E70 injector – No. 2 Fuel	34.7	41.4	44.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:			
Both breathers	2.1	2.3	3.0
Left bank breather	2.6	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-4 6V-TA and 6V-TAC Engines with TV7101 Turbocharger and 1.23 A/R* Turbine Housing — California Coach

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See Figure 11-5 for chart of the operating conditions on 6V-TA and 6V-TAC engines with TV7101 turbocharger and 1.39 A/R* turbine housing — coach

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
7G65 injector – Fed. – No. 1 Fuel	24.4	30.1	33.0
7G70 injector – Fed. – No. 1 Fuel	26.4	32.1	34.9
7G75 injector – Fed. – No. 1 Fuel	28.3	33.9	36.8
7G65 injector – Fed. – No. 2 Fuel	26.3	31.7	34.4
7G70 injector – Fed. – No. 2 Fuel	28.3	33.7	36.4
7G75 injector – Fed. – No. 2 Fuel	30.3	35.7	38.4
7G65 injector – Calif. – No. 1 Fuel	30.7	33.7	36.8
7G70 injector – Calif. – No. 1 Fuel	32.8	35.9	39.0
7G75 injector – Calif. – No. 1 Fuel	34.9	38.0	41.2
7G65 injector – Calif. – No. 2 Fuel	31.9	34.9	38.0
7G70 injector – Calif. – No. 2 Fuel	33.9	36.9	40.0
7G75 injector – Calif. – No. 2 Fuel	35.9	38.9	42.0
At max. exhaust back pressure (clean ports):			
7G65 injector – Fed. – No. 1 Fuel	22.1	27.8	30.7
7G70 injector – Fed. – No. 1 Fuel	24.1	29.8	32.6
7G75 injector – Fed. – No. 1 Fuel	26.0	31.6	34.5
7G65 injector – Fed. – No. 2 Fuel	24.0	29.4	32.1
7G70 injector – Fed. – No. 2 Fuel	26.0	31.4	34.1
7G75 injector – Fed. – No. 2 Fuel	28.0	33.4	36.1
7G65 injector – Calif. – No. 1 Fuel	28.4	31.4	34.5
7G70 injector – Calif. – No. 1 Fuel	30.5	33.6	36.7
7G75 injector – Calif. – No. 1 Fuel	32.6	35.7	38.9
7G65 injector – Calif. – No. 2 Fuel	29.6	32.6	35.7
7G70 injector – Calif. – No. 2 Fuel	31.6	34.6	37.7
7G75 injector – Calif. – No. 2 Fuel	33.6	36.6	39.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0

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Figure 11-5 6V-TA and 6V-TAC Engines with TV7101 Turbocharger and 1.39 A/R* Turbine Housing — Coach

See Figure 11-6 for chart of the operating conditions on 6V-TA and 6V-TAC engines with TV7101 turbocharger and 1.39 A/R* turbine housing — coach continued.

	1800 rpm	2000 rpm	2100 rpm
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm 500			
Minimum – at 600 rpm 450			

*Turbine housing designation (area over radius).
†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.

When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-6 6V-TA and 6V-TAC Engines with TV7101 Turbocharger and 1.39 A/R* Turbine Housing — Coach Continued

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See Figure 11-7 for chart of the operating conditions on 6V-TA and 6V-TAC engines with TV7111 turbocharger and 1.23 A/R* turbine housing — 1981 and 1982 automotive.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9B90 injector – 1.470 timing – Fed.	34.4	40.3	46.4
9F90 injector – 1.520 timing – Calif.	38.1	43.9	49.8
At max. exhaust back pressure (clean ports):			
9B90 injector – 1.470 timing – Fed.	32.2	38.1	44.2
9F90 injector – 1.520 timing – Calif.	35.8	41.6	47.5
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-7 6V-TA and 6V-TAC Engines with TV7111 Turbocharger and 1.23 A/R* Turbine Housing — 1981 and 1982 Automotive

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See Figure 11-8 for chart of the operating conditions on 6V-TA and 6V-TAC engines with TV7111 turbocharger and 1.23 A/R* turbine housing — 1981 and 1982 automotive.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	36.3	39.9	43.2
At max. exhaust back pressure	34.8	38.2	41.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner	20.0	20.0	20.0
Clean air cleaner	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:			
Both breather	2.1	2.3	3.0
Left bank breather	2.6	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.3	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).
†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-8 6V-TA and 6V-TAC Engines with TV7111 Turbocharger and 1.23 A/R* Turbine Housing — 1981 and 1982 Automotive

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See Figure 11-9 for chart of the operating conditions on 6V-TA engines with TV8102 turbocharger and 1.08 A/R* turbine housing — 9A90 injectors.

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	16.1	32.2	40.4
At max. exhaust back pressure (clean ports)	15.4	30.7	38.5
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	25	28	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-9 6V-TA Engines with TV8102 Turbocharger and 1.08 A/R* Turbine Housing — 9A90 Injectors

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See Figure 11-10 for chart of the operating conditions on 6V-TA and 6V-TAC engines with TV8102 turbocharger and 1.23 A/R* turbine housing — 1979 Federal and California.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
9B80 injector – 1.470 timing – Fed.	26.5	31.7	37.2
9B85 injector – 1.470 timing – Fed.	28.1	33.4	38.9
9B90 injector – 1.470 timing – Fed.	29.7	35.1	40.5
9B80 injector – 1.470 timing – Calif.	26.9	32.2	37.5
9B85 injector – 1.470 timing – Calif.	28.7	34.0	39.4
9B90 injector – 1.470 timing – Calif.	30.3	35.8	41.3
At max. exhaust back pressure (clean ports):			
9B80 injector – 1.470 timing – Fed.	24.2	29.4	34.9
9B85 injector – 1.470 timing – Fed.	25.8	31.1	36.6
9B90 injector – 1.470 timing – Fed.	27.4	32.8	38.2
9B80 injector – 1.470 timing – Calif.	24.6	29.9	35.2
9B85 injector – 1.470 timing – Calif.	26.4	31.7	37.1
9B90 injector – 1.470 timing – Calif.	28.0	33.5	39.0
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.

When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-10 6V-TA and 6V-TAC Engines with TV8102 Turbocharger and 1.23 A/R* Turbine Housing — 1979 Federal and California

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See Figure 11-11 for chart of the operating conditions on 6V-TT engines with TV8102 turbocharger and 1.23 A/R* turbine housing — 9290 Injector.

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
270 BHP	12.5	22.2	25.4
240 BHP	12.5	20.4	23.4
At max. exhaust back pressure (clean ports):			
270 BHP	11.8	20.7	23.7
240 BHP	11.8	18.9	21.7
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.5	17.0
No–load speed	4.0	8.7	10.3
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	10.2
No–load speed	2.0	5.1	6.0
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	2.0	2.4
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-11 6V-TT Engines with TV8102 Turbocharger and 1.23 A/R* Turbine Housing — 9290 Injector

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See Figure 11-12 for chart of the operating conditions on 6V-TTA and 6V-TTAC engines with TV7111 turbocharger and 1.23 A/R* turbine housing — 1981 and 1982 automotive.

	1800 rpm	1900/1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9B90 injector – 1.470 timing – Fed.:			
270 BHP	30.1	33.2/—	39.5
307 BHP	34.4	37.5/—	43.6
9F90 injector – 1.520 timing – Calif.:			
270 BHP	30.6	—/35.1	39.3
307 BHP	34.0	—/38.6	42.9
At max. exhaust back pressure (clean ports):			
9B90 injector – 1.470 timing – Fed.:			
270 BHP	27.8	20.9/—	37.2
307 BHP	32.1	35.2/—	41.3
9F90 injector – 1.520 timing – Calif.:			
270 BHP	28.3	—/32.8	37.0
307 BHP	31.7	—/36.3	40.6
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.2/2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-12 6V-TTA and 6V-TTAC Engines with TV7111 Turbocharger and 1.23 A/R* Turbine Housing — 1981 and 1982 Automotive

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See Figure 11-13 for chart of the operating conditions on 6V-TTA engines with TV7301 turbocharger and 1.08 A/R* turbine housing — 9B90 — 1.470 timing.

	1800 rpm	1900 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
270 BHP	30.1	30.5	33.3
307 BHP	36.3	36.5	38.2
At max. exhaust back pressure (clean ports):			
270 BHP	28.6	28.8	31.4
307 BHP	34.8	34.8	36.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner	20.0	20.0	20.0
Clean air cleaner	12.0	12.0	12.0
Crankcase pressure (inches water) – max.:			
Both breather	2.1	2.2	3.0
Left bank breather	2.6	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.2	2.5
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-13 6V-TTA Engines with TV7301 Turbocharger and 1.08 A/R* Turbine Housing — 9B90 — 1.470 Timing

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See Figure 11-14 for chart of the operating conditions on 6V-TTA engines with TV8102 turbocharger and 1.08 A/R* turbine housing — 9A90 — injectors.

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	16.1	28.5	31.7
At max. exhaust back pressure (clean ports)	15.4	27.0	30.0
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed	4.0	8.7	10.2
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	1.3	2.1	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-14 6V-TTA Engines with TV8102 Turbocharger and 1.08 A/R* Turbine Housing — 9A90 — Injectors

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See Figure 11-15 for chart of the operating conditions on 6V-TTA and 6V-TTAC engines with TV8102 turbocharger and 1.23 A/R* turbine housing — 9B90 — injectors.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
240 (Fed.) – 1.470 timing	23.1	—	—
270 (Fed.) – 1.470 timing	25.7	31.3	35.3
307 (Fed.) – 1.470 timing	29.7	34.5	38.3
240 (Calif.) – 1.490 timing	24.1	—	—
270 (Calif.) – 1.490 timing	26.6	31.4	35.6
307 (Calif.) – 1.490 timing	30.3	34.8	38.8
At max. exhaust back pressure (clean ports):			
240 (Fed.) – 1.470 timing	20.8	—	—
270 (Fed.) – 1.470 timing	23.4	29.0	33.0
307 (Fed.) – 1.470 timing	27.4	32.2	36.0
240 (Calif.) – 1.490 timing	21.8	—	—
270 (Calif.) – 1.490 timing	24.3	29.1	33.3
307 (Calif.) – 1.490 timing	28.0	32.5	36.5
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	2.3	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).
†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.
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Figure 11-15 6V-TTA and 6V-TTAC Engines with TV8102 Turbocharger and 1.23 A/R* Turbine Housing — 9B90 — Injectors

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See Figure 11-16 for chart of the operating conditions on 8V-T and 16V-T engines with T18A90 turbocharger and 1.50 A/R* turbine housing.

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50–70	50–70	50–70
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9280 injector	22.5	27.5	29.5
9285 injector	24.0	29.0	31.0
9290 injector	25.5	31.0	33.0
9295 injector	27.5		
At max. full–load exhaust back pressure (clean ports):			
9280 injector	20.9	25.6	27.4
9285 injector	22.3	27.0	28.8
9290 injector	23.7	28.8	30.7
9295 injector	25.6		
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	14.5	18.0	20.0
Clean air cleaner:			
Dry type with precleaner	8.7	10.8	12.0
Dry type less precleaner	6.3	7.7	8.5
Crankcase pressure (inches water) – max.	2.2	2.7	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	2.5
No load	1.3	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting (8V)	50–70	50–70	50–70
Normal with .070" restriction fitting (two for 16V)	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
.080" restriction fitting (8V)	0.9	0.9	0.9
.070" restriction fitting (two for 16V)	1.4	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-16 8V-T and 16V-T Engines with T18A90 Turbocharger and 1.50 A/R* Turbine Housing

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See Figure 11-17 for chart of the operating conditions on 8V-T (OTM) engines with T8101 turbocharger and 1.84 A/R* turbine housing — 9290 injectors.

	1200 rpm	1800 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	13.6	27.0	35.0
At max. full–load exhaust back pressure (clean ports)	12.9	25.5	33.1
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.4	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	2.3	3.1	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.7	2.0	2.5
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-17 8V-T (OTM) Engines with T8101 Turbocharger and 1.84 A/R* Turbine Housing — 9290 Injectors

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See Figure 11-18 for chart of the operating conditions on 8V-TA and 8V-TAC engines with TV7111 turbocharger and 1.39 A/R* turbine housing — 1981 and 1982 automotive.

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
7G75 injector – 1.470 timing – Fed.	38.1	—	—
7G75 injector – 1.508 timing – Calif.	39.2	—	—
9E65 injector – 1.466 timing – Fed. Transit	32.7	37.9	40.4
9E70 injector – 1.466 timing – Fed. Transit	35.0	40.1	41.4
At max. exhaust back pressure (clean ports):			
7G75 injector – 1.470 timing – Fed.	35.8	—	—
7G75 injector – 1.508 timing – Calif.	36.9	—	—
9E65 injector – 1.466 timing – Fed. Transit	30.4	35.6	38.1
9E70 injector – 1.466 timing – Fed. Transit	32.7	37.8	39.1
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-18 8V-TA and 8V-TAC Engines with TV7111 Turbocharger and 1.39 A/R* Turbine Housing — 1981 and 1982 Automotive

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See Figure 11-19 for chart of the operating conditions on 8V-TA engines with TV8101 turbocharger and 1.39 A/R* turbine housing — 355 BHP.

	1800 rpm
Lubrication System	
Lubricating oil pressure (psi):	
Normal	49–70
Minimum for safe operation	28
†Lubricating oil temperature (deg. F) – Normal	200–250
Air System	
Air box pressure (inches mercury) – full load min.:	
At zero exhaust back pressure:	
9E70 injector – 1.470 timing – Fed.	39.5
9G75 injector – 1.508 timing – Calif.	41.0
At max. exhaust back pressure (clean ports)	
9E70 injector – 1.470 timing – Fed.	37.7
9G75 injector – 1.508 timing – Calif.	39.2
Air inlet restriction (inches water) – full load max.:	
Dirty air cleaner	20.0
Clean air cleaner	12.0
Crankcase pressure (inches water) – max.	3.1
Exhaust back pressure (inches mercury) – max.:	
Full load	2.4
Fuel System	
Fuel pressure at inlet manifold (psi) – Normal	50–70
Fuel spill (gpm) – min. at no load	0.9
Pump suction at inlet (inches mercury) – max.:	
Clean system	6.0
Dirty system	12.0
Cooling System	
Coolant temperature (deg. F) – Normal	170–195
Compression	
Compression pressure (psi at sea level):	
Average – new engine – at 600 rpm	500
Minimum – at 600 rpm	450

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-19 8V-TA Engines with TV8101 Turbocharger and 1.39 A/R* Turbine Housing — 355 BHP

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See Figure 11-20 for chart of the operating conditions on 8V-TA engines with TV8101 turbocharger and 1.60 A/R* turbine housing — 9A90 injectors.

	1200 rpm	1800 rpm	1950/2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9290 Injector	15.0	29.8	—/36.9
9A90 Injector	18.7	35.4	44.0/—
At max. exhaust back pressure (clean ports):			
9290 Injector	14.3	28.3	—/35.0
9A90 Injector	18.0	33.9	42.1/—
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed	4.0	8.7	12.0
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed	2.0	5.1	7.2
Crankcase pressure (inches water) – max.	2.3	3.1	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-20 8V-TA Engines with TV8101 Turbocharger and 1.60 A/R* Turbine Housing — 9A90 Injectors

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See Figure 11-21 for chart of the operating conditions on 8V-TA engines with TV8101 turbocharger and 1.60 A/R* turbine housing — 1979 Federal and California.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
9A80 injector – Fed.	29.3	33.1	36.8
9A80 injector – Calif.	31.0	34.8	38.6
9A85 injector – Fed.	31.2	35.1	38.7
9A85 injector – Calif.	32.8	36.7	40.6
9A90 injector – Fed.	33.1	37.0	40.6
9A90 injector – Calif.	34.6	38.7	42.6
At max. exhaust back pressure (clean ports):			
9A80 injector – Fed.	27.0	30.8	34.5
9A80 injector – Calif.	28.7	32.5	36.3
9A85 injector – Fed.	28.9	32.8	36.4
9A85 injector – Calif.	30.5	34.4	38.3
9A90 injector – Fed.	30.8	34.7	38.3
9A90 injector – Calif.	32.3	36.4	40.3
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-21 8V-TA Engines with TV8101 Turbocharger and 1.60 A/R* Turbine Housing — 1979 Federal and California

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See Figure 11-22 for chart of the operating conditions on 8V-TA and 8V-TAC engines with TV8117 turbocharger and 1.39 A/R* turbine housing — 1981 and 1982 automotive.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9A90 injector – 1.466 timing – Fed.	29.8	34.0	38.2
9F90 injector – 1.520 timing – Calif.	36.9	40.8	44.7
At max. exhaust back pressure (clean ports):			
9A90 injector – 1.466 timing – Fed.	27.5	31.7	35.9
9F90 injector – 1.520 timing – Calif.	34.6	38.5	42.4
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-22 8V-TA and 8V-TAC Engines with TV8117 Turbocharger and 1.39 A/R* Turbine Housing — 1981 and 1982 Automotive

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See Figure 11-23 for chart of the operating conditions on 8V-TA and 8V-TAC engines with TV8301 turbocharger and 1.39 A/R* turbine housing.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
TTA 365 BHP – 9A90 – 1.460 timing	24.6	26.8	29.0
TA 445 BHP – 9A90 – 1.460 timing	29.1	34.7	36.4
TTAC 365 BHP – 9F90 – 1.515 timing	26.4	28.2	30.4
TAC 440 BHP – 9F90 – 1.515 timing	31.6	34.6	37.2
At max. exhaust back pressure (clean ports):			
TTA 365 BHP – 9A90 – 1.460 timing	22.8	24.8	26.7
TA 445 BHP – 9A90 – 1.460 timing	27.3	32.7	34.1
TTAC 365 BHP – 9F90 – 1.515 timing	24.6	26.2	28.1
TAC 440 BHP – 9F90 – 1.515 timing	29.8	32.6	34.9
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	3.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	2.4	2.7	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-23 8V-TA and 8V-TAC Engines with TV8301 Turbocharger and 1.39 A/R* Turbine Housing

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See Figure 11-24 for chart of the operating conditions on 8V-TT engines with TV8101 turbocharger and 1.84 A/R* turbine housing — 9290 injectors.

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	13.6	25.4	28.6
At max. exhaust back pressure (clean ports)	12.9	23.9	26.9
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	14.5	17.0
No–load speed	4.0	8.7	10.3
Clean air cleaner – dry type:			
Full–load speed	4.0	8.7	10.2
No–load speed	2.0	5.1	6.0
Crankcase pressure (inches water) – max.	2.3	3.1	3.3
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	2.0	2.4
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Vehicle engines built 1976 and later	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-24 8V-TT Engines with TV8101 Turbocharger and 1.84 A/R* Turbine Housing — 9290 Injectors

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See Figure 11-25 for chart of the operating conditions on 8V-TTA engines with TV8101 turbocharger and 1.60 A/R* turbine housing.

	1200 rpm	1800 rpm	1950 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	32–52	49–70	49–70
Minimum for safe operation	25	28	30
†Lubricating oil temperature (deg. F) – Normal	200–235	200–235	200–235
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9290 injector	15.0	27.0	29.3
9A90 injector	18.7	35.4	39.5
At max. exhaust back pressure (clean ports):			
9290 injector	14.3	25.5	27.6
9A90 injector	18.0	33.9	37.8
Air inlet restriction (inches water) – max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	20.0	20.0
No–load speed (9290 injector)	4.0	8.7	12.0
No–load speed (9A90 injector)	4.0	8.7	10.3
Clean air cleaner – dry type:			
Full–load speed	4.0	12.0	12.0
No–load speed (9290 injector)	2.0	5.1	7.2
No–load speed (9A90 injector)	2.0	5.1	6.0
Crankcase pressure (inches water) – max.	2.3	3.1	3.3
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	3.0	3.0
No load	0.7	1.4	1.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-25 8V-TTA Engines with TV8101 Turbocharger and 1.60 A/R* Turbine Housing

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See Figure 11-26 for chart of the operating conditions on 8V-TTA and 8VTTAC engines with TV8101 turbocharger and 1.60 A/R* turbine housing – 9A90 injector.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure (clean ports):			
335 BHP (Fed.) – 1.480 timing	27.7	—	—
335 BHP (Calif.) – 1.500 timing	30.7	—	—
365 BHP (Fed.) – 1.480 timing	30.1	32.4	35.6
365 BHP (Calif.) – 1.500 timing	33.3	34.7	37.8
At max. exhaust back pressure (clean ports):			
335 BHP (Fed.) – 1.480 timing	25.4	—	—
335 BHP (Calif.) – 1.500 timing	28.4	—	—
365 BHP (Fed.) – 1.480 timing	27.8	30.1	33.3
365 BHP (Calif.) – 1.500 timing	31.0	32.4	35.5
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.1	3.3	3.5
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-26 8V-TTA and 8VTTAC Engines with TV8101 Turbocharger and 1.60 A/R* Turbine Housing – 9A90 Injector

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See Figure 11-27 for chart of the operating conditions on 8V-TTA and 8V-TTAC engines with TV8117 turbocharger and 1.39 A/R* turbine housing – 1981 and 1982 automotive.

	1800 rpm	1950 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	29	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9A90 injector – 1.466 timing – Fed.	26.4	29.1	31.0
9F90 injector – 1.520 timing – Calif.	32.5	34.3	37.3
At max. exhaust back pressure (clean ports):			
9A90 injector – 1.466 timing – Fed.	24.1	26.8	28.7
9F90 injector – 1.520 timing – Calif.	30.2	32.0	35.0
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	—	—	—
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi) – Normal	50–70	50–70	50–70
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	170–195	170–195	170–195
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-27 8V-TTA and 8V-TTAC Engines with TV8117 Turbocharger and 1.39 A/R* Turbine Housing – 1981 and 1982 Automotive

See Figure 11-28 for chart of the operating conditions on 8V-T and 16V—T engines with TV8101 turbocharger and 1.39 A/R* turbine housing – gen set.

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	1200 rpm	1500 rpm	1800 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal (8V–92)	32–52	41–61	49–70
Normal (16V–92)	40–60	46–66	50–70
Minimum for safe operation	20	27	28
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9285 injector	15.5	26.0	35.0
9200 injector	20.8	31.4	40.5
9215 injector	25.6	36.3	45.2
At max. exhaust back pressure (clean ports):			
9285 injector	14.8	25.0	33.5
9200 injector	20.1	30.4	39.0
9215 injector	24.9	35.3	43.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type:			
Full–load speed	6.5	10.3	14.4
No–load speed	4.0	6.1	8.7
Clean air cleaner – dry type:			
Full–load speed	4.0	6.2	8.7
No–load speed	2.0	3.4	5.1
Crankcase pressure (inches water) – max.	2.3	2.7	3.1
Exhaust back pressure (inches mercury) – max.:			
Full load	0.9	1.4	2.0
No load	0.7	1.0	1.45
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load:			
(8V–92)	0.9	0.9	0.9
(16V–92)	1.4	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).
†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-28 8V-T and 16V—T Engines with TV8101 Turbocharger and 1.39 A/R* Turbine Housing – Generator Set

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See Figure 11-29 for chart of the operating conditions on 8V-TI engines with TH08A turbocharger and 0.096 A/R* turbine housing – marine.

	1800 rpm	2100 rpm	2300 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	49–70	49–70	49–70
Minimum for safe operation	28	30	31
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure:			
9290 injector	20.0	27.9	33.3
9200 injector	23.0	31.3	37.0
9215 injector	26.2	35.3	41.5
At max. exhaust back pressure (clean ports):			
9290 injector	17.7	25.6	31.0
9200 injector	20.7	29.0	34.7
9215 injector	23.9	33.0	39.2
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	20.0	20.0	20.0
Clean air cleaner – dry type	12.0	12.0	12.0
Crankcase pressure (inches water) – max.	2.5	2.8	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	3.0	3.0	3.0
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	0.9	0.9	0.9
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).
†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-29 8V-TI Engines with TH08A Turbocharger and 0.096 A/R* Turbine Housing – Marine

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See Figure 11-30 for chart of the operating conditions on 12V-TAB engines with TW–83 turbocharger and 1.19 A/R* turbine housing – marine.

	2300 rpm
Lubrication System	
Lubricating oil pressure (psi):	
Normal	Greater than 60
Minimum for safe operation	40
†Lubricating oil temperature (deg. F) – max.	
Full load	250
Air System	
Air box pressure (inches mercury) – full load min.:	
145 injector	54.0
Front block	51.0
Rear block	
Turbocharger pressure (inches mercury) – full load min.:	
Front block	44.0
Rear block	41.0
Air inlet restriction (inches water) – full load max.:	
Dirty air cleaner – dry type	14.5
Crankcase pressure (inches water) – full load max.	3.0
Exhaust back pressure (inches mercury) – max.:	
Full load	2.5
Exhaust temperature at full load (approx.) (deg. F)	
(taken at turbo outlet)	650
Fuel System	
Fuel pressure at inlet manifold (psi):	
Normal	50–70
Fuel spill (gpm) – min. at no load	1.4
Pump suction at inlet (inches mercury) – no load max.:	
Clean system	6.0
Dirty system	12.0
Cooling System	
Coolant temperature (deg. F) – Normal–full load	185
Max.	200
Compression	
Compression pressure (psi at sea level):	
Average – new engine – at 600 rpm	500
Minimum – at 600 rpm	450

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-30 12V-TAB Engines with TW–83 Turbocharger and 1.19 A/R* Turbine Housing – Marine

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See Figure 11-31 for chart of the operating conditions on 16V-TA engines with T18A90 turbocharger and 1.32 A/R* turbine housing – 9290 injectors.

	1800 rpm	2000 rpm	2100 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	50–70	50–70	50–70
Minimum for safe operation	28	30	30
†Lubricating oil temperature (deg. F) – Normal	200–250	200–250	200–250
Air System			
Air box pressure (inches mercury) – full load min.:			
At zero exhaust back pressure	18.3	42.6	45.6
At max. exhaust back pressure (clean ports)	16.8	40.7	43.7
Air inlet restriction (inches water) – full load max.:			
Dirty air cleaner – dry type	14.5	18.0	20.0
Clean air cleaner:			
Dry type with precleaner	8.7	10.8	12.0
Dry type less precleaner	6.3	7.7	8.5
Crankcase pressure (inches water) – max.	2.6	2.9	3.0
Exhaust back pressure (inches mercury) – max.:			
Full load	2.0	2.5	2.5
No load	1.3	1.6	1.8
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with .080" restriction fitting	50–70	50–70	50–70
Minimum	30	30	30
Fuel spill (gpm) – min. at no load	1.4	1.4	1.4
Pump suction at inlet (inches mercury) – max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (deg. F) – Normal	160–185	160–185	160–185
Compression			
Compression pressure (psi at sea level):			
Average – new engine – at 600 rpm	500		
Minimum – at 600 rpm	450		

*Turbine housing designation (area over radius).

†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-31 16V-TA Engines with T18A90 Turbocharger and 1.32 A/R* Turbine Housing – 9290 Injectors

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See Figure 11-32 for chart of the operating conditions on 16V-TA engines with TW9401 turbocharger and 1.46 A/R* turbine housing and CMM injectors rated at 2300 RPM.

Lubrication System:

Lubricating oil pressure,
- Normal / Rated Speed (psi) 49-70
- Minimum at 600 rpm Idle (psi) 5

Lubricating oil temperature / Full load, rated speed (deg. F) ..... 200 - 250

Air System:

Air box pressure / Full load rated speed (in. Hg) 61.0
- Crankcase pressure / Max (in. H_2O) 3.0
- Exhaust back pressure / Max (in. Hg) 2.5

Fuel System:

Fuel pump suction / Max (in. Hg)
- Clean system 6.0
- Dirty system 12.0

Cooling System:

Coolant temperature (deg. F) Normal ..... 170 - 200
- Maximum (deg. F) 210

Compression:

- Average New / Idle Speed (psi) 500
- Minimum / Idle Speed (psi) 450

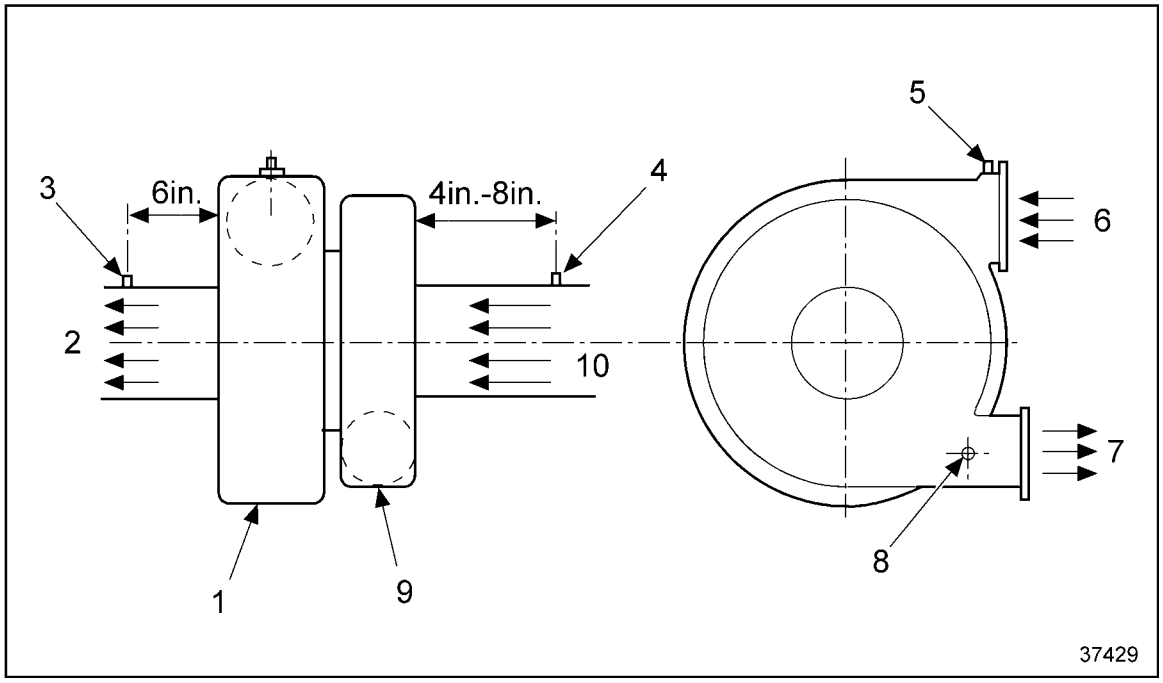
*Turbine housing designation (area over radius).
†The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet.
When measuring the oil temperature at the cylinder block oil gallery, it will be approximately 10° lower than the oil pan temperature.

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Figure 11-32 16V-TA Engines with TW9401 Turbocharger and 1.46 A/R* Turbine Housing and CMM Injectors Rated at 2300 RPM

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See Figure 11-33 for the exhaust restriction intake measurement illustration.



1. Turbine
2. Exhaust-to-Muffler (Back Pressure)
3. Turbine Back Pressure
4. Air Into Compressor Pressure
5. Exhaust Into Turbine Pressure
6. Exhaust Into Turbine from Engine
7. Air-to-Engine from Compressor
8. Compressor Air-to-Engine Pressure
9. Compressor
10. Air Into Compressor from Air Cleaner

Figure 11-33 Point to Measure Intake and Exhaust Restriction

11.6 ENGINE RUN-IN PROCEDURES

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners, or bearings, the engine should be "Run-In" on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect the engine while it is operating. It detects improper tune-up, misfiring injectors, low compression, and other malfunctions.

The operating temperature within the engine affects the operating clearances between the various moving engine parts and determines how the parts will wear. Normal coolant temperature should be maintained throughout the Run-In. Refer to section 11.5.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 6°C (10°F) or higher than the water inlet temperature. Though a 6°C (10°F) rise across an engine is recommended, an 8°C (15°F) temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Ensure they are in place and fully operative, or the engine will overheat during the Run-In. If the dynamometer has a water standpipe with a temperature control regulator, such as a Taylor valve or equivalent, the engine should be tested without thermostats.

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NOTICE:

Because of the wet cylinder liners in the V-92 engine, the engine Run-In should be performed on a closed (heat exchanger type) cooling system, where the coolant can be treated with a rust inhibitor. Refer to section 5.3. A good rust inhibitor used in the coolant system during engine Run-In will prevent the outside diameter of the cylinder liners from rusting after the engine has been removed from the dynamometer test stand.

The Run-In Schedules are listed in Table 11-4 and listed in Table 11-5. The horsepower shown is at SAE conditions: dry air density 0.0705 lb/cu. ft. (1.129 Kg/cu. m), air temperature of 29.4°C (85°F) and 5000 ft. elevation.

Time Min.	Speed RPM	Injectors	Engine Brake Horse-power 6V	Engine Brake Horse-power 6VT	Engine Brake Horse-power 8V	Engine Brake Horse-power 8VT	Engine Brake Horse-power 16V	Engine Brake Horse-power 16VT
10	1200	All	54	54	72	72	144	144
30	1800	All	195	225	260	300	520	600
30*	2100	70	216	-	288	-	576	-
30*	2100	75	230	-	306	-	612	-
30*	2100	80	243	-	324	-	648	-
30*	2100	85	257	-	342	-	684	-
30*	2100	80	-	252	-	338	-	675
30*	2100	85	-	270	-	360	-	720
30*	2100	90	-	290	-	387	-	774

* Use speed-injector combination applicable to engine on test

Table 11-4 Basic Engine Run-In Schedule

Time Min.	Speed RPM	Injectors	+ Engine Brake Horse-power 6V	+ Engine Brake Horse-power 6VT	+ Engine Brake Horse-power 8V	+ Engine Brake Horse-power 8VT	+ Engine Brake Horse-power 16V	+ Engine Brake Horse-power 16VT
30*	2100	70	240	-	320	-	640	-
30*	2100	75	255	-	340	-	680	-
30*	2100	80	270	280	360	375	720	750
30*	2100	85	285	300	380	400	760	800
30*	2100	90	-	322	-	430	-	860

* Use speed-injector combination applicable to engine on test

+ Within 5% of brake horsepower rating shown at governor speed.

Table 11-5 Final Engine Run-In Schedule

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11.6.1 The Basic Engine

The great variety of applications makes any attempt to establish performance standards for each individual engine impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. Adding engine driven accessories will result in a brake horsepower figure less than the values shown in the "Basic Engine Run-In Schedule." The blower, fuel pump, water pump, and governor are included on the basic engine. The fan and battery-charging alternator typify accessories not considered on the basic engine.

Situations where other than basic engine equipment is used during the test should be recorded on the engine test report. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

11.6.2 Dynamometer

The dynamometer absorbs and measures the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. Decreasing or increasing the resistance in the unit varies the engine load from zero to maximum. For example, the fluid volume within the working system governs the amount of power absorbed in a water brake type dynamometer. The fluid offers resistance to a rotating motion. Controlling the water volume in the absorption unit allows the load to be increased or decreased, as required.

NOTE:
The power absorbed is generally measured in torque (lb·ft) on a suitable scale. Use the following formula to incorporate the value for a given engine speed to show the brake horsepower developed in the engine:

BHP = (T x RPM) / 5250 Where: BHP = Brake Horsepower T = Torque in ib·ft RPM = Revolution Per Minute

Some dynamometers indicate direct brake horsepower readings. 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.

11.6.3 Instrumentation

Certain instrumentation is necessary to obtain required data to complete the engine test report. See Figure 11-34. The following list contains both the minimum amount of instruments and the proper fitting locations on the engine so that the readings represent a true engine condition evaluation:

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ENGINE TEST REPORT

Date _____ Unit Number _____

Repair Order Number _____ Model Number _____

A — PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B — BASIC ENGINE RUN-IN

TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUBE OIL PRESS.

C — BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D — INSPECTION AFTER BASIC RUN-IN

1. Tighten Cylinder Head & Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E — FINAL RUN-IN

TIME START	TIME STOP	TOP RPM NO LOAD	TOP RPM FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE FULL LOAD	LUBE OIL PRESSURE IDLE	IDLE SPEED

F — INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd _____ Dynamometer Operator _____ Date _____

NOTE: Operator must initial each check and sign this report.

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Figure 11-34 Engine Test Report

- ☐ Oil pressure gage installed in one of the engine main oil galleries.
- ☐ Oil temperature gage installed in the oil pan, or thermometer installed in the oil pan dipstick hole.
- ☐ Adaptor for connecting a pressure gage or mercury manometer to the engine air box.
- ☐ Water temperature gage installed in the thermostat housing or water outlet manifold.

- ☐ Adaptor for connecting a pressure gage or water manometer to the crankcase.
- ☐ Adaptor for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.
- ☐ Adaptor for connecting a vacuum gage or water manometer to the blower inlet.
- ☐ Adaptor for connecting a fuel pressure gage to the fuel inlet passage.
- ☐ Adaptor for connecting a pressure gage or mercury manometer to the turbocharger.

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. The scale on this gage must have a low range and be finely divided for accuracy. The following conversion factors may be helpful:

Inches of water = psi x 27.7 in.

Inches of mercury = psi x 2.04 in.

Inches of water = kPa x 4.02 in.

Inches of mercury = kPa x 0.30 in.

NOTICE:
Before starting the Run-In or starting the engine for any reason following an overhaul, observe the instructions on preparation for a first time start. Refer to section 11.1. If these instructions are ignored, serious engine damage may result.

NOTE:
The operator must initial each check and sign this report.

11.6.4 Block Oil Filter Bypass Before Initial Start-Up and Dynamometer Test of Rebuilt Engines

Cold engine start-up causes the lubricating oil filter bypass valve to open until the oil temperature increases. When an engine is rebuilt and dynamometer tested, this bypass condition may circulate abrasive debris introduced into the engine during rebuild.

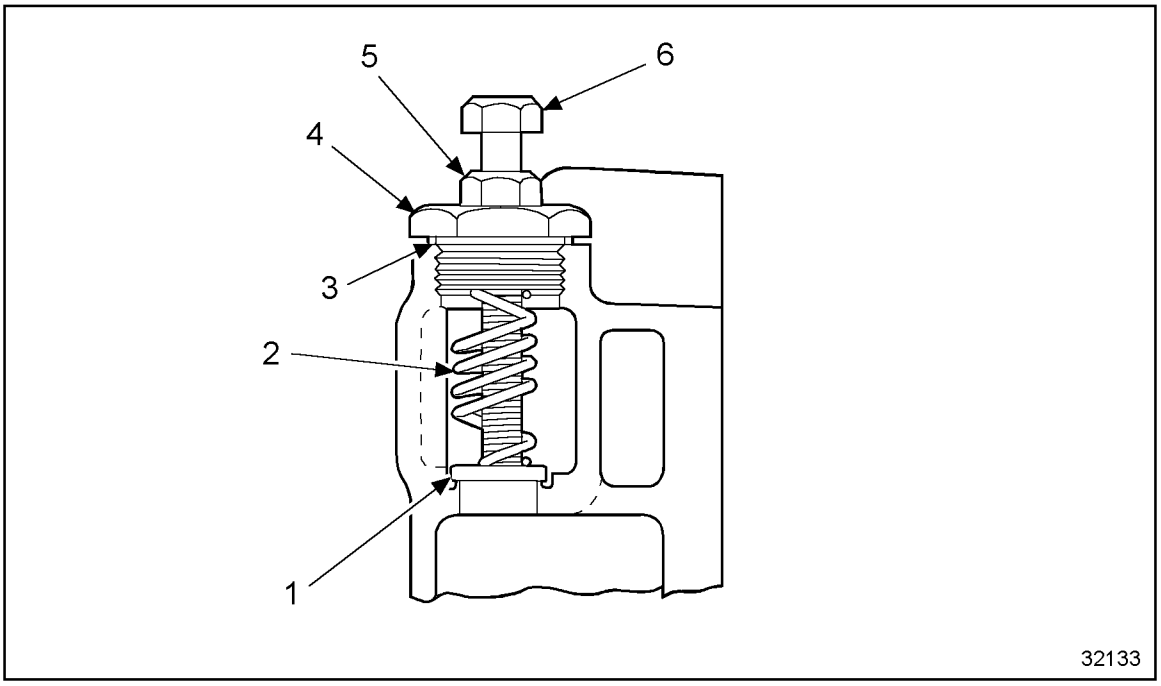
To prevent unnecessary debris circulation through the lube oil system, DDC recommends plugging the filter bypass before start-up and during basic engine run-in. This allows all the lube oil to flow through the filter(s), trapping contaminants. Plug the bypass as follows:

1. Drill and tap a 1/4 in.-20 hole in a filter bypass valve plug.

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NOTICE:
To avoid damaging the phenolic bypass valve, the bolt should be finger-tightened only and secured in place with the locknut. On filter adaptors with more than one bypass valve, install modified valve plugs in all valve openings before starting or dynamometer testing the engine.

2. Install a bolt long enough to contact the valve and keep it from opening.
3. Install a nut to lock the bolt in position. See Figure 11-35.



1. Valve
2. Spring
3. Gasket
4. Plug
5. Nut
6. Bolt

Figure 11-35 Bypass Valve with Modified Valve Plug Installed

4. When the dynamometer test is completed, replace the modified plug with a standard plug, and change the filter(s).

NOTICE:
Prior to testing, DDC recommends bringing lube oil temperature up to at least 15.6°C (60°F) before starting the engine. If the lube oil is too cold when the engine is started, the resistance to the heavier oil flow may cause filter gasket leakage or bearing surface damage from inadequate oil film.

11.6.5 Pre-Start the Engine

Prestart the engine as follows:

1. Fill the lubrication system. Refer to section 13.5.1and refer to section 11.1.2.
2. Prime the fuel system. Refer to section 11.1.5.
3. Make a preliminary valve clearance adjustment before the engine is started. Refer to section 12.2 valve clearance adjustment.
4. Make a preliminary injector timing check before starting the engine. Refer to section 12.3.
5. Make a preliminary governor adjustments. Refer to section 12.4.
6. Make a preliminary injector rack adjustment. Refer to section 12.4.

NOTICE:
Prior to starting a turbocharged engine, remove the oil supply line at each turbocharger, and add clean engine oil to the oil inlet to ensure prelubrication of the turbochargers. Reconnect the oil lines and idle the engine for at least one minute after starting and before increasing the speed. Failure to take this precaution may cause turbocharger damage.

11.6.6 Basic Engine Run-In

Perform the basic engine run-in as follows:

1. After performing the preliminary steps, ensure all water valves, fuel valves, etc. are open.
2. Inspect the exhaust system, air cleaner, and air inlet piping to ensure that it is properly connected to the engine.

NOTE:
Always start the engine with minimum dynamometer resistance.

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NOTICE:
Allowing water into the dynamometer is necessary on some units to lubricate the absorption unit seals and to protect them from damage.

3. After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 7 N·m (5 lb·ft) on the torque gage (or 10-15 HP on a horsepower gage).
4. Set the engine throttle at idle speed.
5. Check the lubricating oil pressure, and check all connections to ensure there are no leaks.

6. The sample engine test report establishes the sequence of events for the Test and Run-In, and the Basic Engine Run-In Schedule indicates the speed (RPM), length of time, and the brake horsepower required for each test phase. See Figure 11-36.

ENGINE TEST REPORT

Date _____ Unit Number _____

Repair Order Number _____ Model Number _____

A — PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B — BASIC ENGINE RUN-IN

TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUBE OIL PRESS.

C — BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D — INSPECTION AFTER BASIC RUN-IN

1. Tighten Cylinder Head & Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E — FINAL RUN-IN

TIME START	TIME STOP	TOP RPM NO LOAD	TOP RPM FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE FULL LOAD	LUBE OIL PRESSURE IDLE	IDLE SPEED

F — INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd _____ Dynamometer Operator _____ Date _____

NOTE: Operator must initial each check and sign this report.

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Figure 11-36 Engine Test Report

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7. Refer to section 11.5, which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

NOTE:
Engine governors in most cases must be reset at the maximum full-load speed designated for the Run-In. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the Run-In.

8. After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the Basic Engine Run-In Schedule.

NOTE:
The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range.

9. Record length of time, speed, brake horsepower, coolant temperature, and lubricating oil pressure on the engine test report.
10. Run the engine at each speed and rating for the length of time indicated in the Basic Engine Run-In Schedule.

NOTE:
During the basic run-in, engine performance will improve as new parts begin to "seat in."

11. Record all required data.

11.6.7 Basic Run-In Inspection

Perform the basic run-in inspection:

1. Check the oil at the rocker arm mechanism. Check for fuel oil or water leaks in the rocker arm compartment.
2. Inspect for lube oil leaks.
3. Inspect for fuel oil leaks.
4. Inspect for water leaks.
5. Check and tighten all external bolts.
6. During the final portion of the Basic Run-In, the engine should be inspected for fuel oil, lubricating oil and water leaks.
7. Upon completion of the Basic Run-In and Inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle.
8. Stop the engine.

11.6.8 Post Basic Run-In Inspection

Perform the post basic run-in inspection as follows:

This inspection provides a fine engine tune-up.

1. Tighten the cylinder head and rocker arm shaft bolts to the proper torque.
2. Complete the applicable tune-up procedure. Refer to section 12.1.

11.6.9 Final Run-In

Perform the final run-in as follows:

NOTE:
After all tests have been performed and the engine test report is completed through section "D", the engine is ready for the final test. This portion of the test and run-in procedure assures that the engine has been rebuilt to delivery factory rated performance at the same maximum speed and load which will be experienced in the installation.

1. If the engine has been shut down for one hour or longer, allow it to warm-up for 10 minutes at the same speed and load used for warm-up in the Basic Run-In.
2. If piston rings, cylinder liners, or bearings have been replaced as a result of the Basic Run-In results, the entire Basic Run-In must be repeated.

NOTE:
All readings observed during the Final Run-In should fall within the range specified in the Operating Conditions and should be taken at full load, unless otherwise specified. Refer to section 11.5.

3. Take the engine water temperature at full load during the last portion of the Basic Run-In. Readings should be within the specified range.
4. Record the engine water temperature.
5. Take the lubricating oil temperature reading while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. Readings should be within the specified range.
6. Record the lubricating oil temperature.
7. Take the lubricating oil pressure after engine speeds indicated in the Operating Conditions. Refer to section 11.5.
8. Record the lubricating oil pressure in "psi".
9. Take the fuel oil pressure at the fuel manifold inlet passage. It should fall within the specified range.

NOTE:
Fuel pressure should be recorded at maximum engine speed during the Final Run-In.

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10. Record the fuel oil pressure.
11. Check the air box pressure while the engine is operating at maximum speed and load. Attach a suitable gage (0-15 lb/in.^{2}) or manometer (15-0-15) to an air box drain or to a hand hole plate prepared for this purpose.

NOTE:
If an air box drain is used as a source for this check, it must be clean.

12. Record the air box pressure in inches of mercury.
13. Check the crankcase pressure while the engine is operating at maximum Run-In speed.
14. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening.

NOTE:
Normally, crankcase pressure should decrease during the Run-In, indicating that new rings are beginning to "seat-in".

15. Record the crankcase pressure.
16. Check the air inlet restriction.
17. Connect a water manometer to a fitting in the air inlet ducting located 2 in. above the air inlet housing.
18. If fitting insertion is difficult at this point, connect the manometer to a fitting installed in the 1/4 in. pipe tapped hole in the engine air inlet housing on naturally aspirated engines.
19. If a hole is not provided, a stock housing should be drilled, tapped, and kept on hand for future use.
20. Inspect the restriction at full-load engine speed.
21. Remove the air cleaner and ducting from the air inlet housing.
22. Operate the engine again at the same speed, while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of one turbocharger. Refer to section 11.5.

NOTE:
The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction from the air cleaner and ducting.

23. Check the normal air intake vacuum at various speeds at no-load, and compare the results with the Engine Operating Conditions. Refer to section 11.5.
24. Record these readings on the engine test report.
25. Check the exhaust back pressure (except turbocharged engines) at the exhaust manifold companion flange or within one inch of this location. Use a mercury manometer through a tube adaptor installed at the tapped hole.
26. If the exhaust manifold does not provide a 1/8 in. pipe tapped hole, rework the exhaust manifold.

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27. Install a fitting for a pressure gage or manometer in this hole.

NOTE:
The fitting must not protrude into the stack.

28. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6-12 in. from the turbine outlet.

NOTE:
The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the Maximum Exhaust Back Pressure for the engine. Refer to section 11.5.

29. Take turbocharger compressor outlet pressure and turbine inlet pressures at full-load and no-load speeds.

30. Refer to the Final Engine Run-In Schedule listed in Table 11-6.

Time Min.	Speed RPM	Injectors	+ Engine Brake Horse-power 6V	+ Engine Brake Horse-power 6VT	+ Engine Brake Horse-power 8V	+ Engine Brake Horse-power 8VT	+ Engine Brake Horse-power 16V	+ Engine Brake Horse-power 16VT
30*	2100	70	240	-	320	-	640	-
30*	2100	75	255	-	340	-	680	-
30*	2100	80	270	280	360	375	720	750
30*	2100	85	285	300	380	400	760	800
30*	2100	90	-	322	-	430	-	860

* Use speed-injector combination applicable to engine on test

+ Within 5% of brake horsepower rating shown at governor speed.

Table 11-6 Final Engine Run-In Schedule

31. Determine the maximum rated brake horsepower and the full-load speed to be used during the Final Run-In.

32. Apply the load determined to the dynamometer.

33. If a hydraulic governor is used, the droop may be adjusted as follows:

    [a] The engine should be run at this speed and load for 1/2 hour.

NOTE:
While making the Final Run-In, the engine should develop, within 5%, the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrected.

    [b] When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either

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higher or lower than the maximum speed used during the Basic Run-In. This will ordinarily require a governor adjustment.

34. 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.
35. Stop the engine.
36. Rustproof the fuel system. Refer to section 14.1.

NOTICE:
Because of the wet cylinder liners, a rust inhibitor must be added to the cooling system. Without a rust inhibitor, the cylinder liners outside diameter will rust.

37. Add a rust inhibitor into the cooling system. Refer to section 5.3.
38. Change the lubricating oil filters.

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12 ENGINE TUNE-UP

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12.1 ENGINE TUNE-UP

There is no scheduled interval for performing an engine tune-up. As long as the engine performance is satisfactory, no tune-up should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations for on-highway vehicle engines, injector timing, exhaust valve clearance, engine idle and no-load speeds, and throttle delay or fuel modulator settings must be checked and adjusted if necessary, at 50,000 mile intervals. Refer to section 12.18.1.

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tune-up procedure varies accordingly. The following types of governors are used:

- Limiting speed mechanical
- Variable speed mechanical
- Hydraulic

A name plate attached to the governor housing identifies the mechanical governors. The letters D.W.-L.S. stamped on the name plate denote a double-weight limiting speed governor. A single-weight variable speed governor name plate is stamped S.W.-V.S.

When performing a tune-up on an engine in service, check the various adjustments for a possible change in the settings. If a cylinder head, governor, or injectors have been replaced or overhauled, then certain tune-up adjustments are required. Accurate tune-up adjustments are essential for maximum performance and economy.

If a supplementary governing device, such as the throttle delay mechanism, is used, disconnect it prior to the tune-up. After the governor and injector rack adjustments are completed, reconnect and adjust the supplementary governing device.

To tune-up an engine completely, perform all of the adjustments in the applicable tune-up sequence.

Use new valve rocker cover gaskets after the tune-up is completed, and reinstall the valve rocker covers.

12.1.1 Tune-Up Sequence of Mechanical Governor

Perform tune-up for mechanical governor in the following sequence:

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CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

1. While the engine is cold, adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor cap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the Belleville spring for "TT" horsepower.
8. Adjust the buffer screw.
9. Adjust the throttle booster spring (variable speed governor only).
10. Adjust the supplementary governing device, if used.

12.1.2 Tune-Up Sequence of Hydraulic Governor

Perform the following sequence for a hydraulic governor tune-up:

CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Position the injector rack control levers.
4. Adjust the governor linkage.
5. Adjust the load limit screw.
6. Compensation adjustment (PSG governors only).
7. Adjust the speed droop.
8. Adjust the maximum no-load speed.

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12.1.3 Emissions Regulations (On-Highway Vehicle Engine)

Detroit Diesel Allison on-highway vehicle engines are certified to be in compliance with Federal and California Emission Regulations established for each model year.

Engine certification is dependent on the following five physical characteristics:

1. Fuel injector type.
2. Maximum full-load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size).When serviced, all on-highway vehicle engines should comply with the specifications for the specific model year in which the engine was built.

   Trucks in a fleet containing various model year engines can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

12.1.4 Engine Certification Charts

This section contains charts summarizing the pertinent data concerning the specific engine configurations required for each model year.

See Figure 12-1 for chart of the 1974 certified automotive engines.

Engine	Injectors	*Maximum Full-Load Engine Speed	Camshaft Timing	Injector Timing	Injector Timing Gage	Throttle Delay	Yield Link
6V, 8V	9270	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9275	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9280	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9280	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6V, 8V	9285	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9285	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6VT, 8VT	9290	2100	Standard	1.484"	J 1242	‡ Yes	Yes

* Not to exceed fuel injector size and maximum operating speed that has been established for the specific application of the engine.

‡ .078" diameter fill hole, .016" diameter discharge orifice.

Use minimum idle speed of 500 rpm on all engines.

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Figure 12-1 1974 Certified Automotive Engines

See Figure 12-2 for chart of the 1975 certified automotive engines.

FEDERAL							
Engine	Injectors	*Maximum Full-Load Engine Speed	Camshaft Timing	Injector Timing	Injector Timing Gage	Throttle Delay	Yield Link
6V, 8V	9270	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9275	2100	Standard	1.460"	J 1853	No	No
6V, 8V	9280	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9280	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6V, 8V	9285	2100	Standard	1.460"	J 1853	No	No
6VT, 8VT	9285	2100	Standard	1.484"	J 1242	‡ Yes	Yes
6VT, 8VT	9290	2100	Standard	1.484"	J 1242	‡ Yes	Yes
FEDERAL AND CALIFORNIA							
6VTA, 8VTA	9280	2100	Standard	1.484"	J 1242	§‡ Yes	Yes
6VTA, 8VTA	9285	2100	Standard	1.484"	J 1242	§‡ Yes	Yes
6VTA, 8VTA	9290	2100	Standard	1.484"	J 1242	§‡ Yes	Yes

* Not to exceed fuel injector size and maximum operating speed that has been established for the specific application of the engine.

‡ .078" diameter fill hole, .016" diameter discharge orifice.

§ Offset piston linkage.

Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

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Figure 12-2 1975 Certified Automotive Engines

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See Figure 12-3 for chart of the 1976 certified automotive engines.

Engine	CALIFORNIA				FEDERAL							
	6V-92TA Aftercooled		8V-92TA Aftercooled		6V-92	8V-92	6V-92T			8V-92T		
	TA	TTA	TA	TTA			T	OTM	TT	T	OTM	TT
Injectors	9A80 9A85 9A90	9A90	9280 9285 9290	9290	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290	9290	9280 9285 9290	9280 9285 9290	9290
Approved Constant Horsepower for TTA Engines		270		365					240-270			365
*Maximum Full-Load Engine Speed	2100	▲ 1900 min. 1950 max.	2100	▲ 1900 min. 1950 max.	2100	2100	2100	2100	▲ 1900 min 1950 max	2100	2100	▲ 1900 min. 1950 max.
Camshaft Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.500"	1.500"	1.484"	1.484"	1.460"	1.460	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"
Throttle Delay Yield Link	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	Not Req'd.	Not Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.	‡ Req'd.
Turbocharger A/R	TV 8102 1.08	TV 8102 1.08	TV 8101 1.60	TV 8101 1.60			T 18A40 1.14	TV 8102 1.2.3	TV 8102 1.23	T 18A40 1.50	TV 8101 1.84	TV 8101 1.84

* Use a minimum idle speed of 400 rpm on all coach engines with throttle delay, and a minimum idle speed of 500 rpm on all other automotive applications.

▲ TT (TTA) must have full load rpm within the range shown.

‡ .078" diameter fill hole, .016" diameter discharge orifice.

6V and 8V-92 engine cylinder liners have a 1.05" port height; 1.95:1 blower drive ratio (6V-92TA). 37435

Figure 12-3 1976 Certified Automotive Engines

See Figure 12-4 for chart of the 1977 certified automotive engines (Federal).

Engine	6V-92		8V-92	
	TA	TTA	TT	TTA
(a) Injectors	9A80 9A85 9A90	9A90	9A80 9A85 9A90	9A90
(a) Approved Minimum Constant Horsepower		Min. - Max. 240-270		335
(a) Maximum Rated Speed	2100	1950	2100	2100
(a) Minimum Rated Speed	1950	1900	1950	1800
Gear Train Timing	Std.	Std.	Std.	Std.
Injector Timing	1.484"	1.484"	1.484"	1.484"
Throttle Delay (Yield Link)	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.
Setting	.636" (9A90) .570" (9A80 and 9A85)	.636"	.636" (9A90) .570" (9A80 and 9A85)	.636
Liner Port Height	.950"	.950"	.950"	.950"
Compression Ratio	17:1	17:1	17:1	17:1
Blower Drive Ratio	2.05:1	2.05:1	2.05:1	2.05:1
Governor Type	Limiting Speed			
Thermostat	170-180° F (77-82° C) Nominal Opening Temperature			
Turbocharger A/R	TV8102 1.08	TV8102 1.08	TV8101 1.60	TV8101 1.60

(a) Not to exceed fuel injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type

(f) Small fill hole (.078" Dia.), .016" discharge orifice.

% Offset piston linkage.
Use minimum idle speed of 500 rpm on all engines, except coach engines where a minimum of 400 rpm is allowed.

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Figure 12-4 1977 Certified Automotive Engines (Federal)

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See Figure 12-5 for chart of the 1977 certified automotive engines (California).

Engine	6V-92	8V-92	6V-92T			8V-92T			8V-92TA	
			T	OTM	TT	T	OTM	TT	T	TT
(a) Injectors	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290	9280 9285 9290	9290	9280 9285 9290	9280 9285 9290	9290 9A90	9290	9290
(a) Approved Minimum Constant Horsepower					Min. - Max. 240-270			365 (9290) 335 (9A90)		365
(a) Maximum Rated Speed	2100	2100	2100	2100	1950	2100	2100	2100 (9290)	2100	2100
(a) Minimum Rated Speed	2100 (9270) 1950 (9275) 1950 (9280) 2100 (9285)	2100 (9270) 1950 (9275) 1950 (9280) 2100 (9285)	2100 (9280) 1950 (9285) 1950 (9290)	2100 (9280) 1950 (9285) 1900 (9290)	1900	2100 (9280) 1950 (9285) 1950 (9290)	2100 (9280) 1950 (9285) 1900 (9290)	1800 (9A90)	1900	1900
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.460"	1.460"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"	1.484"
Throttle Delay (Yield Link)	None	None	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.	(f) % REQ.
Setting			.636" (9290) .570" (9280 and 9285)		.636"	.636" (9290) .570" (9280 and 9285)		.636" (9290) .570" (9A90)	.636"	.636"
Liner Port Height	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"	1.05"
Compression Ratio	19:1	19:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Blower Drive Ratio	2.6:1	2.6:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1	2.05:1
Governor Type		Limiting Speed								
Thermostat		170-180° F (77-82° C) Nominal Opening Temperature								
Turbocharger A/R			T18A40 1.14	TV8102 1.23	TV8102 1.23	TI8A90 1.50	TV8101 1.84	TV8101 1.84	TV8101 1.60	TV8101 1.60

37438

Figure 12-5 1977 Certified Automotive Engines (California)

See Figure 12-6 for chart of the 1978 certified automotive engines (Federal).

ENGINE FAMILIES	6V-92	8V-92	6V-92T			8V-92T			8V-92TA	
			T	OTM	TT	T	OTM	TT	TA	TTA
INJECTORS (a)	9270 9275 9280 9285	9270 9275 9280 9285	9280 9285 9290(g)	9280 9285 9290(g)	9290(g)	9280 9285 9290(g)	9280 9285 9290(g)	9290(g) 9A90(g)	9290(g)	9290(g)
APPROVED CONSTANT HORSEPOWER FOR TT & TTA ENGINES					240-270			9290-365 9A90 335-365		365
MAXIMUM FULL LOAD SPEED (b)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
MINIMUM FULL LOAD SPEED	9270-1950 9275-1950 9280-1950 9285-2100	9270-1950 9275-1950 9280-1950 9285-2100	1900	1900	1800	1900	1900	9290-1900 9A90-1800**	1900	1900
CAMSHAFT LOBE POSITION	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.	STD.
INJECTOR TIMING	1.460	1.460	1.484	1.484	1.484	1.484	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	NOT REQ.	NOT REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.
TURBOCHARGER A/R			*T18A40 1.14	TV8102 1.23	TV8102 1.23	*T18A90 1.50	TV8101 1.84	TV8101 1.84	TV8101 1.60	TV8101 1.60

**335 BHP 8V-92TT use 9A90 injectors only @ 1800 RPM.

(a) See Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.

(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.

(f) Small fill hole (.078" dia.), .016" discharge orifice.

(g) .570" setting — gage J-25559.

37442

Figure 12-6 1978 Certified Automotive Engines (Federal)

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See Figure 12-7 for chart of the 1978 certified automotive engines (California).

ENGINE FAMILIES	6V-92TAC		8V-92TAC	
	TAC	TTAC	TAC	TTAC
INJECTORS (a)	9A80 9A85 9A90(g)	9A90(g)	9A80 9A85 9A90(g)	9A90(g)
APPROVED CONSTANT HORSEPOWER FOR TTAC ENGINES		240-270		335-365
MAXIMUM (b) FULL LOAD SPEED	2100	2100	2100	2100
MINIMUM FULL LOAD SPEED	1950	1900	1950	1800
CAMSHAFT LOBE POSITION	RET.	RET.	RET	RET.
INJECTOR TIMING	1.484	1.484	1.484	1.484
THROTTLE DELAY YIELD LINK	(f) REQ.	(f) REQ.	(f) REQ.	(f) REQ.
TURBOCHARGER A/R	TV8102 1.08	TV8102 1.08	TV8101 1.60	TV8101 1.60

(a) See Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full-load speed combination. No-load speed will vary with injector size and governor type.
(b) Use a minimum idle speed of 400 rpm on all coach engines with throttle delay and a minimum idle speed of 500 rpm on all other engines.
(f) Small fill hole (.078" dia.), .016" discharge orifice.
(g) .570" setting — gage J-25559.

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Figure 12-7 1978 Certified Automotive Engines (California)

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See Figure 12-8 for chart of the 1979 certified automotive engines.

	FEDERAL ENGINES					CALIFORNIA ENGINES				
FAMILIES	6V-92TA COACH	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA	6V-92TAC COACH	6V-92TAC	6V-92TTAC	8V-92TAC	8V-92TTAC
Injectors	9B70 9B75 9B80	9B70, 9B75 9B80, 9B85 9B90	9B90	9A80 9A85 9A90	9A90	9B70 9B75 9B80	9B70, 9B75 9B80, 9B85 9B90	9B90	9A80 9A85 9A90	9A90
Maximum Full Load Speed	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	1800	1800	1800	1900	1800	1800	1800	1800	1900	1800
Minimum Idle Speed	500	500	500	500	500	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.470	1.480	1.480	1.490	1.490	1.490	1.500	1.500
Throttle Delay Setting	.636 ①	§ .504 9B90-.570	§ .570	§ .570 9A90-.636	.636 §	.636 ①	.570 § 9B90-.636	.636 §	.594 § 9A90-.660	.660 §
Liner Port Height	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Liner Part Number	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176
Turbocharger A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 ▲ 1.60 A/R	TV8101 ▲ 1.60 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 ▲ 1.60 A/R	TV8101 ▲ 1.60 A/R
Turbocharger Part Number	5102353	5102353	5102353	‡ 5101513	‡ 5101513	5102353	5102353	5102353	‡ 5101513	‡ 5101513
Blower Drive Ratio	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1	2.05:1	2.05:1	2.05:1	1.95:1	1.95:1
Blower Part Number	5101528	5101528	5101528	5101483	5101483	5101528	5101528	5101528	5101483	5101483
Compression Ratio	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Exhaust Valve Material	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X	Stellite Face Inconel X
Exhaust Valve Part Number	5100437 †	5100437 †	5100437 †	5100437	5100437	5100437	5100437	5100437	5100437	5100437
Certification Label Number	14B7-270	14B7-270	14B7-270	14B7-272	14B7-272	14B7-271	14B7-271	14B7-271	14B7-273	14B7-273

① Double fill hole (.250) .016 diameter discharge orifice.

† 6V-92TA - Carpenter valve. Available.

‡ Double 0-92 (5107590).

§ Small fill hole (.078 dia.) .016 diameter discharge orifice.

▲ Optional 5LM-864, 6.5 sq. in., 5107687.

PIN GAGE

J-25558 For .069" & .072"

TIMING GAGES

Series 53, 71 & 92

J-1853 For 1.460"
J-26888 For 1.466"
J-24236 For 1.470"
J-29065 For 1.480"
J-1242 For 1.484"
J-29066 For 1.490"
J-9595 For 1.496"
J-25454 For 1.500"
J-8909 For 1.508"
J-25502 For 1.520"

THROTTLE DELAY AND STARTING AID GAGES

J-24889 For .345"
J-28779 For .365"
J-24882 For .385"
J-9509-2 For .404"
J-23190 For .454"
J-29062 For .504"
J-25559 For .570"
J-26927 For .586" & .686"
J-25560 For .636"
J-29064 For .660"

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Figure 12-8 1979 Certified Automotive Engines

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See Figure 12-9 for chart of the 1980 certified automotive engines Federal and California.

	FEDERAL						CALIFORNIA					
ENGINE FAMILIES	(b) 6V-92TA Coach	(b) (c) 6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA	(b) 6V-92TAC Coach	(b) (c) 6V-92TAC Coach	6V-92 TAC	6V-92 TTAC	8V-92 TAC	8V-92 TTAC
Injectors (a)	9B70 9B75 9B80	7G65 7G70 7G75	9B90	9B90	9A90	9A90	9C70 9C75 9C80	7G65 7G70 7G75	9C90	9C90	9C90	9C90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	1800	1800	1800	1800	1800	1800	1900	1900	1900	1900	1900	1900
Minimum Idle Speed	500	500	500	500	500	500	500	500	700	700	700	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.470	1.470	1.480	1.480	1.480	1.460	1.480	1.480	1.480	1.480
Throttle Delay Setting	(e) .636	(e) .636	(d) .570	(d) .570	(d) .636	(d) .636	(e) .636	(e) .636	(d) .660	(d) .660	(d) .660	(d) .660
Turbocharger A/R	TV8102 1.23 A/R	TV7101 1.39 A/R	TV8102 1.23 A/R	TV8102 1.23 A/R	TV8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV8102 1.08	TV7101 1.39 A/R	TV8102 1.08	TV8102 1.08	TV8101 1.39	TV8101 1.39

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(b) Use No. 1 Diesel Fuel.

(c) Engines built June, 1980 or later.

(d) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(e) Double fill hole (.250 dia.) .016 dia. discharge orifice.

37434

Figure 12-9 1980 Certified Automotive Engines Federal and California

See Figure 12-10 for chart of the 1980 certified automotive engines California coach.

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach #)	9B70 9B75 9B80	253 @ 2100 265 @ 2100 277 @ 2100	722 @ 1200 762 @ 1200 805 @ 1200
6V-92TA	9B90	335 @ 2100	957 @ 1300
6V-92TTA	9B90	250 @ 1800 270 @ 1950 270 @ 2100 307 @ 1900 335 @ 2100	957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300
6V-92TAC (California) (Coach)	9C70 9C75 9C80	204 @ 2100 224 @ 2100 248 @ 2100	622 @ 1300 683 @ 1300 743 @ 1300
6V-92TAC (California)	9C90	305 @ 2100	921 @ 1300
6V-92TTAC (California)	9C90	270 @ 1950 305 @ 2100	921 @ 1300 921 @ 1300
8V-92TA	9A90	435 @ 2100	1242 @ 1400
8V-92TTA	9A90	335 @ 1800 365 @ 1950 365 @ 2100 435 @ 2100	1242 @ 1400 1242 @ 1400 1242 @ 1400 1242 @ 1400
8V-92TAC (California)	9C90	405 @ 2100	1236 @ 1300
8V-92TTAC (California)	9C90	365 @ 1950 405 @ 2100	1236 @ 1300 1236 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS
85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

No. 1 DIESEL FUEL

37452

Figure 12-10 1980 Certified Automotive Engines California Coach

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See Figure 12-11 for chart of the 1981 certified automotive engines.

FEDERAL

ENGINE FAMILIES	6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
Injectors (a)	7G65 7G70 7G75	9B90	9B90	9A90	9A90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100
Minimum Full Load Speed	1800	1800	1800	1900	1800
Minimum Idle Speed	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.470	1.470	1.480	1.480
Throttle Delay Setting	.504 (b) .636 (c)	(b) .570	(b) .570	(b) .636	(b) .636
Turbocharger A/R	TV-7101 1.39 A/R	TV-8102 1.23 A/R	TV-8102 1.23 A/R	TV-8101 1.60 A/R 5LM-864 6.5 Sq. In.	TV-8101 1.60 A/R 5LM-864 6.5 Sq. In.

CALIFORNIA

ENGINE FAMILIES	6V-92TAC Transit Coach	6V-92TAC All Others Coaches	6V-92 TAC	6V-92 TTAC	8V-92 TAC	8V-92 TTAC
Injectors (a)	9E65 9E70	7G65 7G70 7G75	9C90	9C90	9C90	9C90
Maximum Full Load Speed (a)	2100	2100	2100	2100	2100	2100
Minimum Full Load Speed	1900	1900	1900	1900	1900	1900
Minimum Idle Speed	500	700	700	700	700	700
Gear Train Timing	Std.	Std.*	Std.	Std.	Std.	Std.
Injector Timing	1.460	1.460	1.480	1.480	1.480	1.480
Throttle Delay Setting	(c) .636	(b) .636	(b) .660	(b) .660	(b) .660	(b) .660
Turbocharger A/R	TV-7101 1.23	TV-7101 1.39 A/R	TV-8102 1.08	TV-8102 1.08	TV-8101 1.39	TV-8101 1.39

1981 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA	9B90	335 @ 2100	957 @ 1300
6V-92TTA	9B90	250 @ 1800 270 @ 1950 270 @ 2100 307 @ 1900 335 @ 2100	957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300 957 @ 1300
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	230 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC (California)	9C90	305 @ 2100	921 @ 1300
6V-92TTAC (California)	9C90	270 @ 1950 305 @ 2100	921 @ 1300 921 @ 1300
8V-92TA	9A90	435 @ 2100	1242 @ 1400
8V-92TTA	9A90	335 @ 1800 365 @ 1950 365 @ 2100 404 @ 1900 435 @ 2100	1242 @ 1400 1242 @ 1400 1242 @ 1400 1242 @ 1400 1242 @ 1400
8V-92TAC (California)	9C90	405 @ 2100	1236 @ 1300
8V-92TTAC (California)	9C90	365 @ 1950 405 @ 2100	1236 @ 1300 1236 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS

85°F (29.4°C) — AIR INLET TEMPERATURE

29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

(a) Refer to Engine Application Rating (Sales Tech Data Book I, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(b) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(c) Double fill hole (.250 dia.) .016 dia. discharge orifice.

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Figure 12-11 1981 Certified Automotive Engines

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See Figure 12-12 for chart of the 1982 certified automotive engines.

FEDERAL

FAMILIES	6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
INJECTORS	7G65 7G70 7G75	9B80 9B85 9B90	9B90	9A80 9A85 9A90 7G75 S	9A90
MAX. FULL LOAD SPEED	2100	2100	2100	2100	2100
MIN. FULL LOAD SPEED	1800	1800	1800	1800	1800
MIN. IDLE SPEED	500/500 ##	500	500	500	500
GEAR TR. TIMING	Std.	Std.	Std.	Std.	Std.
INJECTOR TIMING	1.470	1.470	1.470	1.466	1.466
THROTTLE DELAY SETTING ⊕	.636 .504##	%% 9B90-.570	.570%%	.570%% 9A90-.636	.636%%
LINER PORT HGHT.	.95	.95	.95	.95	.95
LINER PART NO.	5107176	5107176	5107176	5107176	5107176
TURBO-CHARGER A/R	TV-7101 1.39 A/R	TV-7111 1.23 A/R	TV-7111 1.23 A/R	TV-8117 1.39 A/R	TV-8117 1.39 A/R
TURBO-CHARGER P/N	5103760	8923051	8923051	S 8923340	8923340
BLOWER DR. RATIO	2.05:1	1.95:1	1.95:1	1.95:1	1.95:1
BLOWER PART NO.	5101528 5104936 5103854	5101528 5104936 5103854	5101528 5104936 5103854	5101484 8920613 8923371	5101484 8920613 8923371
COMP. RATIO	17:1	17:1	17:1	17:1	17:1
EXHAUST VALVE P/N	5106136	5106136	5106136	5106136	5106136
CERT. LABEL NO.	14B7-337	14B7-337	14B7-337	14B7-337	14B7-339

CALIFORNIA

6V-92TA Coach	6V-92TA	6V-92TTA	8V-92TA	8V-92TTA
9E65 9E70 7G75 Ⓧ	9F90	9F90	7G75 Ⓢ 9F80 9F85 9F90	9F90
2100	2100	2100	2100	2100
1900	1800	1800	1800	1800
Ⓧ ## 500/700	500	500	700	700
Std.	Std.	Std.	Std.	Std.
1.460	1.520	1.520	1.520	1.520
X .636	9F80, 85-.570 9F90-.636	.636	9F90-.660 9F80, 85-.594	.660
.95	.95	.95	.95	.95
5107176	5107176	5107176	5107176	5107176
TV-7101 Ⓧ 1.23	TV-7111 1.23 A/R	TV-7111 1.23 A/R	TV-8117 1.39 A/R	TV-8117 1.39 A/R
5101509	8923051	8923051	8923340	8923340
2.05	1.95	1.95	2.00 S	2.00
Ⓟ	Ⓡ	Ⓡ	8923474 8923476 8923475	8923474 8923476 8923475
17:1	17:1	17:1	17:1	17:1
5106136	5106136	5106136	5106136	5106136

S SILVER ENGINE - 7G75, 1800 RPM, TV-7111 TURBO, 8923648, 1.39 A/R (48-1), .465 THROTTLE DELAY, 1.470 INJ. TIMING, 700 RPM IDLE.

SINGLE FILL HOLE-UPRIGHT PARLOR COACH

%% SMALL FILL HOLE (.078 DIA.) .016 DIA. DISCHARGE ORIFICE

⊕ DOUBLE FILL HOLE (.250 DIA.) .016 DIA. DISCHARGE ORIFICE

Ⓟ 5101528, 5104936, 5103854

Ⓡ 8923495, 8923497, 8923497

SINGLE FILL HOLE-UPRIGHT COACH

Ⓧ PARLOR COACH - 7G65, 70, 75 - TV-7101 A/R 1.39 (P/N 5103760) 700 RPM IDLE, .078 DIA. THROTTLE DELAY FILL HOLE

Ⓢ SILVER ENGINE - 7G75, 1800 RPM, TV-7111, 8923735, 1.39 A/R (52-3), THROTTLE DELAY .594, 1.508 INJECTOR TIMING, 1.95:1 BLOWER DRIVE RATIO, USES FEDERAL BLOWERS.

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA/TTA	9B90	307 @ 1800 270 @ 1800 270 @ 2100 330 @ 2100	963 @ 1200 963 @ 1200 963 @ 1200 963 @ 1200
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	232 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC/TTAC (California)	9F90	304 @ 1800 270 @ 1800 270 @ 2100 325 @ 2100	958 @ 1200 958 @ 1200 958 @ 1200 958 @ 1200

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS
85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

1982 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
8V-92TA (355)	7G75	355 @ 1800	1150 @ 1200
8V-92TA/TTA	9A90	365 @ 1950 365 @ 2100 445 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300
8V-92TAC (California 355)	7G75	355 @ 1800	1150 @ 1200
8V-92TAC/TTAC (California)	9F90	365 @ 1950 365 @ 2100 440 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

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Figure 12-12 1982 Certified Automotive Engines

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See Figure 12-13 for chart of the 1983 certified automotive engines.

	FEDERAL					CALIFORNIA				
ENGINE FAMILIES	**6V-92TA Coach**	**6V-92TA/ TTA**	**8V-92TA Transit Coach**	**8V-92TA (355)**	**8V-92TA/ TTA**	**6V-92TAC Transit Coach**	**6V-92TAC All Other Coaches**	**6V-92TAC/ TTAC**	**8V-92TAC (355)**	**8V92TAC/ TTAC**
Injectors (a)	7G65 7G70 7G75	9B90	9E65 9E70	9E70	9A90	9E65 9E70	7G65 7G70 7G75	9F90	7G75	9F90
Maximum Full Load Speed (a)	2100	2100	2100	1800	2100	2100	2100	2100	1800	2100
Minimum Full Load Speed	1800	1800	1800	1800	1800	1900	1900	1800	1800	1800
Minimum Idle Speed	500	500	500	500	500	500	700	500	500	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.464	1.466	1.470	1.460	1.460	1.460	1.520	1.508	1.515
Throttle Delay Setting	.636 (h) .504 (f)	(f) (l)	(h) .636	DNA	(f) .594	(h) .636	(f) .636	(f) .636	DNA	(f) .660
Modulator Setting	DNA	.480	DNA	.345	.480	DNA	DNA	.480	.454	.490
Turbocharger A/R	TV7101 1.39 A/R	TV7301 1.08 A/R	TV7111 1.39 A/R	TV7301 1.23 A/R	TV8301 1.39 A/R	TV7101 1.23 A/R	TV7101 1.39 A/R	TV7111 1.23 A/R	TV7301 1.23 A/R	TV8301 1.39 A/R
Turbocharger Part No.	5103760	8924252 (m)(o) 8923051 (n)	89236498 (n)	8924682 (m)	8923340 (n) 8924254 (m)(o)	5101509	5103760	8924253 (m)(o) 8923051 (n)	8924682 (m)	8923340 (n) 8924254 (m)(o)
Blower Drive Ratio	2.05:1	1.95:1	1.95:1	1.95:1	1.95:1	2.05:1	2.05:1	1.95:1	1.95:1	1.95:1
Blower Part No.	5101528 (m)	5104936 (n) 8923953 (m) 8924627 (o)	5101484 (m)	8923954 (m)	8920613 (n) 8923954 (m) 8924629 (o)	5101528 (m)	5101528 (m)	8923495 (m) 8923496 (o) 8923497 (n)	8923954 (m) 8924629 (o)	8924047 (m) 8924630 (o) 8923475 (n)
Comparison Ratio	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1	17:1
Exhaust Valve Part No.	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136	5106136
Liner Part No.	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176	5107176
Liner Port Height	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95

DNA—Does not apply.

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(f) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(h) Double fill hole (.250 dia.) .016 dia. discharge orifice.

(l) 6V-92 TA with rated speed below 1900 RPM use throttle delay setting .636". For rated speed 1900 and above use .610".

(m) Front Blower - Mounted Turbo.

(n) Rear Blower - Mounted Turbo.

(o) Rear Bracket - Mounted Turbo.

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
6V-92TA (Coach)	7G65	253 @ 2100	766 @ 1200
	7G70	277 @ 2100	816 @ 1300
	7G75	294 @ 2100	873 @ 1300
6V-92TA/TTA	9B90	307 @ 1800	963 @ 1200
		270 @ 1800	963 @ 1200
		270 @ 2100	963 @ 1200
		330 @ 2100	963 @ 1200
6V-92TAC (California) (Transit Coach)	9E65	240 @ 2100	798 @ 1000
	9E70	260 @ 2100	846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65	232 @ 2100	744 @ 1200
	7G70	253 @ 2100	800 @ 1300
	7G75	271 @ 2100	856 @ 1300
6V-92TAC/TTAC (California)	9F90	304 @ 1800	958 @ 1200
		270 @ 1800	958 @ 1200
		270 @ 2100	958 @ 1200
		325 @ 2100	958 @ 1200

1983 CERTIFIED AUTOMOTIVE ENGINES

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT)
8V-92TA (Transit Coach)	9E65	330 @ 2100	1043 @ 1200
	9E70	345 @ 2100	1090 @ 1200
8V-92TA (355)	9E70	355 @ 1800	1150 @ 1200
8V-92TA/TTA	9A90	365 @ 1950	1250 @ 1300
		365 @ 2100	1250 @ 1300
		445 @ 2100	1250 @ 1300
8V-92TAC (California 355)	7G75	355 @ 1800	1150 @ 1200
8V-92TAC/TTAC (California)	9F90	365 @ 1950	1250 @ 1300
		365 @ 2100	1250 @ 1300
		440 @ 2100	1250 @ 1300

ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE CONDITIONS
85°F (29.4°C) — AIR INLET TEMPERATURE
29.00 IN. HG (98.19 kPa) — BAROMETER (DRY)

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

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Figure 12-13 1983 Certified Automotive Engines

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See Figure 12-14 for chart of the 1984 certified automotive engines.

FEDERAL

ENGINE FAMILIES	6V-92TA Coach	6V-92TA (1600 RPM)	6V-92 TA/TTA	8V-92TA Transit Coach	8V-92TA (355)	8V-92TA (1600 RPM)	8V-92 TA/TTA
Injectors (a)	7G65 7G70 7G75	9E85	9B90	9E65 9E70	7G75	9E80	9A90
Maximum Full Load Speed (a)	2100	1600	2100	2100	1800	1600	2100
Minimum Full Load Speed	1800	1600	1750	2100	1800	1600	1800
Minimum Idle Speed	500	500	500	500	500	500	500
Gear Train Timing	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.470	1.500	1.475	1.470	1.470	1.496	1.470
Throttle Delay Setting	.636 (h) .504 (f)	DNA	(f) .636	(h) .636	DNA	DNA	(f) .594
Modulator Setting	DNA	.404	.465	DNA	.465	.404	.404
Turbocharger A/R	TV7101 1.39 A/R	TV7301 1.08 A/R	TV7301 1.08 A R	TV7111 1.39 A R	TV7301 1.23 A R	TV7301 1.23 A R	TV8301 1.39 A R

CALIFORNIA

ENGINE FAMILIES	6V-92TAC TRANSIT COACH	6V-92TAC ALL OTHER COACHES	6V-92TAC/TTAC	8V-92TAC (355)	8V-92 TAC/ TTAC
Injectors (a)	9E65 9E70	7G65 7G70 7G75	9F90	7G75	9F90
Maximum Full Load Speed (a)	2100	2100	2100	1800	2100
Minimum Full Load Speed	1900	1900	1800	1800	1800
Minimum Idle Speed	500	700	500	500	700
Gear Train Timing	Std.	Std.	Std.	Std.	Std.
Injector Timing	1.460	1.460	1.520	1.508	1.520
Throttle Delay Setting	(h) .636	(f) .636	DNA	DNA	(f) .660
Modulator Setting	DNA	DNA	.490	.454	.490
Turbocharger A/R	TV-7101 1.23 A/R	TV-7101 1.39 A/R	TV-7301 1.23 A/R	TV-7301 1.23 A/R	TV-8301 1.39 A/R

DNA Does not apply

(a) Refer to Engine Application Rating (Sales Tech Data Book 18SA315) for specific application usage of injector size and full load speed combination. No load speed will vary with injector size and governor.

(f) Small fill hole (.078 dia.) .016 dia. discharge orifice.

(h) Double fill hole (.250 dia.) .016 dia. discharge orifice.

6V Cam Assy. – LB 8926265 (Fed.)
6V Cam Assy. – RB 8926264 (Fed.)
8V Cam Assy. – LB 8926246 (Fed.)
8V Cam Assy. – RB 8926245 (Fed.)
6V Cam Assy. – LB 5108111 (Cal.)
6V Cam Assy. – RB 5108112 (Cal.)
8V Cam Assy. – LB 5108117 (Cal.)
8V Cam Assy. – RB 5108118 (Cal.)

ENGINE	INJECTOR	RATED BHP	PEAK TORQUE (LB-FT.)
6V-92TA (Coach)	7G65 7G70 7G75	253 @ 2100 277 @ 2100 294 @ 2100	766 @ 1200 816 @ 1300 873 @ 1300
6V-92TA (1600 RPM)	9E85	290 @ 1600	1015 @ 1000
6V-92TA/ TTA	9B90	307 @ 1800 270 @ 1800 270 @ 2100 330 @ 2100	963 @ 1200 963 @ 1200 963 @ 1200 963 @ 1200
6V-92TAC (California) (Transit Coach)	9E65 9E70	240 @ 2100 260 @ 2100	798 @ 1000 846 @ 1000
6V-92TAC (California) (All Other Coaches)	7G65 7G70 7G75	232 @ 2100 253 @ 2100 271 @ 2100	744 @ 1200 800 @ 1300 856 @ 1300
6V-92TAC/ TTAC (California)	9F90	304 @ 1800 270 @ 1800 270 @ 2100 325 @ 2100	958 @ 1200 958 @ 1200 958 @ 1200 958 @ 1200
8V-92TA (Transit Coach)	9E65 9E70	330 @ 2100 345 @ 2100	1043 @ 1200 1090 @ 1200
8V-92TA (1600 RPM)	9E80	350 @ 1600	1275 @ 1000
8V-92TA (355)	7G75	355 @ 1800	1150 @ 1200
8V-92TA/ TTA	9A90	365 @ 1950 365 @ 2100 400 @ 1800 445 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300 1250 @ 1300
8V-92TAC (California 355)	7G75	355 @ 1800	1150 @ 1200
8V-92TAC/ TTAC (California)	9F90	365 @ 1950 365 @ 2100 440 @ 2100	1250 @ 1300 1250 @ 1300 1250 @ 1300
ALL ENGINE HORSEPOWER RATINGS ARE BASED ON SAE J 1349 CONDITIONS			

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

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Figure 12-14 1984 Certified Automotive Engines

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See Figure 12-15 for chart of the 1985 certified automotive engines.

ENGINE	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	THROTTLE DELAY SETTING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T (AIR/AIR)	9K85	290	1600	1050	1000	1600	1600	500	1.475	DNA	.454	TA-7501	2.59
	9J85	300	1800	975	1200	1800	1750	500	1.464	DNA	.465	TA-7501	2.69
6V-92TA (1600 RPM)	9E85	290	1600	1015	1000	1600	1600	500	1.480	DNA	.385	TV-7511	1.08
6V-92TA	9B80	268	1800	862	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B80	286	2100	862	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B90	307	1800	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B90	330	2100	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9G85	300	1800	975	1200	1800	1750	500	1.466	DNA	.465	TV-7511	1.08
	9G90	350	2100	1020	1200	2100	1900	500	1.466	.636	.480	TV-7511	1.08
6V-92TTA	9B90	270	1800	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9B90	270	2100	963	1200	2100	1800	500	1.470	.570	DNA	TV-7111	1.23
	9G85	270	1800	975	1200	1800	1750	500	1.466	DNA	.465	TV-7511	1.08
	9G85	270	2100	975	1200	2100	1750	500	1.466	DNA	.455	TV-7511	1.08
	9G90	300	2100	1020	1200	2100	1900	500	1.466	.636	.480	TV-7511	1.08
6V-92TAC (CAL)	9F85	294	1800	950	1200	2100	1800	500	1.520	.660	.490	TV-7511	1.23
	9F85	320	2100	950	1200	2100	1800	500	1.520	.660	.490	TV-7511	1.23
	9F90	300	1800	1000	1200	2100	1800	500	1.520	DNA	.490	TV-7511	1.23
	9F90	340	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TTAC (CAL)	9F90	270	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	300	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TA (ALCC)	9H85	300	1800	975	1200	1800	1750	500	1.475	DNA	.454	TV-7511	1.08
6V-92TA (COACH)	9F70, 9T70 #1	245	2100	775	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9F70, 9T70 #2	253	2100	775	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #1	260	2100	823	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #2	277	2100	840	1200	2100	1800	500	1.460	.594	DNA	TV-7511	0.96
	9F80, 9S80 #1	280	2100	849	1200	2100	1800	500	1.460	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	294	2100	875	1200	2100	1800	500	1.460	.636	DNA	TV-7511	1.08
	9H85 #1	315	2100	976	1200	2100	1800	700	1.460	.636	.480	TV-7511	1.08
	9H85 #2	325	2100	1007	1200	2100	1800	700	1.460	.636	.480	TV-7511	1.08
6V-92TAC (COACH/CAL)	9E65, 9S65 #1	230	2100	793	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9E65, 9S65 #2	240	2100	825	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #1	245	2100	835	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #2	260	2100	872	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #1	255	2100	846	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	270	2100	882	1000	2100	1800	500	1.470	.636	DNA	TV-7511	1.08
	9F90 #1	310	2100	954	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
	9F90 #2	320	2100	989	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
6V-92TA (PARLOR) (COACH)	9F70 #2	253	2100	775	1200	2100	1800	500	1.460	.504	DNA	TV-7511	0.96
	9G75 #2	277	2100	840	1200	2100	1800	500	1.460	.504	DNA	TV-7511	0.96
	9F80 #2	300	2100	893	1200	2100	1800	500	1.460	.504	.454	TV-7511	0.96
	9H85 #2	330	2100	1007	1200	2100	1800	500	1.460	.636	.480	TV-7511	1.08
8V-92TA (1600 RPM)	9E80	350	1600	1250	1000	1600	1600	500	1.470	DNA	.385	TV-8512	1.23
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.460	DNA	.385	TV-8512	1.23
	9G85	400	1800	1250	1300	2100	1800	500	1.458	DNA	.404	TV-8511	1.39
	9G85	450	2100	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90	475	2100	1330	1300	2100	1900	500	1.458	.610	.454	TV-8511	1.39
8V-92TTA	9G85	365	1900	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90	400	2100	1330	1300	2100	1900	500	1.458	.610	.454	TV-8511	1.39
8V-92TAC (CAL)	7G75	350	1800	1175	1200	1800	1800	500	1.508	DNA	.454	TV-8512	1.23
	9F90	400	1800	1250	1300	2100	1800	700	1.520	DNA	.490	TV-8511	1.39
	9F90	450	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TTAC (CAL)	9F90	400	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TA (ALCC)	7G75	350	1800	1175	1200	1800	1800	500	1.470	DNA	.404	TV-8512	1.23
	9G85	400	1800	1250	1300	1800	1800	500	1.475	DNA	.454	TV-8511	1.39
8V-92TA (COACH)	9E65 #2	340	2100	1134	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
	9E70 #2	365	2100	1187	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
8V-92TA (PARLOR) (COACH)	9A80 #2	404	2100	1143	1300	2100	2100	500	1.458	.594	.404	TV-8511	1.39

Effective January 1, 1982, California allowed the use of Federal certified engines in *Public Transit Busses* and in *Authorized Emergency Vehicles* as defined in section 165 of the California Vehicle Code.

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Figure 12-15 1985 Certified Automotive Engines

See Figure 12-16 for chart of the 1986 certified automotive engines.

ENGINE	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	THROTTLE DELAY SETTING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T	9K85	290	1600	1050	1000	1600	1600	500	1.496	DNA	.454	TA-7501	2.59
(AIR/AIR)	9J85	300	1800	975	1200	1800	1750	500	1.464	DNA	.465	TA-7502	2.95
6V-92TA (1600 RPM)	9E85	290	1600	1015	1000	1600	1600	500	1.480	DNA	.385	TV-7511	1.08
6V-92TAC	9F85	306	2100	917	1200	2100	1950	700	1.520	.570	.454	TV-7111	1.23
(CAL) @	9F90	325	2100	958	1200	2100	1950	700	1.520	.636	.480	TV-7111	1.23
6V-92TA	9G85	300	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G90	350	2100	1020	1200	2100	2100	500	1.466	.636	.480	TV-7511	1.08
6V-92TTA	9G85	270	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G85	270	2100	975	1200	2100	2100	500	1.466	DNA	.465	TV-7511	1.08
	9G90	300	2100	1020	1200	2100	2100	500	1.466	.636	.480	TV-7511	1.08
6V-92TAC	9F85	320	2100	950	1200	2100	1950	500	1.520	.660	.490	TV-7511	1.23
(CAL)	9F90	300	1800	1000	1200	2100	1800	500	1.520	DNA	.490	TV-7511	1.23
	9F90	340	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TTAC	9F90	270	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
(CAL)	9F90	300	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	270	1800	1000	1200	1800	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TA (ALCC)	9H85	300	1800	975	1200	1800	1800	500	1.475	DNA	.454	TV-7511	1.08
6V-92TA	9F70, 9T70 #1	245	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
(COACH)	9F70, 9T70 #2	253	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #1	260	2100	823	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75, 9S75 #2	277	2100	840	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9F80, 9S80 #1	280	2100	849	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	294	2100	875	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9H85 #1	315	2100	976	1200	2100	2100	700	1.460	.636	.480	TV-7511	1.08
	9H85 #2	325	2100	1007	1200	2100	2100	700	1.460	.636	.480	TV-7511	1.08
6V-92TAC	9E65, 9S65 #1	230	2100	793	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
(COACH/CAL)	9E65, 9S65 #2	240	2100	825	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #1	245	2100	835	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70, 9S70 #2	260	2100	872	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #1	255	2100	846	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80, 9S80 #2	270	2100	882	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F90 #1	310	2100	954	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
	9F90 #2	320	2100	989	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
6V-92TA	9F70 #2	253	2100	775	1200	2100	2100	500	1.460	.504	DNA	TV-7511	0.96
(PARLOR)	9G75 #2	277	2100	840	1200	2100	2100	500	1.460	.504	DNA	TV-7511	0.96
(COACH)	9F80 #2	300	2100	893	1200	2100	2100	500	1.460	.504	.454	TV-7511	0.96
	9H85 #2	330	2100	1007	1200	2100	2100	500	1.460	.636	.480	TV-7511	1.08
8V-92TA (1600 RPM)	9E80	350	1600	1250	1000	1600	1600	500	1.470	DNA	.454	TV-8512	1.23
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.460	DNA	.385	TV-8512	1.23
	9G85	400	1800	1250	1300	2100	1800	500	1.458	DNA	.404	TV-8511	1.39
	9G85	450	2100	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90	475	2100	1330	1300	2100	2100	500	1.458	.610	.454	TV-8511	1.39
8V-92TTA	9G90	400	2100	1330	1300	2100	1900	500	1.458	.610	.454	TV-8511	1.39
8V-92TAC	7G75	350	1800	1175	1200	1800	1800	500	1.508	DNA	.454	TV-8512	1.23
(CAL)	9F90	400	1800	1250	1300	2100	1800	700	1.520	DNA	.490	TV-8511	1.39
	9F90	450	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TTAC (CAL)	9F90	400	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.470	DNA	.454	TV-8512	1.23
(ALCC)	9G85	400	1800	1250	1300	1800	1800	500	1.475	DNA	.465	TV-8511	1.39
8V-92TA	9E65 #2	340	2100	1134	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
(COACH)	9E70 #2	365	2100	1187	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
8V-92TA (PARLOR) (COACH)	9A80 #2	404	2100	1143	1300	2100	2100	500	1.458	.594	.404	TV-8511	1.39

TA Turbocharged/Jacket Water Aftercooled.
TTA Constant Horsepower/Turbocharged/Jacket Water Aftercooled.
All Engine Horsepower Ratings Are Based On SAE J1349 Conditions.
Specifications Subject to Change Without Notice.

JWAC Jacket Water Aftercooled.
AIR/AIR Air-to-Air Charge Cooling.
ALCC Advanced Liquid Charge Cooling.

#1 Diesel Fuel #1.
#2 Diesel Fuel #2.
DNA Does Not Apply.
@ With Blower 8923497.

*** Minimum Idle Speed: 500 W/Fuel Modulator, 700 W/Throttle Delay.

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Figure 12-16 1986 Certified Automotive Engines

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See Figure 12-17 for chart of the 1987 certified automotive engines.

ENGINE	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	THROTTLE DELAY SETTING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T (AIR/AIR)	9K85	290	1600	1050	1200	1600	1600	500	1.496	DNA	.454	TA-7501	2.59
	9J85	300	1800	975	1200	1800	1750	500	1.464	DNA	.465	TA-7502	2.95
6V-92T (DDEC) (AIR/AIR)	5234770	300	1800	1050	1200	1800	1800	500	1.460	DNA	DNA	TA-7502	2.95
6V-92T (A/A) DDEC-CAL	5234770	300	1800	1050	1200	1800	1800	500	1.460	DNA	DNA	TA-7502	2.95
6V-92TA (1600 RPM)	9E85	290	1600	1015	1000	1600	1600	500	1.460	DNA	.385	TV-7511	1.08
6V-92TA	9G85	300	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G90	350	2100	1020	1200	2100	1900	500	1.466	.636	.480	TV-7511	1.08
6V-92TA (JWAC) +	5234770	300	1800	975	1200	1800	1800	500	1.460	DNA	DNA	TV-7511	1.08
(DDEC) +	5234770	350	2100	1020	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	1.08
6V-92TTA	9G85	270	1800	975	1200	1800	1800	500	1.466	DNA	.465	TV-7511	1.08
	9G85	270	2100	975	1200	2100	2100	500	1.466	DNA	.465	TV-7511	1.08
	9G90	300	2100	1020	1200	2100	2100	500	1.466.	.636	.480	TV-7511	1.08
6V-92TAC (CAL)	9F85	320	2100	950	1200	2100	1950	500	1.520	.660	.490	TV-7511	1.23
	9F90$	325	2100	958	1200	2100	1800	700	1.520	.636	.480	TV-7511	1.23
	9F90	300	1800	1000	1200	2100	1800	500	1.520	DNA	.490	TV-7511	1.23
	9F90	340	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F80	300	2100	920	1200	2100	1800	500	1.520	.660	.490	TV-7511	1.08
6V-92TTAC (CAL)	9F90	270	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	300	2100	1000	1200	2100	1800	500/700***	1.520	.660	.490	TV-7511	1.23
	9F90	270	1800	1000	1200	1800	1800	500/700***	1.520	.660	.490	TV-7511	1.23
6V-92TA (ALCC)	9H85	300	1800	975	1200	1800	1800	500	1.475	DNA	.454	TV-7511	1.08
	DDEC	300	1800	975	1200	1800	1800	500	1.460	DNA	.454	TV-7511	1.08
6V-92TA	9E60,#1	205	2100	672	1000	2100	2100	500	1.475	.636	DNA	TV-7503	1.08
	9E60,#2	220	2100	710	1000	2100	2100	500	1.475	.636	DNA	TV-7503	1.08
(COACH)	9F70,9T70#1	245	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9F70,9T70#2	253	2100	775	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75,9S75#1	260	2100	823	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9G75,9S75#2	277	2100	840	1200	2100	2100	500	1.460	.594	DNA	TV-7511	0.96
	9F80,9S80#1	280	2100	849	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9F80,9S80#2	294	2100	875	1200	2100	2100	500	1.460	.636	DNA	TV-7511	1.08
	9H85#1	315	2100	976	1200	2100	2100	500	1.460	.636	.480	TV-7511	1.08
	9H85#2	325	2100	1007	1200	2100	2100	500	1.460	.636	.480	TV-7511	1.08
6V-92TA (DDEC) (COACH)	5234850#1	245	2100	757	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#1	245	2100	823	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#2	253	2100	780	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#2	253	2100	840	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#1	260	2100	823	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#2	277	2100	840	1200	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
6V-92TA (DDEC) (PARLOR) (COACH)	5234850	300	1950	1042	1300	1950	1950	600	1.460	DNA	DNA	TV-7511	0.96
	5234850	287	1950	893	1200	1950	1950	600	1.460	DNA	DNA	TV-7511	0.96
	5234850#2	300	2100	893	1200	2100	2100	600	1.460	DNA	DNA	TV-7511	0.96
	5234850#1	285	2100	870	1200	2100	2100	600	1.460	DNA	DNA	TV-7511	0.96
6V-92TAC (DDEC) (COACH/CAL)	5234850#2	260	2100	867	1000	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
	5234850#1	245	2100	815	1000	2100	2100	500	1.460	DNA	DNA	TV-7511	0.96
6V-92TAC (COACH/CAL)	9E65#1	230	2100	793	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E65#2	240	2100	825	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70#1	245	2100	835	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9E70#2	260	2100	872	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80#1	255	2100	846	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
	9F80#2	270	2100	882	1000	2100	2100	500	1.470	.636	DNA	TV-7511	1.08
6V-92TAC (COACH/CAL)	9F90#1	310	2100	954	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
	9F90#2	320	2100	989	1200	2100	2100	500	1.470	.660	DNA	TV-7511	1.23
6V-92TA (PARLOR COACH)	9F80#2	300	2100	893	1200	2100	2100	500	1.460	.504	.454	TV-7511	0.96
	9H85#2	330	2100	1007	1200	2100	2100	500	1.460	.636	.454	TV-7511	1.08
8V-92TA (1600 RPM)	9E80	350	1600	1250	1000	1600	1600	500	1.470	DNA	.454	TV-8512	1.23
8V-92TA	7G75	350	1800	1175	1200	1800	1800	500	1.460	DNA	.385	TV-8512	1.23
	9G85	400	1800	1250	1300	2100	1800	500	1.458	DNA	.404	TV-8511	1.39
	9G85	450	2100	1250	1300	2100	1800	500	1.458	.594	.404	TV-8511	1.39
	9G90†	475	2100	1330	1300	2100	2100	500	1.475	.570	.404	TV-8511	1.39
8V-92TA (DDEC)	5234770	400	1800	1315	1300	1800	1800	500	1.460	DNA	DNA	TV-8511	1.23
	5234775†	475	2100	1425	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.39
	+5234770	450	2100	1330	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.39
	5234770	400	2100	1330	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.23
8V92TAC DDEC-CAL	5234770	400	1800	1315	1300	1800	1800	500	1.460	DNA	DNA	TV-8511	1.39
8V-92TTA	9G90	400	2100	1330	1300	2100	2100	500	1.458	.570	.404	TV-8511	1.39
8V-92TAC (CAL)	7G75	350	1800	1175	1200	1800	1800	500	1.508	DNA	.454	TV-8512	1.23
	9F90	400	1800	1250	1300	1800	1800	700	1.520	.660	.490	TV-8511	1.39
	9F90	450	2100	1250	1300	2100	1800	700	1.520	.660	.490	TV-8511	1.39
8V-92TTAC (CAL)	9F90	400	2100	1250	1300	2100	700	1800	1.520	.660	.490	TV-8511	1.39
8V-92TA (ALCC)	7G75	350	1800	1175	1200	1800	1800	500	1.470	DNA	.454	TV-8512	1.23
	9G85	400	1800	1250	1300	1800	1800	500	1.475	DNA	.465	TV-8511	1.39
8V-92TA (PARLOR COACH)	9E65#2	340	2100	1134	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
	9E70#2	365	2100	1187	1000	2100	2100	500	1.470	.636	DNA	TV-8512	1.23
	9A80#2	404	2100	1143	1300	2100	2100	500	1.458	.594	.404	TV-8511	1.39
8V-92TA (DDEC) (PARLOR COACH)	5234770#2	400	2100	1150	1300	2100	2100	500	1.460	DNA	DNA	TV-8511	1.23

NOTES: ***Minimum Idle Speed: 500 w/Fuel Modulator, 700 w/Throttle Delay.
$ Non Bypass Blower
† Full-Sized Blower
‹ Pending 4-87
#1 Diesel Fuel #1
#2 Diesel Fuel #2

DNA — Does Not Apply
AIR/AIR — Air to Air Charge Cooling
ALCC — Advanced Liquid Charge Cooling
TA — Turbocharged/Jacket Water Aftercooled.
TTA — Constant Horsepower/Turbocharged/Jacket Water Aftercooled.
All Engine Horsepower Ratings are Based on SAE J1349 Conditions.
Specifications Subject to Change without Notice.

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Figure 12-17 1987 Certified Automotive Engines

See Figure 12-18 for chart of the 1987 certified automotive engines (coach models).

ENGINE	CERTI-FICATION	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92TA (DDEC)	F	5234775#2◇	330	2100	1020	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.23
	F	5234915#2◇	300	1950	1050	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#1◇	285	2100	800	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#2◇	300	2100	880	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#1◇	276	1950	800	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#2◇	289	1950	890	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	F	5234915#1■	260	2100	800	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	F	5234915#2■	277	2100	880	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	F	5234915#1■	245	2100	705	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	F	5234915#2■	253	2100	775	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
6V-92TA (MUI)	F	9G85◇	330	2100	990	1200	DNA	DNA	500	1.475	.404	TV-7512	1.23
	F†	9F80◇	300	2100	890	1200	DNA	DNA	500	1.466	.365	TV-7512	1.08
	F†	9G75#2■	277	2100	880	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
	F†	9F70#2■	253	2100	825	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
	F†	9G75#1■	267	2100	867	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
	F†	9F70#1■	245	2100	814	1000	DNA	DNA	500	1.475	.594*	TV-7511	0.96
6V-92TAC (DDEC)	C	5234915#2◇	300	2100	975	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
	C	5234915#2◇	300	2100	820	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
	C	5234915#1■	260	2100	815	1000	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	C	5234915#2■	277	2100	880	1200	DNA	DNA	600	1.520	DNA	TV-7512	1.08
	C	5234915#1■	245	2100	730	1000	DNA	DNA	600	1.520	DNA	TV-7512	0.96
	C	5234915#2■	253	2100	775	1200	DNA	DNA	600	1.520	DNA	TV-7512	0.96
8V-92TA (DDEC)	F	5234775◇	475	2100	1350	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	F	5234915◇	400	2100	1150	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.23
8V-92TAC (MUI)	F	9F80◇	400	2100	1235	1200	DNA	DNA	500	1.470	.404	TV-8513	1.23
8V-92TAC (DDEC)	C	5234775◇	450	2100	1425	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.39
	C	5234915◇	400	2100	1150	1200	DNA	DNA	600	1.520	DNA	TV-8513	1.23

DNA=Does Not Apply ◇=Parlor ■=Transit #1=Diesel Fuel #1 #2=Diesel Fuel #2
* Throttle Delay
† Data Also Applies to 9S80, 9S75 and 9T70 Injectors

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Figure 12-18 1987 Certified Automotive Engines (Coach Models)

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See Figure 12-19 for chart of the 1987 certified automotive engines (truck models).

ENGINE	CERTI-FICATION	INJECTOR	RATED BHP	RPM	PEAK TORQUE (LB-FT)	RPM	MAX FL SPEED	MIN FL SPEED	MIN IDLE SPEED	INJECTOR TIMING	FUEL MODULATOR SETTING	TURBO	A/R
6V-92T (A/A DDEC)	F	5234915	300	1800	1050	1200	DNA	DNA	500	1.520	DNA	TA-7503	2.95 Sq In.
6V-92TAC (DDEC)	C	5234915	300	2100	975	1200	DNA	DNA	500	1.520	DNA	TV-7512	1.08
6V-92TA (DDEC)	F F	5234775 5234915	350 300	2100 1800	1020 975	1200 1200	DNA DNA	DNA DNA	500 500	1.520 1.520	DNA DNA	TV-7512 TV-7512	1.23 1.08
6V-92TA (MUI)	F	9G90	350	2100	995	1200	DNA	DNA	500	1.480	.454	TV-7512	1.23
8V-92TA (DDEC)	F F F	5234775 5234775 5234915	475 475 400	2100 2100 1800	1425 1350 1315	1200 1200 1200	DNA DNA DNA	DNA DNA DNA	600 600 600	1.520 1.520 1.520	DNA DNA DNA	TV-8513 TV-8513 TV-8513	1.39 1.39 1.23
8V-92TA (MUI)	F	9G85	445	2100	1330	1200	DNA	DNA	500	1.480	.404	TV-8513	1.39
8V92TAC (DDEC)	C C	5234775 5234915	450 400	2100 1800	1425 1315	1200 1200	DNA DNA	DNA DNA	600 600	1.520 1.520	DNA DNA	TV-8513 TV-8513	1.39 1.23

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Figure 12-19 1987 Certified Automotive Engines (Truck Models)

Listed in Table 12-1 are the 1991–1992 certified automotive engine configurations.

Engine, Components and Parameters	1991 (C)	1991 (F) (C)	1991 (F)	1991 (C)	1992 (F)
Engine	6V-TA JWAC	6V-TA JWAC (Coach)	8V-TA JWAC (Truck and Parlor Coach)	8V-TA JWAC (Truck and Parlor Coach)	6V-TA 8V-TA* JWAC
Injector	5234960 5234985 5234965 5234775†	5234960 (1) (2)	5234960 5234965	5234980 5234985	5234960 5234965
Injector Timing	1.520	1.520	1.520	1.520	1.520
Turbocharger	TV7512	TV7512	TV8513	TV7513	TV7512 TV8513

* These particular specifications are used together.

† Firetruck only

(1) Number one diesel fuel

(2) Number two diesel fuel

(C) California certification

(F) Federal certification

Number two diesel fuel is the standard if not otherwise designated.

Table 12-1 Certified Automotive Engine Configurations 1991–1992

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Listed in Table 12-2 are the 1992–1993 certified automotive engine configurations.

Engine, Components and Parameters	1992 (C)	1992 (F)	1992 (F) (C)	1992 (F)	1993 (F) (C)
Engine	6V-TA 8V-TA* JWAC	6V-TA JWAC (Transit Coach)	6V-TA JWAC (Transit Coach)	6V-TA* 8V-TA† JWAC Parlor Coach)	6V-TA JWAC (Parlor Coach)
Injector	5234980 5234985 5234775‡	5234960	5234955§	5234960*† 5234965*	5234980
Injector Timing	1.520	1.520	1.520	1.520	1.520
Turbocharger	TV7512 TV8513*	TV7512	TV7502	TV7512* TV8513†	TV7512

* These particular specifications are used together.

† These particular specifications are used together.

‡ Firetruck only

§ M85 and M100 methanol fuel

(C) California

(F) Federal

Number two diesel fuel is the standard if not otherwise designated.

Table 12-2 Certified Automotive Engine Configurations 1992–1993

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Listed in Table 12-3 are the 1993 certified automotive engine configurations.

Engine, Components and Parameters	1993 (F) (C)	1993 (F)	1993 (C)	1993 (F)	1993 (F)
Engine	6V-TA JWAC	8V-TA JWAC (Truck and Parlor Coach)	8V-TA JWAC	6V-TA JWAC (Transit Coach)	6V-TA JWAC
Injector	5234965* 5234985†	5234960 5234965	5234980 5234985‡	5234960 (1) (2) 5234965 (2)	5234955
Injector Timing Height (in.)	1.520	1.520	1.520	1.520	1.520
Turbocharger	TV7512	TV8513	TV8513	TV7512	TV7512 § TV7502 ‖ TV7503 #

* Firetruck only

† California certification for truck and parlor coach

‡ Truck and parlor coach

§ M85 and M100 methanol fuel (50 state certification)

‖ M100 methanol fuel (50 state certification)

Ethanol fuel (E95) (50 state certification)

(1) Number one diesel fuel

(2) Number two diesel fuel

(C) California certification

(F) Federal certification

Number two diesel fuel is the standard if not otherwise designated.

Table 12-3 Certified Automotive Engine Configurations 1993

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Listed in Table 12-4 are the 1993–1994 certified automotive engine configurations.

Engine, Components and Parameters	1993 (MSHA) †	1993 (MSHA) †	1994 (F)	1994 (F)
Engine	6V-TA JWAC (Industrial)	8V-TA JWAC (Industrial)	6V-TA JWAC Truck, Parlor Coach, and Motor Home	8V-TA JWAC Truck, Parlor Coach, and Motor Home
Injector	5234775 5234965 *	5234965	5234960 ‡ 5234965 5234775 ‡	5234960 ‡ 5234965 ‡
Injector Timing H%eight (in.)	1.520	1.520	1.520	1.520
Turbocharger	TV7512 TV7503 *	TV8513	TV7512	TV8513

* These particular specifications are used together.

† Underground mine certification

‡ Firetruck also

(F) Federal certification

Number two diesel fuel is the standard if not otherwise designated

Table 12-4 Certified Automotive Engine Configurations 1993–1994

Listed in Table 12-5 are the 1994 certified automotive engine configurations.

Engine, Components and Parameters	1994 (F)	1994 (F) (C)	1994 (MSHA) §	1994 (MSHA) §
Engine	6V-TA JWAC (Transit Coach)	6V-TA JWAC (Transit Coach)	6V-TA JWAC (Industrial)	8V-TA JWAC (Industrial)
Injector	5234960 (1) (2) * 5234965 (1) (2) †	234955	5234960 5234965	5234965
Injector Timing Height (in.)	1.520	1.520	1.520	1.520
Turbocharger	TV7512 (A/R 0.96) * TV7512 (A/R 1.08) †	TV7512 ‡ TV7502 ‖ TV7503 #	TV7512	TV8513

* These particular specifications are used together.

† These particular specifications are used together.

‡ M85 and M100 methanol fuel

§ Underground mining certification

‖ M100 methanol fuel only

E95 enthanol fuel

(C) California certification

(F) Federal certification

Number two diesel fuel is the standard if not otherwise designated.

Table 12-5 Certified Automotive Engine Configurations 1994

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Listed in Table 12-6 are the 1995–1996 certified automotive engine configurations.

Engine, Components and Parameters	1995 (F)	1995 (F)	1995 (F)	1995	1995	1996
Engine	6V-TA JWAC Truck	8V-TA JWAC Truck	6V-TA JWAC Motor Coach	6V-TA MSHA	8V-TA MSHA	8V-TA JWAC Motor Coach
Injector	5234960 5234965 5234975	5234965	5234960 5234965	5234960 5234965	5234965	5234965
Injector Timing Height (in.)	1.520	1.520	1.520	1.520	1.520	1.520
Turbocharger	TV7512	TV8513	TV7512	TV7512	TV7513	TV8513

(F) Federal certification

Number two diesel fuel is the standard if not otherwise designated.

Table 12-6 Certified Automotive Engine Configurations 1995–1996

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12.2 EXHAUST VALVE CLEARANCE ADJUSTMENT

The correct exhaust valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in compression loss, misfiring cylinders, and burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear, and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, adjust the valve clearance to the cold setting to allow normal engine part expansion during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

The exhaust valve bridges must be adjusted and the adjustment screws locked securely at the time the cylinder head is installed on the engine. Refer to section 1.5.8 for chart of the necessary adjustment procedure.

The exhaust valve bridge balance should be checked when a general valve adjustment is performed. After the bridges are balanced, adjust the valve clearance at the push rod only.

NOTE:
Do not disturb the exhaust valve bridge adjusting screw.

All exhaust valves may be adjusted in firing order sequence during one full crankshaft revolution. Refer to the *General Specifications* shown at the beginning of this manual.

12.2.1 Adjustment of Valve Clearance (Cold Engine)

Adjust the valve clearance on a cold engine as follows:

1. Clean the loose dirt from the engine exterior.
2. Remove the valve rocker covers. Discard the gaskets.
3. Cover any drain cavities in the cylinder head to prevent foreign material from entering.
4. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

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CAUTION:

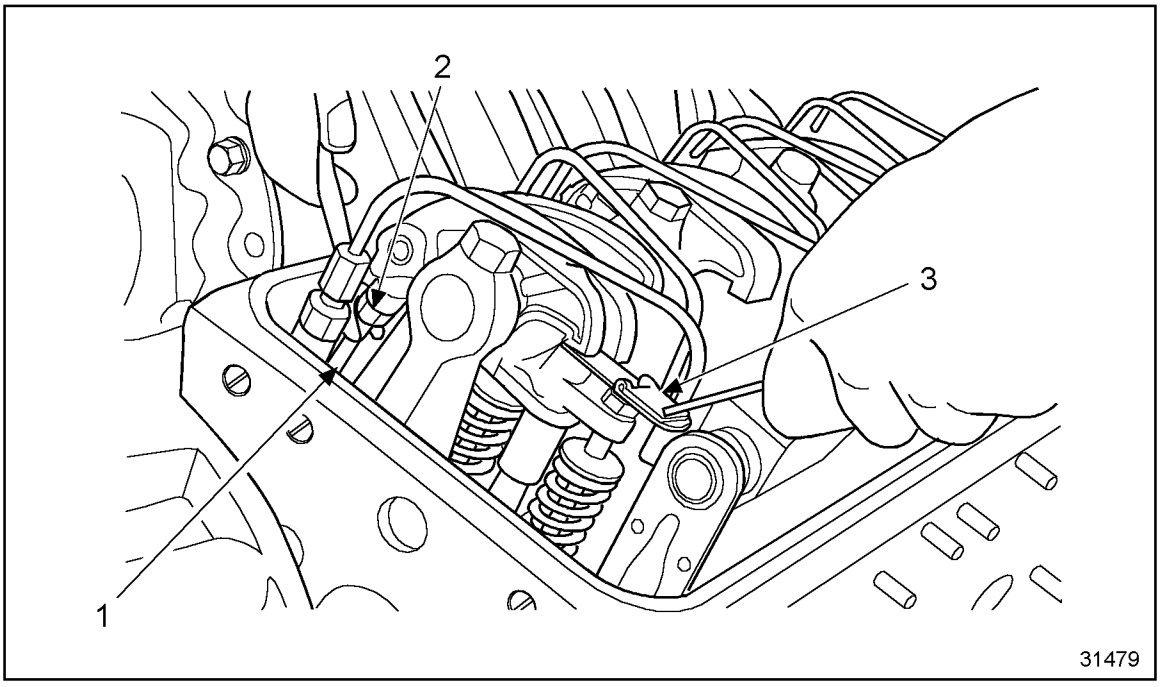
To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

NOTICE:

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. To avoid engine damage, always bar the engine in the direction of normal rotation to avoid loosening the bolt.

5. Rotate the crankshaft with engine barring tool J 22582 or with the starting motor until the injector follower is fully depressed on the particular cylinder to be adjusted.
6. Loosen the exhaust valve rocker arm push rod locknut.
7. Place a 0.016 in. feeler gage between the valve bridge and the valve rocker arm pallet. See Figure 12-20.

NOTE:
For marine engines, models 8062–7K10 and 8062–7K11, place a 0.019 in. feeler gage between the valve bridge and the valve rocker arm pallet.



1. Push Rod
2. Locknut
3. Feeler Gage

Figure 12-20 Adjusting Valve Clearance

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8. Adjust the push rod to obtain a smooth "pull" on the feeler gage.
9. Remove the feeler gage.
10. Hold the push rod with a 5/16 in. wrench, and tighten the locknut with a 1/2 in. wrench.
11. Check the clearance.

NOTE:
If the adjustment is correct for non-marine engines, a 0.015 in. feeler gage will pass freely between the valve bridge and the rocker arm pallet, but a 0.017 in. feeler gage will not pass through. If the adjustment is correct for marine engines, models 8062–7K10 and 8062–7K11, the 0.018 in. feeler gage will pass freely between the valve bridge and the rocker arm pallet, but a 0.020 in. feeler gage will not pass through. Adjust the push rod further, if necessary.

12. Adjust and check the remaining exhaust valves.
13. With the engine at 38°C (100°F) or more, check the valve clearance.

NOTE:
If, on non-marine engines, a 0.014 in. feeler gage ± 0.004 in. will pass between the valve bridge and the valve rocker arm pallet, the valve clearance is satisfactory. If, on marine engines, models 8062–7K10 and 8062–7K11, a 0.017 in. feeler gage ± 0.004 in. will pass between the valve bridge and the valve rocker arm pallet, the valve clearance is satisfactory. If necessary, adjust the push rod.

12.2.2 Adjustment of Valve Clearance (Hot Engine)

It is not necessary to make a final hot engine exhaust valve clearance adjustment after a cold engine adjustment has been performed. However, if a hot engine adjustment is desired, use the following procedure:

NOTICE:
Maintaining normal engine operating temperature is particularly important when making the hot engine exhaust valve clearance adjustment. If the engine is allowed to cool off before setting any valves, the clearance, when running at full load, may become insufficient.

NOTE:
Since these adjustments are normally made while the engine is stopped, run the engine between adjustments to maintain normal operating temperature.

1. With a non-marine engine at normal operating temperature, set the exhaust valve clearance with a 0.014 in. feeler gage. With a marine engine, models 8062–7K10 and 8062–7K11,

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at normal operating temperature, set the exhaust valve clearance with a 0.017 in. feeler gage. Refer to section 11.5 for normal coolant operating temperatures.

NOTE:
If the valve clearance is correct on a non-marine engine, a 0.013 in. feeler gage will pass freely between the valve bridge and the valve rocker arm pallet, but the 0.015 in. feeler gage will not pass through. If the valve clearance is correct on a marine engine, models 8062–7K10 and 8062–7K11, a 0.016 in. gage will pass freely between the valve bridge and the valve rocker arm pallet, but the 0.018 in. feeler gage will not pass through. Adjust the push rod further, if necessary.

2. After the exhaust valve clearance has been adjusted, check the fuel injector timing. Refer to section 12.3.
3. With the engine at 38°C (100°F) or less, check the valve clearance.

NOTE:
If a 0.016 in. feeler gage ± 0.004 in. will pass between the valve bridge and the valve rocker arm pallet on non-marine engines, the valve clearance is satisfactory. If a 0.019 in. feeler gage ± 0.004 in. will pass between the valve bridge and the valve rocker arm pallet on a marine engine, models 8062–7K10 and 8062–7K11, the valve clearance is satisfactory. If necessary, adjust the push rod.

12.3 FUEL INJECTOR TIMING

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All injectors can be timed in firing order sequence during one full crankshaft revolution. Refer to General Specifications at the beginning of this manual.

12.3.1 Timing of Fuel Injector

After the exhaust valve clearance has been adjusted, time the fuel injectors as follows:

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

1. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

NOTICE:

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. To avoid engine damage, always bar the engine in the direction of normal rotation to avoid loosening the bolt.

⚠ CAUTION:

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

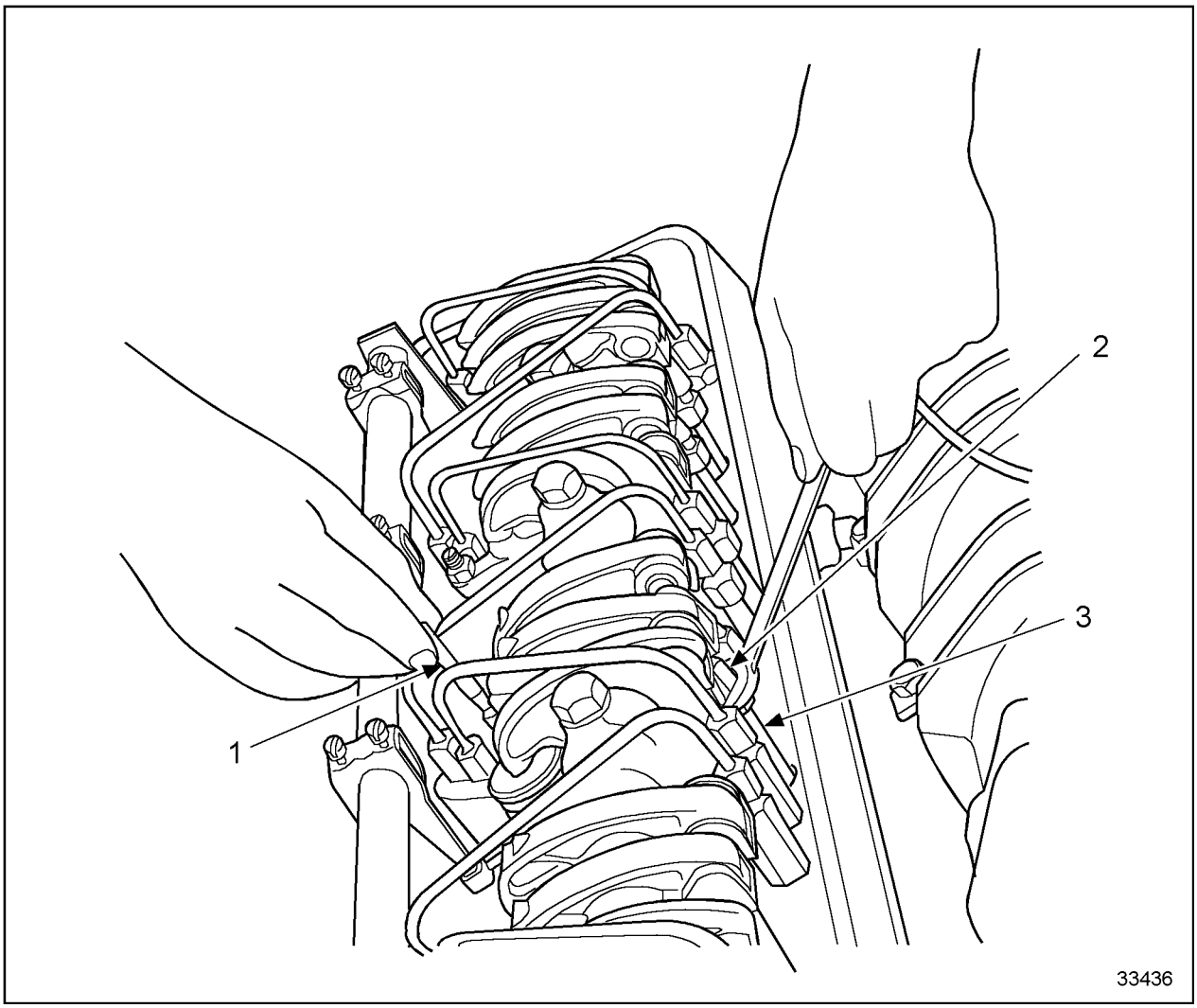
2. Rotate the crankshaft, with the starting motor or with engine barring tool J 22582, until the exhaust valves are fully depressed on the particular cylinder to be timed.

NOTICE:

Failure to set injector timing at the correct height can result in push rod bending and/or other serious damage to the overhead when the engine is cranked.

3. Place the small end of the injector timing gage in the hole provided in the top of the injector body with the flat of the gage toward the injector follower. See Figure 12-21. Timing gages are listed in Table 12-7. Refer to section 12.3.1.

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1. Timing Gage
2. Push Rod
3. Locknut

Figure 12-21 Timing Fuel Injector

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Injector §	Timing Dimension	Timing Gage	Camshaft Timing
9270 *	37.08 mm (1.460 in.)	J 1853	Standard
9275 *	37.08 mm (1.460 in.)	J 1853	Standard
9280 *	37.08 mm (1.460 in.)	J 1853	Standard
9285 *	37.08 mm (1.460 in.)	J 1853	Standard
9290 *	37.08 mm (1.460 in.)	J 1853	Standard
9295 ‡	37.69 mm (1.484 in.)	J 1242	Standard
9200 †	37.69 mm (1.484 in.)	J 1242	Standard
9215	37.69 mm (1.484 in.)	J 1242	Standard
M15 ||	37.08 mm (1.460 in.)	J 1853	Standard
M15 #	37.34 mm (1.470 in.)	J 24236	Standard

* Turbocharged engines use 37.69 mm (1.484 in.) timing (gage J 1242).

† 16V92T (1800 RPM generator set – 860 bhp).

‡ Generator set only.

§ For automotive applications, refer to section 12.1.

|| Marine pleasurecraft and all purpose industrial (non–FP). Exceptions: Models 8063–7400, 8083–7400 use 37.34 mm (1.470 in.).

All purpose industrial (FP).

Table 12-7 Injector Timing

4. Loosen the injector rocker arm push rod locknut.
5. Turn the push rod, and adjust the injector rocker arm until the gage extension just passes over the top of the injector follower.
6. Hold the push rod, and tighten the locknut.
7. Check the adjustment and, if necessary, readjust the push rod.
8. Time the remaining injectors.
9. If no further engine tune-up is required, reinstall the valve rocker covers using new gaskets.

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12.4 LIMITING SPEED MECHANICAL GOVERNOR INJECTOR RACK CONTROL ADJUSTMENT (6V AND 8V ENGINES)

Two different limiting speed mechanical governors are used on the Series 92 engine. The high speed spring retainer and spring housing assembly differ between each type. Depending on the application, some engines use the standard limiting speed governor and other engines use the dual range limiting speed governor. The only variation in the tune-up procedure between each type of governor is in setting the maximum no-load speed.

A properly adjusted governor gap will accomplish the following:

- Provide sufficient weight travel in the idle range to prevent stalling during deceleration. A tight gap reduces weight travel in the idle range.
- Provide enough weight travel in the high speed control range to prevent engine overspeed with light loads at full throttle. A loose gap reduces weight travel in the high speed range.
- Prevent the low speed weight generated force (double weight governors) from compressing the high speed spring. If the gap is too tight, the force of the heavy idle weights operating on the high speed spring will cause the high speed spring to compress at a low speed, resulting in low power.

12.4.1 Adjustment of Governor Gap (Static Method)

DDC recommends using the "static" or weight pry method to set the gap on double weight limiting speed governors. The "engine-on" method may be used, but the "static" method is accurate, efficient, and cost effective.

Stop the engine, and use governor weight wedge tool J 35516 to perform the following procedure:

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

NOTE:
Governor gap setting verification should not be considered necessary until "Vehicle Low Power/Performance at Low Mileage" has been used to troubleshoot an engine performance concern.

12.4.2 Check Gap

Check the gap as follows:

1. In a vehicle, set the engine idle speed at 600 RPM, and stop the engine.

NOTE:
This static governor gap setting is established at the factory based upon a 600 RPM engine idle. When verifying a factory tune-up the governor idle speed should be set at 600 RPM.

⚠ CAUTION:

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

2. Clean the remove the governor cover. Discard the gasket.

NOTICE:

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. To avoid engine damage, always bar the engine clockwise to avoid loosening the bolt.

NOTICE:

On left hand rotating marine engines equipped with a Jabsco raw water pump, detach the cover, and remove the impeller before barring the engine to avoid rubber impeller damage. Mark the front of the impeller for easy reinstallation.

⚠ CAUTION:

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

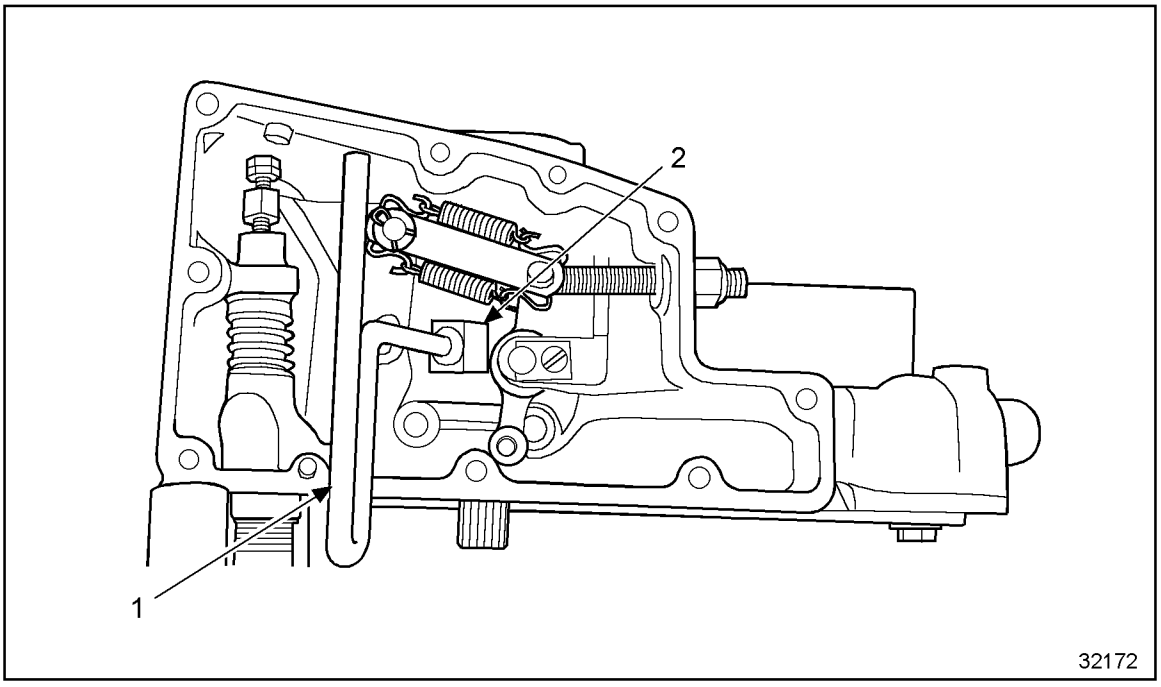
3. With the engine stopped, manually bar the engine over until the governor weights are horizontal.

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NOTICE:
Do not use a screwdriver to pry the weights. Damage to the weights, riser, or housing could result.

NOTE:
On "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately 1.52 mm (0.060 in.) clearance between the washers and the retainer nut before checking or resetting the governor gap.

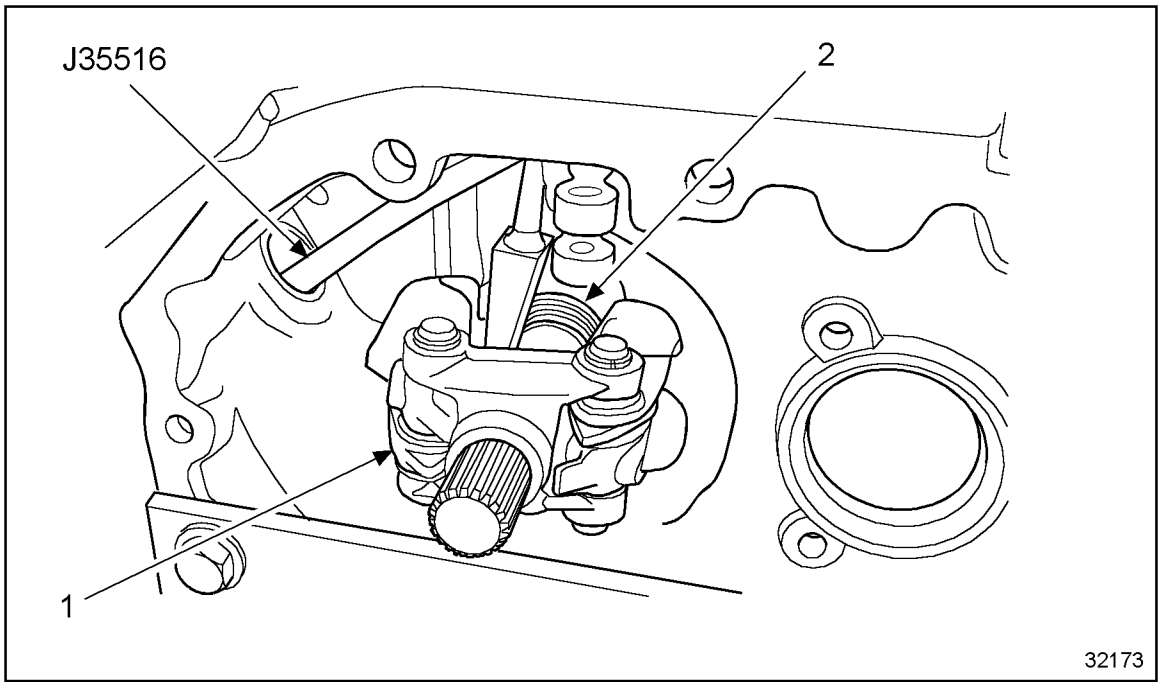
4. Insert governor weight wedge J 35516 between the low-speed weight and the governor riser. See Figure 12-22, and see Figure 12-23.



1. Tool Handle
2. Tool Wedge

Figure 12-22 Tool J 35516 Inserted Between Low Speed Weight and Riser

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1. Low Speed Weight
2. Riser

Figure 12-23 Wedge of Tool J 35516 Between Riser and Low Speed Weight

NOTE:
The tapered face of the wedge should be against the riser and between the flanges on the riser ends.

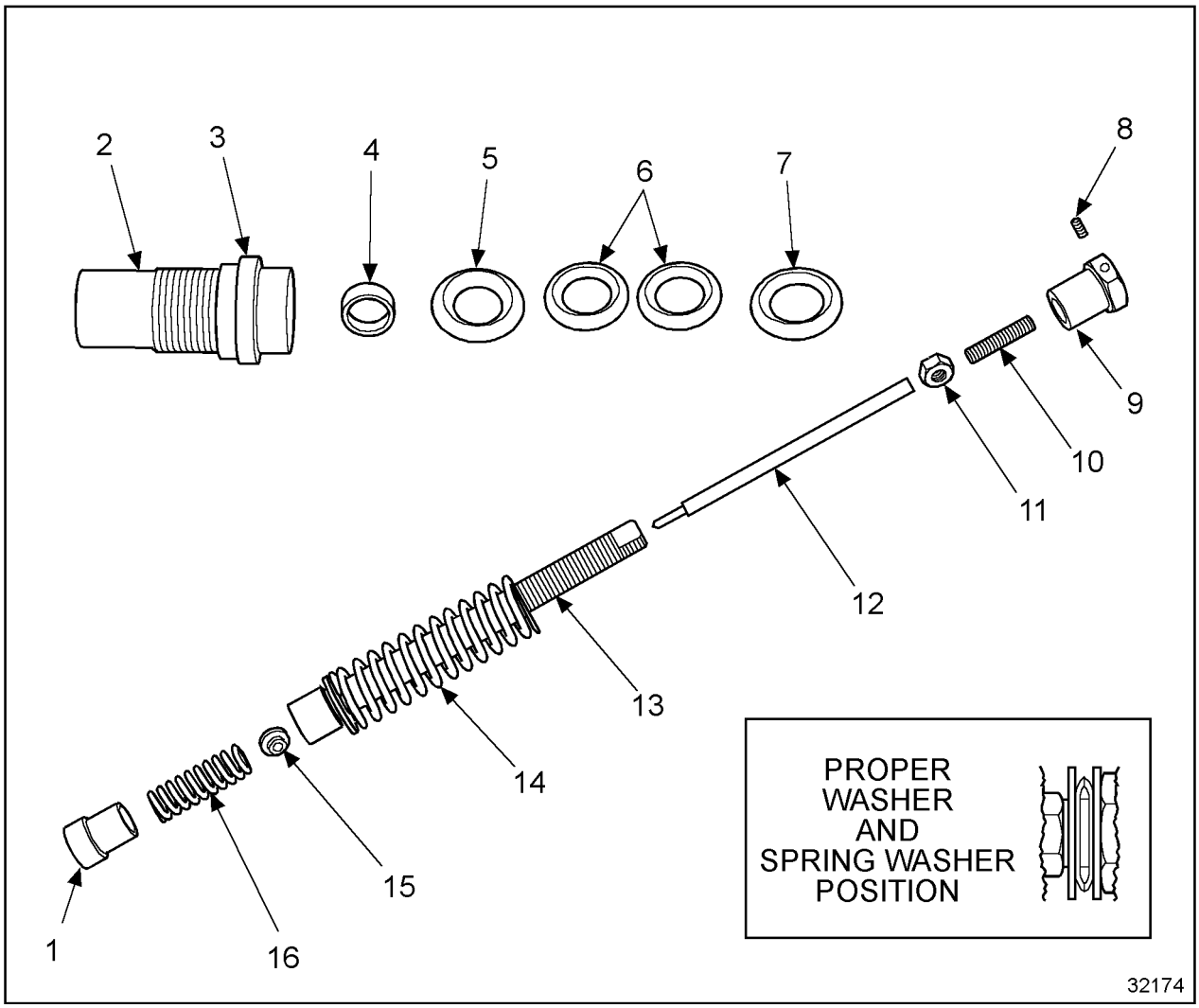
5. Push the wedge to the bottom, forcing the weights against the maximum travel stop.

NOTICE:
Do not use a screwdriver to pry the weights. This could damage the weights, riser, and housing.

6. While holding the wedge in the bottom position, use a feeler gage to measure the gap between the low speed spring cap and the high speed spring plunger. See Figure 12-24.

NOTE:
The gap should measure 0.0762 mm - 0.4826 mm (0.003 in. - 0.019 in.). Reset the gap to 0.20 mm (0.008 in.) if the measured gap is out of limits.

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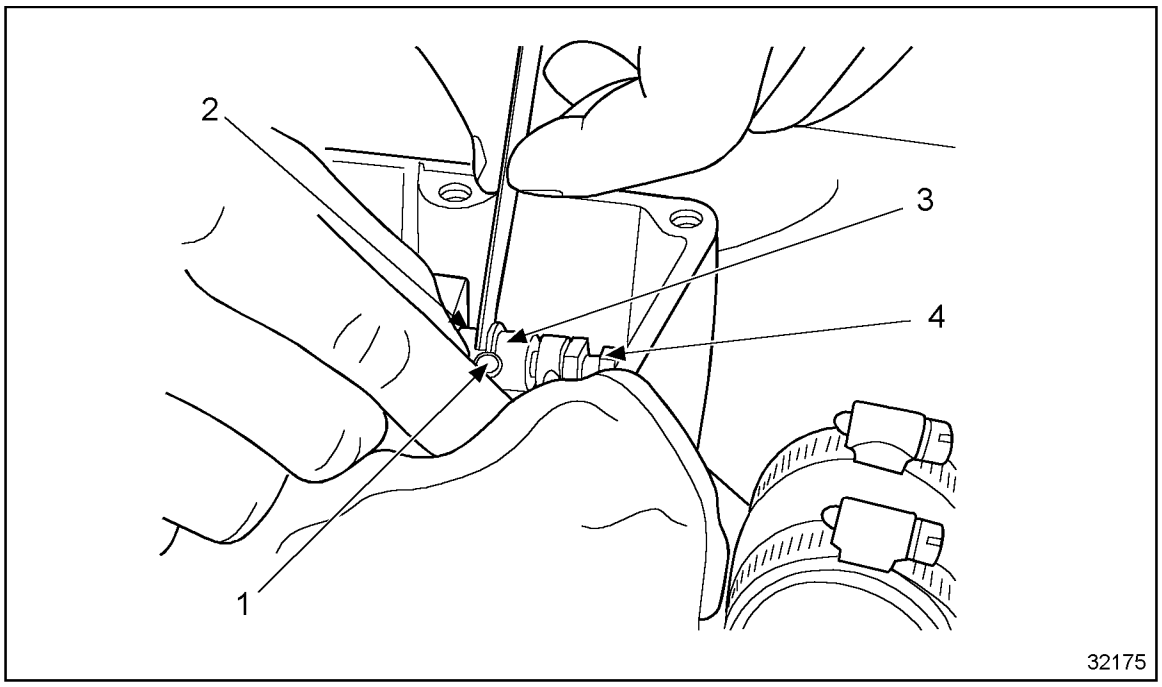


1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Set Screw
9. Retainer Nut
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Pin
13. Plunger
14. High Speed Spring
15. Low Speed Spring Seat
16. Low Speed Spring

Figure 12-24 High and Low-Speed Spring and Plunger (TTA Engines)

7. Remove the wedge and replace the governor cover, using a new gasket.

8. Reset Belleville springs. See Figure 12-25. Refer to section 12.9.



1. Differential Lever Pin
2. High Speed Plunger
3. Low Speed Spring Cap
4. Gap Adjusting Screw

Figure 12-25 Adjusting Governor Gap

12.4.3 Set Gap (Governor On Engine)

Prior to adjustment, perform the following:

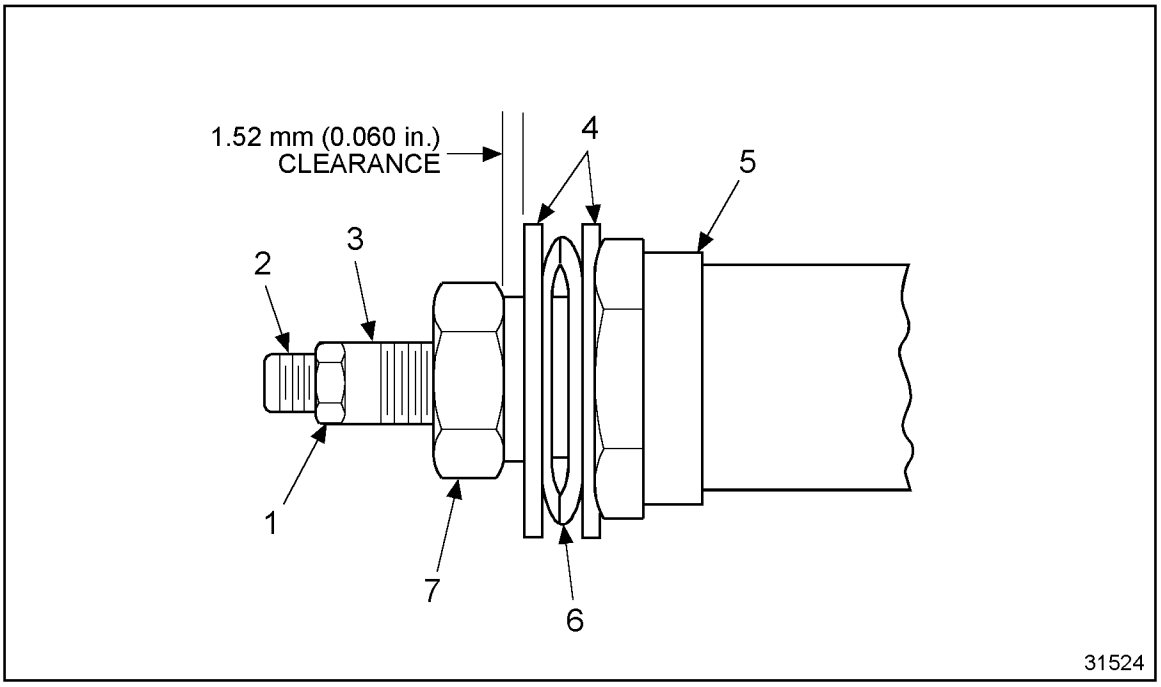
⚠ CAUTION:

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

1. Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device.
2. Back out the external starting aid screw.

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3. On "TT" engines, back out the Belleville spring retainer nut until approximately 1.52 mm (0.060 in.) clearance between the washers and the retainer nut exists. See Figure 12-26.



1. Locknut
2. Idle Screw
3. Plunger
4. Washers
5. High Speed Spring Retainer
6. Belleville Springs
7. Belleville Spring Retainer Nut

Figure 12-26 Belleville Washer Location

NOTE:
The following procedures permit gap adjustment while the governor is on or removed from an engine.

Set the governor gap as follows:

1. Set the engine idle speed at 600 RPM, and stop the engine.
2. Clean and remove the governor cover. Discard the gasket.

⚠ CAUTION:

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

NOTICE:

The hex head of the crankshaft bolt may be used to bar, or turn, the crankshaft. To avoid engine damage, always bar the engine in the direction of normal rotation to avoid loosening the bolt.

⚠ CAUTION:

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

3. With the engine stopped, manually bar the engine over until the governor weights are horizontal.

NOTICE:

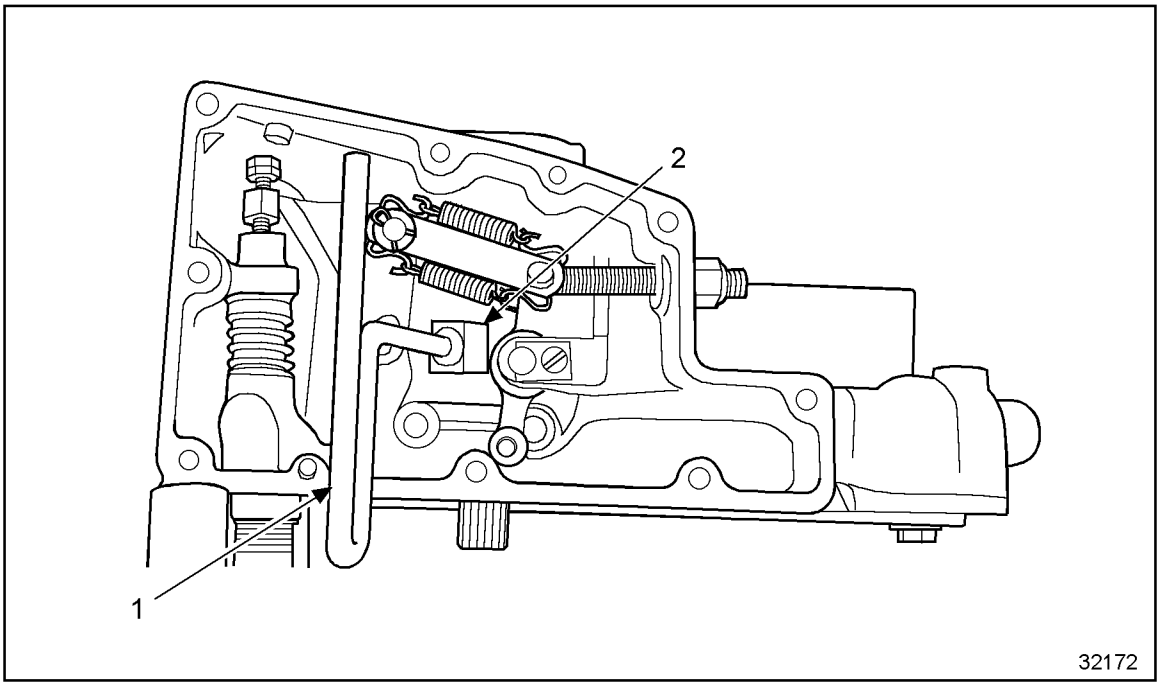
To avoid damaging the rubber impeller while barring a left-hand rotating marine engine equipped with a Jabsco raw water pump, detach the cover, and remove the impeller before barring the engine. Mark the front of the impeller for easy reinstallation.

NOTICE:

Do not use a screwdriver to pry the weights, since damage to the weights, riser, or housing could result.

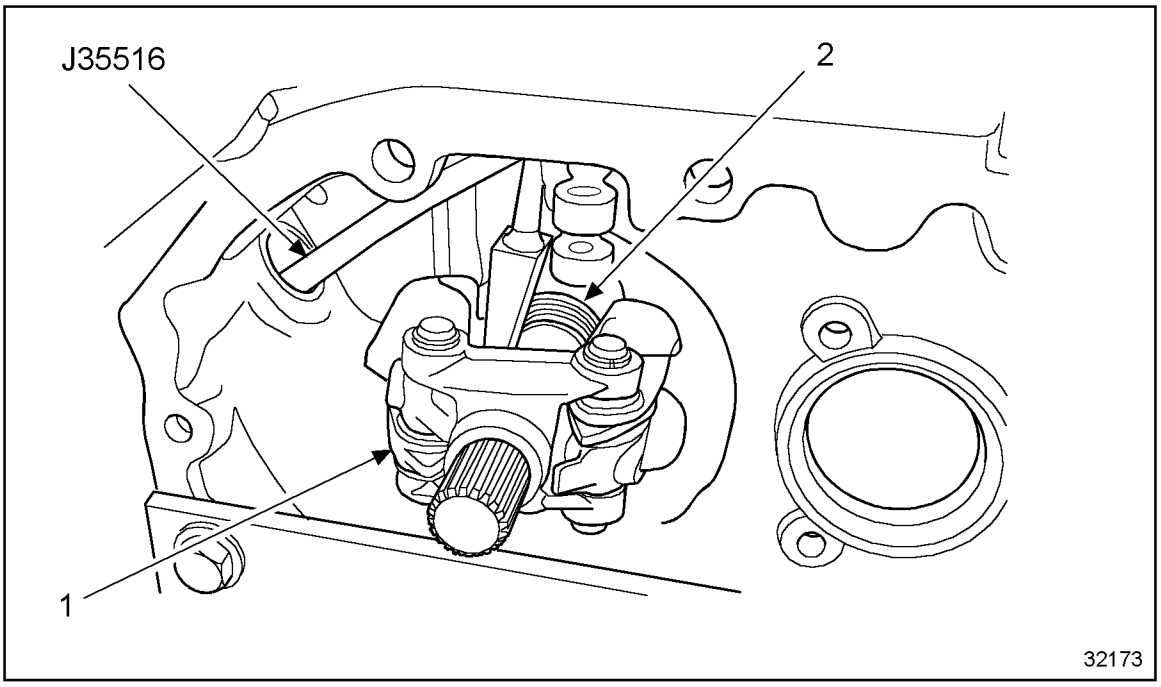
4. Insert governor weight wedge Tool J 35516 between the low-speed weight and the governor riser. See Figure 12-27 and see Figure 12-28.

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1. Tool Handle
2. Tool Wedge

Figure 12-27 Tool J 35516 Inserted Between Low Speed Weight and Riser



1. Low Speed Weight
2. Riser

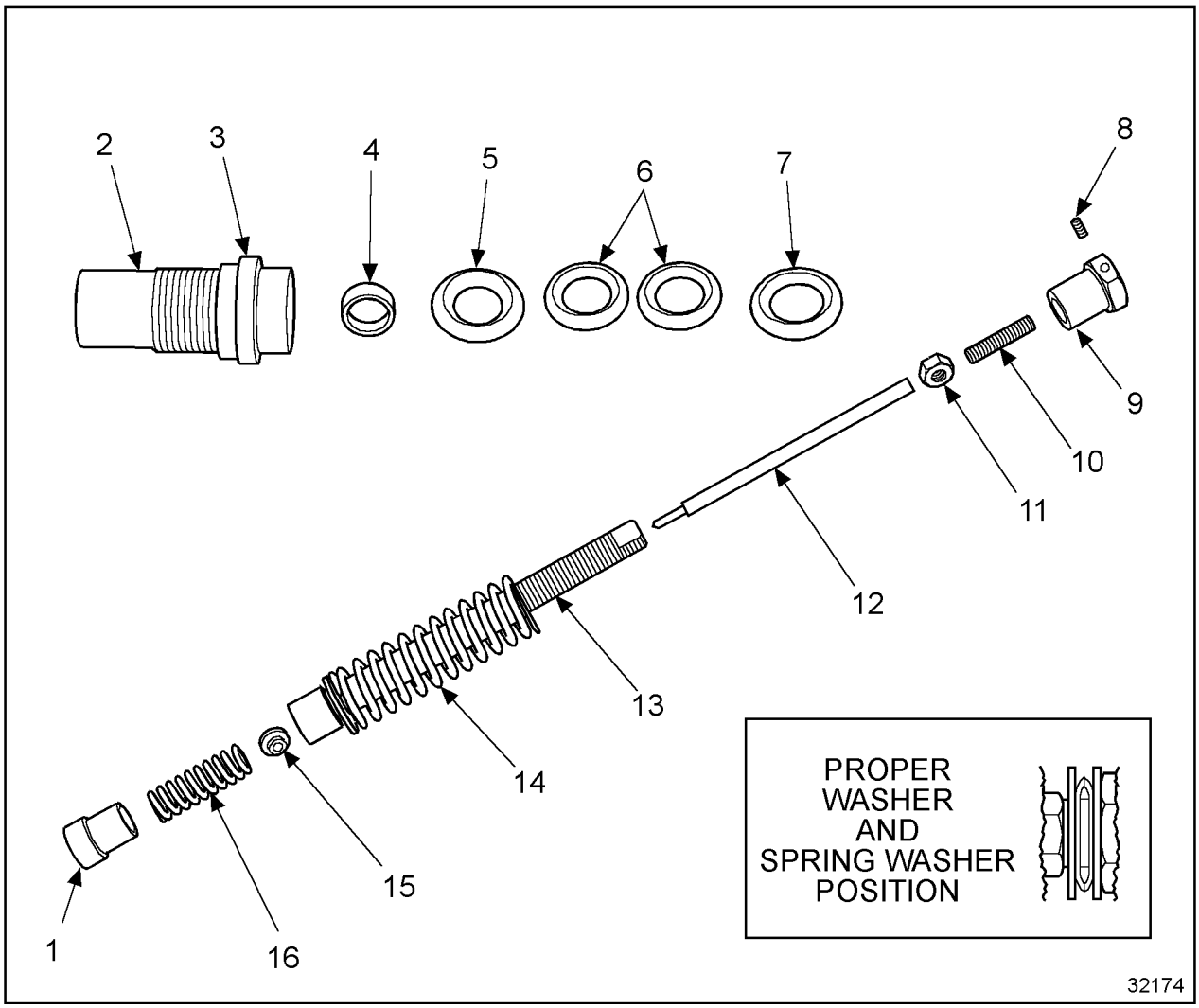
Figure 12-28 Wedge of Tool J 35516 Between Riser and Low Speed Weight

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NOTE:
The tapered wedge face should be against the riser and between the flanges on the riser ends.

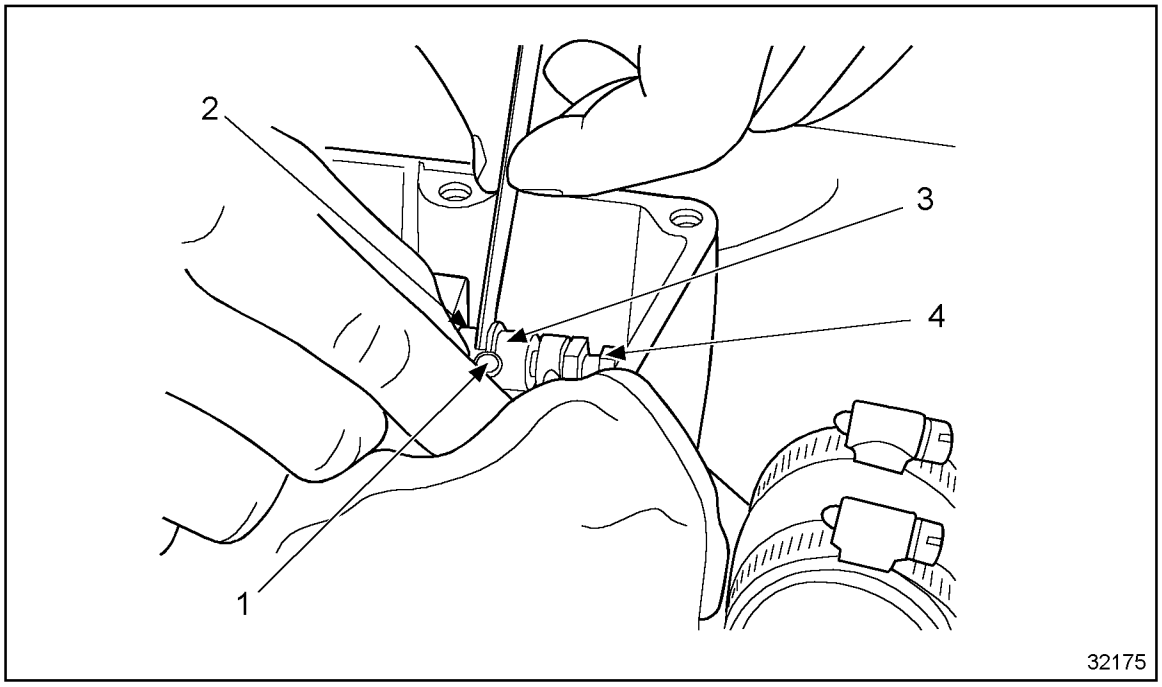
5. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.
6. With the wedge in the bottom position, use a feeler gage to set the gap between the low speed spring cap and the high speed spring plunger at 0.20 mm (0.008 in.).
7. Tighten the governor gap adjusting screw locknut. See Figure 12-29 and see Figure 12-30.

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1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Set Screw
9. Retainer Nut
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Pin
13. Plunger
14. High Speed Spring
15. Low Speed Spring Seat
16. Low Speed Spring

Figure 12-29 High and Low-Speed Spring and Plunger (TTA Engines)



1. Differential Lever Pin
2. High Speed Plunger
3. Low Speed Spring Cap
4. Gap Adjusting Screw

Figure 12-30 Adjusting Governor Gap

8. Push down on the governor weight wedge tool to ensure it did not move while the gap was being set.
9. Check the gap while holding the tool in this position. If the gap is incorrect, reset to 0.20 mm (0.008 in.).
10. Remove the wedge.

NOTE:
The buffer, idle speed, no-load speed and starting aid screws, the injector racks, and supplemental governor devices require adjustment whenever the governor gap is changed.

11. Reset the Belleville springs. Refer to section 12.9.

12.4.4 Set Gap (On Bench)

Set the gap with the governor on a bench as follows:

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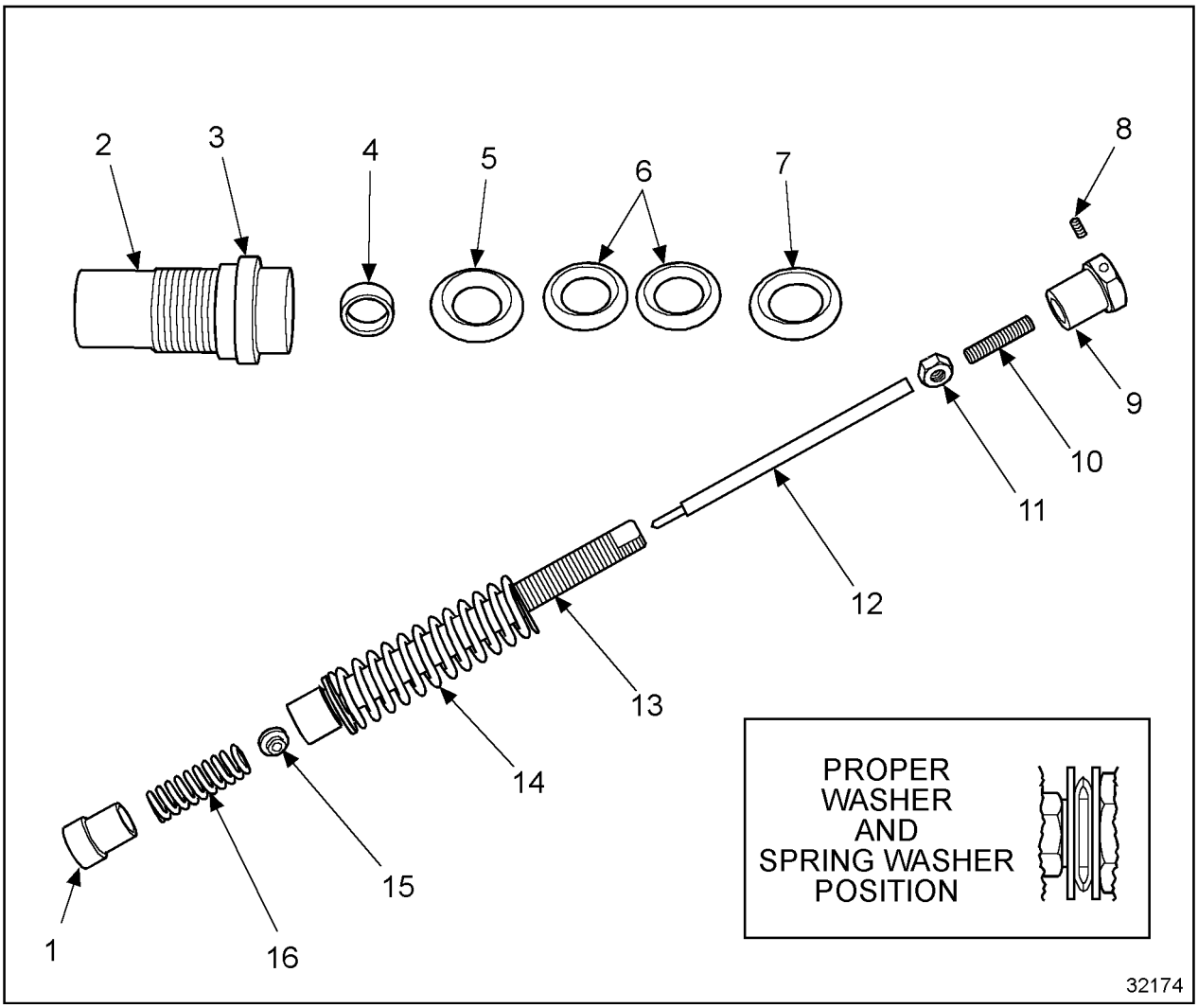
NOTICE:
When setting the governor gap on a bench, mount the governor on a blower to support and protect the governor weight carrier shaft. This prevents damage to the governor weight carrier shaft.

1. Position the idle screw.

NOTE:
On all non- "TT" governors with a normal 1.00 in. long idle adjustment screw, the screw should be set so that it extends 8.26 mm (0.325 in.). On all "TT" governors with a normal 1.00 in. long idle adjustment screw, the screw should be set to extend 10.16 mm (0.400 in.).

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2. Measure this dimension from the idle speed adjusting screw locknut face to the end of the idle speed adjusting screw with a tolerance of ± 0.38 mm (± 0.015 in.). See Figure 12-31.



1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Set Screw
9. Retainer Nut
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Pin
13. Plunger
14. High Speed Spring
15. Low Speed Spring Seat
16. Low Speed Spring

Figure 12-31 High and Low-Speed Spring and Plunger (TTA Engines)

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3. For governors with a variable high-speed option, which use a 1.75 in. long idle adjustment screw, seat the screw to extend 27.31 mm (1.075 in.) on all non- "TT" governors or 29.21 mm (1.150 in.) on all "TT" governors.

NOTE:
These idle screw projections result in a nominal 600 RPM idle speed.

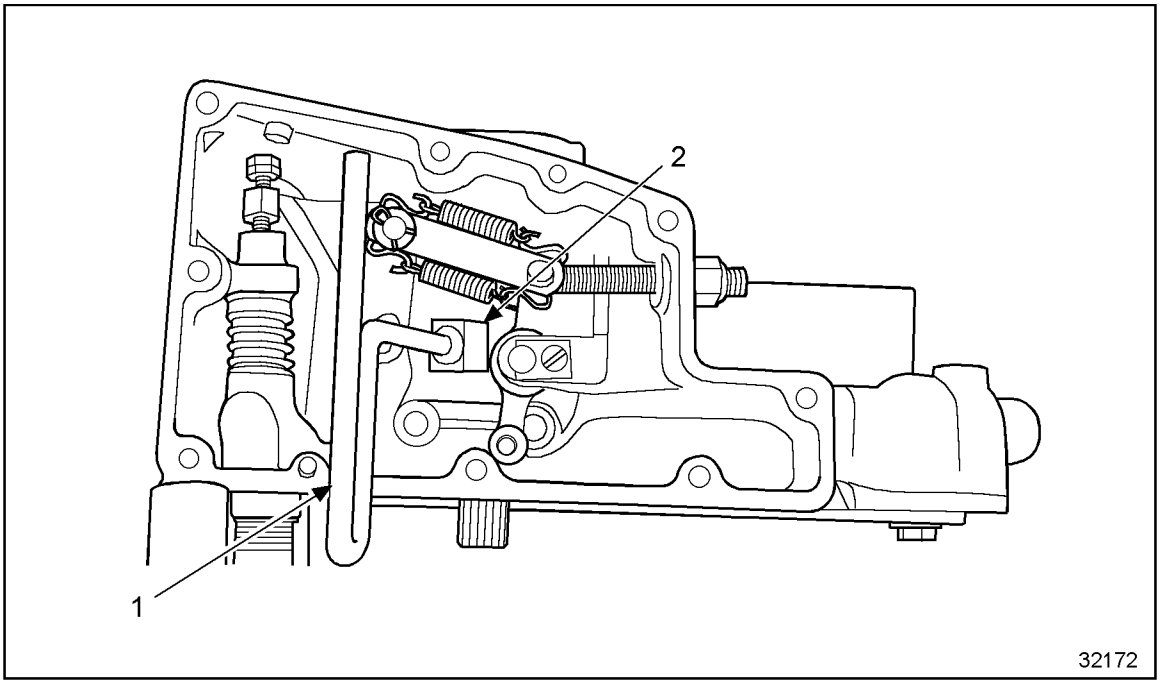
4. Rotate the governor weights until they are horizontal.

NOTICE:
Do not use a screwdriver to pry the weights. Damage to the weights, riser, or housing could result.

5. Insert governor weight wedge Tool J 35516 between the low-speed weight and the governor riser. See Figure 12-32 and see Figure 12-33.

NOTE:
The tapered face of the wedge should be against the riser and between the flanges on the riser ends.

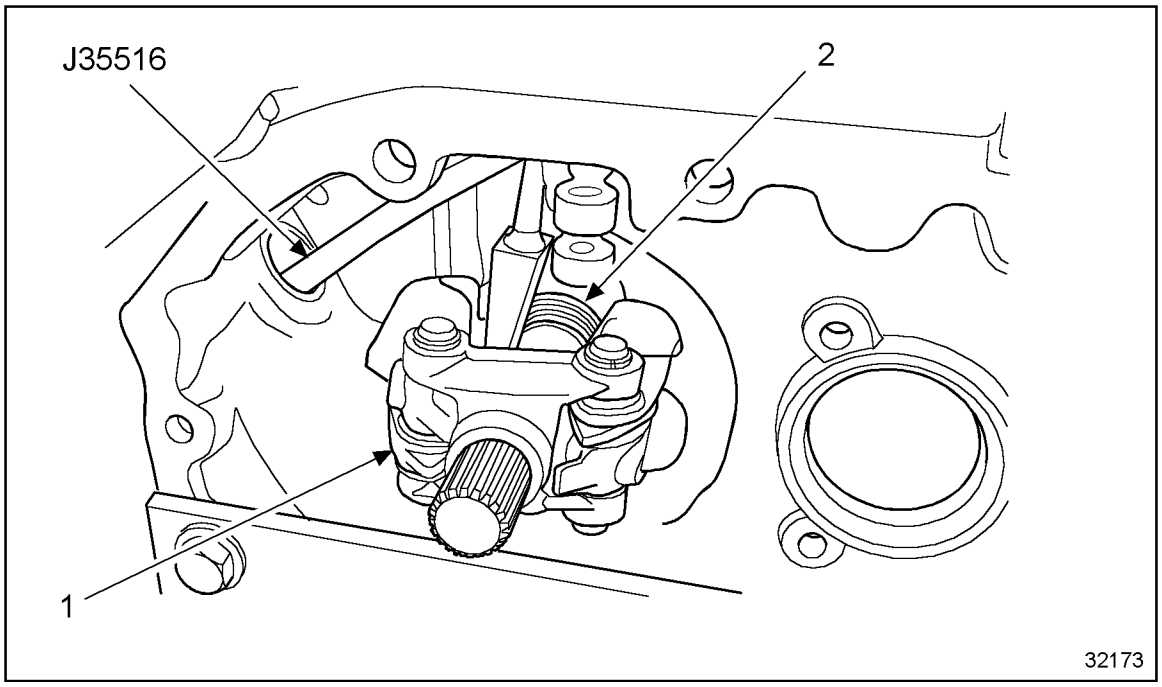
NOTE:
To prevent the weights from rotating when the governor weight wedge tool is inserted, wedge a clean, soft rag between the blower housing and the blower rotors.



1. Tool Handle
2. Tool Wedge

Figure 12-32 Tool J 35516 Inserted Between Low Speed Weight Riser

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1. Low Speed Weight
2. Riser

Figure 12-33 Wedge of Tool J 35516 Between Riser and Low Speed Weight

6. Push the wedge to the bottom, forcing the weights against the maximum travel stop.

NOTICE:
Do not use a screwdriver to pry the weights. Damage to the weights, riser, or housing could result.

7. Ensure governor high-speed spring plunger is seated. Turn in the high-speed retainer as required to seat the plunger.
8. With the wedge in the bottom position, use a feeler gage between the low speed spring cap and the high speed spring plunger to set the gap at 0.20 mm (0.008 in.).
9. Tighten the governor gap adjusting screw locknut.
10. Push down on the governor weight wedge tool to ensure it did not move while the gap was set.
11. Check the gap while holding the tool in this position. If the gap is incorrect, reset to 0.20 mm (0.008 in.).
12. Remove the wedge, and install the cover using a new gasket.

12.4.5 Governor Gap Adjustment (Double-Weight Governor)

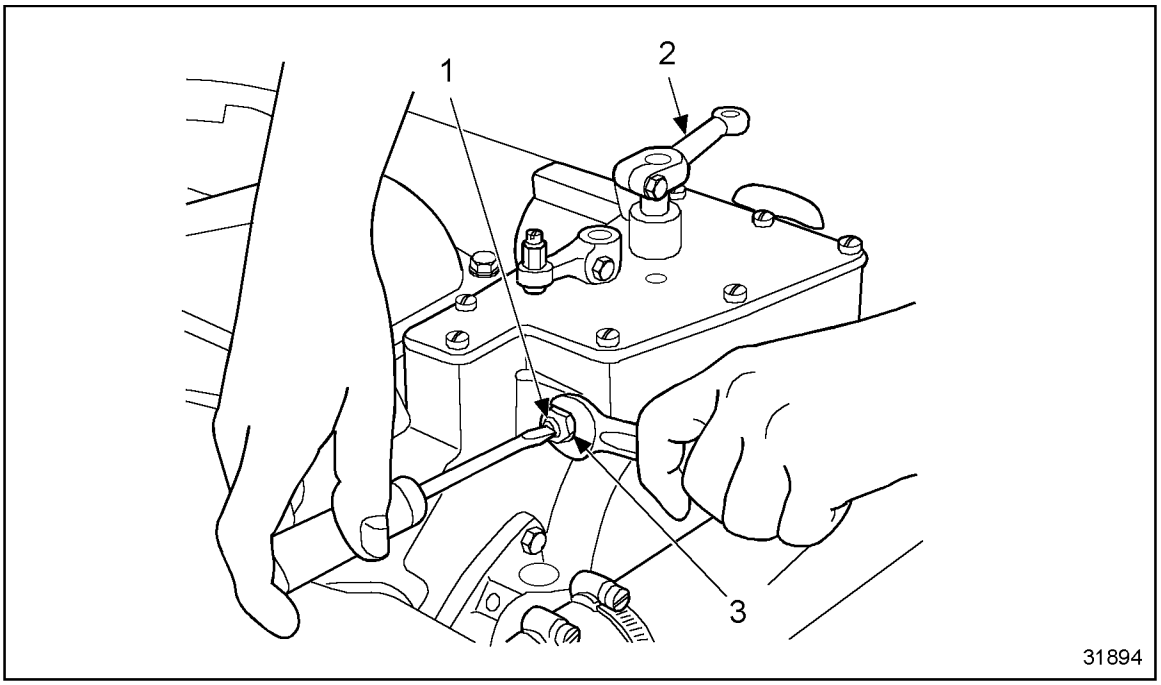
With the engine stopped and at normal operating temperature, adjust the governor gap as follows:

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CAUTION:

To avoid injury from rotating belts and fans, do not remove and discard safety guards.

1. Remove the high-speed spring retainer cover.
2. Back out the buffer screw until it extends 15.88 mm (0.625 in.) from the locknut. See Figure 12-34.

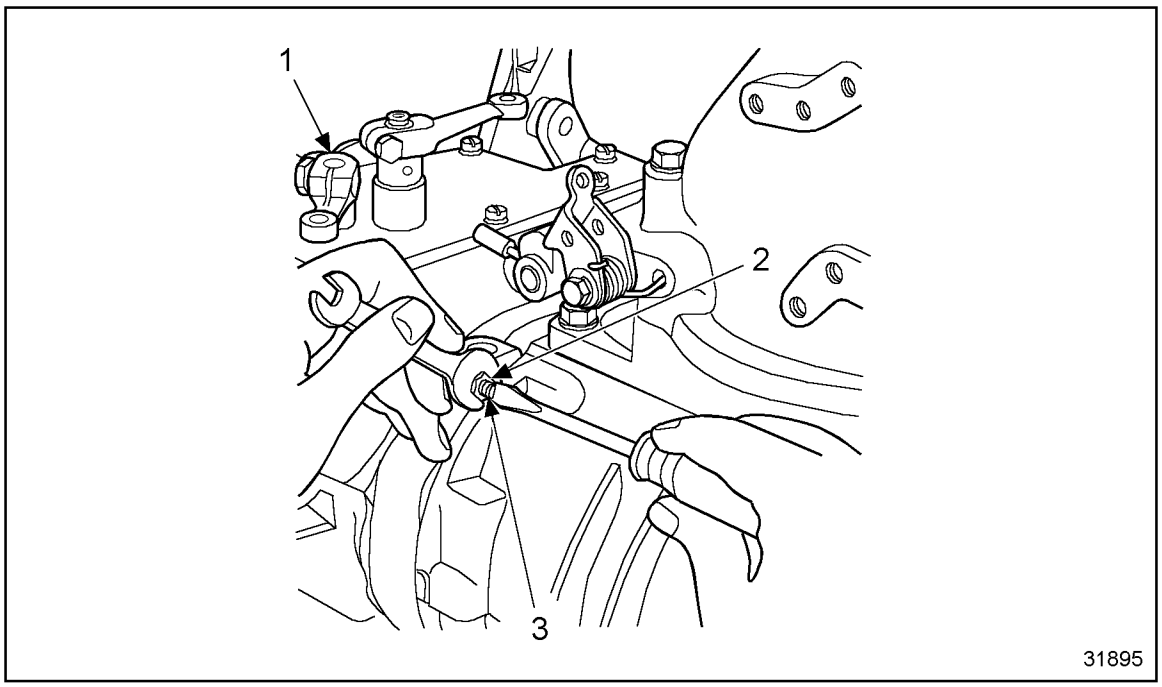


1. Screw
2. Speed Control Lever
3. Locknut

Figure 12-34 Adjusting Buffer Screw

3. Start the engine, and loosen the idle speed adjusting screw locknut.

4. Adjust the idle screw to obtain the desired engine idle speed. See Figure 12-35.



1. Speed Control Lever
2. Idle Speed Adjusting Screw Locknut
3. Idle Speed Adjusting Screw

Figure 12-35 Adjusting Engine Idle Speed

5. Hold the screw, and tighten the locknut to keep the adjustment.
6. For "TT" engines, set the idle speed to 500 RPM.

NOTE:
EPA certified minimum idle speeds are 500 RPM for trucks and highway coaches and 400 RPM for city coaches.

7. Stop the engine.
8. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.
9. Use the differential lever to manually start and run the engine between 1100 and 1300 RPM.
10. Manually operate the differential lever to start and run the engine between 1100 and 1300 RPM.

NOTE:
Do not overspeed the engine.

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11. Check the gap between the low-speed spring cap and the high-speed spring plunger with a feeler gage.

NOTE:
The gap should be 0.0508 mm - 0.1016 mm (0.002 in. - 0.004 in.). If the gap setting is incorrect, reset the gap adjusting screw.

12. Check the gap with the engine operating between 1100 and 1300 RPM. Readjust, if necessary.
13. Stop the engine.
14. Using a new gasket, install the governor cover and lever assembly. Tighten the screws.

12.4.6 Governor Gap Adjustment (Single-Weight Governor)

Adjust the single-weight governor gap as follows:

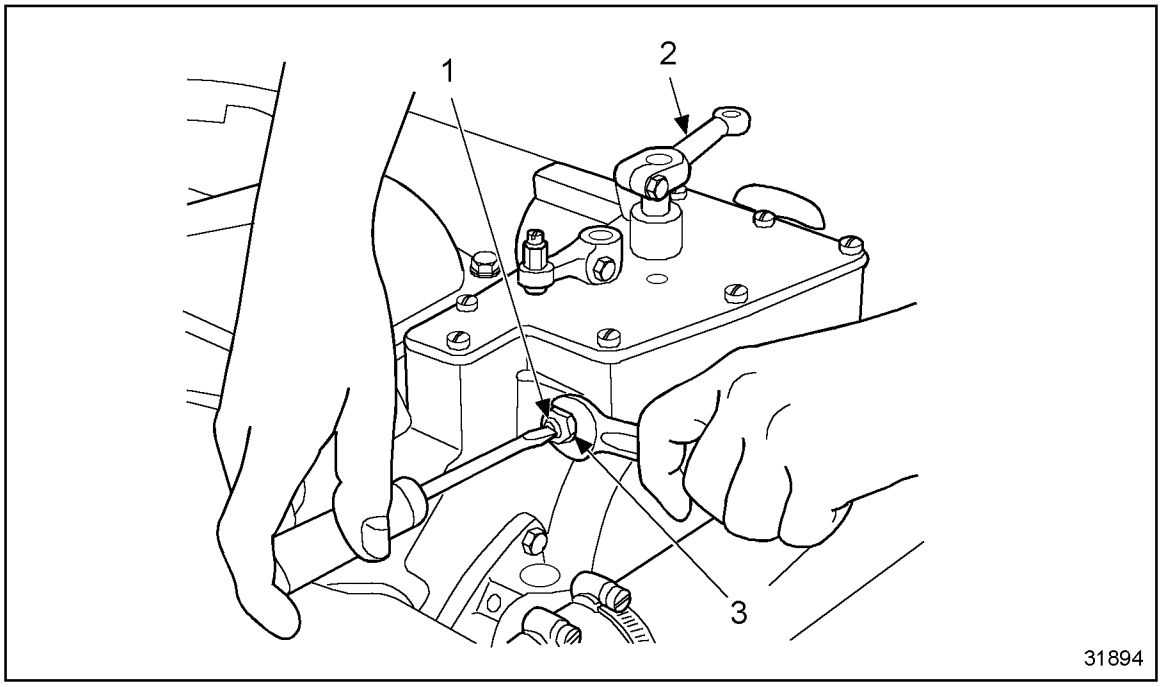
⚠ CAUTION:

To avoid injury from rotating belts and fans, do not remove and discard safety guards.

1. Remove the high-speed spring retainer cover.

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2. Back out the buffer screw until it extends 15.88 mm (0.625 in.) from the locknut. See Figure 12-36.



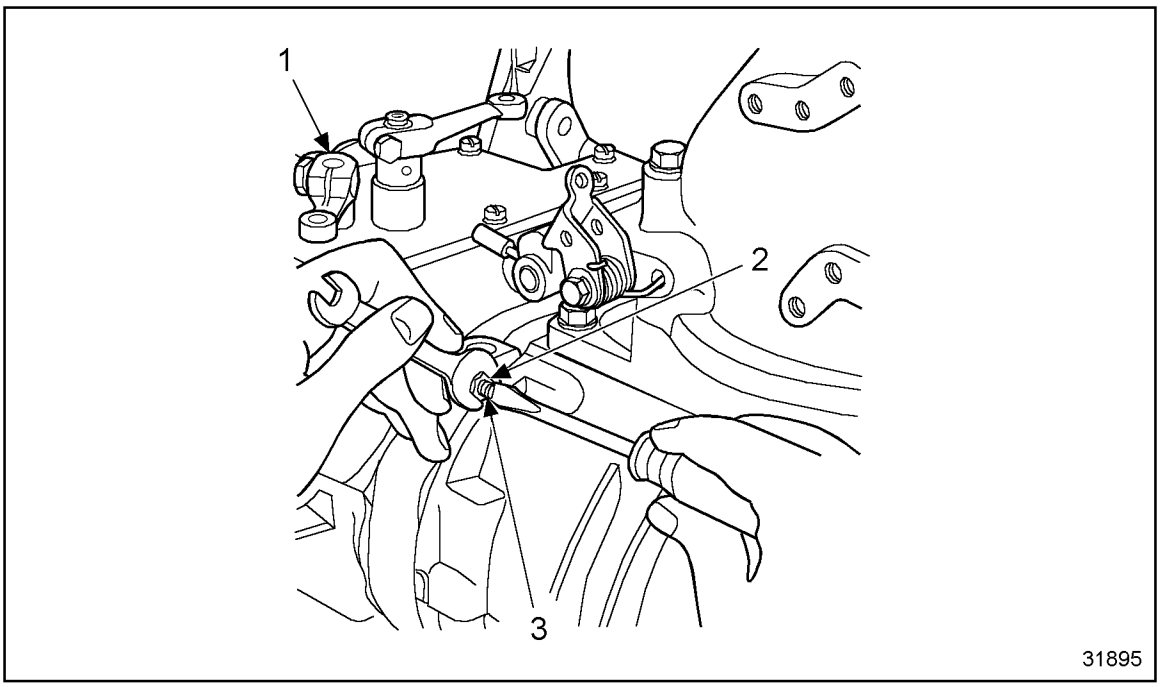
1. Screw
2. Speed Control Lever
3. Locknut

Figure 12-36 Adjusting Buffer Screw

3. Start the engine, and loosen the idle speed adjusting screw locknut.

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4. Adjust the idle screw to obtain the desired engine idle speed. See Figure 12-37.



1. Speed Control Lever
2. Idle Speed Adjusting Screw Locknut
3. Idle Speed Adjusting Screw

Figure 12-37 Adjusting Engine Idle Speed

5. Hold the screw, and tighten the locknut to keep the adjustment.

NOTE:
EPA certified minimum idle speeds are 500 RPM for trucks and highway coaches and 400 RPM for city coaches.

NOTE:
If, when going from top no-load speed to idle speed, the engine governor will not recover and the engine stalls, increase the idle speed to the minimum speed of 600 RPM, listed in Table 12-8.

Engine	Injector	Droop	Idle Speed
6 and 8V Turbo	90 mm (Regardless of Prefix)	175 RPM (was 125 RPM)	600 RPM minimum (was 500 RPM minimum) All Injector Sizes

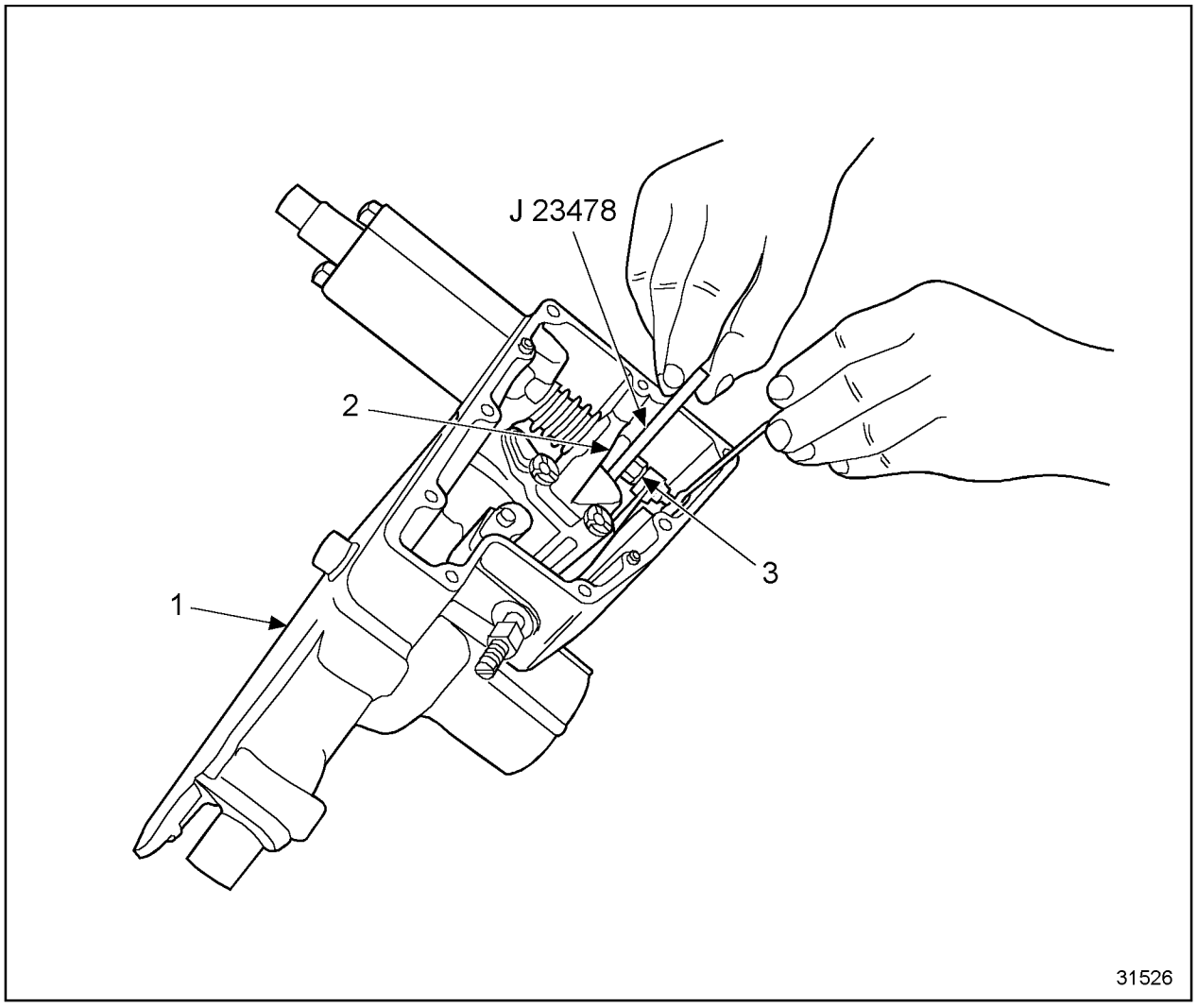
Table 12-8 Top No-Load Speed to Idle Speed

6. Stop the engine.
7. Clean and remove the governor cover and lever assembly and the valve rocker cover. Discard the gaskets.

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8. Remove the fuel rod from the differential lever and the injector control tube lever.
9. Check the gap between the low-speed spring cap and the high-speed spring plunger with gage J 23478 (5.08 mm 0.200 in.). See Figure 12-38.

NOTE:
Ensure external starting aid screw, if used, is backed out far enough to make it ineffective when making this adjustment.



1. Governor Housing Assembly
2. High Speed Spring Plunger
3. Low Speed Spring Cap

Figure 12-38 Adjusting Governor Gap (Single Weight Governor) with Feeler Gage J 23478

10. If required, loosen the locknut and turn the gap adjusting screw until it slightly drags.
11. Hold the adjusting screw, and tighten the locknut.
12. Recheck the gap and readjust, if necessary.

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13. Install the fuel rod between the governor and injector control tube lever.
14. Use a new gasket, and install the governor cover and lever assembly.

12.4.7 Position Injector Rack Control Lever (Non "TT" Engines)

The injector rack control lever must be positioned in relation to the governor. Their positions determine the fuel amount injected into each cylinder and ensures equal load distribution.

NOTICE:
To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that will be used with the governor.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Governor low-speed gap closed.
3. High-speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the full-fuel position.

NOTE:
The letters "R" and "L" indicate the injector location in the right or left cylinder bank viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank.

NOTE:
Adjusting the No. 1L injector rack control lever first establishes a guide for adjusting the remaining injector rack control levers.

5. Disconnect any linkage attached to the governor speed control lever.
6. Turn the idle speed adjusting screw until 12.7 mm (0.5 in.) of the threads (12-14 threads) project from the locknut when the nut is against the high-speed plunger.

NOTE:
This adjustment lowers the tension of the low-speed spring so it can be easily compressed. The low speed gap can close without bending the fuel rods or causing the yield mechanism springs to yield or stretch. A false fuel rack setting may result if the idle speed adjusting screw is not backed out.

Injector racks must be adjusted so the effort to move the throttle from the idle speed position to the maximum speed position is uniform. A sudden increase in effort usually near the full-fuel position can result from:

[a] Injector racks adjusted too tight causing the yield link to separate.

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[b] Binding of the fuel rods on the cylinder head.

[c] Failure to back out the idle screw.

7. If not previously performed, back out the buffer screw approximately 15.88 mm (0.625 in.).
8. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.
9. Loosen all inner and outer injector rack control lever adjusting screws and locknuts.

NOTE:
Ensure all of the injector rack control levers are free on the injector control tubes.

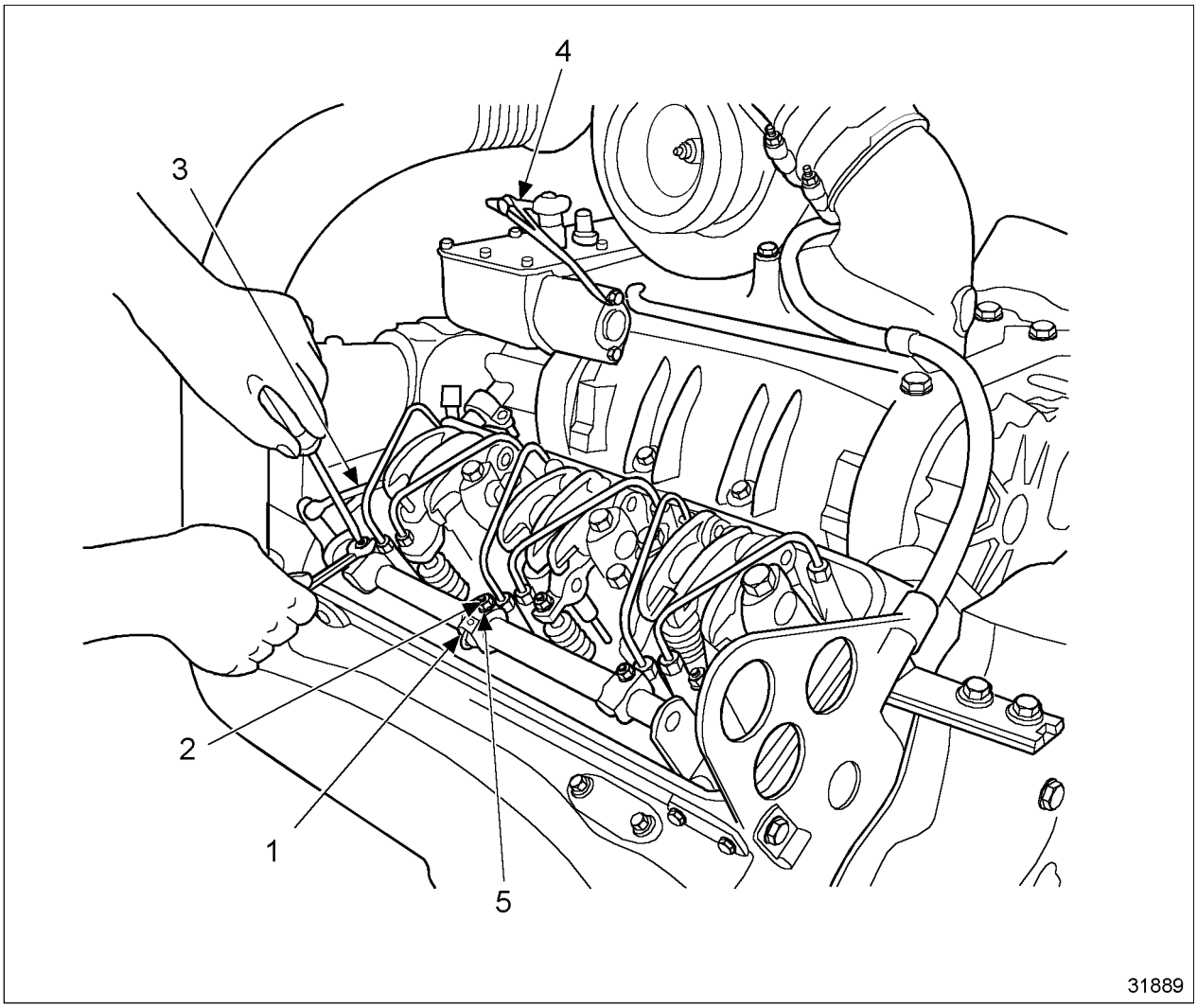
10. Move the speed control lever to the maximum speed position, and hold it lightly with your finger.

12.4.8 Adjustment of One Screw and Locknut Lever Assembly (Non "TT" Engines)

Adjust the one screw and locknut lever assembly on non- "TT" engines as follows:

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1. Tighten the No. 1L injector rack control lever screw until the injector rack clevis rolls. See Figure 12-39.



1. Lever
2. Screw
3. Fuel Rod
4. Speed Control Lever Held at Maximum Speed Position
5. Locknut

Figure 12-39 Injector Control Lever One Screw and Locknut Assembly (Position No. 1)

NOTICE:
To prevent possible damage to the injector control tube, do not overtighten the injector rack control lever adjusting screws during installation or adjustment. The recommended torque is 3-4 N·m (24-36 lb·in).

2. Tighten the screw an additional 1/8 turn, and lock securely with the adjusting screw locknut. This will place the No. 1L injector rack in the full-fuel position.

NOTE:
The governor linkage and control tube assembly should be in the same position that they would attain while the engine is running at full load.

3. Check the rack adjustment. Refer to section 12.4.10.
4. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.
5. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever.
6. To position the No. 1L injector rack control lever, move the speed control lever to the maximum speed position, and hold it in that position lightly with a finger.
7. Insert the clevis pin in the fuel rod and the left bank injector control tube lever.
8. Check the Injector rack control levers. Refer to section 12.4.10.
9. Check for and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.

To adjust the remaining injector rack control levers, proceed as follows:

1. Remove the clevis pins from the fuel rods and the injector control tube levers.
2. Hold the injector control racks in the full-fuel position with the lever on the end of the control tube.

NOTICE:
Do not overtighten the injector rack control tube lever adjusting screw during installation or adjustment. This could damage the injector control tube. The recommended torque is 3-4 N·m (24-36 lb·in).

3. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
4. Securely lock the adjusting screw locknut.
5. Verify the injector rack adjustment of No. 1L. Refer to section 12.4.10.
6. If No. 1L does not spring upward, turn the No. 2L adjusting screw counterclockwise until the No. 1L injector rack returns to its full-fuel position. Secure the adjusting screw locknut.

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7. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors. Refer to section 12.4.10.
8. Turn the No. 2L injector rack adjusting screw clockwise or counterclockwise until both No. 1L and No. 2L injector racks are in the full-fuel position when the locknut is securely tightened.
9. Adjust the remaining injectors using the procedures outlined in step 5 through step 8.

NOTE:
Always verify proper injector rack adjustment. Refer to section 12.4.10 and refer to section 12.10.3.

NOTE:
Once the No. L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

10. When all of the injector rack control levers are adjusted, check their settings. Refer to section 12.4.10.

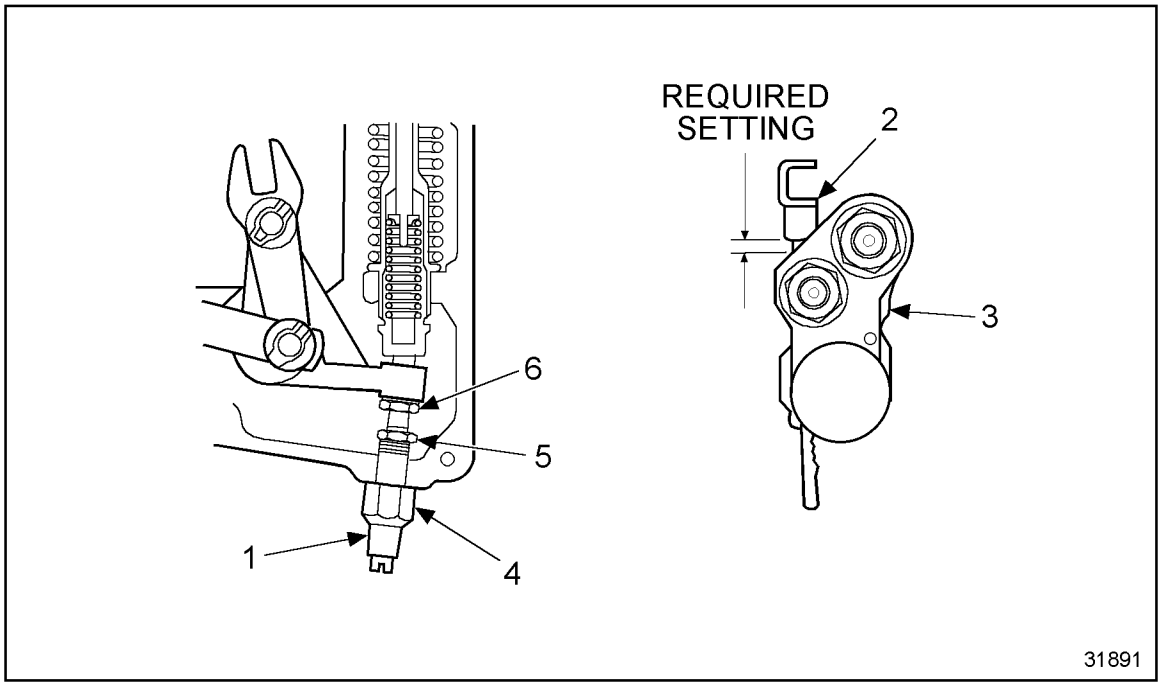
NOTE:
All the control racks must have the same spring condition with the control tube lever in the fuel-fuel position.

11. Insert the clevis pin in the fuel rod and the injector control tube lever.
12. Turn the idle speed adjusting screw in until it projects 4.7625 mm (0.1875 in.) from the locknut to permit engine starting.

12.4.9 Adjustment of External Starting Aid Screw

On current turbocharged engines, adjust the external starting aid screw as follows:

1. With the engine stopped, place the governor stop lever in the run position and the speed control lever in the idle speed position.
2. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body. See Figure 12-40. The required setting specifications are listed in Table 12-9.



1. Starting Aid Screw
2. Injector Rack Clevis
3. Injector Body
4. Locknut
5. Gap Adjustment Screw
6. Locknut

Figure 12-40 Starting Aid Screw Adjustment

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Injector	Gage Setting	Tool Number	Injector	Gage Setting	Tool Number
9200	11.532 mm (0.454 in.)	J 23190	9E80	9.778 mm (0.385 in.)	J 24882
9215	11.532 mm (0.454 in.)	J 23190	9E85	9.778 mm (0.385 in.)	J 24882
9225	11.532 mm (0.454 in.)	J 23190	9F70	11.532 mm (0.454 in.)	J 23190
9280	9.778 mm (0.385 in.)	J 24882	9F80	11.532 mm (0.454 in.)	J 23190
9285	9.778 mm (0.385 in.)	J 24882	9F85	11.532 mm (0.454 in.)	J 23190
9290	11.532 mm (0.454 in.)	J 23190	9F90	11.532 mm (0.454 in.)	J 23190
9295	11.532 mm (0.454 in.)	J 23190	7G65	9.778 mm (0.385 in.)	J 24882
9A80	9.778 mm (0.385 in.)	J 24882	7G70	9.778 mm (0.385 in.)	J 24882
9A85	9.778 mm (0.385 in.)	J 24882	7G75	9.778 mm (0.385 in.)	J 24882
9A90	11.532 mm (0.454 in.)	J 23190	9G75	11.532 mm (0.454 in.)	J 23190
9B70	9.778 mm (0.385 in.)	J 24882	9G85	11.532 mm (0.454 in.)	J 23190
9B75	9.778 mm (0.385 in.)	J 24882	9G90	11.532 mm (0.454 in.)	J 23190
9B80	9.778 mm (0.385 in.)	J 24882	9H85	10.26 mm (0.404 in.)	J 9509-C
9B85	9.778 mm (0.385 in.)	J 24882	9J85	11.532 mm (0.454 in.)	J 23190
9B90	11.532 mm (0.454 in.)	J 23190	9K85	10.26 mm (0.404 in.)	J 9509-C
9C70	9.778 mm (0.385 in.)	J 24882	9S65	11.532 mm (0.454 in.)	J 23190
9C75	9.778 mm (0.385 in.)	J 24882	9S70	11.532 mm (0.454 in.)	J 23190
9C80	9.778 mm (0.385 in.)	J 24882	9S75	11.532 mm (0.454 in.)	J 23190
9C90	11.532 mm (0.454 in.)	J 23190	9S80	11.532 mm (0.454 in.)	J 23190
9E65	9.778 mm (0.385 in.)	J 24882	9T70	11.532 mm (0.454 in.)	J 23190
9E70	9.778 mm (0.385 in.)	J 24882		—	—

Table 12-9 Starting Aid Screw Adjustment Specifications

3. Select the proper gage, and measure the setting at No. 2R cylinder.

NOTE:
When the starting aid screw is properly adjusted, the gage should have a small clearance of 0.3969 mm (0.0156 in.) in the space along the injector rack shaft between the rack clevis and the injector body.

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4. After completing the adjustment, hold the starting aid screw, and tighten the locknut.
5. Place the stop lever in the run position.
6. Move the speed control lever from the idle speed position to the maximum speed position.

CAUTION:
To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

NOTICE:
To avoid engine damage, ensure injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever.

7. Return the speed control lever to the idle speed position.

NOTE:
Governor speed control lever movement takes up the clearance in the governor linkage. The injector rack clevis-to-body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out. The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start-up.

8. Use new gaskets and install the valve rocker covers.

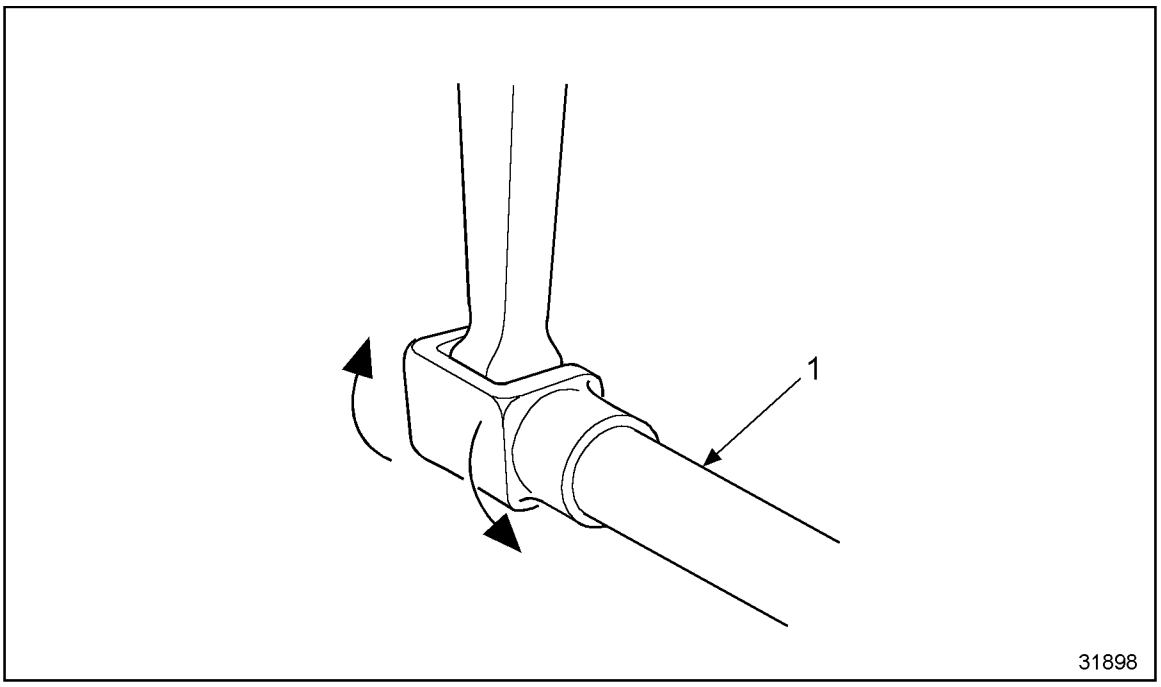
12.4.10 Check Rack Adjustment (One Screw and Locknut Assembly)

Check the rack adjustment as follows:

1. Hold the speed control lever in the maximum speed position, and press the injector rack down with a screwdriver or finger tip.

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2. Observe the injector control rack "rotation". See Figure 12-41.



1. Injector Control Rack

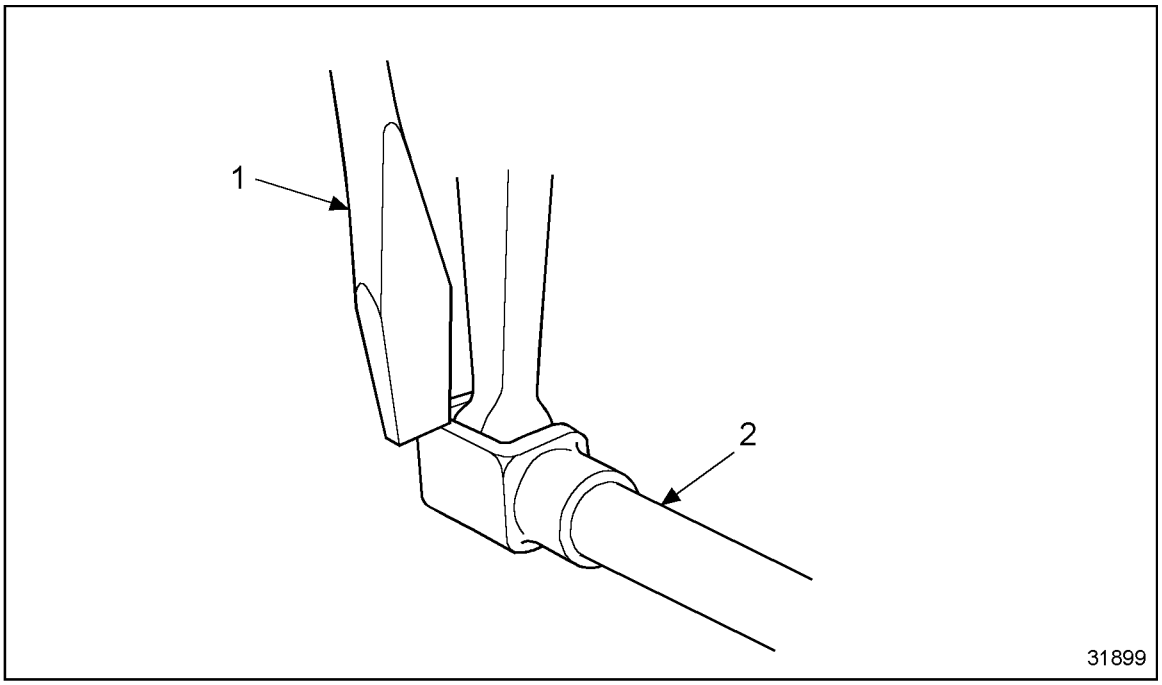
Figure 12-41 Checking Rotating Movement of Injector Control Rack

3. Hold the speed control lever in the maximum speed position.

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4. Using a screwdriver, press the injector control rack down. See Figure 12-42.

NOTE:
The rack should tilt downward, and when the screwdriver is removed, the control rack should "spring" upward.



1. Screwdriver
2. Injector Control Rack

Figure 12-42 Checking Injector Control Rack "Spring"

If the rack does not return to its original position, it is too loose. Correct the one screw and locknut assembly as follows:

1. Loosen the locknut, and turn the adjusting screw clockwise.
2. Tighten the locknut.

The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel. Correct the one screw and locknut assembly as follows:

1. Loosen the locknut, and turn the adjusting screw counterclockwise.
2. Tighten the locknut.

12.4.11 Adjustment of One Screw and Locknut Lever Assembly

Adjust the one screw and locknut lever assembly as follows:

1. Tighten the adjusting the No. 1R injector rack control lever screw until the injector rack clevis rolls.

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NOTICE:
To prevent possible damage to the injector control tube, do not overtighten the injector rack control lever adjusting screws during installation or adjustment. The recommended torque is 3-4 N·m (24-36 lb·in).

2. Tighten the screw an additional 1/8 turn, and lock securely with the adjusting screw locknut. This will place the No. 1R injector rack in the full-fuel position. The governor linkage and control tube assembly should be in the same position that they would attain while the engine is running at full load.

12.4.12 Position Injector Rack Control Lever (Non "TT" Engines with Two Screw Assemblies)

Adjust the two screw lever assembly on non- "TT" engines as follows:

NOTE:
The letters "R" and "L" indicate the injector location in the right or left cylinder bank viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank.

NOTE:
Adjusting the No. 1L injector rack control lever first establishes a guide for adjusting the remaining injector rack control levers.

1. Disconnect any linkage attached to the governor speed control lever.
2. Turn the idle speed adjusting screw until 12.7 mm (0.5 in.) of the threads (12-14 threads) project from the locknut when the nut is against the high-speed plunger.

NOTE:
This adjustment lowers the tension of the low-speed spring so it can be easily compressed. The low speed gap can close without bending the fuel rods or causing the yield mechanism springs to yield or stretch. A false fuel rack setting may result if the idle speed adjusting screw is not backed out.

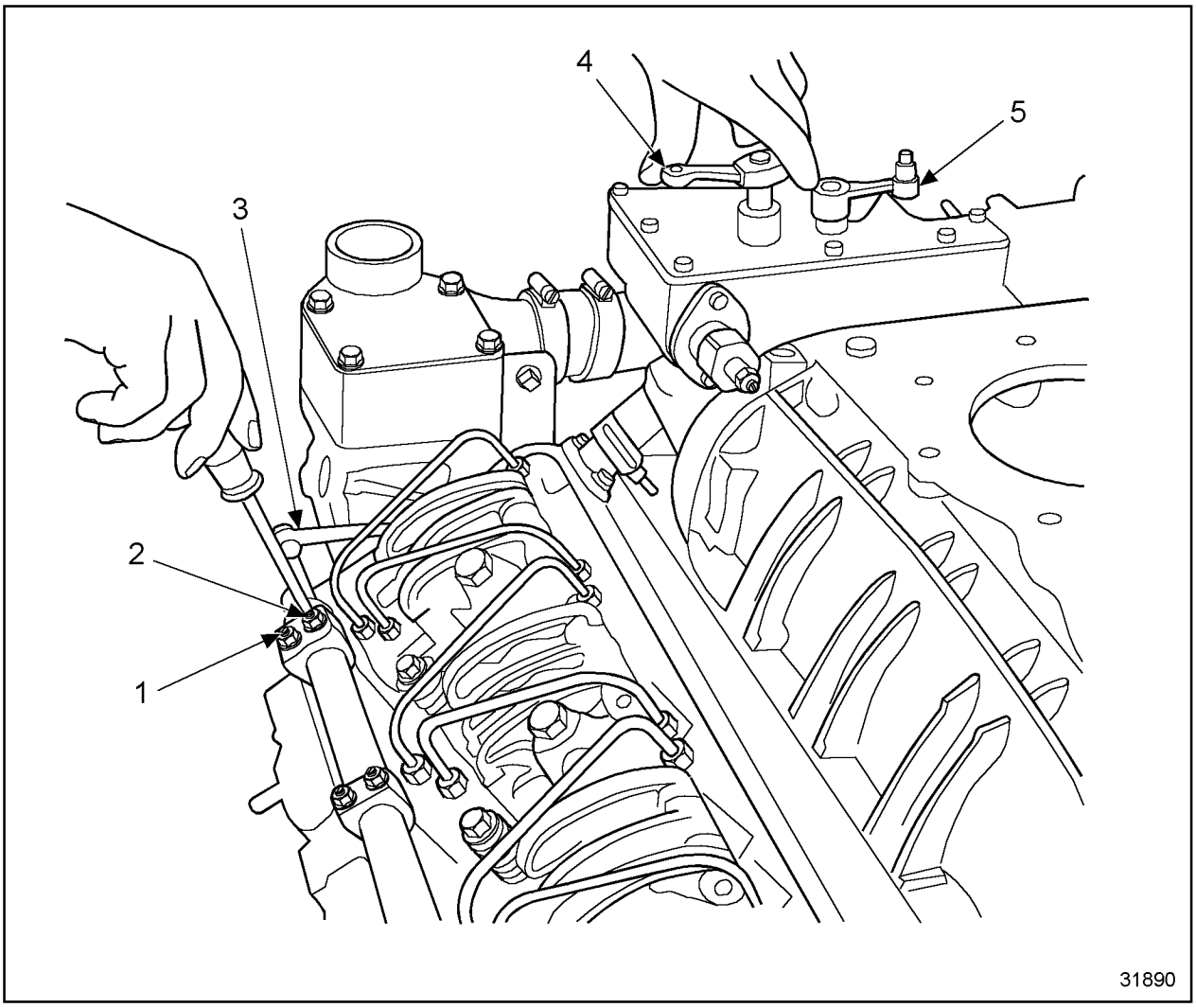
3. If not previously performed, back out the buffer screw approximately 15.88 mm (0.625 in.).
4. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.
5. Loosen all inner and outer injector rack control lever adjusting screws and locknuts.

NOTE:
Ensure all of the injector rack control levers are free on the injector control tubes.

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6. Move the speed control lever to the maximum speed position, and hold it lightly with your finger.
7. Turn the inner adjusting screw of the No. 1L injector rack control lever down until the control tube lever moves slightly or a step up in effort to turn the screw is observed. See Figure 12-43.

NOTE:
This will place the No. 1L injector rack in the full-fuel position.



1. Outer Adjusting Screw
2. Inner Adjusting Screw
3. Fuel Rod
4. Speed Control Lever
5. Stop Lever

Figure 12-43 Injector Rack Control Lever Two Screw Assembly (Position No. 1)

8. Turn down the outer adjusting screw until it bottoms lightly on the injector control tube.

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NOTICE:
Do not overtighten the injector rack control lever adjusting screws during installation or adjustment. This can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in.).

9. Alternately tighten both the inner and outer adjusting screws.
10. Check the rack adjustment. Refer to section 12.4.14.
11. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.
12. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever.
13. To position the No. 1L injector rack control lever, move the speed control lever to the maximum speed position, and hold it in that position lightly with a finger.
14. Insert the clevis pin in the fuel rod and the left bank injector control tube lever.
15. Check the Injector rack control levers. Refer to section 12.4.10.
16. Check for and eliminate any deflection which occurs at the bend in the fuel rod where it enters the cylinder head.

To adjust the remaining injector rack control levers, proceed as follows:

1. Remove the clevis pins from the fuel rods and the injector control tube levers.
2. Hold the injector control racks in the full-fuel position with the lever on the end of the control tube.

NOTICE:
Do not overtighten the injector rack control tube lever adjusting screw during installation or adjustment. This could damage the injector control tube. The recommended torque is 3-4 N·m (24-36 lb·in).

3. Turn down the inner adjusting screw of the injector rack control lever until the screw bottoms (injector control rack in the full-fuel position).
4. Turn down the outer adjusting screw of the injector rack control lever until it bottoms on the injector control tube.
5. While still holding the control tube lever in the full-fuel position, adjust the inner and outer adjusting screws to make the rack tilt downward. The control rack should spring back upward when released.

NOTICE:
Do not overtighten the injector rack control tube lever adjusting screw during installation or adjustment. This could damage the injector control tube. The recommended torque is 3-4 N·m (24-36 lb·in).

6. Tighten the screw.
7. Adjust the remaining injectors using the procedures outlined in step 3 through step 6.

NOTE:
Always verify proper injector rack adjustment.

NOTE:
Once the No. 1L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

8. When all of the injector rack control levers are adjusted, check their settings. Refer to section 12.4.12.

NOTE:
All the control racks must have the same spring condition with the control tube lever in the fuel-fuel position.

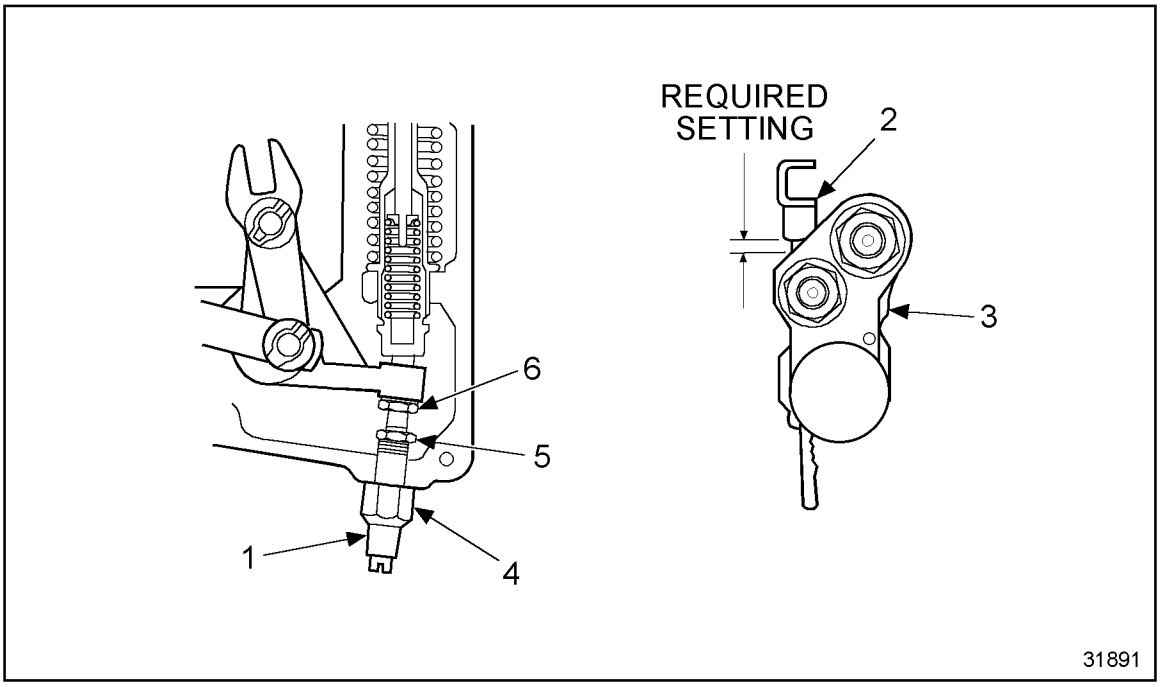
9. Insert the clevis pin in the fuel rod and the injector control tube lever.
10. Turn the idle speed adjusting screw in until it projects 4.7625 mm (0.1875 in.) from the locknut to permit engine starting.

12.4.13 Adjustment of External Starting Aid Screw (Turbocharged Engines)

On current turbocharged engines, adjust the external starting aid screw as follows:

1. With the engine stopped, place the governor stop lever in the run position and the speed control lever in the idle speed position.
2. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body. See Figure 12-44. The required setting specifications are listed in Table 12-10.

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1. Starting Aid Screw
2. Injector Rack Clevis
3. Injector Body
4. Locknut
5. Gap Adjusting Screw
6. Locknut

Figure 12-44 Starting Aid Screw Adjustment

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Injector	Gage Setting	Tool Number	Injector	Gage Setting	Tool Number
9200	11.532 mm) (0.454 in.	J 23190	9E80	9.778 mm (0.385 in.)	J 24882
9215	11.532 mm (0.454 in.)	J 23190	9E85	9.778 mm (0.385 in.)	J 24882
9225	11.532 mm (0.454 in.)	J 23190	9F70	11.532 mm (0.454 in.)	J 23190
9280	9.778 mm (0.385 in.)	J 24882	9F80	11.532 mm (0.454 in.)	J 23190
9285	9.778 mm (0.385 in.)	J 24882	9F85	11.532 mm (0.454 in.)	J 23190
9290	11.532 mm (0.454 in.)	J 23190	9F90	11.532 mm (0.454 in.)	J 23190
9295	11.532 mm (0.454 in.)	J 23190	7G65	9.778 mm (0.385 in.)	J 24882
9A80	9.778 mm (0.385 in.	J 24882	7G70	9.778 mm (0.385 in.)	J 24882
9A85	9.778 mm) (0.385 in.)	J 24882	7G75	9.778 mm (0.385 in.)	J 24882
9A90	11.532 mm (0.454 in.)	J 23190	9G75	11.532 mm (0.454 in.)	J 23190
9B70	9.778 mm (0.385 in.)	J 24882	9G85	11.532 mm (0.454 in.)	J 23190
9B75	9.778 mm (0.385 in.)	J 24882	9G90	11.532 mm (0.454 in.)	J 23190
9B80	9.778 mm (0.385 in.)	J 24882	9H85	10.26 mm (0.404 in.)	J 9509-C
9B85	9.778 mm (0.385 in.)	J 24882	9J85	11.532 mm (0.454 in.)	J 23190
9B90	11.532 mm (0.454 in.)	J 23190	9K85	10.26 mm (0.404 in.)	J 9509-C
9C70	9.778 mm (.385 in.)	J 24882	9S65	11.532 mm (0.454 in.)	J 23190
9C75	9.778 mm (0.385 in.)	J 24882	9S70	11.532 mm (0.454 in.)	J 23190
9C80	9.778 mm (0.385 in.)	J 24882	9S75	11.532 mm (0.454 in.)	J 23190
9C90	11.532 mm (0.454 in.)	J 23190	9S80	11.532 mm (0.454 in.)	J 23190
9E65	9.778 mm (0.385 in.)	J 24882	9T70	11.532 mm (0.454 in.)	J 23190
9E70	9.778 mm (0.385 in.)	J 24882	—	—	—

Table 12-10 Starting Aid Screw Adjustment Specifications

3. Select the proper gage, and measure the setting at No. 2R cylinder.

NOTE:
When the starting aid screw is properly adjusted, the gage should have a small clearance of 0.3969 mm (0.0156 in.) in the space along the injector rack shaft between the rack clevis and the injector body.

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4. After completing the adjustment, hold the starting aid screw, and tighten the locknut.
5. Place the stop lever in the run position.
6. Move the speed control lever from the idle speed position to the maximum speed position.

> **⚠ CAUTION:**
>
> **To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.**

7. Return the speed control lever to the idle speed position.

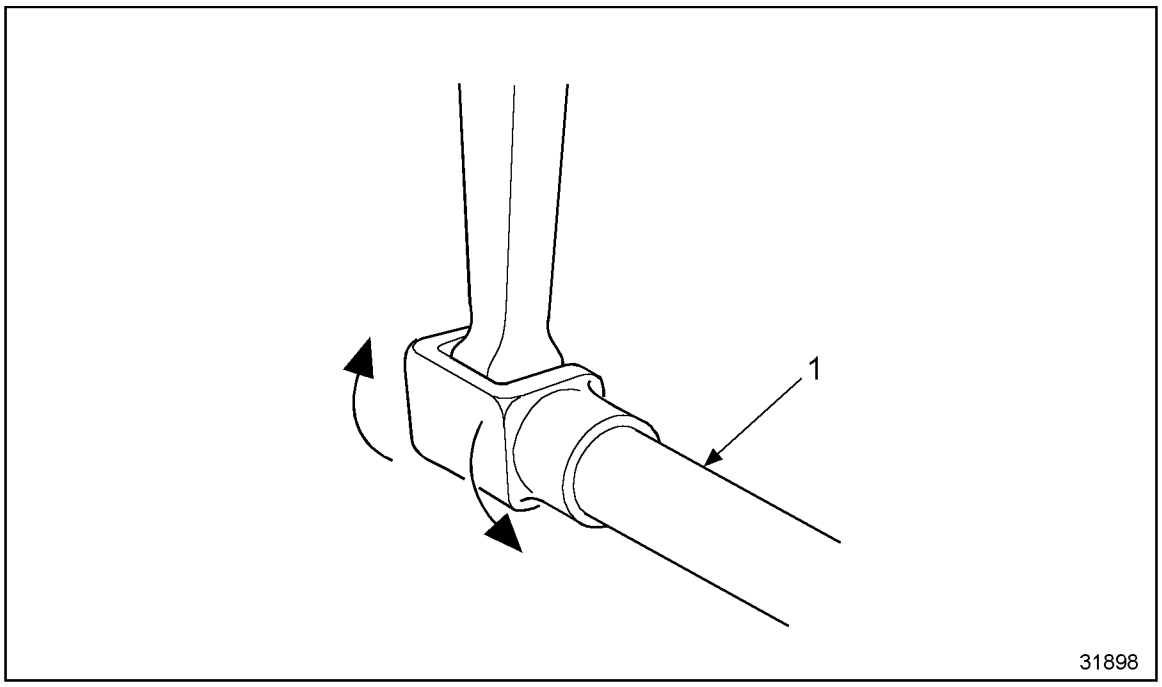
NOTE:
Governor speed control lever movement takes up the clearance in the governor linkage. The injector rack clevis-to-body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out. The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start-up.

12.4.14 Check Rack Adjustment (Two Screw Assembly)

Check the rack adjustment as follows:

1. Hold the speed control lever in the maximum speed position, and press the injector rack down with a screwdriver or finger tip.

2. Observe the injector control rack "rotation". See Figure 12-45.



1. Injector Control Rack

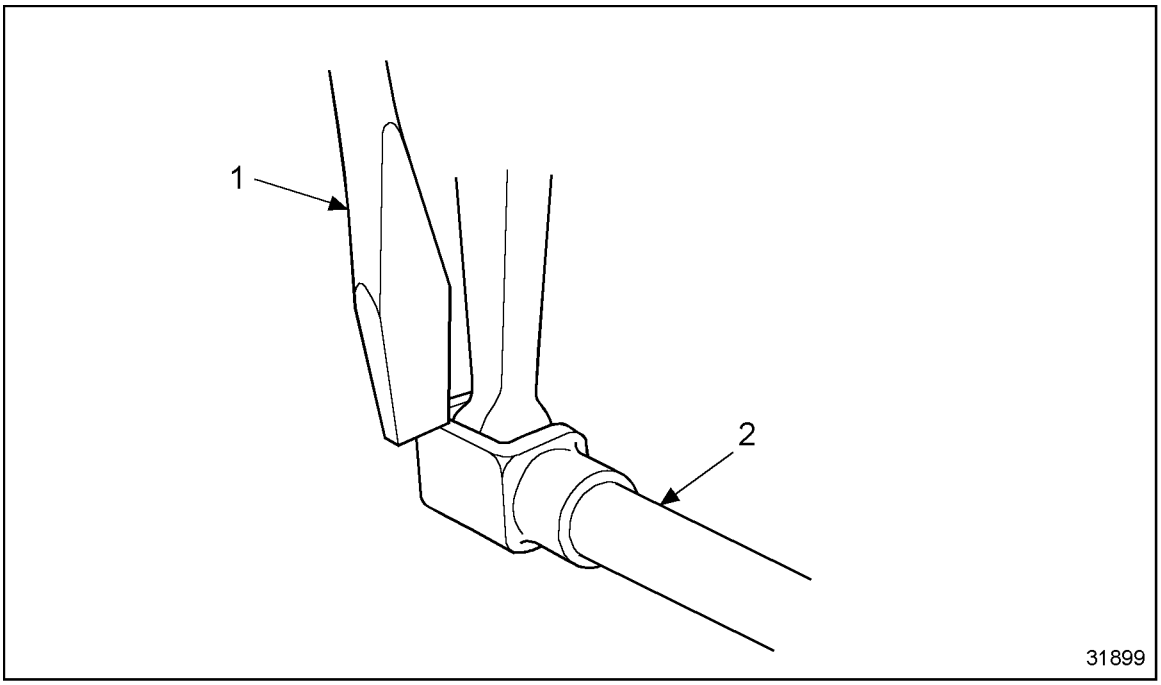
Figure 12-45 Checking Rotating Movement of Injector Control Rack

3. Hold the speed control lever in the maximum speed position.

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4. Using a screwdriver, press the injector control rack down. See Figure 12-46.

NOTE:
The rack should tilt downward, and when the screwdriver is removed, the control rack should "spring" upward.



1. Screwdriver
2. Injector Control Rack

Figure 12-46 Checking Injector Control Rack "Spring"

If the rack does not return to its original position, it is too loose. Correct the one screw and locknut assembly as follows:

1. Slightly back off the outer adjusting screw.
2. Slightly tighten the inner adjusting screw.

The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel. Correct the one screw and locknut assembly as follows:

1. Slightly back off the inner adjusting screw.
2. Slightly tighten the outer adjusting screw.

12.4.15 Position Injector Rack Control Levers ("TT" Engines)

Position the injector rack as follows:

NOTE:
The letters "R" and "L" indicate the injector location in the right or left cylinder bank viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank.

1. Disconnect any linkage attached to the governor speed control lever.
2. Turn the idle speed adjusting screw until no tension in the idle spring exists.

NOTE:
A false fuel rack setting may result if the idle speed adjusting screw is not backed out.

3. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.
4. Loosen all inner and outer injector rack control lever adjusting screws and locknuts.

NOTE:
Ensure all of the injector rack control levers are free on the injector control tubes.

5. Move the speed control lever to the maximum speed position, and hold it lightly with your finger.

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6. Turn the inner adjusting screw of the No. 1L injector rack control lever down until the injector rack clevis is bottomed against the injector body.

NOTE:
The injector rack should be easily rotated but not moved in and out. See Figure 12-47.

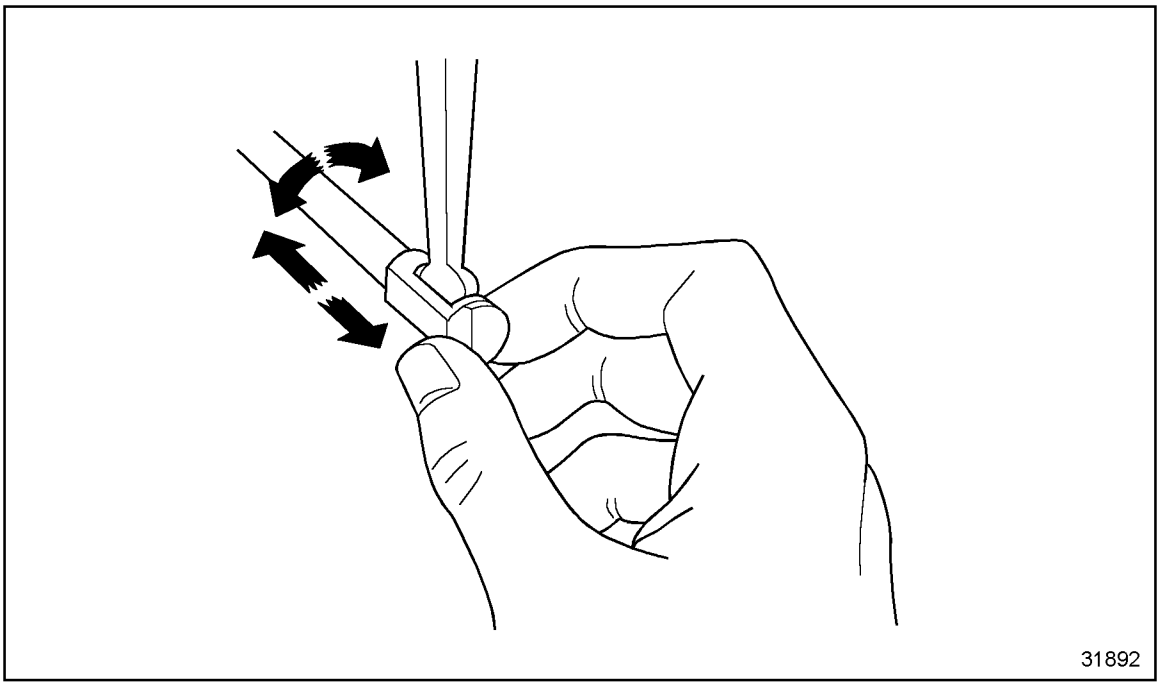


Figure 12-47 Checking Rotating Movement of Injector Control Rack

NOTE:
This will place the No. 1L injector rack in the full-fuel position. The governor linkage and control tube assembly should be in the same position they will attain while the engine is operating at full load.

7. Using a screwdriver or finger, hold the speed control lever in the maximum speed position.
8. Observe whether injector rack clevis moves freely but not inboard or outboard.

NOTE:
If the rack lever moves inboard or outboard, it is loose. The injector rack is too tight if the rack clevis springs back after being depressed with a screwdriver.

9. If not moving correctly, adjust and verify.
10. Remove the clevis pin from the fuel rod at the left bank injector control tube lever.
11. Insert the clevis pin in the fuel rod at the right cylinder bank injector control tube lever, and position the No. 1L injector rack control lever.
12. Move the speed control lever to the maximum speed position, and hold it lightly with your finger.

13. Turn the inner adjusting screw of the No. 1L injector rack control lever down until the injector rack clevis is bottomed against the injector body.

NOTE:
The injector rack should be easily rotated but not moved in and out. See Figure 12-48.

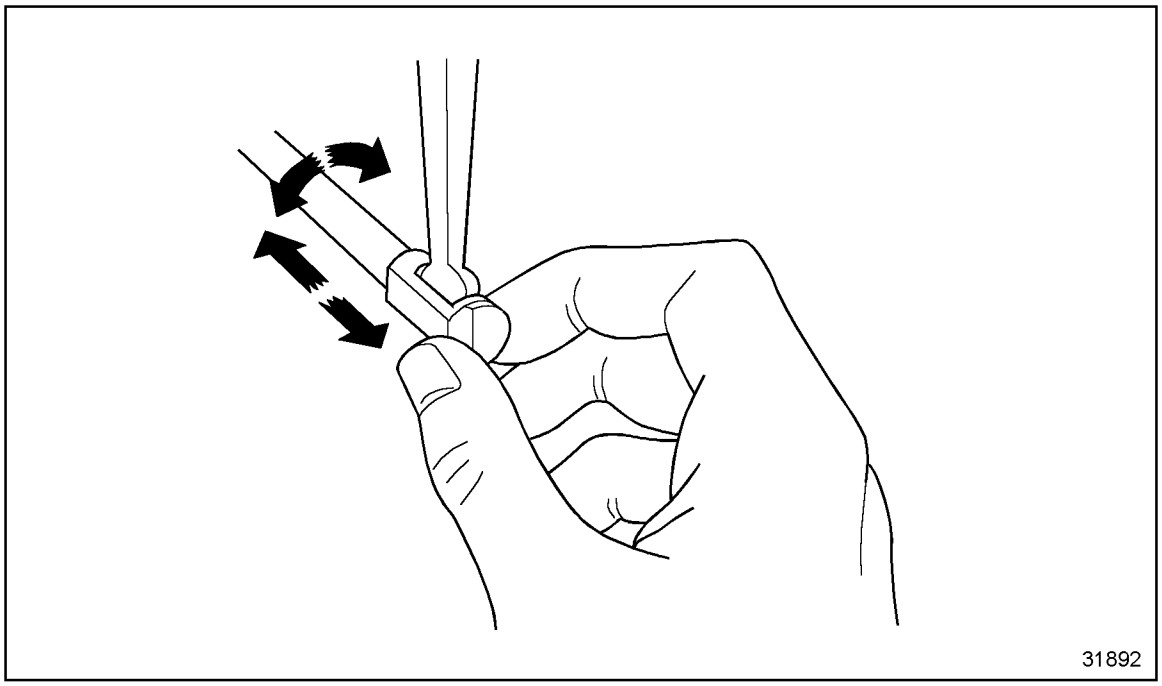


Figure 12-48 Checking Rotating Movement of Injector Control Rack

NOTE:
This will place the No. 1L injector rack in the full-fuel position. The governor linkage and control tube assembly should be in the same position they will attain while the engine is operating at full load.

14. Using a screwdriver or finger, hold the speed control lever in the maximum speed position.
15. Observe whether the injector rack clevis moves freely but not inboard or outboard.

NOTE:
If the rack lever moves inboard or outboard, it is loose. The injector rack is too tight if the rack clevis springs back after being depressed with a screwdriver.

16. Insert the clevis pin in the fuel rod at the left bank injector control tube lever.
17. Verify that the adjustment for chart of the No. 1L and No. 1R injector racks are equal.
18. Move the speed control lever to the maximum speed position.

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19. Rotate the clevis pins at the injector control tube levers, and observe a slight drag or resistance.

NOTE:
The pin should move freely back and forth by finger with no fuel rod deflection. This slight drag should be equal for both pins.

20. If the drag is not equal, turn either the No. 1R or No. 1L rack adjusting screw until both 1L and 1R pins Are the same.
21. Move the speed control lever back to the idle position and back to the full-fuel position.
22. Observe whether the fuel rods do not deflect.

NOTE:
If they do deflect, the rack adjustment for either bank is too tight and must be readjusted.

NOTE:
Once the No. 1L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

Adjust the remaining injector rack control levers as follows:

1. Remove the clevis pins from the fuel rod at the injector control tube levers.
2. Hold the left bank injector control racks in the full-fuel position with the lever on the end of the control tube.
3. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
4. Securely lock the adjusting screw locknut.
5. Verify the injector rack adjustment on No. 1L.
6. If No. 1L does not spring back upward, slightly turn the No. 2L adjusting screw counterclockwise until the No. 1L injector rack returns to its full-fuel position.
7. Secure the adjusting screw locknut.
8. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors.
9. Turn the No. 2L injector rack adjusting screw clockwise or counterclockwise until both No. 1L and No. 2L injector racks are in the full-fuel position when the locknut is securely tightened.
10. Adjust the remaining injectors. Refer to step 5 through step 9.
11. When all the injector rack control levers are adjusted, recheck their settings.
12. With the control tube level in the full-fuel position, check each injector control rack. Refer to step 1 through step 9.

NOTE:
All injector control racks must have the same spring condition with the control tube levers in the full-fuel position.

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13. Insert the clevis pin in the fuel rods at the injector control tube lever, and secure with a cotter pin.
14. Recheck the rack settings. Refer to step 12 through step 13.
15. Turn the idle speed adjusting screw in until it projects 4.7625 mm (0.1875 in.) from the locknut to permit engine starting.

CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

16. Use new gaskets, and install the valve rocker covers.

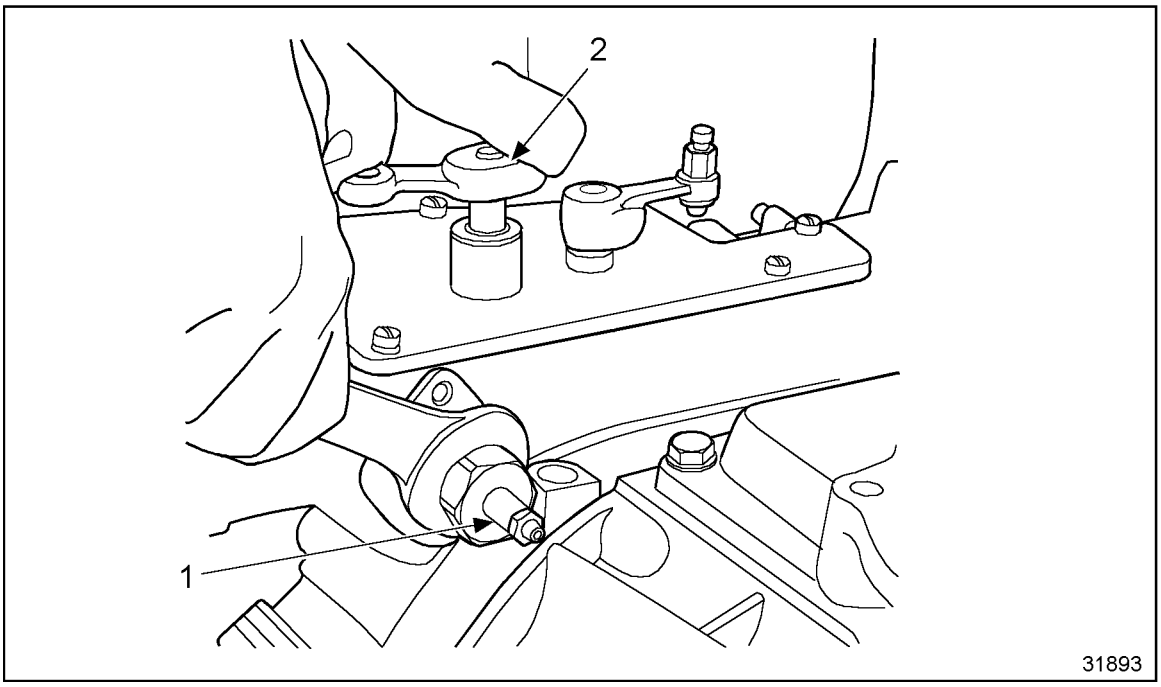
12.4.16 Adjust Maximum No-Load Engine Speed (Standard Governor)

After positioning the injector rack control levers, set the maximum no-load engine speed as follows:

NOTE:
Ensure buffer screw projects 15.88 mm (0.625 in.) from the locknut to prevent interference while adjusting the maximum no-load speed.

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1. Loosen the spring retainer locknut, and back off the high-speed spring retainer approximately five turns. See Figure 12-49.



1 High Speed Spring Retainer 2. Speed Control Lever

Figure 12-49 Adjusting Maximum No-Load Speed

2. With the engine running at operating temperature and no load on the engine, place the speed control lever in the maximum speed position.
3. Turn the high-speed spring retainer until the engine is operating at the recommended no-load speed.
4. Hold the high-speed spring retainer and tighten the locknut using spanner wrench J 5345-E.

12.4.17 Adjust Maximum No-Load Engine Speed (Dual Range Governor)

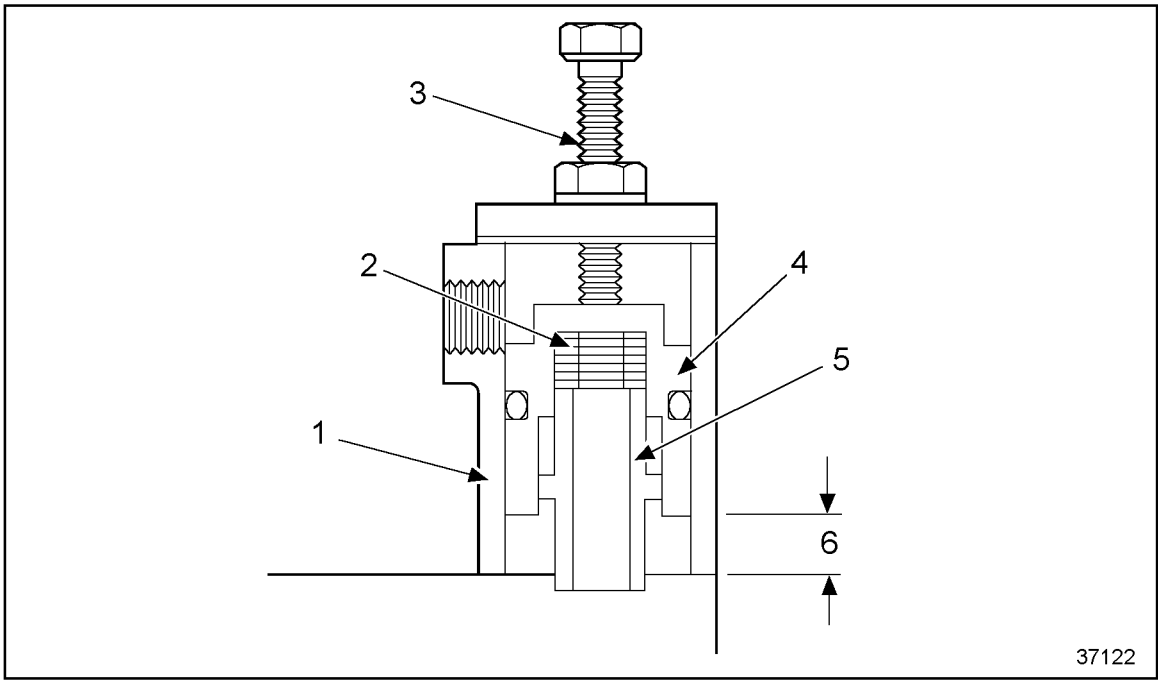
After positioning the injector control levers, set the maximum engine speeds as follows:

NOTE:
Ensure buffer screw or fast idle air cylinder projects 15.88 mm (0.625 in.) from the locknut to prevent interference while adjusting the maximum no-load speeds.

NOTE:
Before proceeding, ensure spring housing assembly is mounted on the governor, the piston and sleeve assembled with four 0.100 in. shims and ten 0.010 in. shims, and the low maximum speed screw extends from the spring housing 31.75 mm (1.25 in.).

1. Start and warm-up the engine.

2. Position the speed control lever in the maximum speed position.
3. Turn the low maximum speed adjustment screw in until obtaining the high maximum speed desired.
4. Stop the engine, and remove the spring housing assembly.
5. Observe the distance the piston is from the bottom of the spring housing when it is against the low maximum speed screw. See Figure 12-50("X" distance).



1. Spring Housing
2. Shims
3. Maximum Low Speed Adjusting Screw
4. Piston
5. Sleeve
6. "X" Distance

Figure 12-50

6. Remove the sleeve from the piston.

NOTE:
When checking this distance, the piston should be held tight against the cover adjustment screw.

NOTICE:
To avoid seal ring damage, do not permit the seal ring on the piston to slide past the air inlet port.

7. Remove some shims from within the piston equal to the "X" distance.
8. Start the engine, and position the speed control lever in the maximum speed position.

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9. Apply air or oil pressure to the governor, and observe engine speed.
10. Remove the air or oil pressure form the governor, and stop the engine.
11. Install or remove shims as required to obtain the correct high maximum no-load speed.

NOTE:
Removing shims will decrease the engine speed and adding shims will increase the engine speed. Each 0.010 in. shim removed or added will decrease or in crease the engine speed approximately 10 RPM.

Set the low maximum no-load engine speed as follows:

1. Adjust the low maximum speed adjusting screw, with the speed control lever held in the maximum speed position, until the desired low maximum speed is obtained.

NOTE:
Turn the screw in to increase or out to decrease the engine speed.

2. Check the engine speed, and adjust if necessary.
3. Check both the high maximum and low maximum engine speeds.
4. Make any necessary adjustments.

12.4.18 Adjust Idle Speed

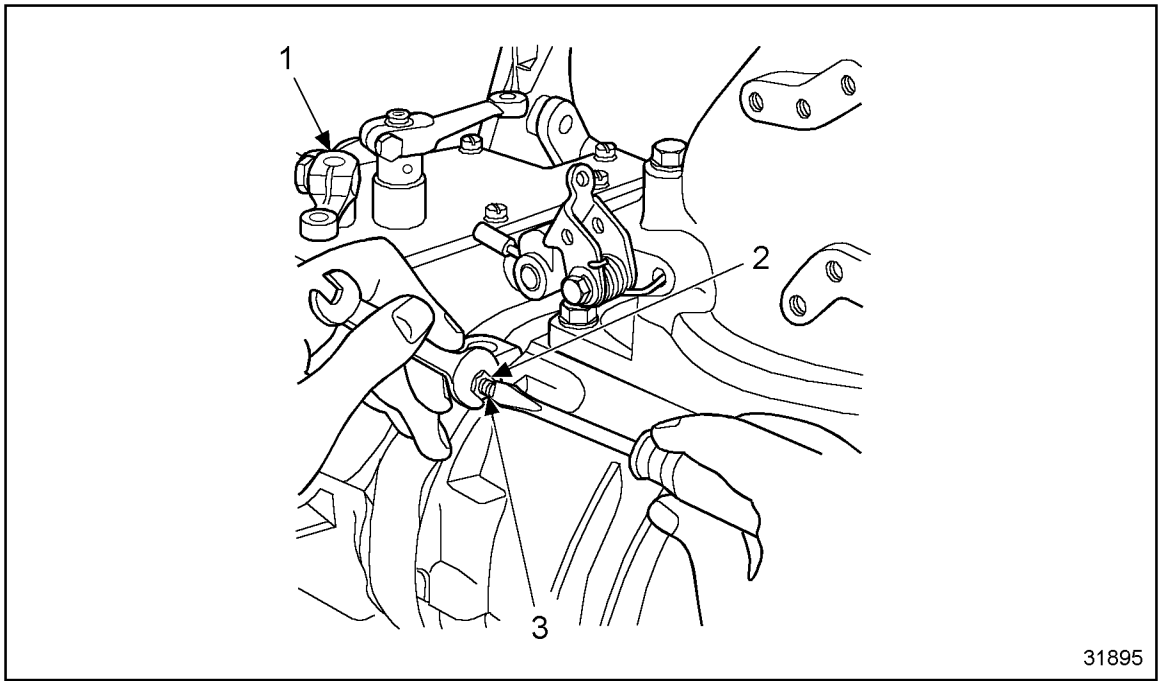
With the maximum no-load speed properly set, adjust the idle speed as follows:

1. With the engine running at normal operating temperature and the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw until

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the engine operates at approximately 15 RPM below the recommended idle speed. See Figure 12-51.

NOTE:
It may be necessary to use the buffer screw to eliminate engine roll. After the idle speed is established, back out the buffer screw to the previous setting (15.875 mm or 0.625 in.).



1. Speed Control Lever
2. Idle Speed Adjusting Screw Locknut
3. Idle Speed Adjusting Screw

Figure 12-51 Adjusting Engine Idle Speed

2. Hold the idle screw, and tighten the locknut.
3. Install the high-speed spring retainer cover, and tighten the two bolts.
4. For "TT" engines, refer to section 12.9 for chart of the Belleville spring adjustment.

12.4.19 Adjust Buffer Screw

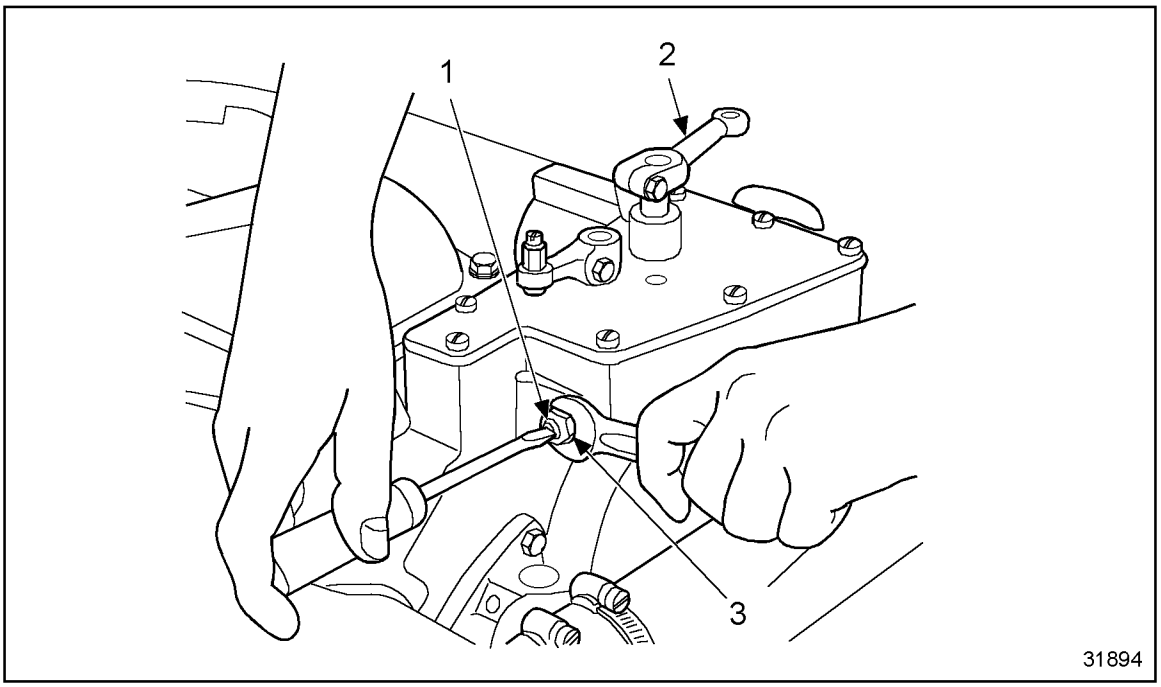
With the idle speed properly set, adjust the buffer screw as follows:

NOTE:
If the engine is running satisfactorily and has no roll, do not set the buffer screw.

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1. With the engine running at normal operating temperature, turn the buffer screw in so it contacts the differential lever as lightly as possible and still eliminate engine roll. See Figure 12-52.

NOTE:
Do not increase the engine idle speed more than 15 RPM with the buffer screw.



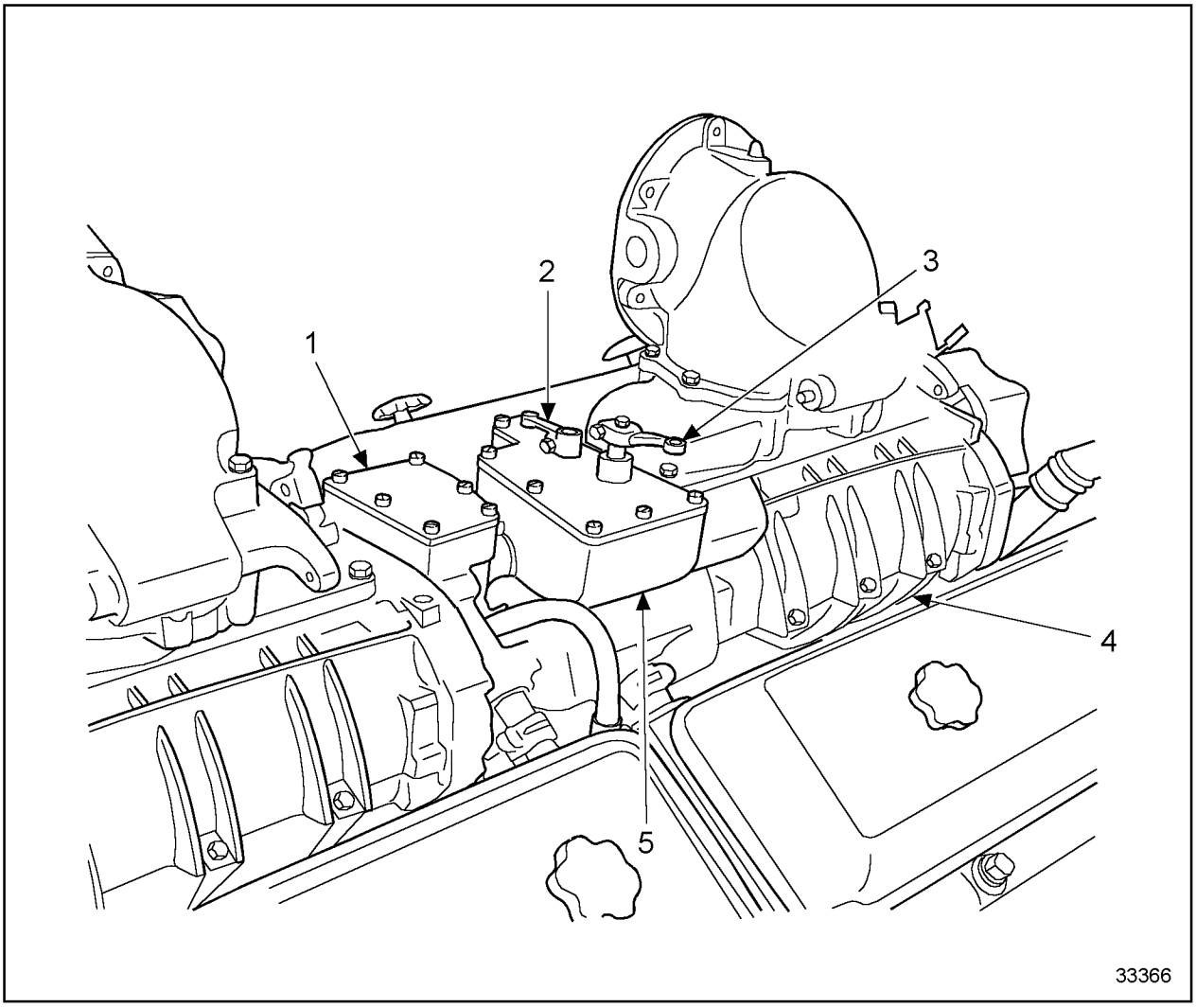
1. Screw
2. Speed Control Lever
3. Locknut

Figure 12-52 Adjusting Buffer Screw

2. Recheck the maximum no-load speed.
3. If the maximum no-load speed has increased more than 25 RPM, back off the buffer screw until the increase is less than 25 RPM.
4. Hold the buffer screw, and tighten the locknut.
5. Shutdown the engine.

12.5 LIMITING SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (12V AND 16V ENGINES)

The governor on the 12V and 16V engine is mounted on and driven from the front end of the rear blower. See Figure 12-53.



1. Auxiliary Control Link Housing
2. Stop Lever
3. Speed Control Lever
4. Rear Blower
5. Governor

Figure 12-53 Governor Assembly Mounting

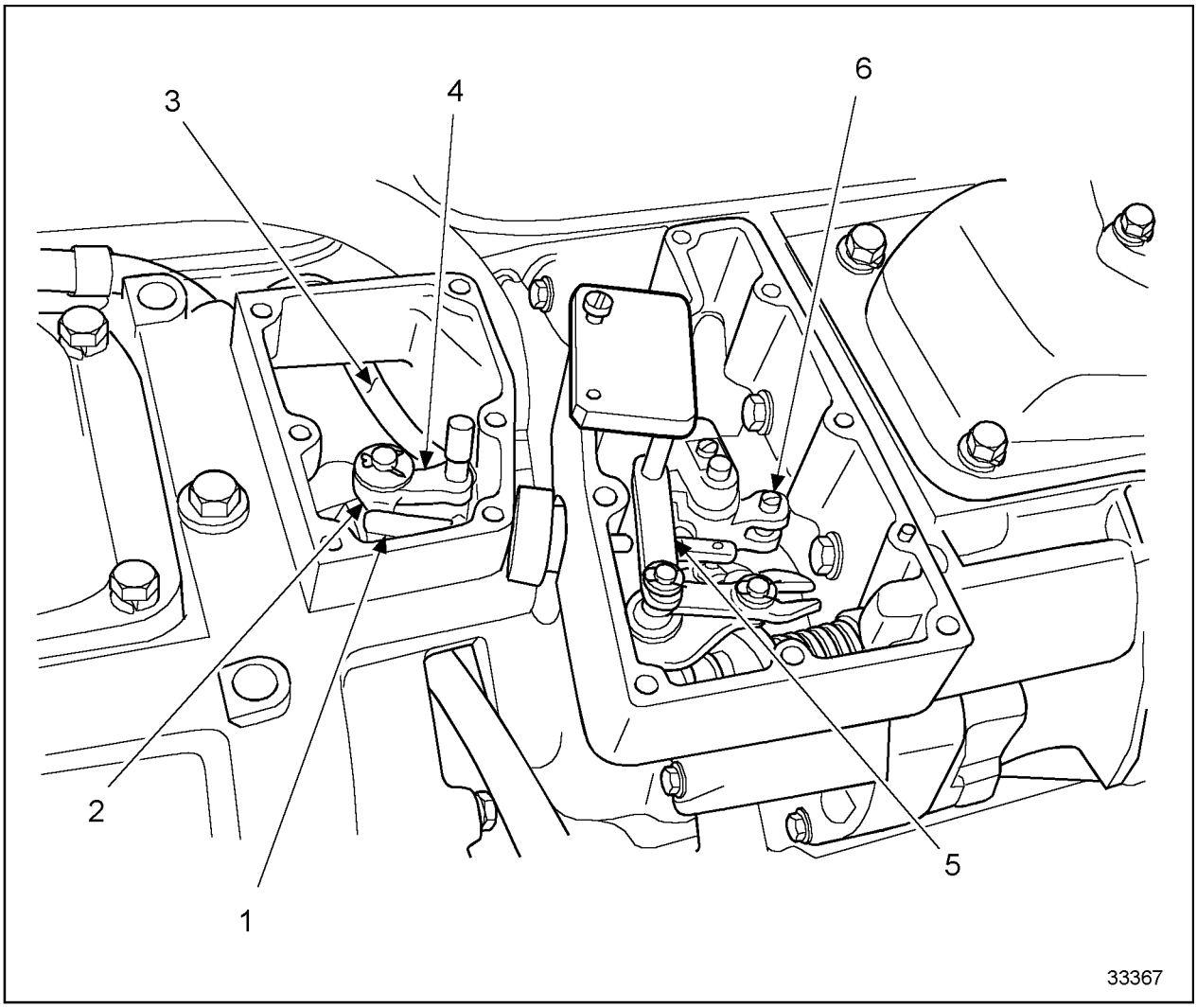
NOTE:
Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device. Refer to section 12.15.

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Back out the external starting aid screw. After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and position the injector rack control levers.

12.5.1 Position Control Link Levers

If the engine or governor has been overhauled, or the injector control linkage has been disturbed, the control link levers in the governor housing and auxiliary control link housing must be aligned before proceeding with the engine tune-up. See Figure 12-54, and position the control link levers, as follows:



1. Auxiliary Control Link Housing
2. Control Link Lever
3. Fuel Rod
4. Adjustable Link
5. Connecting Link
6. Governor Operating Lever Control Link

Figure 12-54 Positioning Control Link Levers with Tools J 21779 and J 21780

1. Disconnect the linkage to the governor speed control lever and stop levers.

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2. Remove the covers from the governor housing and auxiliary control link housing.
3. Disconnect the adjustable link from the lever in the auxiliary control link housing.
4. Remove the connecting pin from the auxiliary governor control link lever.
5. Install gage J 21779 so it extends through the lever and fuel rod and into the gage hole in the bottom of the housing.

NOTE:
With the gage in place, the auxiliary control link lever will be in the mid-travel position.

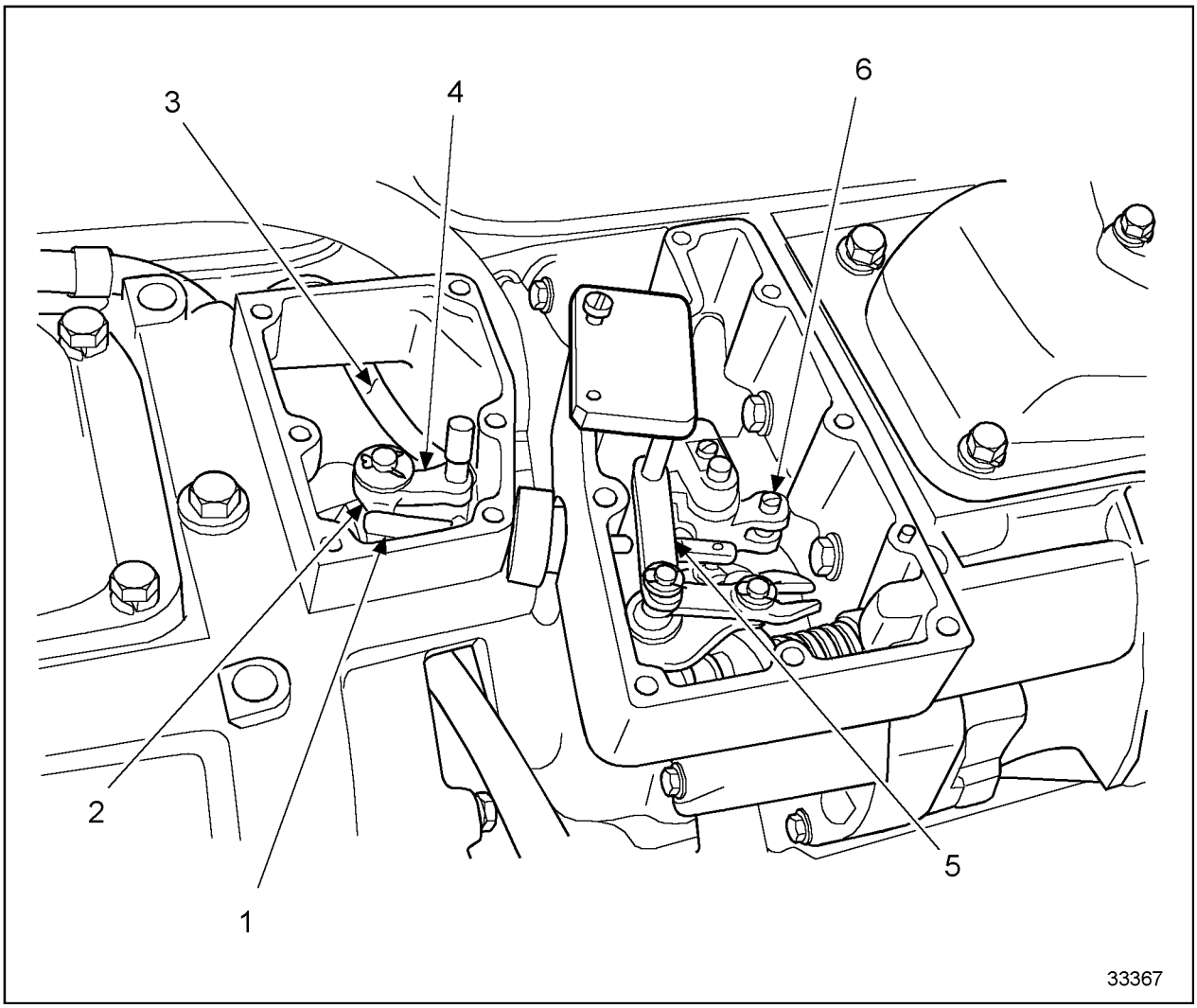
6. Remove the connecting pin from the control link lever in the governor housing and install gage J 21780.

NOTE:
Install the gage so the pin extends through the connecting link, control lever and fuel rod and the governor housing dowel pin extends into the small hole in the gage.

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7. Install a governor cover bolt. See Figure 12-55.

NOTE:
With gage J 21780 in place, the governor control link lever will be in the mid-travel position and parallel to the auxiliary control link lever.



1. Auxiliary Control Link Housing
2. Control Link Lever
3. Fuel Rod
4. Adjustable Link
5. Connecting Link
6. Governor Operating Lever Control Link

Figure 12-55 Positioning Control Link Levers with Tools J 21779 and J 21780

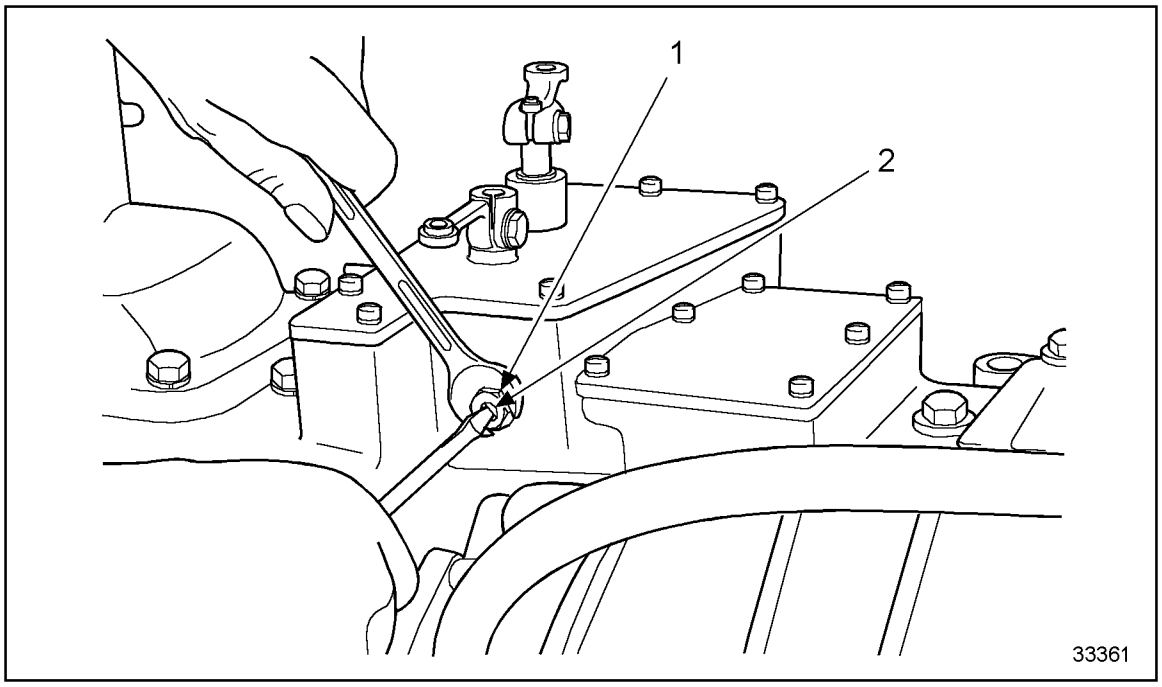
8. Adjust the length of the adjustable connecting link to retain the lever positions, and install the link.
9. Remove gages J 21779 and J 21780, and reinstall the control link lever connecting pins.
10. Install the governor housing and auxiliary control link housing covers.

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12.5.2 Adjust the Governor Gap

With the engine stopped and at operating temperature, set the governor gap as follows:

1. Remove the governor high speed spring retainer cover.
2. Back out the buffer screw until it extends 15.88 mm (0.625 in.) from the locknut. See Figure 12-56.



1. Locknut
2. Buffer Screw

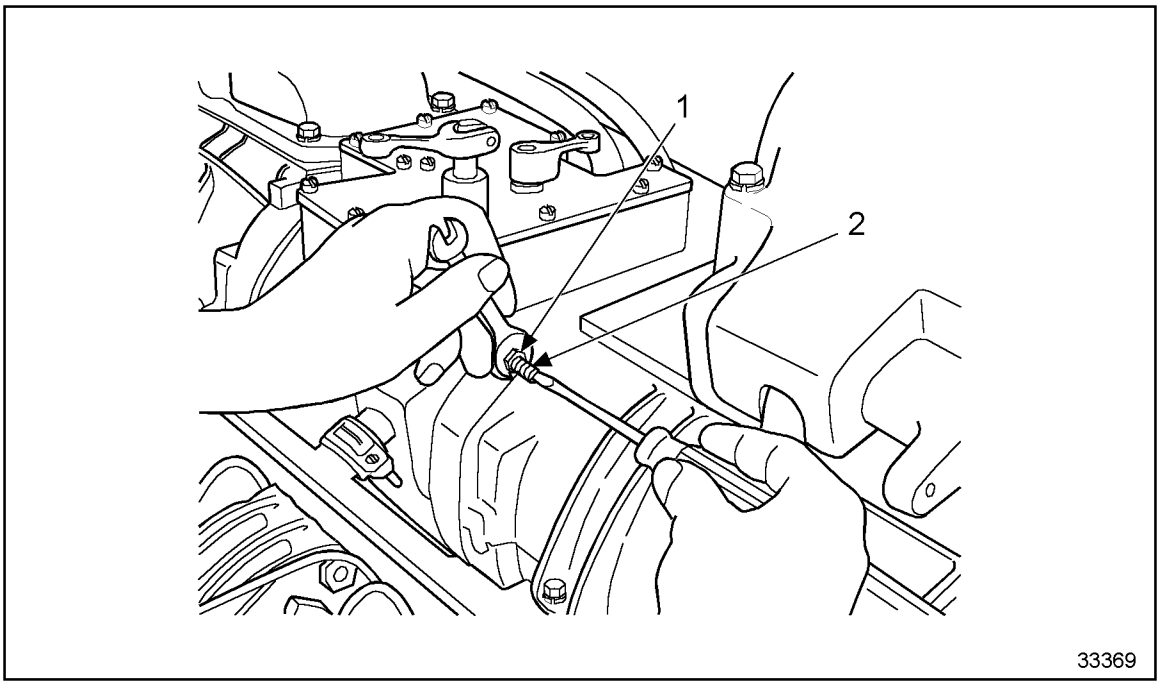
Figure 12-56 Adjusting Buffer Screw

3. Start the engine, and loosen the idle speed adjusting screw locknut.

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4. Adjust the idle screw to obtain the desired idle speed. See Figure 12-57.

NOTE:
The recommended idle speed is 400-450 RPM, but may vary with special engine applications.



1. Locknut
2. Idle Speed Adjusting Screw

Figure 12-57 Adjusting Engine Idle Speed

5. Hold the screw, and tighten the locknut to hold the adjustment.

NOTE:
Governors used in turbocharged engines include a starting aid screw threaded into the governor housing (current engines) or the governor gap adjusting screw (early engines). A locknut is not required on early engines. Both the gap adjusting screw and the starting aid screw incorporate a nylon patch in lieu of locknuts.

6. Stop the engine.
7. Clean and remove the governor cover and lever assembly and the valve rocker covers. Discard the gaskets.

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⚠ CAUTION:

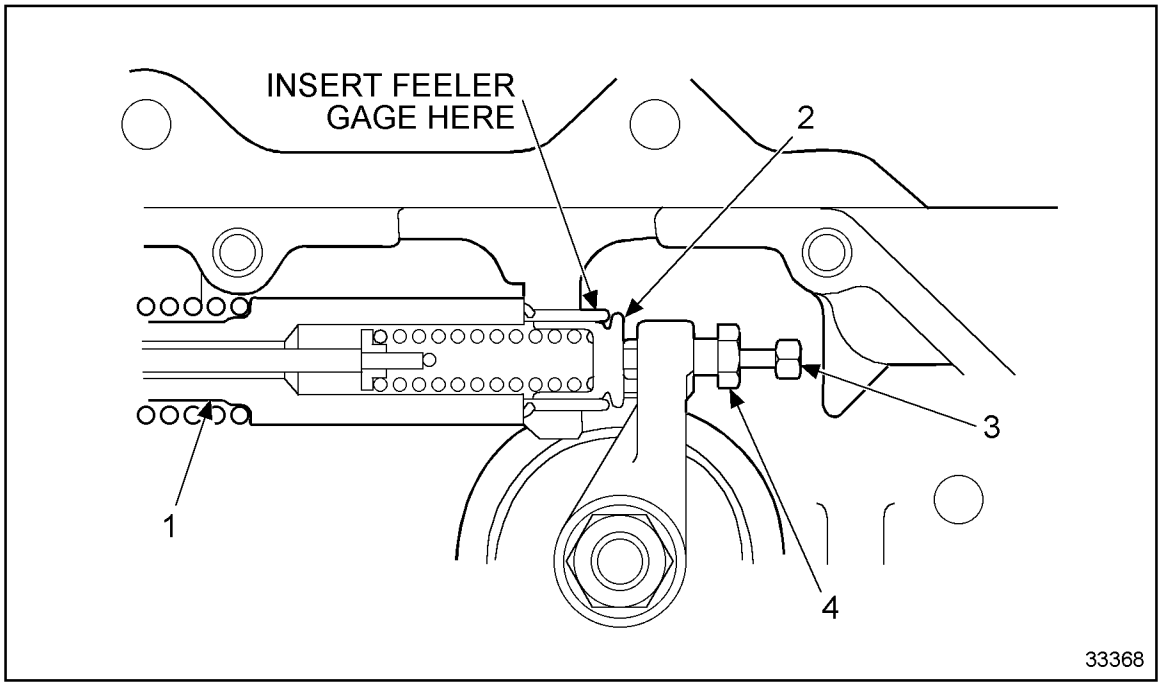
To avoid injury from rotating belts and fans, do not remove and discard safety guards.

NOTICE:

To avoid engine damage, do not overspeed the engine.

8. Start and run the engine between 1100 and 1300 RPM by manual operation of the differential lever.
9. Check the gap between the low speed spring cap and the high speed spring plunger with a feeler gage. See Figure 12-58.

NOTE:
The gap should be 0.002–0.004 in. If the gap setting is incorrect, reset the gap adjusting screw.



1. High Speed Spring Plunger
2. Low Speed Spring Cap
3. Internal Starting Aid Screw
4. Gap Adjusting Screw

Figure 12-58 Governor Gap Adjustment

10. On governors without the internal starting aid screw, hold the gap adjusting screw, and tighten the locknut.

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11. Recheck the governor gap with the engine operating between 1100 and 1300 RPM, and readjust, if necessary.

NOTE:
Do not install the governor cover and lever assembly on early engines that include the internal starting aid screw.

12. Stop the engine, and using a new gasket, install the governor cover and lever assembly.

12.5.3 Position Injector Rack Control Levers (Two Screw Assembly)

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

NOTE:
To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that will be used with the governor.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Governor low speed gap closed.
3. High speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the full-fuel position.

The letters "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 4R (16V) or the No. 3R (12V) injector rack control lever first to establish a guide for adjusting the remaining right bank injector rack control levers.

Injector racks must be adjusted so the effort to move the throttle from the idle speed position to the maximum speed position is uniform. A sudden increase in effort can result from:

1. Injector racks adjusted too tightly, causing the yield link to separate.
2. Binding of the fuel rods.
3. Failure to back out the idle screw.

NOTE:
A false full-fuel rack setting may result if the idle speed adjusting screw is not backed out.

Position the rack as follows:

1. Adjust the idle speed adjusting screw until 12.7 mm (0.5 in.) of the threads (12-14 threads) project from the locknut when the nut is against the high-speed plunger.
2. Back out the buffer screw 15.88 mm (0.625 in.), if this has not already been done.

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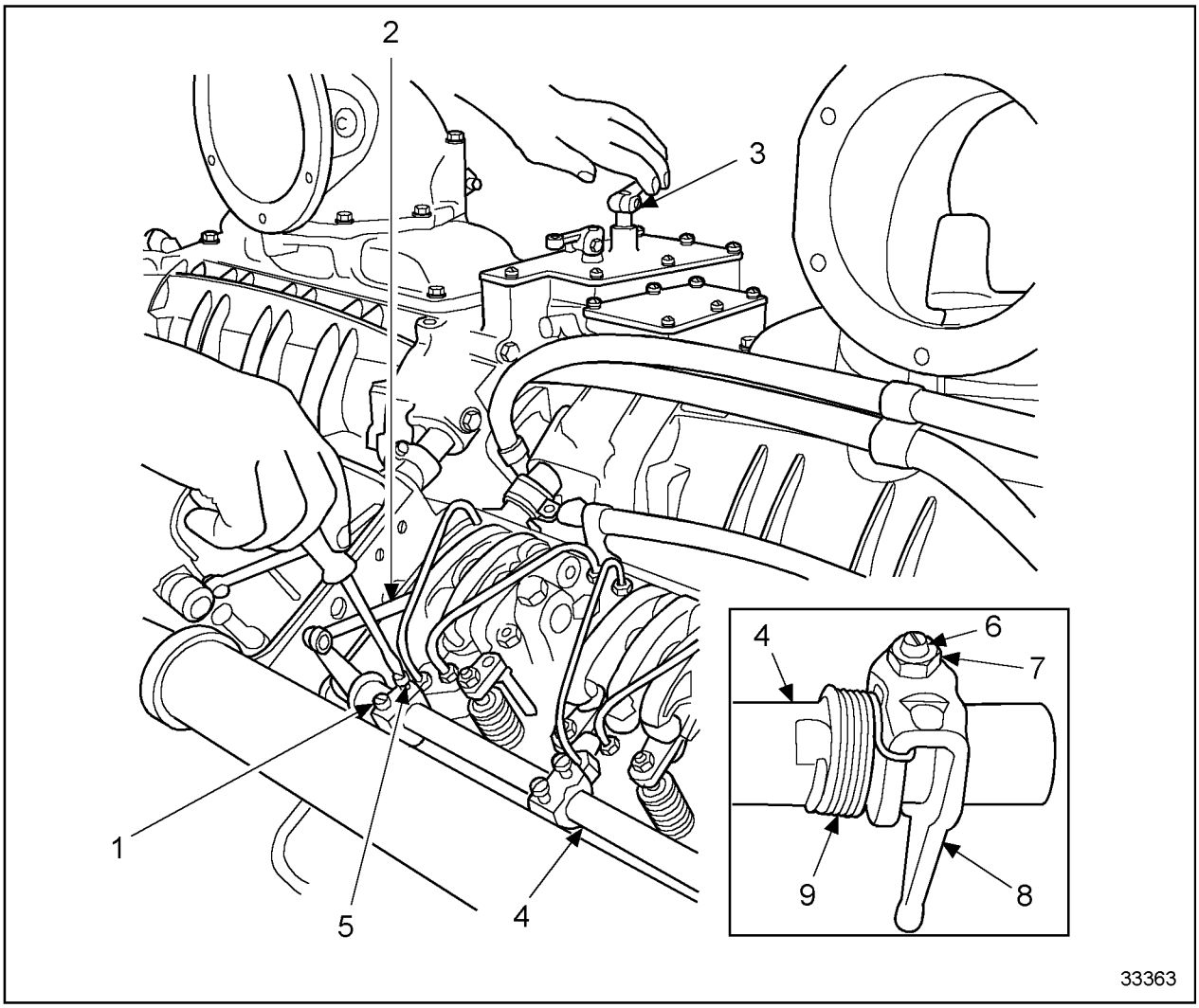
3. Loosen all inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts on both cylinder banks.

NOTE:
Ensure all levers are free on the injector control tubes.

4. Move the linkage through its full range of travel to check for binding in the governor to control tube linkage.
5. Remove the clevis pins that attach the right rear bank and both left bank fuel rods to the injector control tube levers.
6. Move the speed control lever to the maximum speed position.

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7. Hold the speed control lever lightly with your finger. See Figure 12-59.



1. Outer Adjusting Screw
2. Fuel Rod
3. Speed Control Lever
4. Injector Control Tube
5. Inner Adjusting Screw
6. Adjusting Screw
7. Locknut
8. Injector Rack Control Lever
9. Spring

Figure 12-59 Injector Rack Control Lever, Positioning No. 4R (16V) or No. 3R (12V)

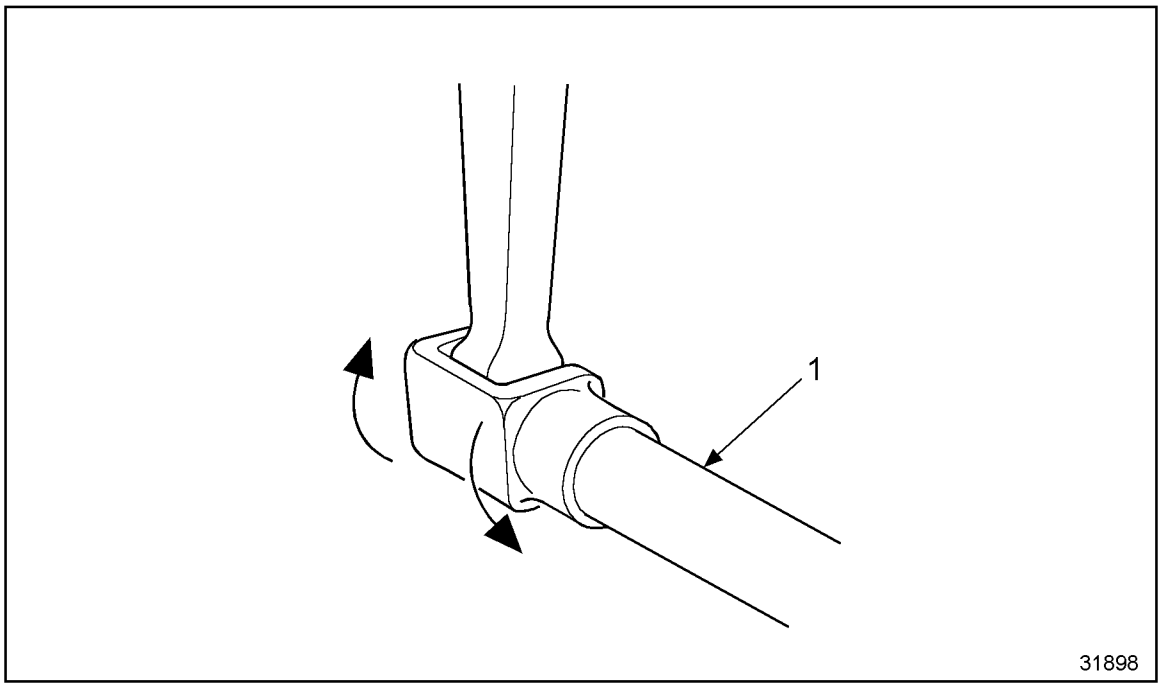
8. Adjust the No. 4R (16V) or No. 3R (12V) injector rack by turning the inner adjusting screw down until the control tube moves slightly or a step-up in effort to turn the screwdriver is noted.

NOTE:
This will place the rack in the full-fuel position.

9. Turn the outer adjusting screw until it bottoms lightly on the control tube.
10. Alternately tighten both the inner and outer adjusting screws.

NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in).

11. To be sure of the proper rack adjustment, hold the speed control lever in the maximum speed position, and press down on the injector rack with a screwdriver or finger tip.
12. Observe the "rotating" movement of the injector control rack. See Figure 12-60.



1. Injector Control Rack

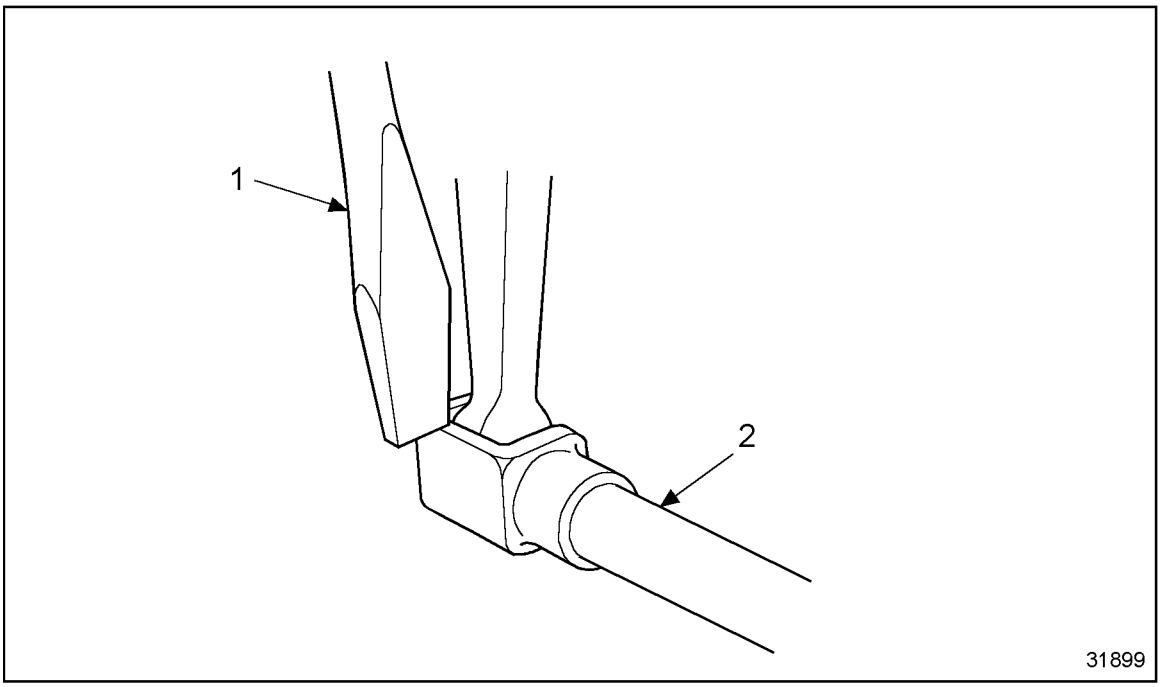
Figure 12-60 Checking Rotating Movement of Injector Control Rack

13. Hold the speed control lever in the maximum speed position, and using a screwdriver, press downward on the injector control rack.

NOTE:
The rack should tilt downward, and when the pressure of the screwdriver is released, the control rack should "spring" back upward. See Figure 12-61. If the rack does not return to its original position, it is too loose. The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined

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by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel.



1. Screwdriver
2. Injector Control Rack

Figure 12-61 Checking Injector Control Rack "Spring"

14. If the rack is loose, slightly back off the outer adjusting screw, and tighten the inner adjusting screw.
15. If the rack is tight, slightly back off the inner adjusting screw, and slightly tighten the outer adjusting screw.
16. Remove the fuel rod-to-control tube lever clevis pin from the right front bank fuel rod, and install it on the right rear bank fuel rod.

Adjust the No. 5R (16V) or No. 4R (12V) injector rack as follows:

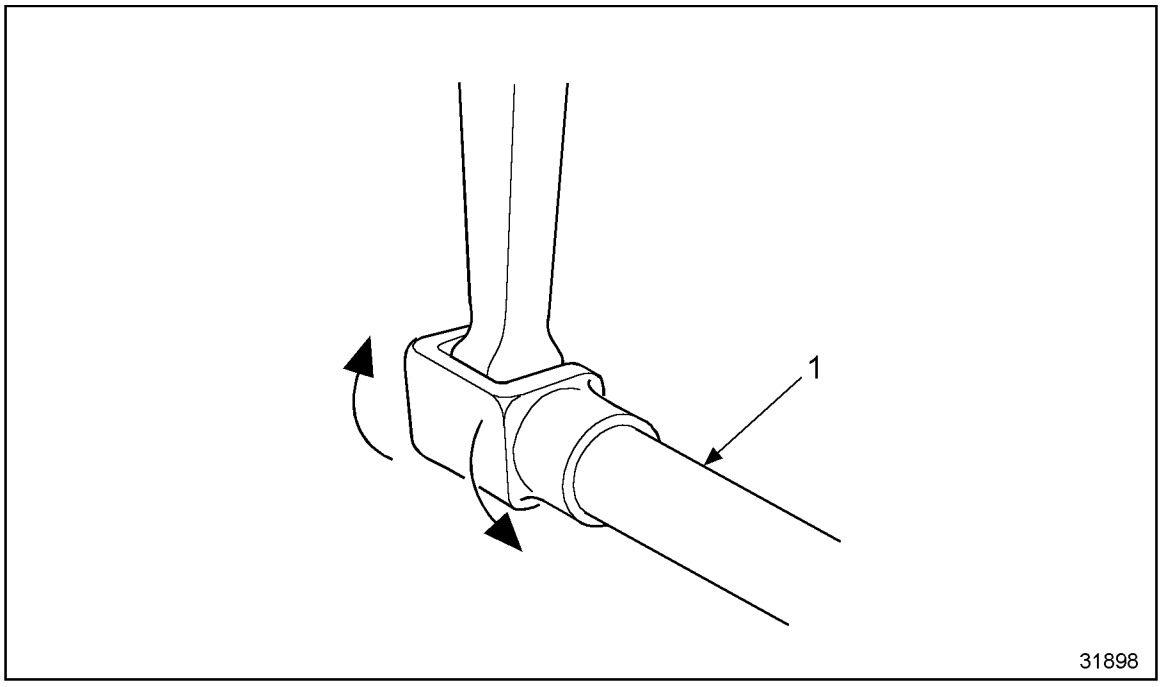
1. Move the speed control lever to the maximum speed position.
2. Hold the speed control lever lightly with your finger.
3. Adjust the No. 5R (16V) or No. 4R (12V) injector rack by turning the inner adjusting screw down until the control tube moves slightly or a step-up in effort to turn the screwdriver is noted.

NOTE:
This will place the rack in the full-fuel position.

4. Turn the outer adjusting screw until it bottoms lightly on the control tube.
5. Alternately tighten both the inner and outer adjusting screws.

NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in).

6. To ensure proper rack adjustment, hold the speed control lever in the maximum speed position, and press down on the injector rack with a screwdriver or finger tip.
7. Observe the "rotating" movement of the injector control rack. See Figure 12-62.



1. Injector Control Rack

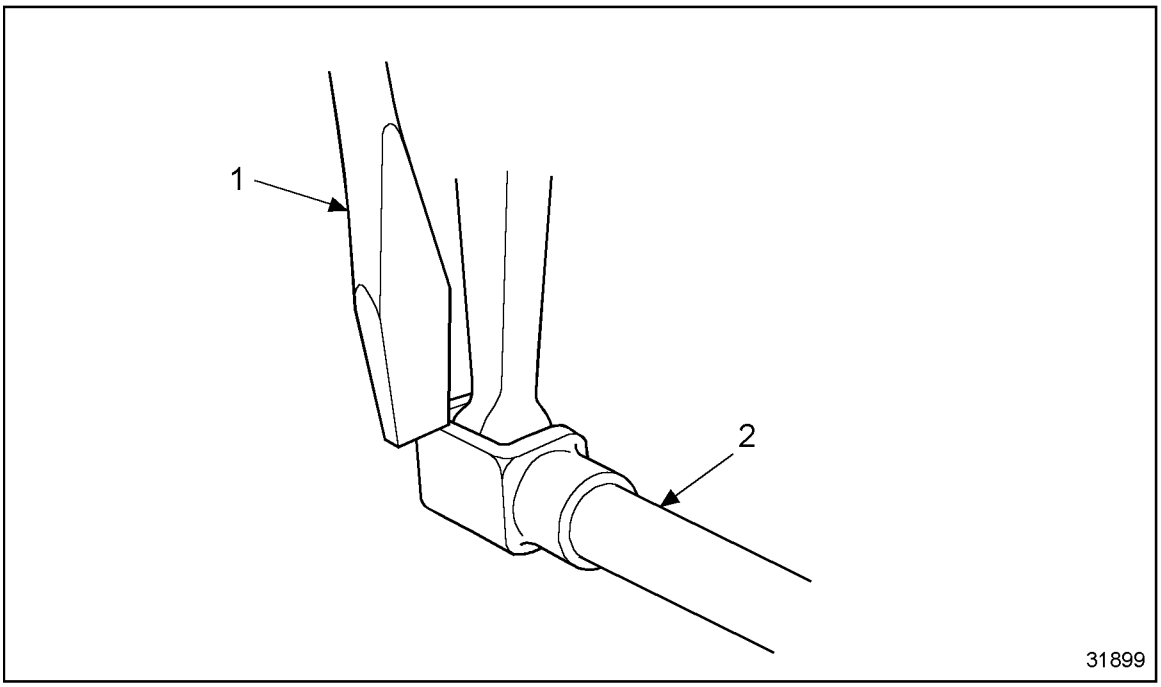
Figure 12-62 Checking Rotating Movement of Injector Control Rack

8. Hold the speed control lever in the maximum speed position, and using a screwdriver, press downward on the injector control rack.

NOTE:
The rack should tilt downward, and when the pressure of the screwdriver is released, the control rack should "spring" back upward. See Figure 12-63. If the rack does not return to its original position, it is too loose. The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined

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by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel.



1. Screwdriver
2. Injector Control Rack

Figure 12-63 Checking Injector Control Rack "Spring"

9. If the rack is loose, slightly back off the outer adjusting screw, and tighten the inner adjusting screw.
10. If the rack is tight, slightly back off the inner adjusting screw, and slightly tighten the outer adjusting screw.
11. Remove the fuel rod-to-control tube lever clevis pin from the right front bank fuel rod, and install it on the right rear bank fuel rod.

NOTE:
When the settings are correct, the No. 4R, 5R, 4L and 5L (16V) or No. 3R, 4R, 3L and 4L (12V) injector racks will be snug on the ball end of the control levers when the injectors are in the full-fuel position.

With the fuel rod disconnected from the injector control tube lever, adjust the remaining injector rack control levers on the right front bank as follows:

1. Hold the No. 4R (16V) or No. 3R (12V) injector rack in the full-fuel position with the control tube lever.
2. Turn the inner adjusting screw of the No. 3R (16V) or No. 2R (12V) injector rack control lever until the injector rack has moved into the full-fuel position.
3. Turn the outer adjusting screw down until it bottoms lightly on the injector control tube.

4. Alternately tighten both the inner and outer adjusting screws.

NOTICE:
Overtightening injector rack control tube lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in.).

5. Check the No. 4R (16V) or No. 3R (12V) injector rack to be sure it has remained snug on the ball end of the injector rack control lever.
6. If the rack of the No. 4R (16V) or No. 3R (12V) injector has become loose, back off the inner adjusting screw slightly on the No. 3R (16V) or No. 2R (12V) injector rack control lever, and tighten the outer adjusting screw.

NOTICE:
Overtightening the injector rack control tube lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended torque of the adjusting screws is 3-4 N·m (24-36 lb·in).

7. Verify the injector rack adjustment of No. 4R (16V) or No. 3R (12V).
8. If No. 4R (16V) or No. 3R (12V) does not "spring" back upward, turn the No. 3R counterclockwise slightly until the No. 4R (16V) or No. 3R (12V) injector rack returns to its full-fuel position.

NOTE:
When the settings are correct, both injector racks must respond in the same manner on the ball ends of the control levers when the injector control tube lever is held in the full-fuel position.

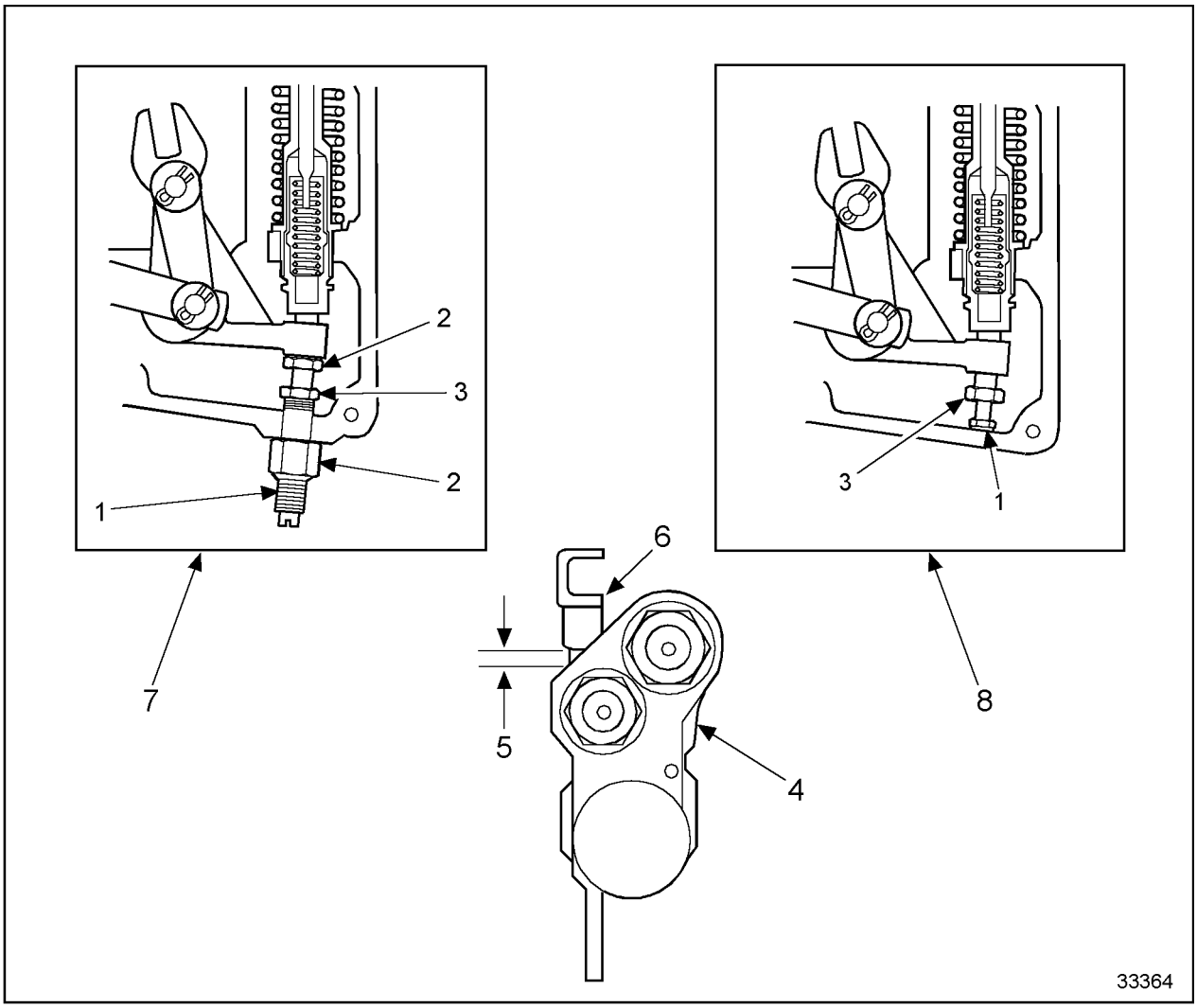
9. Position the remaining injector rack control levers on the right front cylinder bank. Refer to step 1 through step 8.
10. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder banks. Refer to step 1 through step 11.
11. Install the four fuel rod-to-control tube lever clevis pins, and check the adjustment of the injector rack control levers.
12. Turn the idle speed adjusting screw in until it projects 4.7625 mm (0.1875 in.) from the locknut.

On current turbocharged engines, adjust the external starting aid screw, as follows:

1. With the engine stopped, place the governor stop lever in the run position and the speed control lever in the idle speed position.

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2. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body. See Figure 12-64. The gage setting and tool numbers are listed in Table 12-11.



1. Starting Aid Screw
2. Locknut
3. Gap Adjusting Screw
4. Injector Body
5. Required Setting
6. Injector Aid Screw Adjustment
7. External Screw
8. Internal Screw

Figure 12-64 Starting Aid Screw Adjustment

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Injector	Gage Setting	Tool Number
9200	11.532 mm (0.454 in.)	J 23190
9215	11.532 mm (0.454 in.)	J 23190
9225	11.532 mm (0.454 in.)	J 23190
9280	9.778 mm (0.385 in.)	J 24882
9285	9.778 mm (0.385 in.)	J 24882
9290	11.532 mm (0.454 in.)	J 23190
9295	11.532 mm (0.454 in.)	J 23190
9A80	9.778 mm (0.385 in.)	J 24882
9A85	9.778 mm (0.385 in.)	J 24882
9A90	11.532 mm (0.454 in.)	J 23190
9B70	9.778 mm (0.385 in.)	J 24882
9B75	9.778 mm (0.385 in.)	J 24882
9B80	9.778 mm (0.385 in.)	J 24882
9B85	9.778 mm (0.385 in.)	J 24882
9B90	11.532 mm (0.454 in.)	J 23190
9C70	9.778 mm (0.385 in.)	J 24882
9C75	9.778 mm (0.385 in.)	J 24882
9C80	9.778 mm (0.385 in.)	J 24882
9C90	11.532 mm (0.454 in.)	J 23190
9E65	9.778 mm (0.385 in.)	J 24882
9E70	9.778 mm (0.385 in.)	J 24882
9F90	11.532 mm (0.454 in.)	J 23190
7G65	9.778 mm (0.385 in.)	J 24882
7G70	9.778 mm (0.385 in.)	J 24882
7G75	9.778 mm (0.385 in.)	J 24882

Table 12-11 Starting Aid Screw Required Settings

3. Select the proper gage and measure the setting at any convenient cylinder.

NOTE:
When the starting aid screw is properly adjusted, the gage should have a small clearance of 0.396875 mm (0.015625 in.) in the space along the injector rack shaft between the rack clevis and the injector body.

4. After completing the adjustment, hold the starting aid screw, and tighten the locknut.
5. Position the stop lever in the run position.
6. Move the speed control lever from the idle speed position to the maximum speed position.
7. Return the speed control lever to the idle speed position.

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8. Check the injector rack clevis-to-body clearance.

NOTE:
The speed control lever will move to take-up the clearance in the governor linkage. The injector rack clevis-to-body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out.

NOTE:
The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start-up.

9. Use new gaskets, and reinstall the valve rocker covers.

12.5.4 Position Injector Rack Control Levers (One Screw and Locknut Assembly)

The position of the injector racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

NOTE:
To ensure proper injector control rack adjustment, the injector racks must be adjusted with the yield link and governor cover that will be used with the governor.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Governor low speed gap closed.
3. High speed spring plunger on the seat in the governor control housing.
4. Injector fuel control racks in the full-fuel position.

The letters "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 4R (16V) or the No. 3R (12V) injector rack control lever first to establish a guide for adjusting the remaining right bank injector rack control levers.

Injector racks must be adjusted so the effort to move the throttle from the idle speed position to the maximum speed position is uniform. A sudden increase in effort can result from:

- Injector racks adjusted too tightly, causing the yield link to separate.
- Binding of the fuel rods.
- Failure to back out the idle screw.

NOTE:
A false full-fuel rack setting may result if the idle speed adjusting screw is not backed out.

Position the rack as follows:

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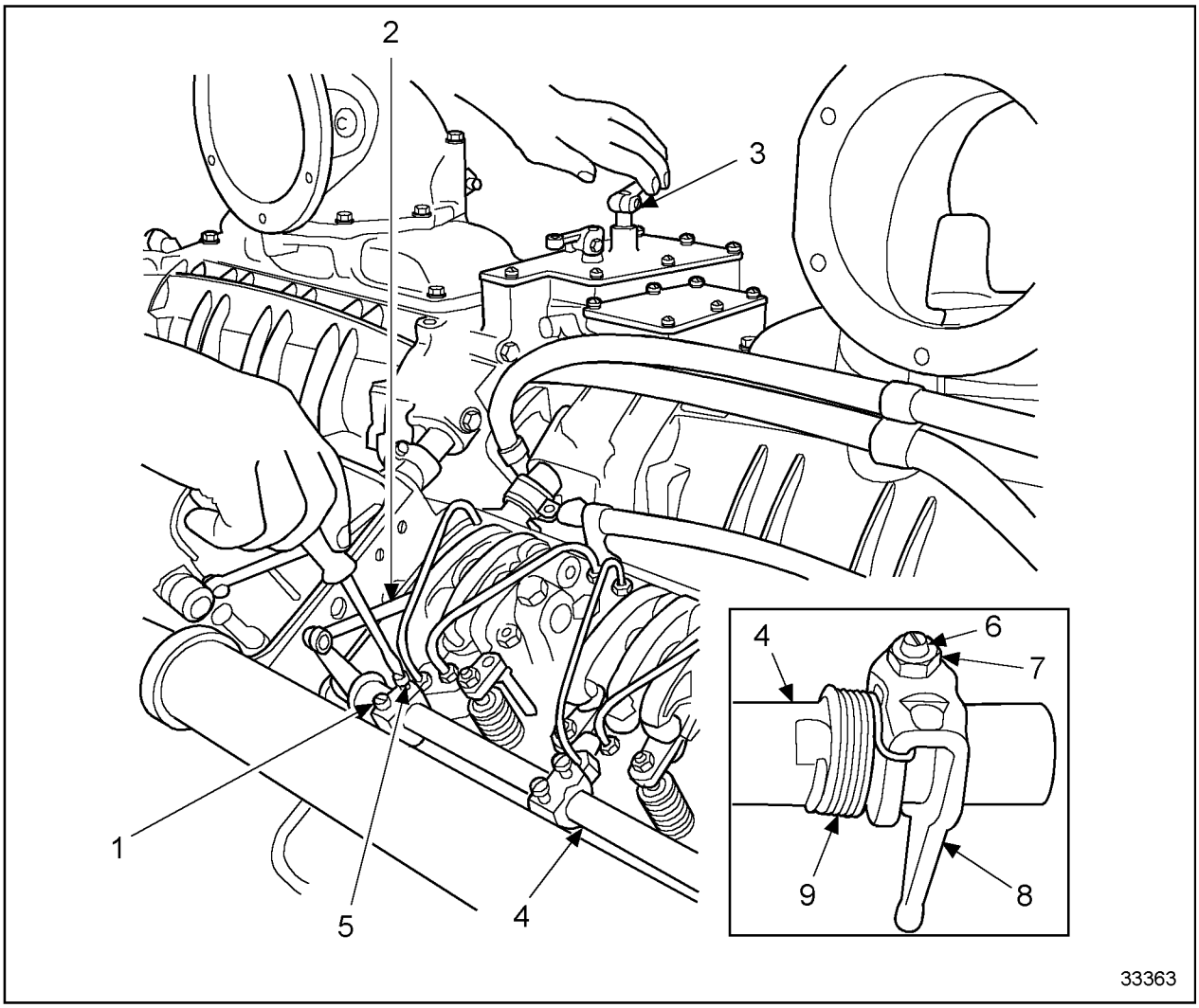
1. Adjust the idle speed adjusting screw until 12.7 mm (0.5 in.) of the threads (12-14 threads) project from the locknut when the nut is against the high-speed plunger.
2. Back out the buffer screw 15.88 mm (0.625 in.) if it has not already been done.
3. Loosen all inner and outer injector rack control lever adjusting screws or adjusting screws and locknuts on both cylinder banks.

NOTE:
Ensure all levers are free on the injector control tubes.

4. Move the linkage through its full range of travel to check for any bind in the governor to control tube linkage.
5. Remove the clevis pins that attach the right rear bank and both left bank fuel rods to the injector control tube levers.
6. Move the speed control lever to the maximum speed position.

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7. Hold the speed control lever lightly with your finger. See Figure 12-65.



1. Outer Adjusting Screw
2. Fuel Rod
3. Speed Control Lever
4. Injector Control Tube
5. Inner Adjusting Screw
6. Adjusting Screw
7. Locknut
8. Injector Rack Control Lever
9. Spring

Figure 12-65 Injector Rack Control Lever, Positioning No. 3R (12V) or No. 4R (12V)

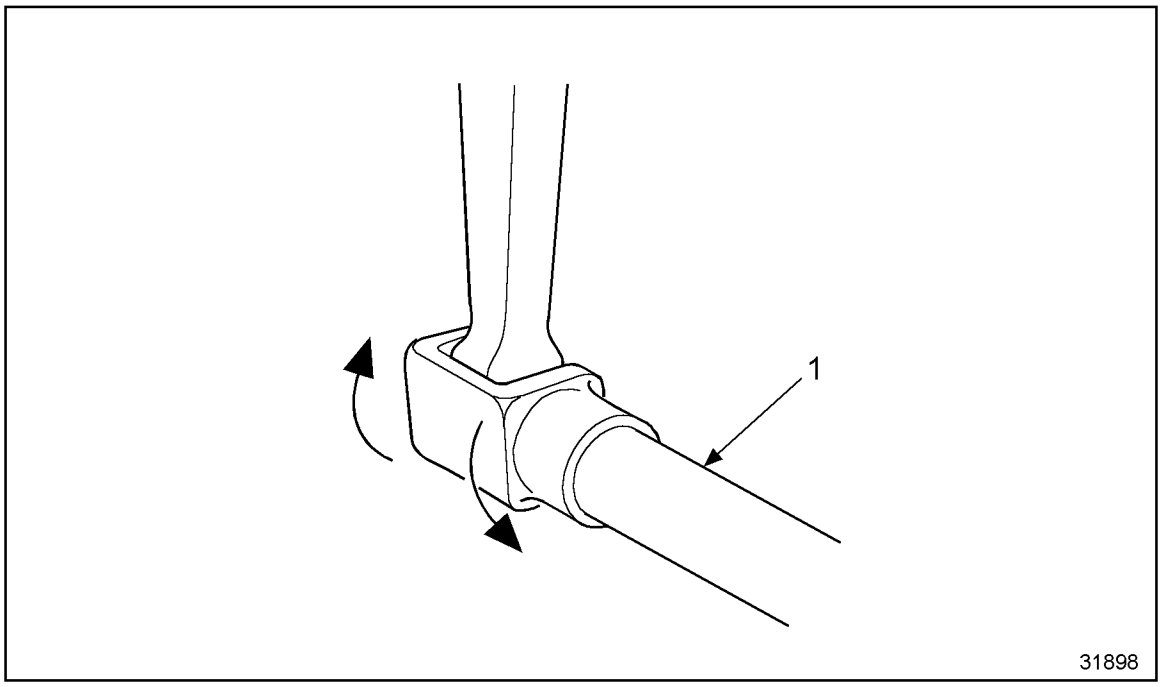
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NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in).

8. Tighten the adjusting screw of the No. 4R (16V) or No. 3R (12V) injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
9. Tighten the screw approximately 1/8 of a turn more, and lock securely with the adjusting screw locknut.

NOTE:
This will place the No. 4R (16V) or No. 3R (12V) injector rack in the full-fuel position.

10. To be sure of the proper rack adjustment, hold the speed control lever in the maximum speed position, and press down on the injector rack with a screwdriver or finger tip.
11. Observe the "rotating" movement of the injector control rack. See Figure 12-66.



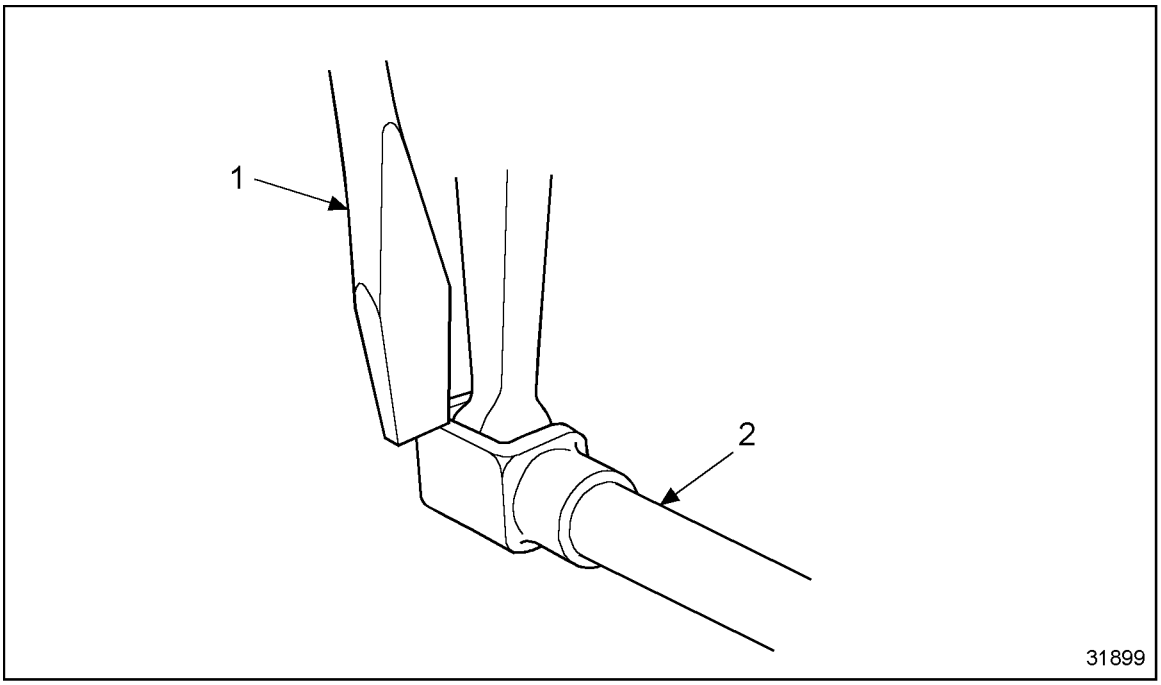
1. Injector Control Rack

Figure 12-66 Checking Rotating Movement of Injector Control Rack

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12. Hold the speed control lever in the maximum speed position, and using a screwdriver, press downward on the injector control rack.

NOTE:
The rack should tilt downward, and when the pressure of the screwdriver is released, the control rack should "spring" back upward. See Figure 12-67. If the rack does not return to its original position, it is too loose. The setting is too tight if, when moving the speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel.



1. Screwdriver
2. Injector Control Rack

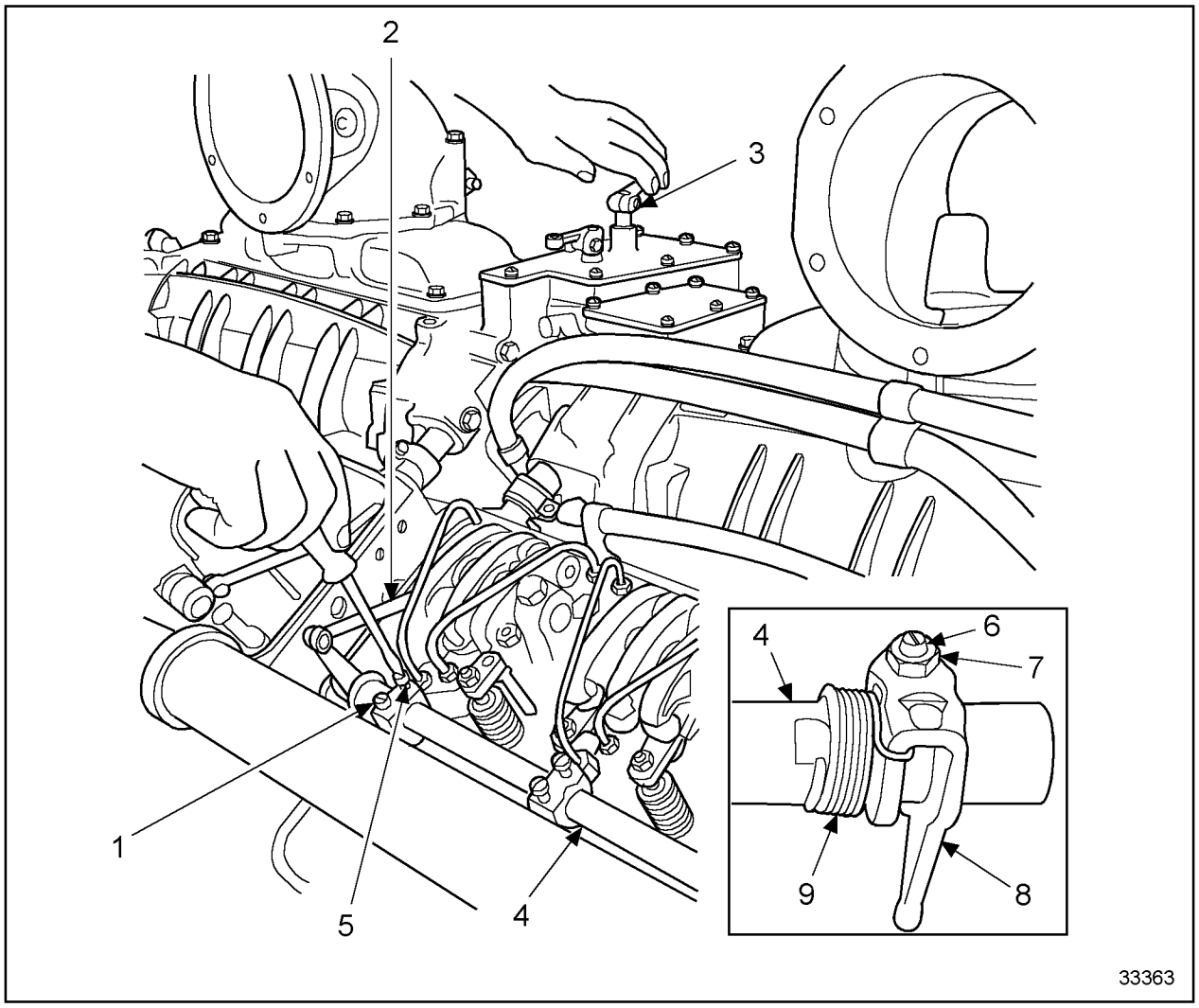
Figure 12-67 Checking Injector Control Rack "Spring"

13. If the rack is loose, slightly back off the outer adjusting screw, and tighten the inner adjusting screw.
14. If the rack is tight, slightly back off the inner adjusting screw, and slightly tighten the outer adjusting screw.
15. Remove the fuel rod-to-control tube lever clevis pin from the right front bank fuel rod, and install it on the right rear bank fuel rod.

Adjust the No. 5R (16V) or No. 4R (12V) injector rack as follows:

1. Move the speed control lever to the maximum speed position.

2. Hold the speed control lever lightly with your finger. See Figure 12-68.



1. Outer Adjusting Screw
2. Fuel Rod
3. Speed Control Lever
4. Injector Control Tube
5. Inner Adjusting Screw
6. Adjusting Screw
7. Locknut
8. Injector Rack Control Lever
9. Spring

Figure 12-68 Injector Rack Control Lever, Positioning No. 3R (12V) or No. 4R (12V)

3. Tighten the No. 4R (16V) or No. 3R (12V) injector rack adjusting screw until the control tube moves slightly or a step-up in effort to turn the screwdriver is noted.

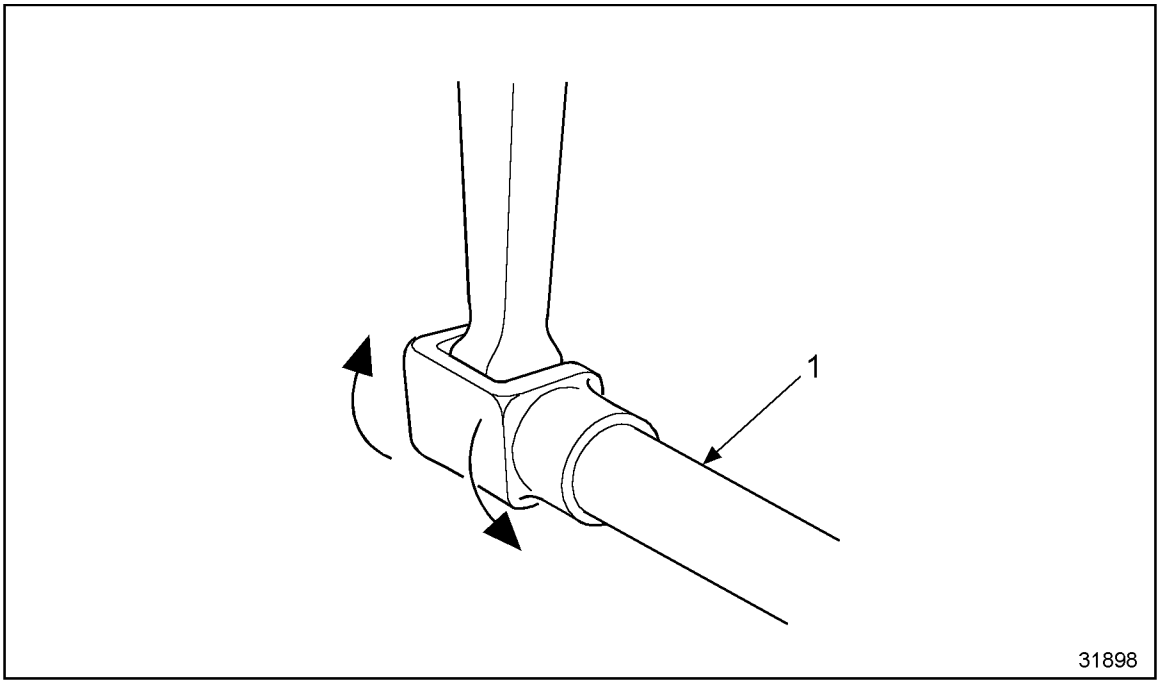
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4. Tighten the screw approximately 1/8 of a turn more, and lock securely with the adjusting screw locknut.

NOTE:
This will place the No. 4R (16V) or No. 3R (12V) injector rack in the full-fuel position.

NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in).

5. To ensure proper rack adjustment, hold the speed control lever in the maximum speed position, and press down on the injector rack with a screwdriver or finger tip.
6. Observe the "rotating" movement of the injector control rack. See Figure 12-69.



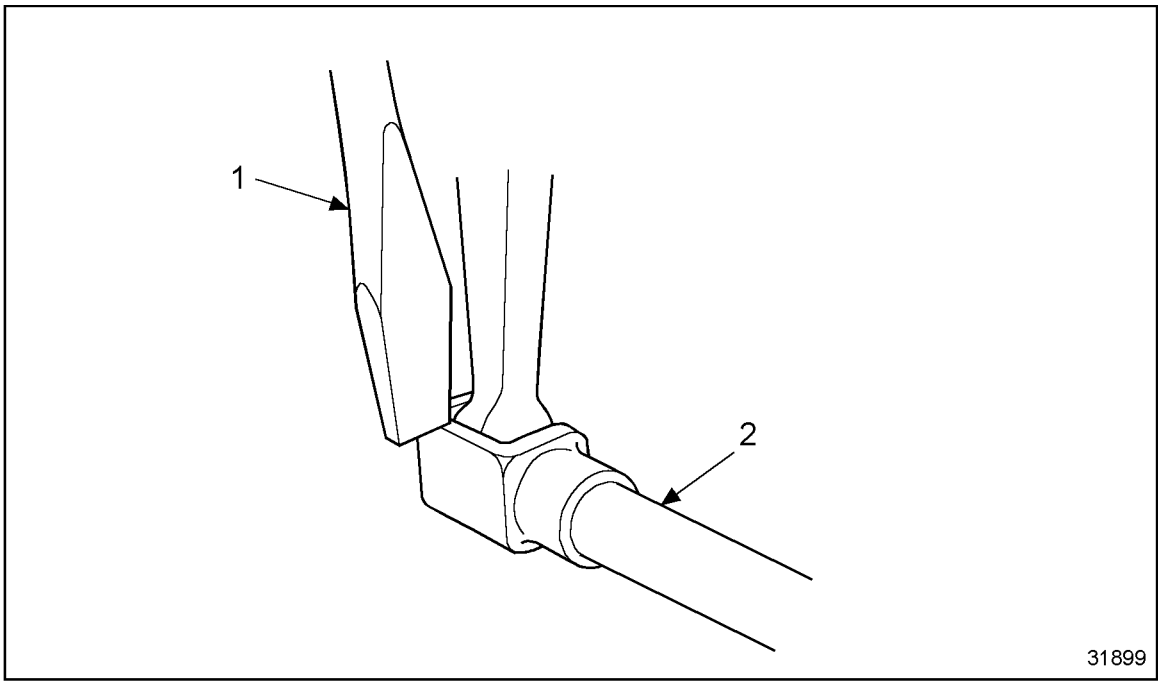
1. Injector Control Rack

Figure 12-69 Checking Rotating Movement of Injector Control Rack

7. Hold the speed control lever in the maximum speed position, and using a screwdriver, press downward on the injector control rack.

NOTE:
The rack should tilt downward, and when the pressure of the screwdriver is released, the control rack should "spring" back upward. See Figure 12-70. If the rack does not return to its original position, it is too loose. The setting is too tight if, when moving the

speed control lever from the no-speed to the maximum speed position, the injector rack becomes tight before the speed control lever reaches the end of its travel (as determined by the stop under the governor cover). This will result in a step-up in effort required to move the speed control lever to the end of its travel.



1. Screwdriver
2. Injector Control Rack

Figure 12-70 Checking Injector Control Rack "Spring"

8. If the rack is loose, slightly back off the outer adjusting screw, and tighten the inner adjusting screw.
9. If the rack is tight, slightly back off the inner adjusting screw, and slightly tighten the outer adjusting screw.
10. Remove the fuel rod-to-control tube lever clevis pin from the right front bank fuel rod, and install it on the right rear bank fuel rod.

NOTE:
When the settings are correct, the No. 4R, 5R, 4L and 5L (16V) or No. 3R, 4R, 3L and 4L (12V) injector racks will be snug on the ball end of the control levers when the injectors are in the full-fuel position.

With the fuel rod disconnected from the injector control tube lever, adjust the remaining injector rack control levers on the right front bank as follows:

1. Hold the No. 4R (16V) or No. 3R (12V) injector rack in the full-fuel position with the control tube lever.

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NOTICE:
Overtightening injector rack control tube lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended adjusting screw torque is 3-4 N·m (24-36 lb·in.).

2. Tighten the adjusting screw of the No. 3R (16V) or No. 2R (12V) injector rack control lever until the injector rack clevis is observed to roll up or an increase in effort to turn the screwdriver is noted.
3. Securely lock the adjusting screw locknut.
4. Verify the injector rack adjustment of No. 4R (16V) or No. 3R (12V).
5. If No. 4R (16V) or No. 3R (12V) does not "spring" back upward, turn the No. 3R counterclockwise slightly until the No. 4R (16V) or No. 3R (12V) injector rack returns to its full-fuel position.
6. Secure the adjusting screw locknut. Verify proper injector rack adjustment for both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injectors.
7. Turn the No. 3R (16V) or No. 2R (12V) injector rack adjusting screw clockwise or counterclockwise until both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injector racks are in the full-fuel position when the locknut is securely tightened.

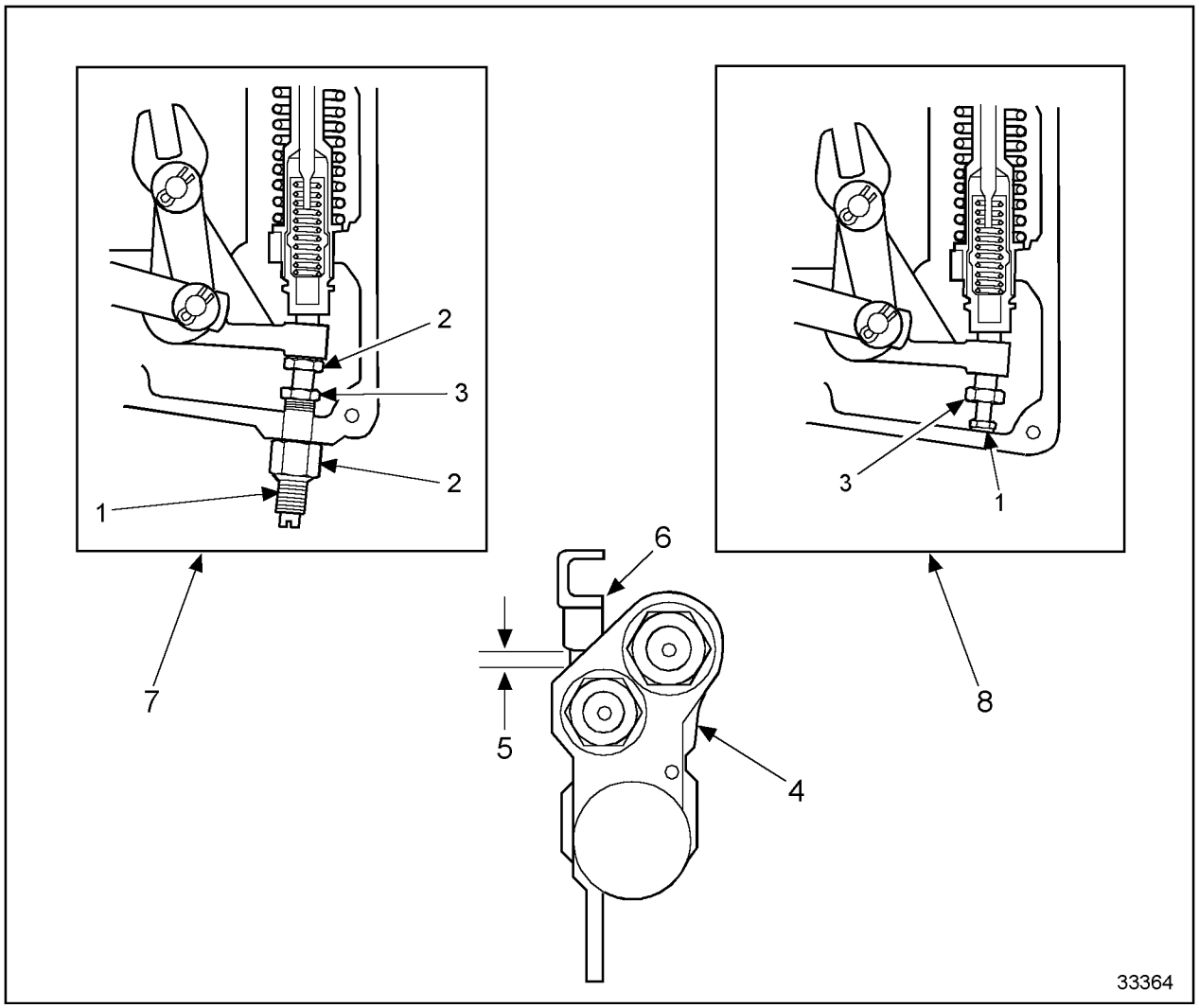
NOTE:
When the settings are correct, both injector racks must respond in the same manner on the ball ends of the control levers when the injector control tube lever is held in the full-fuel position.

8. Position the remaining injector rack control levers on the right front cylinder bank. Refer to step 1 through step 7.
9. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder banks. Refer to step 1 through step 11.
10. Install the four fuel rod-to-control tube lever clevis pins, and check the adjustment of the injector rack control levers.
11. Turn the idle speed adjusting screw in until it projects 4.7625 mm (0.1875 in.) from the locknut.

On current turbocharged engines, adjust the external starting aid screw, as follows:

1. With the engine stopped, place the governor stop lever in the run position and the speed control lever in the idle speed position.
2. Adjust the starting aid screw to obtain the required setting between the shoulder on the injector rack clevis and the injector body. See Figure 12-71. The gage setting and tool numbers are listed in Table 12-12.

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1. Starting Aid Screw
2. Locknut
3. Gap Adjusting Screw
4. Injector Body
5. Required Setting
6. Injector Rack Clevis
7. External Screw
8. Internal Screw

Figure 12-71 Starting Aid Screw Adjustment

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Injector	Gage Setting	Tool Number
9200	11.532 mm (0.454 in.)	J 23190
9215	11.532 mm (0.454 in.)	J 23190
9225	11.532 mm (0.454 in.)	J 23190
9280	9.778 mm (0.385 in.)	J 24882
9285	9.778 mm (0.385 in.)	J 24882
9290	11.532 mm (0.454 in.)	J 23190
9295	11.532 mm (0.454 in.)	J 23190
9A80	9.778 mm (0.385 in.)	J 24882
9A85	9.778 mm (0.385 in.)	J 24882
9A90	11.532 mm (0.454 in.)	J 23190
9B70	9.778 mm (0.385 in.)	J 24882
9B75	9.778 mm (0.385 in.)	J 24882
9B80	9.778 mm (0.385 in.)	J 24882
9B85	9.778 mm (0.385 in.)	J 24882
9B90	11.532 mm (0.454 in.)	J 23190
9C70	9.778 mm (0.385 in.)	J 24882
9C75	9.778 mm (0.385 in.)	J 24882
9C80	9.778 mm (0.385 in.)	J 24882
9C90	11.532 mm (0.454 in.)	J 23190
9E65	9.778 mm (0.385 in.)	J 24882
9E70	9.778 mm (0.385 in.)	J 24882
9F90	11.532 mm (0.454 in.)	J 23190
7G65	9.778 mm (0.385 in.)	J 24882
7G70	9.778 mm (0.385 in.)	J 24882
7G75	9.778 mm (0.385 in.)	J 24882

Table 12-12 Starting Aid Screw Required Setting

3. Select the proper gage and measure the setting at any convenient cylinder.

NOTE:
When the starting aid screw is properly adjusted, the gage should have a small clearance of 0.396875 mm (0.015625 in.) in the space along the injector rack shaft between the rack clevis and the injector body.

4. After completing the adjustment, hold the starting aid screw, and tighten the locknut.
5. Position the stop lever in the run position.
6. Move the speed control lever from the idle speed position to the maximum speed position.
7. Return the speed control lever to the idle speed position. Check the injector rack clevis-to-body clearance.

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8. Check the injector rack clevis-to-body clearance.

NOTE:
The speed control lever will move to take-up the clearance in the governor linkage. The injector rack clevis-to-body clearance can be increased by turning the starting aid screw farther in against the gap adjusting screw, or reduced by backing it out.

NOTE:
The starting aid screw will be ineffective if the speed control lever is advanced toward wide open throttle during start-up.

9. Use new gaskets, and reinstall the valve rocker covers.

12.5.5 Adjust Idle Speed

Adjust the idle speed as follows:

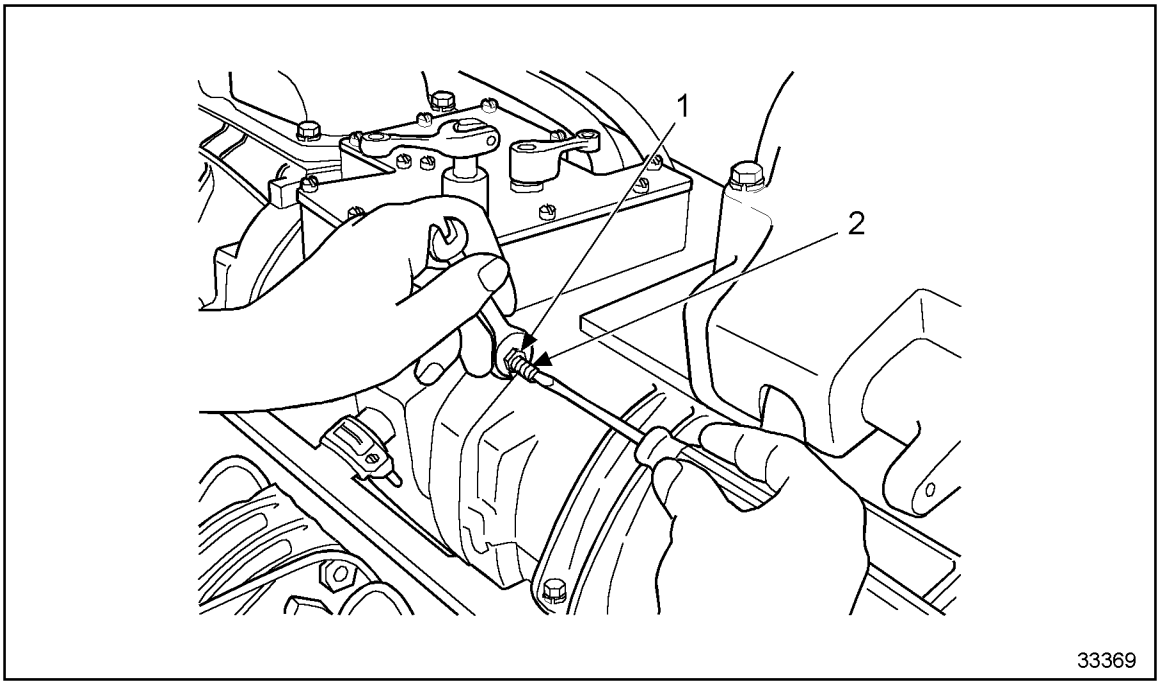
1. With the engine running, at normal operating temperature and with the buffer screw backed out to avoid contact with the differential lever, turn the idle speed adjusting screw

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until the engine is operating approximately 15 RPM below the recommended idle speed. See Figure 12-72.

NOTE:
The recommended idle speed is 400-450 RPM but may vary with certain engine applications.

NOTE:
It may be necessary to use the buffer screw to eliminate engine roll. After idle speed is established, back out the buffer screw to the previous setting (15.875 mm or 0.625 in.).



1. Locknut
2. High Speed Adjusting Screw

Figure 12-72 Adjusting Engine Idle Speed

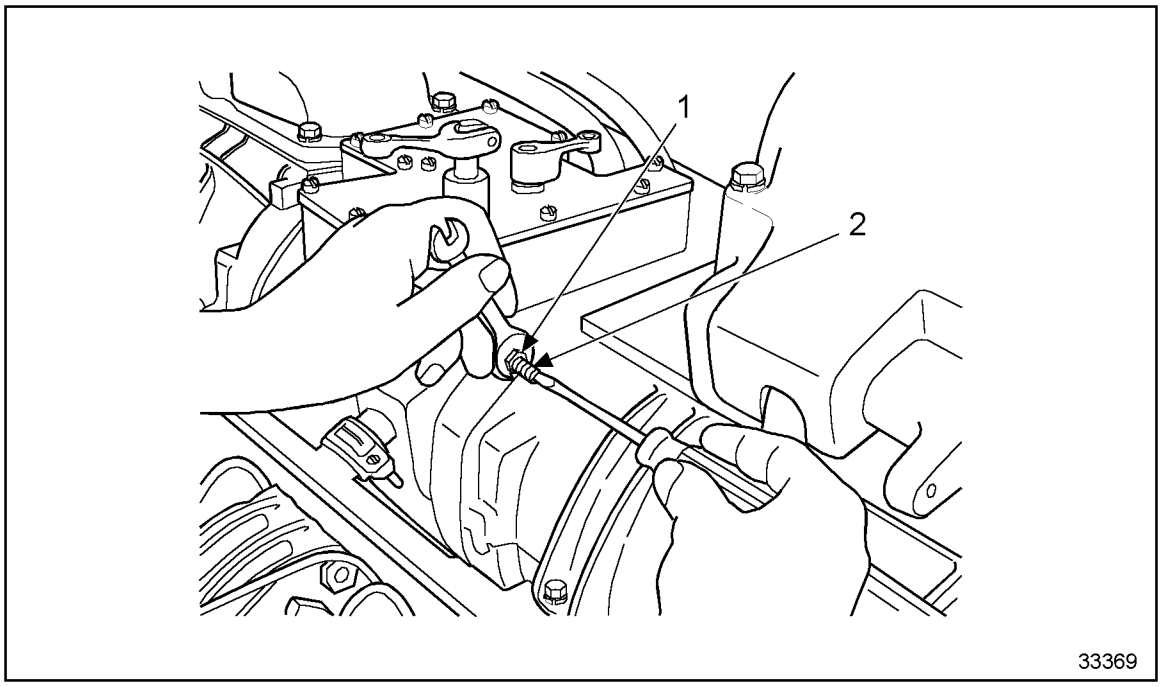
2. Hold the idle screw and tighten the locknut.
3. Install the high speed spring retainer cover.

12.5.6 Adjust Maximum No-Load Engine Speed

All governors are properly adjusted before leaving the factory. If the governor has been reconditioned or replaced and to ensure the engine speed will not exceed the recommended no-load speed as given on the option plate, set the maximum no-load speed as follows:

NOTE:
Ensure buffer screw projects 15.88 mm (0.625 in.) to prevent interference while adjusting the maximum no-load speed.

1. Loosen the spring retainer locknut, and back off the high-speed spring retainer approximately five turns. See Figure 12-73.



1. Locknut
2. Idle Speed Adjusting Screw

Figure 12-73 Adjusting Engine Idle Speed

2. With the engine running at operating temperature, and no load on the engine, place the speed control lever in the maximum speed position.
3. Turn the high speed spring retainer until the engine is operating at the recommended no-load speed.
4. Hold the high speed spring retainer, and tighten the locknut using spanner wrench J 5345-E.

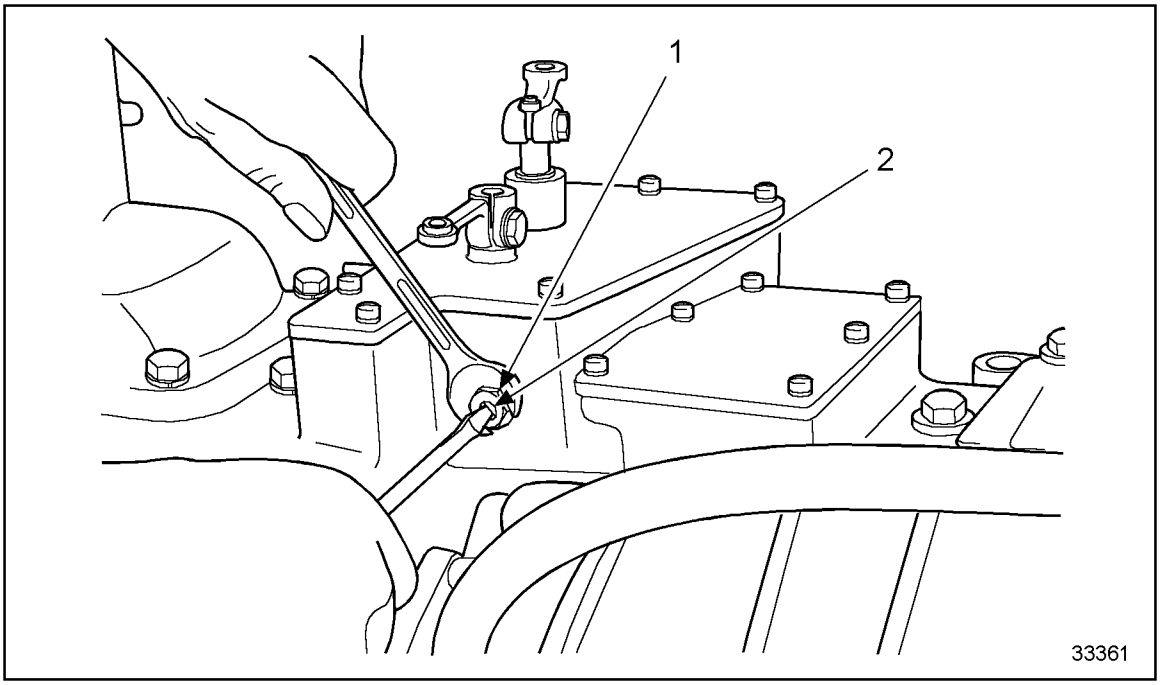
12.5.7 Adjust Buffer Screw

With the idle speed properly set, adjust the buffer screw, as follows:

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1. With the engine running at normal operating temperature, turn the buffer screw in so it contacts the differential lever as lightly as possible and still eliminates engine roll. See Figure 12-74.

NOTE:
Do not increase the engine idle speed more than 15 RPM with the buffer screw.



1. Locknut
2. Buffer Screw

Figure 12-74 Adjusting Buffer Screw

2. Check the maximum no-load speed. If it has increased more than 25 RPM, back off the buffer screw until the increase is less than 25 RPM.
3. Hold the buffer screw, and tighten the locknut.

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12.6 STATIC DOUBLE WEIGHT LIMITING SPEED GOVERNOR GAP CHECKING AND SETTING PROCEDURE

The following is accomplished with the engine stopped.

A new governor weight wedge tool J 35516 and the accompanying procedure can be used only on double weight limiting speed governors.

⚠ 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 from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

Verification of the governor gap setting should not be considered necessary until "Vehicle Low Power/Performance at Low Mileage" has been used to troubleshoot the engine performance concern.

12.6.1 Governor Gap Checking Procedure

Check governor gap as follows:

1. With the governor on the vehicle, set the engine idle speed at 600 RPM, and stop the engine.

NOTE:
The static governor gap setting is established at the factory based upon a 600 RPM engine idle. Therefore, when verifying a factory tune-up, the governor idle speed should be set at 600 RPM.

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CAUTION:

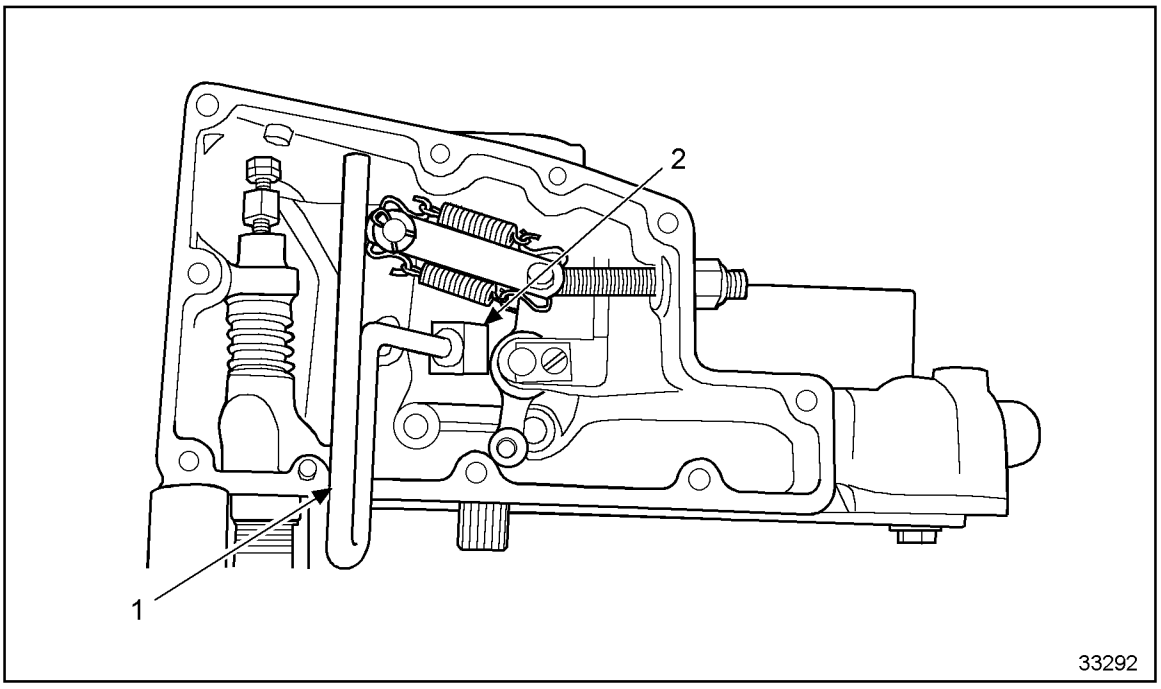
To avoid injury from accidental engine startup while servicing the engine, disconnect/disable the starting system.

2. Clean and remove the governor cover. Discard the gasket.
3. With the engine stopped, manually bar the engine over in the direction of normal engine rotation until the governor weights are in a horizontal position.

NOTE:
On "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately 1.52 mm (0.060 in.) clearance between the washers and the retainer nut before checking or resetting the governor gap.

4. Insert governor weight wedge J 35516 between the low-speed weight and the governor riser. See Figure 12-75 and see Figure 12-76.

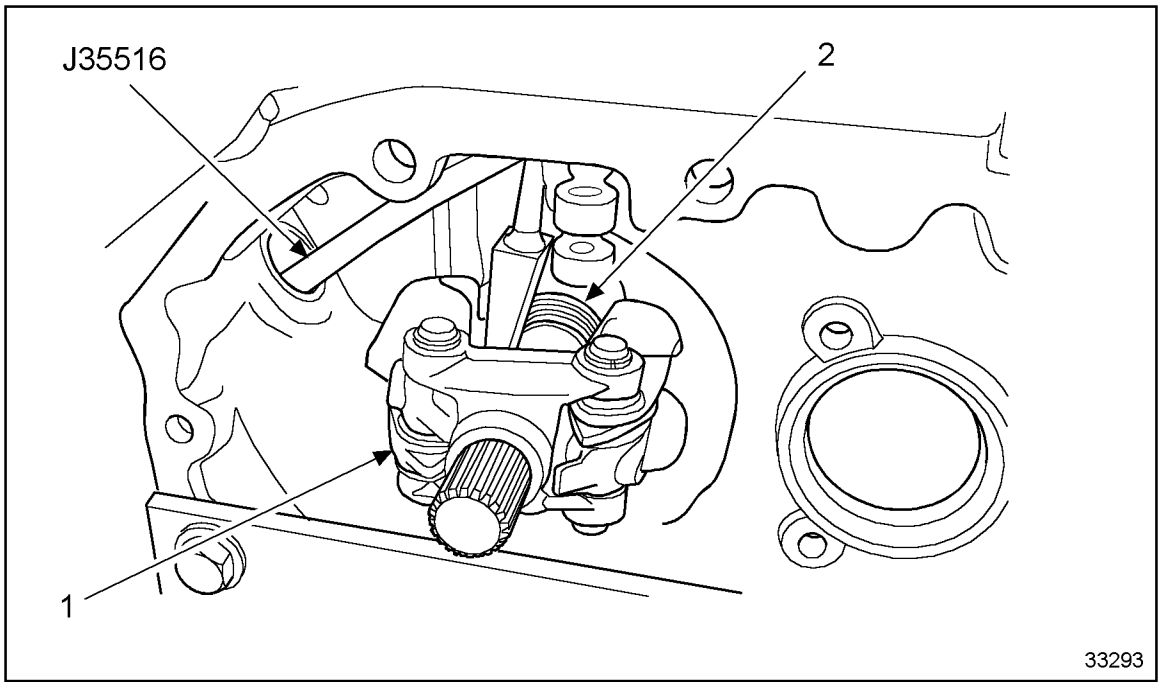
NOTE:
The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser.



1 Tool Handle 2. Tool Wedge

Figure 12-75 Tool J 35516 Inserted Between Low Speed Weight and Riser

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1. Low Speed Weight
2. Riser

Figure 12-76 Wedge of Tool J 35516 Between Riser and Low Speed Weight

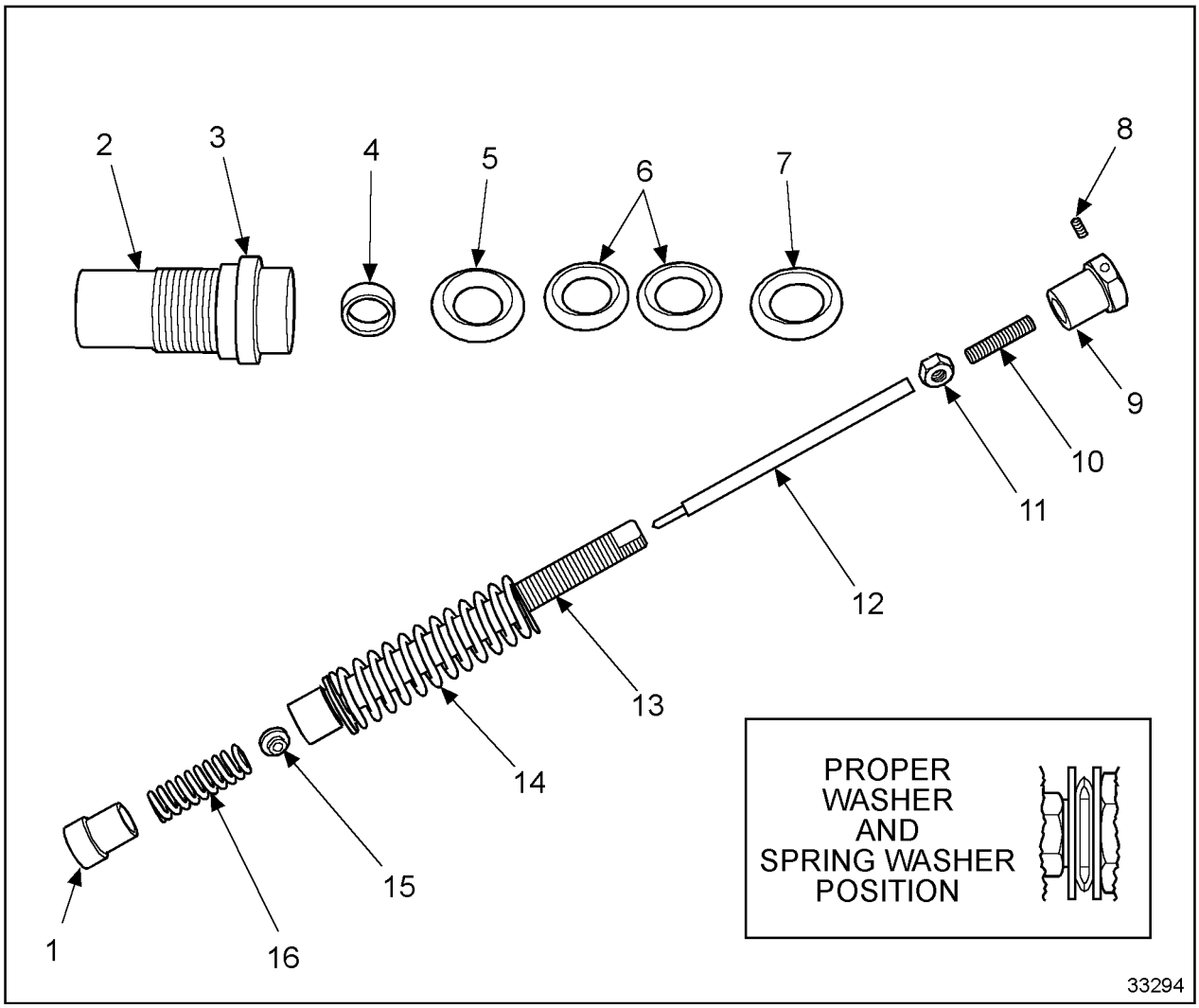
5. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

NOTICE:
Do not use a screwdriver to pry the weights, since damage to the weights, riser, or housing could result.

6. While holding the wedge in the bottom position, use a feeler gage to measure the gap between the low speed spring cap and the high speed spring plunger. See Figure 12-77 and see Figure 12-78.

NOTE:
The gap should measure 0.08–0.48 mm (0.003–0.019 in.). Reset the gap to 0.20 mm (0.008 in.) if the measured gap is out of limits. Refer to section 12.7.1.

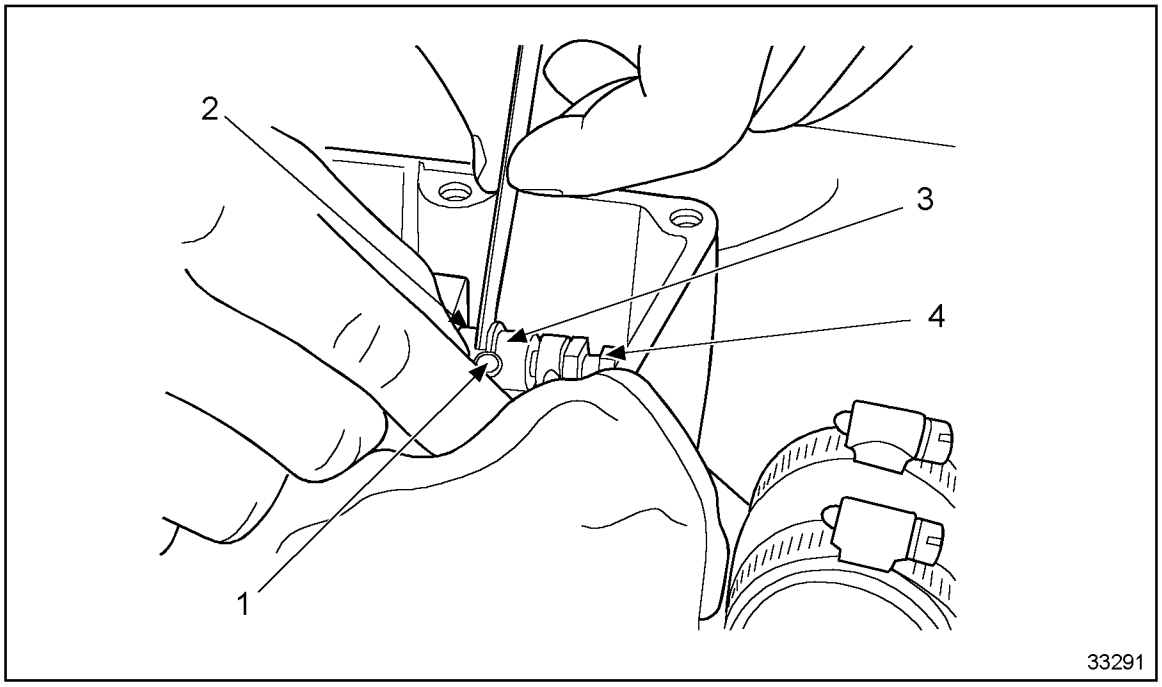
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1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Set Screw
9. Retainer Nut
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Pin
13. Plunger
14. High Speed Spring
15. Low Speed Spring Seat
16. Low Speed Spring

Figure 12-77 High and Low Speed Spring and Plunger

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1. Differential Lever Pin
2. High Speed Spring
3. Low Speed Spring Cap
4. Gap Adjusting Screw

Figure 12-78 Adjusting Governor Gap

7. Remove the wedge and replace the governor cover using a new gasket.
8. Reset Belleville springs. Refer to section 12.9.

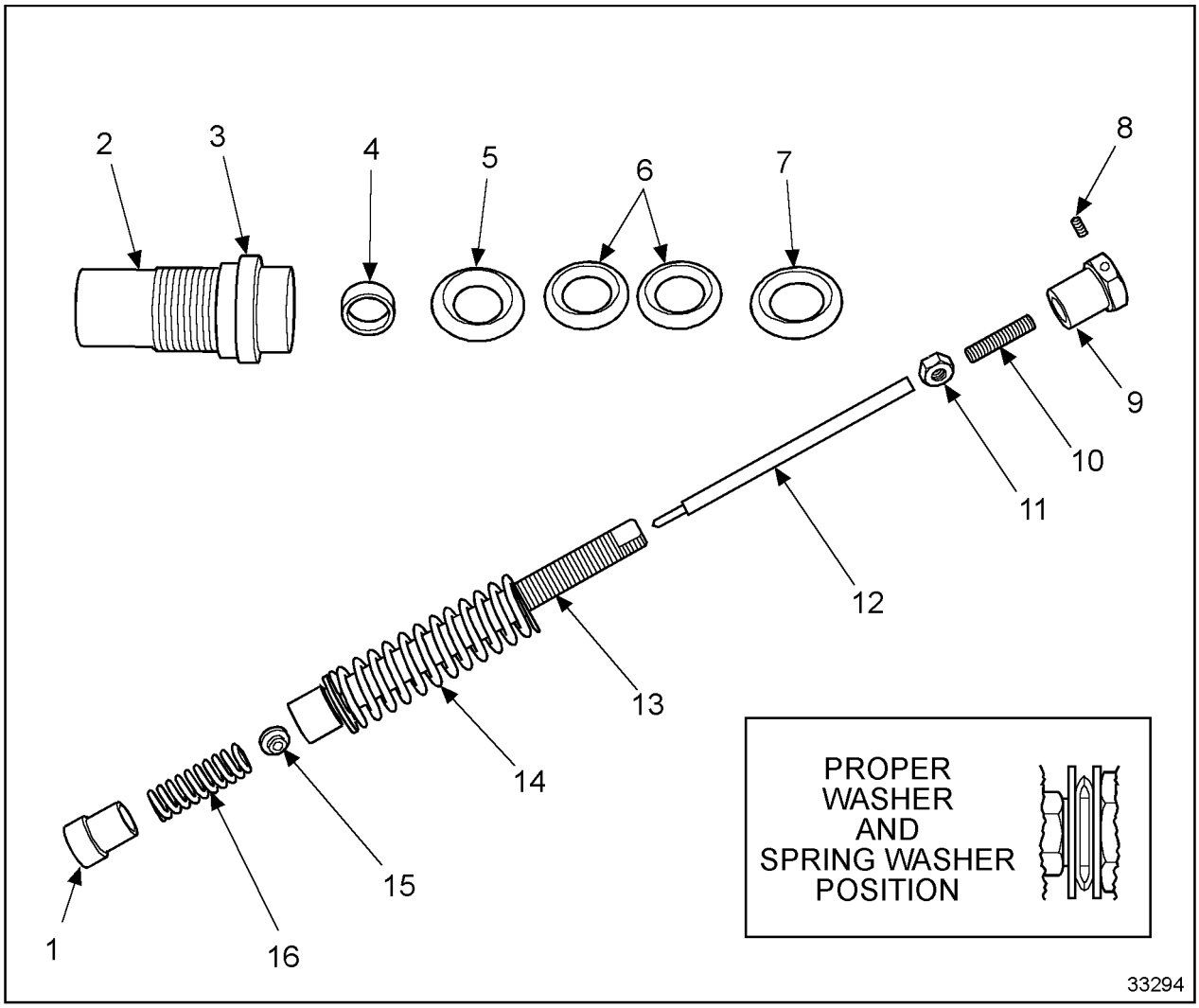
12.6.2 Set Governor Gap (Governor on Engine)

Set the governor gap as follows:

These procedures permit adjusting the gap while the governor is installed on an engine or removed and on a bench.

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Before adjusting the gap on "TT" governors, the Belleville spring retainer nut must be backed out until there is approximately 1.52 mm (0.060 in.) clearance between the washers and the retainer nut. See Figure 12-79.



1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Set Screw
9. Retainer Nut
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Pin
13. Plunger
14. High Speed Spring
15. Low Speed Spring Seat
16. Low Speed Spring

Figure 12-79 High and Low Speed Spring and Plunger

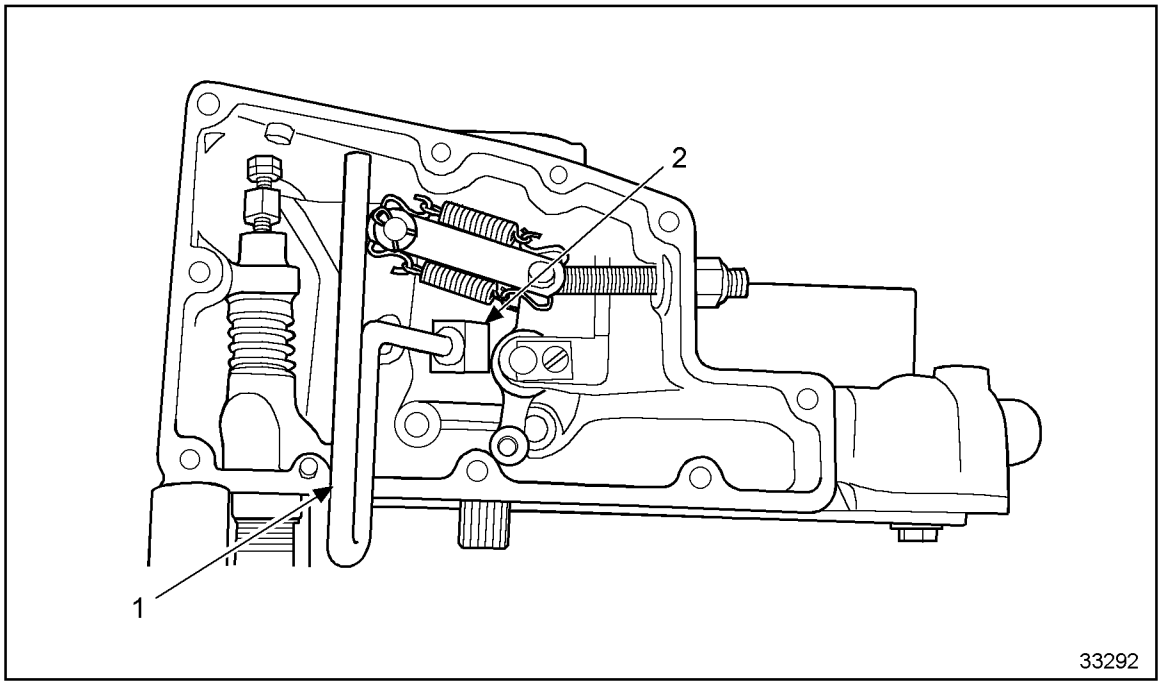
1. Disconnect any supplementary governor devices.

2. Set the engine idle speed at 600 RPM, and stop the engine.

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

3. Clean and remove the governor cover. Discard the gasket.
4. With the engine stopped, manually bar the engine over in the direction of normal engine rotation until the governor weights are in a horizontal position.
5. Insert governor weight wedge Tool J 35516 between the low-speed weight and the governor riser. See Figure 12-80 and see Figure 12-81.

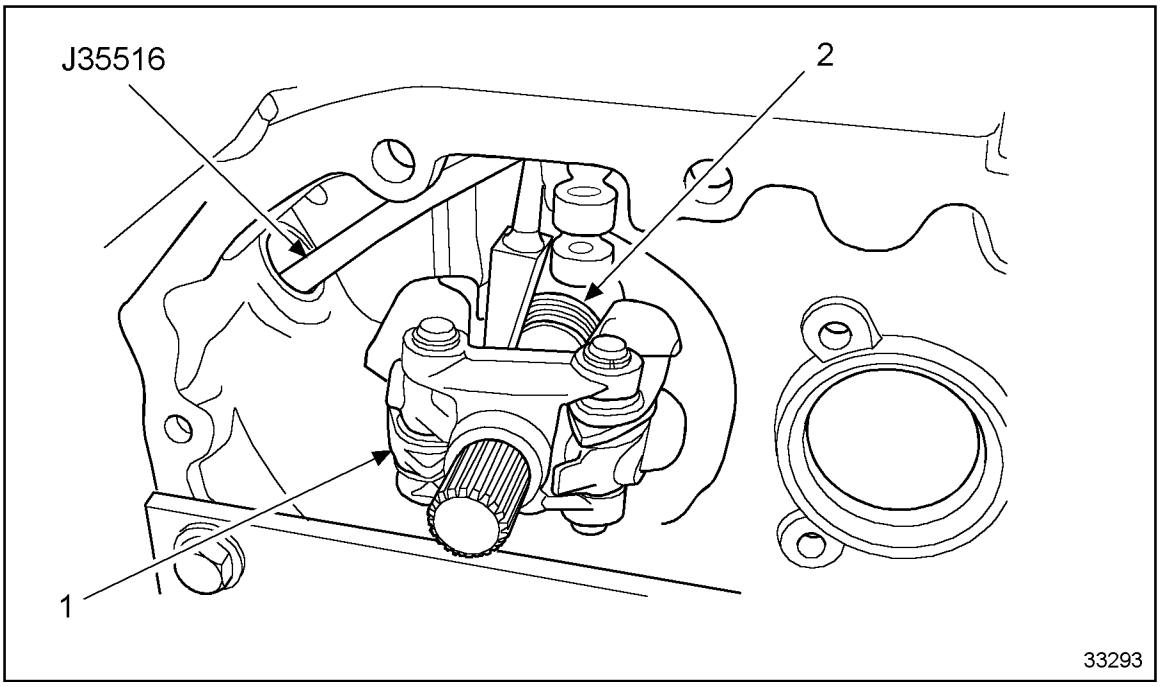
NOTE:
The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser.



1. Tool Handle
2. Tool Wedge

Figure 12-80 Tool J 35516 Inserted Between Low Speed Weight and Riser

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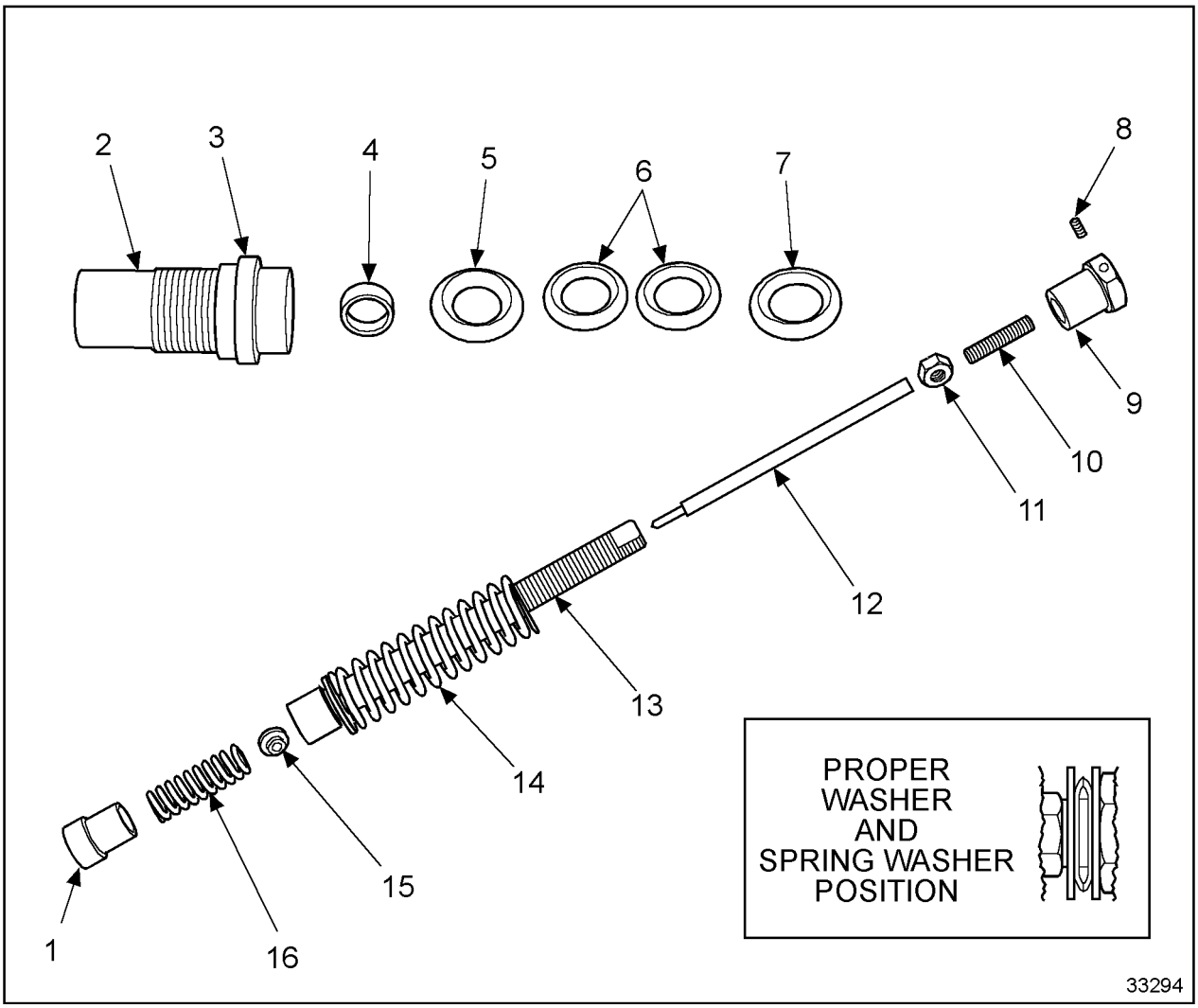
1. Low Speed Spring
2. Riser

Figure 12-81 Wedge of Tool J 35516 Between Riser and Low Speed Weight

6. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

NOTICE:
Do not use a screwdriver to pry the weights, since damage to the weights, riser, or housing could result.

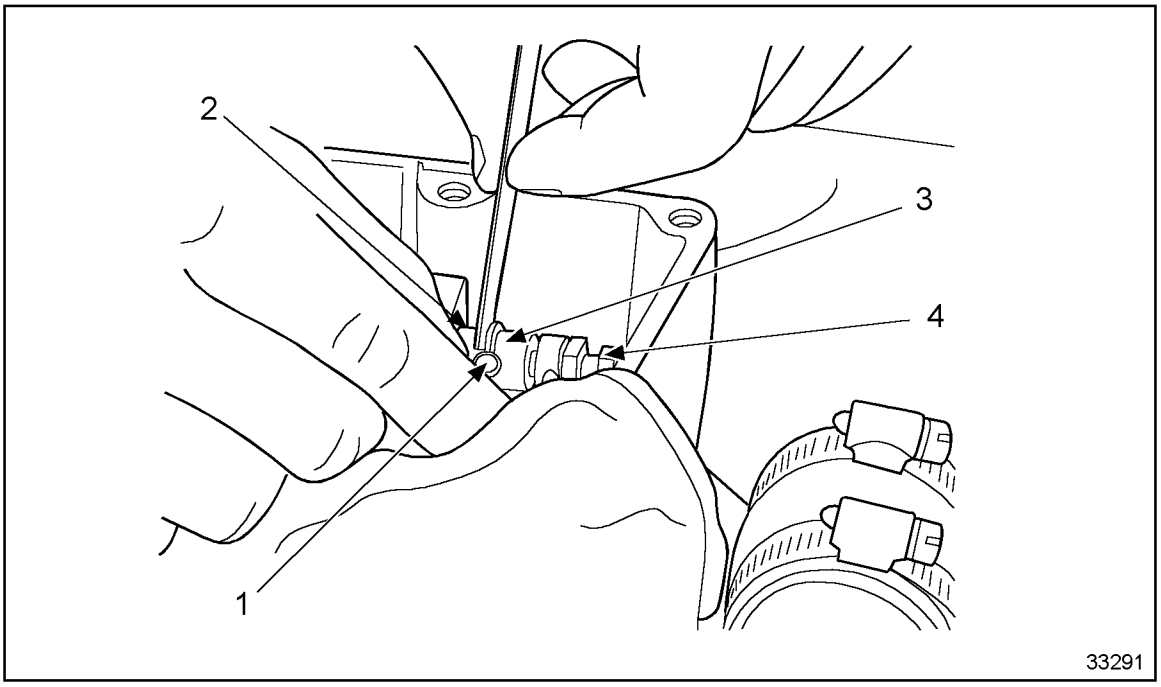
7. Use a feeler gage to set the gap between the low speed spring cap and the high speed spring plunger at 5.161 mm (0.2032 in.).
8. Tighten the governor gap adjusting screw locknut. See Figure 12-82 and see Figure 12-83.



1. Spring Cap
2. Spring Retainer
3. Locknut
4. Bushing
5. Washer
6. Belleville Spring Washer
7. Washer
8. Set Screw
9. Retainer Nut
10. Idle Speed Adjusting Screw
11. Locknut
12. Idle Speed Ping
13. Plunger
14. High Speed Spring
15. Low Speed Spring Seat
16.. Low Speed Spring

Figure 12-82 High and Low Speed Spring and Plunger

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1. Differential Lever Pin
2. High Speed Plunger
3. Low Speed Spring Cap
4. Gap Adjusting Screw

Figure 12-83 Adjusting Governor Gap

9. Push down on the governor weight wedge tool to ensure it did not move while the gap was being set.
10. Check the gap while holding the tool in this position.
11. If the gap is incorrect, reset to 0.20 mm (0.008 in.).
12. Remove the wedge.

NOTE:
The buffer, idle speed, no-load speed and starting aid screws, the injector racks, and supplemental governor devices require adjustment whenever the governor gap is changed.

13. Reset Belleville springs. Refer to section 12.9.

12.6.3 Setting the Gap (Governor on a Bench)

Set the gap as follows:

NOTE:
When setting the governor gap on a bench, the governor must be mounted on a blower to support and protect the governor weight carrier shaft.

1. Position the idle screw.

NOTE:
On all Non- "TT" governors with a normal 25.4 mm (1.00 in.) long idle adjustment screw, the screw should be set so that it extends 8.26 mm (0.325 in.). On all "TT" governors with a normal 25.4 mm (1.00 in.) long idle adjustment screw, the screw should be set to extend 10.16 mm (0.400 in.). This dimension is measured from the face of the idle speed adjusting screw locknut to the end of the idle speed adjusting screw with a tolerance of ± 0.38 mm (± 0.015 in.). For governors with a variable high-speed option, which use a 44.5 mm (1.75 in.) long idle adjustment screw, the screw should be set to extend 27.31 mm (1.075 in.) on all non- "TT" governors or 29.21 mm (1.150 in.) on all "TT" governors. These idle screw projections result in a nominal 600 RPM idle speed.

2. Rotate the governor weights until they are in a horizontal position.
3. Insert governor weight wedge tool J 35516 between the low-speed weight and the governor riser.

NOTE:
The tapered face of the wedge should be against the riser and positioned between the flanges on the ends of the riser. To prevent the weights from rotating when the governor weight wedge tool is inserted, a clean, soft rag should be wedged between the blower housing and the blower rotors.

4. Push the wedge as far to the bottom as it will go, forcing the weights against the maximum travel stop.

NOTICE:
To prevent damage to the weights, riser, or housing, do not use a screwdriver to pry the weights.

5. Ensure governor high-speed spring plunger is seated.
6. Turn in the high-speed retainer as required to seat the plunger.
7. With the wedge in the bottom position, use a feeler gage between the low speed spring cap and the high speed spring plunger to set the gap at 0.20 mm (0.008 in.).
8. Tighten the governor gap adjusting screw locknut.
9. Push down on the governor weight wedge tool to ensure it did not move while the gap was being set.
10. Check the gap while holding the tool in this position.
11. If the gap is incorrect, reset to 0.20 mm (0.008 in.).
12. Remove the wedge, and install the cover using a new gasket.

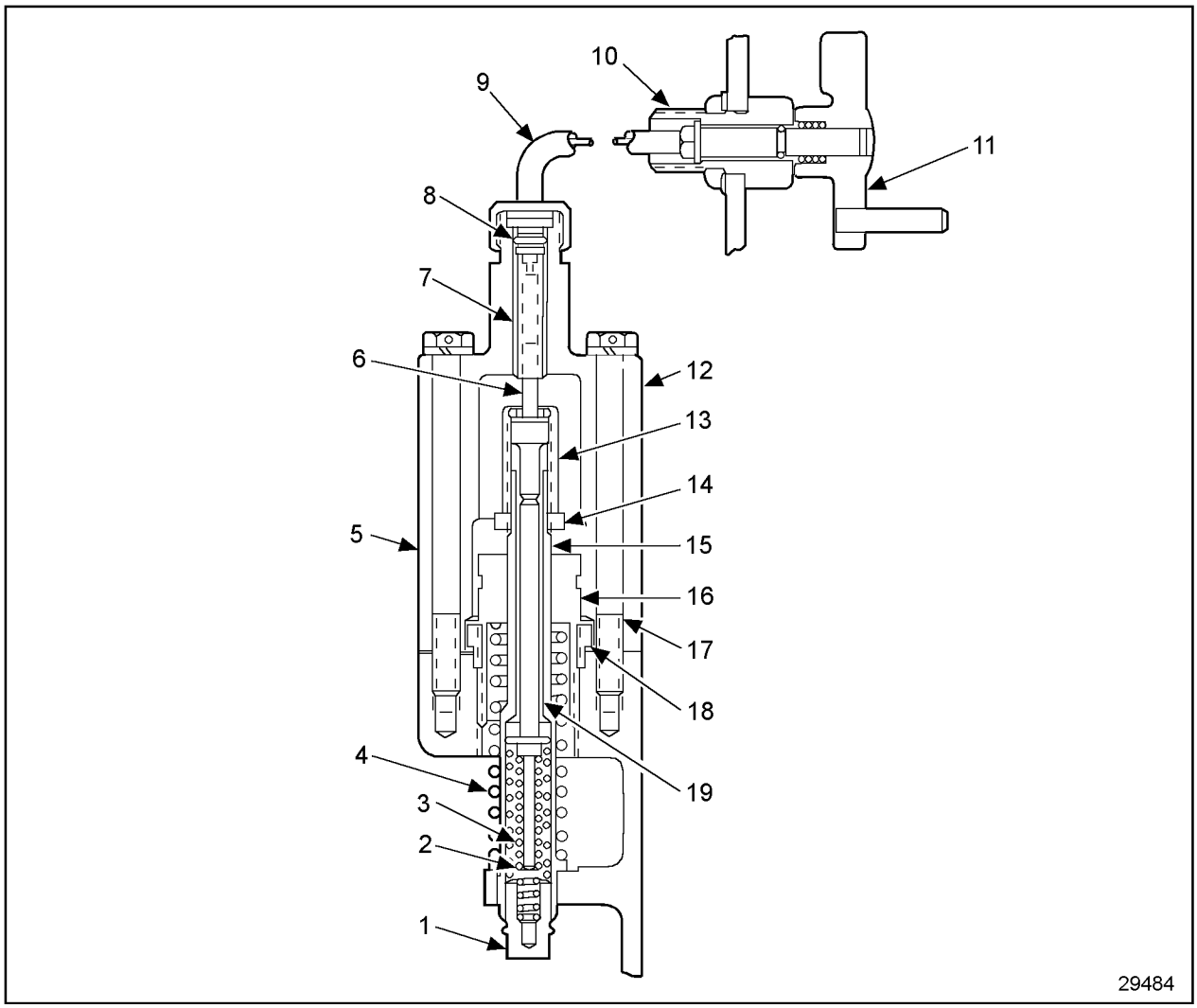
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12.7 LIMITING SPEED MECHANICAL GOVERNOR ADJUSTMENT (VARIABLE LOW-SPEED)

The governor is a single-weight type and provides an idle speed range of 500 to 1800 RPM.

At the unloading area, the throttle is left in the idle speed position and the speed adjusting handle on the cable operated governor is turned to the speed required within the above range to operate the auxiliary equipment. See Figure 12-84. For the air operated governor, increasing or decreasing the air supply pressure to the governor changes the engine speed as required. See Figure 12-85 and see Figure 12-86. The governor functions as a variable speed governor, maintaining a constant speed when the load is constantly changing during the unloading operation. Before resuming highway operations, the speed adjusting handle on the cable operated governor must be turned to the stop, then turned ahead about one-quarter turn. The air operated governor air supply pressure must be vented before resuming highway operations.

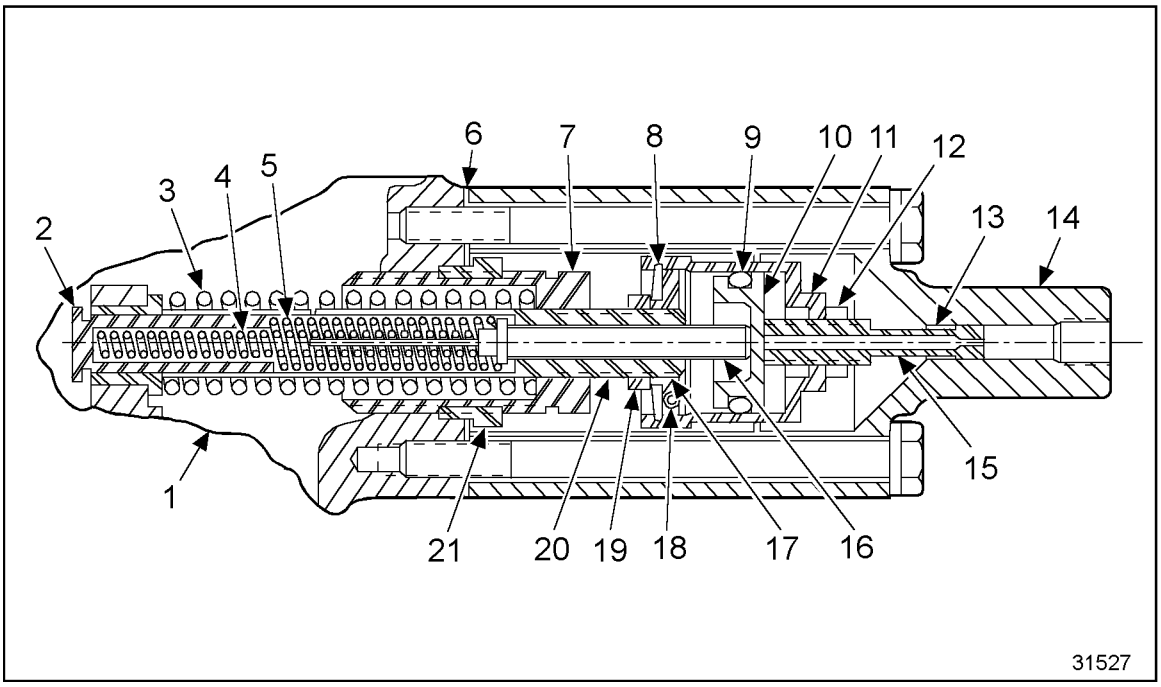
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1. Low Speed Spring Cap
2. Low Speed Spring (Outer)
3. Low Speed Spring (Inner)
4. High Speed Spring
5. Governor Housing
6. Adjusting Shaft
7. Adjusting Coupling
8. Seal Ring
9. Flexible Shaft
10. Manual Control Assembly
11. Speed Adjusting Handle
12. Spring Housing
13. Adjusting Shaft Retainer
14. Adjusting Locknut
15. High Speed Spring Plunger
16. High Speed Spring Retainer
17. Gasket
18. Spring Retainer Locknut
19. Low Speed Spring Plunger

Figure 12-84 Cable Operated Governor Spring Housing and Components

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1. Governor Housing
2. Spring Cap
3. High Speed Spring
4. Idle Spring (Inner)
5. Idle Spring (Outer)
6. Gasket
7. Spring Retainer
8. Retainer Nut
9. Seal Ring
10. Piston
11. Air Cylinder
12. Idle Speed Jam Nut
13. Seal Ring
14. Spring Housing
15. Idle Speed Adjusting Screw
16. Idle Speed Plunger
17. Air Cap
18. Pin
19. High Speed Jam Nut
20. High Speed Plunger
21. Retainer Locknut

Figure 12-85 Air Operated Variable Low Speed Limiting Speed Governor (1 of 2)

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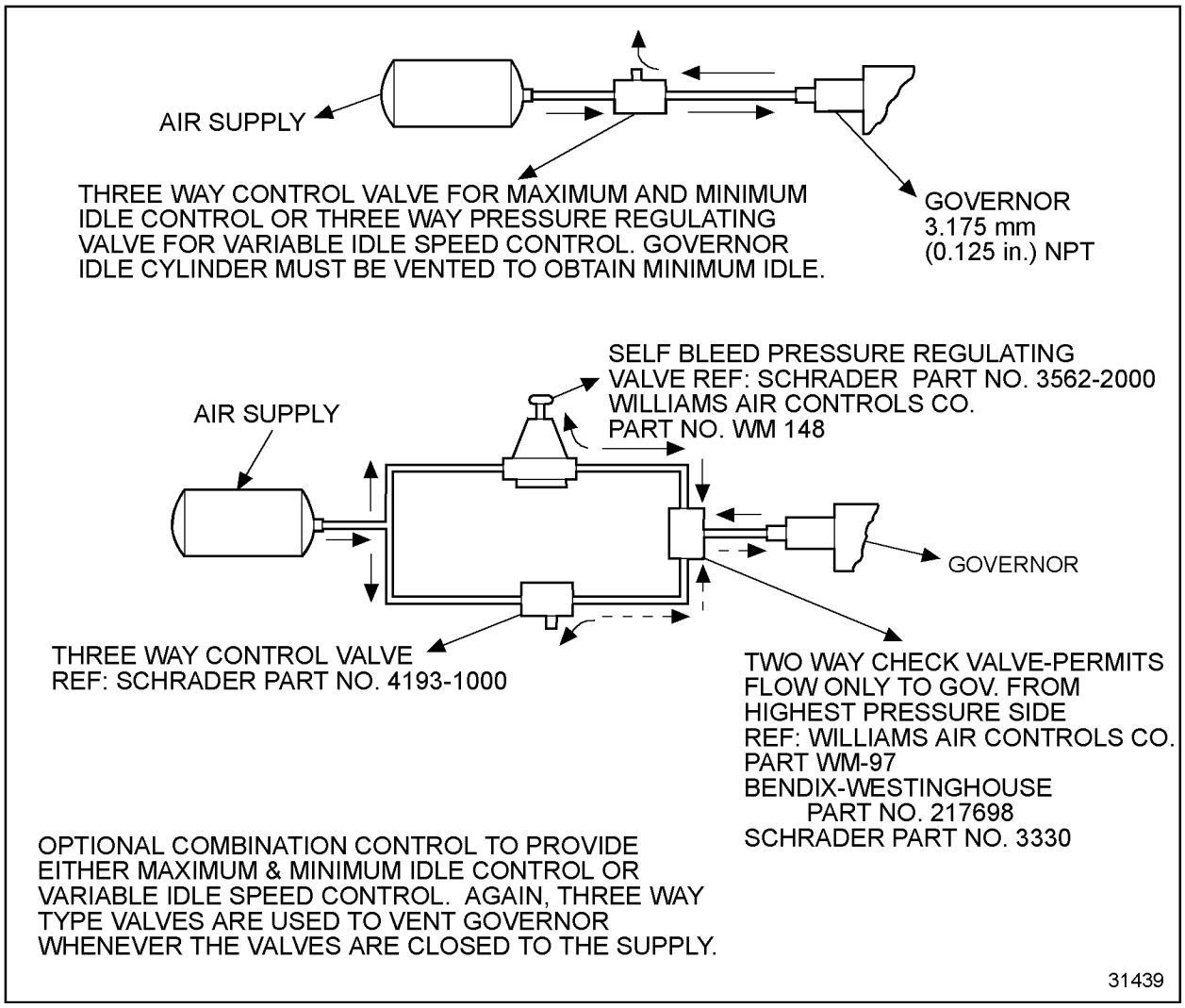


Figure 12-86 Variable Low Speed Limiting Speed Governor Optional Combination Air Controls (2 of 2)

CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

After adjusting the exhaust valves and timing the injectors, adjust the governor and position the injector rack control levers.

12.7.1 Governor Gap Adjustment

With the engine at operating temperature, adjust the governor gap as follows:

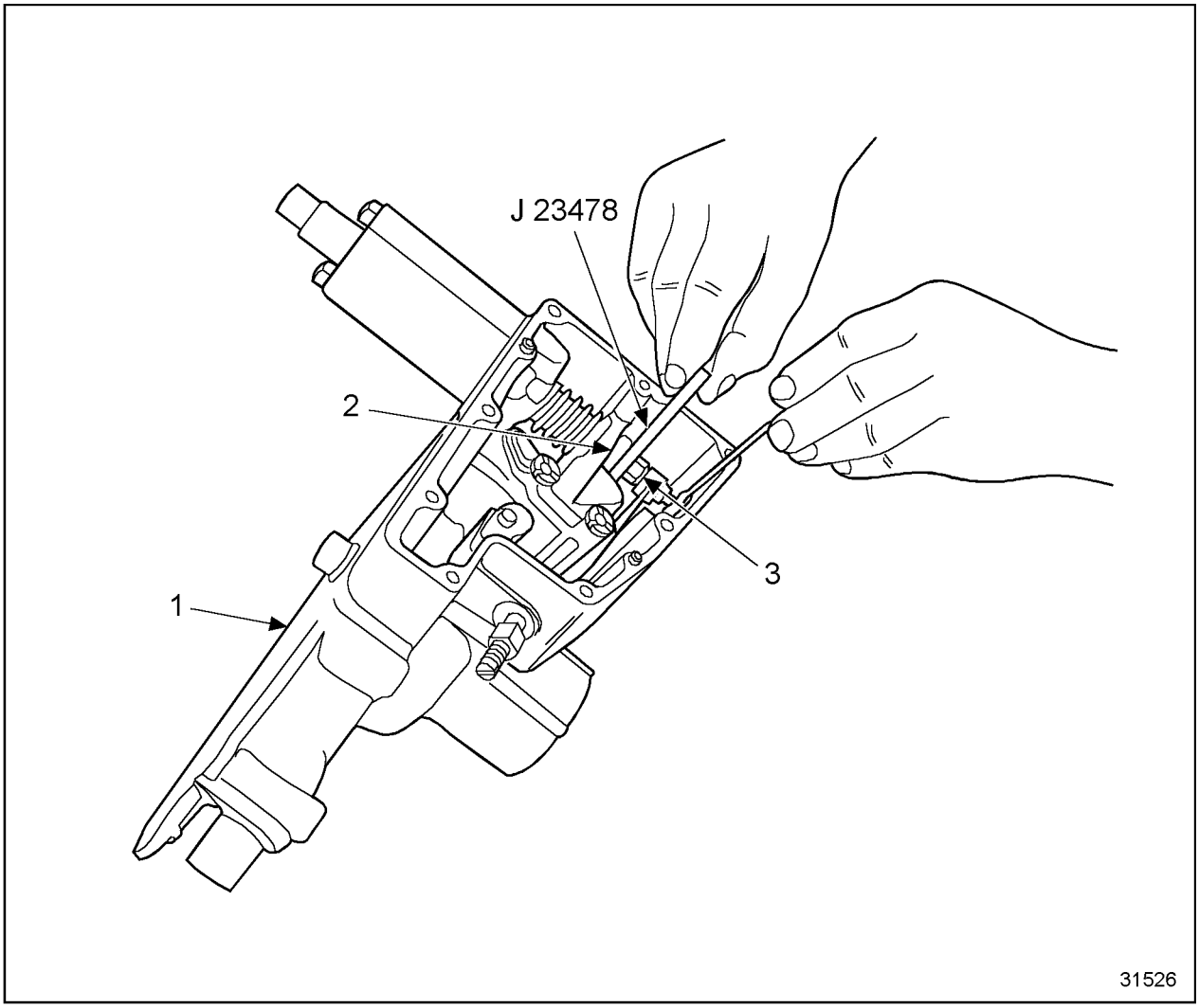
1. Stop the engine.

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2. Back out the buffer screw until it extends approximately 15.88 mm (0.625 in.) from the locknut.
3. Remove the governor cover and lever assembly.

NOTE:
Ensure external starting aid screw is backed out far enough to make it ineffective when making this adjustment.

4. Check the gap 5.08 mm (0.200 in.) between the low-speed spring cap and the high-speed spring plunger with gage J 23478. See Figure 12-87. A 5.08 mm (0.200 in.) stack-up of feeler gages can be used to check the gap if the gage is not available.



1. Governor Housing Assembly
2. High Speed Spring Assembly
3. Low Speed Spring Cap

Figure 12-87 Adjusting Governor Gap (Single Weight Governor) with Feeler Gage J 23478

5. If required, loosen the locknut, and turn the gap adjusting screw until the gage slightly drags.
6. Hold the adjusting screw, and tighten the locknut.
7. Check the gap, and adjust, if necessary.
8. Affix a new gasket to the top of the governor housing.

CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

9. Place the governor cover assembly on the governor housing with the stop control shaft assembly pin in the differential lever slot and the housing dowel pins in the cover dowel pin holes.

12.7.2 Position Injector Rack Control Levers

If the governor gap was adjusted, position the injector rack control levers. Refer to section 12.4.7.

12.7.3 Inspection of Spring Housing Gasket

Inspect the spring housing gasket as follows:

1. Remove the spring housing from the governor housing.
2. Check the gasket for tears or breaks.
   [a] If torn or broken, replace the gasket.
   [b] If not torn or broken, continue inspection.

NOTE:
When removing the spring pack, care should be taken so that the low-speed spring cap does not fall off the spring pack into the governor.

3. If the gasket requires replacement, remove the spring pack from the governor housing, replace the gasket, and install the spring pack.

12.7.4 Maximum No-Load Engine Speed Adjustment

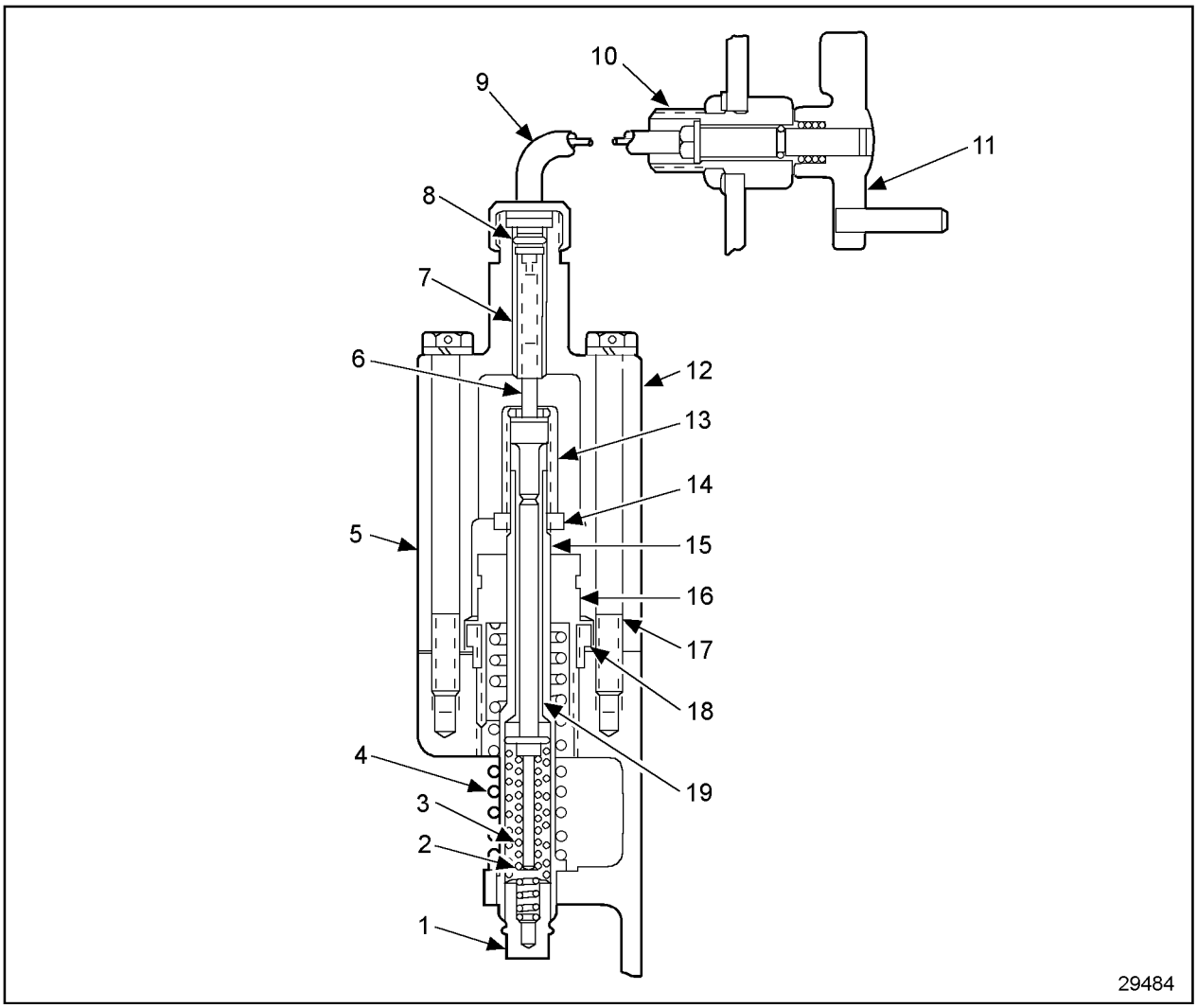
Adjust the maximum no-load engine speed. Refer to section 12.4.16.

12.7.5 Adjustment of Cable Operated Governor Idle Speed

Adjust cable operated governor idle speed as follows:

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1. Back out the variable low-speed adjusting shaft until the shoulder on the shaft contacts the shaft retainer. See Figure 12-88.



1. Low Speed Spring Cap
2. Low Speed Spring (Outer)
3. Low Speed Spring (Inner)
4. High Speed Spring
5. Governor Housing
6. Adjusting Shaft
7. Adjusting Coupling
8. Seal Ring
9. Flexible Shaft
10. Manual Control Assembly
11. Speed Adjusting Handle
12. Spring Housing
13. Adjusting Shaft Retainer
14. Adjusting Locknut
15. High Speed Spring Plunger
16. High Speed Spring Retainer
17. Gasket
18. Spring Retainer
19. Low Speed Spring Plunger

Figure 12-88 Cable Operated Governor Spring Housing and Components

2. Hold the locknut, and loosen the low-speed adjusting shaft retainer.
3. Start the engine.
4. Adjust the retainer and shaft assembly to obtain the desired idle speed (500 RPM minimum).
5. Hold the retainer, and tighten the locknut to retain the adjustment.

NOTE:
It may be necessary to use the buffer screw to eliminate engine roll.

6. Place the spring housing over the spring pack.
7. Install the variable low-speed adjuster coupling.
8. Center the coupling before securing the spring housing to the governor.
9. Tighten the attaching bolts.
10. Install the flexible shaft and manual control assembly.
11. Use the speed adjusting handle to check idle speed settings.

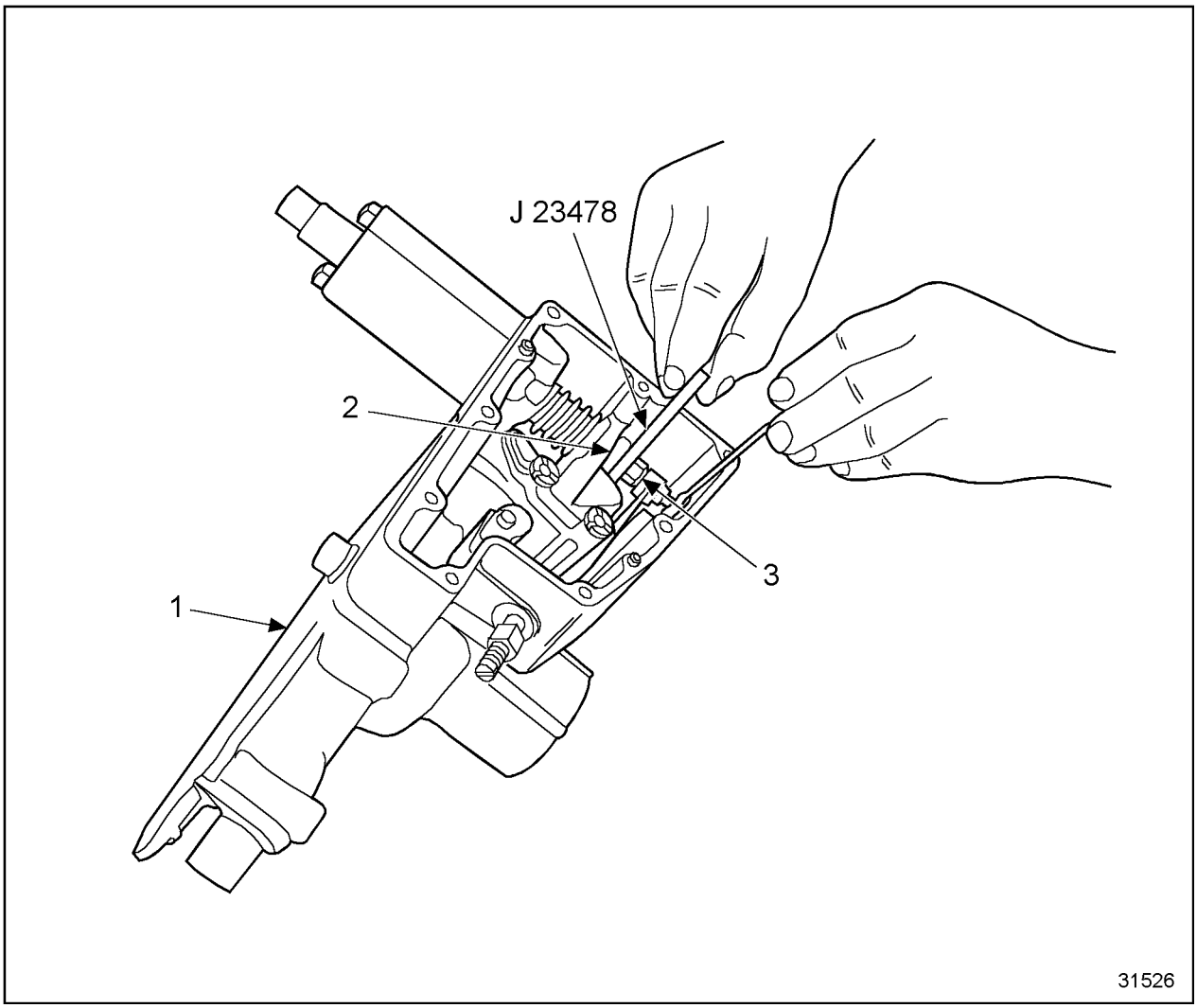
12.7.6 Adjustment of Air Operated Governor Maximum Idle Speed

Adjust the air operated governor maximum idle speed as follows:

1. Remove the air cylinder assembly from the high-speed plunger.
2. Loosen the idle speed jam nut.

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3. Turn the idle speed adjusting screw clockwise into the air cylinder until the piston contacts the air cap and the air cap contacts the retainer ring. See Figure 12-89.



1. Governor Housing Assembly
2. High Speed Spring Plunger
3. Low Speed Spring Cap

Figure 12-89 Adjusting Governor Gap (Single Weight Governor) with Feeler Gage J 23478 (0.200 in.)

4. Rotate the air cylinder on the high-speed plunger 2-3 turns.
5. Start the engine.
6. With the speed control lever in the idle position, turn the air cylinder clockwise to raise the idle speed and counterclockwise to lower the idle speed.

NOTE:
Initial observed idle speed will be between the minimum and maximum idle speeds.

7. Lock the air cylinder to the high-speed plunger with the jam nut in the maximum idle speed position.

12.7.7 Adjustment of Air Operated Governor Minimum Idle Speed)

Adjust the air operated governor minimum idle speed as follows:

NOTE:
Make this adjustment after the maximum idle speed adjustment is completed.

1. Run the engine with the speed control lever in the idle speed position.
2. Turn the idle speed adjusting screw counterclockwise to lower the idle speed.

NOTE:
Over 3.18 mm (0.125 in.) screw travel is required to reach minimum idle speed.

3. Tighten the jam nut when desired minimum idle speed is reached.

NOTE:
It may be necessary to use the buffer screw to eliminate engine roll.

4. Install the spring housing over the spring pack.
5. Tighten the attaching bolts.
6. Connect the air supply to the spring housing.
7. Apply and vary air pressure to check the idle speed settings.

NOTE:
If speeds of less than 1800 RPM are always required, the speed can be set and achieved with unregulated air. Additional lower speeds can be achieved with regulated air pressure.

12.7.8 Adjustment of Buffer Screw

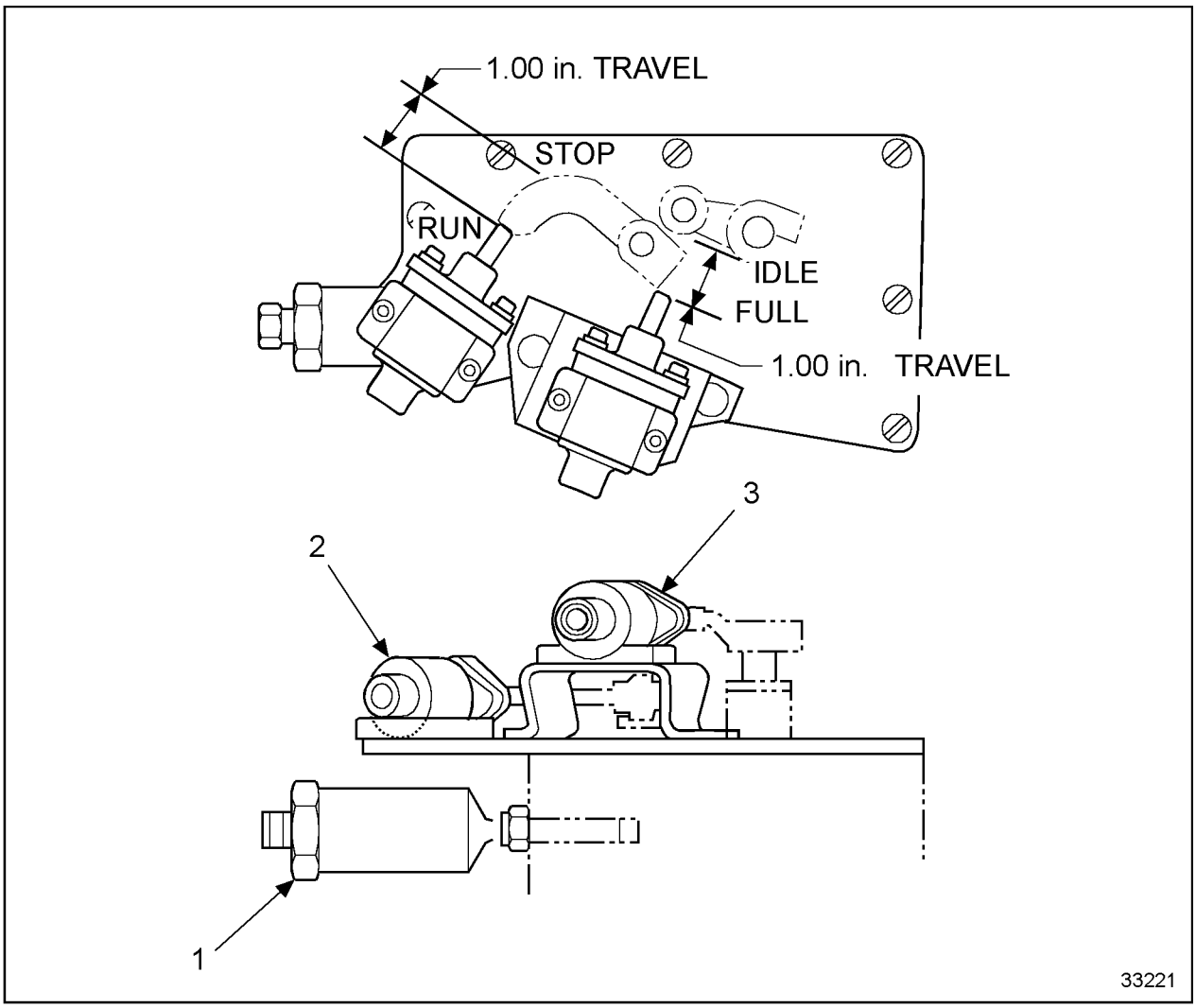
Adjust the buffer screw if not already done during the tune-up. Refer to section 12.10.6.

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12.8 LIMITING SPEED MECHANICAL GOVERNOR FAST IDLE CYLINDER

The limiting speed governor equipped with a fast idle air cylinder is used on vehicle engines where the engine powers both the vehicle and auxiliary equipment.

The fast idle system consists of a fast idle air cylinder installed in place of the buffer screw and a throttle locking air cylinder mounted on a bracket fastened to the governor cover. See Figure 12-90. An engine shutdown air cylinder, if used, is mounted on the governor cover.



1. Fast Idle Air Cylinder
2. Shutdown Air Cylinder
3. Throttle Locking Air Cylinder

Figure 12-90 Governor with Fast Idle Cylinder

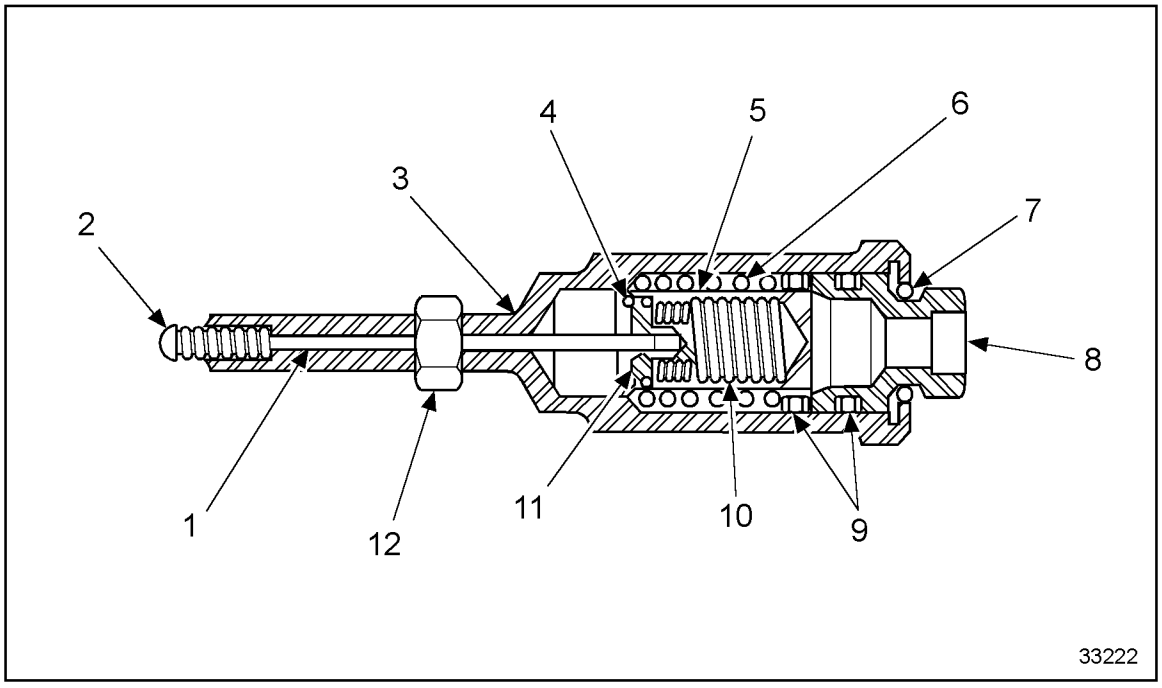
Air from a common air line actuates the fast idle air cylinder and the throttle locking air cylinder in unison. The engine shutdown air cylinder is connected to a separate air line.

An electric solenoid actuated air valve controls the air supply for the fast idle air cylinder. The fast idle system should be installed so that it will function only when the parking brake system is in operation. This makes it tamper-proof.

The vehicle accelerator-to-governor throttle linkage is connected to a yield link. The operator cannot overcome the force of the air cylinder holding the speed control lever in the idle position while the engine is operating at the single fixed high idle speed.

During highway operation, the governor functions as a limiting speed governor.

For auxiliary equipment operation, the vehicle is stopped and the parking brake set. With the engine running, the low speed switch is placed in the on position. When the fast idle air cylinder is actuated, the dual idle spring force is added to the governor low-speed spring force, increasing the engine idle speed. See Figure 12-91.



1. Plunger
2. Spring
3. Cylinder
4. Follower
5. Piston
6. Return Spring
7. Ring
8. Inlet Plug
9. O-rings
10. Dual Idle Spring
11. Ring
12. Nut

Figure 12-91 Cutaway of Fast Idle Air Cylinder

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The governor now functions as a constant speed governor at the high idle speed setting, maintaining a near constant engine speed regardless of the load within the engine capacity. The fast idle system provides a single fixed high idle speed that is not adjustable, except by disassembling the fast idle air cylinder and changing the dual idle spring. As with all mechanical governors, when load is applied, the governor droop will determine the engine speed.

12.8.1 Governor Adjustment

To adjust the governor, refer to section 12.4.16. Before adjusting the governor gap, back out the de-energized fast idle air cylinder until it will not interfere with the governor adjustments. After the normal idle speed setting is made, adjust the de-energized fast idle air cylinder as follows:

1. Turn in the fast idle cylinder assembly until the speed increases.

NOTE:
The increase in idle speed should not exceed 15 RPM.

2. Tighten the fast idle jam nut.

⚠ CAUTION:

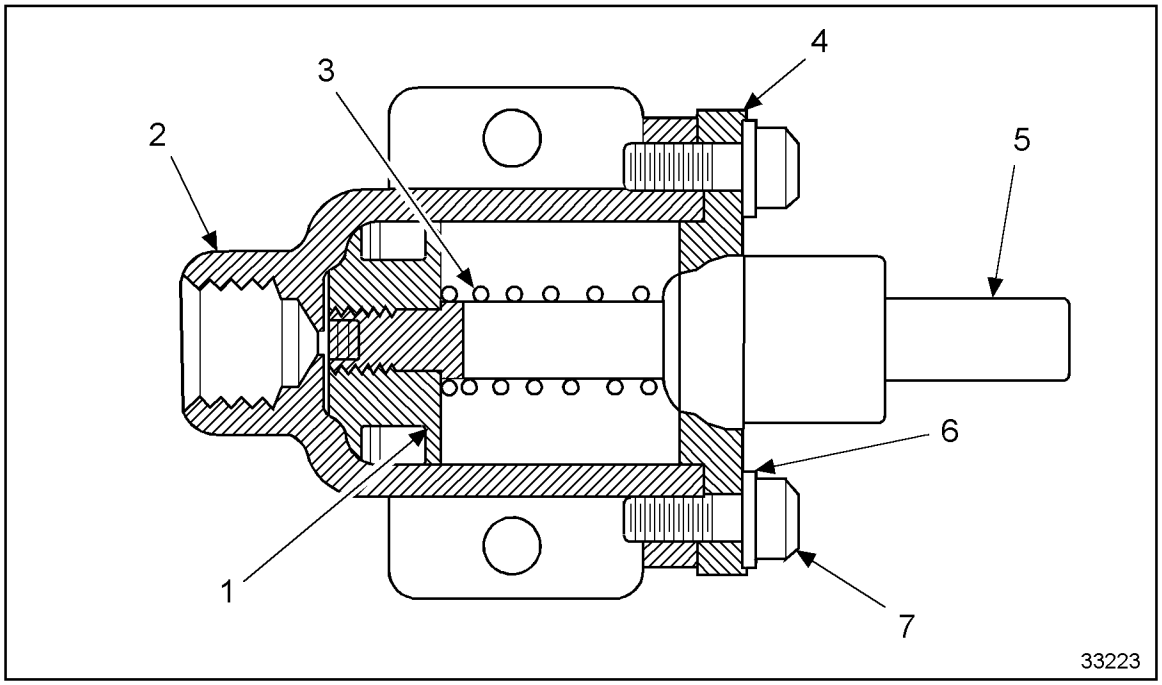
To avoid injury from flying debris when using compressed air, wear adequate eye protection (face shield or safety goggles) and do not exceed 40 psi (276 kPa) air pressure.

3. Lock the governor throttle in the idle position, and apply full shop air pressure to the fast idle air cylinder.

NOTE:
The engine idle speed must increase from 325 to 500 RPM ± 50 RPM, depending on the original idle speed setting and fast idle spring used.

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The throttle locking air cylinder is adjusted on its mounting bracket so it will lock the throttle in the idle position when it is activated, but will not limit the throttle movement when not activated. See Figure 12-92.



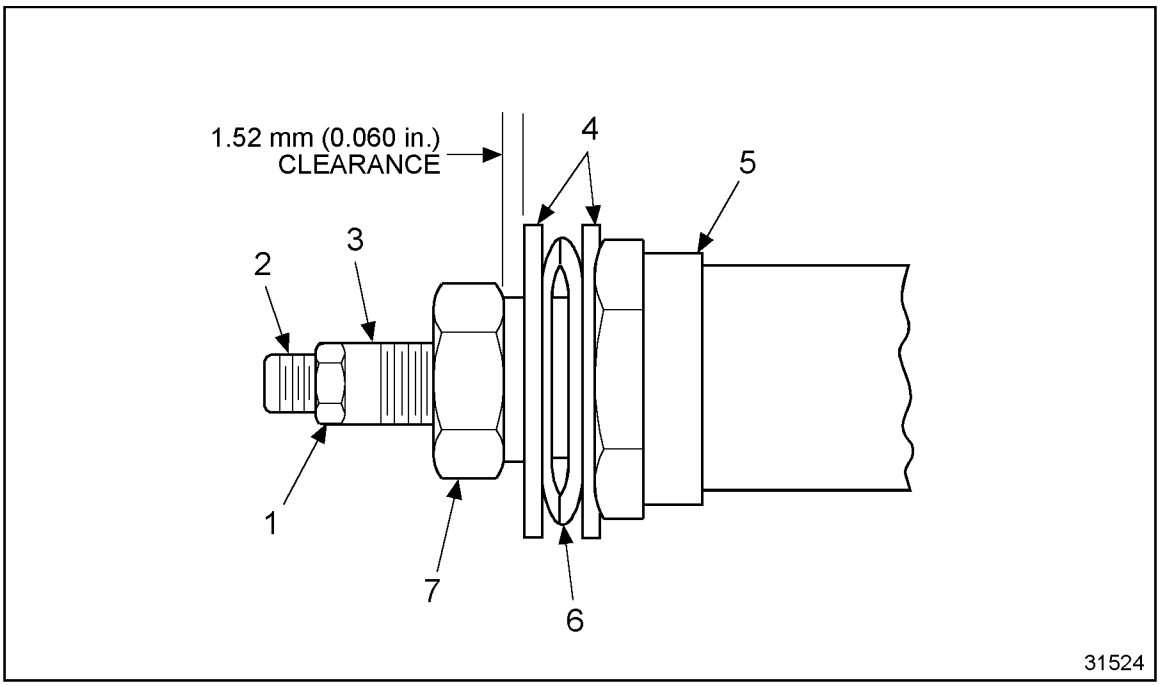
1. Piston
2. Cylinder
3. Return Spring
4. Cap
5. Piston Rod
6. Lock Washer
7. Screw

Figure 12-92 Cutaway of Throttle Locking Air Cylinder

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12.9 GOVERNOR SETTINGS FOR "TT" ENGINES

Two Belleville springs (washers) in a limiting speed governor achieves the ability to maintain reasonably constant horsepower over a wide speed range and a 6% torque rise per 100 RPM. See Figure 12-93.



1. Locknut
2. Idle Screw
3. Plunger
4. Washers
5. High Speed Spring Retainer
6. Belleville Springs
7. Belleville Spring Retainer Nut

Figure 12-93 Belleville Washer Location

NOTE:
The horsepower for "TT" engines indicate a flat horsepower performance curve. During dynamometer testing, an engine may exhibit horsepower readings slightly above or below the flat curve. A 5% horsepower variation from the flat published curve is acceptable.

The Belleville springs force works with the governor weights to pull the injector racks out of fuel as the engine speed is increased. As increased load reduces the engine speed, the high-speed spring overcomes the Belleville springs force and moves the injector racks to an increased fuel position. The racks move progressively into more fuel to maintain the constant horsepower until the racks are in full fuel at a speed near 1500 RPM.

12.9.1 Horsepower Rating and Cooling System Capacity

On-highway truck manufacturers provide cooling systems compatible with the horsepower ratings on their customer's engines. Vehicles are normally equipped with a base cooling system when a low horsepower engine is specified. A higher engine horsepower rating increases the heat rejection rate for the engine and will require an upgraded cooling system. When vehicles are ordered with higher engine horsepower ratings, truck manufacturers automatically provide upgraded cooling systems.

Most Detroit Diesel vehicle engines horsepower can be easily upgraded after the engine is put in service. Increasing the horsepower output without modifying the cooling system will lead to engine overheating when the engine is used in certain service applications and geographic areas of operation. Damage resulting from engine modifications contrary to manufacturer's recommendations will not be covered under warranty.

NOTE:
Installation and use of any fuel injectors other than those which have been certified for each engine may constitute tampering and be in violation of Federal and/or State laws.

If increased horsepower is essential to vehicle operation, the truck dealer/distributor or local Detroit Diesel distributor should be contacted to determine whether the cooling system can handle additional heat load or to specify the parts necessary to up the rating the cooling system.

A truck buyer who knows that a higher horsepower rating will be required during the vehicle life should order the vehicle with cooling system components for the higher horsepower engine or order the vehicle with the higher horsepower rating.

If the higher horsepower rating is specified, a Detroit Diesel dealer/distributor can decrease the rating of the engine to the output desired. This procedure ensures adequate cooling for all horsepower levels at which the engine will be operated. Cooling system components compatibility with other options and accessories will be provided if this procedure is followed.

12.9.2 Belleville Spring "TT" Device Adjustment

Tune-up the "TT" engine the same as a standard engine tune-up. Refer to section 12.1.

After completing the standard engine tune-up of setting injector timing, valve clearance, governor gap, injector racks and engine speeds, adjust the Belleville spring (washer) "TT" (tailor torqued) device.

Remove the piston from the throttle delay or apply shop air pressure to the fuel modulators to ensure they are inoperative during the tune-up process.

NOTE:
Use spanner wrench J 5345-E to loosen or tighten the spring retainer locknut during the no-load speed adjustment. Always use the yield link in the governor when performing the engine tune-up.

Two methods can be used for the Belleville springs adjustment for the "TT" horsepower, depending on the equipment available at the service outlet. These methods are:

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- ☐ Idle Drop - without a dynamometer
- ☐ Power Reduction Factor - using an engine, chassis or output shaft dynamometerFor satisfactory results, both methods require an engine in good condition and properly tuned.

NOTICE:
Do not attempt a Belleville spring (washer) adjustment, an idle droop setting, or a power reduction setting until an engine tune-up has been properly performed.

12.9.3 Idle Drop (Method 1)

The idle drop method is an effective, accurate means for setting "TT" horsepower.

The idle drop method requires a specific reduction in engine speed to position the Belleville springs and the governor low and high-speed springs. The governor components positions obtain the desired "TT" horsepower.

When performing an idle drop horsepower adjustment on a "TT" engine having a 102 or 118 tooth flywheel, an accurate tachometer is mandatory. Digital Tachometer J 26791 is recommended. Each one RPM error in setting the idle drop results in a two or three horsepower error.

The tachometer is installed in the flywheel housing drain plug hole. It counts the flywheel teeth, using a magnetic probe to pick up impulses off the flywheel ring gear. The electronic module displays the engine speed digitally to one decimal place within one RPM accuracy. These capabilities make it ideal for setting horsepower on the "TT" engines using the idle drop method.

To determine the number of teeth on the flywheel, when the engine flywheel part number is unknown, measure the distance from the camshaft flywheel housing cover lower bolt head and the outer circumference of the flywheel housing bell. See Figure 12-94. If this distance is approximately 1.25 in., it is a 118 tooth flywheel. For the 102 tooth flywheel, the distance will be approximately 2.5 in.

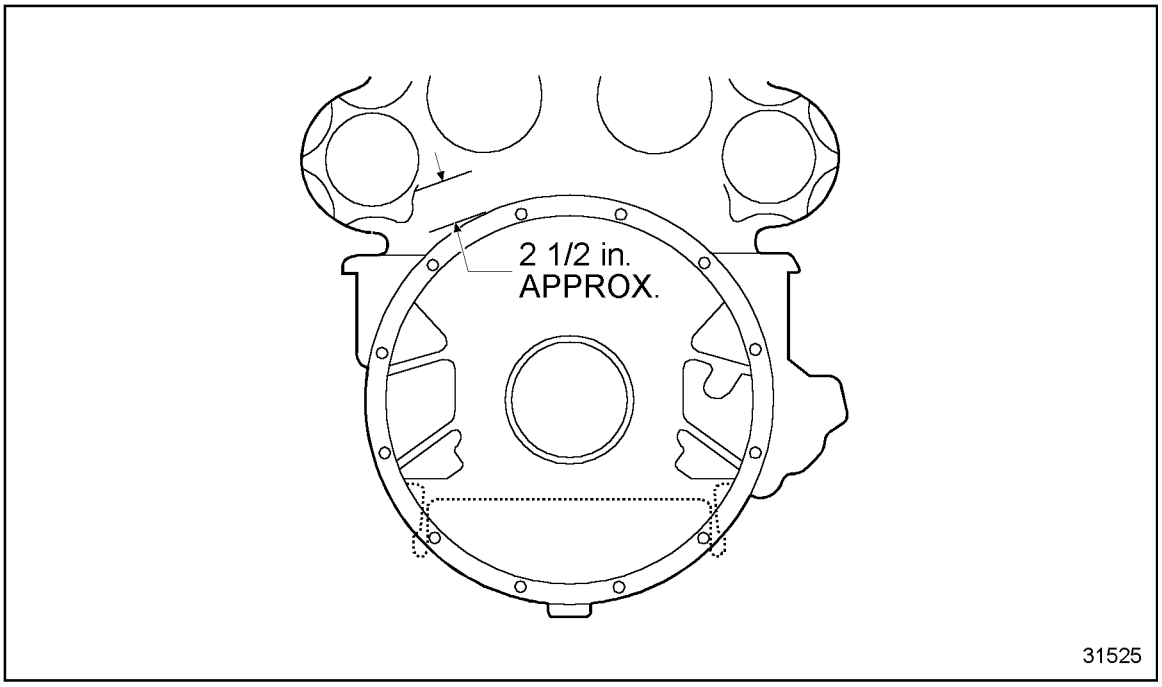


Figure 12-94 Identification of Engine Flywheel

When the number of teeth on the flywheel is known, set the switch on the tachometer to the proper position. Proceed as follows:

1. Perform the standard engine tune-up. Set the no-load speed as required by the engine type, injector size, and governor. Refer to section 12.9.6, listed in Table 12-13.
2. Disconnect the accelerator linkage from the governor speed control lever if it has not already been done.
3. Run the engine until a stabilized engine coolant temperature is obtained.
4. Use engine type, injector size, and governor listed in the 1978 Chart, and select the initial and specified idle drop numbers for the rated "TT" horsepower and rated engine speed at which the engine is to operate. Refer to section 12.9.6, listed in Table 12-13.
5. Each idle drop Chart (1979 on) includes the following information:
   - □ Maximum Full Load RPM
   - □ Governor Part Numbers
   - □ Belleville Washer Part Numbers
   - □ Injector Size
   - □ Initial Idle Drop Starting RPM

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The above should be considered to ensure the correct chart is being used. To maintain certification as required by law, the engine horsepower cannot be adjusted beyond the limits outlined on each chart.Refer to section 12.9.6, See Figure 12-96 and see Figure 12-97.

6. Using the idle adjusting screw, set the initial idle speed to that previously determined in the charts. Refer to section 12.9.6.
7. With the governor speed control lever in the idle position, turn the Belleville spring retainer nut clockwise on the plunger until the specified idle drop speed is achieved.
8. Secure the retainer nut with the locking screw. When the specified idle speed is achieved, the engine is power controlled to the "TT" horsepower rating.

NOTE:
Idle speeds must be exact and steady. If they are not, check for bind or rubbing in the governor, fuel rods, injector control tubes, and injector control racks.

9. Using the idle adjusting screw, lower the idle speed to the desired operating idle speed.
10. Adjust the buffer screw and the starting aid screw.

12.9.4 Power Reduction Factor (Method 2)

This method consists of setting "TT" engine horsepower to a specific percentage below full throttle horsepower as observed on an engine, chassis, or output shaft dynamometer.

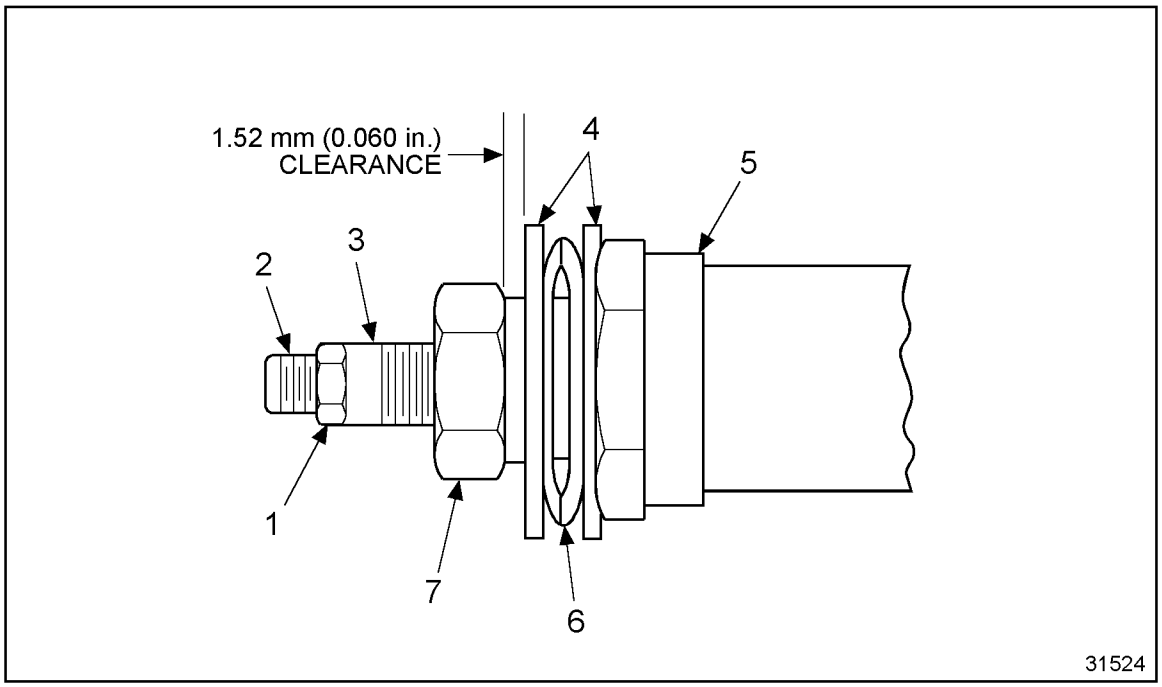
1. This method will provide the desired horsepower, within a reasonable tolerance, even with normal variations of test conditions. Some of these variations would be:
   - Dynamometer Calibration
   - Driveline Efficiency
   - Fuel Grade and Temperature
   - Air Density
   - Tire Slippage

   Proceed as follows:

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2. Perform the standard engine tune up.

NOTE:
The throttle delay piston must be removed and the Belleville spring retainer nut must be backed out until there is approximately 1.52 mm (0.060 in.) clearance between the washers and retainer nut prior to operating the engine on the dynamometer.



1. Locknut
2. Idle Screw
3. Plunger
4. Washers
5. High Speed Spring Retainer
6. Belleville Springs
7. Belleville Spring Retainer Nut

Figure 12-95 Belleville Washer Location

3. Set the no-load speed as listed in the Charts. Refer to section 12.9.6.
4. Run the engine until the engine coolant temperature is above 77°C (170°F).

NOTE:
Satisfactory power adjustment can be obtained only if the full throttle horsepower and adjusted horsepower are obtained with the engine cooling in the same mode, i.e., operating or not operating.

5. Using an engine, chassis, or output shaft dynamometer, measure and record full throttle horsepower at 100 RPM below rated engine speed with the Belleville springs loose.
6. Refer to section 12.9.6, select the power reduction factor listed in Table 12-15 or listed in Table 12-16 for the proper engine type, desired rated horsepower, and rated engine speed.

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7. Multiply the horsepower by the factor. Record this value.
8. Adjust the Belleville spring retainer nut clockwise so that the observed horsepower is reduced to that previously recorded. Refer to step 6 at 100 RPM below rated engine speed, with the governor speed control lever in the maximum speed position and the fan operating in the same mode as previously noted. Refer to step 4.
9. Verify that the engine is obtaining adjusted "TT" horsepower, within 5%, at rated engine speed.

NOTE:
If the adjusted "TT" horsepower cannot be obtained at rated engine speed, governor droop interference may be the cause.

10. To eliminate droop interference, readjust the engine no-load speed from 150 to 175 RPM above rated engine speed and repeat the power reduction factor method.
11. Check the idle speed and, if necessary, reset to the specified idle speed.
12. Adjust the buffer screw and starting aid screw.

12.9.5 Flexispec Engine Governor Adjustments "TT" Engine

When it is desirable to adjust a "TT" 6V or 8V engine to obtain non-TT maximum rated horsepower, proceed as follows:

1. Adjust the engine governor to obtain a no-load speed 175 RPM above the desired rated speed. Refer to section 12.4.16 for the no-load engine speed adjustment.
2. Position the Belleville spring retainer to provide 1.52 mm (0.060 in.) clearance between the Belleville washers and the retainer when the engine is not running.

12.9.6 Governor Idle Droop Settings for TT Engines

Listed in Table 12-13 are the 1978 governor idle droop settings for TT engines:

Engine Type	Injector Size	Throttle Delay Setting	Rated Horsepower at Rated Speed	Initial Idle	Idle Droop Setting
6V-92TT*	9290	0.570	270 at 1800 260 at 1800 250 at 1800 240 at 1800	880 880 880 880	810 804 798 792
6V-92TT*	9290	0.570	270 at 1850 260 at 1850 250 at 1850 240 at 1850	880 880 880 880	808 802 796 790

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Engine Type	Injector Size	Throttle Delay Setting	Rated Horsepower at Rated Speed	Initial Idle	Idle Droop Setting
6V-92TT*	9290	0.636	270 at 1900 260 at 1900 250 at 1900 240 at 1900	915 915 915 915	850 845 840 835
6V-92TT*	9290	0.636	270 at 1950 260 at 1950 250 at 1950 240 at 1950	915 915 915 915	848 843 838 833
6V-92TT*	9290	0.636	270 at 1900 260 at 1900 250 at 1900 240 at 1900	950 950 950 950	877 873 879 865
6V-92TT*	9290	0.636	270 at 1950 260 at 1950 250 at 1950 240 at 1950	950 950 950 950	875 871 867 863
6V-92TT*	9290	0.636	290 at 1900	915	860
6V-92TT*	9290	0.636	290 at 1950	915	858
6V-92TT*	9290	0.636	270 at 1950 260 at 1950 250 at 1950 240 at 1950	950 950 950 950	875 871 867 863
6V-92TT*	9290	0.636	270 at 2100	1075	995
6V-92TTA*	9A90	0.636	270 at 1900	975	900
6V-92TTA*	9A90	0.636	270 at 1950	975	899
6V-92TTA	9A90	0.636	270 at 1900 260 at 1900 250 at 1900 240 at 1900	915 915 915 915	838 832 825 819
6V-92TTA	9A90	0.636	270 at 1950 260 at 1950 250 at 1950 240 at 1950	915 915 915 915	837 831 824 818
6V-92TTA	9A90	0.636	270 at 2100	1075	995
8V-92TT*	9A90	0.570	335 at 1800	830	765
8V-92TT*	9A90	0.570	335 at 1850	830	763
8V-92TT	9290	0.636	365 at 1900	915	850
8V-92TT	9290	0.636	365 at 1950	915	848
8V-92TT*	9A90	0.570	365 at 1900 335 at 1900	950 950	880 870
8V-92TT*	9A90	0.570	365 at 1950 335 at 1950	950 950	878 868
8V-92TT	9290	0.636	365 at 2100	1075	1005
8V-92TTA*	9A90	0.636	335 at 1800	880	795
8V-92TTA*	9A90	0.636	335 at 1850	880	793

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Engine Type	Injector Size	Throttle Delay Setting	Rated Horsepower at Rated Speed	Initial Idle	Idle Droop Setting
8V-92TTA*	9A90	0.636	365 at 1900 335 at 1900	950 950	877 865
8V-92TTA*	9A90	0.636	365 at 1950 335 at 1950	950 950	875 863
8V-92TTA	9A90	0.636	365 at 1900 335 at 1900	950 950	867 845
8V-92TTA	9A90	0.636	365 at 1950 335 at 1950	950 950	865 843
8V-92TTA	9A90	0.636	365 at 2100	1075	1000

* Uses Belleville Spring (Orange Dye)

Table 12-13 Governor 1978 Idle Droop Settings for TT Engines

See Figure 12-96 and see Figure 12-97 containing the 1979 6V TTA idle droop settings for automotive engines.

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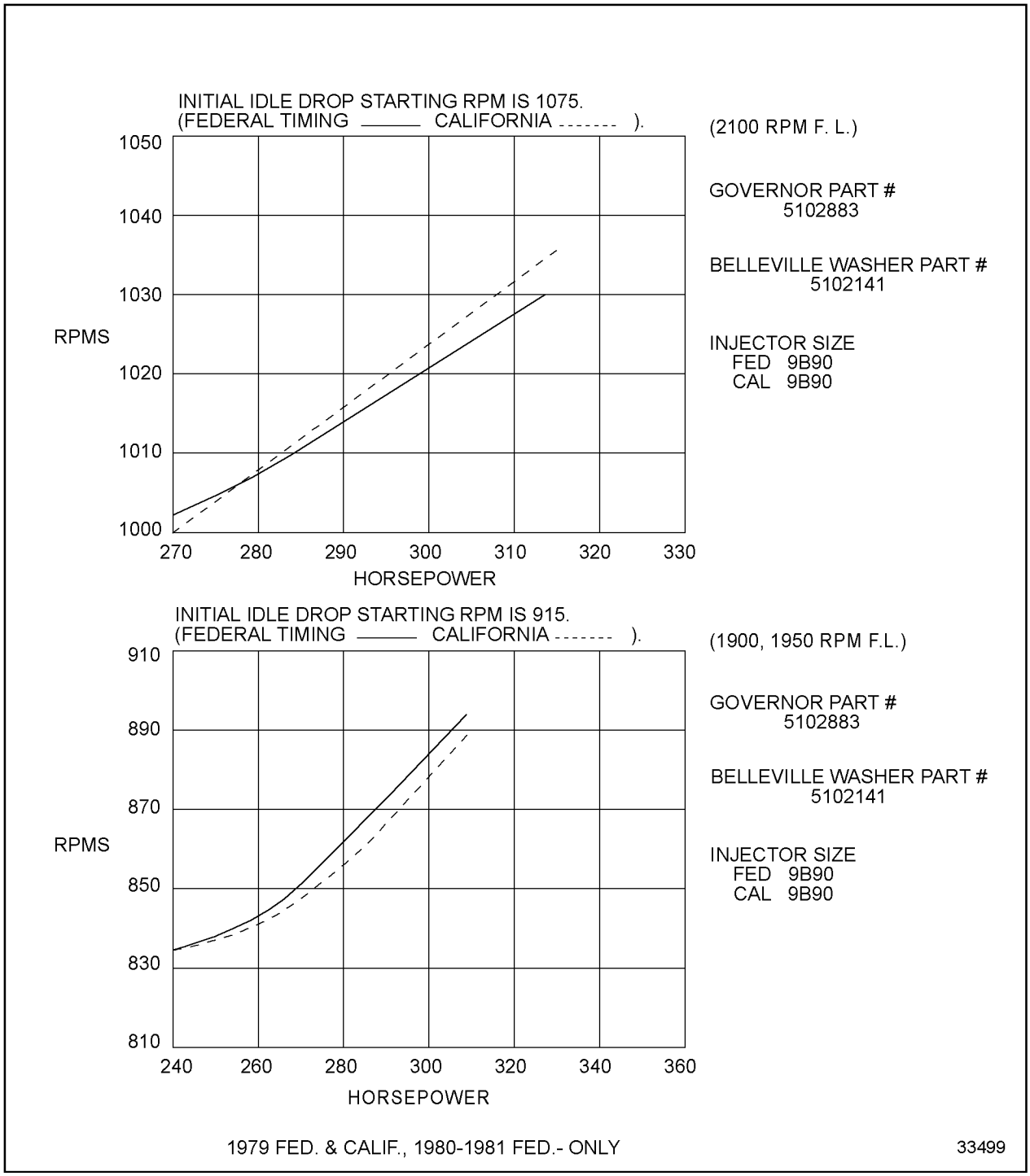


Figure 12-96 Idle Droop Settings 6V TTA for 1979 (1 of 2)

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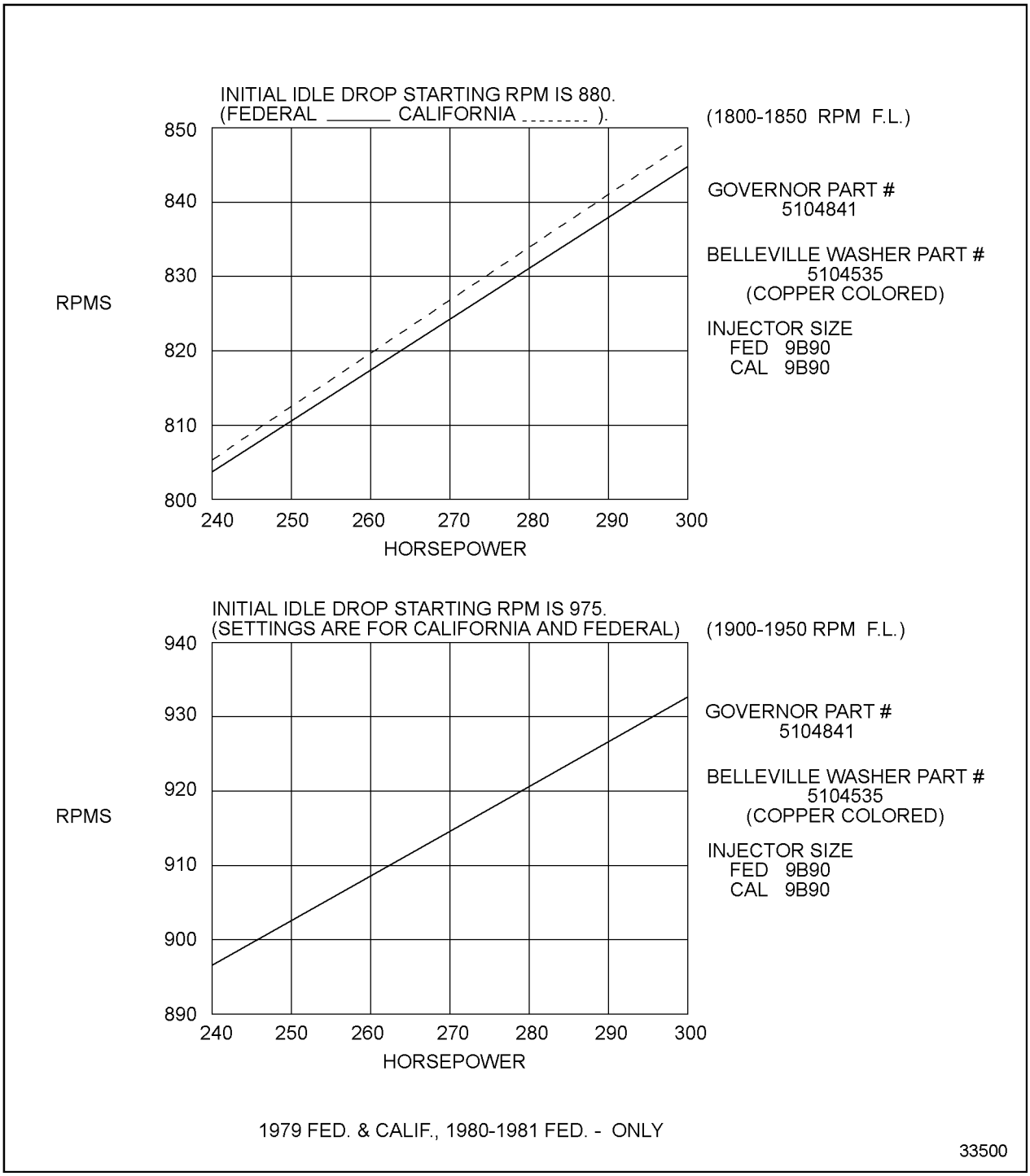


Figure 12-97 Idle Droop Settings 6V TTA for 1979 (2 of 2)

See Figure 12-98 and see Figure 12-99 for the 1982 6V typical torque settings.

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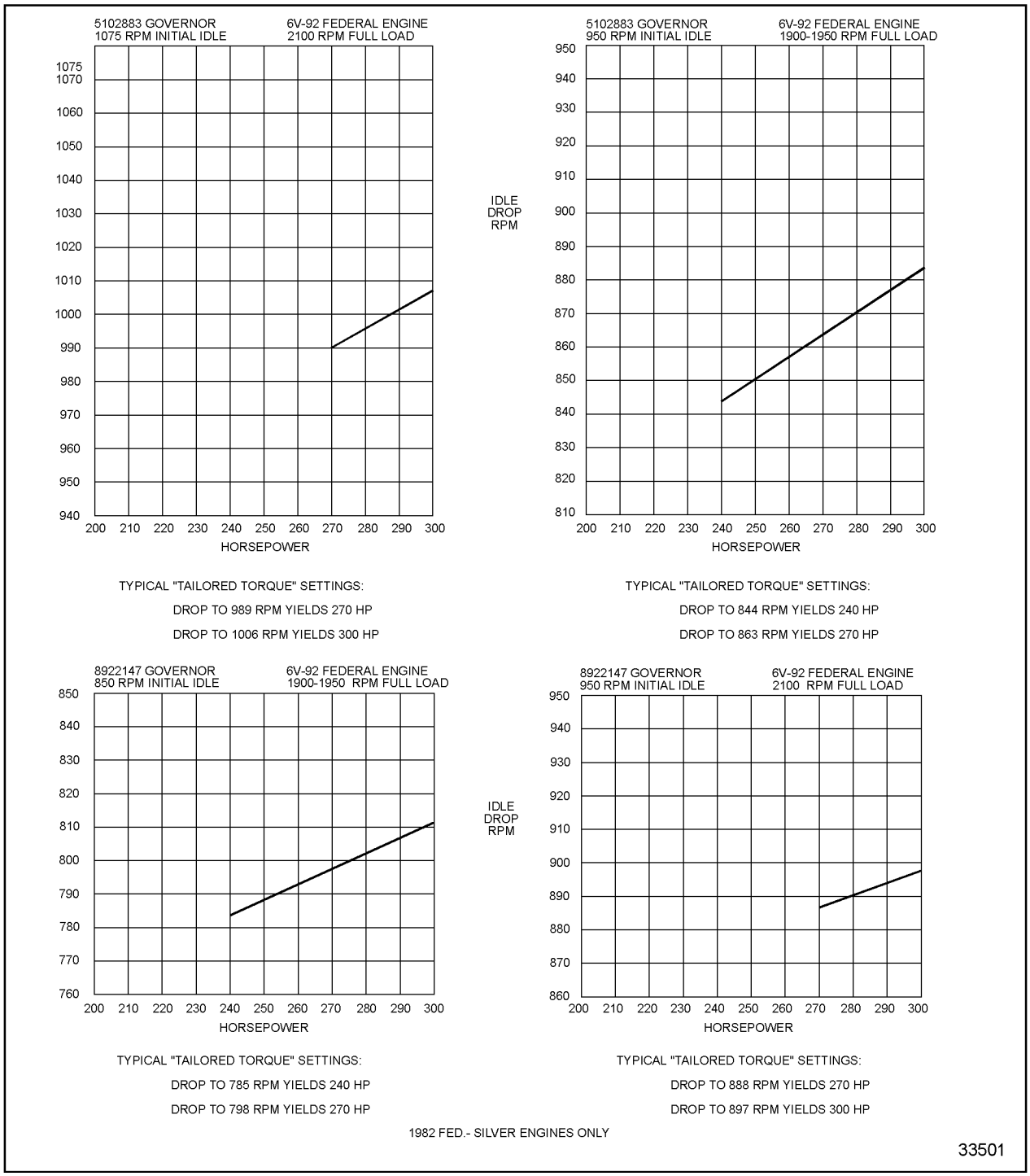


Figure 12-98 Typical Torque Settings 6V for 1982 (1 of 2)

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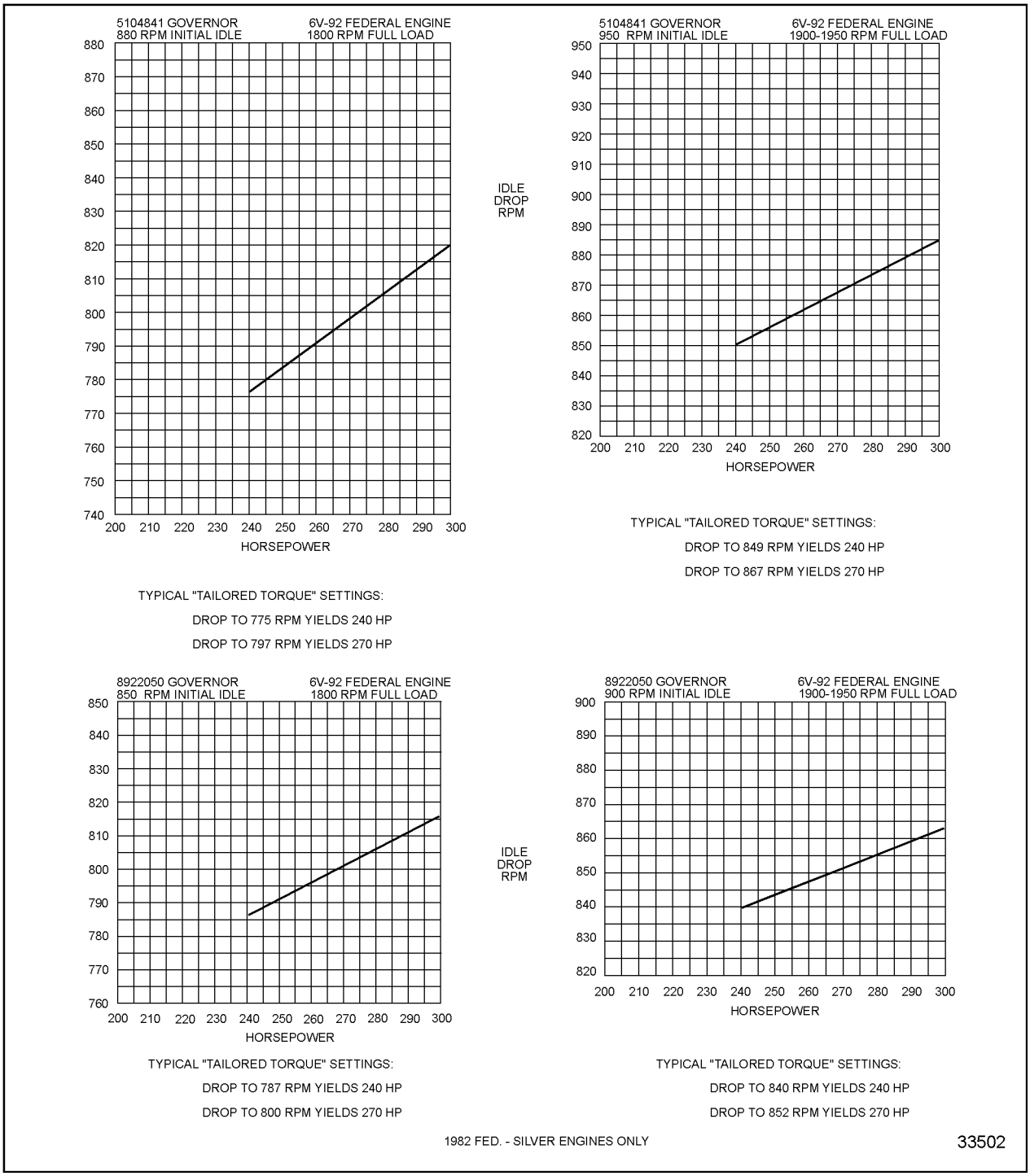


Figure 12-99 Typical Torque Settings 6V for 1982 (2 of 2)

See Figure 12-100 and see Figure 12-101 for the 1983 6V typical torque settings.

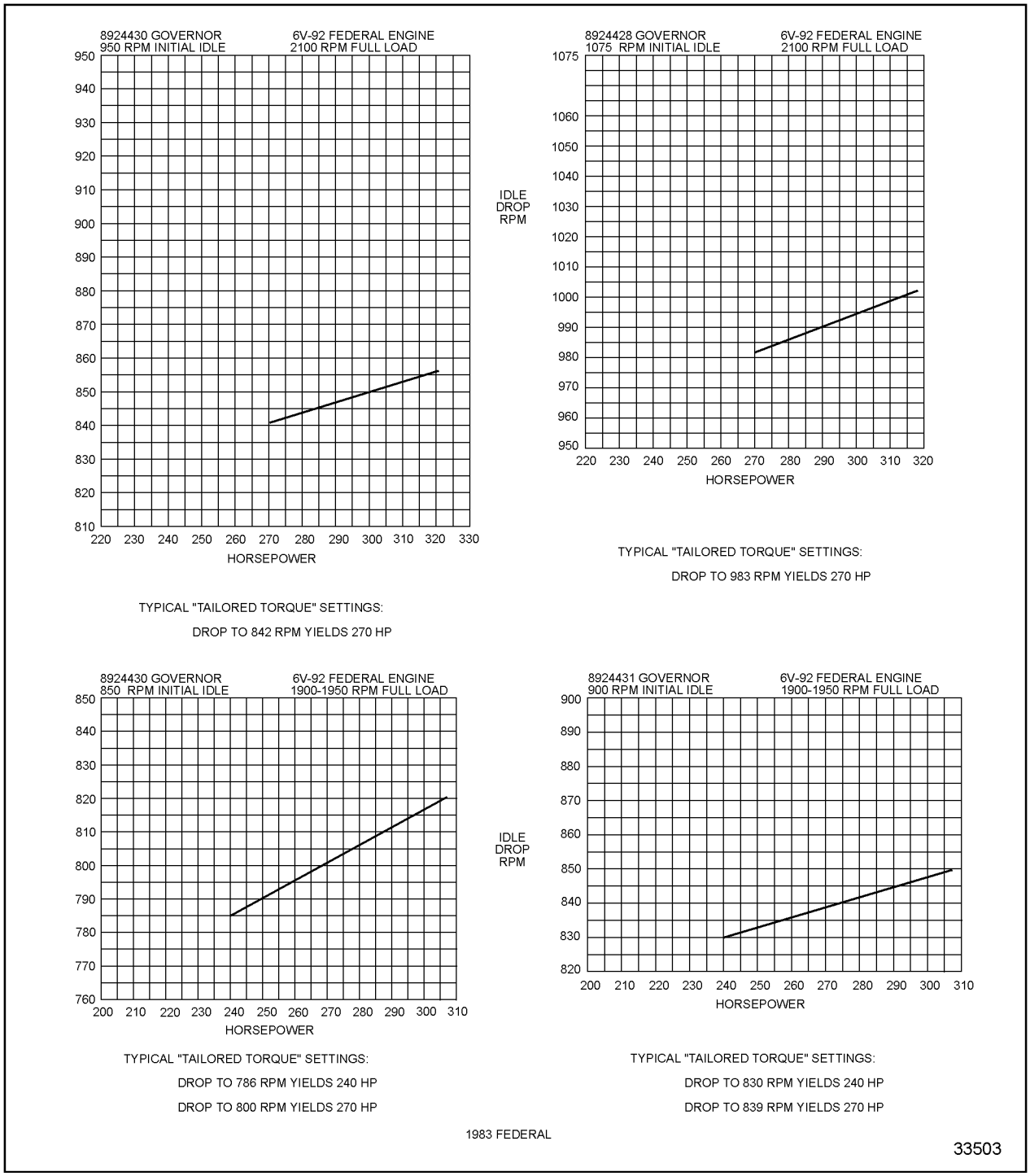


Figure 12-100 Typical Torque Settings 6V for 1983 (1 of 2)

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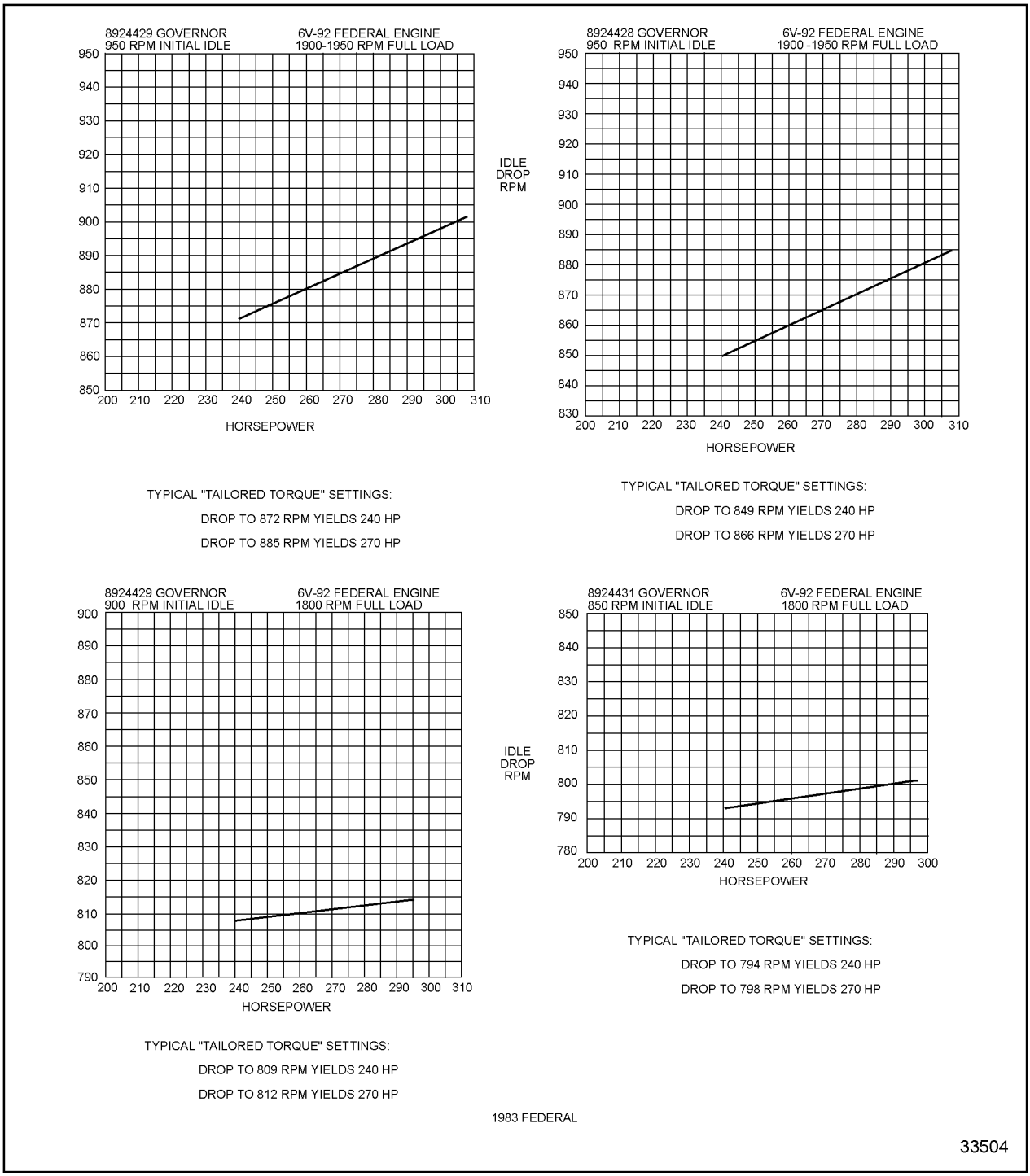


Figure 12-101 Typical Torque Settings 6V for 1983 (2 of 2)

See Figure 12-102 and see Figure 12-103 containing the 8V TTA idle droop settings for automotive engines.

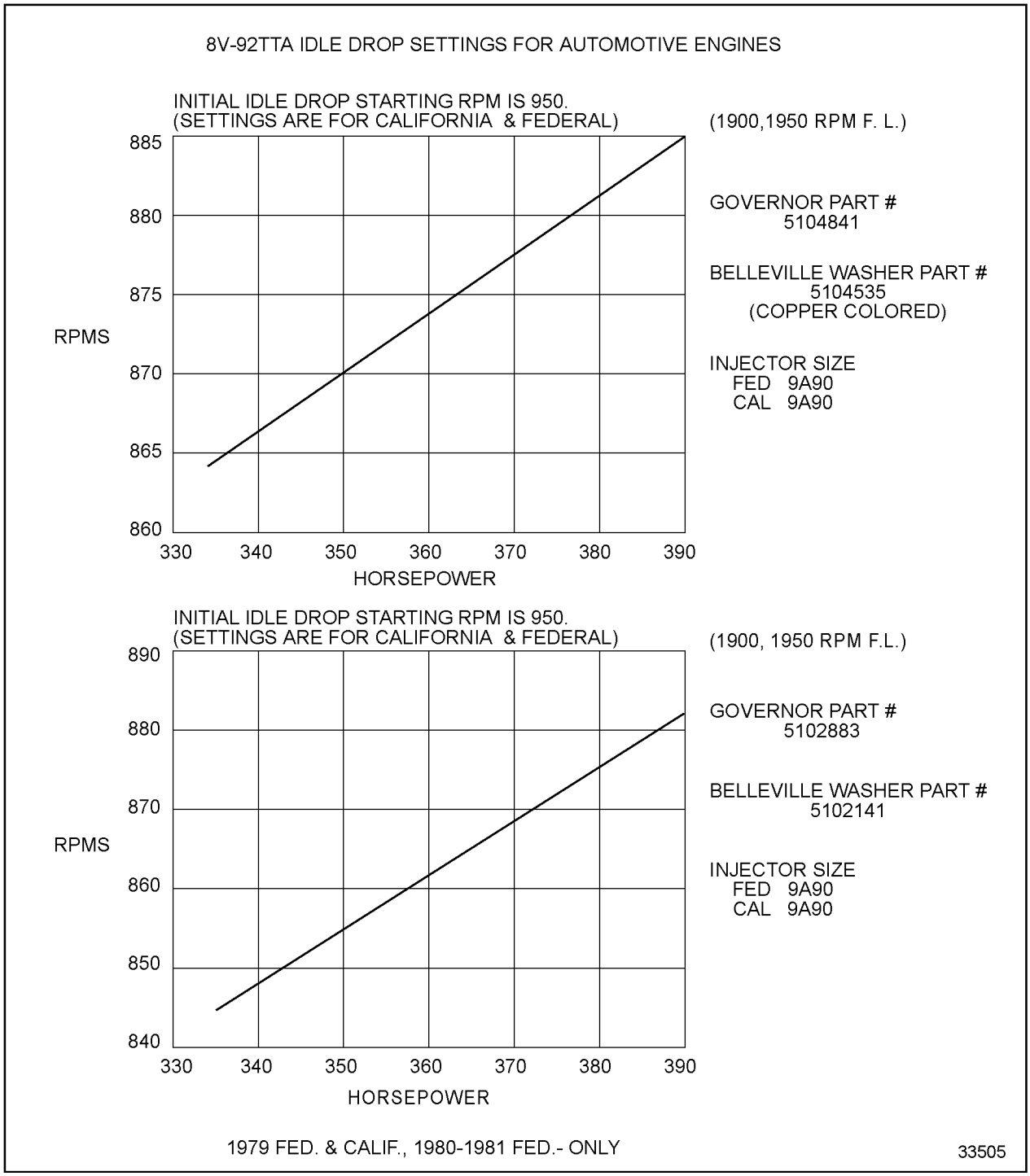


Figure 12-102 Idle Droop Settings 8V TTA (1 of 2)

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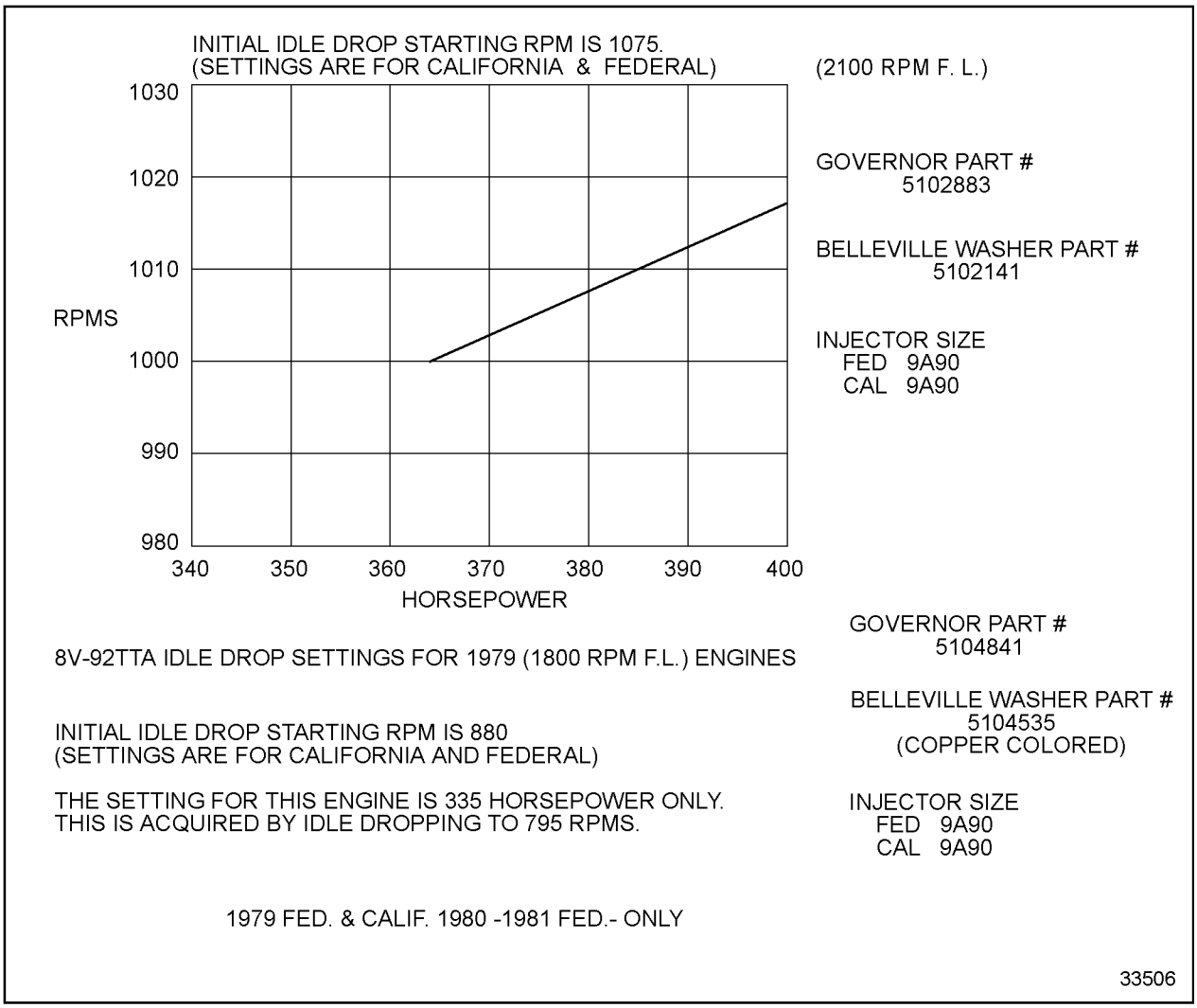


Figure 12-103 Idle Droop Settings 8V TTA (2 of 2)

See Figure 12-104 and see Figure 12-105 for the 1982 8V typical torque settings.

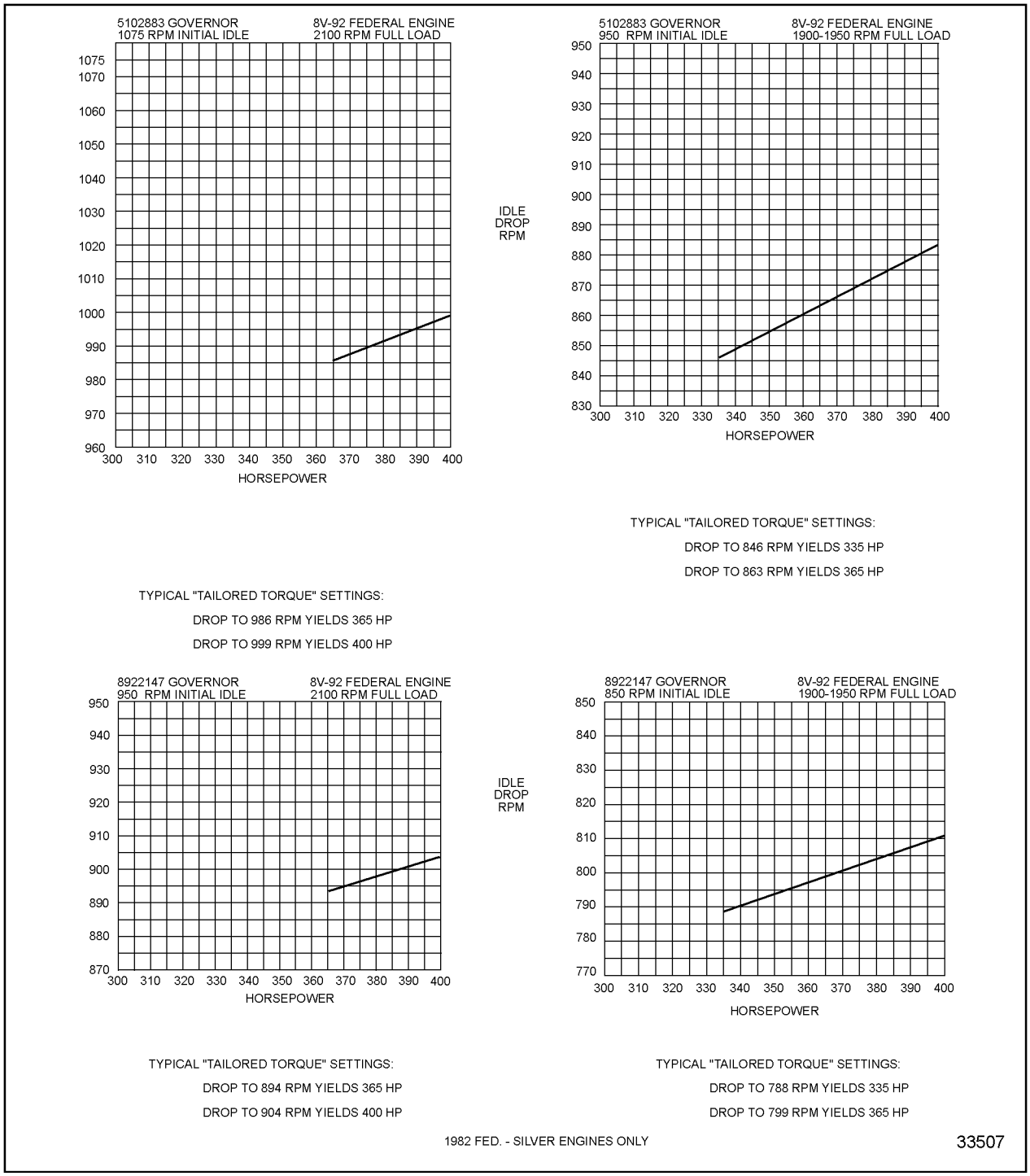


Figure 12-104 Typical Torque Settings 8V for 1982 (1 of 2)

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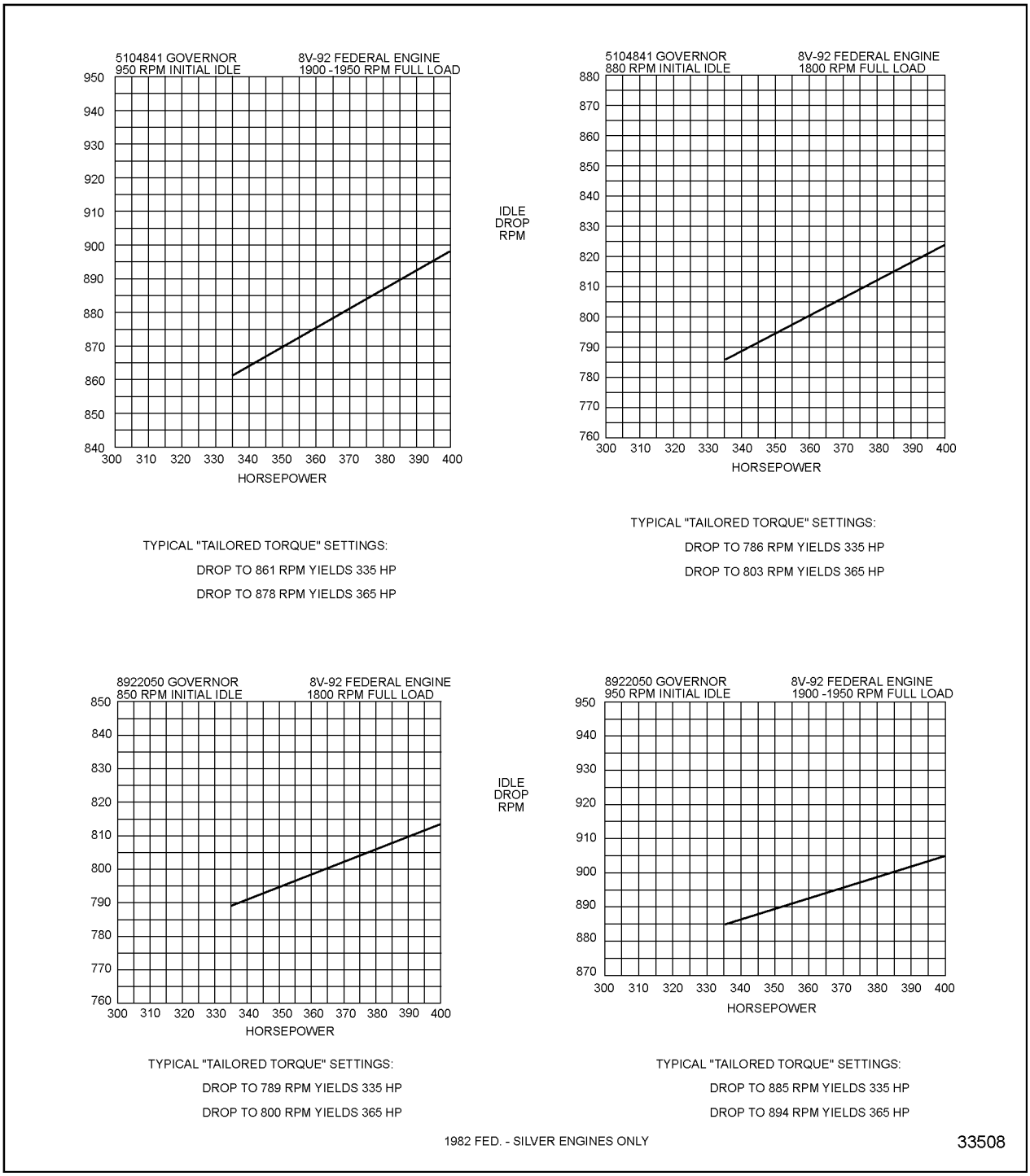


Figure 12-105 Typical Torque Settings 8V for 1982 (2 of 2)

See Figure 12-106 and see Figure 12-107 for the 1983 8V typical torque settings.

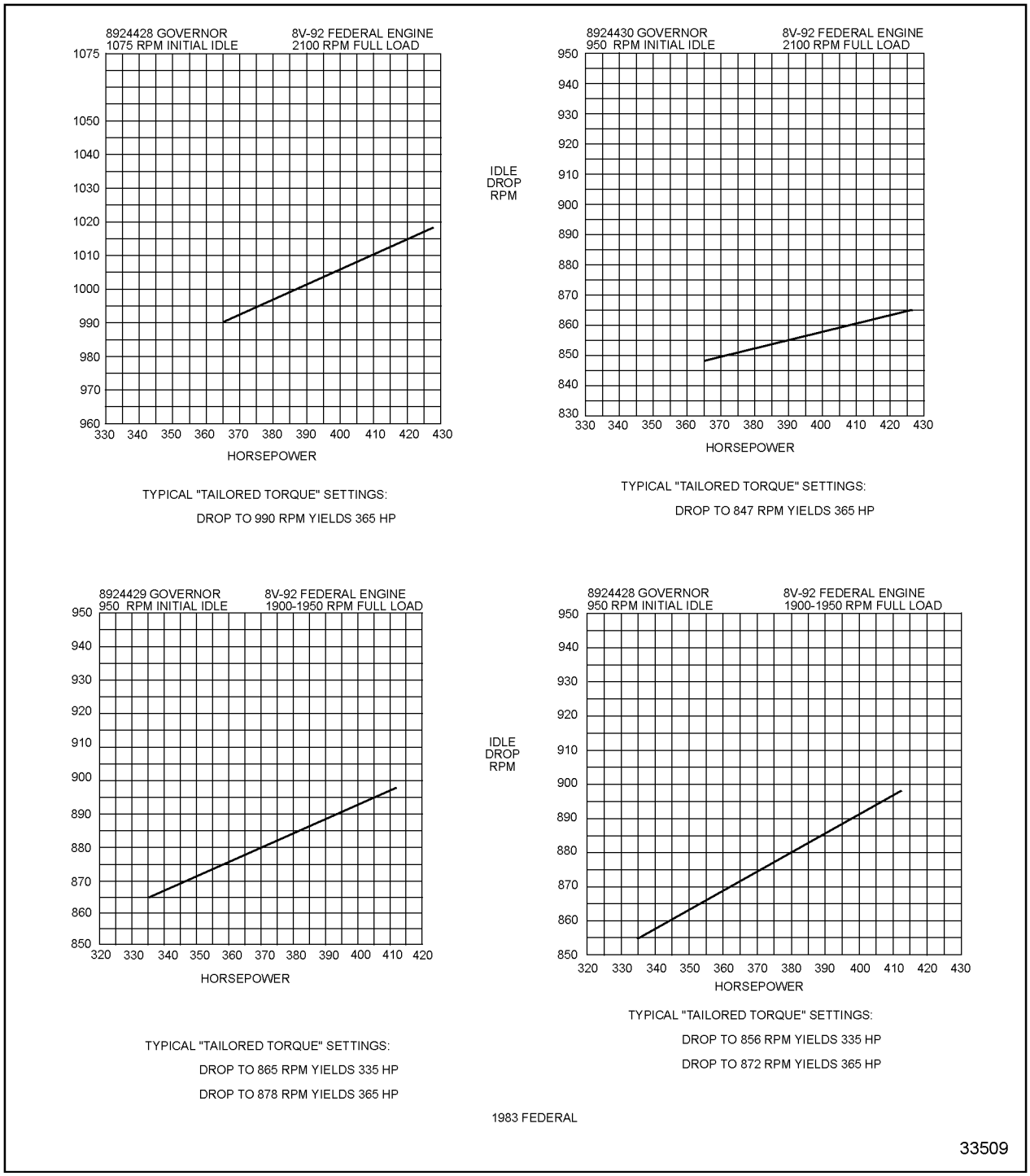


Figure 12-106 Typical Torque Settings 8V for 1983 (1 of 2)

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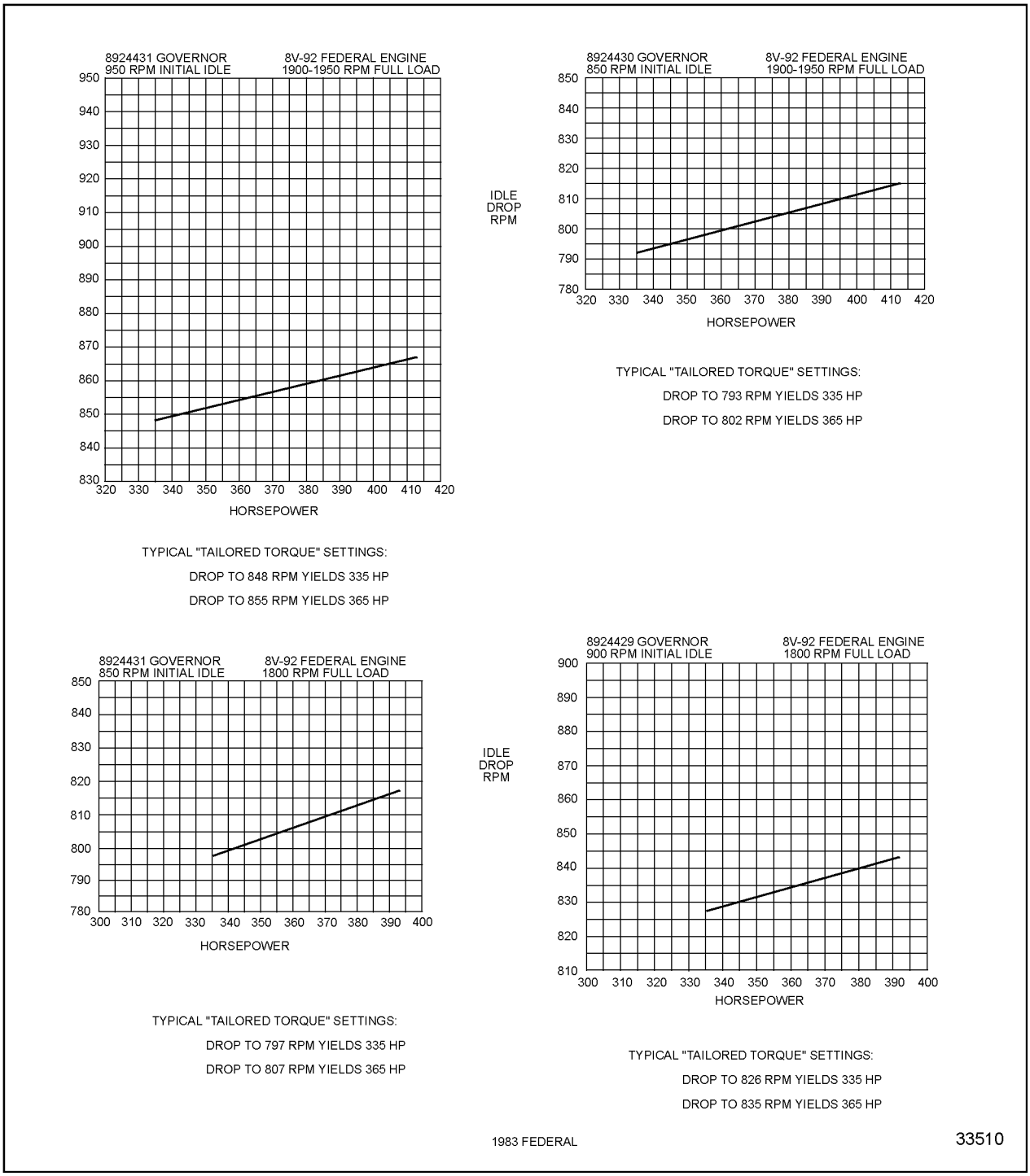


Figure 12-107 Typical Torque Settings 8V for 1983 (2 of 2)

12.9.7 Selected Engine Ratings

Listed in Table 12-14 are the 1978 selected engine ratings.

Engine Type	Maximum Rated BHP	Rated "TT" Horsepower	Rated Engine Speed	No-Load Speed	Power Reduction Factor
6V TT - 9290 Injectors Federal Certified Throttle Delay Setting 0.636	335 at 2100 RPM 2275 RPM Maximum No-Load Speed	270 *	1800	1950	0.91
		270 *	1850	2000	0.89
		270	1900	2050	0.88
		270	1950	2100	0.86
		270	2100	2250	0.82
		260 *	1800	1950	0.88
		260 *	1850	2000	0.86
		260	1900	2050	0.84
		260	1950	2100	0.83
		250 *	1800	1950	0.84
		250 *	1850	2000	0.83
		250	1900	2050	0.81
		250	1950	2100	0.80
		240 *	1800	1950	0.81
		240 *	1850	2000	0.79
		240	1900	2050	0.78
		240	1950	2100	0.77
6V TT - 9290 Injectors Federal Certified Throttle Delay Setting 0.636	335 at 2100 RPM 2275 RPM Maximum No-Load Speed	290	1900	2050	0.94
		290	1950	2100	0.93
6V TTA - 9A90 Injectors California Approved Federal Certified Throttle Delay Setting 0.636	335 at 2100 RPM 2275 RPM Maximum No-Load Speed	270	1900	2050	0.91
		270	1950	2100	0.89
		270	2100	2250	0.86
		260	1900	2050	0.87
		260	1950	2100	0.86
		250	1900	2250	0.84
		250	1950	2100	0.83
		240	1900	2050	0.81
		240	1950	2100	0.79
8V TT - 9290 Injectors Federal Certified Throttle Delay Setting 0.636	430 at 2100 RPM 2275 RPM Maximum No-Load Speed	365	1900	2050	0.92
		365	1950	2100	0.91
		365	2100	2250	0.87
8V TT - 9A90 Injectors Certified Throttle Delay Setting 0.570	430 at 2100 RPM 2275 RPM Maximum No-Load Speed	335	1800	1950	0.87
		335	1850	2000	0.86
		335	1900	2050	0.85
		335	1950	2100	0.83

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Engine Type	Maximum Rated BHP	Rated "TT" Horsepower	Rated Engine Speed	No-Load Speed	Power Reduction Factor
8V TTA - 9A90 Injectors California Approved Federal Certified Throttle Delay Setting 0.636	430 at 2100 RPM	365	1900	2050	0.92
	2275 RPM Maximum No-Load Speed	365	1950	2100	0.91
		365	2100	2250	0.87
		335	1800	1950	0.88
		335	1850	2000	0.86
		335	1900	2050	0.84
			1950	2100	0.83
8V TTA - 9290 Injectors Federal Certified Throttle Delay Setting 0.636	430 at 2100 RPM	365	1900	2050	0.90
	2275 RPM Maximum No-Load Speed	365	1950	2100	0.89
		365	2100	2250	0.85

* Throttle Delay Setting 0.570

Table 12-14 Selected 1978 Engine Ratings

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Listed in Table 12-15 are the Federal and California 1979 selected engine ratings, also included are the Federal 1980 and 1981 ratings.

Engine Type	Maximum Rated BHP	Rated TT Horsepower	Rated Engine Speed	No-Load Speed	Power Reduction Factor
†6V TTA Federal and California Engines	335 at 2100 RPM 2275 RPM Maximum No-Load Speed	290	2100	2250	0.89
		280	2100	2250	0.86
		270	2100	2250	0.82
		290	1950	2100	0.93
		280	1950	2100	0.90
		270	1950	2100	0.86
		260	1950	2100	0.83
		250	1950	2100	0.80
		240	1950	2100	0.77
		290	1900	2050	0.94
		280	1900	2050	0.91
		270	1900	2050	0.88
		260	1900	2050	0.84
		250	1900	2050	0.81
		240	1900	2050	0.78
		290 *	1850	2000	0.96
		280 *	1850	2000	0.93
		270 *	1850	2000	0.89
		260 *	1850	2000	0.86
		250 *	1850	2000	0.83
		240 *	1850	2000	0.79
		307 *	1800	1950	N/A
		290 *	1800	1950	0.98
		280 *	1800	1950	0.95
		270 *	1800	1950	0.91
		260 *	1800	1950	0.88
		250 *	1800	1950	0.84
		240 *	1800	1950	0.81
‡ 8V TTA Federal Engines § 8V TTA California Engines	435 at 2100 RPM 2275 RPM Maximum No-Load 430 at 2100 RPM 2275 RPM Maximum No-Load	365	1900	2050	0.92
		365	1950	2100	0.91
		365	2100	2250	0.87
		335	1800	1950	0.88
		335	1850	2000	0.86
		335	1900	2050	0.84
		335	1950	2100	0.83

* Used Belleville Spring (Copper Flashed) P/N 5 104535

† 6V TTA Federal and California Engines: Injectors – 9B90, Timing – 1.470, Throttle Delay – 0.370

‡ 8V TTA Federal Engines: Injectors – 9A90, Timing – 1.480, Throttle Delay – 0.636

§ 8V TTA California Engines: Injectors – 9A90, Timing – 1.500, Throttle Delay – 0.660

Table 12-15 Selected 1979 Federal and California Engine Ratings; 1980–1981 Federal — Only

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Listed in Table 12-16 are the California 1980 and 1981 selected engine ratings.

Engine Type	Maximum Rated BHP	Rated TT Horsepower	Rated Engine Speed	No-Load Speed	Power Reduction Factor
† 6V TTA California Engines	305 at 2100 RPM 2275 RPM Maximum No-Load Speed	270	2100	2250	0.88
		270	1950	2100	0.91
		260	1950	2100	0.87
		250	1950	2100	0.84
		240	1950	2100	0.81
		270	1900	2050	0.92
		260	1900	2050	0.89
		250	1900	2050	085
		240	1900	2050	0.82
		270 *	1850	2000	0.93
		260 *	1850	2000	0.90
		250 *	1850	2000	0.86
		240 *	1850	2000	0.83
		270 *	1800	1950	0.95
		260 *	1800	1950	0.91
		250 *	1800	1950	0.88
		240 *	1800	1950	0.84
‡ 8V TTA California Engines	405 at 2100 RPM 2275 RPM Maximum No-Load Speed	365	1900	2050	0.93
		365	1950	2100	0.92
		365	2100	2250	0.90
		335	1800	1950	0.88
		335	1850	2000	0.87
		335	1900	2050	0.85
		335	1950	2100	0.84

* Uses Belleville Spring (Copper Flashed) P/N 5104535

†6V TTA Injector – 9C90, Timing – 1.480, Throttle Delay – 0.660

‡8V TTA Injector – 9C90, Timing – 1.480, Throttle Delay – 0.660

Table 12-16 Selected 1980 and 1981 California Engine Ratings

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Listed in Table 12-17 are the Federal and California 1982 selected engine ratings.

Engine Type	Maximum Rated Horsepower	Rated TT Horsepower	Rated Engine Speed	No-Load Speed	Prior Reduction Factor
† 6V TTA Federal	330 at 2100 RPM	270	2100	2250	0.83
	2275 RPM	270	1950	2100	0.86
	Maximum	240	1950	2100	0.76
	No-Load Speed	270	1900	2050	0.88
		240	1900	2050	0.78
		307*	1800	1950	N/A
		270 *	1800	1950	0.91
		240 *	1800	1950	0.81
‡ 8V TTA Federal	445 at 2100 RPM	365	2100	2250	0.84
	2275 RPM	365	1950	2100	0.87
	Maximum	335	1950	2100	0.80
	No-Load Speed	365	1900	2050	0.89
		335	1900	2050	0.82
		411 *	1800	1950	N/A
		365 *	1800	1950	0.92
		335 *	1800	1950	0.82
§ 6V TTA California	325 at 2100 RPM	270	2100	2250	0.85
	2275 RPM	270	1950	2100	0.87
	Maximum	240	1950	2100	0.77
	No-Load Speed	270	1900	2050	0.89
		240	1900	2050	0.79
		304 *	1800	1950	N/A
		270 *	1800	1950	0.92
		240 *	1800	1950	0.82
|| 8V TTA California	440 at 2100 RPM	365	2100	2250	0.85
	2275 RPM	365	1950	2100	0.89
	Maximum	335	1950	2100	0.81
	No-Load Speed	365	1900	2050	0.91
		335	1900	2050	0.83
		403 *	1800	1950	N/A
		365 *	1800	1950	0.94
		335 *	1800	1950	0.87

* Uses Belleville Spring (Copper Flashed) P/N 5104535

† 6V TTA Federal: Injector – 9B90, Timing – 1.470, Throttle Delay – 0.570

‡ 8V TTA Federal: Injector – 9A90, Timing – 1.466, Throttle Delay – 0.636

§ 6V TTA California: Injector – 9F90, Timing – 1.520, Throttle Delay – 0.636

|| 8V TTA California: Injector – 9F90, Timing – 1.520, Throttle Delay – 0.660

Table 12-17 Selected 1982 Federal and California Engine Ratings

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Listed in Table 12-18 are the Federal and California 1983 selected engine ratings.

Engine Type and Maximum Rated BHP	Settings	Rated TT Horsepower	Rated Engine Speed (RPM)	No-Load Speed (RPM)	Power Reduction Factor
6V TTA Federal 330 at 2100 RPM (B) 2275 RPM Maximum No-Load Speed	Injector: 9B90 Timing: 1.464 Throttle Delay: 0.636 (A) 0.610 (B) Modulator Setting 0.480	270 (B)	2100	2225	0.83
		270 (B)	1950	2075	0.86
		240 (B)	1950	2075	0.76
		270 (B)	1900	2025	0.88
		240 (B)	1900	2025	0.78
		307 (A) *	1800	1925	N/A
		270 (A) *	1800	1925	0.91
		240 (A) *	1800	1925	0.81
8V TTA Federal 445 at 2100 RPM 2275 RPM Maximum No-Load Speed	Injector: 9A90 Timing: 1.460 Throttle Delay: 0.594 Modulator Setting 0.480	365	2100	2225	0.84
		365	1950	2075	0.87
		411 *	1950	2075	0.80
		365	1900	2025	0.89
		335	1900	2025	0.82
		411 *	1800	1925	N/A
		365 *	1800	1925	0.92
		335 *	1800	1925	0.85
6V TTA California 325 at 2100 RPM 2275 RPM Maximum No-Load Speed	Injector: 9F90 Timing: 1.520 Throttle Delay: 0.636 Modulator Setting 0.480	270	2100	2225	0.85
		270	1950	2075	0.87
		240	1950	2075	0.77
		270	1900	2025	0.89
		240	1900	2025	0.79
		304 *	1800	1925	N/A
		270 *	1800	1925	0.92
		240 *	1800	1925	0.82
8V TTA California 440 at 2100 RPM 2275 RPM Maximum No-Load Speed	Injector: 9F90 Timing: 1.515 Throttle Delay: 0.660 Modulator Setting 0.490	365	2100	2225	0.85
		365	1950	2075	0.89
		335	1950	2075	0.81
		365	1900	2025	0.91
		335	1900	2025	0.83
		403 *	1800	1925	N/A
		365 *	1800	1925	0.94
		335 *	1800	1925	0.87

* Uses Belleville Spring (Washer) 5104535 (Copper Flashed).

Table 12-18 Selected 1983 Federal and California Engine Ratings

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Listed in Table 12-19 are the Federal and California 1984 selected engine ratings.

Engine Type and Maximum Rated BHP	Settings	Rated TT Horsepower	Rated Engine Speed (RPM)	No-Load Speed (RPM)	Power Reduction Factor
6V TA 330 at 2100 RPM	Injector: 9B90 Timing: 1.475 Throttle Delay: 0.636 Modulator Setting: 0.465	270 270	1800 2100	1950 2250	0.91 0.83
6V TAC 325 at 2100 RPM	Injector: 9F90 Timing: 1.520 Throttle Delay: DNA Modulator Setting: 0.490	270 270	1800 2100	1950 2250	0.92 0.84
8V TA 445 at 2100 RPM	Injector: 9A90 Timing: 1.470 Throttle Delay: 0.594 Modulator Setting: 0.404	365 365	1950 2100	2100 2250	0.87 0.84
8V TAC 440 at 2100 RPM	Injector: 9F90 Timing: 1.520 Throttle Delay: 0.660 Modulator Setting: 0.490	365 365	1950 2100	2100 2250	0.89 0.85

Table 12-19 Selected 1984 Federal and California Engine Ratings

Listed in Table 12-20 are the Federal 1985 selected engine ratings.

Engine Type and Maximum Rated BHP	Settings	Rated TT Horsepower	Rated Engine Speed (RPM)	No-Load Speed (RPM)	Power Reduction Factor
6V TA 300 at 1800 RPM	Injector: 9G85 Timing: 1.466 Throttle Delay: DNA Modulator Setting: 0.465	270 270	1800 2100	1925 2250	0.91 0.83

Table 12-20 Selected 1985 Federal Engine Ratings

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Listed in Table 12-21 are the Federal and California 1985 and 1986 selected engine ratings.

Engine Type and Maximum Rated BHP	Settings	Rated TT Horsepower	Rated Engine Speed (RPM)	No-Load Speed (RPM)	Power Reduction Factor
6V TA 350 at 2100 RPM	Injector: 9G90 Timing: 1.466 Throttle Delay: 0.636 Modulator Setting: 0.480	300	2100	2250	0.88
6V TA 300 at 2100 RPM	Injector: 9G90 Timing: 1.470 Throttle Delay: 0.570 Modulator Setting: DNA	270 270	1800 2100	1950 2250	0.93 0.86
6V TAC 340 at 2100 RPM	Injector: 9F90 Timing: 1.520 Throttle Delay: 0.660 Modulator Setting: 0.490	300 270	2100 2100	2250 2250	0.90 0.81
8V TA 475 at 2100 RPM	Injector: 9G90 Timing: 1.458 Throttle Delay: 0.610 Modulator Setting: 0.454	400 400	2100 1800	2250 1950	0.87 0.87
8V TAC 450 at 2100 RPM	Injector: 9F90 Timing: 1.520 Throttle Delay: 0.660 Modulator Setting: 0.490	400	2100	2250	0.91

Table 12-21 Selected 1985 and 1986 Federal and California Engine Ratings

Listed in Table 12-22 are the Federal 1986 selected engine ratings.

Engine Type and Maximum Rated BHP	Settings	Rated TT Horsepower	Rated Engine Speed (RPM)	No-Load Speed (RPM)	Power Reduction Factor
8V TA 475 at 2100 RPM	Injector: 9G90 Timing: 1.475 Throttle Delay: 0.570 Modulator Setting: 0.404	400	2100	2250	0.97

Table 12-22 Selected 1986 Federal Engine Ratings

Listed in Table 12-23 are the Federal and California 1987 selected engine ratings.

Engine Type and Maximum Rated BHP	Settings	Rated TT Horsepower	Rated Engine Speed (RPM)	No-Load Speed (RPM)	Power Reduction Factor
6V TA 300 at 2100 RPM	Injector: 9G85 Timing: 1.466 Throttle Delay: DNA Modulator Setting: 0.465	270 270	1800 2100	1925 2250	0.91 0.83
6V TA 350 at 2100 RPM	Injector: 9G90 Timing: 1.466 Throttle Delay: 0.636 Modulator Setting: 0.480	300	2100	2250	0.87
6V TAC 340 at 2100 RPM	Injector: 9F90 Timing: 1.520 Throttle Delay: 0.660 Modulator Setting: 0.490	270 300 270	1800 2100 2100	1925 2250 2250	0.90 0.81 0.90
8V TA 475 at 2100 RPM	Injector: 9G90 Timing: 1.475 Throttle Delay: 0.570 Modulator Setting: 0.404	400	2100	2250	0.97
8V TAC 450 at 2100 RPM	Injector: 9F90 Timing: 1.520 Throttle Delay: 0.660 Modulator Setting: 0.490	400	2100	2250	0.90

Table 12-23 Selected 1987 Federal and California Engine Ratings

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12.10 VARIABLE SPEED MECHANICAL GOVERNOR INJECTOR RACK CONTROL ADJUSTMENT (6V AND 8V ENGINES)

The 6V and 8V single-weight variable speed governor is mounted at the front of the engine and is driven by a blower rotor.

After adjusting the exhaust valves and timing the fuel injectors, adjust the variable speed mechanical governor, and position the injector rack control levers.

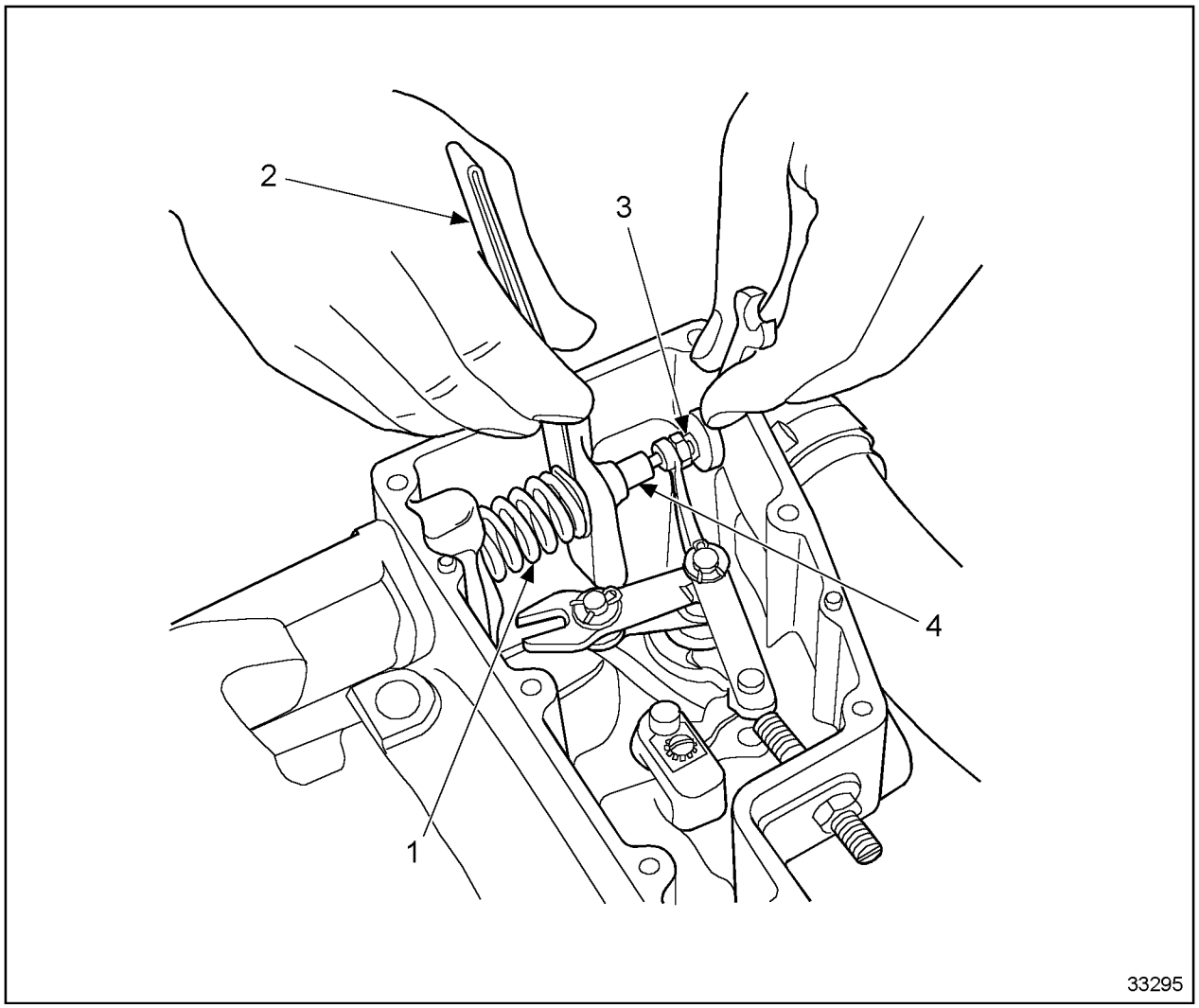
Before proceeding with the governor and injector rack adjustments, disconnect any supplementary governing device. After the adjustments are completed, reconnect and adjust the supplementary governing device.

12.10.1 Adjustment of Governor Gap

With the engine stopped and at normal operating temperature, adjust the 6V and 8V governor gap as follows:

1. Disconnect any linkage attached to the governor levers.
2. Back out the buffer screw until it extends 15.88 mm (0.625 in.) from the locknut.
3. Clean and remove the governor cover and valve rocker covers. Discard the gaskets.
4. Place the speed control lever in the maximum speed position.

5. Insert a 0.1524 mm (0.006 in.) feeler gage between the spring plunger and the plunger guide. See Figure 12-108.



1. Governor Spring
2. Feeler Gage
3. Gap Adjusting Screw
4. Spring Plunger

Figure 12-108 Adjusting Governor Gap

6. If required, loosen the locknut and turn the adjusting screw until it slightly drags.
7. Hold the adjusting screw, and tighten the locknut.
8. Check the gap again and, if necessary, readjust.
9. Affix a new gasket on the top of the governor housing.
10. Place the governor cover assembly on the governor housing with the throttle control shaft assembly pin in the differential lever slot and the housing dowel pins in the cover dowel pin holes.

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11. Tighten the screws.

12.10.2 Position Injector Rack Control Levers

The position of the injector rack control levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal load distribution.

The engines use spring-loaded injector control tube assemblies which have a yield spring at each injector rack control lever with one screw and locknut to keep each injector rack properly positioned.

1. Properly positioned injector rack control levers, with the engine at full load, will result in the following:
   - Speed control lever at the maximum speed position.
   - Stop lever in the run position.
   - High-speed spring plunger within 0.127–0.1778 mm (0.005–0.007 in.) of its seat in the governor control housing.
   - Injector fuel control racks in the full fuel position.

   The letters "R" and "L" indicate the injector location in the right or left cylinder bank, viewed from the rear of the engine. The cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 1L injector rack control lever first to establish a guide for adjusting the remaining control levers.

   Adjust the levers as follows:
2. Remove the clevis pin from the fuel rod and the right cylinder bank injector control tube lever.
3. Loosen all adjusting screws and locknuts on both injector control tubes.

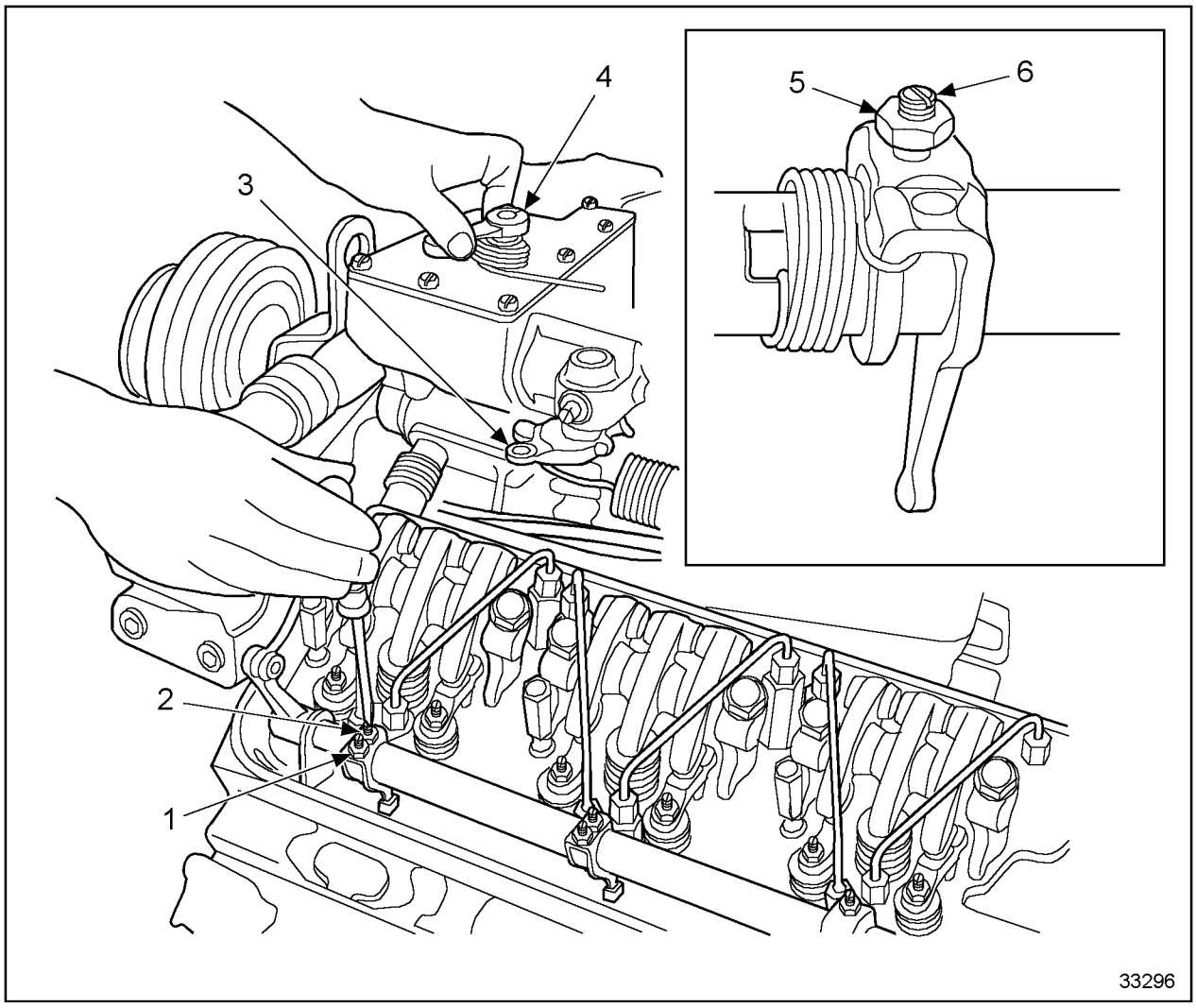
NOTE:
Ensure all injector rack control levers are free on the injector control tubes.

4. Move the speed control lever to the maximum speed position.
5. Move the stop lever to the run position, and hold it with your finger.

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NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended torque for the adjusting screw is 3-4 N·m (24-36 lb·in.).

6. Tighten the No. 1L injector rack control lever adjusting screw until it rolls up or an increase in effort to turn the screwdriver is noted. See Figure 12-109.



1. Outer Adjusting Screw
2. Inner Adjusting Screw
3. Speed Control Lever
4. Stop Lever
5. Locknut
6. Adjusting Screw

Figure 12-109 Positioning No. 1 Injector Rack Control Lever

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7. Tighten the screw approximately 1/8 turn, and lock securely with the adjusting screw locknut.

NOTE:
This will place the No. 1L injector rack in the full fuel position - the same position it would attain at full load.

8. Verify rack adjustment. Refer to section 12.4.10 and refer to section 12.10.3.
9. Remove the clevis pin from the fuel rod and the left bank injector control tube lever.
10. Insert the clevis pin in the fuel rod and the right cylinder bank injector control tube lever, and position the No. 1R injector rack control lever. Refer to step 4 through step 7.
11. Insert the clevis pin in the fuel rod and the left bank injector control tube lever.
12. Verify the No. 1L and No. 1R adjustment. Refer to section 12.4.10.
13. Carefully observe and eliminate any defection which occurs at the bend in the fuel rod where it enters the cylinder head.Adjust the remaining injector rack control levers as follows:
14. Remove the clevis pins from the fuel rods and the injector rack control tube levers.
15. Hold the injector control racks in the full fuel position with the lever on the end of the control tube.

NOTICE:
Overtightening the injector rack control tube lever adjusting screws during installation or adjustment can damage to the injector control tube. The recommended torque is 3-4 N·m (24-36 lb·in.)

16. Tighten the adjusting screw of the No. 2L injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
17. Securely lock the adjusting screw locknut.
18. Verify injector rack adjustment. Refer to section 12.4.10.
19. If No. 1L does not "spring" back upward, turn the No. 2L adjusting screw until the No. 1L injector rack returns to its full fuel position.
20. Secure the adjusting screw locknut.
21. Verify proper injector rack adjustment for both No. 1L and NO. 2L injectors.
22. Turn the No. 2L injector rack adjusting screw clockwise or counterclockwise until both No. 1L and No. 2L injector racks are in the full fuel position when the locknut is securely tightened.

23. Adjust the remaining injector. Refer to step 5 through step 9.

NOTE:
Always verify proper injector rack adjustment.

NOTE:
Once the No. 1L and No. 1R injector rack control levers are adjusted, do not try to alter their settings. All adjustments are made on the remaining control racks.

24. When all injector rack control levers are adjusted, check their settings.
25. With the control tube lever in the full fuel position, check each control rack. Refer to section 12.4.10.

NOTE:
All control racks must "spring" with the control tube lever in the full fuel position.

26. Insert the clevis pins in the fuel rods and the injector control tube levers.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

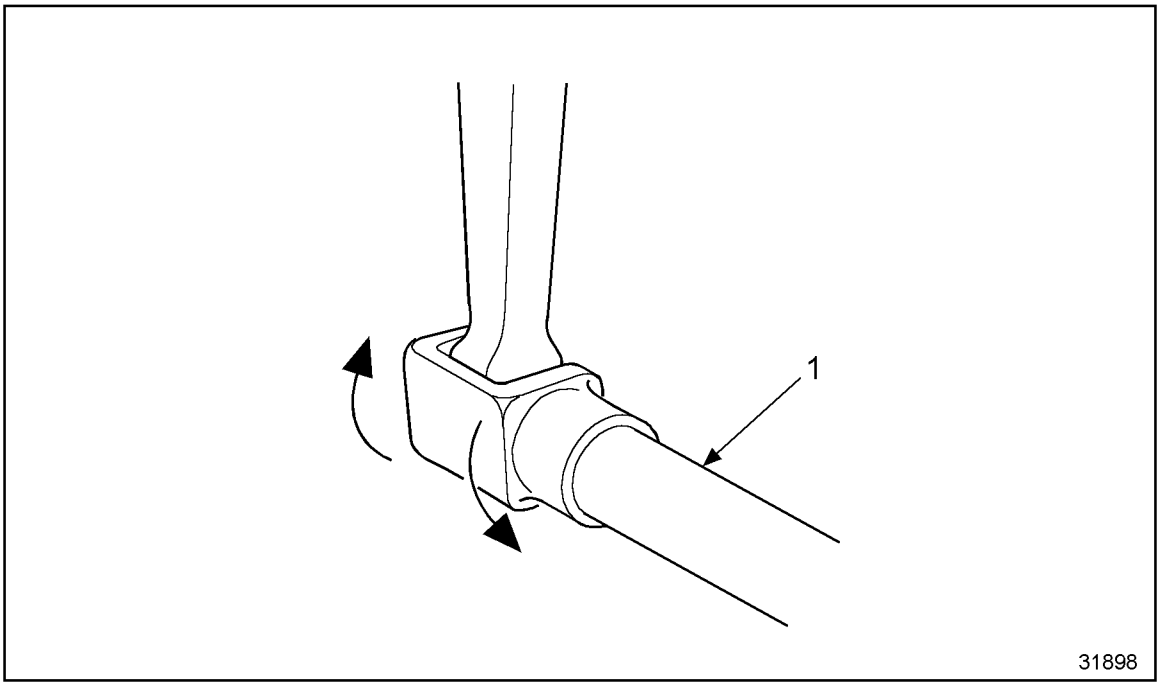
12.10.3 Check Rack Adjustment

Verify rack adjustment as follows:

1. Hold the stop lever in the run position, and press down on the injector rack with a screwdriver or finger tip.

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2. Observe the "rotating" movement of the injector control rack when the stop lever is in the run position. See Figure 12-110.



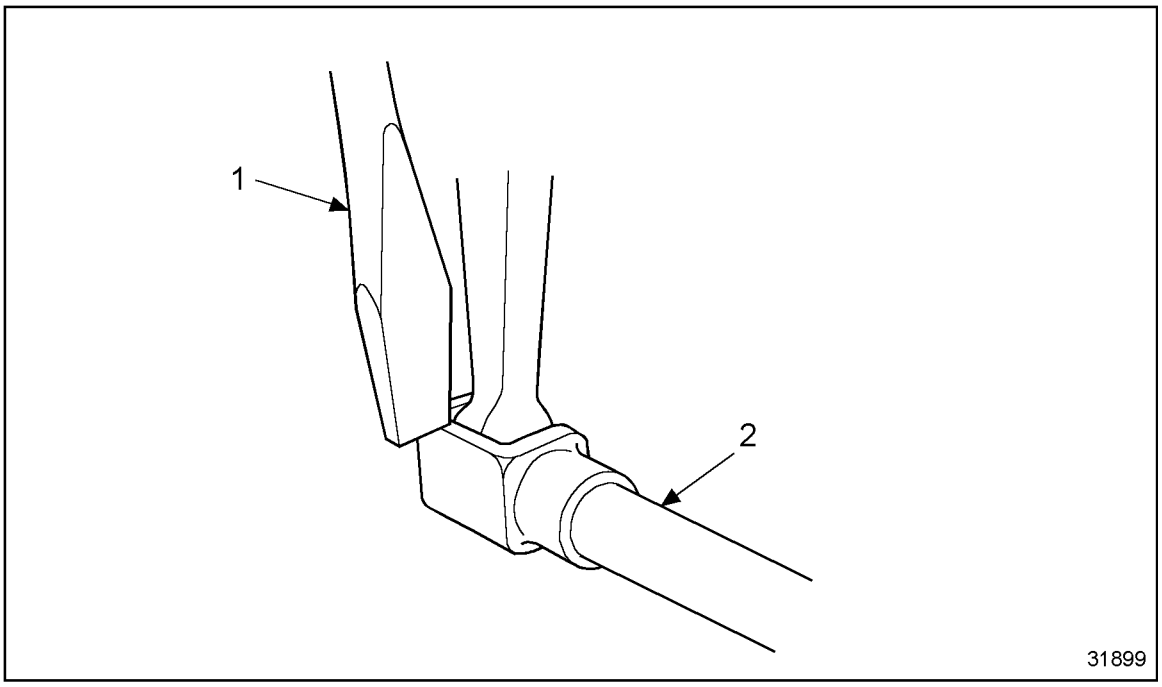
1. Injector Control Rack

Figure 12-110 Checking Rotating Movement of Injector Control Rack

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3. Hold the stop lever in the run position, and using a screwdriver, press downward on the injector control rack.

NOTE:
The rack should tilt downward. When the screwdriver is removed, the control rack should "spring" back up. See Figure 12-111. If the rack does not return to its original position, it is too loose.



1. Screwdriver
2. Injector Control Rack

Figure 12-111 Checking Injector Control Rack "Spring"

4. To correct a loose rack, loosen the locknut and turn the adjusting screw clockwise. Tighten the locknut.

NOTE:
When moving the stop lever from the stop to the rung position the injector rack becomes tight before the stop lever reaches the end of its travel, the rack is too tight.

5. To correct a tight rack, loosen the locknut, and turn the adjusting screw counterclockwise. Tighten the locknut.

12.10.4 Adjust Maximum No Load Speed

All governors are properly adjusted before leaving the factory. If the governor has been reconditioned or replaced, set the maximum no load speed. This ensures the engine speed will not exceed the recommended no load speed.

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Start the engine, and after it reaches normal operating temperature, determine the maximum engine no load speed with an accurate hand tachometer. Stop the engine, and make the following adjustments, if required:

1. Disconnect the booster spring and the governor stop lever spring.
2. Remove the variable speed spring housing and the spring retainer, located inside the housing, from the governor housing.
3. Determine the stop or shims required for the desired full load speed. Stops and shim requirements are listed in Table 12-24.

Full-Load Speed *	Stops	Shims
11200 - 1750	2	Up to 8.26 mm (0.325 in.) in Shims Maximum
1750 - 2100	1	
2100 - 2300	0	

* No-load is 150–200 RPM above full-load speed depending on engine application.

Table 12-24 Stops and Shims Required

NOTE:
The speed will increase approximately 1 RPM for each 0.001 in. shim added.

4. Install the variable speed spring retainer and housing, and tighten the two bolts.
5. Connect the booster spring.
6. Start the engine, and check the maximum no load speed.
7. If required, add or remove shims to obtain the necessary operating speed.
8. If the maximum no load speed is raised or lowered more than 50 RPM with the installation or removal of shims, check the governor gap.
9. If the governor gap must be adjusted, check the position of the injector racks.

NOTE:
Governor stops are used to limit the compression of the governor spring, which determines the maximum engine speed.

12.10.5 Adjust Idle Speed

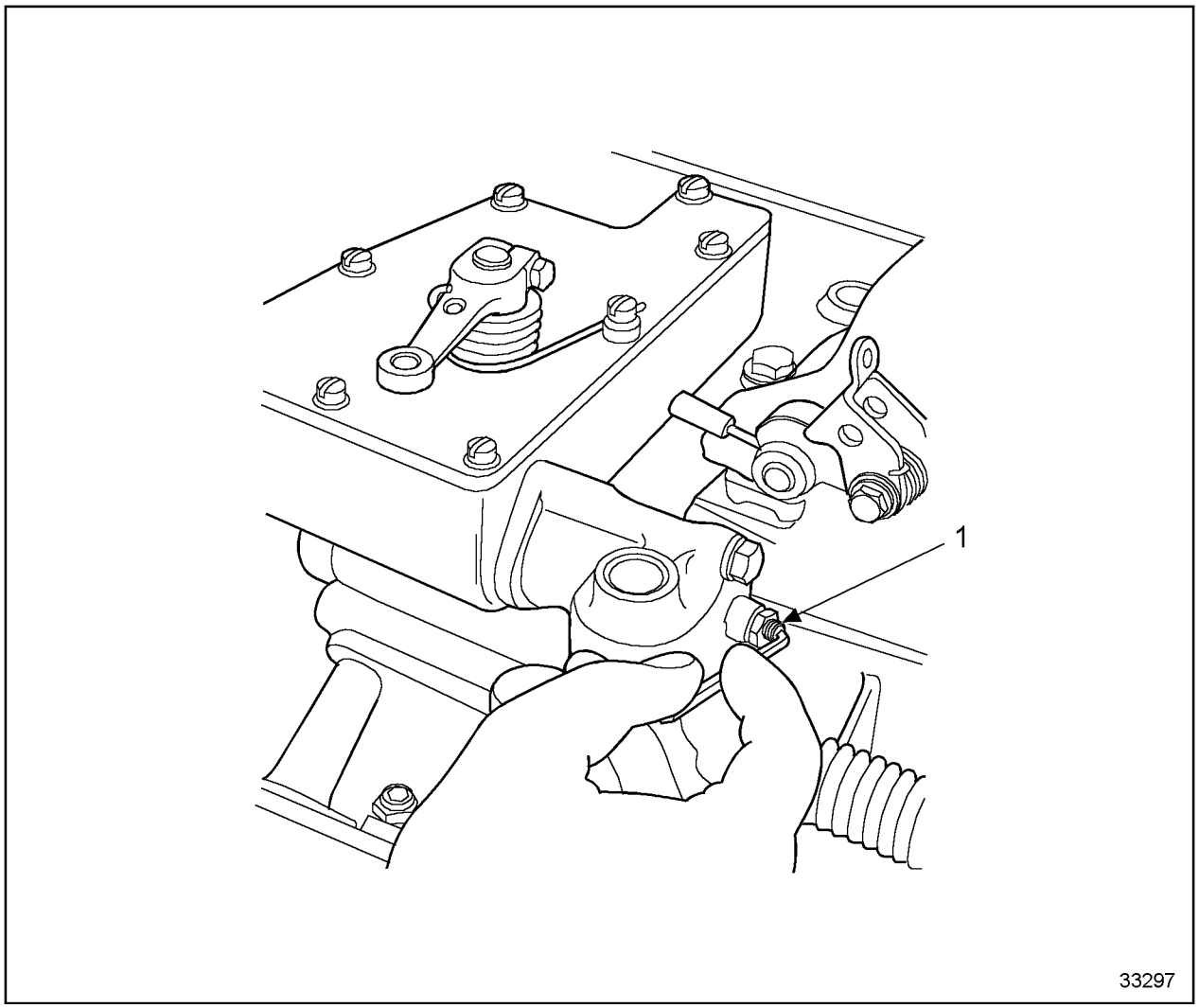
With the maximum no load speed properly set, adjust the idle speed as follows:

1. Place the speed control lever in the idle position and the stop lever in the run position.
2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

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3. Loosen the locknut, and turn the idle speed adjusting screw until the engine is operating at approximately 15 RPM below the recommended idle speed. See Figure 12-112.

NOTE:
The recommended idle speed is 500 RPM, but may vary with special engine applications.



1. Idle Speed Adjusting Screw

Figure 12-112 Adjusting Idle Speed

4. Hold the idle speed adjusting screw, and tighten the locknut.

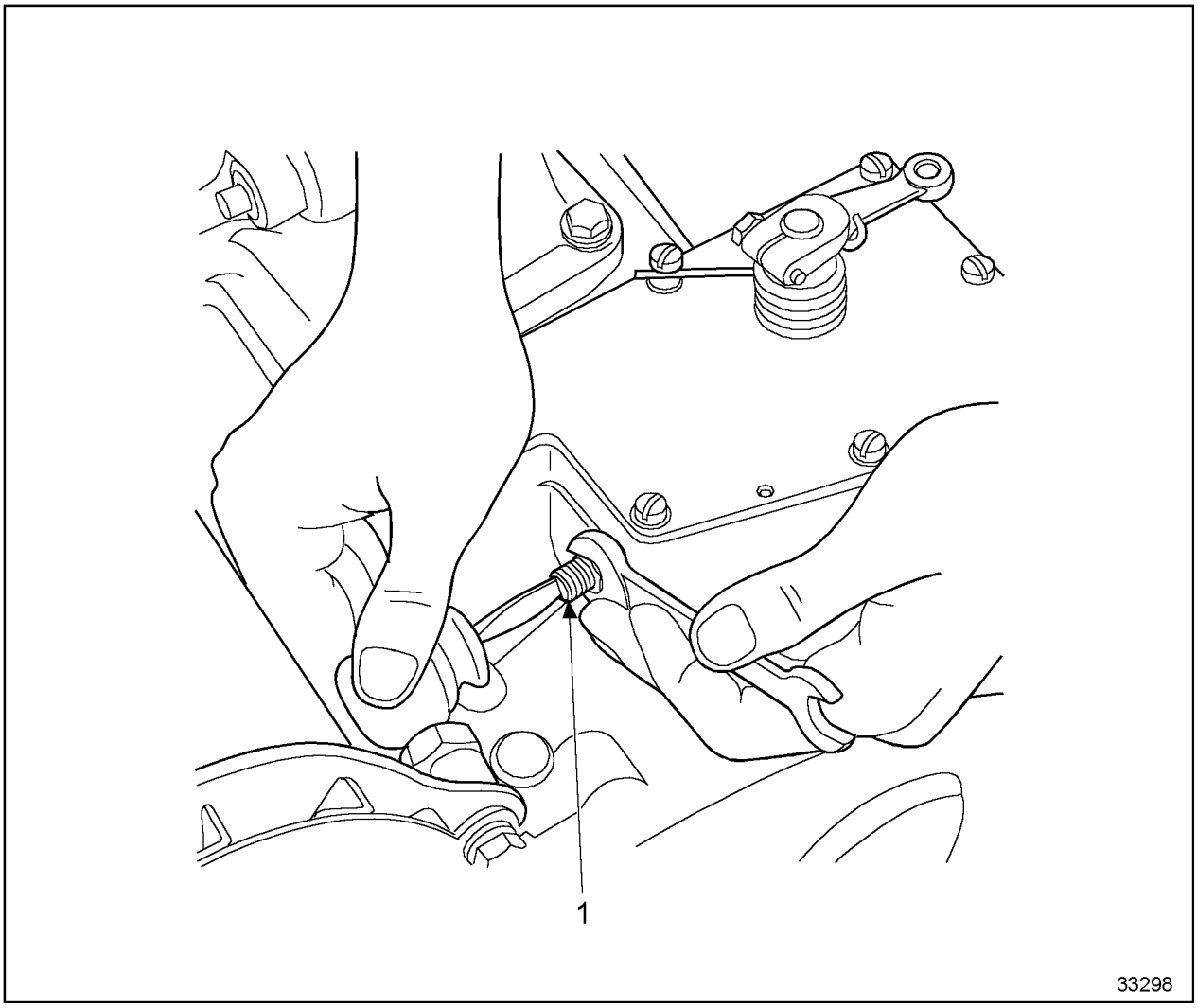
12.10.6 Adjust Buffer Screw

Adjust the buffer screw as follows:

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1. With the engine running at normal operating temperature, turn the buffer screw in so that it lightly contacts the differential lever and still eliminates engine roll. See Figure 12-113.

NOTE:
Do not raise the engine idle speed more than 15 RPM with the buffer screw.



1. Buffer Screw

Figure 12-113 Adjusting Buffer Screw

2. Hold the buffer screw, and tighten the locknut.

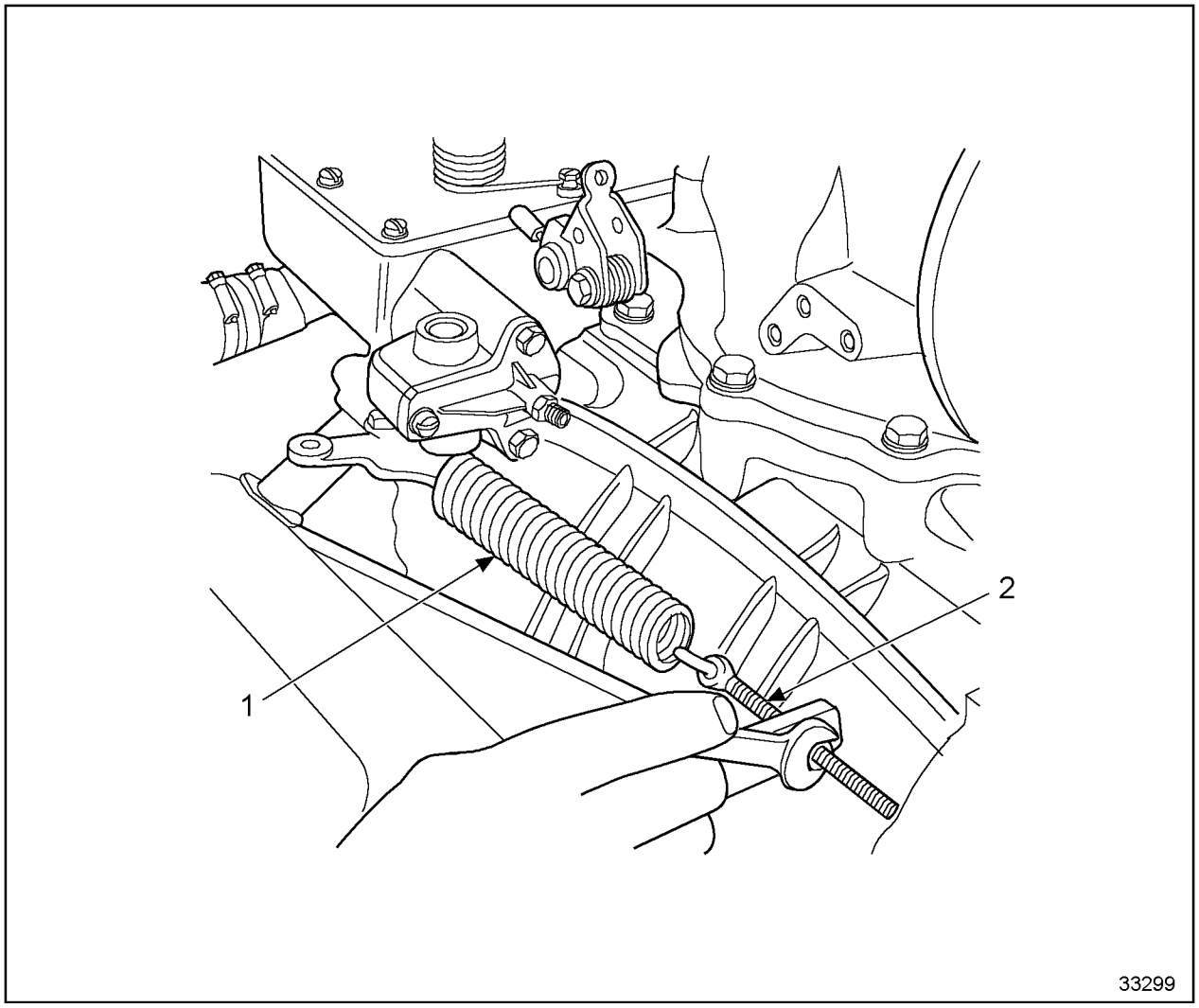
12.10.7 Adjust Booster Spring

With the idle speed adjusted, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

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2. Loosen the booster spring retaining nut on the speed control lever. See Figure 12-114.



1. Booster Spring
2. Booster Spring Adjusting Eye Bolt

Figure 12-114 Adjusting Booster Spring

3. Loosen the locknuts on the eyebolt at the opposite end of the booster spring.
4. With the speed control lever in the idle position, move the bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the bolt, lever shaft, and eyebolt.
5. Hold the bolt from turning, and tighten the locknut.
6. Start the engine, and move the speed control lever to the maximum speed position. Release it.
7. If the lever does not return to the idle speed position, reduce the booster spring tension.

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8. If the speed control lever returns to the idle speed position, continue to increase the spring tension until it does not return to idle.
9. Reduce the spring tension until it returns to idle.
10. Tighten the locknut on the eyebolt.

NOTE:
This setting will result in the minimum force required to operate the speed control lever.

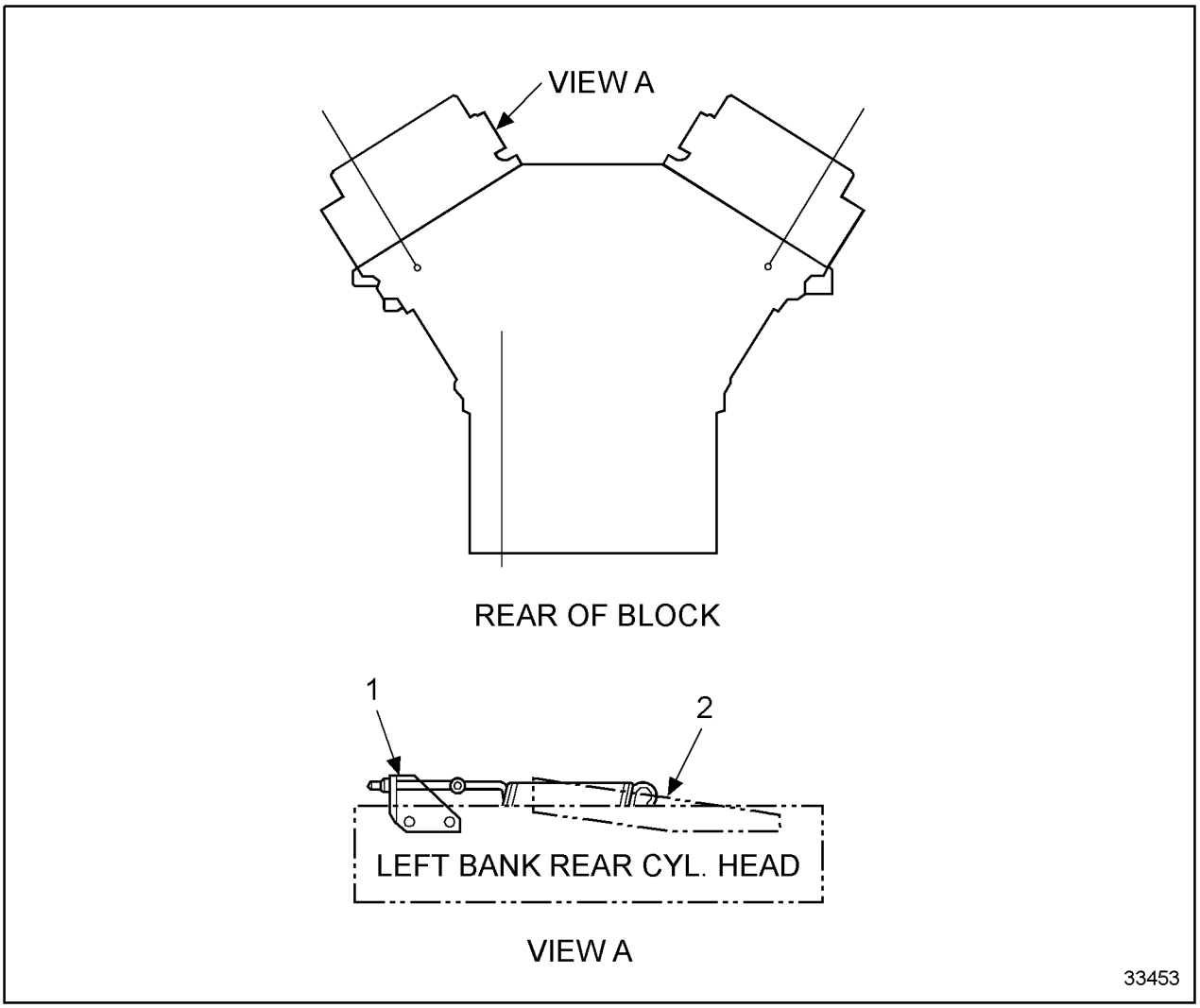
11. Connect the linkage to the governor levers.

12.11 VARIABLE SPEED MECHANICAL GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT (12V AND 16V ENGINES)

An improved throttle control mechanism has been released to ease control lever movement on marine engine model 8122-7400. This mechanism reduces the effort required to move the throttle lever, permitting more uniform movement of the lever through the entire throttle range.

The improved mechanism is similar to the former, except that it includes a lighter tension booster spring, a shorter, stiffer bracket, and a longer eyebolt (4.75 in. instead of 4.0 in.).

The new parts are installed in the same location as the former parts, except for the bracket. This is mounted on the rear of the left-bank cylinder head with two bolts and lock washers. See Figure 12-115.



1. New Bracket
2. Old Bracket

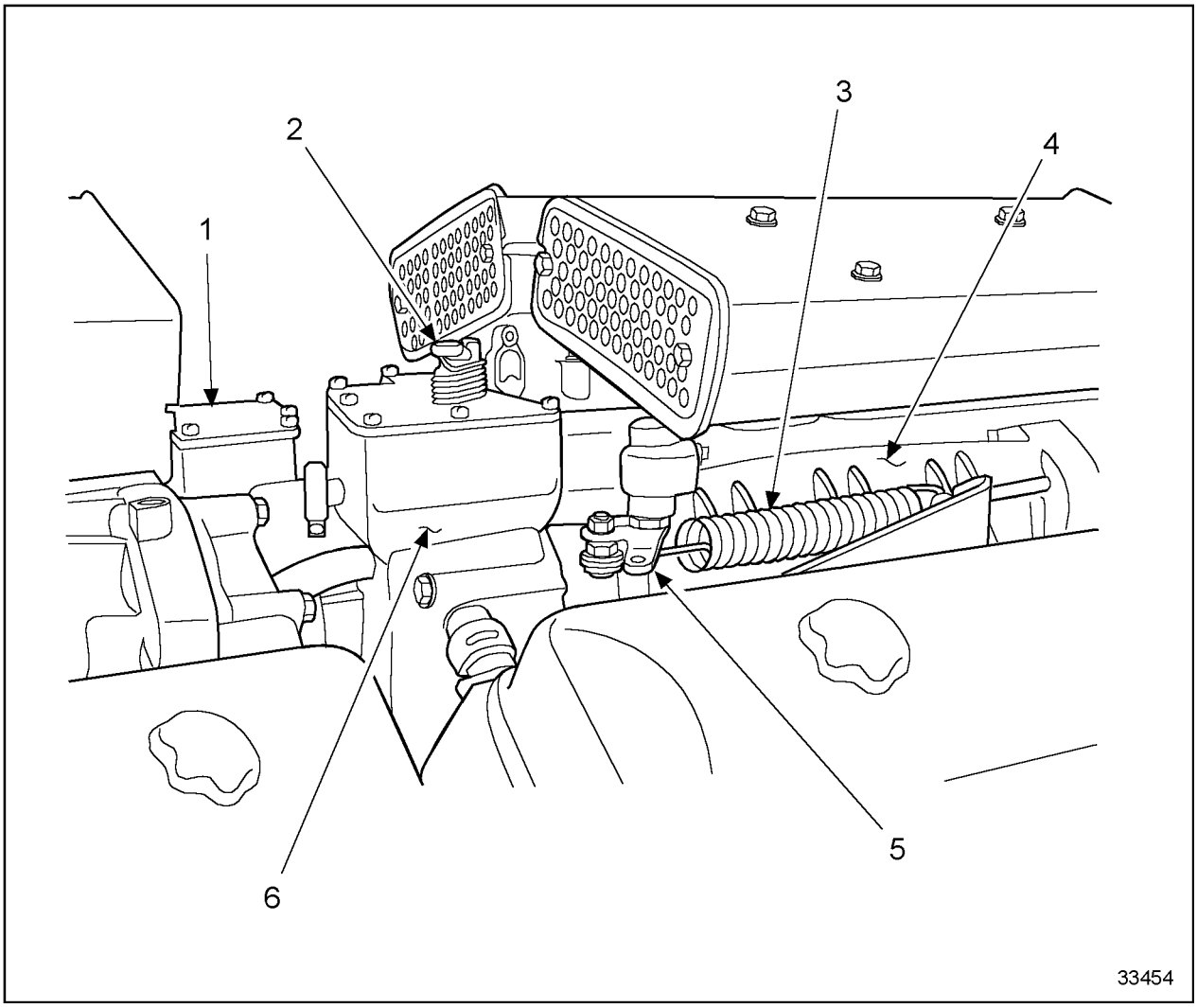
Figure 12-115 Improved Throttle Control Mechanism and Location

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DDC recommends replacing the former throttle control mechanism parts on marine model 8122-7400 with the new parts whenever practical. Former parts will be retained for other applications.

12.11.1 Position Control Link Levers

The governor on the 12V and 16V engines is mounted on and driven from the front end of the rear blower. See Figure 12-116.

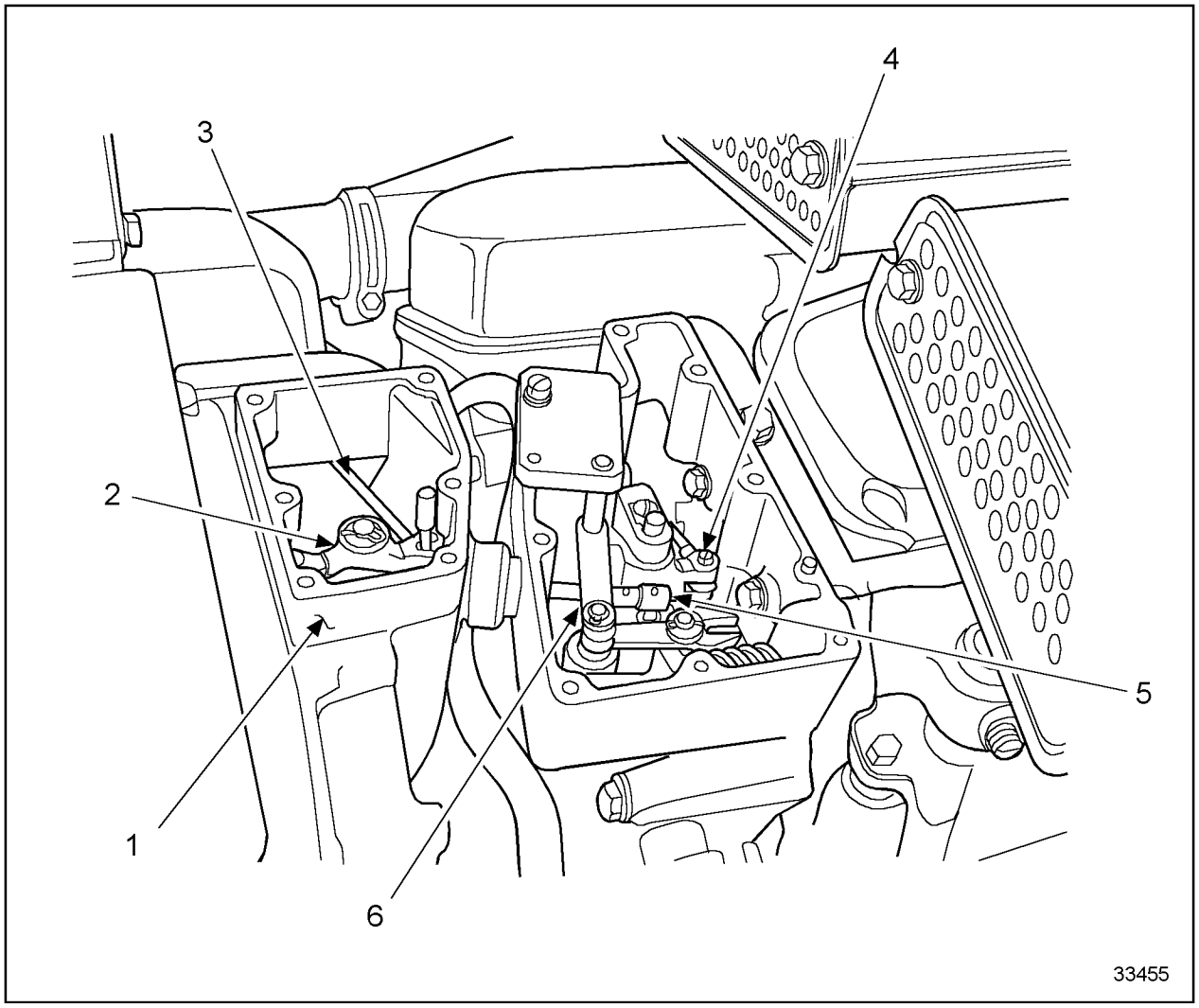


1. Auxiliary Control Link Housing
2. Shutdown Lever
3. Booster Spring
4. Rear Blower
5. Speed Control Lever
6. Governor

Figure 12-116 Improved Throttle Control Mechanism and Location

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor and injector rack control levers.

If the engine or governor has been overhauled, or the injector control linkage has been disturbed, the control link levers in the governor housing and auxiliary control link housing must be aligned before proceeding with the engine tune-up. See Figure 12-117, and position the control link levers as follows:



1. Auxiliary Control Link Housing
2. Control Lever Link
3. Fuel Rod
4. Governor Operating Lever Control Link
5. Adjustable Link
6. Connecting Link

Figure 12-117 Governor Mounting

1. Disconnect the linkage to the governor speed control and stop levers.
2. Remove the covers from the governor housing and auxiliary control link housing.
3. Disconnect the adjustable link from the lever in the auxiliary control link housing.
4. Remove the connecting pin from the auxiliary governor control link lever.

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5. Install gage J 21779 so it extends through the lever and fuel rod and into the gage hole in the bottom of the housing.

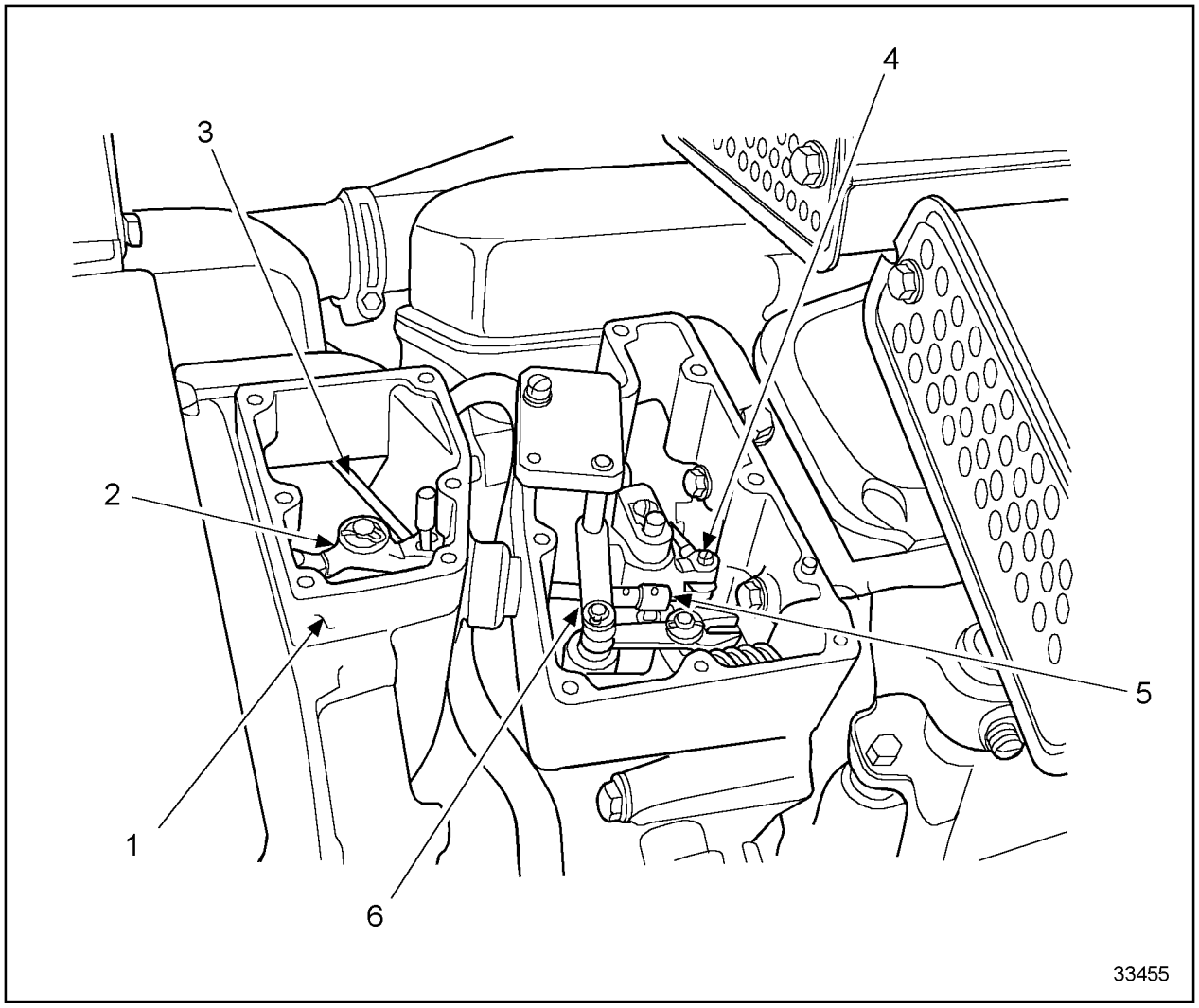
NOTE:
With the gage in place, the auxiliary control link lever will be in the mid-travel position.

6. Remove the connecting pin from the control link lever in the governor housing and install gage J 21780.
7. Install the gage so the pin extends through the connecting link, control lever, and fuel rod, and the governor housing dowel pin extends into the small hole in the gage.

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8. Install a governor cover bolt to lock the gage in place. See Figure 12-118.

NOTE:
With gage J 21780 in place, the governor control link lever will be in the mid-travel position and parallel to the auxiliary control link lever.



1. Auxiliary Control Link Housing
2. Control Lever Link
3. Fuel Rod
4. Governor Operating Lever Control Link
5. Adjustable Link
6. Connecting Link

Figure 12-118 Positioning Control Link Levers

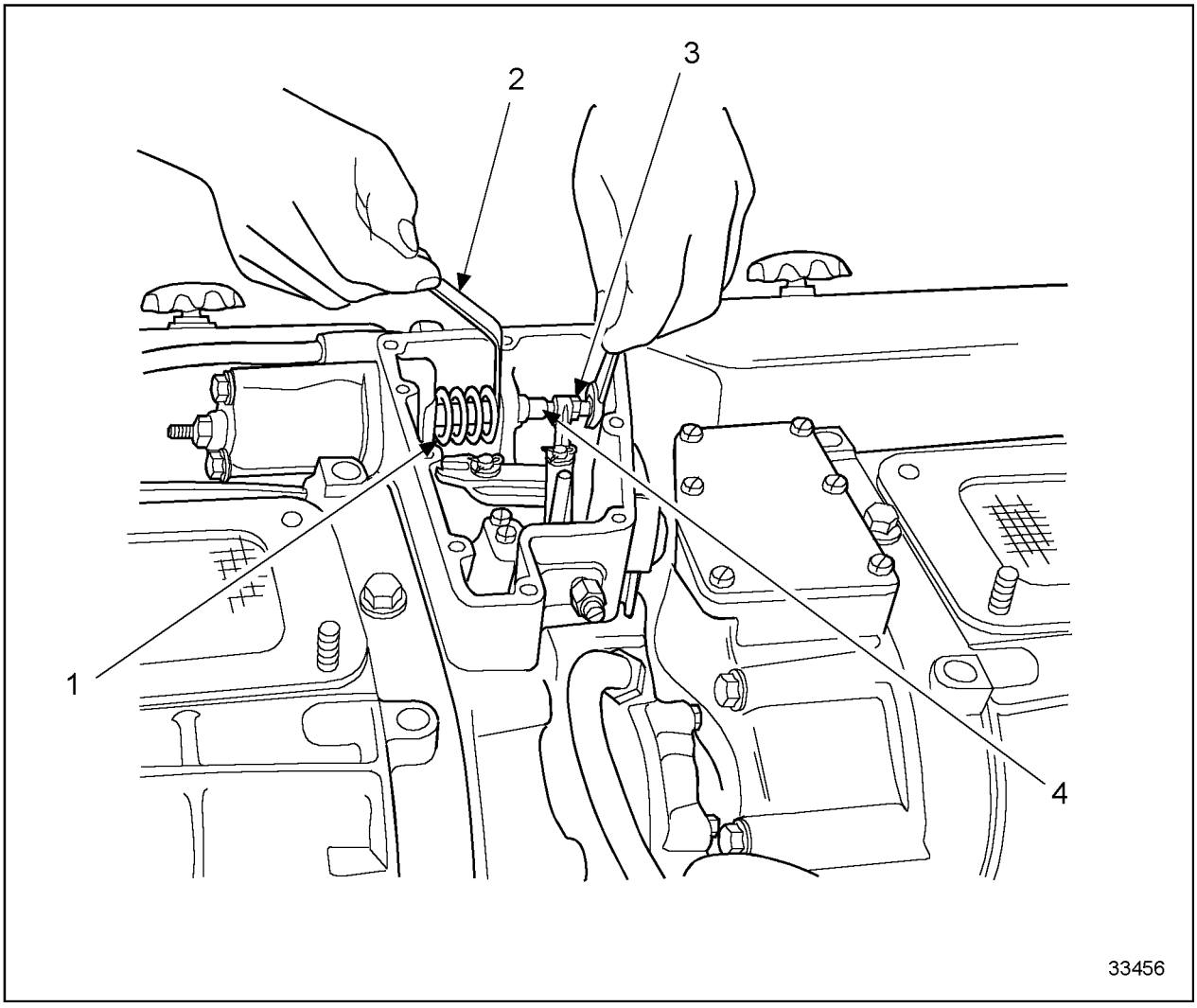
9. Adjust the length of the adjustable connecting link to retain the lever positions, and install the link.
10. Remove gages J 21779 and J 21780, and reinstall the control link lever connecting pins.
11. Install the governor housing and auxiliary control link housing covers.

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12.11.2 Adjust Governor Gap

With engine stopped and at normal operating temperature, adjust the governor gap as follows:

1. Clean and remove the governor cover and the valve rocker covers. Discard the gaskets.
2. Back out the buffer screw until it extends approximately 15.88 mm (0.625 in.) from the locknut.
3. Place the speed control lever in the maximum speed position.
4. Insert a 0.1524 mm (0.006 in.) feeler gage between the spring plunger and the plunger guide. See Figure 12-119.



1. Governor Spring
2. Feeler Gage
3. Gap Adjusting Screw
4. Spring Plunger

Figure 12-119 Adjusting Governor Gap

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5. If required, loosen the locknut, and turn the adjusting screw until it drags slight.
6. Hold the adjusting screw, and tighten the locknut.
7. Check the gap, and readjust if necessary.
8. Affix a new gasket to the top of the governor housing.
9. Place the governor cover assembly on the governor housing with the pin in the throttle control shaft assembly in the slot of the differential lever and the dowel pins in the cover. Tighten the screws.

12.11.3 Position Injector Rack Control Levers

The position of the injector rack control levers must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load.

The engines are spring-loaded injector control tube assemblies which have a yield spring at each injector rack control lever with one screw and locknut to keep each injector rack properly positioned.

Properly positioned injector rack control levers with the engine at full load will result in the following:

1. Speed control lever at the maximum speed position.
2. Stop lever in the run position.
3. High-speed spring plunger within 0.127–0.1778 mm (0.005–0.007 in.) of its seat in the governor control housing.
4. Injector fuel control racks in the full fuel position.The letters "R" and "L" indicate the injector location on the right or left cylinder bank, viewed from the rear of the engine. Cylinders are numbered starting at the front of the engine on each cylinder bank. Adjust the No. 4R injector rack control lever first to establish a guide for adjusting the remaining right bank injector rack control levers.

12.11.4 Adjustment of Control Levers

Adjust the control levers as follows:

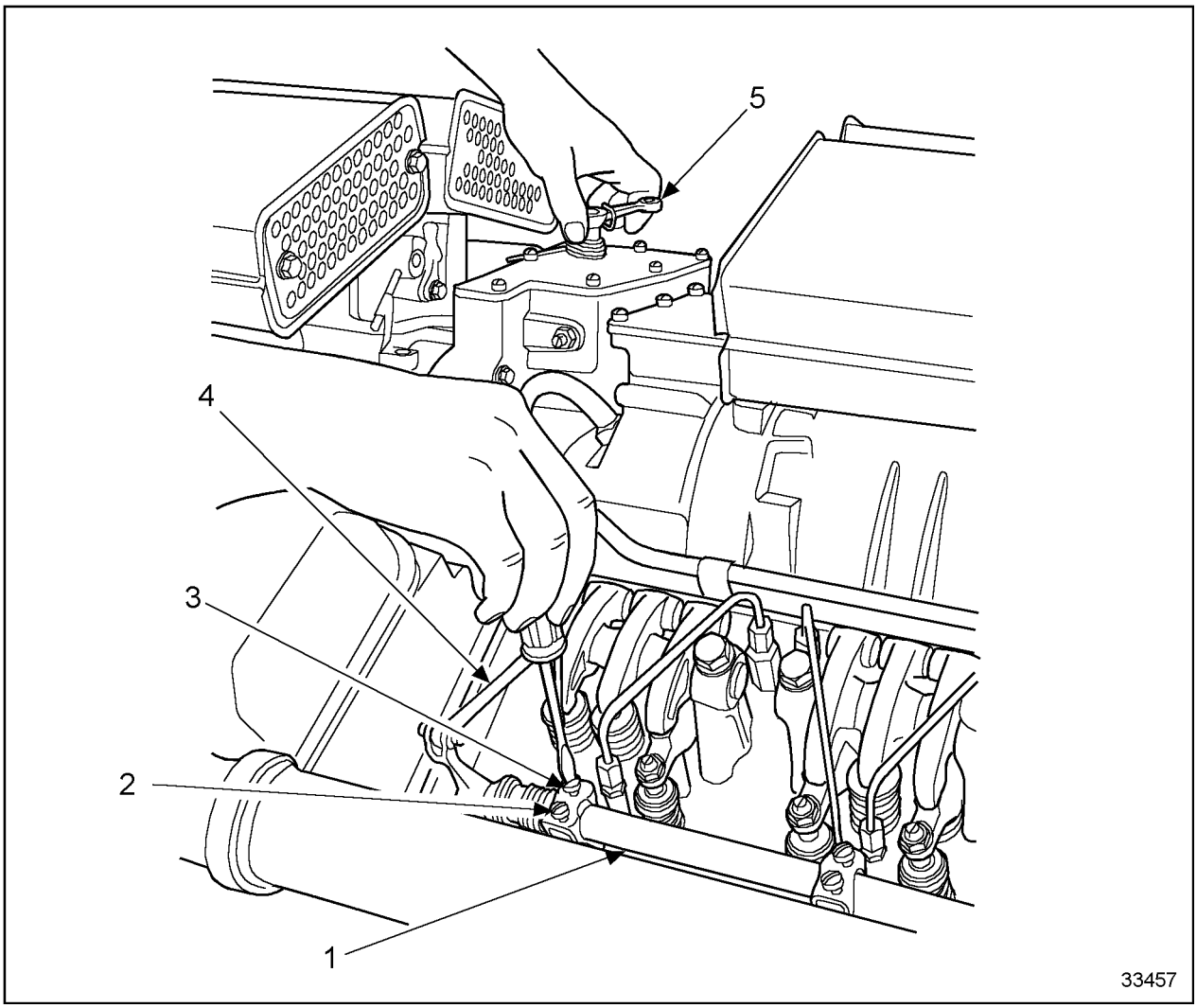
1. Remove the clevis pins which attach the right rear bank and both left-bank fuel rods to the injector control tube levers.
2. Loosen all adjusting screws and locknuts on both injector control tubes.

NOTE:
Ensure all levers are free on the injector control tubes.

3. Move the speed control lever to the maximum speed position.

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4. Move the stop lever to the run position, and hold it in that position with your finger. See Figure 12-120.



1. Injector Control Tube
2. Outer Adjusting Screw
3. Inner Adjusting Screw
4. Fuel Rod
5. Stop Lever

Figure 12-120 Positioning No. 4R Injector Rack Control Lever

NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended torque of the adjusting screws is 3-4 N·m (24-36 lb·in).

5. Tighten the adjusting screw of the No. 4R (16V) or No. 3R (12V) injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
6. Tighten the screw approximately 1/8 of a turn more, and lock securely with the adjusting screw locknut.

NOTE:
This will place the No. 4R (16V) or No. 3R (12V) injector rack in the full fuel position. The governor linkage and control tube assembly should be in the same position that they will attain while the engine is running at full load.

7. Remove the fuel rod-to-control tube lever clevis pin from the right front bank fuel rod, and install it on the right rear bank fuel rod.
8. Adjust the No. 5R (16V) or No. 4R (12V) injector rack. Refer to step 4 through step6.
9. Verify rack adjustment. refer to section 12.4.10 and refer to section 12.10.3.
10. Adjustment of the No. 4L and 5L (16V) or No. 3L and 4L (12V) injector racks. Refer to step 4 through step 6.

NOTE:
When the settings are correct, the No. 4R, 5R, 4L and 5L (16V) or No. 3R, 4R, 3L and 4L (12V) injector racks will be snug on the ball end of the control levers when the injectors are in the full fuel position.

11. With the fuel rod disconnected from the injector control tube lever, adjust the remaining injector rack control levers on the right front bank.
12. Hold the No. 4R (16V) or No. 3R (12V) injector rack in the full fuel position with the control tube lever.

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NOTICE:
Overtightening the injector rack control lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended torque of the adjusting screws is 3-4 N·m (24-36 lb·in.).

13. Tighten the adjusting screw of the No. 3R (16V) or No. 2R (12V) injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
14. Securely lock the adjusting screw locknut.
15. Verify the injector rack adjustment of No. 4R (16V) or No. 3R (12V). Refer to section 12.4.10 and refer to section 12.10.3.
16. If No. 4R (16V) or No. 3R (12V) does not "spring" back upward, turn the No. 3R (16V) or No. 2R (12V) adjusting screw counterclockwise slightly until the No. 4R (16V) or No. 3R (12V) injector rack returns to its full fuel position, and secure the adjusting screw locknut.
17. Verify proper injector rack adjustment for both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injectors.
18. Turn the No. 3R (16V) or No. 2R (12V) injector rack adjusting screw clockwise or counterclockwise until both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injector racks are in the full-fuel position when the locknut is securely tightened.

NOTE:
When the settings are correct, both injector racks must respond in the same manner on the ball ends of the control levers when the injector control tube lever is held in the full fuel position.

19. Position the remaining injector rack control levers on the right front cylinder bank. Refer to step 11 through step 18.
20. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder banks. Refer to step 11 through step 19.
21. Install the four fuel rod-to-control tube lever clevis pins, and check the adjustment of the injector rack control levers.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

NOTICE:

Before starting an engine after an engine speed control adjustment or after the engine governor cover and lever assembly removal, ensure the injector racks return to the no fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no fuel with the governor stop lever. An overspeeding engine can cause engine damage.

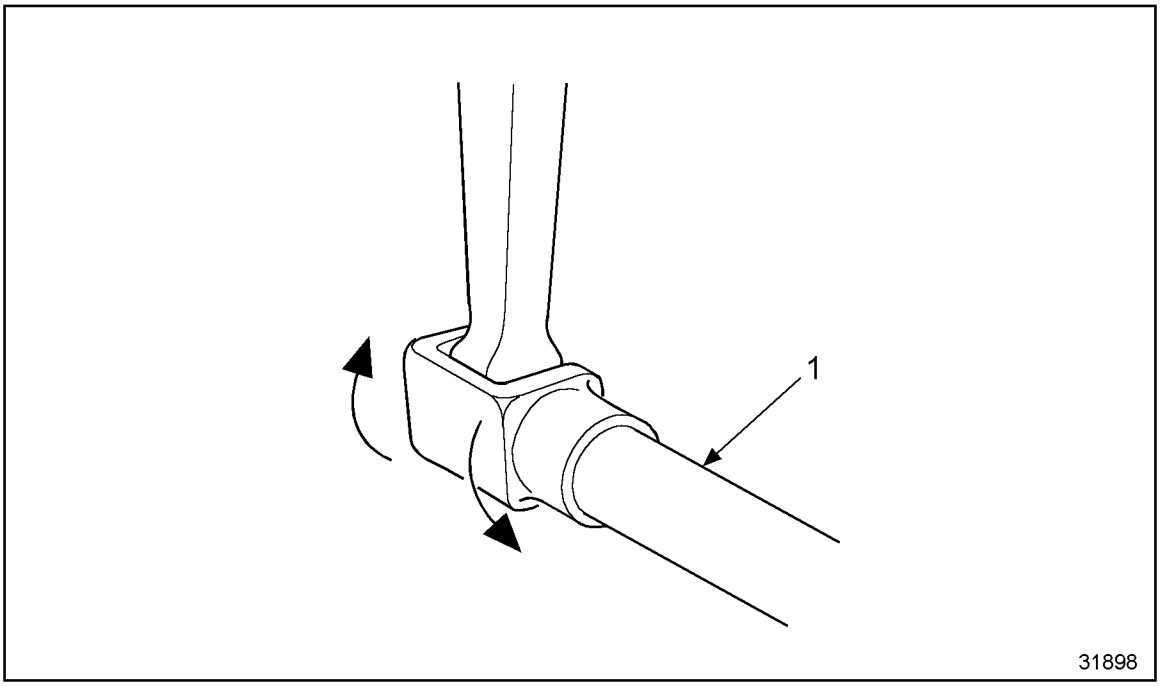
22. Use new gaskets, and reinstall the valve rocker covers.

12.11.5 Check Rack Adjustment

1. In order to ensure proper rack adjustment, hold the stop lever in the run position, and press down on the injector rack with a screwdriver or finger tip.

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2. Note the "rotating" movement of the injector control rack when the stop lever is in the run position. See Figure 12-121.



1. Injector Control Rack

Figure 12-121 Checking Rotating Movement of Injector Control Rack

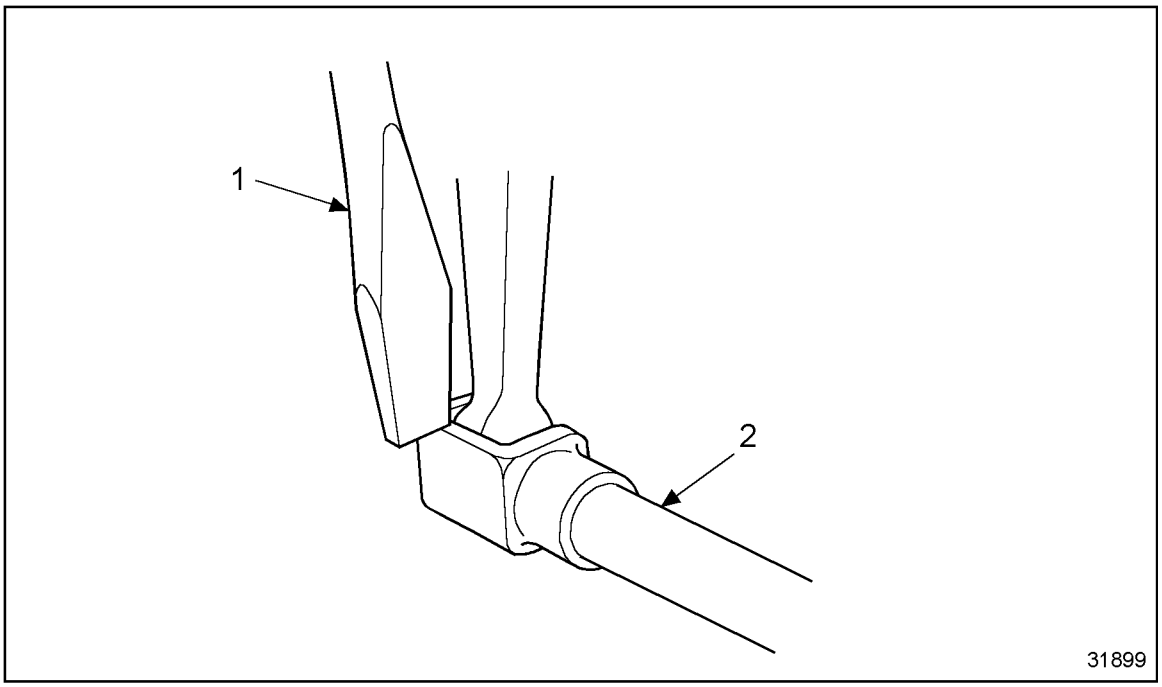
3. Hold the stop lever in the run position and, using a screwdriver, press downward on the injector control rack.

NOTE:
The rack should tilt downward, and when the pressure of the screwdriver is released, the control rack should "spring" back upward. See Figure 12-122.

NOTE:
If the rack does not return to its original position, it is too loose. The setting is too tight if when moving the stop lever from the stop to the run position, the injector rack becomes

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tight before the stop lever reaches the end of its travel. This will result in a step-up in effort required to move the stop lever to the end of its travel.



1. Screwdriver
2. Injector Control Rack

Figure 12-122 Checking Injector Control Rack "Spring"

4. To correct a loose rack, loosen the locknut, and turn the adjusting screw clockwise slightly.
5. Tighten the locknut.
6. To correct a tight rack, loosen the locknut, and turn the adjusting screw counterclockwise slightly.
7. Tighten the locknut.

12.11.6 Adjust Maximum No Load Speed

All governors are properly adjusted before leaving the factory. However, if the governor has been reconditioned or replaced, and to ensure the engine speed will not exceed the recommended no load speed as given on the engine option plate, set the maximum no load speed as follows:

1. Start the engine, and after it reaches normal operating temperature, determine the maximum no load speed of the engine with an accurate hand tachometer.
2. Stop the engine.
3. Disconnect the booster spring and governor stop lever.
4. Remove the variable speed spring housing and the variable speed spring plunger from the governor housing.

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5. Listed in Table 12-25, and determine the stops or shims required for the desired full load speed.

Full-Load Speed *	Stops	Shims
1200 - 1750	2	Up to 8.26 mm (0.325 in.) in Shims Maximum
1750 - 2100	1	
2100 - 2300	0	

* No-load is 150–225 RPM above full-load speed depending on engine application.

Table 12-25 Stops and Shims Required

NOTE:
The speed will increase approximately 1 RPM for each 0.03 mm (0.001 in.) in shims added.

6. Install the variable speed spring plunger and housing, and tighten the two bolts.
7. Connect the booster spring.
8. Start the engine, and check the maximum no load speed.
9. If required, add or remove shims to obtain the desired full load speed.
10. If the maximum no load speed is raised or lowered more than 50 RPM with shim installation or removal, check the governor gap.
11. If governor gap adjustment is required, the position of the injector racks must be rechecked.

NOTE:
Governor stops are used to limit the governor spring compression, which determines the maximum speed of the engine.

12.11.7 Adjust Idle Speed

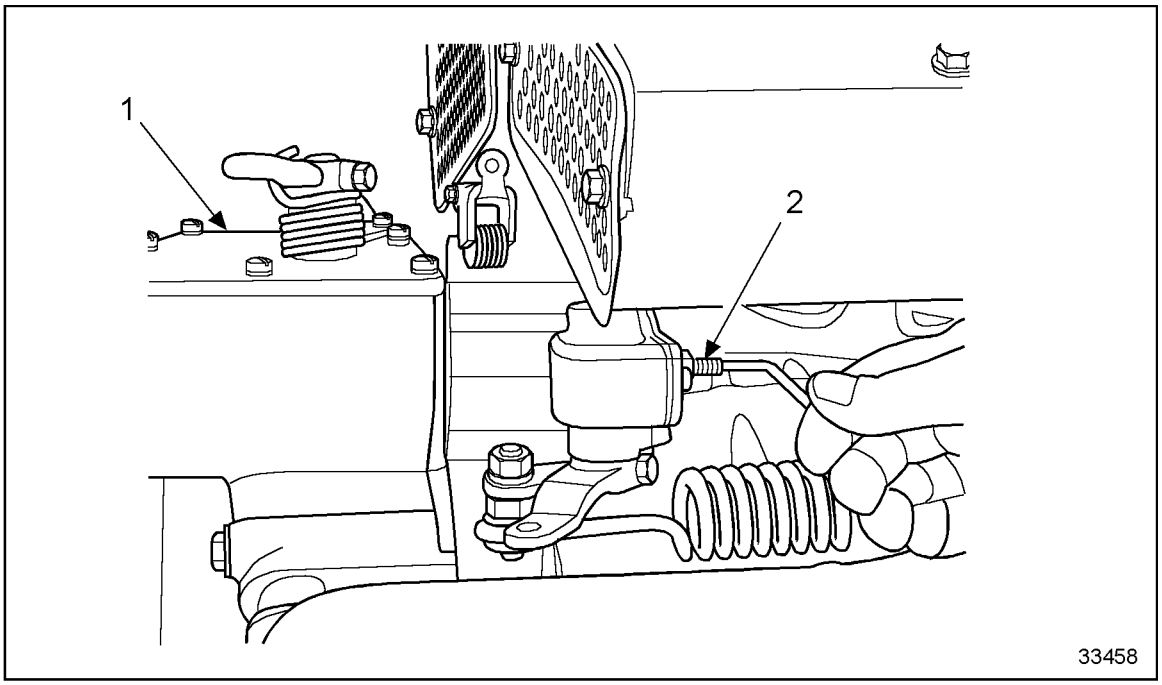
With the maximum no load speed properly set, adjust the idle speed as follows:

1. Place the speed control lever in the idle position and the stop lever in the run position.
2. With the engine running at normal operating temperature, back out the buffer screw to avoid contact with the differential lever.

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3. Loosen the locknut and turn the idle speed adjusting screw until the engine is operating at approximately 15 RPM below the recommended idle speed. See Figure 12-123.

NOTE:
The recommended idle speed is 550 RPM, but may vary with special engine applications.



1. Governor Assembly
2. Idle Speed Adjusting Screw

Figure 12-123 Adjusting Idle Speed

4. Hold the idle speed adjusting screw from turning, and tighten the locknut.

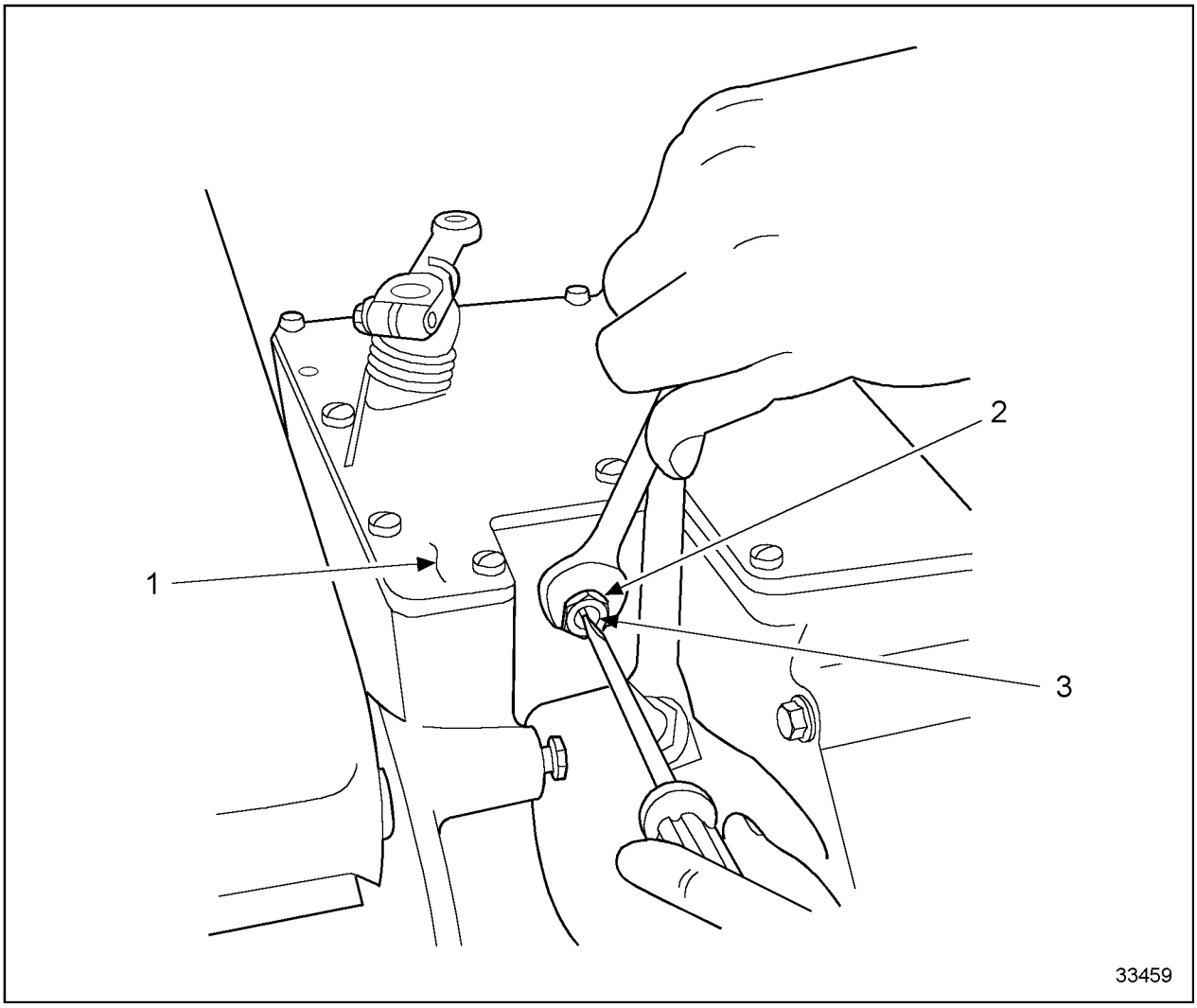
12.11.8 Adjust Buffer Screw

Adjust the buffer screw as follows:

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1. With the engine running at normal operating temperature, turn the buffer screw IN so it contacts the differential lever lightly and eliminates engine roll. See Figure 12-124.

NOTE:
Do not raise the idle speed more than 15 RPM with the buffer screw.



1. Governor Assembly
2. Locking Nut
3. Buffer Screw

Figure 12-124 Adjusting Buffer Screw

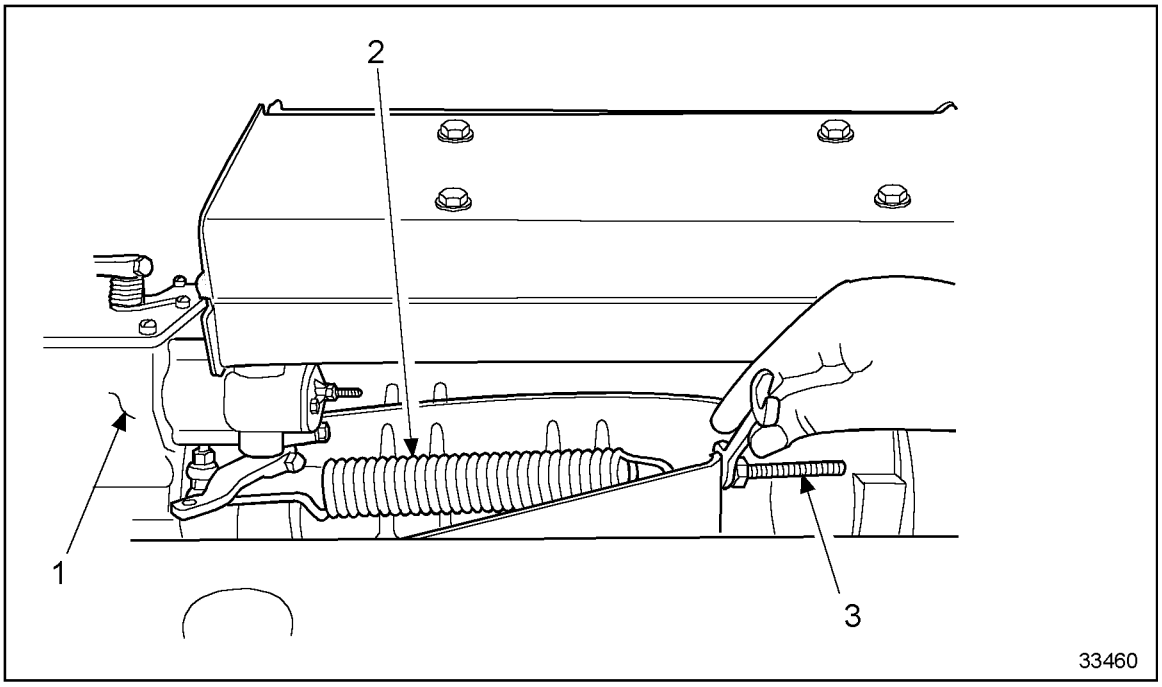
2. Hold the buffer screw from turning, and tighten the locknut.

12.11.9 Adjust Booster Spring

With the idle speed set, adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. See Figure 12-125, and loosen the nut on the booster spring retaining bolt on the governor speed control lever.



1. Governor
2. Booster Spring
3. Eye Bolt

Figure 12-125 Adjusting Booster Spring

3. Loosen the locknuts on the eyebolt at the opposite end of the spring.
4. Move the bolt in the slot of the speed control lever until the center of the bolt is on or slightly over center (toward the idle speed position) of an imaginary line through the bolt, lever shaft and eyebolt.
5. Hold the bolt, and tighten the locknut.
6. Start the engine, and move the speed control lever to the maximum speed position. Release it.

NOTE:
The speed control lever should return to the idle speed position.

7. If the speed control lever does not return to the idle speed position, reduce the spring tension.
8. If the lever does return to the idle position, increase the spring tension until the lever will not return to idle.

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9. Reduce the spring tension until the lever will return to idle, and tighten the locknut on the eyebolt.

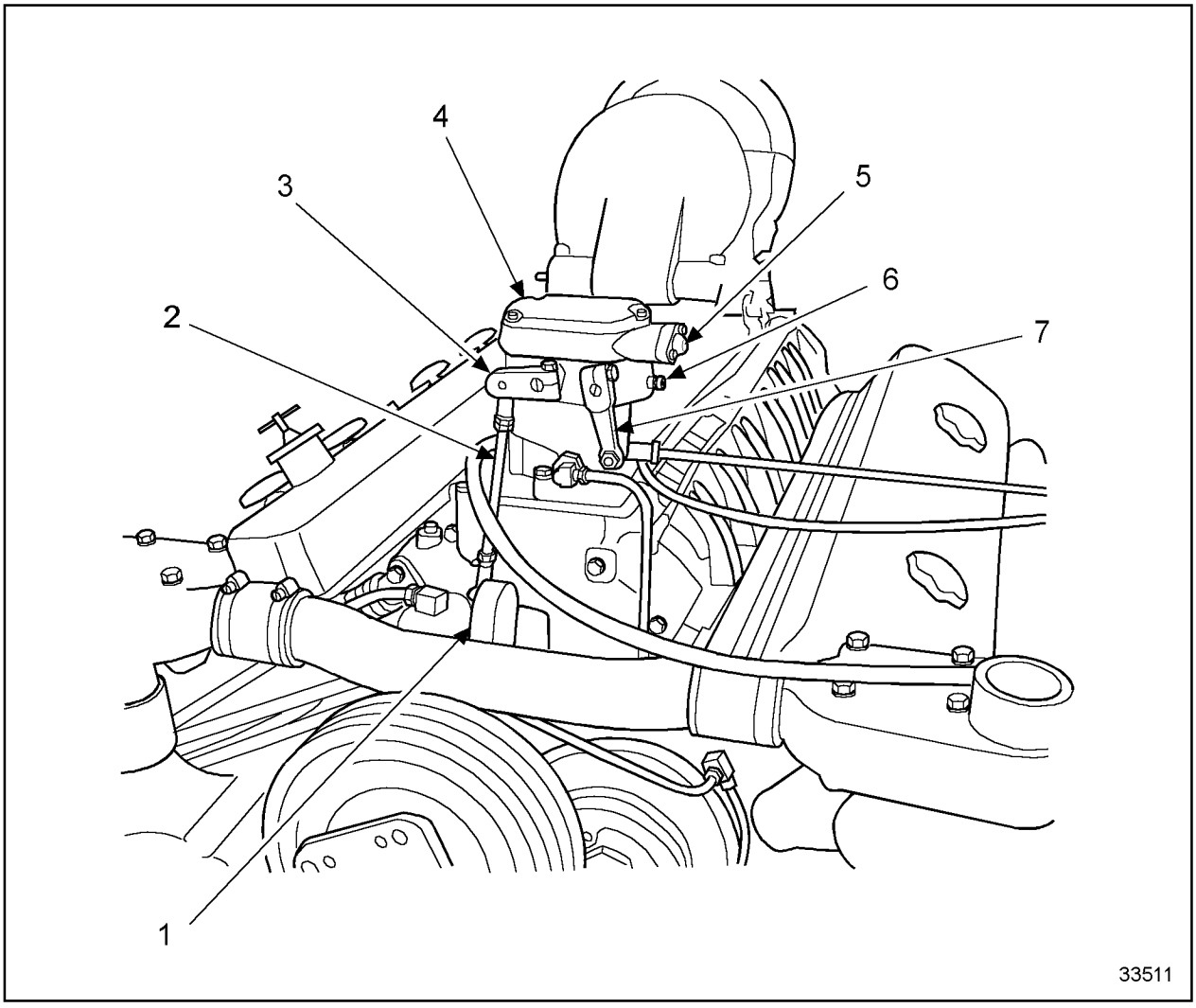
NOTE:
This setting will result in a minimum force required to operate the speed control lever.

10. Connect the linkage to the governor levers.

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12.12 SG VARIABLE SPEED HYDRAULIC GOVERNOR INJECTOR RACK CONTROL ADJUSTMENT (6V AND 8V ENGINES)

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor linkage and position the injector rack control levers. See Figure 12-126.



1. Bell Crank
2. Vertical Link
3. Governor Operating Lever
4. Governor
5. Load Limit Adjusting Screw
6. Maximum Speed Adjusting Screw
7. Speed Control Lever

Figure 12-126 Hydraulic Governor Mounted on Engine

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12.12.1 Position Injector Rack Control Levers and Adjust Governor Linkage

The position of the injector racks must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal load distribution.

Position the injector rack control levers and adjust governor linkage as follows:

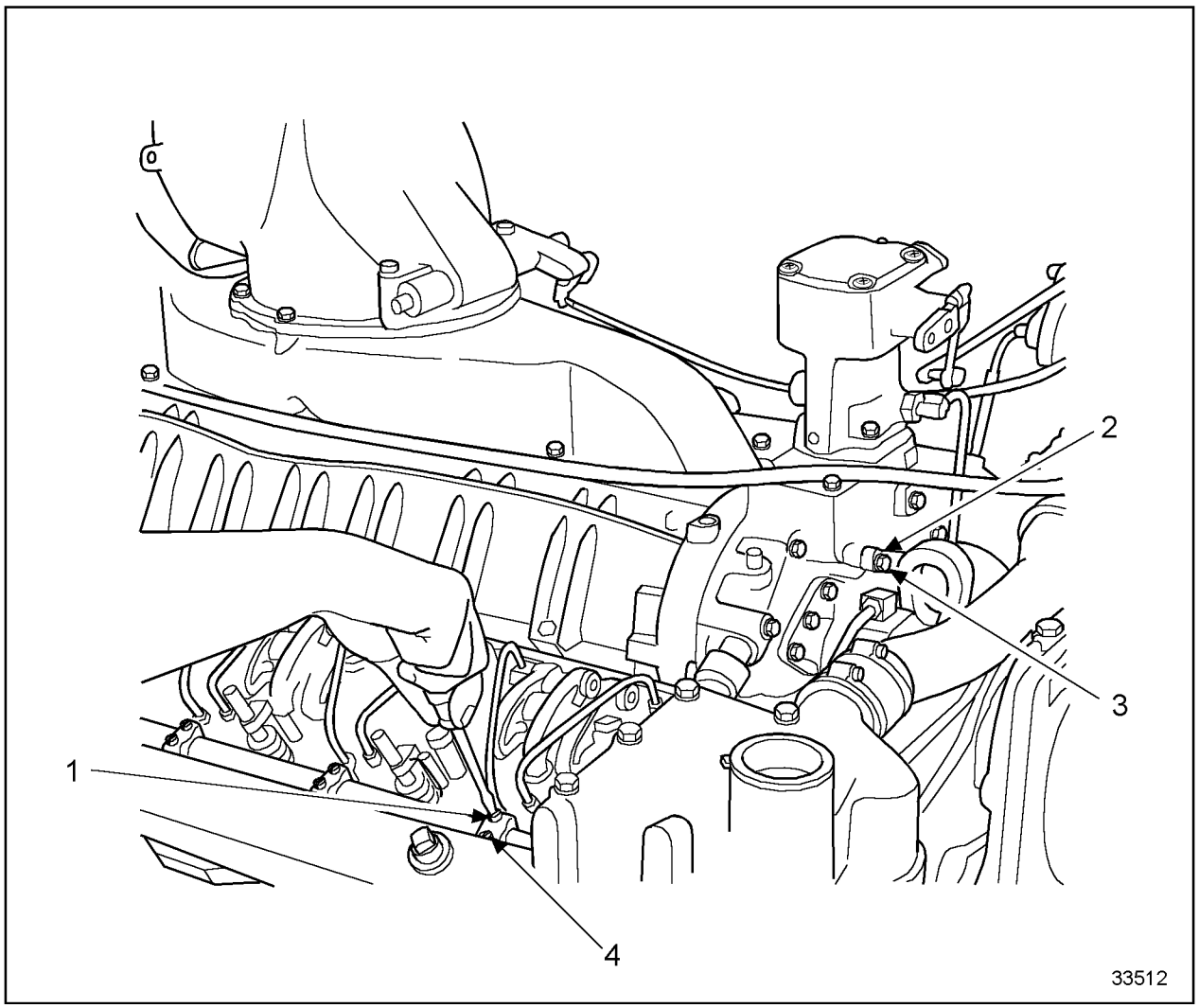
1. Clean and remove the valve rocker cover from each cylinder head. Discard the gaskets.
2. Loosen all the adjusting screws and locknuts.

NOTE:
Ensure all control levers are free on the control tubes.

3. Disconnect the vertical link assembly from the governor operating lever and the bell crank.
4. Loosen the bolt, and slide the governor operating lever from the serrated shaft.

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5. Place the bolt through the bell crank and into the recessed hole in the drive housing. See Figure 12-127.



1. Inner Adjusting Screw
2. Bell Crank Lever
3. Bolt
4. Outer Adjusting Screw

Figure 12-127 Positioning No. 1R Injector Rack Control Lever

NOTICE:
To avoid bending the fuel rod, do not set the racks too tightly.

6. To adjust the No. 1R injector rack, tighten the adjusting screw until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.

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7. Tighten the screw approximately 1/8 turn more, and lock securely with the adjusting screw locknut.

NOTE:
This will place the No. 1R injector rack in the full fuel position.

8. Adjust the No. 1L injector rack control lever. Refer to step 6 and step 7.
9. Verify rack adjustment. Refer to section 12.4.10 and refer to section 12.10.3.
10. To adjust the remaining injector rack control levers, hold the No. 1L injector rack in the full-fuel position with the lever on the end of the control tube assembly.

NOTICE:
Overtightening the injector rack control tube lever adjusting screws during installation or adjustment can cause injector control tube damage. The recommended torque is 3-4 N·m (24-36 lb·ft).

11. Tighten the No. 2L injector rack control lever adjusting screw until the injector rolls up or an increase in effort to turn the screwdriver is observed.
12. Securely lock the adjusting screw locknut.
13. Verify injector rack adjustment. Refer to section 12.12.2.
14. Verify proper injector rack adjustment for both No. 1L and No. 2L injectors. Refer to section 12.12.2.
15. Check that the No. 1L injector rack has remained snug on the ball end of the injector rack control lever while positioning the No. 2L injector rack.
16. If the No. 1L injector rack has become loose, loosen the locknut and turn the adjusting screw clockwise slightly.
17. Tighten the locknut.

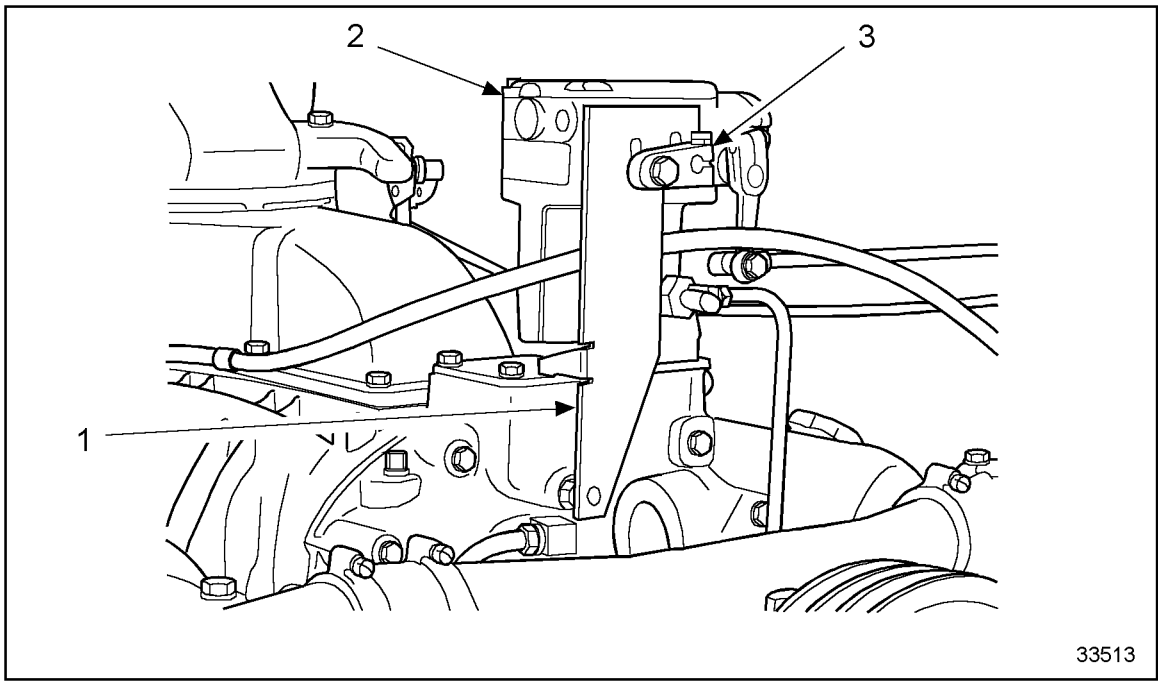
NOTE:
When the settings are correct, both injector racks must respond in the same manner on the ball end of their respective rack control levers.

18. Position the remaining injector rack control levers on the left and right cylinder heads. Refer to step 14 and step 15.

NOTE:
When the settings are correct, all injector racks will be snug on the ball end of the control levers when the injector control tube lever is held in the full fuel position.

19. Replace the governor operating lever on the serrated shaft so that the bolt hole is lined up within the proper lines on the linkage gage. See Figure 12-128.

NOTE:
The governor type will determine the proper lever position.



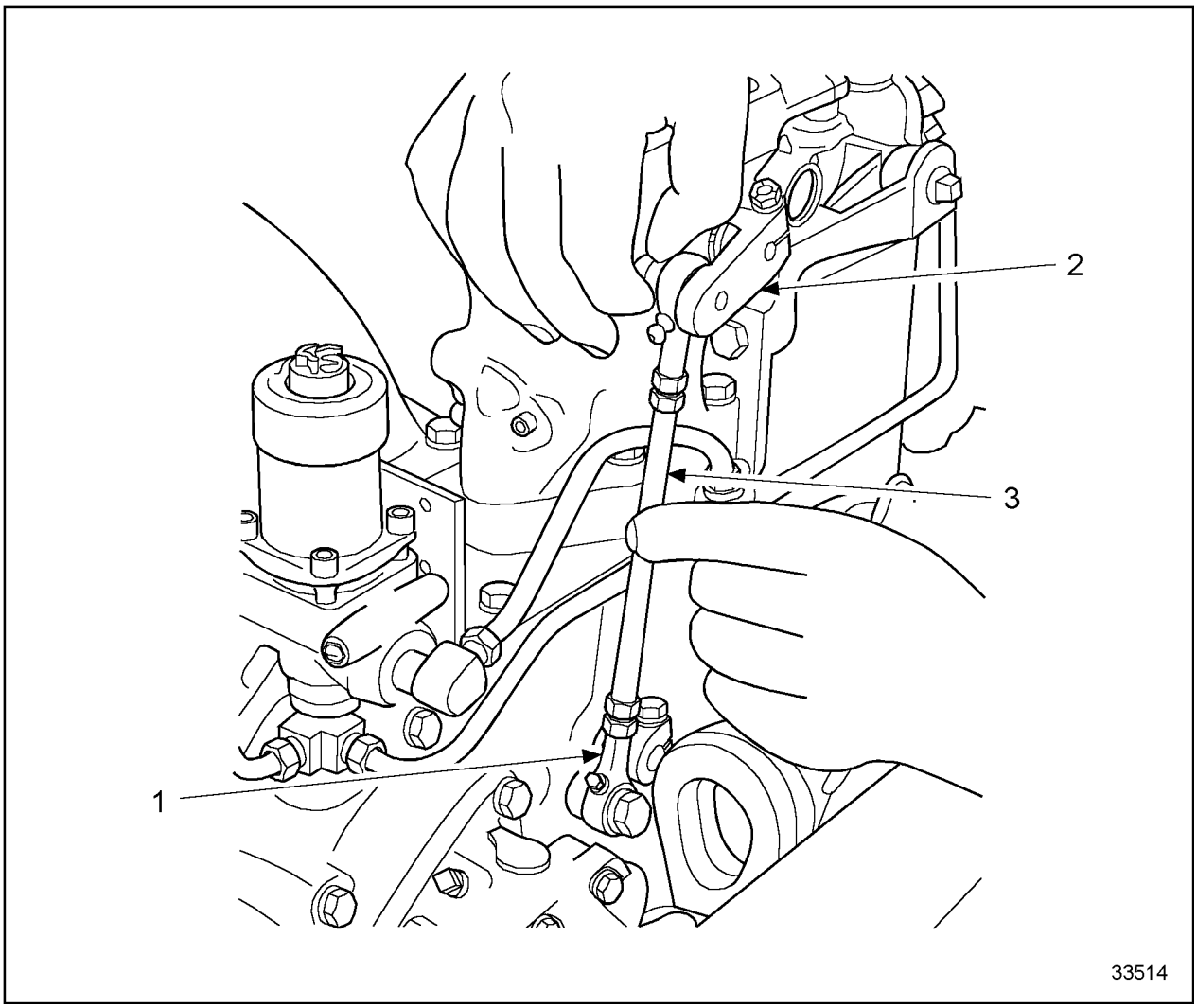
1. Linkage Gage
2. Governor Assembly
3. Governor Operating Lever

Figure 12-128 Positioning Governor Operating Lever

20. Remove the gage.
21. Move the bell crank lever to the no fuel position.

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22. Adjust the length of the vertical link so the lever bolt holes and the center of the rod end bearings line up. See Figure 12-129.



1. Bell Crank Lever
2. Governor Operating Lever
3. Vertical Link

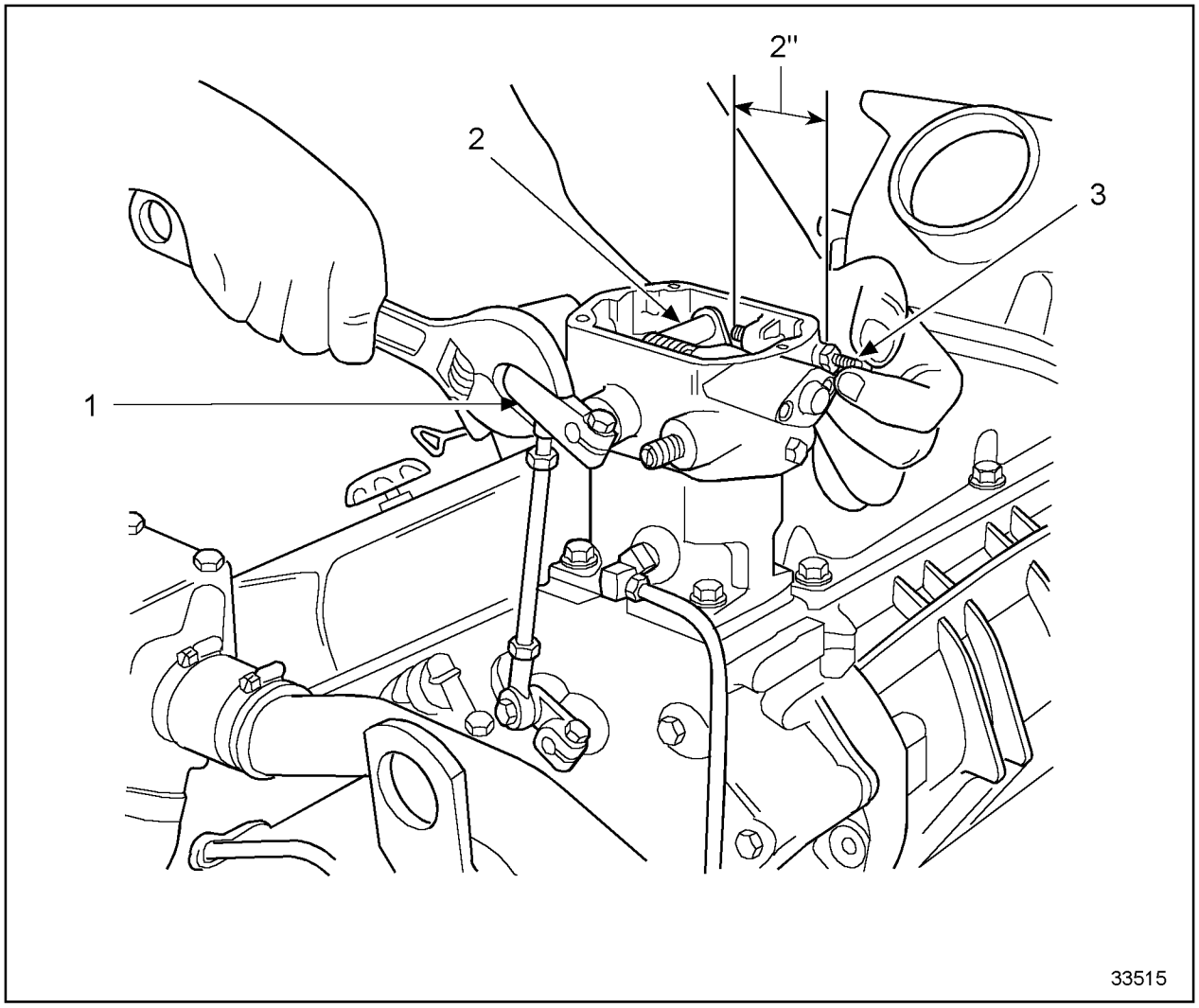
Figure 12-129 Adjusting Vertical Link

23. Replace the two bolts in the levers, and tighten the bolts.
24. Remove the governor cover.

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25. With the load limit screw completely backed out, retain the governor operating lever in the full fuel position.

NOTE:
The governor terminal lever should touch the boss in the governor housing. See Figure 12-130.



1. Governor Operating Lever
2. Terminal Lever
3. Load Limit Screw

Figure 12-130 Adjusting Load Limit Screw

26. Adjust the vertical link so all injector racks are in the full fuel position.
27. Tighten the rod end locknuts securely.
28. Use a new gasket, and install the valve rocker cover on each cylinder head.

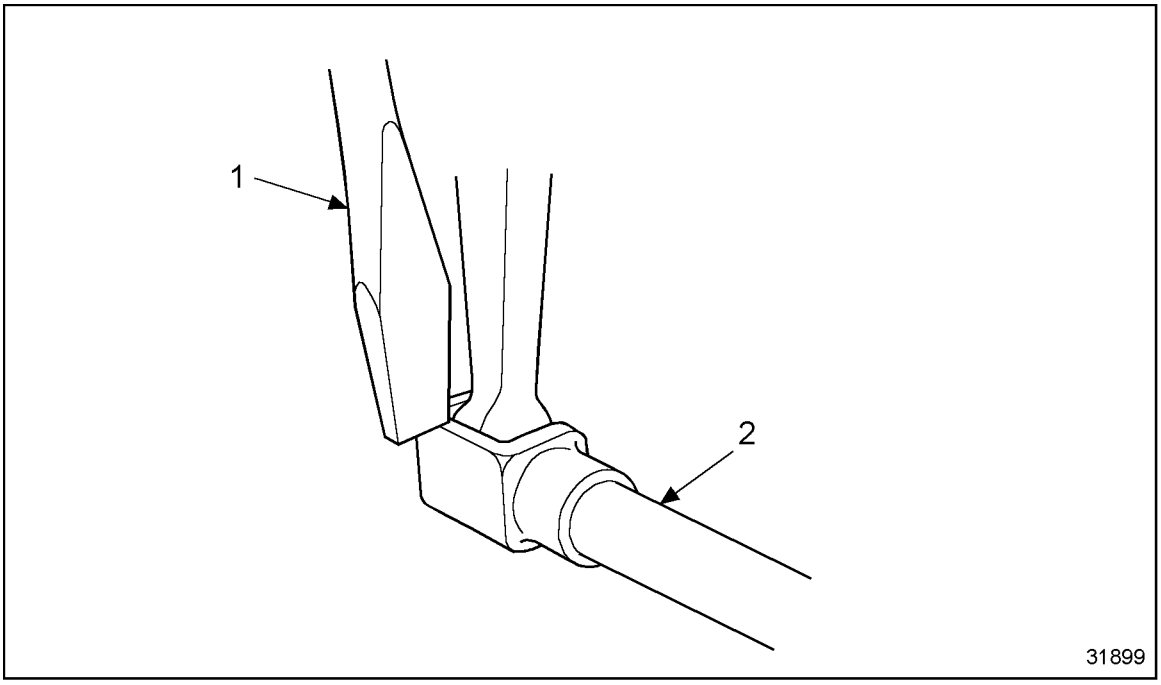
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12.12.2 Check Injector Rack Adjustment

Verify rack control lever adjustment as follows:

1. Press down on the injector rack with a screwdriver or finger tip. See Figure 12-131.

NOTE:
Light pressure should rotate the rack. The rack is sufficiently tightened if it returns or "springs" back to its original position when the pressure is removed. The rack is too tight if a heavy pressure is required to rotate the rack.



1. Screwdriver
2. Injector Control Rack

Figure 12-131 Checking Injector Control Rack "Spring"

2. Check the No. 1R and 1L injector rack control lever.

NOTE:
If the setting is correct, the injector racks will be in the full-fuel position and snug on the ball end of the control levers.

3. If the No. 1L does not "spring" up, turn the No. 2L adjusting screw counterclockwise until the No. 1L injector rack returns to its full fuel position.
4. Secure the adjusting screw locknut.
5. Turn the No. 2L injector rack clockwise or counterclockwise until both the No. 1L and No. 2L injector racks are in the full fuel position.
6. Tighten the locknut.

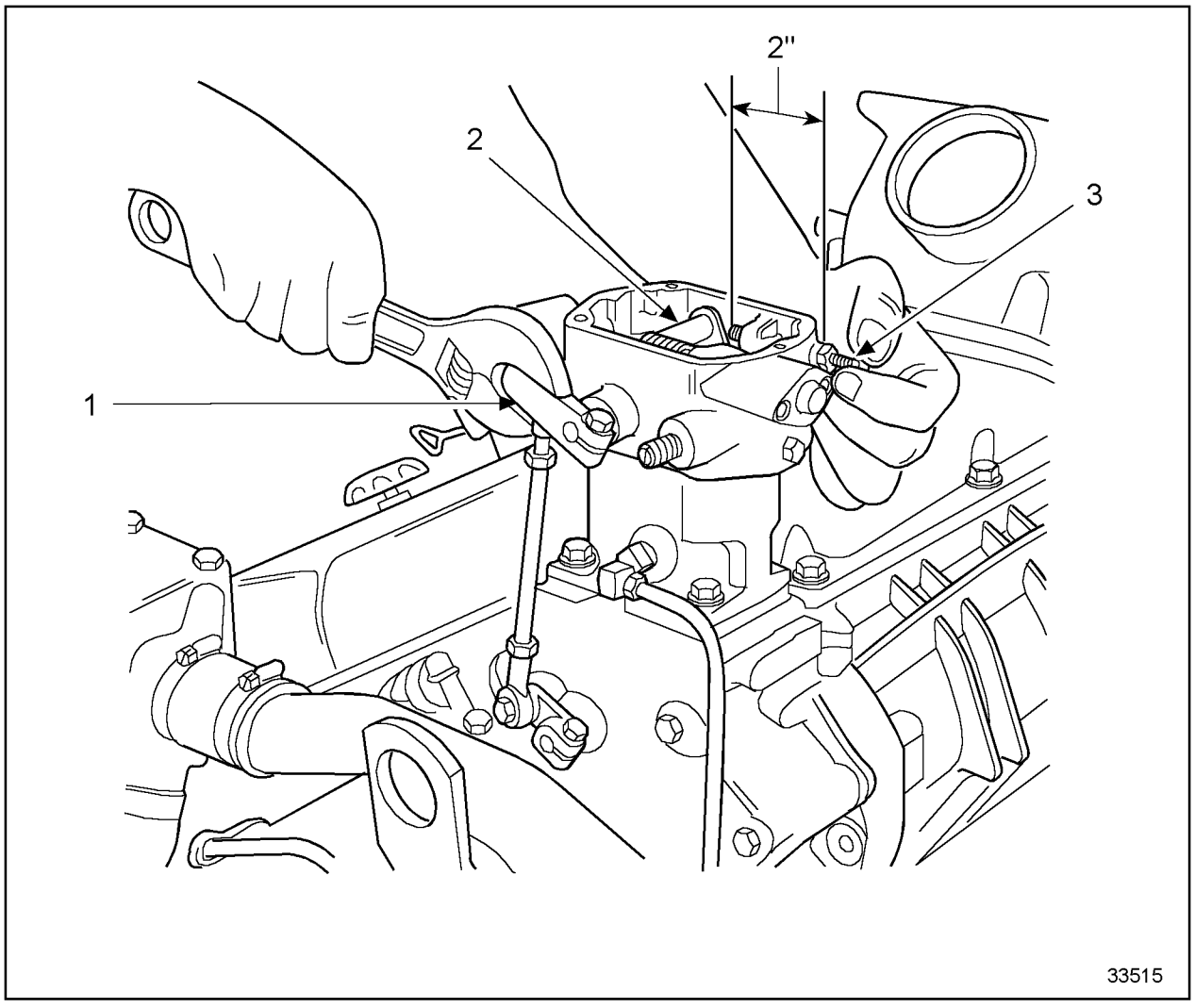
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12.12.3 Adjust Load Limit

The load limit is set at the factory and adjustment is unnecessary. If the governor has had major repairs or the injector rack control levers have been repositioned, the load limit screw should be adjusted. With the injector rack control levers properly adjusted, set the load limit as follows:

1. Loosen the load limit screw locknut, and adjust the load limit screw to obtain a distance of approximately 51 mm (2 in.) from the outside face of the boss on the governor subcap to the end of the screw.
2. Place and retain the governor operating lever in the full fuel position. See Figure 12-132.

NOTE:
Do not overstress the linkage.



1. Governor Operating Lever
2. Terminal Lever
3. Load Limit Screw

Figure 12-132 Adjusting Load Limit Screw

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3. Turn the load limit adjusting screw until a 0.51 mm (0.020 in.) space exists between the fuel rod collar and the terminal lever.

NOTE:
If the adjustment cannot be made with a feeler gage, turn the load limit adjusting screw (with the locknut tight enough to eliminate slack in the threads) inward until the injector racks loosen on the ball end of the control levers.

4. Release the governor operating lever, and hold the adjusting screw while tightening the locknut.
5. Install the governor cover, and tighten the screws.

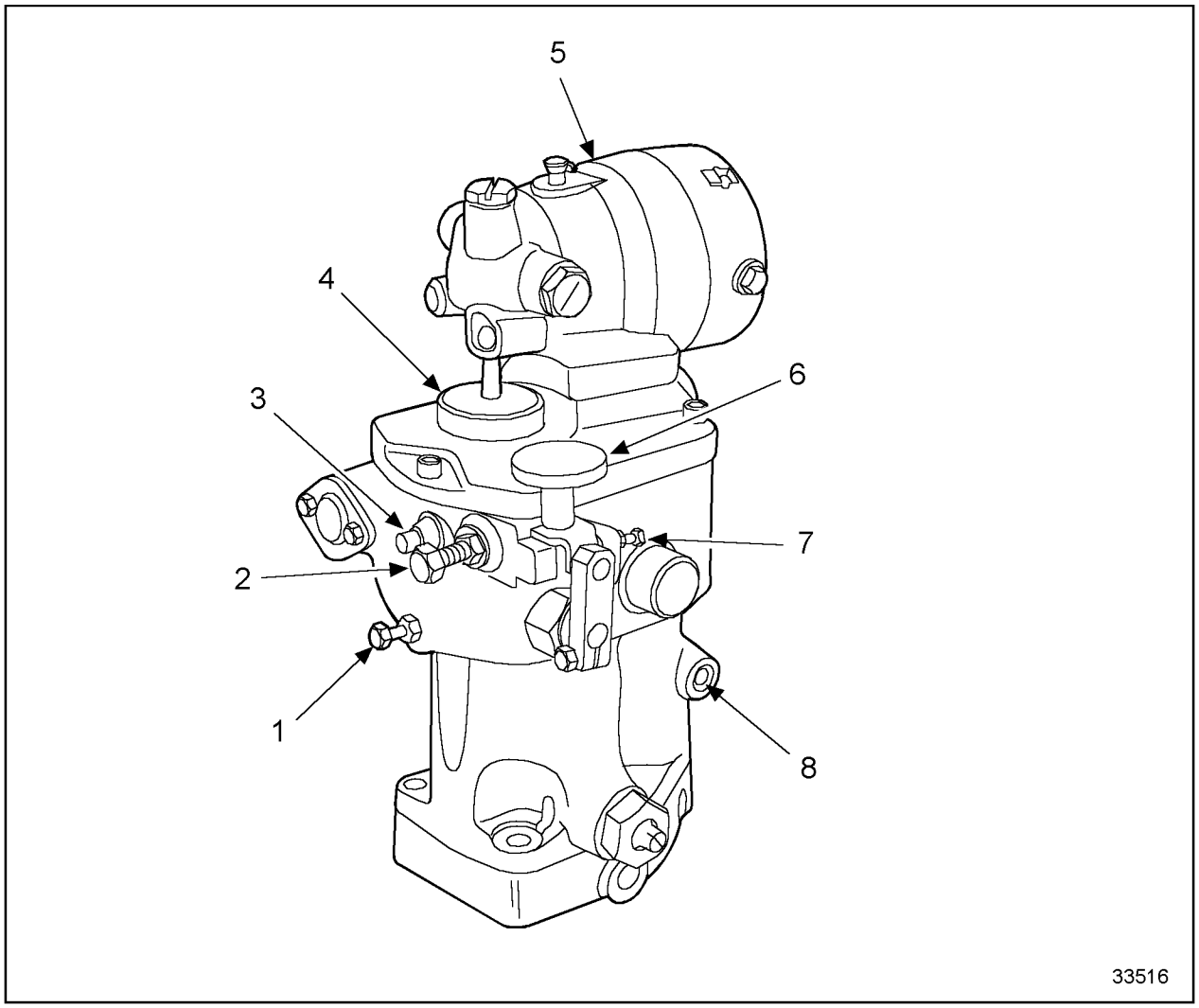
12.12.4 Compensation Needle Valve Adjustment (PSG Governor)

Adjust the governor compensation needle valve as follows:

1. Start the engine, and run until it reaches normal operating temperature.

NOTE:
Ensure the engine is running with no load.

2. Open the compensation needle valve two or three turns, and allow the engine to "hunt" or "surge" for approximately 1/2 minute to bleed any air which may be trapped in the governor oil passages. See Figure 12-133.



1. Maximum Speed Adjustment Screw
2. Load Limit Adjustment Screw
3. Minimum Droop Setting Screw
4. Friction Drive
5. Synchronous Motor
6. Droop Adjusting Screw
7. Maximum Droop Setting Screw
8. Compensation Needle Valve

Figure 12-133 Typical Synchronous Motor Mounting

3. Gradually close the valve until the "hunting" just stops.
4. Close the valve completely, and note the number of turns required to close it.
5. Open the valve to the previous position at which the "hunting" stopped.

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6. Manually disturb the engine speed to test the governor action.

NOTE:
The engine should promptly return to the original steady speed with only a small overshoot. The correct valve setting will be between 1/8 and 1/2 turn open. Closing the valve further than necessary will slow the governor in returning the engine to normal speed after a load change.

12.12.5 Adjust Internal Governor Speed Droop

Adjusting the speed droop establishes a definite engine speed at no load with a given speed at rated full load.

The governor speed droop is set at the factory and further adjustment is unnecessary. If the governor has been overhauled, the speed droop must be adjusted.

The best method for determining the engine speed is using an accurate hand tachometer.

If a full rated load can be established on the unit, and the fuel rods, injector rack control levers, and the load limit have been adjusted, set the speed droop as follows:

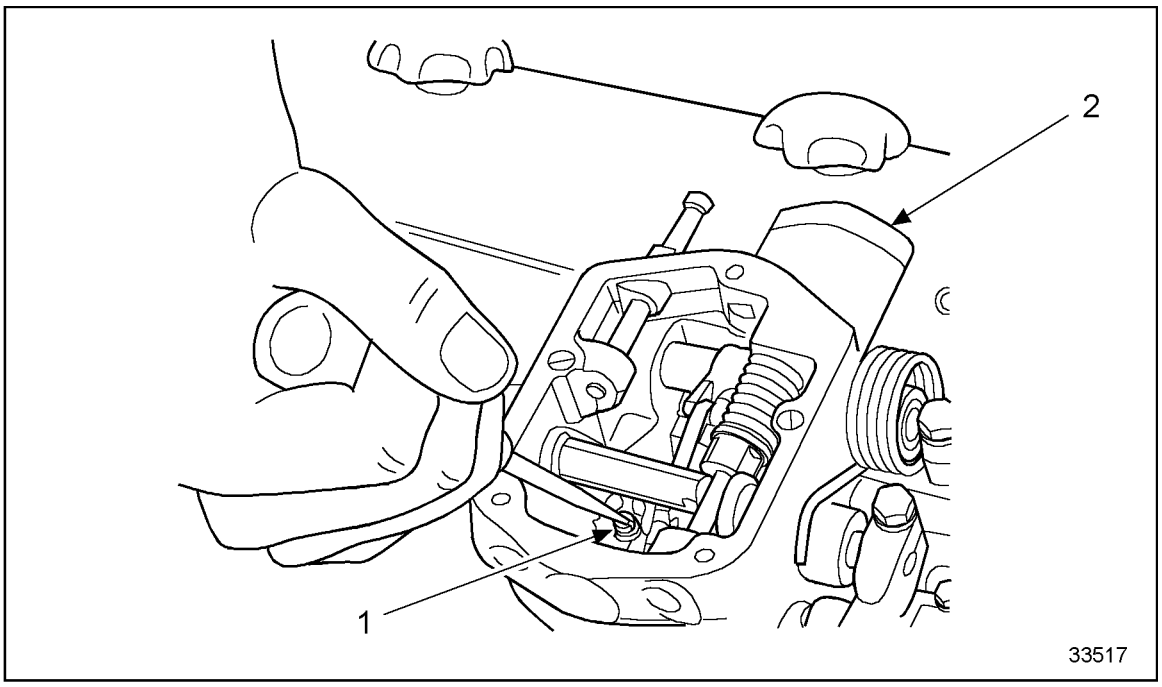
1. Start the engine, and run it at approximately one-half the rated no load speed until the lubricating oil temperature stabilizes.

NOTE:
When the engine lubricating oil is cold, the governor regulation may be erratic. Regulation will become stable as the oil temperature increases.

2. Stop the engine, and remove the governor cover.
3. Loosen the locknut, and back off the maximum speed adjusting screw 15.88 mm (0.625 in.).
4. Loosen the screw, and move the bracket so the screw is midway between the ends of the slot in the bracket.

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5. Tighten the screw. See Figure 12-134.



1. Speed Droop Screw
2. Governor Assembly

Figure 12-134 Adjusting Speed Droop Screw

6. With the throttle in the run position, adjust the engine speed until the engine is operating a 3 to 5% above the recommended full load speed.
7. Apply the full rated load on the engine, and adjust the engine speed to the correct full load speed.
8. Remove the rated load, and note the engine speed after the speed stabilizes under no load.

NOTE:
If the speed droop is correct, the engine speed will be approximately 3 to 5% higher than the full load speed.

NOTE:
If the speed droop is too high move the adjusting bracket toward the center of the governor. If the speed droop is too low, move the adjusting bracket away from the center of the governor.

9. To adjust the speed droop, stop the engine, loosen the droop adjusting screw, and move the adjusting bracket toward the center of the governor or away from the center of the governor.

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10. Tighten the screw.

NOTE:
The speed droop in governors which control parallel generator engines must be identical, otherwise the electrical load will not be equally divided.

11. Adjust the speed droop bracket in each governor to obtain the desired variation between engine no load and full load speeds.

NOTE:
The recommended speed droop for generator sets operating in parallel is 50 RPM (2-2 1/2 cycles) for units operating at 1,000 and 1,200 RPM, 75 RPM (2-2 1/2 cycles) for units operating at 1,500 and 1,800 RPM. Recommended speed droop is listed in Table 12-26. The speed droop recommendation may be varied to suit the individual application.

Full Load	No Load
50 Cycles, 1000 RPM	52.5 Cycles, 1050 RPM
60 Cycles, 1200 RPM	62.5 Cycles, 1250 RPM
50 Cycles, 1500 RPM	52.5 Cycles, 1575 RPM
60 Cycles, 1800 RPM	62.5 Cycles, 1875 RPM

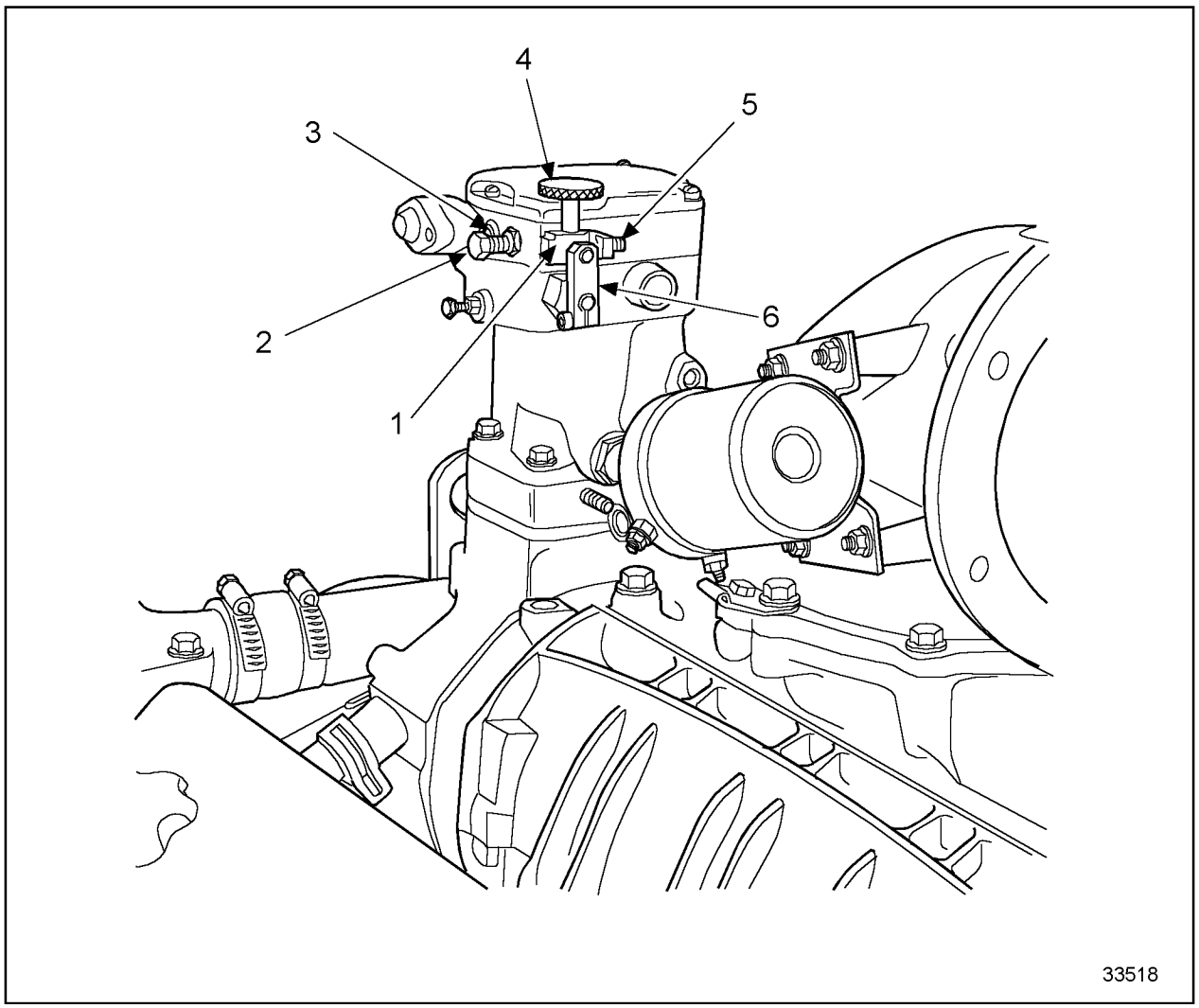
Table 12-26 Recommended Speed Droop

12. Install the governor cover.

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12.12.6 Adjust External Governor Speed Droop

Some PSG type governors are equipped with an external adjustable droop control. See Figure 12-135. This permits the speed droop to be adjusted without removing the governor cover. With this feature, a unit can be paralleled with another unit that is operating at constant frequency (zero droop).



1. Slider
2. Load Limit Adjusting Screw
3. Minimum Droop Setting Screw
4. Droop Adjusting Knob
5. Maximum Droop Setting Screw
6. Slider Arm

Figure 12-135 External Droop Control on PSG Isochronous Governor

The incoming unit must have its droop bracket set in the maximum position while it is paralleled and while operating in parallel as follows:

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1. When stopping the unit at constant frequency, shift the load to the incoming unit, and move the governor droop bracket to zero droop.
2. Adjust the outgoing unit to maximum droop.
3. Remove the outgoing unit from the line
4. Stop the engine.

NOTE:
The incoming unit will now carry the load and operate at constant frequency (zero droop).

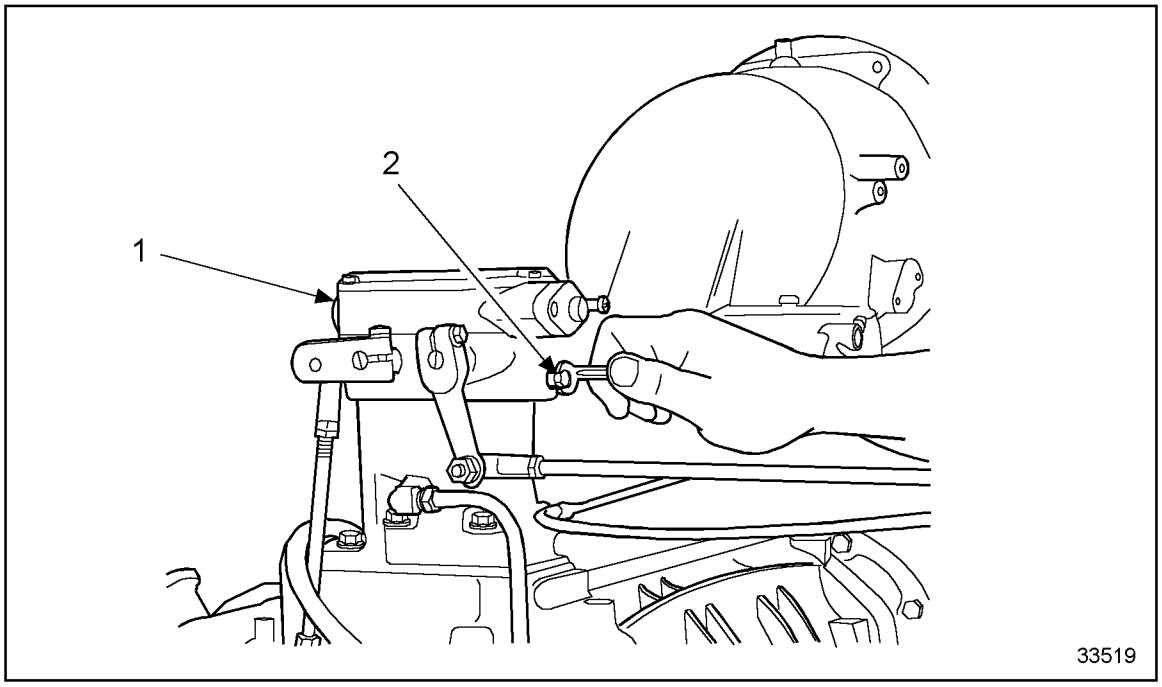
Adjust the governor speed droop as follows:

5. Start the engine, and run it at approximately 1/2 rated full load speed until the lubricating oil temperature stabilizes.
6. Remove the load from the engine.
7. Back off the compensation needle valve to release any air that may be trapped in the system.
8. Turn the needle valve in slowly to reduce governor "hunting".

NOTE:
The correct needle valve setting will be between 1/8 and 1/2 turn open.

9. Back out the minimum and maximum droop setting screws.
10. Loosen the droop adjusting knob, and move the slide all the way in toward the center of the governor.
11. Tighten the knob.

12. Loosen the locknut on the maximum speed adjusting screw, and turn the screw out until 15.88 mm (0.625 in.) of the threads are exposed. See Figure 12-136.



1. Governor Assembly
2. Maximum Speed Adjusting Screw

Figure 12-136 Adjusting Maximum No-Load Engine Speed

13. With the engine operating at the recommended full load speed, apply the full rated load, and check the engine speed.
14. If necessary, adjust the engine to full load speed.
15. Remove the load, and note the engine speed.

NOTE:
If the zero droop setting is correct, the engine speed will remain constant.

16. If the engine speed is higher, loosen the droop adjusting knob, and set the slider to a reduced droop position.
17. When the desired minimum droop setting is reached, loosen the locknut, and turn the minimum droop setting screw inward until it contacts the droop linkage within the governor.

NOTE:
This will be felt by a step up of resistance while turning the adjusting screw.

18. Lock the adjusting screw in this position.
19. Loosen the droop adjusting knob, and slide the droop bracket to increase the droop.

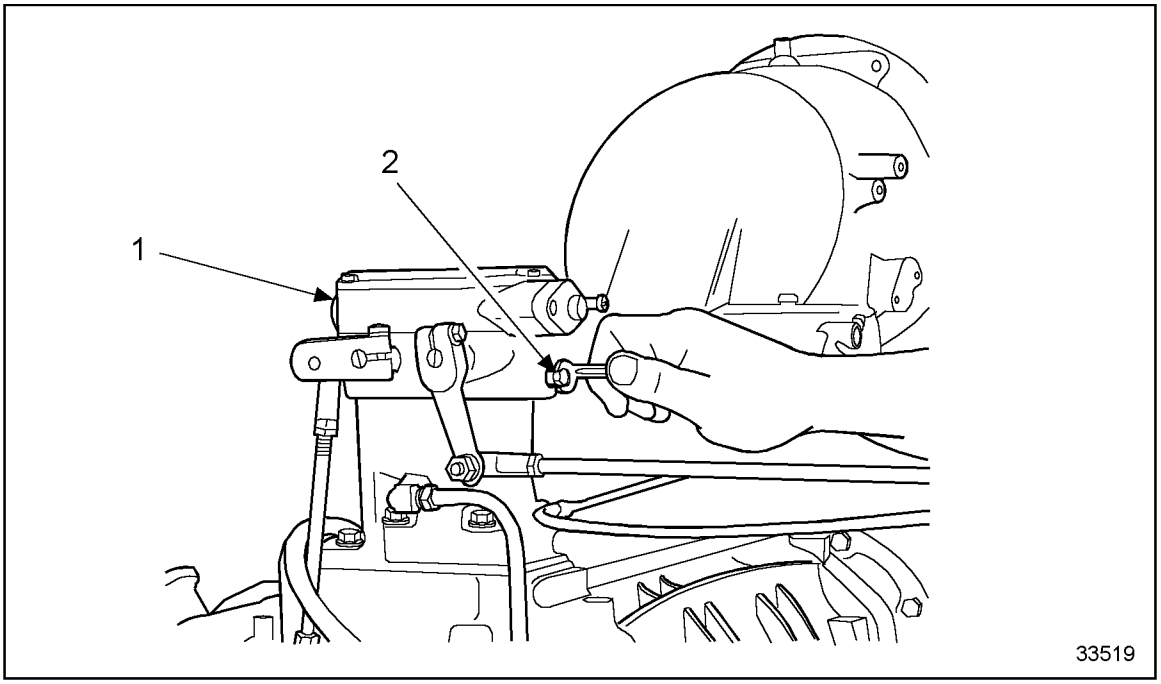
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20. Check droop until the desired maximum droop speed is obtained. Refer to step9 through step 12.
21. When the desired maximum droop setting is reached, loosen the locknut, and turn the maximum droop setting screw inward until it contacts the droop slider arm.
22. Lock the adjusting screw in position.
23. Check the minimum and maximum droop setting. Refer to step 9 through step 12.
24. Adjust the adjusting screws, if necessary, until the correct settings are obtained.

12.12.7 Adjust Maximum No Load Speed

With the speed droop properly adjusted, set the maximum no load speed as follows:

1. With the engine operating at no load, adjust the speed until the engine is operating at approximately 8% higher then the rated full load speed.
2. Turn the maximum speed adjusting screw in until the screw contacts the throttle linkage internally, limiting the maximum speed of the engine at 8% above the rated full load speed. See Figure 12-137.



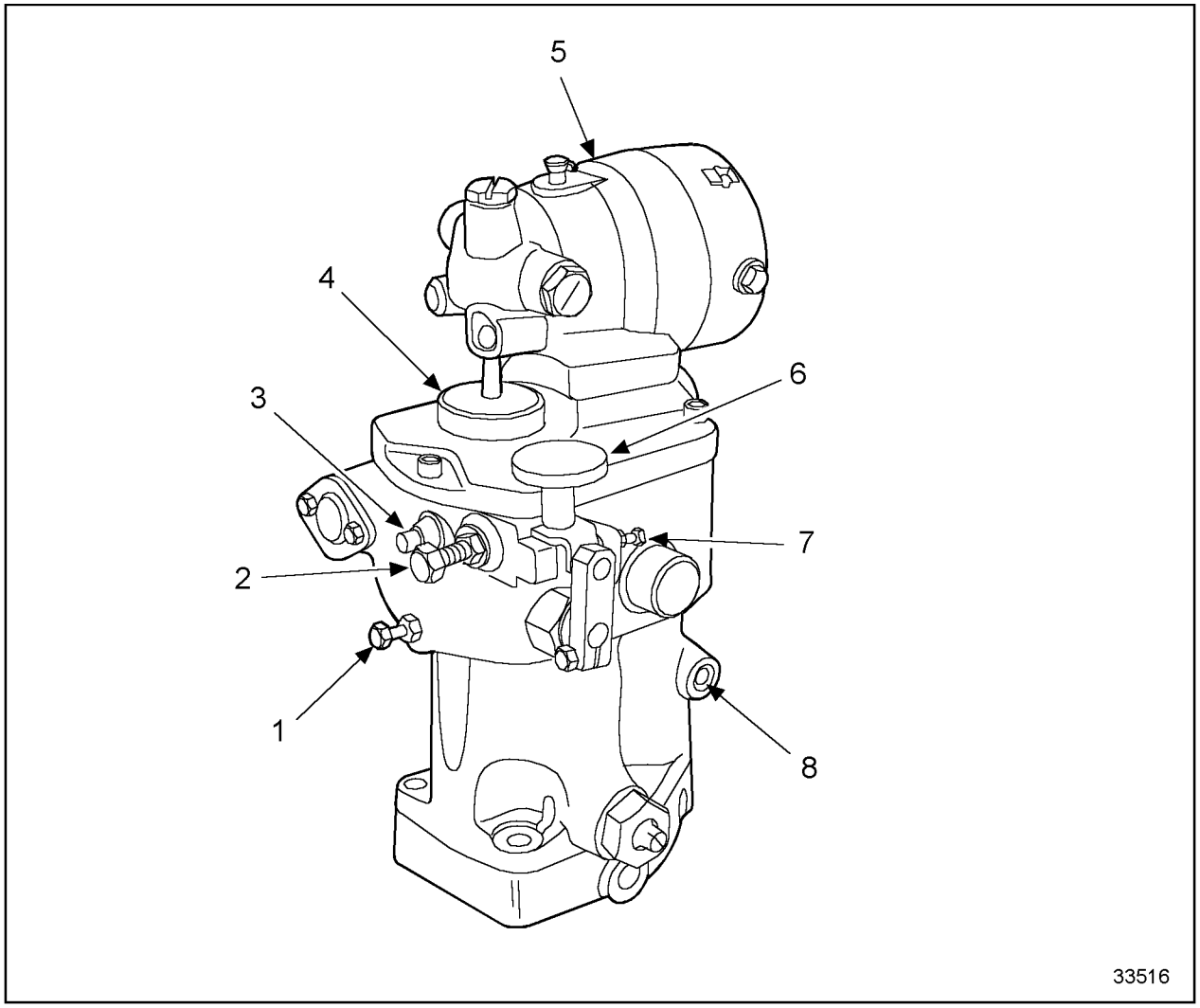
1. Governor Assembly
2. Maximum Speed Adjusting Screw

Figure 12-137 Adjusting Maximum No-Load Engine Speed

3. Hold the screw, and tighten the locknut.

12.12.8 Governors with Synchronizing Motors

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover. See Figure 12-138.



1. Maximum Speed Adjustment Screw
2. Load Limit Adjustment Screw
3. Minimum Droop Setting Screw
4. Friction Drive
5. Synchronous Motor
6. Droop Adjusting Screw
7. Maximum Droop Setting Screw
8. Compensation Needle Valve

Figure 12-138 Typical Synchronous Motor Mounting

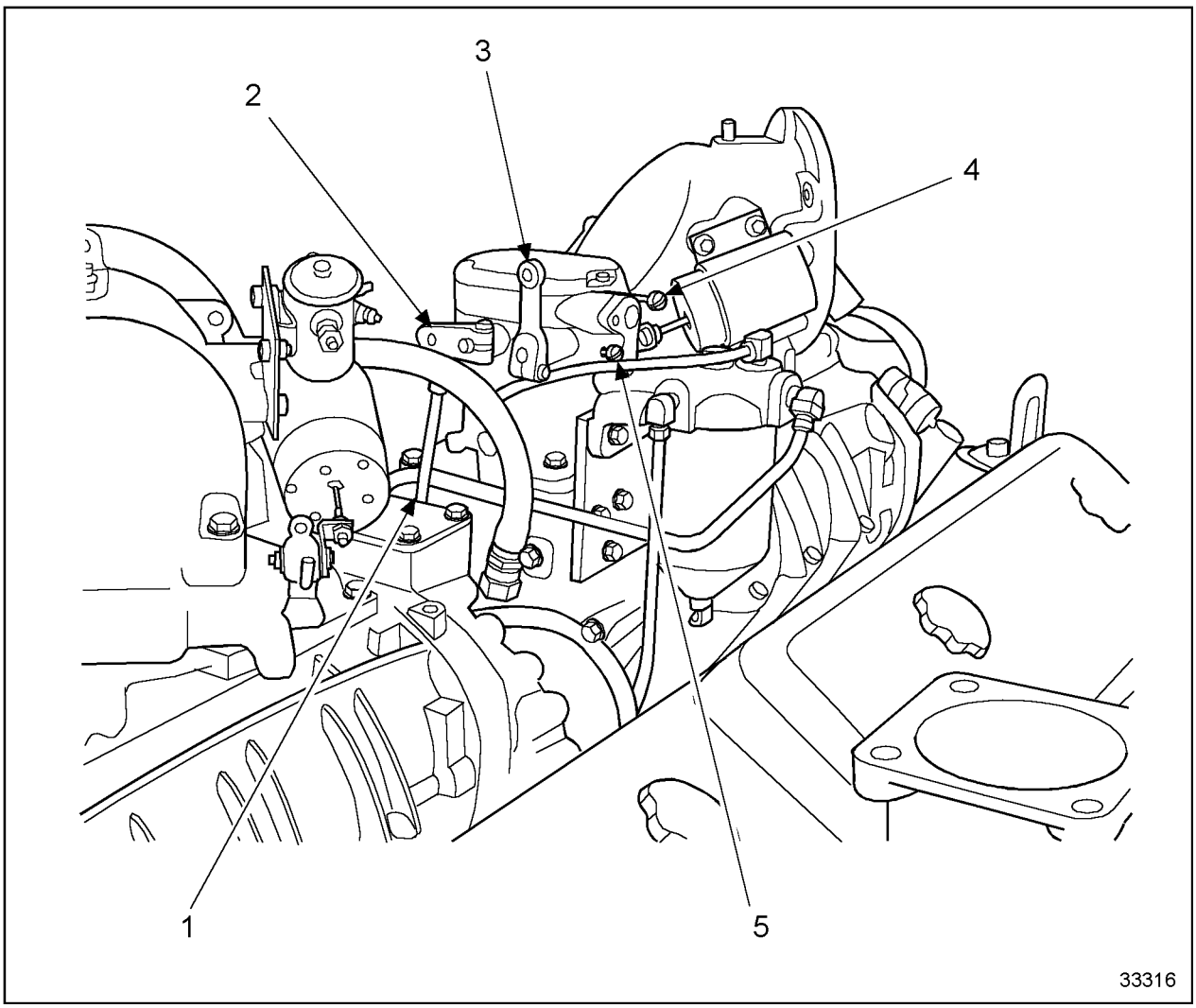
The adjustments on a governor equipped with a synchronizing motor are the same as on a governor without the motor. The governor cover and motor assembly must be removed when setting the engine speed droop (except on a governor equipped with an external droop adjustment). The cover and motor must be installed to check the speed droop.

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12.13 SG VARIABLE SPEED HYDRAULIC GOVERNOR INJECTOR RACK CONTROL ADJUSTMENT (12V AND 16V)

The governor on the 12V and 16V engine is mounted on and driven from the front end of the rear blower.

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor linkage, and position the injector rack control levers. See Figure 12-139.



1. Vertical Link Assembly
2. Governor Operating Lever
3. Speed Control Lever
4. Load Limit Adjusting Screw
5. Maximum Speed Adjusting Screw

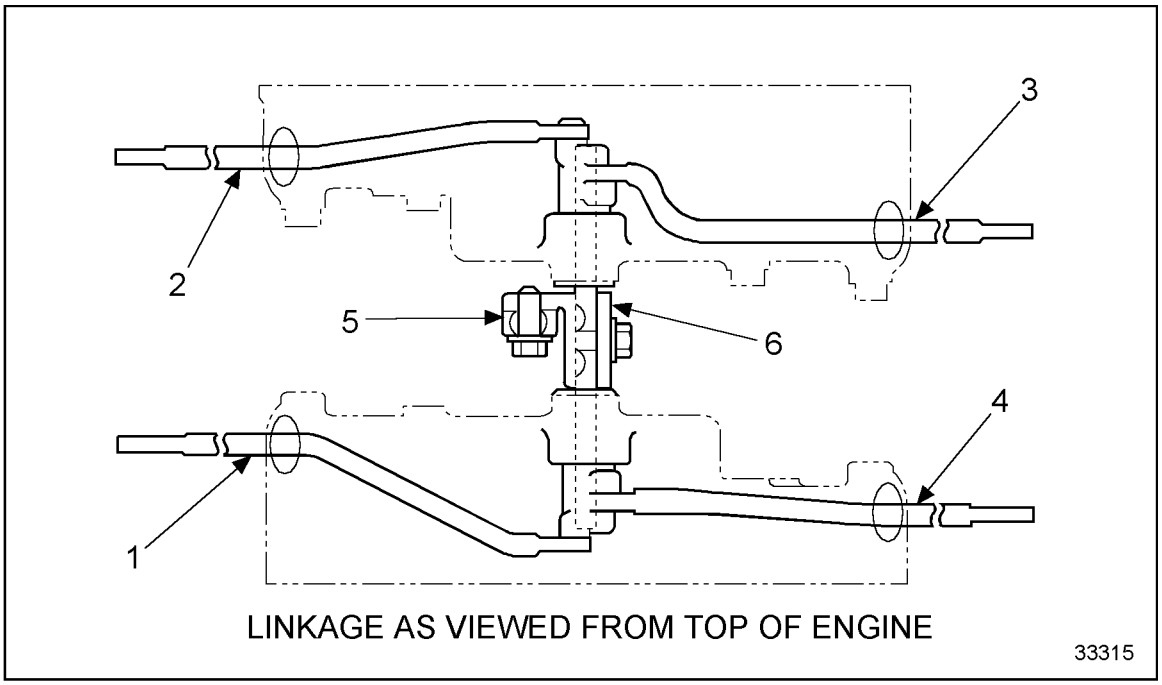
Figure 12-139 Hydraulic Governor Mounting

12.13.1 Adjust Governor-to-Injector Rack Control Linkage

Adjust the governor-to-injector rack control linkage as follows:

NOTICE:
Failure to follow this procedure can cause the injector control linkage to bind during engine operation. The engine will hunt if the linkage binds.

1. On engines equipped with an electric or hydraulic governor that requires a bell crank and vertical link, load both governor control operating link levers in the same direction (in or out).See Figure 12-140.



1. No. 4R Fuel Rod
2. No. 5R Fuel Rod
3. No. 5L Fuel Rod
4. No. 4L Fuel Rod
5. Vertical Link Assembly
6. Bell Crank

Figure 12-140 Governor-to-Injector Rack Control Linkage

2. Install the bell crank, and tighten the attaching bolts.
3. Check injector control tube assemblies and injector control racks operation prior to performing a tune-up.

NOTE:
These components must operate freely.

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12.13.2 Position Injector Rack Control Levers and Adjust Governor Linkage

The position of the injector racks must be correctly set in relation to the governor. Their positions determine the amount of fuel injected into each cylinder and ensures equal load distribution.

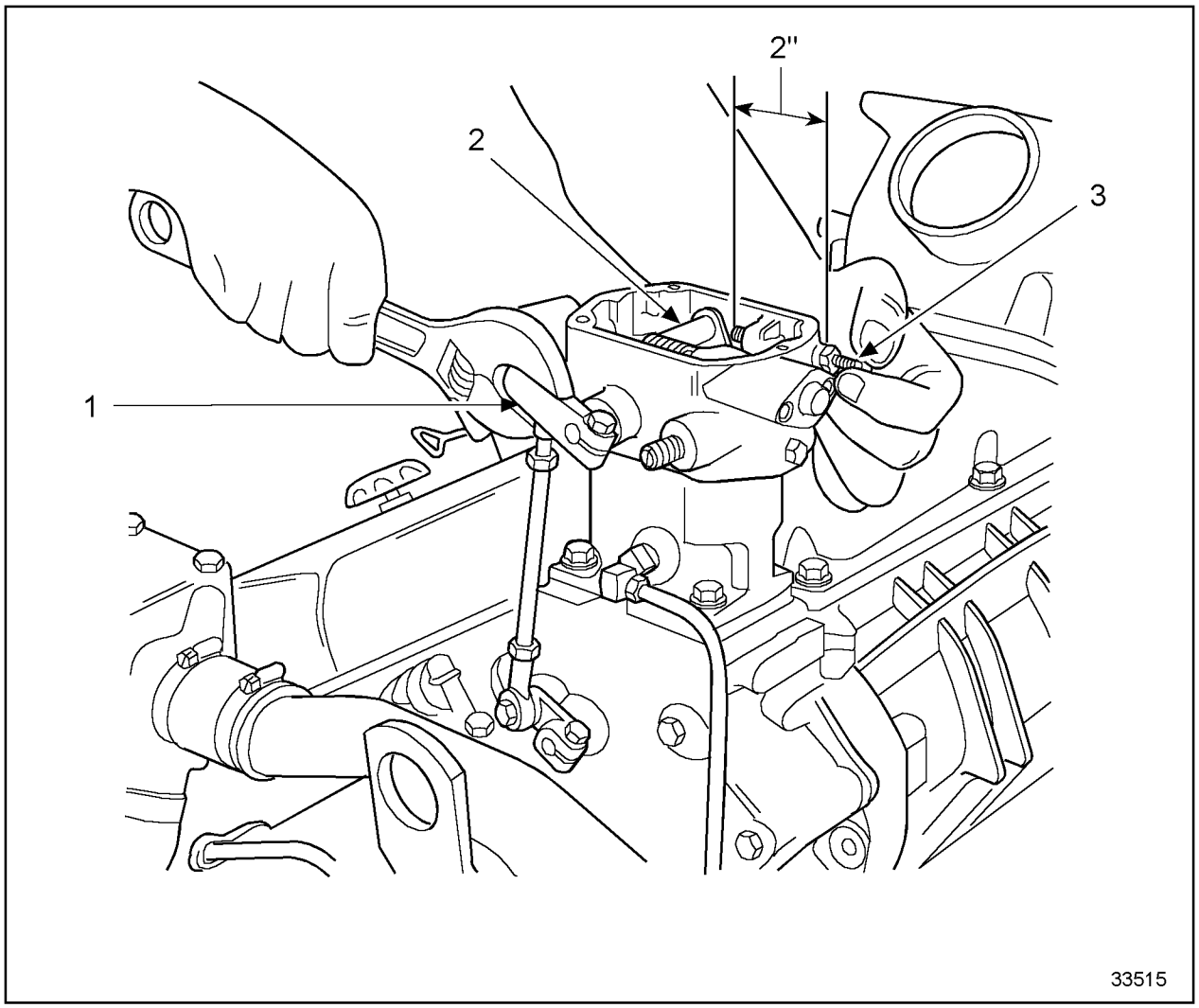
Position the racks, and adjust the linkage as follows:

1. Clean and remove the valve rocker cover from each cylinder head. Discard the gaskets.
2. Loosen all the adjusting screws and locknuts.

NOTE:
Ensure all control levers are free on the control tubes.

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3. Disconnect the vertical link assembly from the governor operating lever and the bell crank. See Figure 12-141.



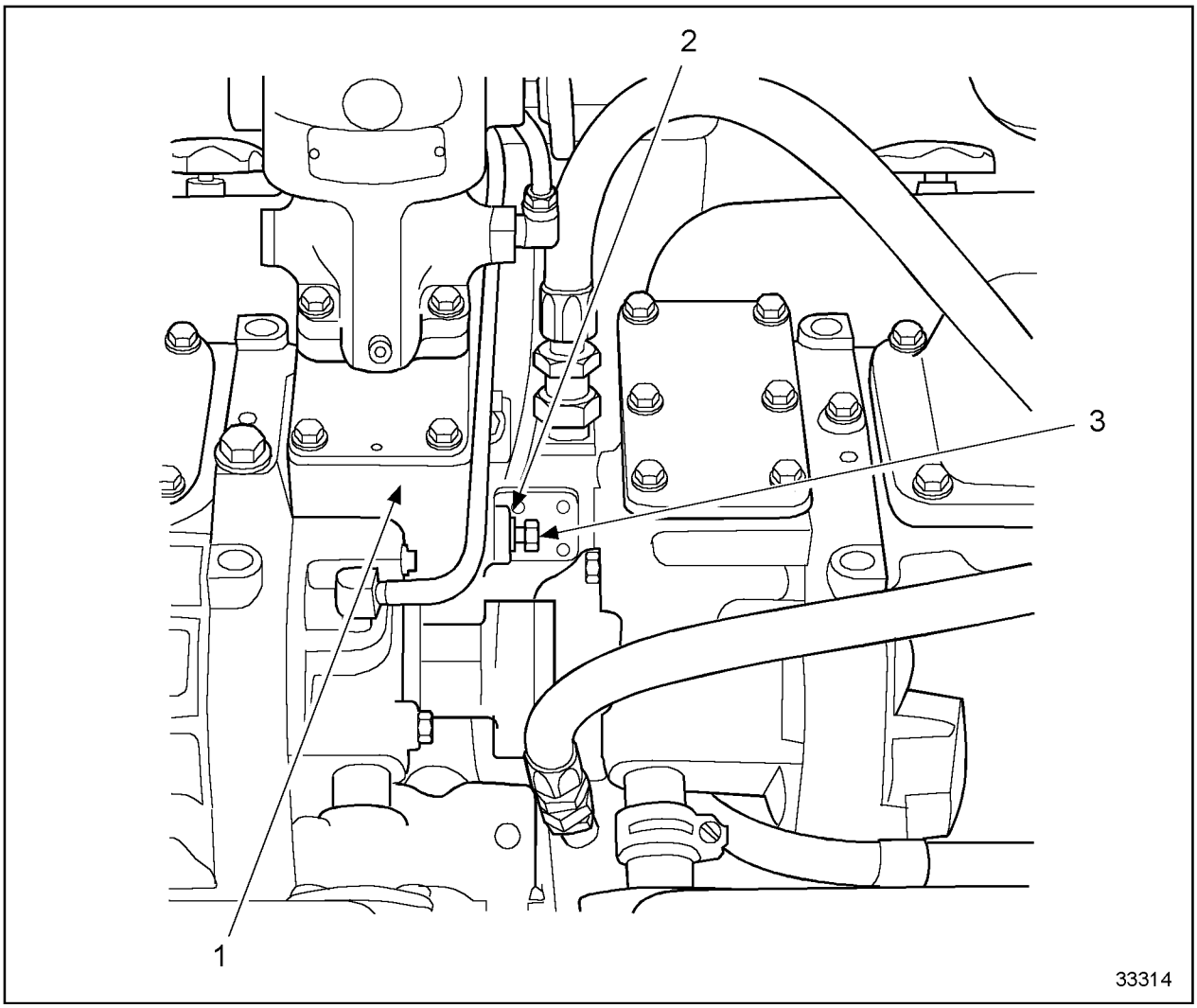
1. No. 4R Fuel Rod
2. No. 5R Fuel Rod
3. No. 5L Fuel Rod
4. No. 4L Fuel Rod
5. Vertical Link Assembly

Figure 12-141 Governor-to-Injector Rack Control Linkage

4. Loosen the bolt, and slide the governor operating lever from the serrated shaft.

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5. Place the bolt (removed from the lower end of the vertical link) through the bell crank and into the recessed hole in the governor drive housing. See Figure 12-142.

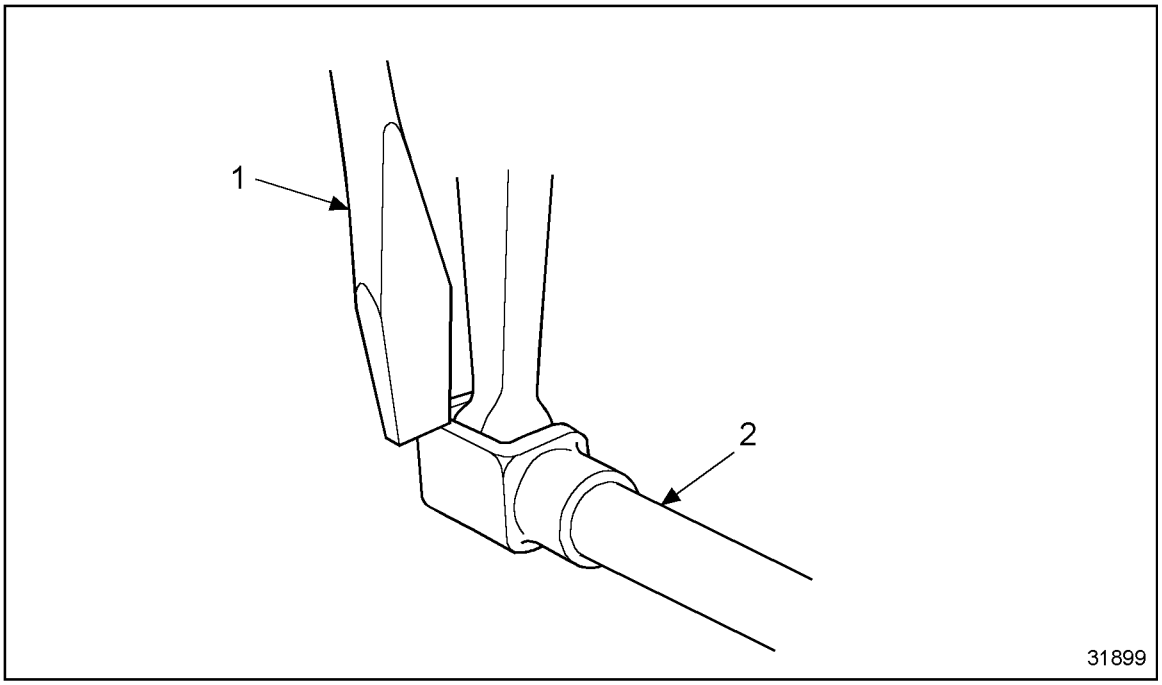


1. Governor Drive Housing
2. Bell Crank Lever
3. Bolt

Figure 12-142 Positioning Bolt through Bell Crank Lever

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6. Adjust the No. 4R (16V) or No. 3R (12V) injector rack by tightening the adjusting screw until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted. See Figure 12-143.



1. Screwdriver
2. Injector Control Rack

Figure 12-143 Checking Injector Control Rack "Spring"

NOTICE:
Care should be taken to avoid setting the racks too tight, causing the fuel rod to bend.

7. Tighten the screw approximately 1/8 turn more, and lock securely with the adjusting screw locknut.

NOTE:
This will place the No. 4R (16V) or No. 3R (12V) injector rack in the full-fuel position.

8. Verify rack adjustment. Refer to section 12.4.10 and refer to section 12.10.3.
9. Adjust the No. 5R, 4L and 5L (16V) or No. 4R, 3L and 4L (12V) injector rack control levers. Refer to step 6 through step 8.

NOTE:
When the settings are correct, all four of the injector racks will be snug on the ball end of the control levers when the injectors are in the full-fuel position.

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10. To adjust the remaining injector rack control levers on the right front bank, hold the No. 4R (16V) or No. 2R (12V) injector rack in the full-fuel position with the lever on the control tube assembly.

NOTICE:
Overtightening the injector rack control tube lever adjusting screws during installation or adjustment can damage the injector control tube. The recommended torque for the adjusting screws is 3-4 N·m (24-36 lb·in).

11. Tighten the adjusting screw of the No. 3R (16V) or No. 2R (12V) injector rack control lever until the injector rack clevis rolls up or an increase in effort to turn the screwdriver is noted.
12. Securely lock the adjusting screw locknut.
13. Verify the injector rack adjustment of No. 4R (16V) or No. 3R (12V). Refer to section 12.12.2.
14. Recheck the No. 4R (16V) or No. 3R (12V) injector rack to ensure it has remained snug on the ball end of the injector rack control lever.
15. If the rack of No. 4R (16V) or No. 3R (12V) injector has become loose, loosen the locknut and turn the adjusting screw clockwise slightly.
16. Tighten the locknut.

NOTE:
When the settings are correct, both injector racks must respond in the same manner on the ball ends of their respective rack control levers.

17. Position the remaining injector rack control levers on the right front cylinder head.

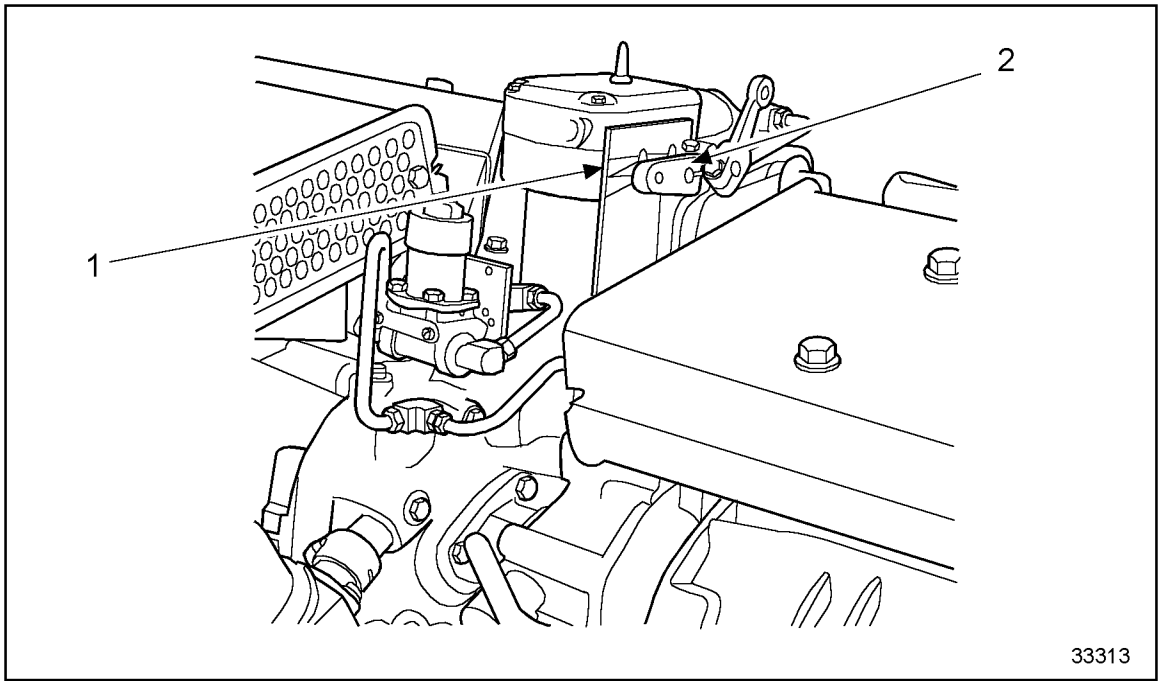
NOTE:
When the settings are correct, all injector racks will be snug on the ball end of the control levers when the injector control tube lever is held in the full-fuel position.

18. Adjust the remaining injector rack control levers on the right rear, left front and left rear cylinder heads. Refer to step 11 through step 16.

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19. Replace the governor operating lever on the serrated shaft so that the bolt hole is lined up within the proper lines on the gage.

NOTE:
The type of governor (SGX or PSG) will determine the proper position of the lever. See Figure 12-144.



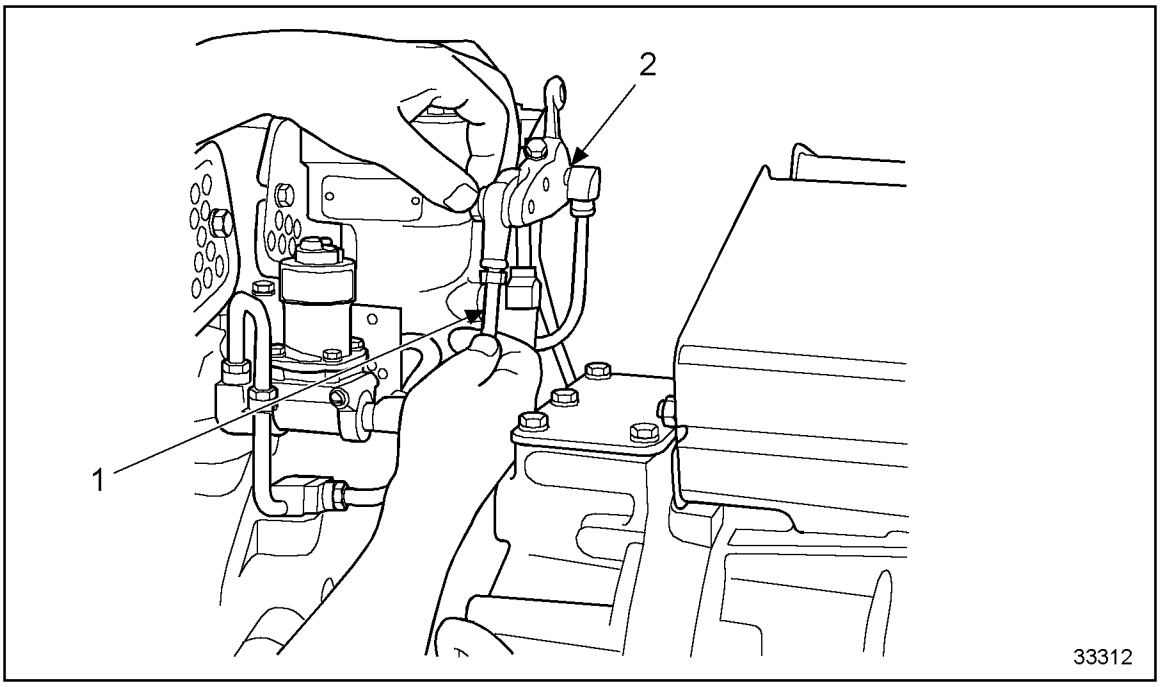
1. Linkage Gage
2. Governor Operating Lever

Figure 12-144 Positioning Governor Operating Lever

20. Remove the gage.
21. Move the bell crank lever to the no-fuel position.

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22. Adjust the length of the vertical link so that the bolt holes of the levers and the centers of the rod end bearings are lined up. See Figure 12-145.



1. Vertical Link
2. Governor Operating Lever

Figure 12-145 Adjusting Vertical Link

23. Replace the two bolts in the levers, and tighten the bolts.
24. Remove the governor cover.
25. With the load limit screw backed all the way out, retain the governor operating lever in the full-fuel position.

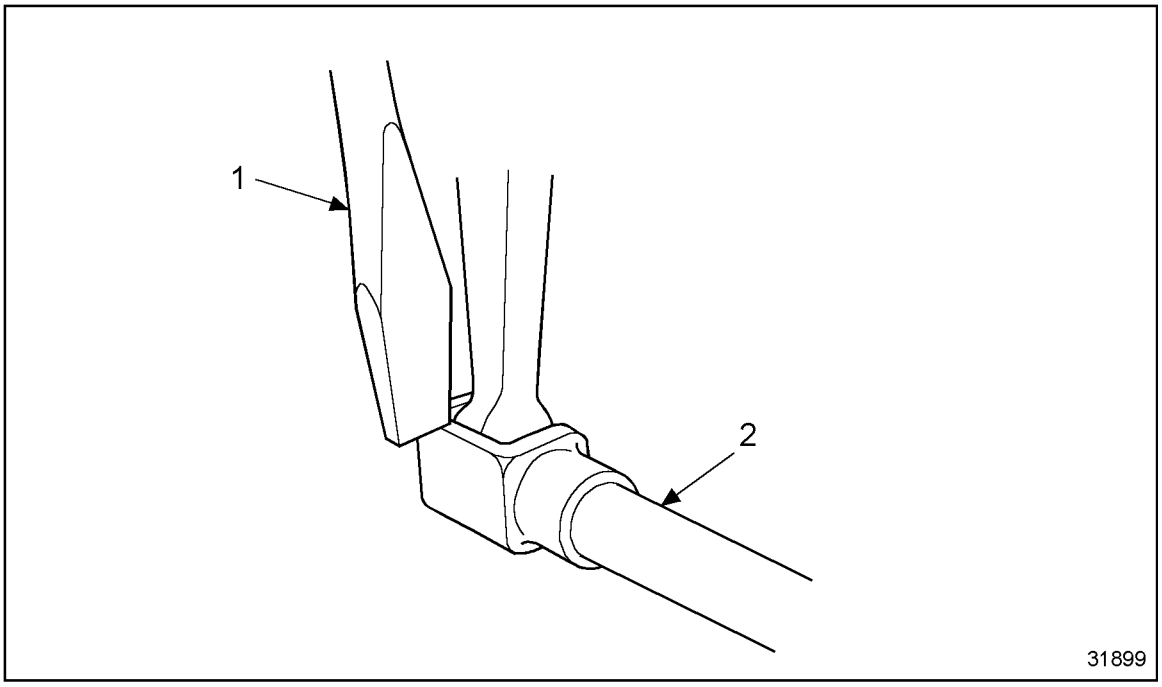
NOTE:
The governor terminal lever should touch the boss on the governor housing.

26. Adjust the vertical link so that all the injector racks are in the full-fuel position, and tighten the rod end locknuts securely.
27. Use a new gasket, and install the valve rocker cover on each cylinder head.

12.13.3 Check Injector Rack Adjustment

Verify rack adjustment as follows:

1. To ensure the rack control lever is properly adjusted, press down on the injector rack with a screwdriver or finger tip. See Figure 12-146.



1. Screwdriver
2. Injector Control Rack

Figure 12-146 Checking Injector Control Rack "Spring"

NOTE:
A light pressure should cause the rack to rotate. The rack is sufficiently tight if the rack returns ("springs" back) to its original position when the pressure is removed. The rack is too tight if heavy pressure is required to rotate it.

2. If No. 4R (16V) or No. 3R (12V) does not "spring" back upward, turn the No. 3R (16V) or No. 2R (12V) adjusting screw counterclockwise slightly until the No. 4R (16V) or No. 3R (12V) injector rack returns to its full-fuel position.
3. Secure the adjusting screw locknut.
4. Verify proper injector rack adjustment for both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injectors.
5. Turn the No. 3R (16V) or No. 2R (12V) injector rack adjusting screw clockwise or counterclockwise until both No. 4R and No. 3R (16V) or No. 3R and No. 2R (12V) injector racks are in the full-fuel position when the locknut is securely tightened.

12.13.4 Adjust Load Limit

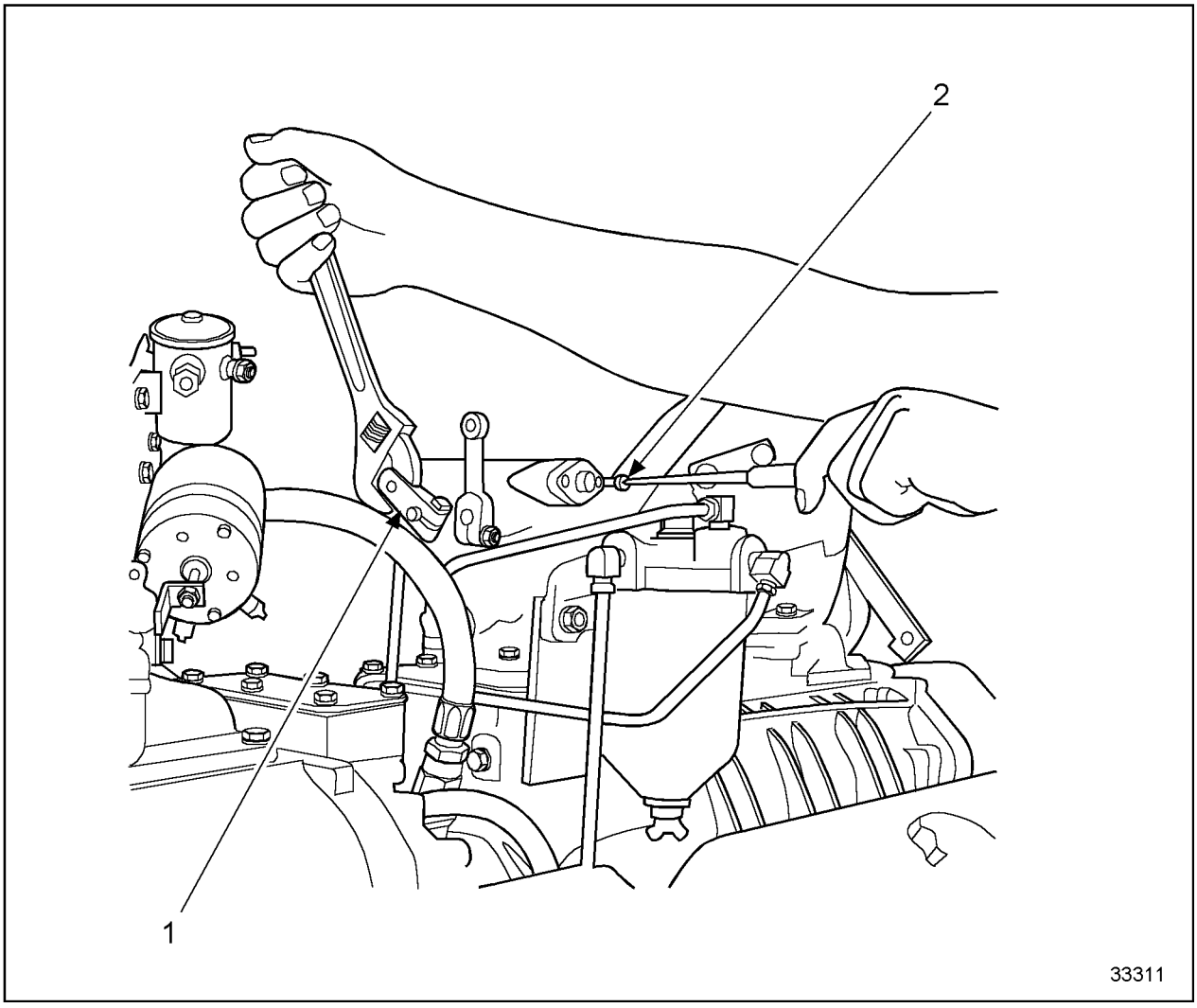
The load limit is set at the factory and further adjustment should be unnecessary. However, if the governor has had major repairs or the injector rack control levers have been repositioned, the load limit screw should be adjusted.

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With the injector rack control levers properly adjusted, set the load limit as follows:

1. With the governor cover off and the load limit screw locknut loosened, place and retain the governor operating lever in the full-fuel position. See Figure 12-147.

NOTE:
Do not overstress the linkage.



1. Governor Operating Lever
2. Load Limit Operating Screw

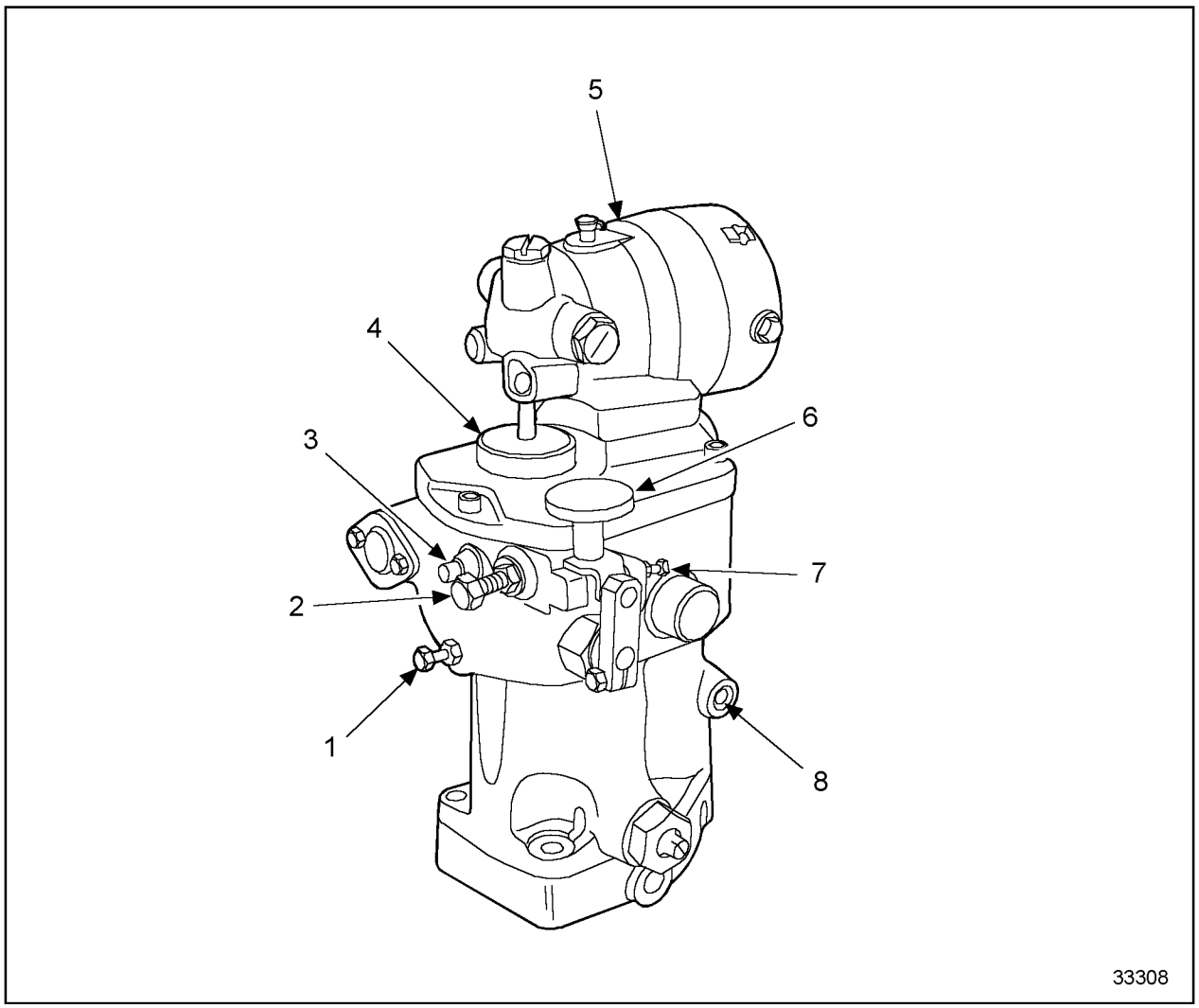
Figure 12-147 Adjusting Load Limit Screw

2. Turn the load limit adjusting screw in until the injector racks just loosen on the ball end of the control levers.
3. Release the governor operating lever, and hold the adjusting screw while tightening the locknut.
4. Install the governor cover, and tighten the screws.

12.13.5 Compensation Needle Valve Adjustment (PSG Governor)

Start the engine, and after the engine reaches normal operating temperature, adjust the governor compensation needle valve, without load on the engine, as follows:

1. Open the valve two or three turns. See Figure 12-148.



1. Maximum Speed Adjustment Screw
2. Load Limit Adjustment Screw
3. Minimum Droop Setting Screw
4. Friction Drive
5. Synchronizing Motor
6. Droop Adjustment Knob
7. Maximum Droop Setting Screw
8. Compensation Needle Valve

Figure 12-148 Typical Synchronizing Motor Mounting

2. Allow the engine to "hunt" or "surge" for about a 1/2 minute to bleed any air which may be trapped in the governor oil passages.
3. Gradually close the valve until the "hunting" just stops.

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4. Close the valve completely, and observe the number of turns required to close it.
5. Open the valve to the previous position.
6. Manually disturb the engine speed to test governor action.

NOTE:
The engine should return promptly to the original steady speed with only a small overshoot. The correct valve setting will be between 1/8 and 1/2 turn open. Closing the valve more than necessary will make the governor slow to return the engine to normal speed after a load change.

12.13.6 Adjust Governor Speed Internal Droop

The purpose of adjusting the speed droop is to establish a definite speed at no load with a given speed at rated full load.

The governor speed droop is set at the factory and further adjustment should be unnecessary. If the governor has been overhauled, the speed droop must be adjusted.

The best method for determining the engine speed is using an accurate hand tachometer.

If a full rated load can be established on the unit, and the fuel rods, injector rack control levers and the load limit have been adjusted, set the speed droop as follows:

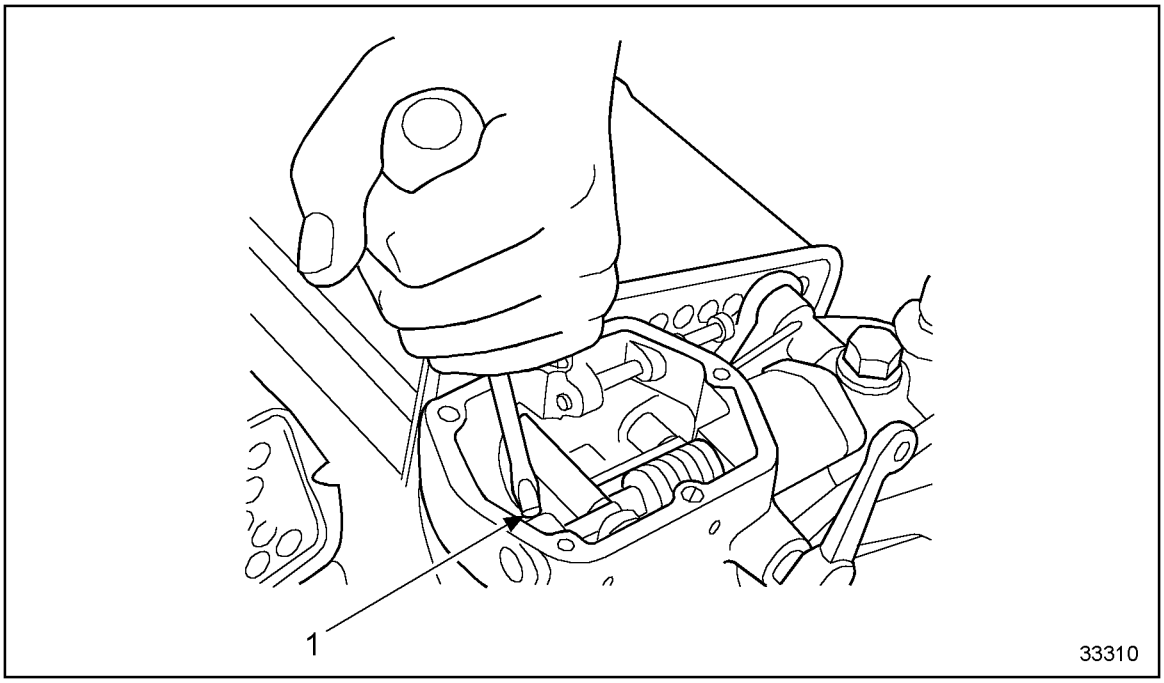
1. Start the engine, and run it at approximately one-half the rated no-load speed until the lubricating oil temperature stabilizes.

NOTE:
When the engine lubricating oil is cold, the governor regulation may be erratic. Regulation will become increasingly stable as the temperature of the oil increases.

2. Stop the engine, and remove the governor cover.
3. Loosen the locknut and back off the maximum speed adjusting screw 15.88 mm (0.625 in.).

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4. Loosen the droop adjusting screw. See Figure 12-149.



1. Droop Adjusting Screw

Figure 12-149 Adjusting Speed Droop

5. Move the droop bracket so that the screw is midway between the ends of the slot in the bracket.
6. Tighten the screw.
7. With the throttle in the run position, adjust the engine speed until the engine is operating at 3 to 5% above the recommended full-load speed.
8. Apply the full rated load on the engine, and adjust the engine speed to the correct full-load speed.
9. Remove the rated load, and observe the engine speed after the speed stabilizes under no load.

NOTE:
If the speed droop is correct, the engine speed will be approximately 3 to 5% higher than the full-load speed.

10. If the speed droop is too high, stop the engine, loosen the droop adjusting screw, and move the adjusting bracket IN toward the center of the governor.
11. Tighten the screw.

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12. To increase the speed droop, move the bracket OUT, away from the center of the governor.

NOTE:
The speed droop in governors which control engines driving generators in parallel must be identical, otherwise the electrical load will not be equally divided.

13. Adjust the speed droop bracket in each governor to obtain the desired variation between engine no-load and full-load speeds.

NOTE:
The recommended speed droop for generator sets operating in parallel is 50 RPM (2-1/2 cycles) for units operating at 1,000 and 1,200 RPM, and 75 RPM (2-1/2 cycles) for units operating at 1,500 and 1,800 RPM. Specifications are listed in Table 12-27. This speed droop recommendation may be varied to suit the individual application.

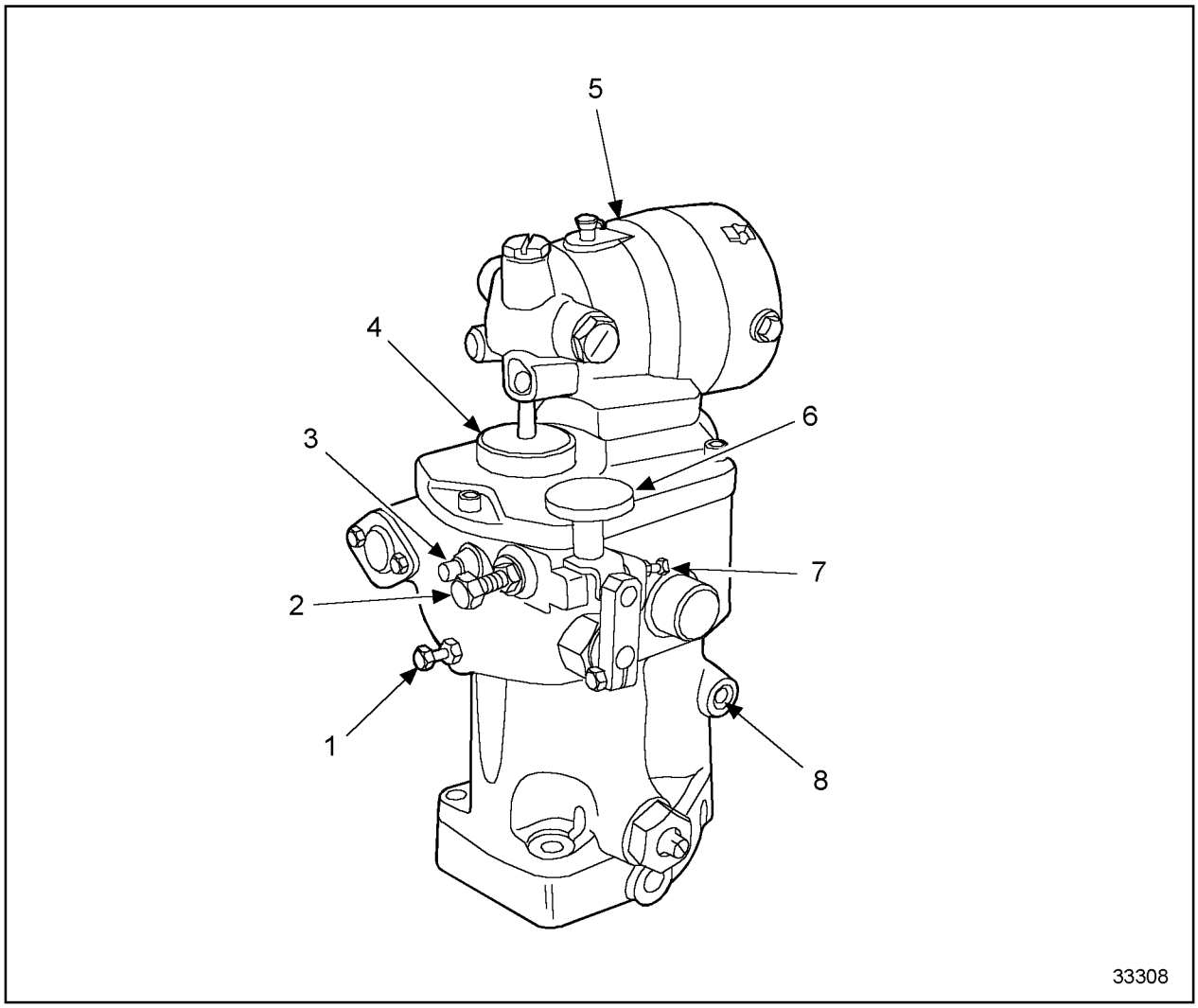
Full Load	No Load
50 Cycles, 1000 RPM	52.5 Cycles, 1050 RPM
60 Cycles, 1200 RPM	62.5 Cycles, 1250 RPM
50 Cycles, 1500 RPM	52.5 Cycles, 1575 RPM
60 Cycles, 1800 RPM	62.5 Cycles, 1875 RPM

Table 12-27 Recommended Speed Droop

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12.13.7 Adjust Governor Speed External Droop

Some PSG type governors are equipped with an external adjustable droop control. See Figure 12-150. This permits the speed droop to be adjusted without removing the governor cover. With this feature, a unit can be paralleled with another unit that is operating at constant frequency (zero droop). The incoming unit must have its droop bracket set in the maximum position while it is paralleled and while operating in parallel.



1. Maximum Speed Adjustment Screw
2. Load Limit Adjustment Screw
3. Minimum Droop Setting Screw
4. Friction Drive
5. Synchronizing Motor
6. Droop Adjustment Knob
7. Maximum Droop Setting Screw
8. Compensation Needle Valve

Figure 12-150 Typical Synchronizing Motor Mounting

When stopping the unit operating at constant frequency, proceed as follows:

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1. Shift the load to the incoming unit, and move the governor droop bracket to zero droop.
2. Adjust the outgoing unit to maximum droop.
3. Remove droop from the line, and stop the engine.

NOTE:
The incoming unit will now be carrying the load and operating at constant frequency (zero droop).

Adjust the governor speed droop as follows:

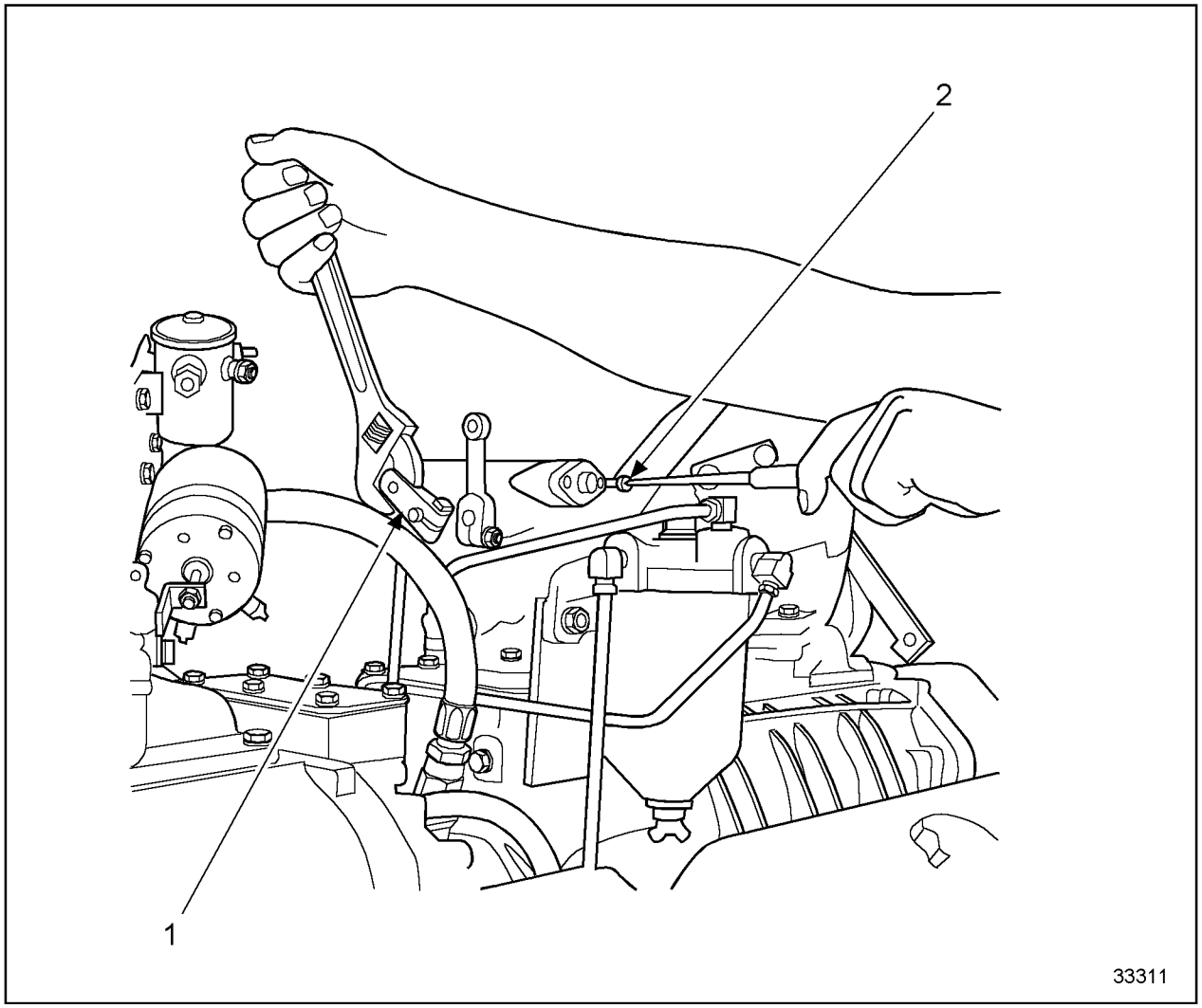
4. Start the engine, and run it at approximately one-half the rated full-load speed until the lubricating oil temperature stabilizes.
5. Remove the load from the engine.
6. Back off the compensation needle valve to release any air that may be trapped in the system.
7. Turn the needle valve in slowly to reduce governor "hunting".

NOTE:
The correct needle valve setting will be between 1/8 and 1/2 turn open.

8. Back out the minimum and maximum droop setting screws.

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9. Loosen the droop adjusting knob, and move the slider all the way in toward the center of the governor. See Figure 12-151.



1. Governor Operating Lever
2. Load Limit Operating Screw

Figure 12-151 Adjusting Load Limit Screw

10. Tighten the knob.
11. Loosen the locknut on the maximum speed adjusting screw, and turn the screw out until 15.88 mm (0.625 in.) of the threads are exposed.
12. With the engine operating at the recommended full-load speed, apply the full rated load, and check the engine speed.
13. If required, adjust the engine to full-load speed.

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14. Remove the load, and observe the engine speed.

NOTE:
If the zero droop setting is correct, the engine speed will remain constant.

15. If the engine speed is higher, loosen the droop adjusting knob, and set the slider to a reduced droop position.
16. When the desired minimum droop setting is reached, loosen the locknut, and turn the minimum droop setting screw in until it contacts the droop linkage within the governor.

NOTE:
This will be felt by a step up in resistance while turning the adjusting screw.

17. Lock the adjusting screw in this position.
18. Loosen the droop adjusting knob, and slide the droop bracket in a direction to increase the droop.
19. Refer to step 9 through step 12 to check the droop until the desired maximum speed droop is attained.
20. When the desired maximum droop setting is reached, loosen the locknut, and turn the maximum droop setting screw inward until it contacts the droop slider arm.
21. Lock the adjusting screw in this position.
22. Recheck the minimum and maximum droop setting. Refer to step 9 through step 12, and turn the adjustment screws, if necessary, until the correct settings are obtained.

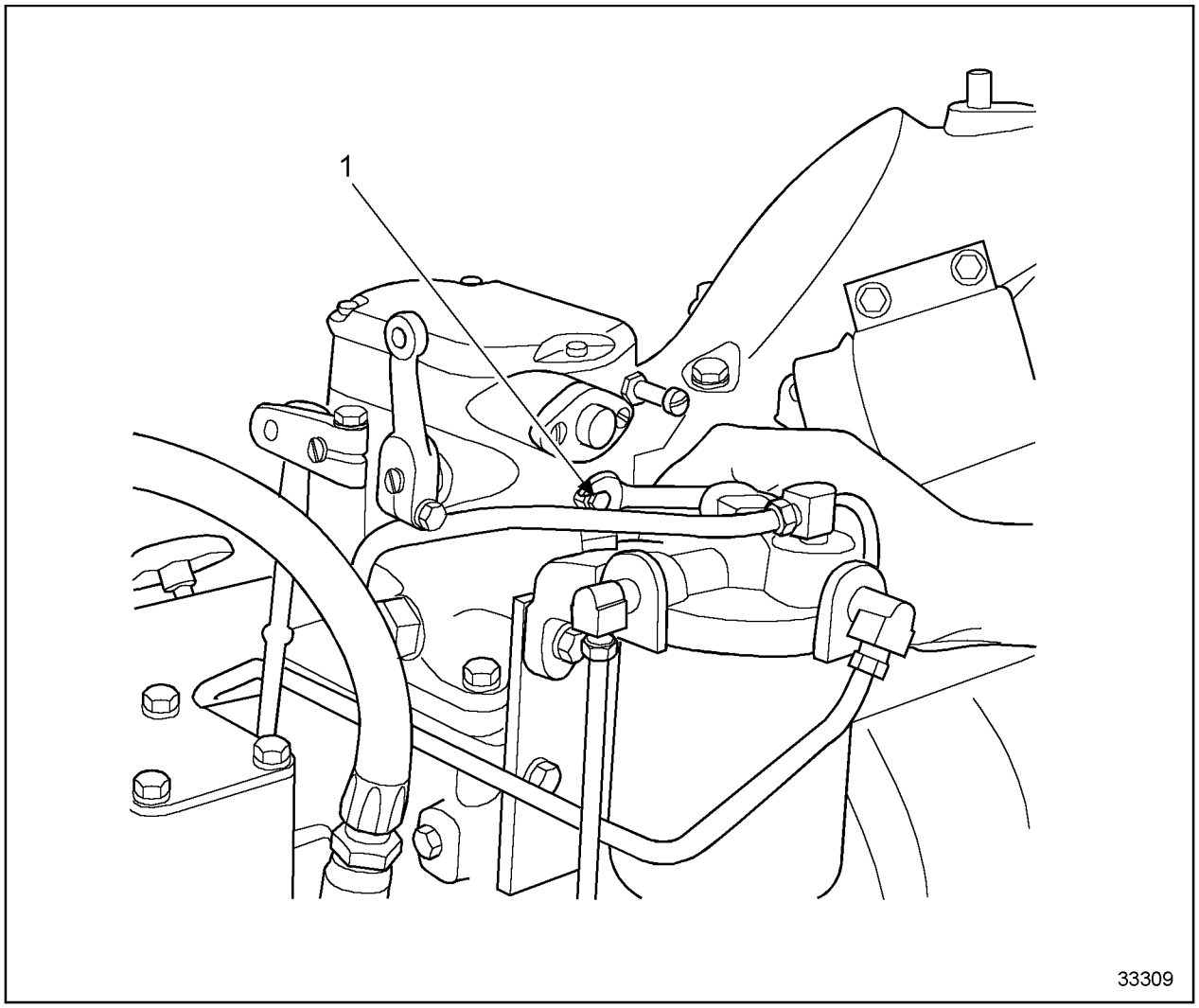
12.13.8 Adjust Maximum No Load Speed

With the speed droop properly adjusted, set the maximum no-load speed as follows:

1. With the engine operating at no-load, adjust the speed until the engine is operating at approximately 8% higher than the rated full-load speed.

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2. Turn the maximum speed adjusting screw in until the screw contacts the throttle linkage internally, limiting the maximum speed of the engine at 8% above the rated full load speed. See Figure 12-152.



1. Maximum Speed Adjusting Screw

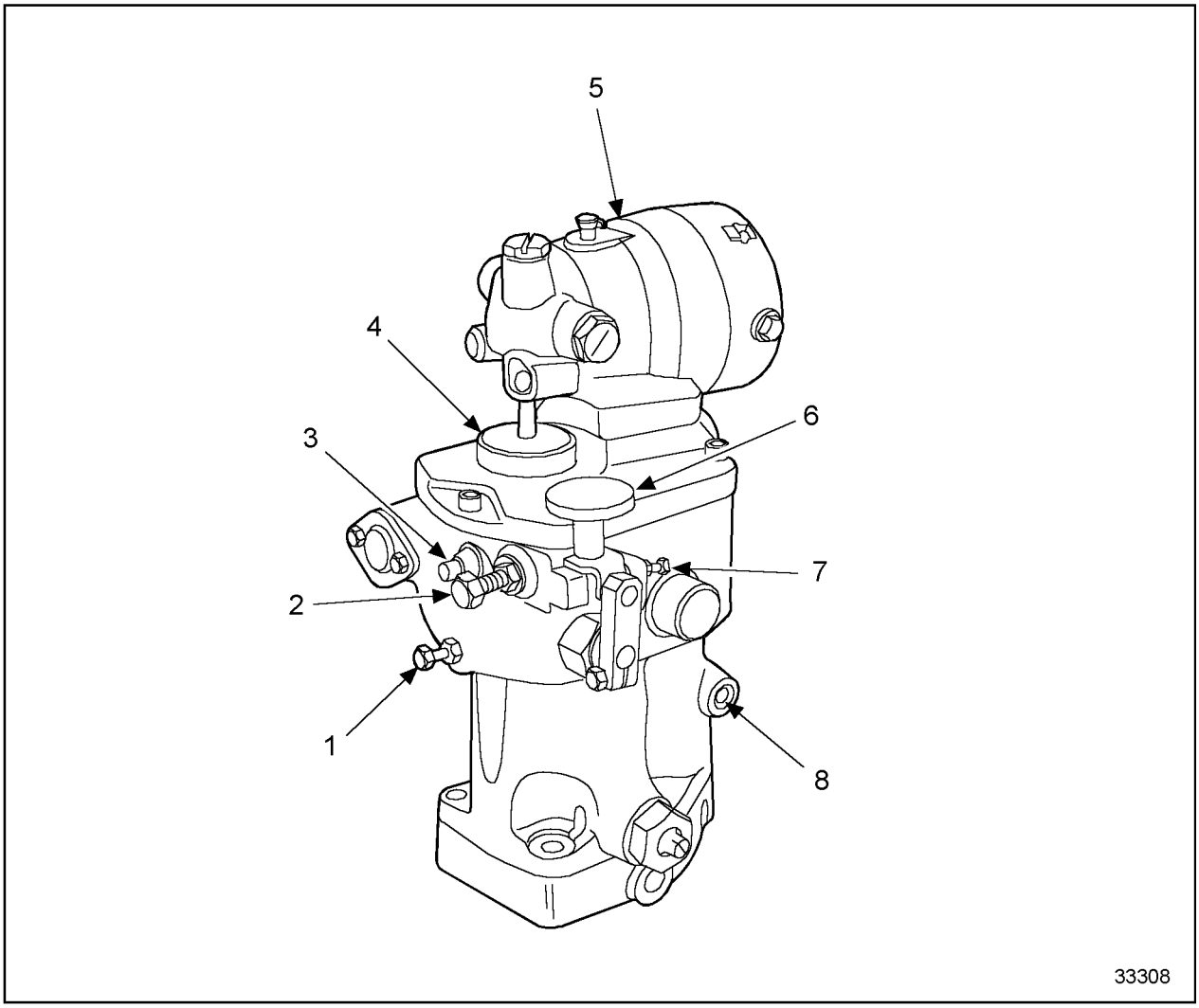
Figure 12-152 Adjusting Maximum No-Load Engine Speed

3. Hold the screw, and tighten the locknut.

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12.14 GOVERNORS WITH SYNCHRONIZING MOTOR

Some hydraulic governors are equipped with a reversible electric synchronizing motor mounted on the governor cover. See Figure 12-153.



1. Maximum Speed Adjustment Screw
2. Load Limit Adjustment Screw
3. Minimum Droop Setting Screw
4. Friction Drive
5. Synchronizing Motor
6. Droop Adjustment Knob
7. Maximum Droop Setting Screw
8. Compensation Needle Valve

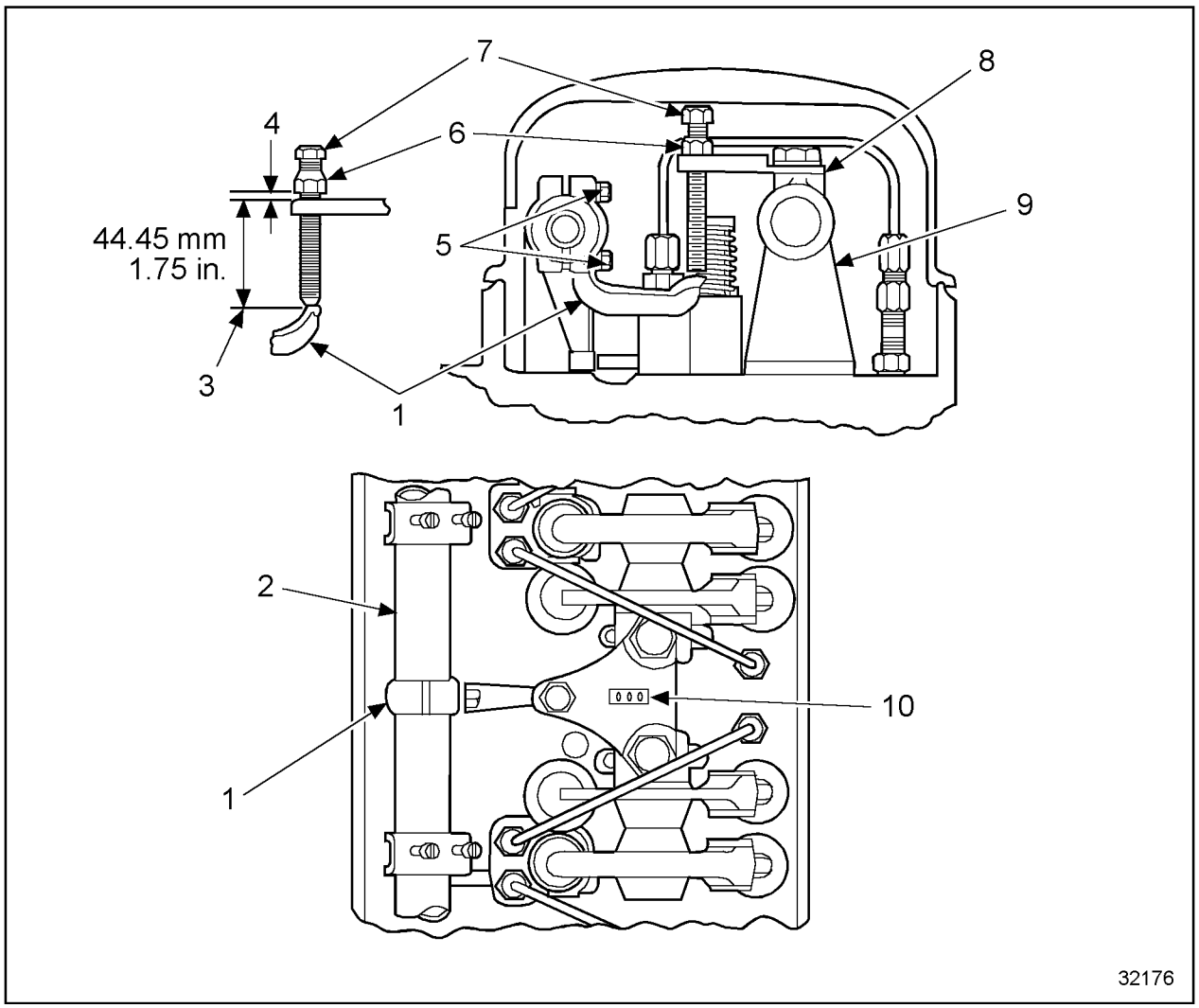
Figure 12-153 Typical Synchronizing Motor Mounting

The adjustments on a governor equipped with a synchronizing motor are the same as on a governor without the motor. However, the governor cover and motor assembly must be removed when setting the engine speed droop (except on a governor equipped with the external droop adjustment). The cover and motor must be reinstalled to check the speed droop.

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12.15 SUPPLEMENTARY GOVERNING DEVICE ADJUSTMENT

Engines with mechanical governors may be equipped with a load limit device to reduce the maximum horsepower. See Figure 12-154. This device consists of a load limit screw threaded into a plate mounted between two adjacent rocker arm shaft brackets. A load limit lever is clamped to the injector control tube.



1. Load Limit Lever
2. Injector Rack Control Tube
3. Fuel Flow Position
4. Setting
5. Clamp Bolts
6. Load Limit Screw Locknut
7. Load Limit Screw
8. Adjusting Screw Plate
9. Rocker Arm Bracket
10. Markings on Adjusting Screw Plate

Figure 12-154 Engine Load Limit Device

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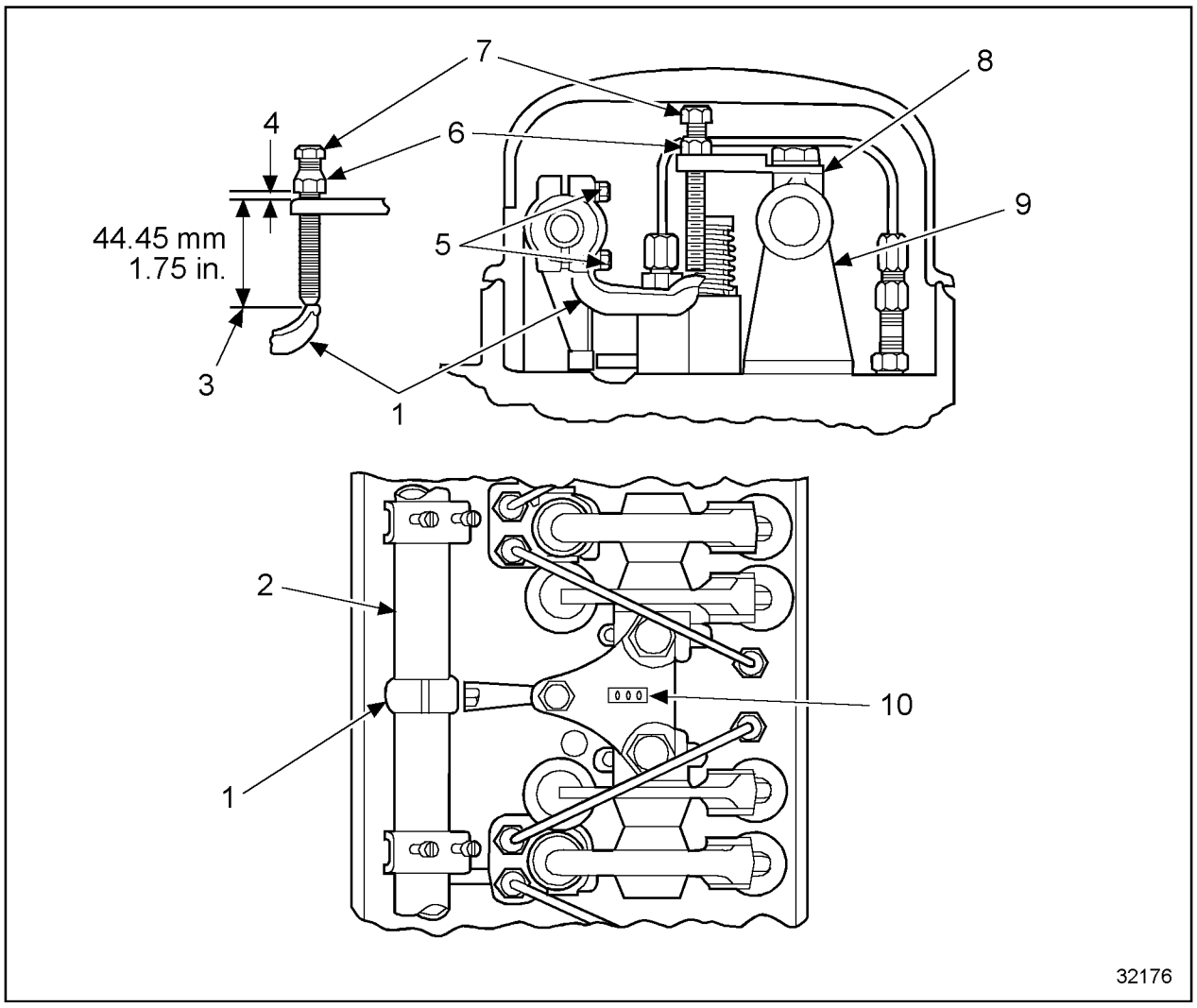
12.15.1 Engine Load Limit Device

The load limit device is located between the No. 1 and No. 2 cylinders on each cylinder bank of a 6V engine and between the No. 2 and No. 3 cylinders on each cylinder bank of an 8V engine. On the 12V and 16V engines, four load limit devices are used (one on each cylinder head). The load limit device is located between the No. 1 and No. 2 cylinders and between the No. 4 and No 0.5 cylinders (12V engines) or between the No. 2 and No. 3 cylinders and between the No. 6 and No. 7 cylinders (16V engines) on each cylinder bank.

When properly adjusted for the maximum horsepower desired, this device limits the travel of the injector control racks and the fuel output of the injectors.

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After the engine tune-up is completed, ensure load limit devices are properly installed. See Figure 12-155. Ensure counterbores in the adjusting screw plates are up. The rocker arm shaft bracket bolts which fasten the adjusting screw plate to the brackets are tightened to 102-115 N·m (75-85 lb·ft) torque. All other rocker arm shaft bracket bolts are tightened to 122-136 N·m (90-100 lb·ft) torque.



1. Load Limit Lever
2. Injector Rack Control Tube
3. Fuel Flow Position
4. Setting
5. Clamp Bolts
6. Load Limit Screw Locknut
7. Load Limit Screw
8. Adjusting Screw Plate
9. Rocker Arm Bracket
10. Markings on Adjusting Screw Plate

Figure 12-155 Engine Load Limit Device

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12.15.2 Adjustment of Load Limit Device on Each Cylinder Head

Adjust the load limit device on each cylinder head as follows:

1. Loosen the load limit screw locknut, and remove the screw.
2. Loosen the load limit lever clamp bolts so the lever is free to turn on the injector rack control tube.
3. With the screw removed from the plate, lock the load limit screw locknut so the bottom of the nut is 44.5 mm (1.75 in.) from the bottom of the load limit screw.
4. Thread the load limit screw into the adjusting screw plate until the locknut bottoms against the top of the plate.
5. Hold the injector rack control tube in the full fuel position, and place the load limit lever against the bottom of the load limit screw.
6. Tighten the load limit lever clamp bolts.
7. Ensure injector racks will just move into the full fuel position. Readjust the load limit lever, if necessary.
8. Hold the load limit screw to keep it from turning.
9. Set the locknut until the distance between the bottom of the locknut and the top of the adjusting screw plate corresponds with the dimension stamped on the plate.

NOTE:
If the plate is not stamped, adjust the load limit screw while operating the engine on a dynamometer test stand, and not the number of turns required to obtain the desired horsepower. Stamp the plate accordingly.

10. Thread the load limit screw into the plate until the locknut bottoms against the top of the plate.

NOTE:
Ensure the nut turns with the screw.

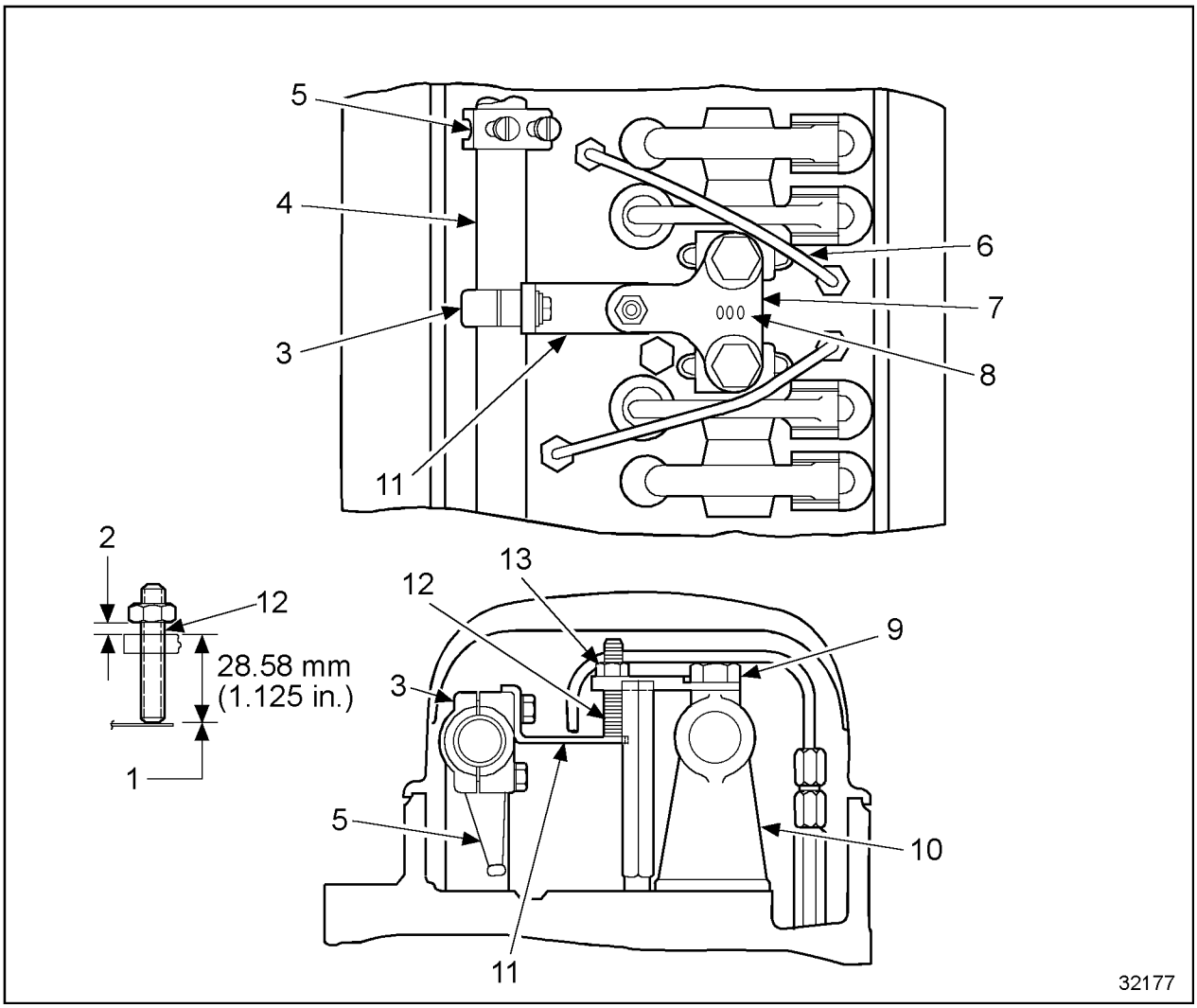
11. Hold the load limit screw to keep it from turning.
12. Tighten the locknut to secure the setting.

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12.16 POWER CONTROL DEVICE

The power control (torque limiting) device is used on some vehicle engines to limit the maximum horsepower output at the wheel without diminishing the performance at lower speeds where full power may be required. See Figure 12-156. It limits the horsepower at or just below the normal full-load governor speed. These limiting characteristics are proportionately lessened as the engine speed is reduced and the horsepower required is reduced.

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1. Full Fuel Position
2. Setting
3. Clamp
4. Injector Control Tube
5. Lever
6. Fuel Pipe
7. Adjusting Screw Plate
8. Markings on Adjusting Screw Plate
9. Bolt
10. Rocker Arm Bracket
11. Spring
12. Adjusting Screw
13. Locknut

Figure 12-156 Power Control Device

This device, one on each cylinder bank, consists of an adjusting screw threaded into a plate mounted between two adjacent rocker arm shaft brackets and a spring attached to a clamp on the injector control tube. The rocker arm shaft bolts that retain the adjusting screw plates are tightened to 102-115 N·m (75-85 lb·ft) torque. All other rocker arm shaft bracket bolts are tightened to 122-136 N·m (90-100 lb·ft) torque.

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The power control device is located between the No. 1 and No. 2 cylinders on each cylinder bank of a 6V engine, between the No. 2 and No. 3 cylinders on each cylinder bank of an 8V engines.

12.16.1 Adjustment of Power Control Device

After the engine tune-up is completed, adjust the power control device on both cylinder banks as follows

1. Place the vehicle on a chassis dynamometer, and check the maximum wheel horsepower.
2. Loosen the power control spring attaching bolts.
3. Adjust both springs until they project parallel to the cylinder heads when the injector control tacks are held in the full fuel position.
4. Tighten the spring attaching bolts to 10-12 N·m (7-9 lb·ft) torque to retain the adjustment.
5. Set each power control device, while holding the injector control racks in the full fuel position.
6. Turn the adjusting screw down (clockwise) until it just touches the spring and the locknut is tight against the plate.
7. Release the injector control rack.
8. Wipe the oil from each spring and the bottom of each adjusting screw.
9. Start the engine.
10. With the engine running at full governed speed, check the horsepower.
11. If necessary, adjust the screws to obtain the specified horsepower.

NOTE:
Turn the screws down to decrease the horsepower. Turn the screws up to increase the horsepower.

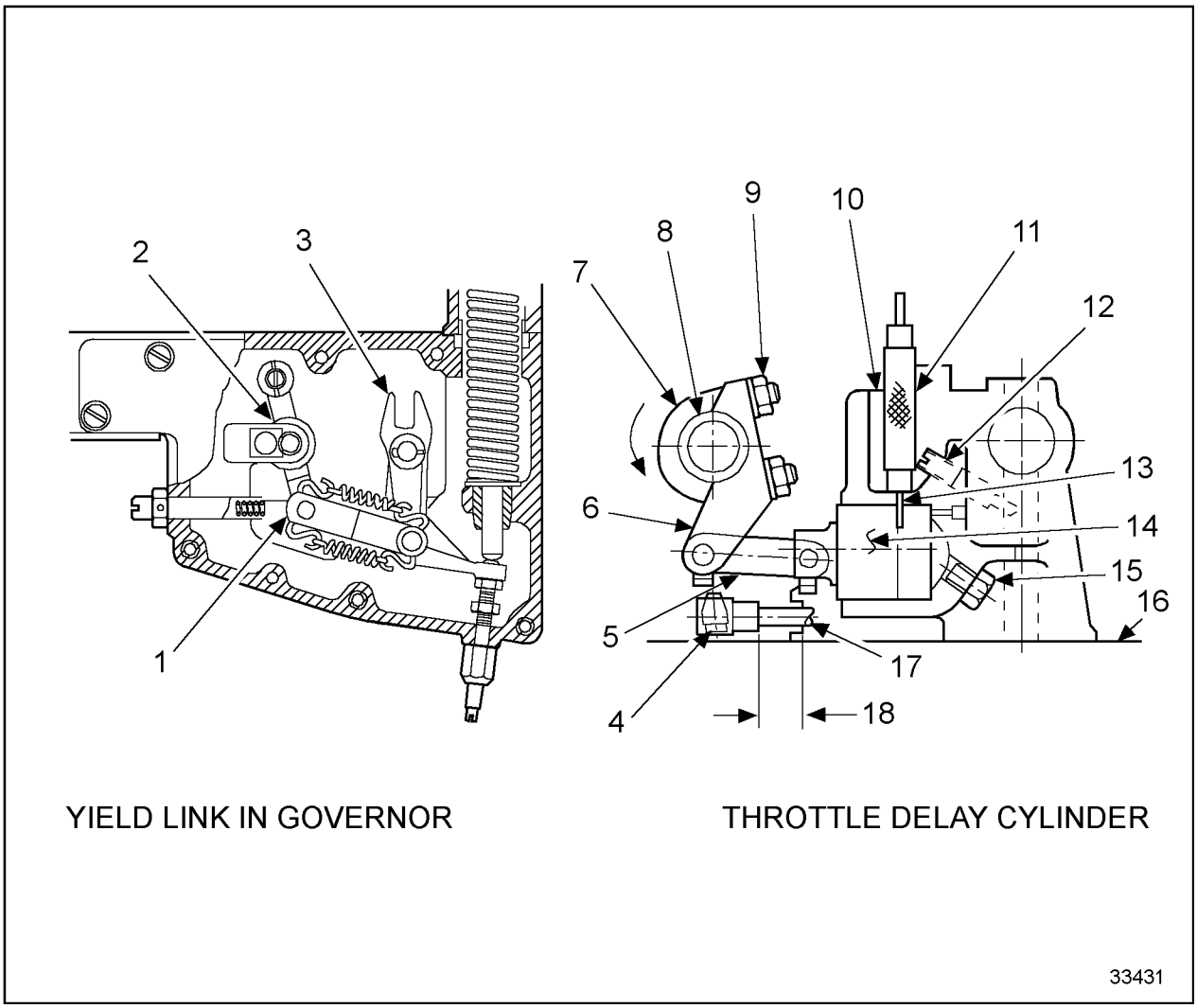
12. When the desired wheel horsepower is obtained, hold the screws from turning, and tighten the locknuts.If a dynamometer is not available, proceed as follows:
13. Back up the locknuts the distance stamped on the plates.
14. Turn the screws and locknuts down together until the locknuts bottom on the plates.
15. Hold the screws from turning, and tighten the locknuts.

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12.17 THROTTLE DELAY MECHANISM ADJUSTMENT

The throttle delay mechanism is used in turbocharged engines to retard full fuel injection when accelerating. This reduces exhaust smoke and improves fuel economy.

The throttle delay mechanism is installed between the No. 1 and No. 2 cylinders on the right bank cylinder head. See Figure 12-157. It consists of a special rocker arm shaft bracket (which incorporates the throttle delay cylinder), a piston, throttle delay lever, connecting link, orifice plug, ball check valve, and U-bolt.



1. Yield Link
2. Control Link Operating Lever
3. Differential Lever
4. Injector Rack Clevis
5. Link
6. Throttle Delay Lever
10. Oil Reservoir
11. Pin Gage (Setting and Checking)
12. Oil Supply Fitting
13. Fill Hole
14. Piston
15. Check Valve

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7. U-Bolt
8. Control Tube
9. Nut
16. Cylinder Head
17. Injector Body-to-Rack Hole Counterbore
18. Gage Length; Insert Timing Gage Here

Figure 12-157 Throttle Delay Cylinder and Yield Link

A throttle delay bracket with two 6.4 mm (0.25 in.) fill holes and a 762-1016 mm (30-40 in.) water restriction check valve is used in some 6V coach engines. All tilt coach engine models and some upright models use this throttle delay.

A yield link replaces the standard operating lever connecting link in the governor.

Oil is supplied to a reservoir above the throttle delay cylinder through and oil supply fitting in the drilled oil passage in the rocker arm shaft bracket. As the injector racks are moved toward the no fuel position, free movement of the throttle delay piston is assured by air drawn into the cylinder through the ball check valve. Further piston movement uncovers an opening which permits oil form the reservoir to enter the cylinder and displace the air. When the engine is accelerated, injector rack movement toward the full fuel position is momentarily retarded while the piston expels the oil from the cylinder through an orifice. To permit full accelerator travel, regardless of the retarded injector rack position, a spring loaded yield link replaces the standard operating lever connecting link in the governor.

The current throttle delay bracket has a closer tolerance on the piston and cylinder bore. The current piston link pin hole is offset below the piston centerline and has a larger pin boss diameter. The current piston link has two tabs to ensure that the piston is installed with the piston pin hole offset downward. The current piston and link must be used together to ensure correct positioning of the piston. The current check valve has a nylon check ball in place of the former brass ball.

12.17.1 Throttle Delay Cylinder Rocker Arm Bracket Modification

The current throttle delay cylinder rocker arm bracket has a 1.984 mm (0.0781 in.) diameter fill hole. The former throttle delay cylinder with a 6.4 mm (0.25 in.) diameter fill hole can be modified as follows:

1. Ream the fill hole to 6.721-6.772 mm (0.2646-0.2666 in.) diameter with a 0.2656 in. reamer.
2. Remove any burrs formed in the throttle delay piston bore with fine emery cloth to ensure piston moves freely.
3. Press a service bushing in the reamed hole, and check the piston for free movement.
4. Remove and discard the original check valve.
5. Install new check valve.
6. Assembly and install the throttle delay cylinder.
7. Adjust the throttle delay cylinder. Refer to section 12.17.4.

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12.17.2 Throttle Delay Check Valve Inspection

When checking the throttle delay hydraulic cylinder, inspect the valve as follows:

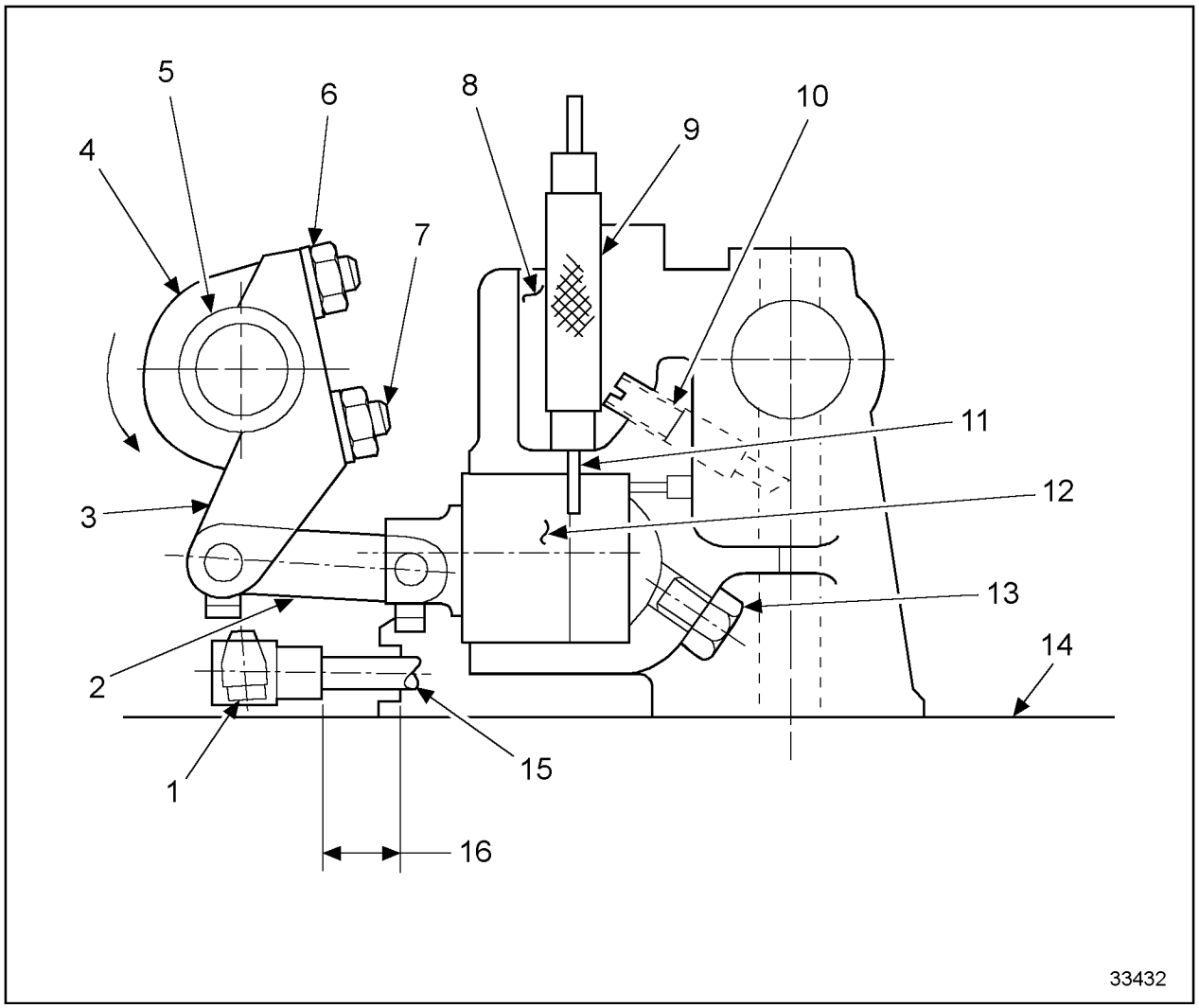
1. Fill the throttle delay cylinder with diesel fuel oil.
2. While moving the engine throttle from the idle position to the full fuel position, watch for leaks in the check valve.
3. If the check valve leaks more than a drop, replace it.

12.17.3 Current Throttle Delay Adjustment

With the engine stopped, adjust the throttle delay as follows:

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1. Loosen the U-bolt which clamps the lever to the injector control tube to disconnect the throttle delay mechanism. See Figure 12-158.



1. Injector Rack Clevis
2. Link
3. Throttle Delay Lever
4. U-Bolt
5. Control Tube
6. Upper Nut
7. Lower Nut
8. Oil Reservoir
9. Pin Gage (Setting and Checking)
10. Oil Supply Fitting
11. Fill Hole
12. Piston
13. Check Valve
14. Cylinder Head
15. Injector Body-Rack Hole Counterbore
16. Gage Length-Insert Timing Gage Here

Figure 12-158 Adjust Throttle Delay Cylinder (Current)

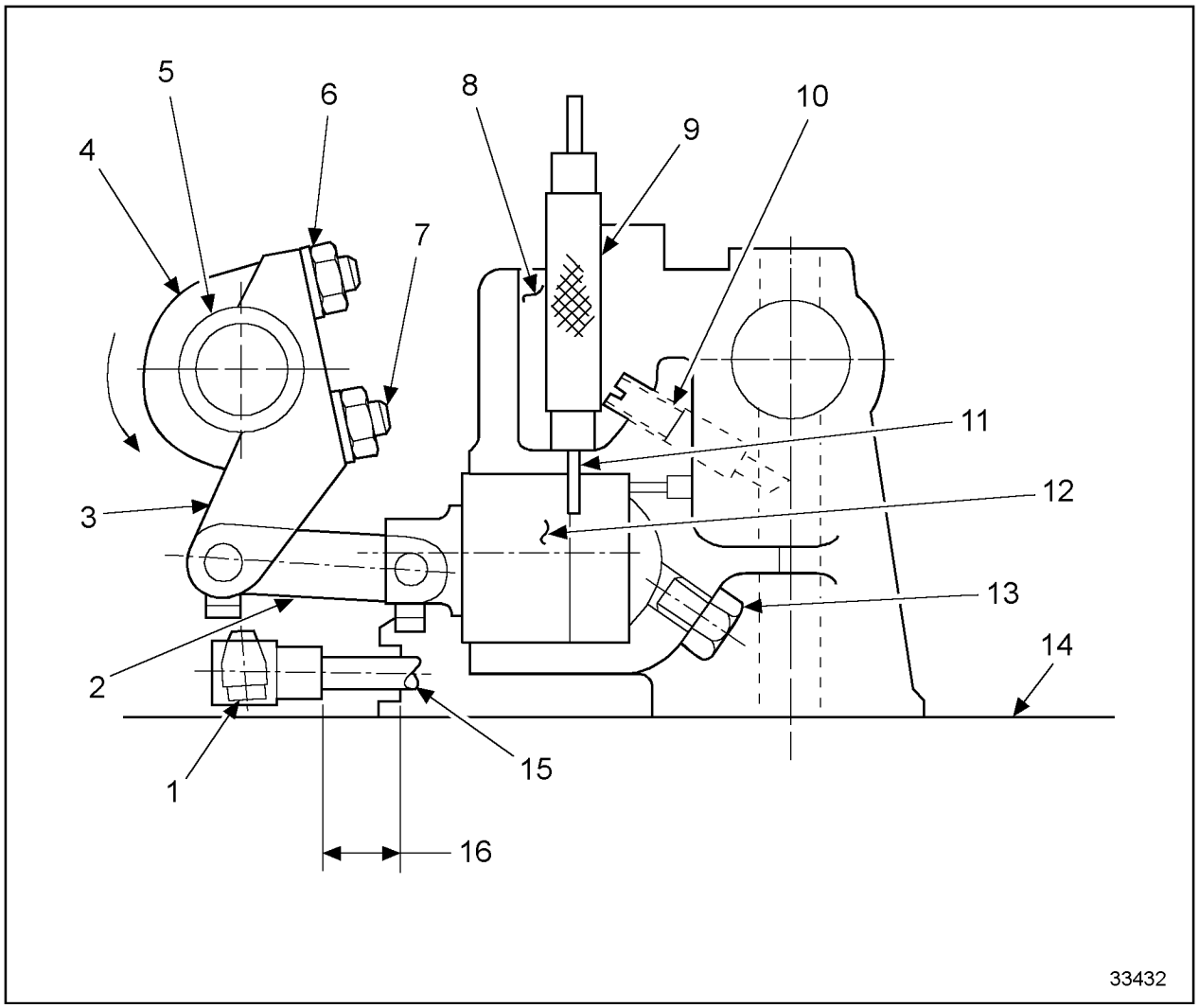
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2. Fill the throttle delay reservoir with clean engine oil.

NOTE:
The oil reservoir does not have to remain full during the entire adjustment procedure.

3. Insert the appropriate throttle delay timing gage on the rack between the injector body rack hole counterbore and the shoulder on the injector rack clevis (the No. 2 injector on

6V and 8V engines, the No. 5 injector on 12V engines, and the No. 6 injector on 16V engines). See Figure 12-159. Refer to section 12.9.7 for throttle delay timing gage tables.



1. Injector Rack Clevis
2. Link
3. Throttle Delay Lever
4. U-Bolt
5. Control Tube
6. Upper Nut
7. Lower Nut
8. Oil Reservoir
9. Pin Gage (Setting and Checking)
10. Oil Supply Fitting
11. Fill Hole
12. Piston
13. Check Valve
14. Cylinder Head
15. Injector Body-Rack Hole Counterbore
16. Gage Length-Insert Timing Gage Here

Figure 12-159 Adjusting Throttle Delay Cylinder (Current)

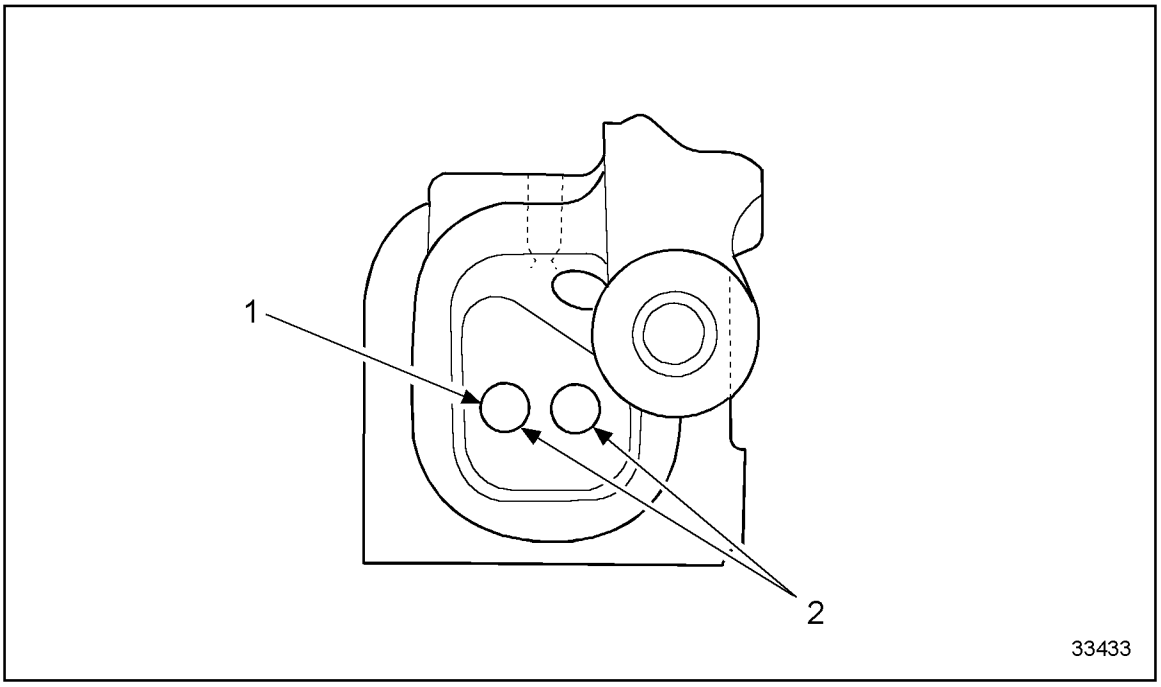
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4. Hold the governor throttle lever in the maximum speed position.

NOTE:
This should cause the injector rack to move toward the full fuel position.

5. Insert pin gage J 25558 with the "go" (green 1.75 mm or 0.069 in.) end in the cylinder fill hole.

NOTE:
If the throttle delay housing has multiple holes, use the hole indicated in the figure. See Figure 12-160.

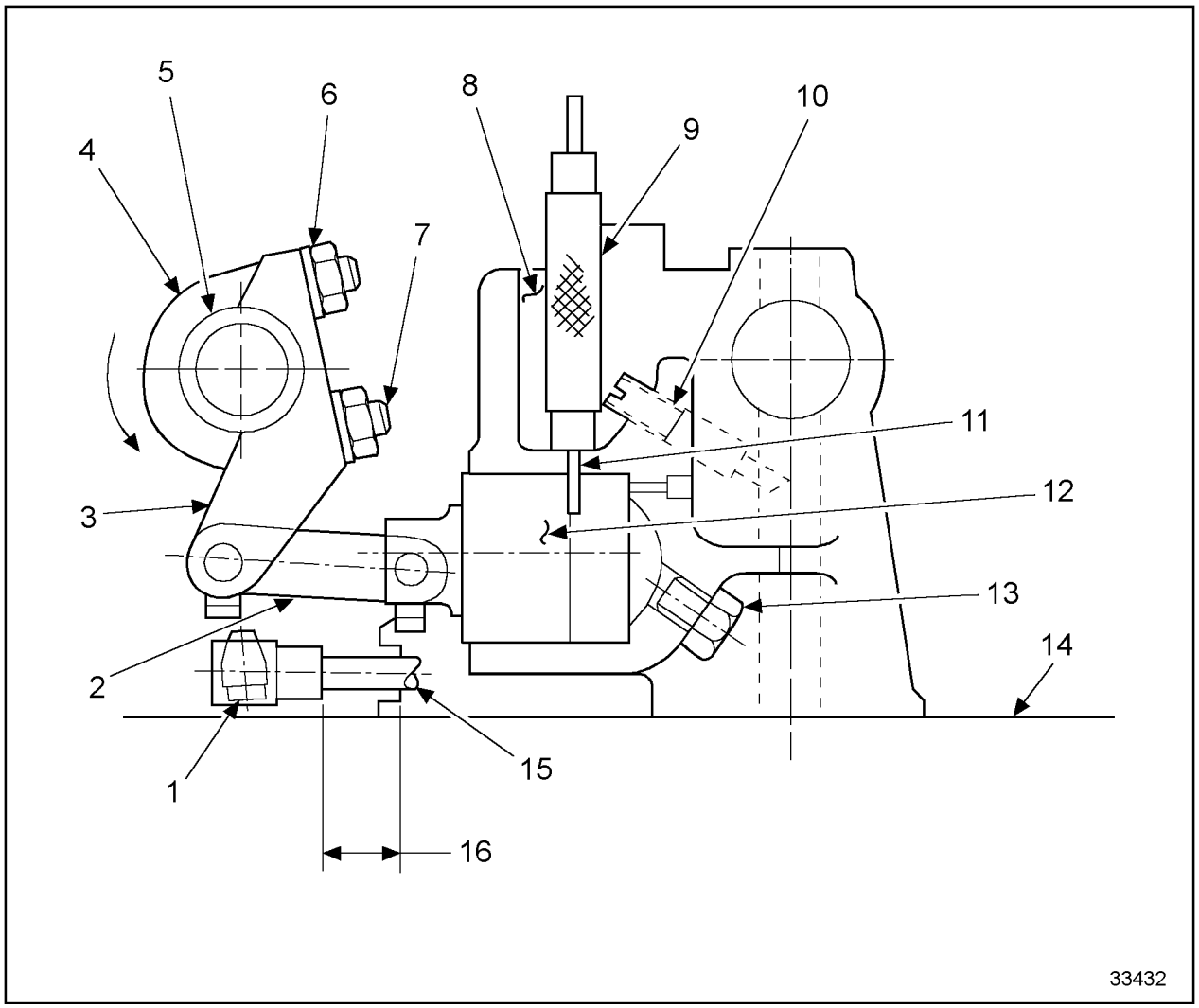


1. Setting Hole
2. Holes (0.25 in.)

Figure 12-160 Throttle Delay Assembly

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6. Rotate the throttle delay lever in the proper direction until movement is limited by the piston contacting the pin gage. See Figure 12-161.



1. Injector Body
2. Link
3. Throttle Delay Lever
4. U-Bolt
5. Control Tube
6. Upper Nut
7. Lower Nut
8. Oil Reservoir
9. Pin Gage (Setting and Checking)
10. Oil Supply Fitting
11. Fill Hole
12. Piston
13. Check Valve
14. Cylinder Head
15. Injector Body-Rack Hole Counterbore
16. Gage Length-Insert Timing Gage Here

Figure 12-161 Adjusting Throttle Delay Cylinder (Current)

7. Tighten the U-bolt while exerting slight pressure on the lever in the direction of rotation.

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8. Remove the pin gage.
9. Insert the "go" (green 1.75 mm or 0.069 in.) end of the gage in the fill hole.
10. If the gage will not go past the piston without resistance, increase the torque on the lower U-bolt nut.
11. Remove the gage.
12. Reverse the pin gage, and insert the "no go" (red 1.83 mm or 0.072 in.) end in the fill hole.
13. If the "no go" end of the gage enters the fill hole past the piston without resistance, increase the torque on the upper U-bolt nut.

NOTE:
It should no be possible to insert the gage past the piston without moving the injector racks toward the no fuel position.

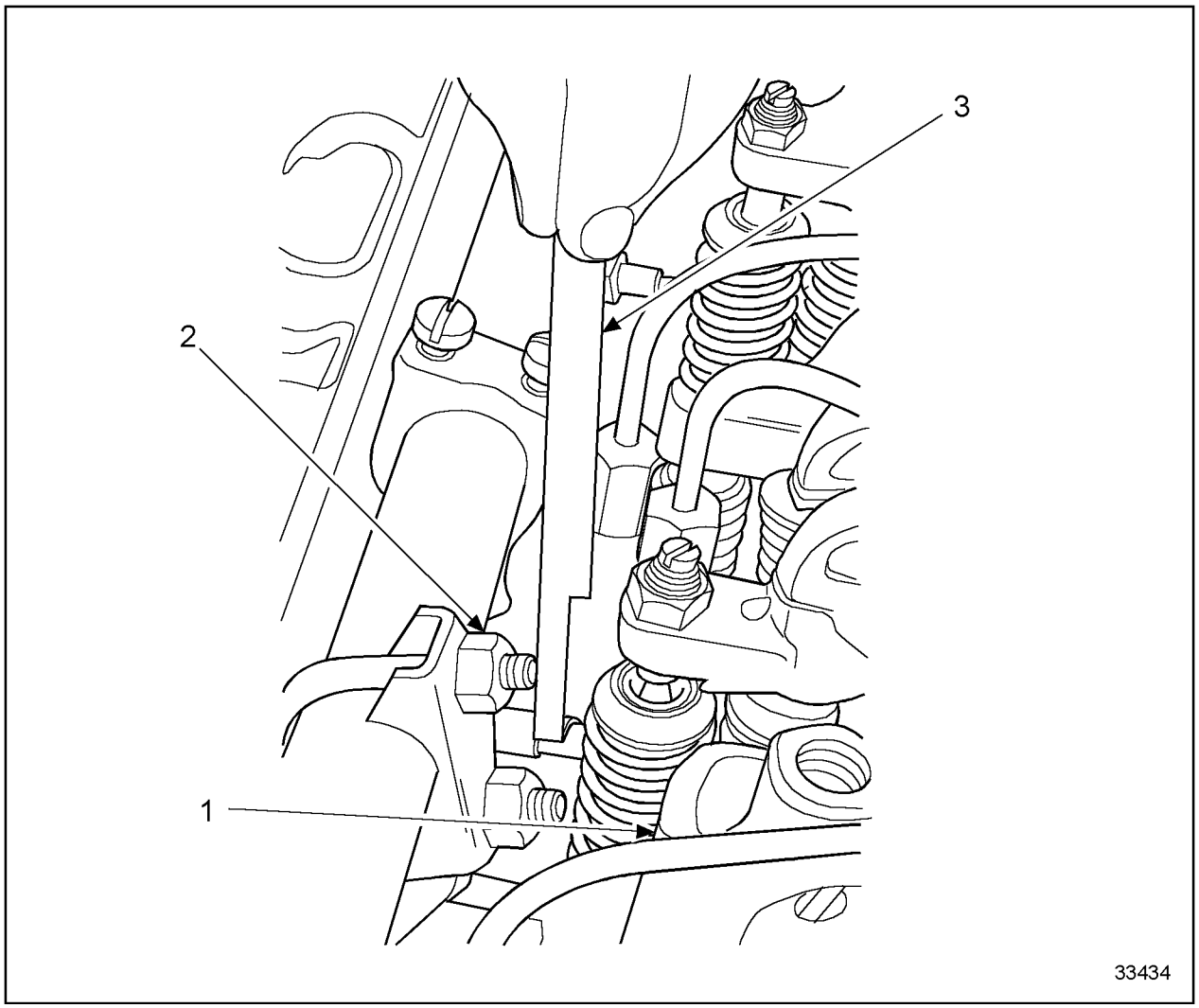
14. Release the governor throttle lever, and remove the timing gage and pin gage.
15. If either U-bolt nut is tightened without the pin gage installed, check the setting.
16. Move the injector control tube assembly between the no fuel and the full fuel position to confirm there is no bind.

12.17.4 Adjustment of Throttle Delay (Former)

After the injector rack control levers have been positioned, the throttle delay mechanism must be adjusted. With the engine stopped, proceed as follows:

1. Loosen the U-bolt which clamps the lever to the injector control tube.

2. Insert gage J 23190 (11.532 mm or 0.454 in. setting) between the injector body and the shoulder on the injector rack. See Figure 12-162.



1. Piston and Housing
2. U-Bolt Nut
3. Gage

Figure 12-162 Throttle Delay Adjustment (Former)

3. Apply light pressure on the injector control tube in the full fuel direction.
4. Align the throttle delay piston to make is flush with the edge of the throttle delay cylinder.
5. Tighten the U-bolt on the injector control tube, and remove the gage.
6. Move the injector rack from the no fuel to the full fuel position to check for bind.

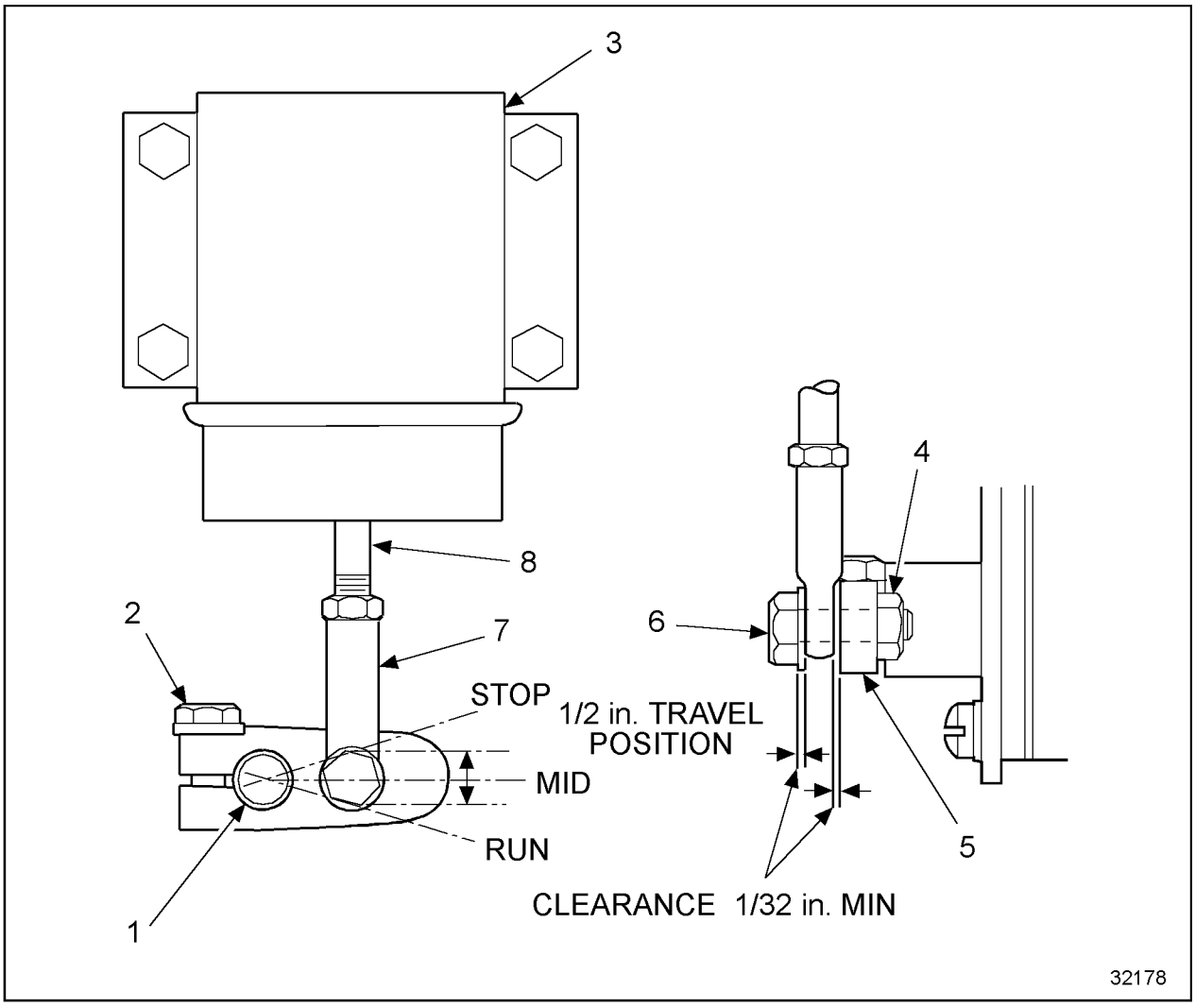
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12.17.5 Mechanical Governor Shutdown Solenoid Adjustment

When a governor shutdown solenoid is used on an engine equipped with a mechanical governor, the governor stop lever must be properly adjusted to match the shutdown solenoid plunger travel.

The solenoid plunger can be properly aligned to the governor stop lever as follows:

1. Remove the bolt connecting the rod end eye (variable speed governor) or the right angle clip (limiting speed governor) to the stop lever. See Figure 12-163.



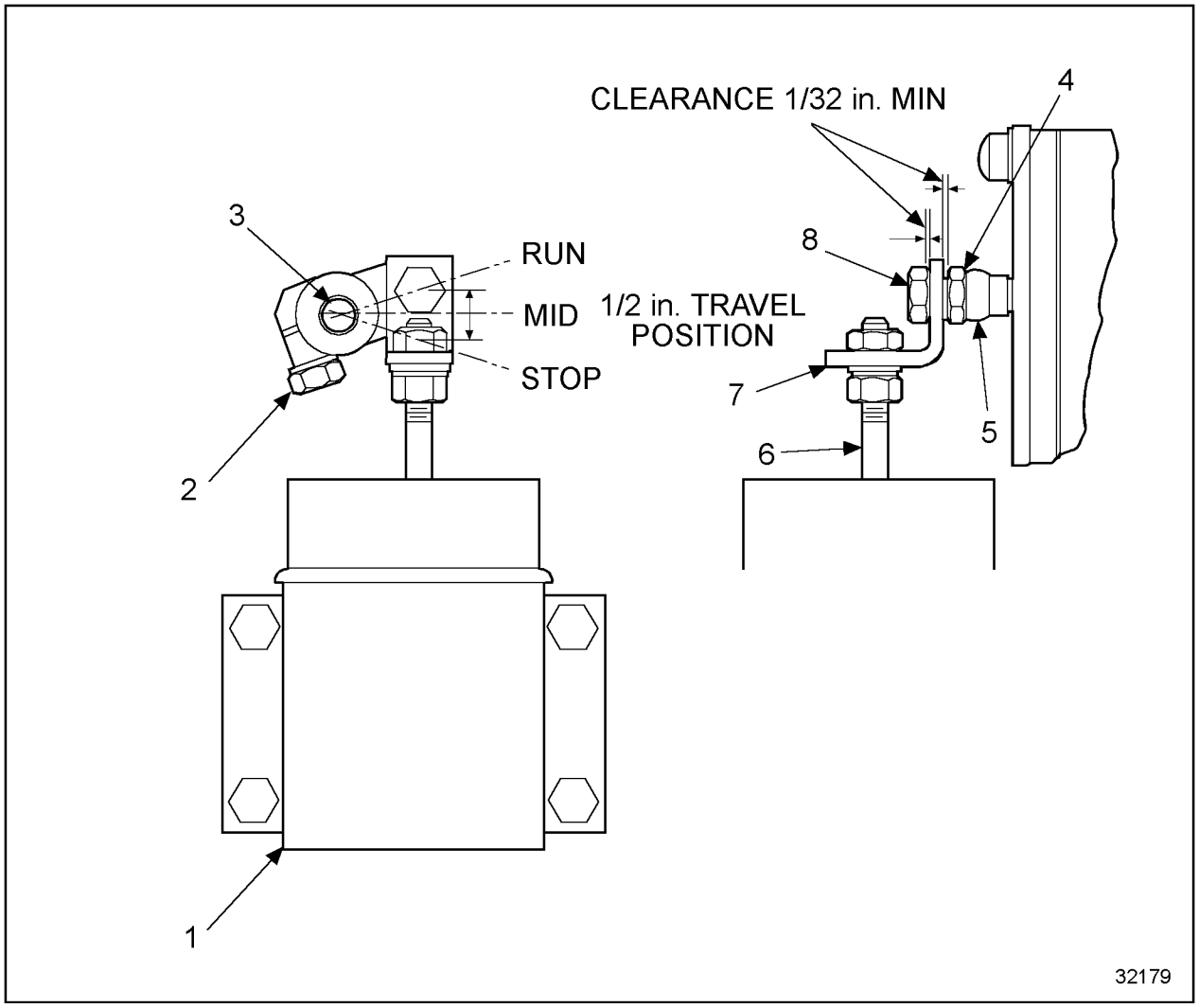
1. Shutdown Shaft
2. Clamping Bolt
3. Solenoid
4. Locknut
5. Stop Lever
6. Bolt
7. Rod End Bolt
8. Plunger

Figure 12-163 Typical Variable Speed Governor Lever Position

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2. Align and clamp the lever to the shutdown shaft so that at mid-travel, the lever is perpendicular to the solenoid plunger.

NOTE:
This assures that the linkage will travel as straight as possible. The solenoid plunger has 0.5 in. travel available. This is enough space to move the injector control racks from the full fuel to the complete no fuel position. Shut down will occur prior to completing travel. See Figure 12-164.



1. Solenoid
2. Clamping Bolt
3. Shutdown Shaft
4. Locknut
5. Stop Lever
6. Plunger
7. Clip
8. Bolt

Figure 12-164 Typical Limiting Speed Governor Lever Position

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3. With the stop lever in the run position, adjust the rod end eye or right angle clip for minimum engagement on the solenoid plunger when the connecting bolt is installed.

NOTE:
The oversize hole in the eye or clip will permit the solenoid to start closing the air gap, resulting in build-up of pull-in force prior to initiating stop lever movement.

4. Lock the bolt through the rod end eye or right angle clip to the stop lever.
5. Adjust the stop lever to a height that will permit the eye or clip to float vertically.

NOTE:
The clearance above and below the eye or clip and the bolt head should be 0.7938 mm (0.03125 in.) minimum.

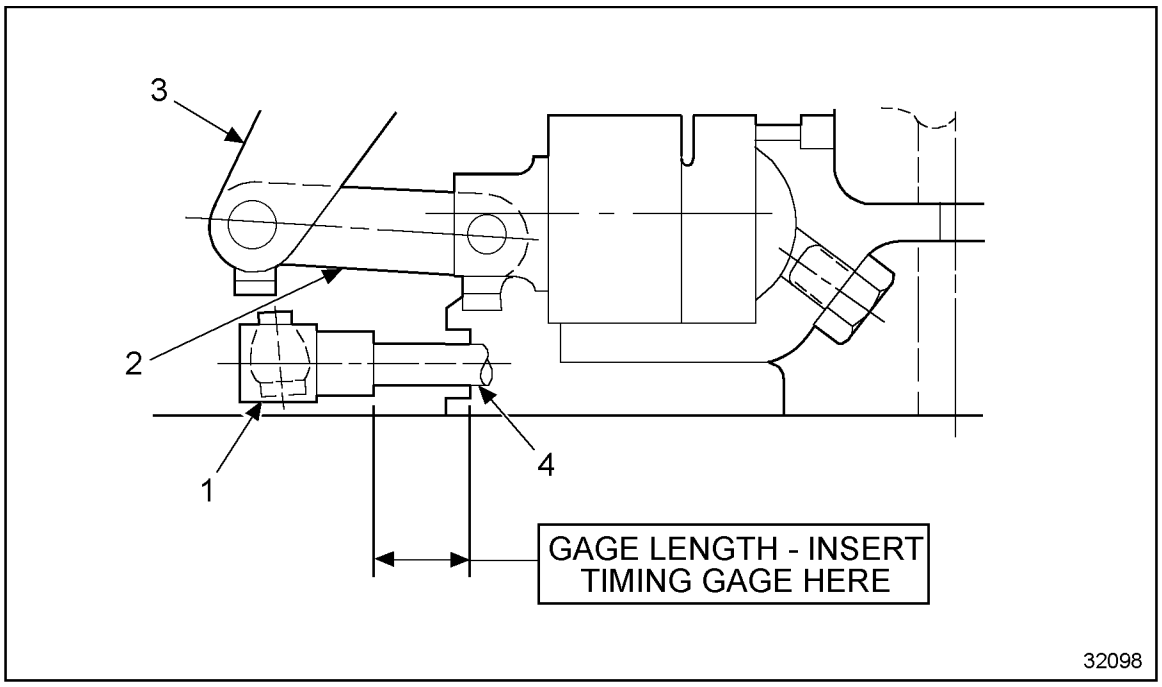
NOTE:
The locknut can be either on top of or below the stop lever.

6. Move the lever to the stop position, and observe the plunger for any bind.
7. If necessary, loosen the mounting bolts, and align the solenoid to provide free plunger motion.

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12.18 FUEL MODULATOR

The fuel modulator is mounted on the left bank cylinder head between the No. 3 and No. 4 cylinder on 8V engines and consists of a cast housing containing a cylinder, piston, cam and spring. See Figure 12-165. The modulator mechanism is installed on the left bank between the No. 2 and No. 3 cylinder on 6V engines. A lever and roller assembly which controls the injector rack is connected to the injector control tube. An air supply line runs from the turbocharger discharge on the air inlet housing to the modulator housing, providing pressure to activate the piston.



1. Injector Rack Clevis
2. Link
3. Throttle Delay Lever
4. Injector Counterbore

Figure 12-165 Rack Clevis

The fuel modulator maintains the proper fuel-to-air ratio in the lower speed ranges where the mechanical governor would normally act to provide maximum injector output. It operates in such a manner that although the engine throttle may be moved into the full fuel position, the injector racks cannot advance to me full fuel position until the turbine speed is high enough to provide sufficient air for combustion.

The modulator tells the fuel system the maximum amount of fuel the engine can efficiently use based on turbocharger boost pressure. Increased pressure forces the piston and cam out of the cylinder, allowing the rack to move toward full fuel. The spring behind the piston is calibrated to the pressure characteristics of the engine.

Effective with engine serial number 8VF-077480, a fuel modulator is available on Federal and California certified 8V-92TA (turbocharged-aftercooled) vehicle engines rated at 355 horsepower at 1800 RPM.

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Effective with unit number 6VF154264, the turbochargers and blower bypass valves on marine engine models 8062-3404 and 8062-7404 were changed to improve fuel combustion efficiency and reduce smoke levels at high RPM. Fuel modulators on these engines must be set at 11.53 mm (0.454 in.) for optimum performance.

For optimum operating efficiency, the engine fuel modulator must be checked periodically, and reset if required.

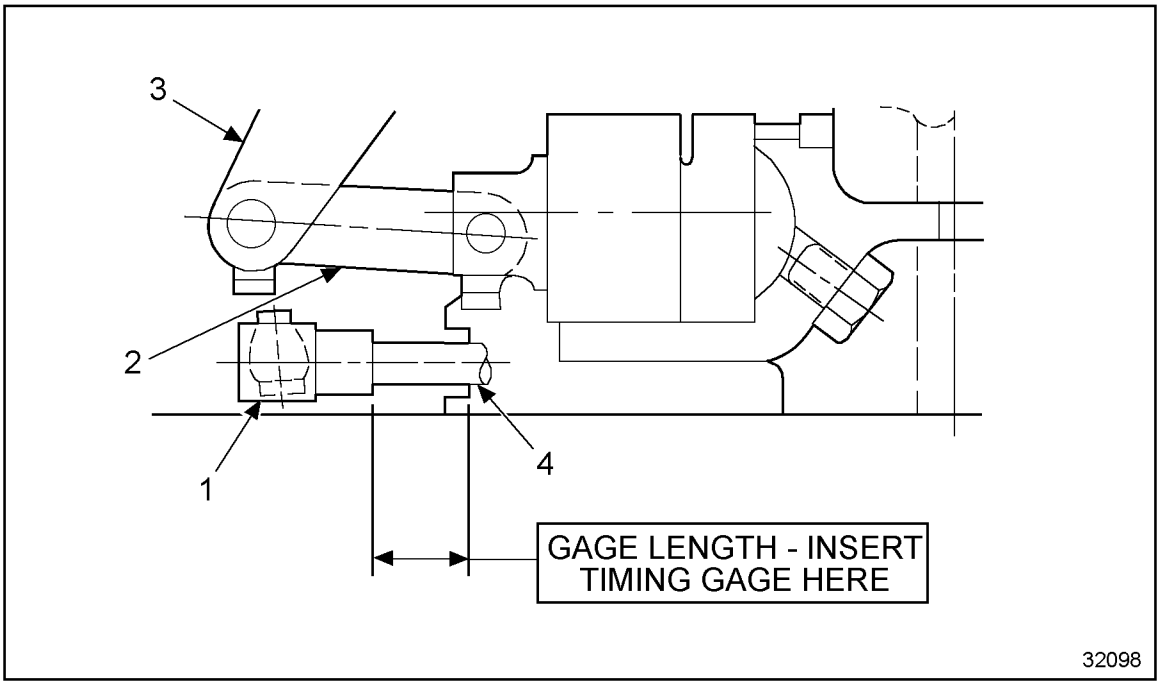
Checking and resetting the fuel modulator ensures the following:

- Engine emission-related adjustments comply with EPA requirements.
- Regulated fuel/air ratio to prevent over fueling and smoke.
- Smooth, free operation of the fuel modulator and linkage.
- Proper adjustment of the modulator to DDC factory specifications, eliminating any previously made incorrect adjustment.

12.18.1 Check Fuel Modulator Setting

Check the fuel modulator setting as follows:

1. With the engine stopped, insert the correct rack gage between the injector body rack recess and the shoulder on the injector rack. See Figure 12-166.



1. Injector Rack Clevis
2. Link
3. Throttle Delay Lever
4. Injector Counterbore

Figure 12-166 Rack Gage Position

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NOTE:
Use the injector next to and forward of the fuel modulator assembly. Insert the gage so the handle is at a 45 degree angle. Fuel modulator specifications and setting tools are listed in Table 12-28.

Tool	Setting
J 9509-C	0.404
J 33156	0.465
J 34080	0.480
J 33157	0.490
J 24889	0.345
J 23190	0.454
J 24882	0.385
J 35735	0.430

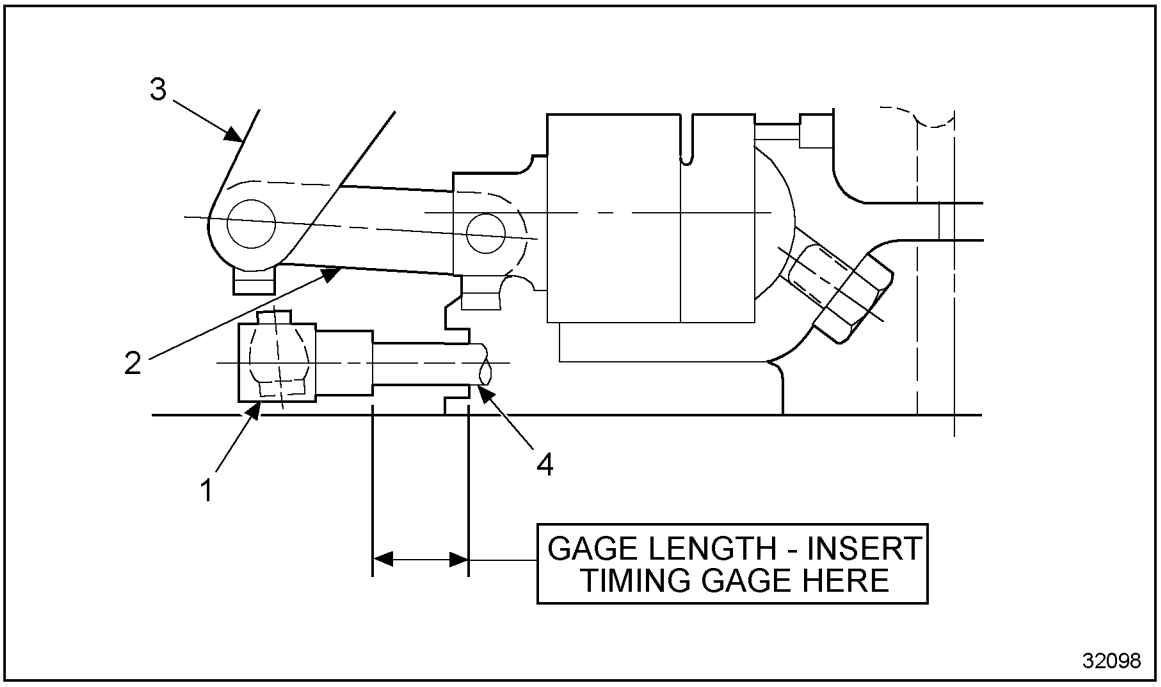
Table 12-28 Modulator Specifications and Setting Tools

NOTE:
Rack gages are marked with the tool number and specific dimensions. Dimensional tolerances are ± 0.05 mm (± 0.002 in.).

2. Hold the governor speed control lever in the maximum speed position and the run/stop lever in the run position.
3. Insert a 0.13 mm (0.005 in.) feeler gage between the modulator roller and cam.

NOTE:
The rack gage must fall over. The rack gage should stand at a 45 degree angle by itself when the 0.13 mm (0.005 in.) feeler gage is removed. See Figure 12-167 and see Figure 12-168.

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1. Injector Rack Clevis
2. Link
3. Throttle Delay Lever
4. Injector Counterbore

Figure 12-167 Rack Gage Position

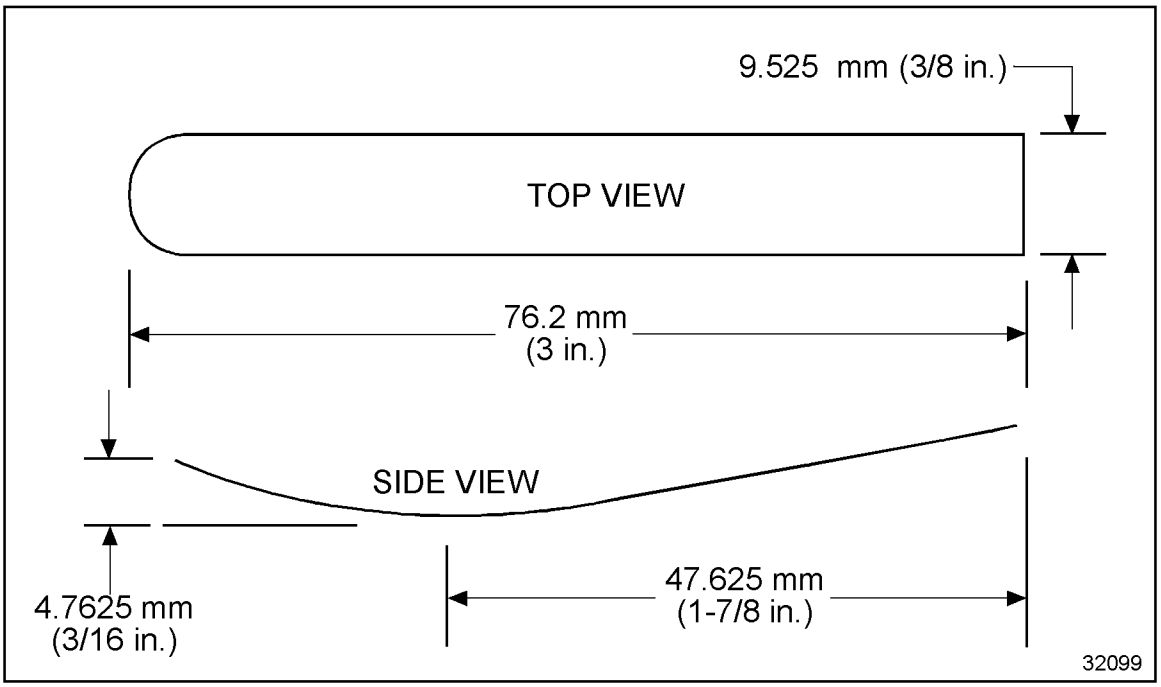


Figure 12-168 Rework of 0.017 in. and 0.004 in. Feeler Gage Stock

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At major repair or overhaul, inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear. Inspect the operating surfaces-the lever roller, the roller pins at the cam pivot, and the cam attachment to the piston.

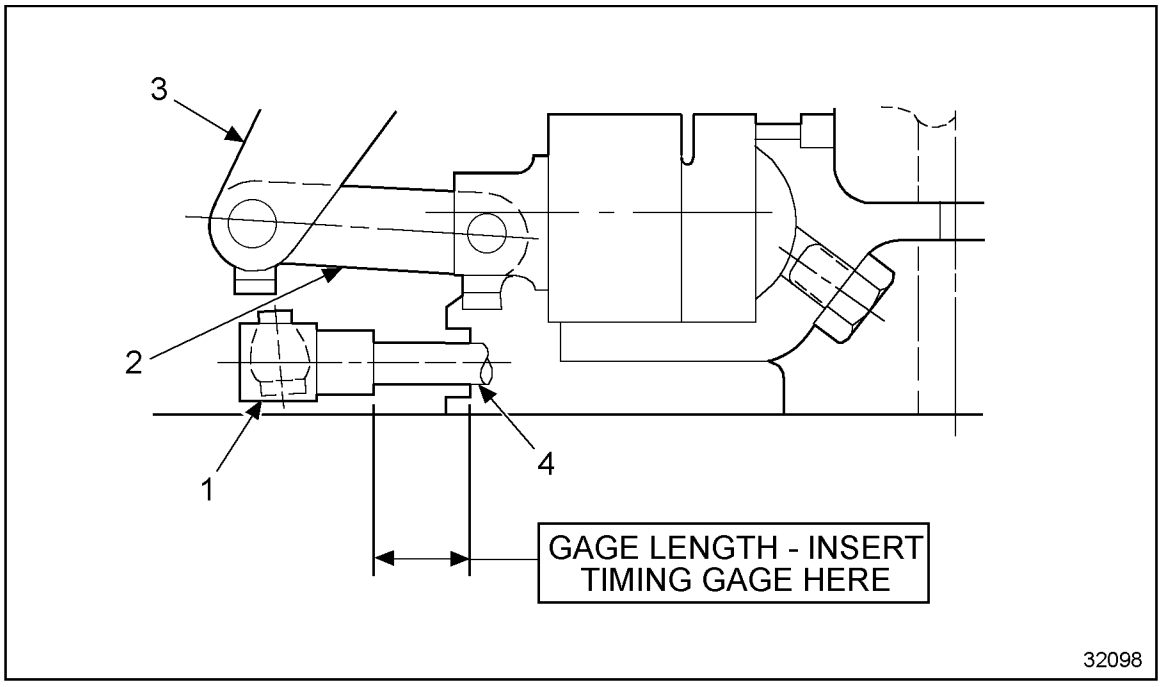
12.18.2 Adjust Fuel Modulator

Before the fuel injector rack control levers are adjusted, the fuel modulator lever and roller assembly must be positioned free from cam contact. Loosen the clamp screw to keep the lever and roller assembly free.

After the injector rack control levers have been properly positioned, adjust the modulator as follows:

1. With the engine stopped, insert the correct rack gage between the injector body rack recess and the shoulder on the injector rack. See Figure 12-169.

NOTE:
Use the injector next to and forward of the fuel modulator assembly. Insert the gage so that the handle is at a 45 degree angle.



1. Injector Rack Clevis
2. Link
3. Throttle Delay Lever
4. Injector Counterbore

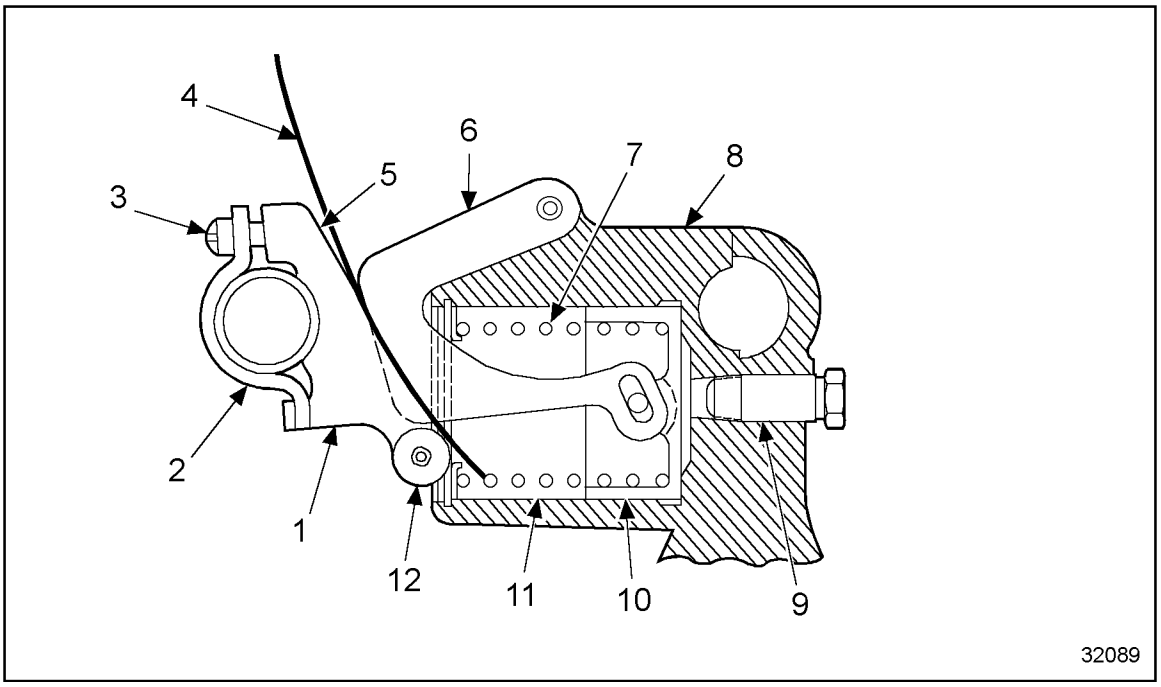
Figure 12-169 Rack Gage Position

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2. Hold the governor speed control lever in the maximum speed position and the run/stop lever in the run position.

NOTE:
The rack gage must stand up while being held in place by the rack.

3. With the clamp loose, push the air box fuel modulator lever assembly until the roller contacts the cam with sufficient force to take up the roller and cam pin clearances.
4. Insert a 3/8 in. x 3 in. x 0.017 in. feeler gage between the cam and the roller. See Figure 12-170 and see Figure 12-171.



1. Lever
2. Clamp
3. Clamp Screw
4. Feeler Gage Position
5. Lever
6. Cam
7. Spring
8. Housing
9. Air Supply from Air Box
10. Piston
11. Cylinder
12. Roller

Figure 12-170 Fuel Modulator Assembly

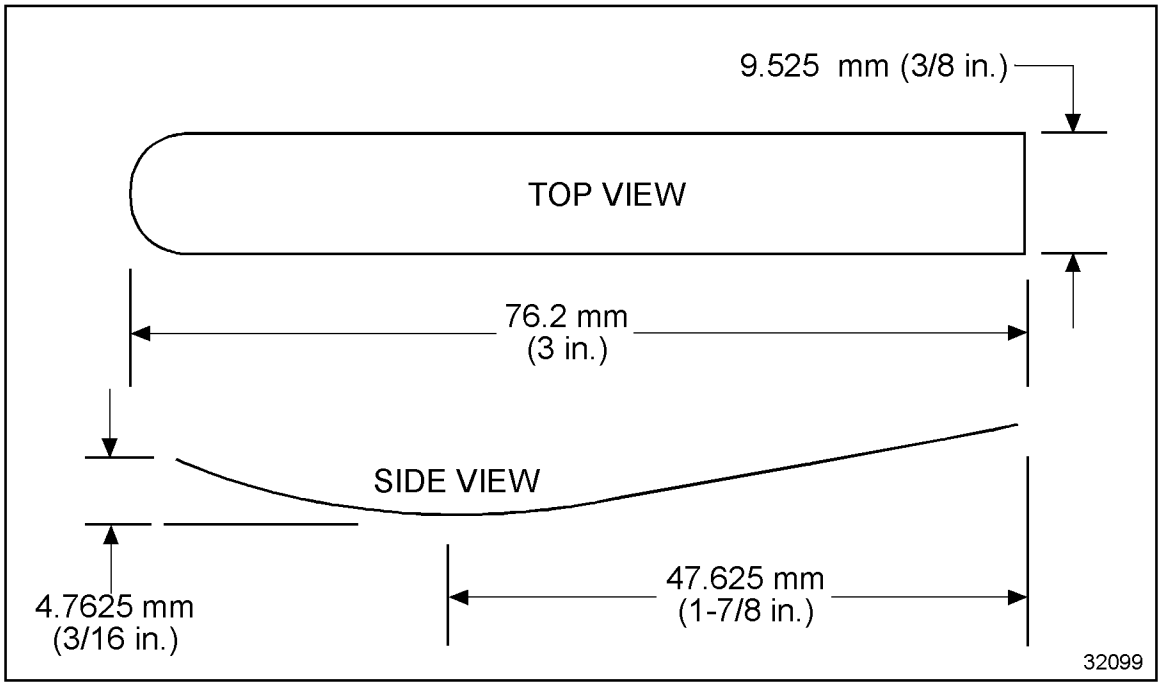


Figure 12-171 Rework of 0.017 in. and 0.004 in. Feeler Gage Stock

5. Ensure cam is centered, and tighten the clamp screw until the gage falls.
6. Replace the 0.43 mm (0.017 in.) thick feeler gage with a 0.10 mm (0.004 in.) thick gage, and tighten the screw until the gage falls again.
7. While holding the governor lever in the maximum speed position, verify the rack gage stands at a 45 degree angle by itself.
8. Insert a 0.13 mm (0.005 in.) feeler gage between the modulator roller and cam.

NOTE:
If the rack gage falls, the setting is correct.

9. Remove the gage.

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13 PREVENTIVE MAINTENANCE

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13.1 PREVENTIVE MAINTENANCE ITEMS DESCRIPTION

The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from the Series 92 engine. The intervals indicated are in time (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 engine starting 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.

Preventive maintenance other than the "each shift" and "daily" checks should be performed by authorized Detroit Diesel service outlets. These outlets have the trained personnel and special tools to properly perform these services.

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13.2 MAINTENANCE OF VEHICLE ENGINE

Engine component must be maintained at various intervals.

13.2.1 Daily Interval Maintenance (Vehicle Engine)

Every day, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Lubricating Oil, refer to section 13.5.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Cooling System, refer to section 13.12.
- ☐ Turbocharger, Exhaust Connections, refer to section 13.17.
- ☐ Air System, refer to section 13.48.
- ☐ Air Compressor, refer to section 13.25.
- ☐ Throttle and Clutch Controls, refer to section 13.26.
- ☐ Power Take-Off, refer to section 13.43.

13.2.2 Every 1,500 Mile Interval Maintenance (Vehicle Engine)

Every 1,500 miles, the following component must be inspected, serviced, corrected or replaced as necessary.

- ☐ Power Take-Off, refer to section 13.43.

13.2.3 Every 3,000 Mile Interval Maintenance (Vehicle Engine)

Every 3,000 miles, the following component must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to section 13.19.

13.2.4 Every 6,000 Mile Interval Maintenance (Vehicle Engine)

Every 6,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Drive Belts, refer to section 13.18.
- ☐ Air Compressor, refer to section 13.25.
- ☐ Throttle and Clutch Controls, refer to section 13.26.

13.2.5 Every 6 Month or 10,000 Mile Interval Maintenance (Vehicle Engine)

Every 6 months or 10,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

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- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Starting Motor, refer to section 13.38.

13.2.6 Every 15,000 Mile Interval Maintenance (Vehicle Engine)

Every 15,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Tank, refer to section 13.9.
- ☐ Dry Type Air Cleaner, refer to section 13.47.
- ☐ Lubricating Oil, refer to section 13.5.
- ☐ Lubricating Oil Filter, refer to section 13.7.2.
- ☐ Coolant Filter/Inhibitor Level, refer to section 13.14.
- ☐ Coolant Filter/Inhibitor Pre-Charge Element, refer to section 13.15.
- ☐ Governor, Overspeed Governor refer to section 13.30.

13.2.7 Every 12 Month or 20,000 Mile Interval Maintenance (Vehicle Engine)

Every 12 months or 20,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Fuel and Fuel Tank, refer to section 13.9.
- ☐ Cooling System, refer to section 13.12.
- ☐ Air Compressor, refer to section 13.25.
- ☐ Air Cleaners, refer to section 13.47.
- ☐ Turbochargers, Exhaust Connections, refer to section 13.17.
- ☐ Engine (Steam Clean), refer to section 13.42.
- ☐ Radiator, refer to section 13.16.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Battery Charging Alternator, refer to section 13.20.
- ☐ Thermostats and Seals, refer to section 13.34.
- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Shutter Operation, refer to section 13.29.
- ☐ Fan Hub, refer to section 13.32.

13.2.8 Every 18 Month or 30,000 Mile Interval Maintenance (Vehicle Engine)

Every 18 months or 30,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.

- ☐ Water Pump, refer to section 13.13.
- ☐ Air Box Drain Tube, refer to section 13.27.
- ☐ Blower Screen, refer to section 13.35.

13.2.9 Every 24 Month or 40,000 Mile Interval Maintenance (Vehicle Engine)

Every 24 months or 40,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Cooling System, refer to section 13.12.
- ☐ Air Compressor, refer to section 13.25.
- ☐ Air Cleaners, refer to section 13.47.
- ☐ Turbochargers, Exhaust Connections, refer to section 13.17.
- ☐ Engine (Steam Clean), refer to section 13.42.
- ☐ Radiator, refer to section 13.16.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Battery Charging Alternator, refer to section 13.20.
- ☐ Thermostats and Seals, refer to section 13.34.
- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Shutter Operation, refer to section 13.29.
- ☐ Fan Hub, refer to section 13.32.

13.2.10 Every 30 Month or 50,000 Mile Interval Maintenance (Vehicle Engine)

Every 30 months or 50,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Throttle Delay/Fuel Modulator, refer to section 13.26.

13.2.11 Every 36 Month or 60,000 Mile Interval Maintenance (Vehicle Engine)

Every 36 months or 60,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Cooling System, refer to section 13.12.

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- ☐ Air Compressor, refer to section 13.25.
- ☐ Air Cleaners, refer to section 13.47.
- ☐ Turbochargers, Exhaust Connections, refer to section 13.17.
- ☐ Engine (Steam Clean), refer to section 13.42.
- ☐ Radiator, refer to section 13.16.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Battery Charging Alternator, refer to section 13.20.
- ☐ Thermostats and Seals, refer to section 13.34.
- ☐ Engine and Transmission Mounts, refer to section 13.21.
- ☐ Crankcase Pressure, refer to section 13.40.
- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Box Drain Tube, refer to section 13.27.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Shutter Operation, refer to section 13.29.
- ☐ Fan Hub, refer to section 13.32.

13.2.12 Every 42 Month or 70,000 Mile Interval Maintenance (Vehicle Engine)

Every 42 months or 70,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.

13.2.13 Every 48 Month or 80,000 Mile Interval Maintenance (Vehicle Engine)

Every 48 months or 80,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Cooling System, refer to section 13.12.
- ☐ Air Compressor, refer to section 13.25.
- ☐ Air Cleaners, refer to section 13.47.
- ☐ Turbochargers, Exhaust Connections, refer to section 13.17.
- ☐ Engine (Steam Clean), refer to section 13.42.
- ☐ Radiator, refer to section 13.16.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Battery Charging Alternator, refer to section 13.20.
- ☐ Thermostats and Seals, refer to section 13.34.
- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Shutdown Valve, refer to section 13.50.

- ☐ Shutter Operation, refer to section 13.29.
- ☐ Fan Hub, refer to section 13.32.
- ☐ Fuel Injectors and Valve Clearance, refer to section 13.36.

13.2.14 Every 54 Month or 90,000 Mile Interval Maintenance (Vehicle Engine)

Every 54 months or 90,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Air Box Drain Tube, refer to section 13.27.

13.2.15 Every 60 Month or 100,000 Mile Interval Maintenance (Vehicle Engine)

Every 60 months or 100,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.
- ☐ Water Pump, refer to section 13.13.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Cooling System, refer to section 13.12.
- ☐ Air Compressor, refer to section 13.25.
- ☐ Air Cleaners, refer to section 13.47.
- ☐ Turbochargers, Exhaust Connections, refer to section 13.17.
- ☐ Engine (Steam Clean), refer to section 13.42.
- ☐ Radiator, refer to section 13.16.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Battery Charging Alternator, refer to section 13.20.
- ☐ Thermostats and Seals, refer to section 13.34.
- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Blower Bypass Valve, refer to section 13.23.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Shutter Operation, refer to section 13.29.
- ☐ Throttle Delay/Fuel Modulator, refer to section 13.26.
- ☐ Air Box Check Valves, refer to section 13.28.
- ☐ Fan Hub, refer to section 13.32.
- ☐ Low Coolant Level Sensor, refer to section 13.12.7.

13.2.16 Every 120 Month or 200,000 Mile Interval Maintenance (Vehicle Engine)

Every 120 months or 200,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

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☐ Water Pump, refer to section 13.13.

13.2.17 Every 240,000 Mile Interval Maintenance (Vehicle Engine)

Every 240,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

☐ Thermostats and Seals, refer to section 13.34.

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13.3 MAINTENANCE OF STATIONARY AND INDUSTRIAL ENGINE

Engine component must be maintained at various intervals.

13.3.1 Daily Interval Maintenance (Stationary and Industrial Engine)

Every day, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Lubricating Oil, refer to section 13.5.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Cooling System, refer to section 13.12.
- ☐ Turbocharger, Exhaust Connections, refer to section 13.17.
- ☐ Throttle and Clutch Controls, refer to section 13.26.
- ☐ Power Take-Off, refer to section 13.43.

13.3.2 Every 50 Hour or 1,500 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 50 hours or 1,500 miles, the following component must be inspected, serviced, corrected or replaced as necessary.

- ☐ Power Take-Off, refer to section 13.43.

13.3.3 Every 100 Hour or 3,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 100 hours or 3,000 miles, the following component must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to section 13.19.

13.3.4 Every 150 Hour Interval Maintenance (Stationary and Industrial Engine)

Every 150 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Strainer and Filter, refer to section 13.8.

13.3.5 Every 150 Hour or 4,500 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 150 hours or 4,500 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Lubricating Oil, refer to section 13.5.

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- ☐ Lubricating Oil Filter, refer to section 13.7.2.

13.3.6 Every 150 Hour or 5,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 150 hours or 5,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Air Compressor, refer to section 13.25.

13.3.7 Every 200 Hour or 6,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 200 hours or 6,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Coolant Filter/Inhibitor Level, refer to section 13.14.
- ☐ Drive Belts, refer to section 13.18.
- ☐ Throttle and Clutch Controls, refer to section 13.26.

13.3.8 Every 600 Hour or 18,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 600 hours or 18,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Water Pump, refer to section 13.13.

13.3.9 Every 9 Month or 500 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 9 months or 500 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Tank, refer to section 13.9.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Cleaner, refer to section 13.47.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Governor, Overspeed Governor, refer to section 13.30.

13.3.10 Every 12 Month or 700 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 12 months or 700 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Tank, refer to section 13.9.
- ☐ Cooling System, refer to section 13.12.

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- ☐ Air Compressor, refer to section 13.25.
- ☐ Air Cleaner, refer to section 13.47.
- ☐ Air System, refer to section 13.48.
- ☐ Turbocharger, Exhaust Connections, refer to section 13.17.
- ☐ Engine (Steam Clean), refer to section 13.42.
- ☐ Radiator, refer to section 13.16.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Battery Charging Alternator, refer to section 13.20.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Shutter Operation, refer to section 13.29.
- ☐ Fan Hub, refer to section 13.32.

13.3.11 Every 18 Month or 1,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 18 months or 1,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Crankcase Pressure, refer to section 13.40.
- ☐ Air Box Drain Tube, refer to section 13.27.

13.3.12 Every 36 Month or 2,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 36 months or 2,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Engine and Transmission Mounts, refer to section 13.21.
- ☐ Blower Screen, refer to section 13.35.

13.3.13 Every 60 Month or 3,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 60 months or 3,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer Drive, refer to section 13.24.
- ☐ Blower Bypass Valve, refer to section 13.23.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Air Box Check Valves, refer to section 13.28.

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13.3.14 Every 120 Month or 6,000 Mile Interval Maintenance (Stationary and Industrial Engine)

Every 120 months or 6,000 miles, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Water Pump, refer to section 13.13.
- ☐ Air System, refer to section 13.48.
- ☐ Thermostats and Seals, refer to section 13.34.
- ☐ Crankcase Pressure, refer to section 13.40.

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13.4 MAINTENANCE OF PLEASURE CRAFT MARINE ENGINES

Engine components must be maintained at various intervals.

13.4.1 Beginning of Boating Season (Pleasure Craft Marine)

At the beginning of the boating season, the following component must be inspected, serviced or corrected as necessary.

- ☐ Cooling System (Marine), refer to section 13.51.

13.4.2 Daily Shift Interval Maintenance (Pleasure Craft Marine)

Every day, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Lubricating Oil, refer to section 13.5.
- ☐ Fuel Tank, refer to section 13.9.
- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Cooling System, refer to section 13.12.
- ☐ Turbocharger, Exhaust Connections, refer to section 13.17.
- ☐ Air Cleaners, refer to section 13.48.
- ☐ Fuel/Water Separator and Filter, refer to section 13.8.2.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Marine Gear, refer to section 13.57.
- ☐ Raw Water Pump, refer to section 13.54.
- ☐ Power Take-Off, refer to section 13.43.

13.4.3 Every 50 Hour Interval Maintenance (Pleasure Craft Marine)

Every 50 hours, the following component must be inspected, serviced, corrected or replaced as necessary.

- ☐ Power Take-Off, refer to section 13.43.

13.4.4 150 Hour Interval Maintenance (Pleasure Craft Marine)

Every 150 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Lubricating Oil, refer to section 13.5.
- ☐ Lubricating Oil Filter, refer to section 13.7.2.
- ☐ Drive belts (Marine), refer to section 13.18.
- ☐ Cooling system, refer to section 13.12.
- ☐ Coolant Filter/Inhibitor Pre-Charge Element, refer to section 13.15.
- ☐ Fuel/Water Separator and Filter, refer to section 13.8.2.

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13.4.5 200 Hour Interval Maintenance (Pleasure Craft Marine)

Every 200 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Cooling Filter/Inhibitor Level, refer to section 13.12.3.

13.4.6 300 Hour Interval Maintenance (Pleasure Craft Marine)

Every 300 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer Drive, refer to section 13.24.
- ☐ Battery Charging Alternator, refer to section 13.20.

13.4.7 500 Hour Interval Maintenance (Pleasure Craft Marine)

Every 500 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Cooling System, refer to section 13.12.
- ☐ Air Cleaner, refer to section 13.48.
- ☐ Air Separators, refer to section 13.49.
- ☐ Oil Pressure, refer to section 13.6.
- ☐ Air Shutdown Valve, refer to section 13.50.
- ☐ Governor, Overspeed Governor, refer to section 13.30.

13.4.8 1000 Hour Interval Maintenance (Pleasure Craft Marine)

Every 1000 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel Lines and Flexible Hoses, refer to section 13.11.
- ☐ Engine and Transmission Mounts, refer to section 13.21.
- ☐ Air Separator, refer to section 13.49.
- ☐ Crankcase Breather, refer to section 13.41.
- ☐ Crankcase Pressure, refer to section 13.40.
- ☐ Air Box Drain Tube, refer to section 13.27.
- ☐ Air Box Check Valves, refer to section 13.28.
- ☐ Marine Gear, refer to section 13.57.
- ☐ Fuel Injectors, refer to section 13.36.

13.4.9 4000 Hour Interval Maintenance (Pleasure Craft Marine)

Every 4000 hours, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Thermostats and Seals, refer to section 13.34.

- ☐ Marine Gear Oil Cooler, refer to section 13.56.
- ☐ Fuel and Boost Coolers, refer to section 13.55.
- ☐ Heat Exchanger, refer to section 13.49.

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13.5 LUBRICATING OIL

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty 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.

13.5.1 Fill Crankcase

Fill the crankcase with oil as follows:

NOTICE:
If the oil level is constantly above normal and excess lubricating oil has not been added to the crankcase, determine the cause. Fuel or coolant diluting the lubricating oil can result in serious engine damage. For additional information, refer to section 5.2.1.10.

1. Fill the oil pan to the full mark on the dipstick.
2. Start and run the engine for approximately ten minutes.
3. Stop the engine, and wait a minimum of twenty minutes.
4. Add the required amount of oil to reach the full mark on the dipstick.

NOTE:
Each engine oil filter will require approximately two additional quarts (1.9 liters) of oil.

Make a visual check for oil leaks around the filters and the external oil lines.

Change the lubricating oil at the intervals listed in Table 13-1.

Service Application	Oil Drain Interval
Highway Truck & Motor Coach	24,000 km (15,000 Miles)
City Transit Coaches	9,600 km (6,000 Miles) or 3 Months*
Pick-up & Delivery Stop & Go, Short Trip	19,000 km (12,000 Miles)
Industrial, Agricultural and Marine	150 Hours
Stationary Units, Continuous	300 Hours or 3 Months*
Stationary Units, Standby	150 Hours or 1 Year*

* Whichever comes first

Table 13-1 Maximum Allowable Oil Drain Intervals - Normal Operation with Low Sulfur Fuel (0.5% or Less)

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Listed in Table 13-2 are drain intervals when using high sulfur fuel (above 0.50 mass percent).

Service Application	Oil Drain Interval
Highway Truck & Motor Coach	16,000 km (10,000 Miles)
City Transit Coaches	6,400 km (4,000 Miles) or 3 Months Maximum*
Pick-up & Delivery Stop & Go, Short Trip	12,500 km (8,000 Miles)
Industrial, Agricultural and Marine	150 Hours or 1 Year*
Stationary Units, Continuous	200 Hours or 1 Month*
Stationary Units, Standby	100 Hours or 8 Months*

* Whichever comes first

Table 13-2 Maximum Allowable Oil Drain Intervals - Normal Operation with High Sulfur Fuel (Above 0.5%) Use Oil Analysis to Determine Optimum Drain Intervals

When using high TBN/ash oils, drain the oil when the TBN drops to one-half of the new oil TBN. Since lubricant composition varies from brand to brand the time and rate of TBN reduction will vary. These differences manifested by the various high TBN/ash oils will influence the drain interval.

The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined.

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily. Select the proper grade of oil in accordance with the instructions given. Refer to section 5.2.

13.5.2 Drain Lubricating Oil

Change the lubricating oil as follows:

NOTE:
Before adding lubricating oil, refer to section 5.2 to select the proper grade of lubricating oil.

1. Position the vehicle or equipment on level ground.
2. If the engine is cold, run it until it is warm. Stop the engine.

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CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

3. Remove the drain plug on the bottom of the oil pan.

NOTICE:

Dispose of used lubricating oil in an environmentally responsible manner, according to EPA and state recommendations.

4. Drain lubricating oil into a suitable container.
5. Coat drain plug(s) with Loctite 567 sealant, or equivalent.
6. Install and tighten the drain plug to 45-56 N·m (33-41 lb·ft).

NOTE:
Lubricating oil filters should be replaced whenever the engine oil is changed.

7. Refer to section 13.7.2 and replace oil filter.

13.5.3 Leak Check Lubrication System

When engine oil analysis reveals that engine coolant or diesel fuel is found in the engine lubricating oil, perform the following procedure:

1. Inspect engine lower main bearings. Refer to section 1.10.2.2.

NOTE:
Examination of all bearing shells is required to determine if damage to the bearings has occurred.

[a] If damage has occurred, replace all lower main bearing shells immediately. Refer to section 1.10.2.

[b] If lubricating oil dilution is detected before the normal engine overhaul period is reached but damage has not occurred, replace the lower main bearing shells at 5,000 hours.

NOTE:
If lubricating oil dilution is recurrent, replace lower main bearing shells at regular intervals of 5,000 hours.

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NOTICE:
Failure to replace lower main bearing shells as recommended will allow the crankshaft to operate without adequate bearing support. This will lead to crankshaft journal damage.

NOTICE:
Coolant leaking into the engine lubricating oil can cause oil dilution and engine damage. If a coolant leak is discovered while the engine is still running, thoroughly flush the lubrication system to avoid damage.

Before flushing perform the following check for leaks:

1. Determine the cause of the internal coolant leak, and correct it.

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

2. Thoroughly drain the lubricating oil. Refer to section 13.5.2.
3. Take a 6-8 ounce sample, and label it for chemical analysis.

NOTICE:
If coolant or fuel dilution of the engine lubricating oil is detected through oil analysis, the lower main bearings must be inspected to determine of damage has occurred. Refer to section 1.10.2.2.

The main bearings are more sensitive to coolant dilution than to fuel oil dilution of the lubricating oil. Fuel oil dilution of the lubricating oil below 2.5% by volume should not cause any lubricating problems. However, any level of coolant is cause for concern and requires immediate corrective action.

- □ If damage has occurred, replace all lower main bearings. Refer to section 1.10.2.
- □ If upon inspection, there is any doubt whether or not the bearings have been damaged, replace all lower main bearings. Refer to section 1.10.2.
- □ If the bearings have been in service for over 5,000 hours when the dilution occurred, replace all lower main bearings. Refer to section 1.10.2.
- □ If upon inspection, bearing damage has not occurred, although a dilution incident has occurred, replace all lower main bearings when the bearings reach 5,000 hours of operations. Refer to section 1.10.2.

NOTE:
If coolant or fuel dilution of the engine lubricating oil is detected through oil analysis, inspect the lower main bearings to determine what damage has occurred.

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4. Examine the drained oil.
5. If the oil is still reasonably fluid and is typical of the used oil at regular drain intervals, refer to section 13.5.4.
6. If the oil is gelled, refer to section 13.5.5.

13.5.4 Draining of (Non-Gelled) Lubricating Oil

Use this procedure if the contaminated lubricating oil is still freely flowing without gelling. This requires only the lubricating oil recommended for normal operation.

1. Drain all lubricating oil. Refer to section 13.5.2.
2. Remove and discard the oil filters, replace with new filters. Refer to section 13.7.
3. Pressure fill the lubrication system to 172 kPa (25 lb/in.^{2}) with the lubricating oil recommended for normal operation, ensuring the crankcase is filled to the proper operating level.
4. Start and run the engine at fast idle (1000-1200 RPM) for 30 minutes to one hour.
5. Check engine running conditions frequently, especially oil pressure; stop immediately if a reading is out of range.
   [a] If reading is *out* of range, proceed to step 6.
   [b] If reading is *not* out of range, procedure is complete.
6. Stop the engine, immediately drain the crankcase. Allow enough time to drain all the fluid.
7. Take a second oil sample, and label it.
8. Remove and discard the oil filters, replace with new filters. Refer to section 13.7.
9. Pressure fill the lubrication system to 172 kPa (25 lb/in.^{2}) with the lubricating oil recommended for normal operation, ensuring the crankcase is filled to the proper operating level.
10. Start and run the engine at fast idle (1000-1200 RPM) for 30 minutes to one hour.
11. Check engine running conditions frequently, especially oil pressure. Stop immediately if a reading is out of range.
    [a] If reading is *out* of range, proceed to step 12.
    [b] If reading is *not* out of range, procedure is complete.
12. Stop the engine, immediately drain the crankcase. Allow enough time to drain all the fluid.
13. Remove and discard all oil filters, replace with new filters. Refer to section 13.7.
14. Replace oil drains, and pressure fill the engine to the proper level with the lubricating oil recommended for normal operation.
15. Have oil samples analyzed for coolant contamination and engine condition.
    [a] If reading is *out* of range, refer to step 1 and repeat procedure.
    [b] If reading is *not* out of range, procedure is complete.

13.5.5 Draining of (Gelled) Lubricating Oil

Use this procedure if the contaminated oil is gelled. This requires the lubricating oil recommended for normal operation with additional solvent.

1. Drain all lubricating oil. Refer to section 13.5.2.
2. Remove and discard all oil filters, and replace with new filters. Refer to section 13.7.

⚠ CAUTION:

To avoid injury from improper use of chemicals, follow the chemical manufacturer's usage, handling, and disposal instructions. Observe all manufacturer's cautions.

3. Mix two parts of the lubricating oil recommended for normal operation with one part butyl cellosolve.
4. Pressure fill the engine with the mixture to 172 kPa (25 lb/in.^{2}) until the crankcase is filled to the proper operating level.
5. Start and run the engine at fast idle (1000-1200 RPM) for 30 minutes to one hour.
6. Check the engine running conditions frequently, especially oil pressure, and stop immediately if a reading is out of range.
   [a] If reading is *out* of range, proceed to step 7.
   [b] If reading is *not* out of range, procedure is complete.
7. Stop the engine, and immediately drain the crankcase. Allow enough time to drain all the fluid.
8. Take a second oil sample, and label it.
9. Remove and discard all oil filters, and replace with new filters. Refer to section 13.7.
10. Replace oil drains, and using a fresh charge of the lubricating oil recommended for normal operation, pressure fill the engine via the oil gallery to 172 kPa (25 lb/in.^{2}) until the crankcase is filled to the proper operating level.
11. Start and run the engine at fast idle (1000-1200 RPM) for 30 minutes to an hour.
12. Check engine running conditions frequently, especially oil pressure, and stop immediately if a reading is out of range.
    [a] If reading is *out* of range, proceed to step 13.
    [b] If reading is *not* out of range, procedure is complete.
13. Stop the engine, and immediately drain the crankcase. Allow enough time to drain all the fluid.
14. Take a third oil sample, and label it.
15. Remove and discard all oil filters; replace with new filters. Refer to section 13.7.

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16. Replace oil drains, and pressure fill the engine to the proper level with the lubricating oil recommended for normal operation.
17. Have oil samples analyzed for coolant contamination and engine condition.
    [a] If reading is *out* of range, refer to step 1 and repeat procedure.
    [b] If reading is *not* out of range, procedure is complete.

NOTE:
This procedure should flush all coolant contamination from the lubricating system. However, a thin coating from the coolant may remain on some moving engine parts. The coating should disappear within one or two oil changes.

13.6 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.

Refer to OEM maintenance guidelines.

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13.7 LUBRICATING OIL FILTER

Lubricating oil filters make up an essential part of the lubrication system. Proper filter selection and maintenance are important to satisfactory engine operation and service life. Filters should be used to maintain a clean system, not to clean up a contaminated system.

13.7.1 Installation of Lubricating Oil Filter

Install the oil filter as follows:

1. Install a new filter at regular change intervals or each time the engine oil is changed, whichever comes first.
2. Fill new filters with clean engine oil.
3. Install the new filters, turning them until they fully contact the gasket with no side movement.
4. Turn an additional 2/3 turn by hand.

13.7.1.1 Inspection of Lubricating Oil Filter

Inspect the oil filter as follows:

1. Inspect all lubricating oil lines for wear and/or chafing.
2. If worn, replace the oil lines and correct the cause.
3. Check for leaks after starting the engine.
4. If the engine is equipped with a turbocharger, prelubricate it. Refer to section 6.6.
5. If equipped with the governor oil filter, change the element every 1000 hours or 48,000 km (30,000 miles).

13.7.2 Replacement of Lubricating Oil Filter

To replace the lube oil filter, perform the following procedure:

1. Remove the spin-on filter cartridges using strap wrench tool J 29917, or equivalent, and a 12.7 mm (0.5 in.) drive socket wrench and extension.

NOTE:
Dispose of the used oil and filters in an environmentally responsible manner, according to EPA and state recommendations.

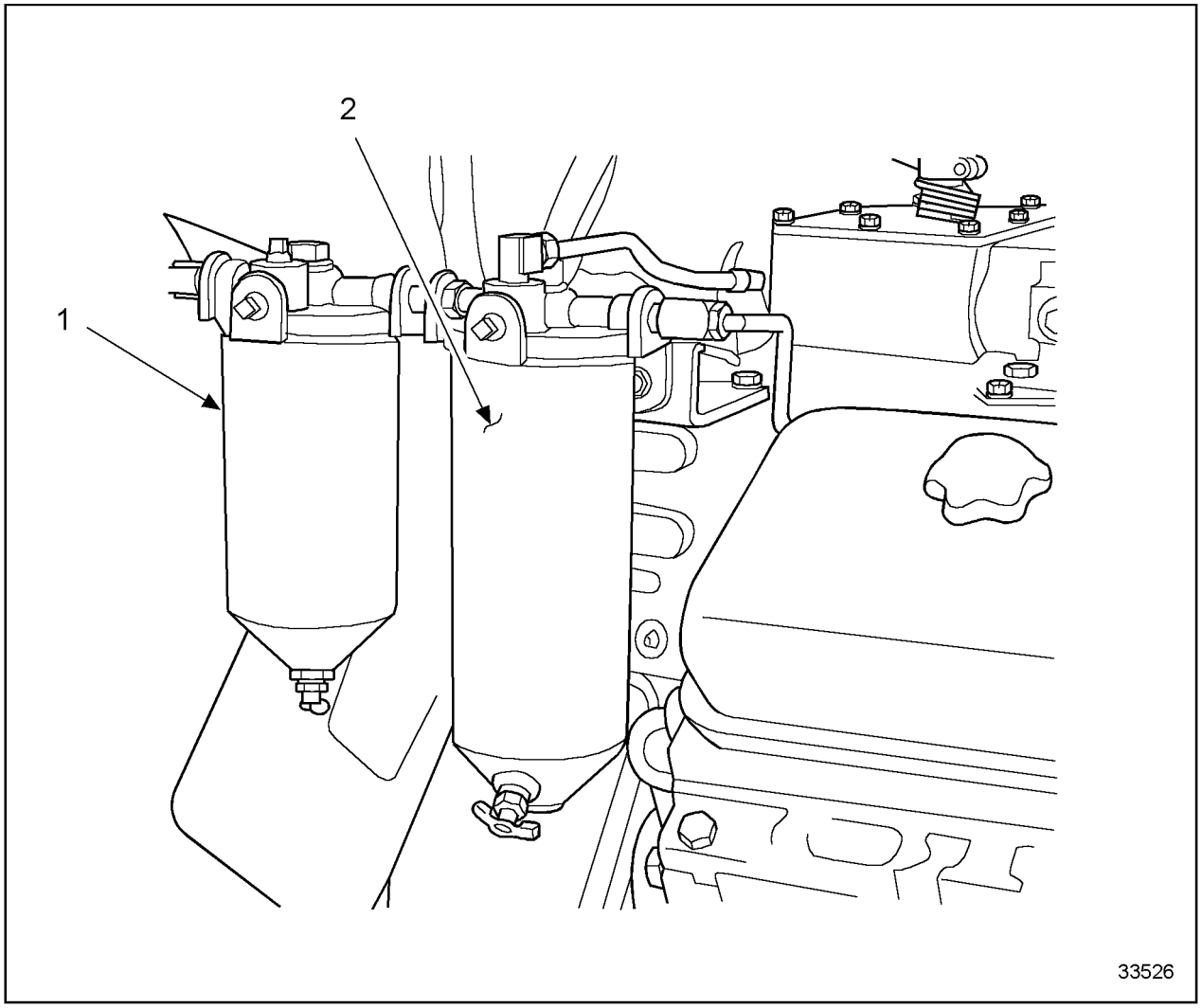
2. Clean the filter adaptor with a clean, lint-free cloth.
3. Fill new filters with clean engine oil.
4. Lightly coat the filter gaskets (seals) with clean engine oil.
5. Start the new filters on the adaptor, and hand tighten until the gaskets touch the mounting adaptor head. Tighten full flow filters and additional 2/3 turn.

6. Add oil as required to bring the level to the "full" mark on the dipstick.
7. Start and run the engine for a short period (at least five minutes), and check for leaks.
8. After leaks have been corrected, stop the engine long enough for the oil to drain back to the crankcase (approximately five minutes).
9. Add oil as required to bring the level to the proper mark on the dipstick.

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13.8 FUEL STRAINER AND FILTER

Replace elements immediately if plugging is indicated, regardless of mileage or hour intervals. Refer to section 5.3.2.7 for filter recommendations. See Figure 13-1.



1. Fuel Strainer
2. Fuel Filter

Figure 13-1 Fuel Filter Elements

Fuel pressure at the cylinder head fuel inlet fitting and the inlet restriction at the fuel pump determines the extent to which the filters are plugged.

- In a clean system, the maximum pump inlet restriction should not exceed 20.3 kPa (6 in. Hg.)
- In a dirty system the maximum pump inlet restriction should not exceed 41 kPa (12 in. Hg).
- On 6V and 8V non-turbocharged engines, at normal operating speeds and with 2.03 mm (0.080 in.) restriction fittings, the fuel pressure is 310-483 kPa (45-70 lb/in.^{2}).

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- ☐ With 12V and 16V non-turbocharged engines at normal operating speeds and with 1.78 mm (0.070 in.) restriction fittings, the fuel pressure is 207-448 kPa (30-65 lb/in.^{2}).
- ☐ On turbocharged engines at normal operating speeds and with either 2.02 mm or 1.78 mm (0.080 in. or 0.070 in.) restriction fittings, the fuel pressure is 345-483 kPa (50-70 lb/in.^{2}).

NOTE:
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 falls to the minimum fuel pressure.

Spin-on type primary and secondary fuel filters are used on these 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.

13.8.1 Installation of Spin-On Type Filters

Install 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.

NOTE:
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. Rotate an additional one-half turn by hand.
6. Turn the handle on the shut-off valve to the open position (in line with the valve).

NOTE:
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.

7. Start the engine, and check for leaks.

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NOTICE:
Never use the starting motor and fuel pump to prime the fuel filters. This could damage the starter and fuel pump.

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 prime the system.

13.8.2 Installation of Fuel/Water Separator

Install fuel/water separator as follows:

1. Open the drain valve to drain off some fuel.
2. Use a strap wrench to remove the element and bowl together. Turn counterclockwise.
3. Remove the bowl form the element.
4. Clean the bowl and O-ring seal.

NOTICE:
To avoid damaging the bowl or the filter, do not use tools when tightening.

5. Apply a light coat of clean fuel oil or grease to the O-ring seal.
6. Spin the bowl onto the new filter, and hand tighten.
7. Apply a light coat of clean fuel or grease to the new O-ring seal on the top of the filter.
8. Spin the filter and bowl assembly onto the filter head. Hand tighten until snug.
9. To eliminate air form the filter, operate the primer pump on the filter head, if equipped, until the fuel purges at the filter assembly.
10. Start the engine, and check for leaks. Correct any leaks with the engine off.

13.8.3 Installation of Fuel Pro 380 Filter

Install a new *"Fuel Pro*" 380 filter element when the fuel level in the see-through cover reaches the top of the element or after one year of service, whichever comes first.

NOTE:
Filter change intervals may be shortened to conform with established preventive maintenance schedules, but should never be extended.

13.9 FUEL TANK

Maintain the fuel tank as follows:

CAUTION:

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

- ☐ Keep the fuel tank filled to reduce condensation to a minimum.

NOTE:
Refill the tank at the end of each days operation.

- ☐ 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 48,000 km (30,000 miles) or (300 hours for industrial applications) to drain off any water and/or sediment.
- ☐ Every 12 months or 192,000 km (120,000 miles) or (600 hours for industrial applications) tighten all fuel tank mountings and brackets.

NOTICE:

Do not use galvanized steel or sheet metal tanks and galvanized pipes or fittings in any diesel fuel storage, delivery, or fuel system. The fuel oil will react chemically with the zinc coating, forming a compound which can clog fuel filters causing damage to the fuel pump and injectors.

- ☐ 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.

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13.10 FUEL CONTAMINATION

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system and promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps, contaminated fuel supply, or condensation).

Condensation is prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Mix isopropyl alcohol (dry gas) into the fuel oil at a ratio of 0.5 liter (1 pint) per 473 liters (125 gallons) fuel (or 0.10 by volume) to control water accumulation.

Marine units in storage are particularly susceptible to microbe growth. The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commercially available biocides. The two basic types on the market are as follows:

- 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. This benefits the entire fuel system.Add the biocide according to the manufacturer's instructions to treat marring units, or any other application, going into storage. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals, and stir with a clean rod.

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13.11 FUEL LINES AND FLEXIBLE HOSES

Make a visual check for fuel leaks at all engine mounted fuel lines, connections, and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, check for fuel under the tanks to best detect leaks in this area.

The engine and auxiliary equipment performance is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant, and fuel oil. Diligent hose maintenance is an important step in ensuring efficient, economical, and safe engine and related equipment operation.

13.11.1 Inspection of Hoses

Inspect hoses as follows:

NOTICE:
Investigate leaks immediately to determine if fittings have loosened or cracked or if hoses have ruptured or worn through. Take corrective action immediately. Leaks are potentially detrimental to machine operation.

1. Check hoses daily as part of the prestart up inspection.
2. Examine hoses for leaks, and check all fittings, clamps, and ties carefully.
   [a] If damaged or worn, replace the hoses, fittings, clamps, or ties. Refer to section 2.21.2.
   [b] If no damage is found, continue maintenance check.
3. Ensure hoses are not resting on or touching shafts, couplings, heated surfaces, including exhaust manifolds, any sharp edges, or other obvious hazardous areas. If hoses are in a hazardous position, relocate them.
4. 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. Tighten or replace them, as necessary.Service life is determined by the following:
   - Air or fluid temperature and pressure within a hose
   - Time in service
   - Mounting
   - Ambient temperatures
   - Amount of flexing and vibrating

   All hoses should be thoroughly inspected at least every 500 operating hours. (1,000 hours for the fire-resistant fuel and lube hoses and heat-insulating turbo/exhaust system blanket) and/or annually.

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⚠ CAUTION:

To avoid injury from fire, contain and eliminate leaks of flammable fluids as they occur. Failure to eliminate leaks could result in fire.

5. Look for cover damage or damaged, twisted, worn, crimped, brittle, cracked, or leaking lines.

   [a] Replace hoses having the outer cover worn through or damaged metal reinforcement. Refer to section 2.21.2.

   [b] If no damage is found, maintenance check is complete.

NOTE:
All hoses in or out of machinery should be replaced during major overhaul and/or after a maximum of five years service.

NOTE:
Replace all cooling system hoses in *pleasure craft marine engines* after 1,000 hours of service, regardless of apparent condition. Cooling system hoses on *commercial marine engines* do not require automatic replacement after 1,000 hours, but should be replaced at overhaul.

Fire resistant fuel and lube oil hose assemblies do not require automatic replacement after five years service or at major overhaul, but should be inspected carefully before being put back into service. Replace if warn, damaged, leaking or brittle.

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13.12 COOLING SYSTEM

The basic engine cooling system capacity, (cylinder block, cylinder heads, water manifolds, thermostat housings and oil cooler housing) is listed in Table 13-3. These quantities do not include the capacity of the radiator, hoses, or related equipment.

Engine	Cooling System Capacity Gallons	Cooling System Capacity Liters
6V-92, T, TT	6	22.7
6V-92TA, TTA	6-1/8	23.2
8V-92T, TT	7	26.5
8V-92TA, TTA	7-1/4	27.4
12V-92, T	12	45.4
16V-92, T	14-1/2	54.9
16V-92TA	15	56.8
Engine	**After Cooler Capacity**	**After Cooler Capacity**
6V-92TA	0.169	0.64
8V-92TA	0.251	0.95
16V-92TA	0.502	1.90

Table 13-3 Cooling System Capacity

Observe the following caution before checking coolant level.

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).

Check the coolant level daily. Ensure it is within 50 mm (2 in.) of the filler neck or vehicle manufacturer recommendation. Add coolant, as necessary. Do not overfill.

Check for coolant accumulation beneath the vehicle during periods when the engine is running and when the engine is stopped.

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Make a visual check for cooling system leaks. See Figure 13-2.

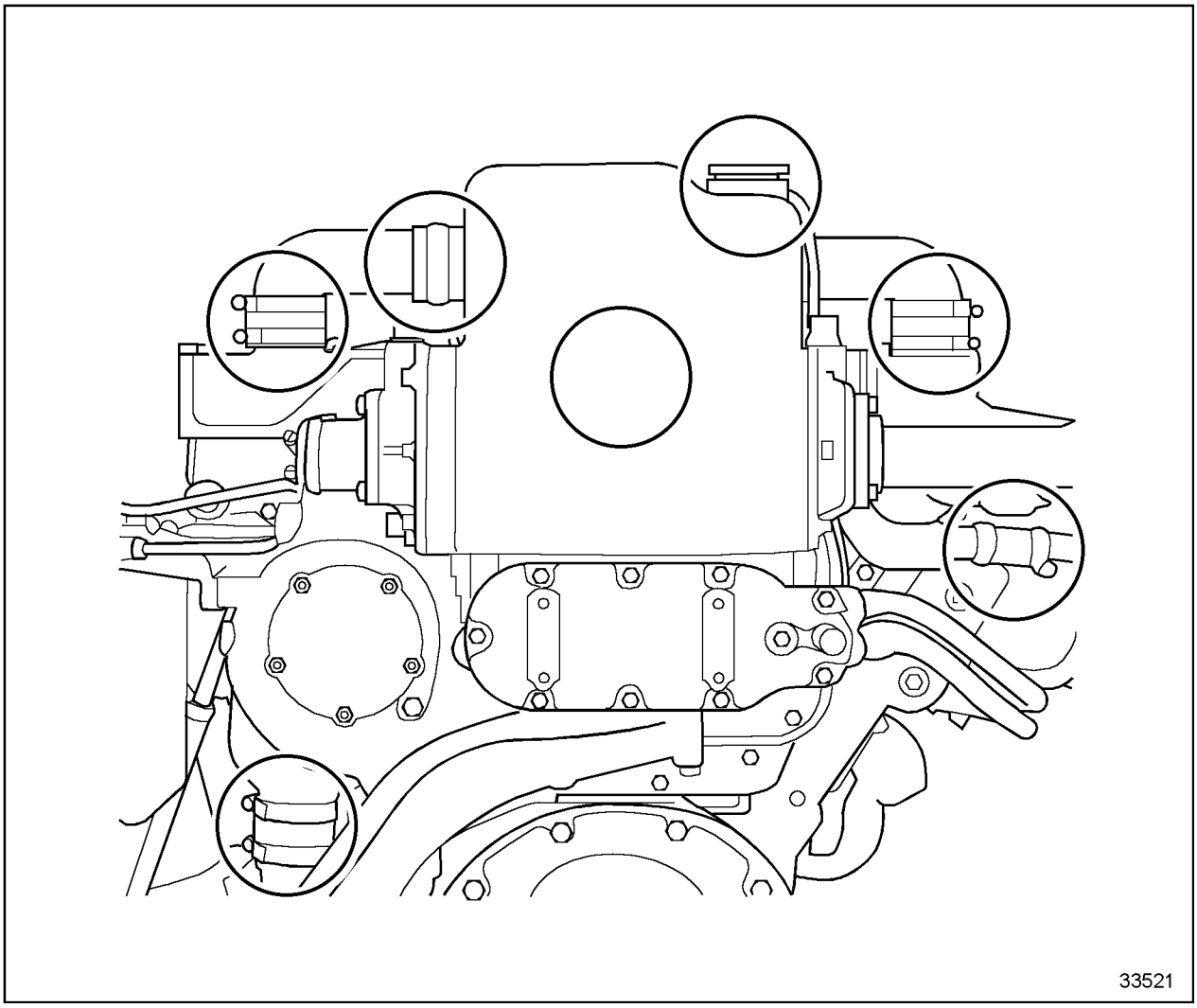


Figure 13-2 Visual Check for Cooling System Leaks

NOTE:
In order to ensure the integrity of the cooling system, DDC recommends that a periodic cooling system pressure check be performed. Refer to section 13.12.1.

13.12.1 Pressure Check

Perform a pressure check as follows:

1. Pressurize the cooling system to 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}).

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2. Any measurable drop in pressure may indicate an external/internal leak.

NOTE:
Whenever the oil pan is removed, the cooling system should be pressure checked to identify any internal coolant system leaks.

13.12.2 Fill Engine Coolant

Fill the engine coolant as follows:

1. Fill the system with proper antifreeze and clean soft water mixture. Refer to section 13.12.2 and refer to section 5.3.
2. To purge air, allow the engine to warm-up without the pressure cap installed.
3. With the transmission in neutral, increase the engine speed above 1000 RPM.
4. Add coolant as required.
5. Allow engine to cool.
6. Install the pressure cap after filling the coolant level to the bottom of the radiator filler neck.

13.12.3 Drain Engine Coolant

Marine engine exhaust manifolds are cooled with the same coolant used in the engine. Whenever the engine cooling system is drained, open the exhaust manifold drain cocks.

To drain a raw water pump, loosen the cover attaching screws, and tap the cover gently to loosen it. After the water has drained, tighten the screws.

A coolant system properly maintained and protected with supplemental coolant inhibitors can be operated up to the intervals shown, listed in Table 13-4. At these intervals, drain and dispose of the coolant in an environmentally responsible manner, according to state and/or federal (EPA) recommendations. Refer to section 5.3.2.2 and use the required supplemental additives or filter/conditioner elements.

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Detroit Diesel recommends replacing coolant at the intervals listed in Table 13-4.

Coolant Type	Coolant Replacement Interval
A 50/50 mix of *POWER COOL* fully formulated Inhibited ethylene glycol antifreeze and water or a 50/50 mix of fully formulated inhibited propylene glycol antifreeze and water.	With proper maintenance*, coolant can be operated 2 years, 320,000 km (200,000 miles), or 4,000 hours, whichever comes first. At this time the cooling system must be completely drained and cleaned before refill.
A 50/50 mix of phosphate-free TMC RP-329 "Type A" (ethylene glycol) or TMC RP-330 "Type A" (propylene glycol) antifreeze and water.	With proper maintenance, coolant can be operated for the life of the engine until overhaul. †At this time the cooling system must be completely drained and cleaned before refill.
A 50/50 mix of NOAT (Nitrited Organic Acid Technology) coolant and water.	With proper maintenance, coolant can be operated 6 years, 960,000 km (600,000 miles), or 8,000 operating hours, whichever comes first. ‡At this time the cooling system must be completely drained and cleaned before refill.

* Proper maintenance involves periodic evaluation using Power Trac 3-Way Coolant Test Strips and the addition of required SCA, as indicated by the test strip.

†To verify coolant acceptability, submit a sample to DDC for coolant analysis every 3 years, 480,000 km (300,000 miles), or 6,000 operating hours, whichever comes first. Submit sample in Power Trac Coolant Test Bottle, part number 23508774.

‡NOAT coolants require the addition of an extender every 200, 000 miles or 4,000 hours. Use 1 pint to 20 gallons of NOAT coolant.

Table 13-4 Coolant Drain Interval

The following pertain to *marine* engines:

- *Raw Water Cooling System:* Drain at the end of each boating season.
- *Sea Strainers:*Inspect sea strainers daily. Clean sea strainers at least annually. Clean more often if surface seaweed growth or water contamination levels are fairly high.

Drain the engine coolant 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. Allow engine to cool.
2. Remove the drain plugs at the top of the thermostat housing and bottom of the oil cooler housing.
3. Remove the radiator pressure cap.
4. Open the valve at the bottom of the radiator.

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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. Refer to section 5.3 and refer to section 13.12.2.
8. To purge air, allow the engine to warm-up without the pressure cap installed.
9. With the transmission in neutral, increase the engine speed above 1000 RPM.
10. Add coolant as required.
11. Allow engine to cool.
12. Install the pressure cap after filling the coolant lever to the bottom of the radiator filler neck.

13.12.3.1 Cleaning of Cooling System

Clean the cooling system as follows:

1. Clean the cooling system annually (vehicle engines) or every 1,000 hours or 48,000 km (30,000 miles) (non-vehicle engines) using a good radiator cleaning compound in accordance with the instructions on the container.
2. Rinse the cooling system with fresh water.
3. Fill the system with soft water, and add a good grade of rust inhibitor or an ethylene glycol base antifreeze. Refer to section 5.3 and refer to section 13.12.

13.12.3.2 Inspection of Cooling System Hoses

Inspect the cooling system hoses as follows:

1. Inspect all cooling system hoses once every 500 hours to ensure the clamps are tight and properly seated on the hoses. Inspect for deterioration.
   [a] If hoses are deteriorated, replace. Refer to OEM maintenance guidelines.
   [b] If clamps are not properly seated, replace clamps. Refer to OEM maintenance guidelines.
   [c] If hoses and clamps are in good condition, continue maintenance inspection.

NOTE:
Should a daily coolant loss occur, and there are no apparent leaks, gases may be leaking past the cylinder head water seal rings into the cooling system. Refer to section 13.12.3.3.

All hoses in and out of machinery should be replaced during major overhaul and/or after a maximum of five years of service.

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13.12.3.3 Test For Air or Gases in Cooling System

Perform the following procedure to detect air or gases in the cooling system:

1. Connect a rubber tube between the overflow pipe and a container of water to detect air or gases in the cooling system.

NOTE:
Water bubbling in the container during engine operation indicates leakage.

NOTE:
Another method for observing air in the cooling system is inserting a transparent tube in the engine coolant outlet line.

13.12.4 Flush Contaminated Cooling System

Coolant Contaminants may be flushed from the engine systems as follows:

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following flushing procedure is recommended.

1. Drain the coolant from the engine. Refer to section 13.5.2.

NOTICE:
If the engine is hot, fill slowly to prevent rapid cooling and engine casting distortion.

2. Prepare a mixture of Calgon, or equivalent detergent, and water at the rate of two ounces (dry measure) to one gallon of water.
3. Remove the engine thermostats to permit the Calgon and water mixture to circulate through the engine and the radiator or heat exchanger. Refer to section 4.5.2.
4. Fill the cooling system with the Calgon solution.
5. Run the engine for five minutes.
6. Drain the cooling system. Refer to section 13.12.3.
7. Repeatedly flush the cooling system.
8. Fill the cooling system with clean water.
9. Run the engine for five minutes.
10. Drain the cooling system completely.
11. Install the engine thermostats. Refer to section 4.5.3.
12. Close all of the drains, and refill the cooling system with fresh coolant. Refer to section 13.12.2.After the engine and radiator have been thoroughly cleaned, they should be reversed flushed. Refer to section 13.12.5.

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13.12.5 Reverse Flush Cooling System

The radiator and engine are reverse flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through the pump. Reverse flushing is accomplished with hot water, under air pressure, forced through the cooling system in a direction opposite to the normal coolant flow, loosening and forcing scale deposits out.

Reverse flush the radiator as follows:

1. Remove the water pump, refer to section 4.2.
2. Remove the radiator inlet and outlet hoses, and replace the radiator cap.
3. Attach a hose to the top of the radiator.
4. Attach a hose to the bottom of the radiator, and insert the flushing gun in the hose.
5. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.

⚠ 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:

Apply air gradually. Do not exert more than 207 kPa (30 lb/in.^{2}) air pressure. Too great a pressure may rupture a radiator tube.

6. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between air blasts.
7. Continue flushing until only clean water is expelled from the radiator.

13.12.6 Reverse Flush Cylinder Block and Cylinder Head Water Passages

Reverse flush cylinder block and cylinder head water passages as follows:

1. Remove the thermostats and the water pump. Refer to section 4.2 and refer to section 4.5.2.
2. Attach a hose to the cylinder block water inlet.
3. Attach a hose to the water outlet at top of the engine, and insert the flushing gun in the hose.

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⚠ 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:

Apply air gradually. Do not exert more than 207 kPa (30 lb/in.^{2}) air pressure. Too great a pressure may rupture a radiator tube.

4. Turn on the water and when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between air blasts.
5. Continue flushing until the water from the engine runs clean.

NOTE:
If scale deposits in the radiator cannot be removed with chemical cleaners or reverse flushing, remove the upper tank, and ream the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

In addition to the above cleaning procedures, the other cooling system components should be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats, and radiator pressure cap should be checked and replaced if defective.

When water connection seals and hoses are installed, ensure the connecting parts are properly aligned, and the seal or hose is in its proper position before tightening the clamps.

NOTICE:

In order to assure the integrity of the cooling system, DDC recommends a periodic cooling system pressure check. 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 for coolant leaks.

The fan belts must be checked and adjusted if necessary, to provide proper tension. The fan shroud must be tight against the radiator core to prevent air recirculation, which may lower the cooling efficiency.

When the engine cooling or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination is a cracked oil cooler core. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating, and when it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines when the cooling system is filled with an ethylene glycol antifreeze solution. When mixed with the oil in the crankcase, this antifreeze forms a varnish which can cause the engine to seize or result in severe bearing wear.

Make certain that the cause of the internal coolant leak has been corrected before flushing the contaminated system(s).

13.12.7 Low Coolant Level Sensor

Test the low coolant level sensor as follows:

1. Allow engine to cool to an ambient temperature.

⚠ 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. Drain the cooling system below the sensor level.
3. Test for a "check engine" light.
   [a] If the light comes on, the sensor is working properly.
   [b] If the light fails to come on, replace the sensor. Refer to section 2.16.2.

13.12.8 Winterfronts

Blocking the radiator is done to increase the cab heat level and improve driver/passenger comfort during severe cold weather operation. This practice is normally not necessary with a properly designed and operating cooling/heater system. Preventing air leakage and reducing exposed metal surfaces in the driver/passenger compartment, plus the use of properly installed shutters, can greatly improve the comfort level.

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NOTICE:
The heat-dissipating capacity of the engine cooling systems and related components must be sufficient to prevent the coolant temperature from rising above 99°C (210°F). This temperature must not be exceeded under any engine operating condition, regardless of altitude, type of coolant used, or cooling system condition. Exceeding this limit can result in malfunction or serious engine damage.

NOTICE:
Winterfronts (cardboard, canvas, etc.) are not recommended with any DDC engine installation. Their use can result in excessive engine coolant, oil, and charge air temperatures. This can lead to turbocharger surge, poor fuel economy, power loss, and reduced engine life. Winterfronts may put abnormal stress on fan and fan drive components, creating the potential for premature malfunction and/or damage.

If winterfronts are used, they should never totally close off the grill frontal area. At least a 25% symmetrical area in the center of the grill should remain open at all times. At no time should the air blockage device be applied directly to the radiator core. The only exception to this is an approved shutter system.

The user should run qualification tests to determine the minimum frontal opening area required. The following is some factors that must be considered:

- ☐ Fluctuations in Ambient Air Temperatures and Load
- ☐ Ice and Snow Intrusion
- ☐ Wind Conditions
- ☐ Vehicle Speed
- ☐ Cooling System Degradation
- ☐ Fuel Economy Loss with Air-to-Air Charge Cooling

Under no conditions should engine specification limits be exceeded. All warning and monitoring devices should be properly located and in good working condition.

All vehicle operators must be given notice to adjust and/or remove winterfronts as conditions warrant to ensure proper engine operation. This is especially important on air-to-air charge cooling systems. Elevated charge air cooling temperatures cause turbocharger surging and fuel economy loss.

Operators must minimize winterfront usage. If used, the grill opening should be restricted only enough to maintain cab heat. Do not restrict the opening so much that the elevated temperature turns on the fan.

These engines are designed to operate with 77°C (170°F) or 82°C (180°F) thermostats which, combined with a radiator or heat exchanger, regulate coolant temperature within a range of 77-86°C (170-187°F) or 82-92°C (180-197°F). Many engines use radiator shutters, clutch fans, or combinations of both to help control coolant temperature. These "add on" cooling system components must operate in proper sequence to prevent coolant temperature instability and/or engine overheating.

A badly adjusted operating sequence can have a detrimental effect on the life of the "add on" components.

NOTICE:
The following charts give the recommended normal temperature settings for various coolant temperature control devices. These settings should not be exceeded, since this will increase the engine coolant and lubricating oil temperature, possibly resulting in serious engine damage. See Figure 13-3 and see Figure 13-4.

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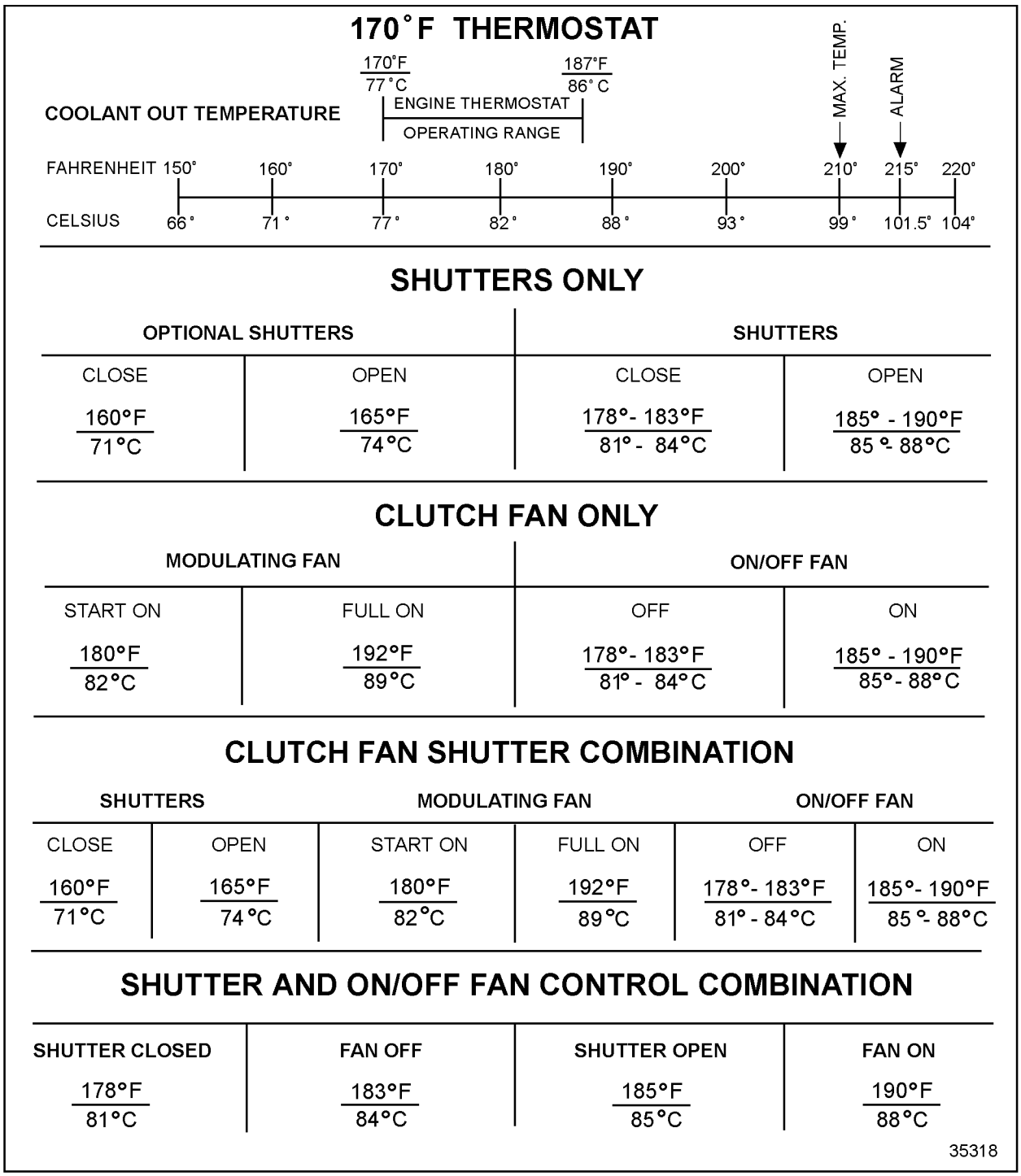


Figure 13-3 Recommended Settings for Coolant Temperature Control Devices (1 of 2)

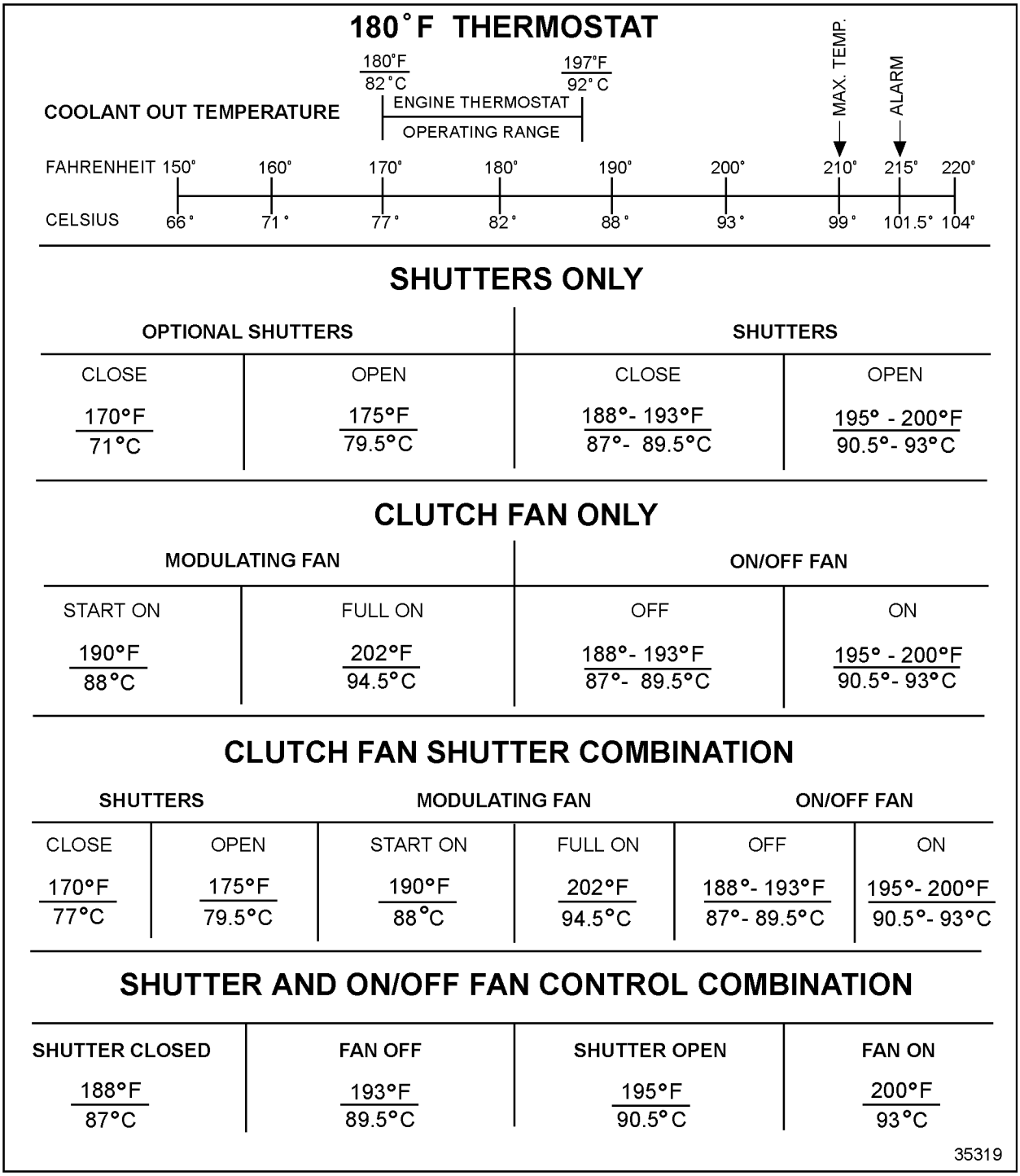


Figure 13-4 Recommended Settings for Coolant Temperature Control Devices (2 of 2)

NOTE:
Coolant temperature instability will result from improper component operating sequence.

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13.13 WATER PUMP

Inspect the water pump as follows:

1. Inspect the water pump drain hole every 600 hours for plugging.
   [a] If plugged, clean the drain hole.
   [b] If drain hole is not plugged, continue maintenance inspection.
2. Inspect the water pump seal for coolant leakage.
   [a] Replace the water pump seal at engine overhaul or earlier, if leaking is found.
   [b] If coolant does not leak from the drain hole under normal operating conditions, do not replace the water pump.

   Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine, and check for leaks.

13.14 COOLANT FILTER

Replace the chemically activated element, following the manufacturer's recommended change periods. The lower corrosion resistor plate (if used) must be buffed each time (discard the plate if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of approximately 200 hours or 6,000 miles, or less to clean up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these change intervals. Refer to section 13.12.3.

Make-up water up to 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

NOTE:
Sea water must never be used for make-up water in a marine engine, except under emergency conditions. If it is necessary to use sea water, the cooling system must be completely drained and flushed with fresh water upon reaching port. The filter element must be changed. Filters with resistor plates must be inspected for pitting. Presence of salt in the coolant results in rapid pitting of the resistor plates.

If it is necessary for any reason to drain the cooling system before an element changes, the treated water should be saved and used again. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

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13.15 COOLANT FILTER/INHIBITOR PRECHARGE ELEMENT

Precharge elements provide the engine with the proper charge of required inhibitors and water softeners at initial fill.

NOTICE:
The element included in each kit will properly precharge the engine cooling system. To avoid over inhibiting the engine coolant when the precharge element is installed, do not use coolant having supplemental coolant inhibitors in the base formulation or any other coolant additives.

NOTICE:
To ensure proper inhibitor strength, the precharge element must be replaced with a maintenance element after 15,000 miles or 150 hours of operation, whichever comes first. A new precharge element must be installed whenever the engine coolant is changed.

Precharge elements can be operated for up to 150 hours or (15,000 miles), whichever comes first. At this point, the element must be removed and replaced with a Detroit Diesel Maintenance Product maintenance element. Refer to section ADDITIONAL INFORMATION.

Replace element 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. With the engine cool, relieve cooling system pressure by carefully loosening the radiator or heat exchanger pressure control cap.
2. Close both shutoff valves on the adaptor head by moving the handles at right angles to the valves.
3. Remove the element from the adaptor head. Dispose of the element in an environmentally responsible manner.
4. Lubricate the seal on a new element with clean engine coolant.
5. Install the element onto the adaptor head, following instructions printed on the element or element package.
6. Open both shutoff valves on the adaptor head by moving the handles in line with the valves.

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7. Start the engine and check for leaks.

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13.16 RADIATOR

Maintain the radiator as follows:

1. Inspect the exterior of the radiator 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.

2. Clean, if necessary, with a quality grease solvent, such as mineral spirits, and dry with compressed air.

NOTE:
It may be necessary to clean the radiator more frequently if the engine is operated in extremely dusty or dirty areas.

NOTE:
Do not use fuel oil, or kerosene to clean radiator, this would cause an abnormal build-up of dirt or dust.

3. Refer to OEM maintenance guidelines.

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13.17 TURBOCHARGER AND EXHAUST CONNECTIONS

Inadequate air filtering and excessive restrictions in air and exhaust flows will adversely affect turbocharger life and performance. Do not permit restriction levels to exceed specified limits. Refer to section 11.5.

The turbocharger should be periodically inspected as follows:

Inspect the turbocharger with compressor inlet screen J 26554-A installed as follows:

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 from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

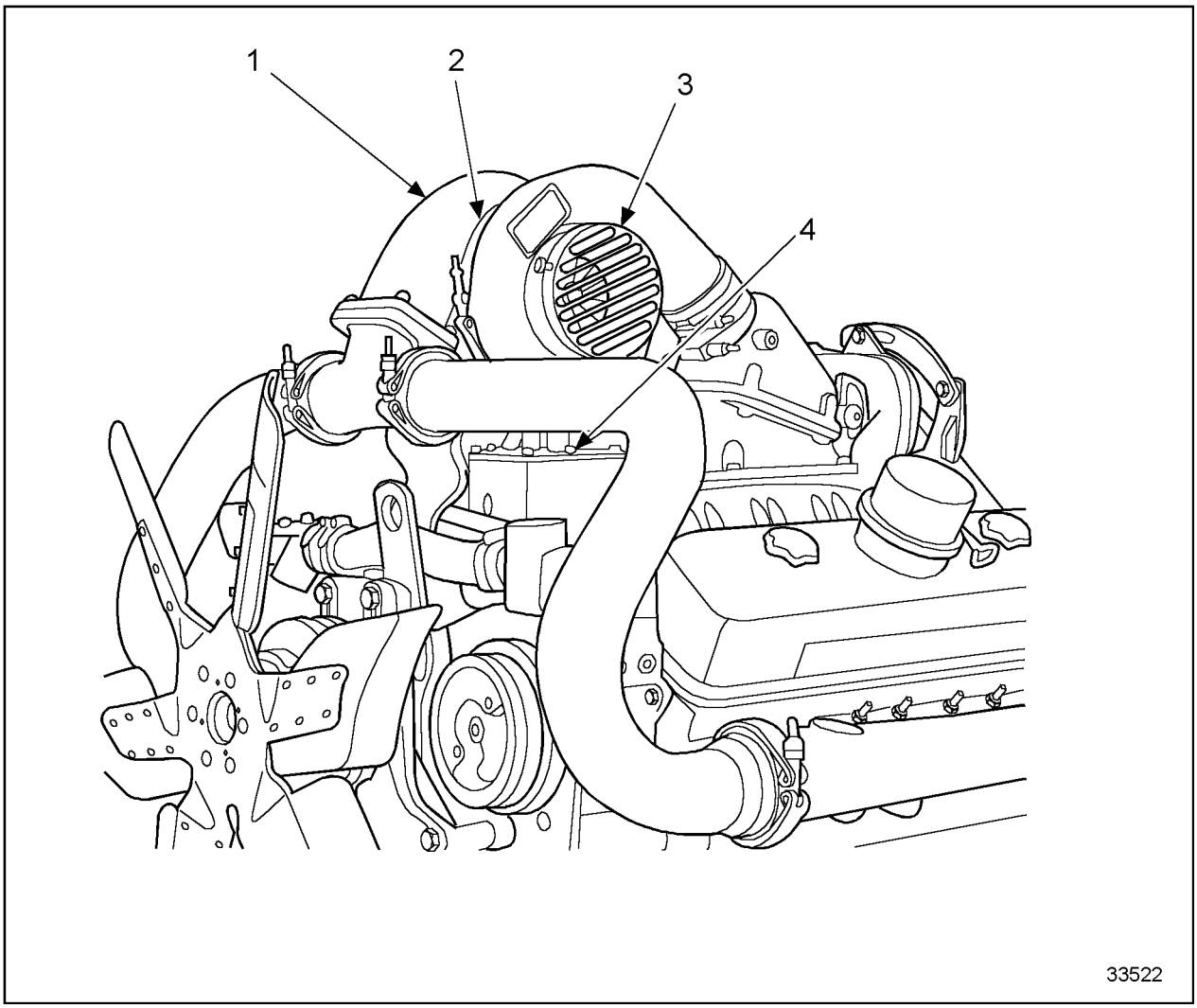
NOTICE:

Do not operate the engine if leaks are found in the turbocharger ducting, or if the air cleaner is not filtering effectively. Dust entering the air ducting can damage the turbocharger and the engine.

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1. Inspect the mountings, intake and exhaust ducting, and connections for leaks daily. See Figure 13-5.

NOTE:
Inspect with the engine running and with it shut down.



1. Turbine Housing
2. Clamp
3. Inlet Screen
4. Mounting

Figure 13-5 Turbocharger Assembly

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NOTICE:

Do not attempt to remove carbon or dirt build-up on the compressor or turbine wheels without first removing the turbocharger from the engine. Turbine wheel blades must be thoroughly cleaned. Deposits on the blades can affect balance and cause premature bearing failure.

⚠ 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.

2. Remove the inlet duct to the turbocharger compressor housing, and check for carbon or dirt build-up on the impeller or in the housing. Excessive accumulations indicate either a ducting leak or a faulty filtering system. Remove all accumulations.
3. With the exhaust ducting removed, spin the turbine wheel by hand. For proper operation, the turbocharger rotating assembly must turn freely.
4. Inspect the compressor and turbine wheels for nicks or material loss. Both wheels are precision balanced. A broken or bent blade can unbalance the rotating assembly and shorten turbocharger life.
5. Inspect oil inlet and return lines to ensure that connections are tight and lines are not dented or looped. Looped oil lines restrict gravity flow of the oil to the engine.
6. Ensure oil inlet lines are filled with oil and clear of the turbine housings.
7. Check the turbocharger housing for evidence of oil leaks.

NOTE:
Lubricant applied under pressure to the center housing while the shaft is not turning may allow oil to enter the turbine and compressor housings. After the turbocharger has been operated under load conditions with normal inlet restrictions, oil should disappear.

8. Check the air cleaner element. A dirty element, or one that is too small, could create excessive airflow and oil pull-over.
9. Oil in the inlet or outlet ducts or dripping from either housing indicates a seal problem that requires turbocharger overhaul. Refer to section 6.6.2.

Tests indicate that three conditions contribute to internal turbocharger oil seal leaks:

1. A worn or defective seal.
2. Air inlet restriction above specified limits.
3. Long periods of operation with the engine being motored (used as a braking device while traveling downhill).

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Perform the following to confirm oil leaks from one or more of these conditions:

1. Remove the compressor housing, and inspect the backplate for oil.

   [a] If the surface is wet with oil, this indicates leakage. Replace compressor Refer to section ADDITIONAL INFORMATION.

   [b] If this test does not reveal leakage, the oil seal assembly is suitable for normal operation.

Use the following procedure to determine turbocharger compressor end shaft oil seal effectiveness:

1. Determine that air inlet restriction falls within the recommended maximum limit. Refer to section 11.5.
2. Ensure the turbocharger oil drain is unrestricted.
3. Ensure the turbocharger has suffered no obvious major damage.
4. Remove air intake ducting. Inspect ducting interior for oil. If oil is found in the intake system, determine its source before proceeding with the compressor seal test. Remove all oil from the intake.
5. Thoroughly clean the internal surfaces of the compressor housing, the impeller cavity, and the backplate annulus with a suitable solvent spray.

⚠ 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. Completely dry using shop air.
7. Spray the backplate annulus with a light coating of Spot-Check developer type SKD-MF, or equivalent. This surface should be completely free of oil streaks after the test.
8. If leaks are detected, and oil is **not** entering through the intake duct, the turbocharger should be removed and thoroughly inspected for damaged components. Refer to section 6.6.2.
9. If leaking, restricted, or excessively noisy and vibrating, remove the turbocharger and correct the cause. Refer to section 6.6.2.Every 12 months, 700 hours or 20,000 miles (32,000 km), the exhaust manifold retaining nuts, exhaust flange clamp and other connections should be checked for tightness. Check for proper operation of the exhaust pipe rain cap, if one is used.

   Check heat-insulating exhaust system blankets for damage daily. Torn, matted, crushed, oil-soaked, or otherwise damaged insulation blankets *must* be replaced immediately.

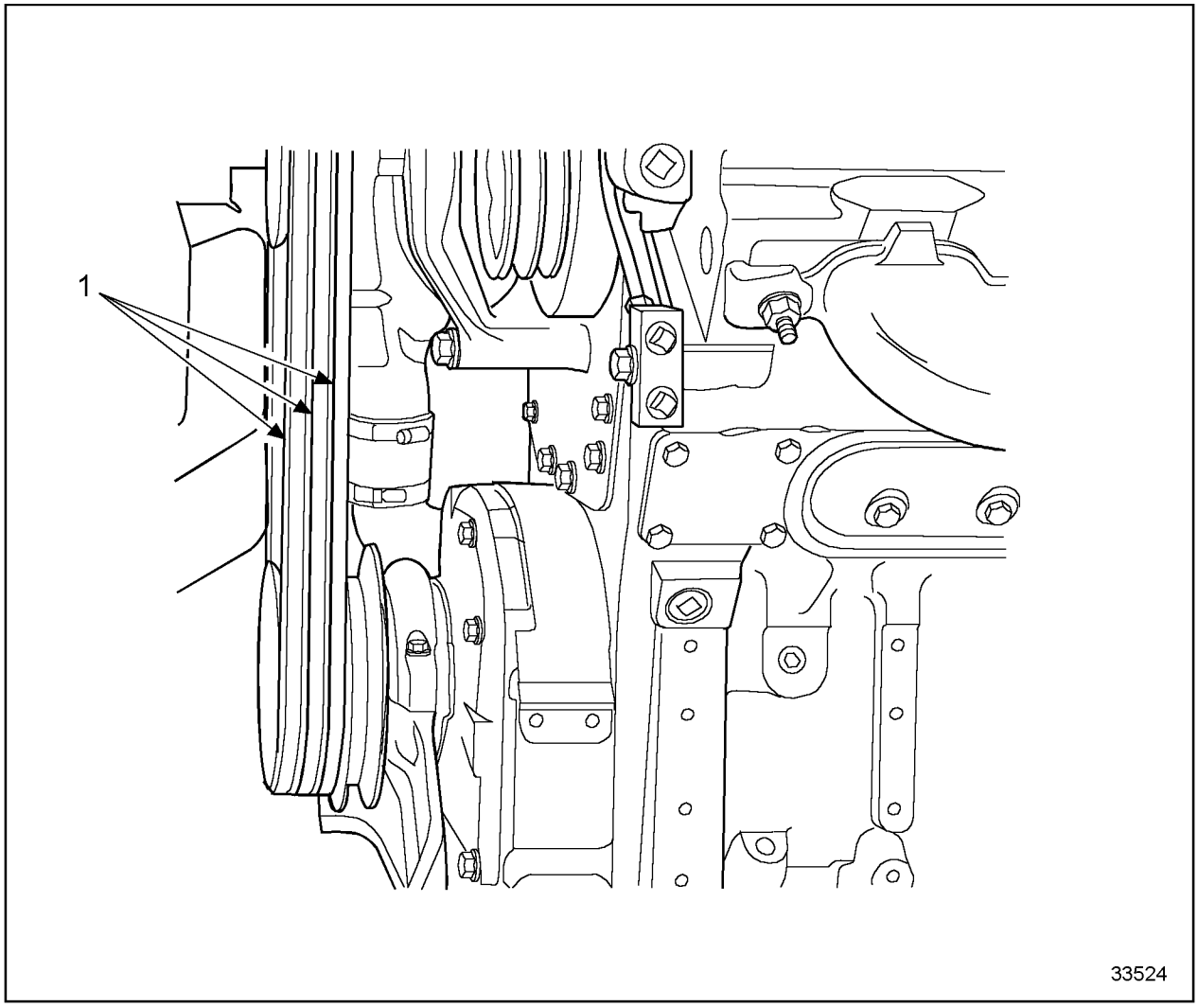
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13.18 DRIVE BELTS

New standard vee belts will stretch after the first few hours of operation.

13.18.1 Vee Belt

See Figure 13-6 for illustration of vee belt.



1. Drive Belts

Figure 13-6 Drive Belts

13.18.1.1 Adjustment of Vee Belt

Perform the following procedure for adjusting the vee belt:

1. Run the engine for 10 to 15 minutes at 1200 RPM to seat the belts.

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NOTICE:
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 break the crankshaft. Loose belts could slip, causing damage to accessory components.

NOTICE:
Similar size single belts should not be used as a substitute for a matched belt set. Premature belt wear can result from belt length variation. All belts in a matched belt set are within 0.81 mm (0.032 in) of their specified center distances.

NOTE:
Replace all belts in a set when one is worn.

2. With belt tension gage BT-3373-F, J 23586, or equivalent, adjust the belt tension as listed in Table 13-5 and listed in Table 13-6.

Engine	One Belt	2 or 3 Belts
6V, 8V	80-100 lbs	60-80 lbs
12V	-	70-90 lbs
16V	-	90-120 lbs
16V	10 Rib Poly-Vee	310-360 lbs

Air Compressor: Belt tension is 60 lbs (± 10 lbs) for a single premium high capacity belt (0.785 in. wide) used to drive a 12 CFM air compressor.

Table 13-5 Belt Tensioning Values (Fan Drive)

Two 3/8 in. or 1/2 in. Belts	One 1/2 in. Belt	8 Rib Poly-Vee Belt
40-50 lbs.	50-70 lbs.	110-130 lbs.

Air Compressor: Belt tension is 60 lbs (± 10 lbs) for a single premium high capacity belt (0.785 in. wide) used to drive a 12 CFM air compressor.

Table 13-6 Belt Tensioning Values (Alternator Drive)

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3. 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 and the bolt in the adjusting slot are properly tightened.

NOTE:
Drive belts (vee or poly-vee) should be replaced every 2,000 hours or 160,000 km (100,000 miles).

NOTE:
Pleasure craft marine belts should be replaced every 1,000 hours of operation, regardless of condition.

4. Check the belts, and tighten the fan drive, battery-charging generator or alternator, and other accessory drive belts after 1/2 hour or 24 km (15 miles).
5. Inspect them again after 8 hours or (402 km) 250 miles.
6. After the belts are broken in, check the tension every 100 hours or 12,000 km (7,500 miles). Adjust, if necessary.

13.18.2 Poly-Vee Belt

Insufficient belt tension may create a high-pitched squeal or rasping sound during engine acceleration or deceleration.

Poly-vee belts are used with the 50 DN alternator. The 50 DN alternator drive belt tension is set at 1335 N (300 lbs) during engine assembly and belt replacement. A new belt loses tension rapidly during the first few minutes of operation.

1. Check the tension after 10 minutes of operation.
2. Allow the belt to cool with the engine off for 10 to 15 minutes before measuring tension.
   [a] If the tension on the belt is greater than or equal to 890 N (200 lbs), adjusting tension is not required.
   [b] If the tension on the belt is less than 200 lbs., adjust the belt tension to 890 N (200 lbs).

Periodic tensioning on the belt is required to maximize belt life. The belt tension should be measured once per month or every 16,000 km (10,000 miles), whichever comes first.

Belt tensioning tool J 39966 is available from Detroit Diesel. The gage is calibrated from 779 to 1558 N (175 to 350 lbs.).

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13.18.2.1 Adjustment of Poly-Vee Belt

Poly-vee belts are very sensitive to under tension. Without a gage and proper tension measurement, the belt tension will probably be too low. Under tensioning wears belts rapidly and will lead to premature belt failure.

Properly use the tensioning tool as follows:

NOTICE:
To prevent gear breakage, do not let gage handle snap back after pressing it when not installed on a belt under tension.

1. Fully press the plunger on the belt gage.

NOTE:
The belt must pass between the hook and the leg pads. The hook and leg pads must support the entire belt width.

2. Use quick release on the gage handle. Read tension on the face of the gage.
3. Repeat the measurement 2 or 3 times to ensure accuracy.

NOTE:
The support legs on the gage should not contact pulleys or any other engine hardware.

NOTE:
Keep gage clean. Dirt will wear out the leg pads.

13.18.2.2 Inspection of Poly-Vee Belt

As a poly-vee belt goes through its natural life, it passes through several phases.

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After an extended time in service, minor rib cracks may appear, usually one or two cracks per inch of belt. See Figure 13-7. This condition is considered normal.

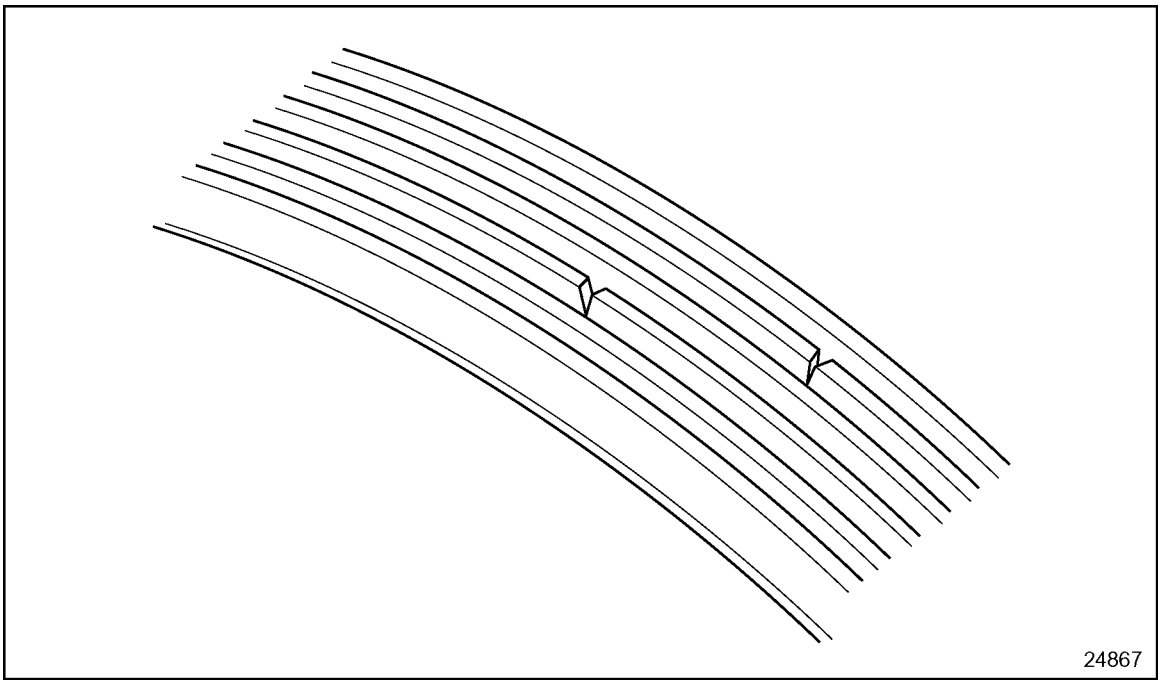


Figure 13-7 Minor Rib Cracking

Inspect for rib cracking as follows:

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1. When the belt ribs exhibit severe multiple cracking, See Figure 13-8. Replace.

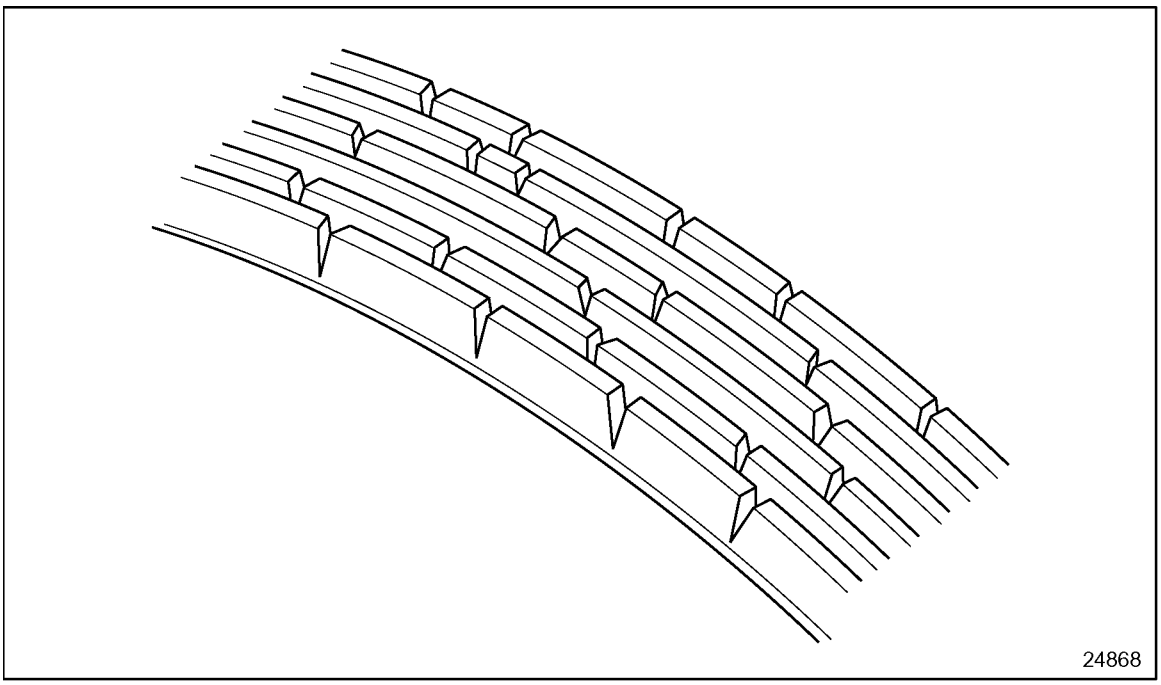


Figure 13-8 Severe Rib Cracking

- Cracking leads to "chunking" or breaking away of rib material. See Figure 13-9**.** Replace.

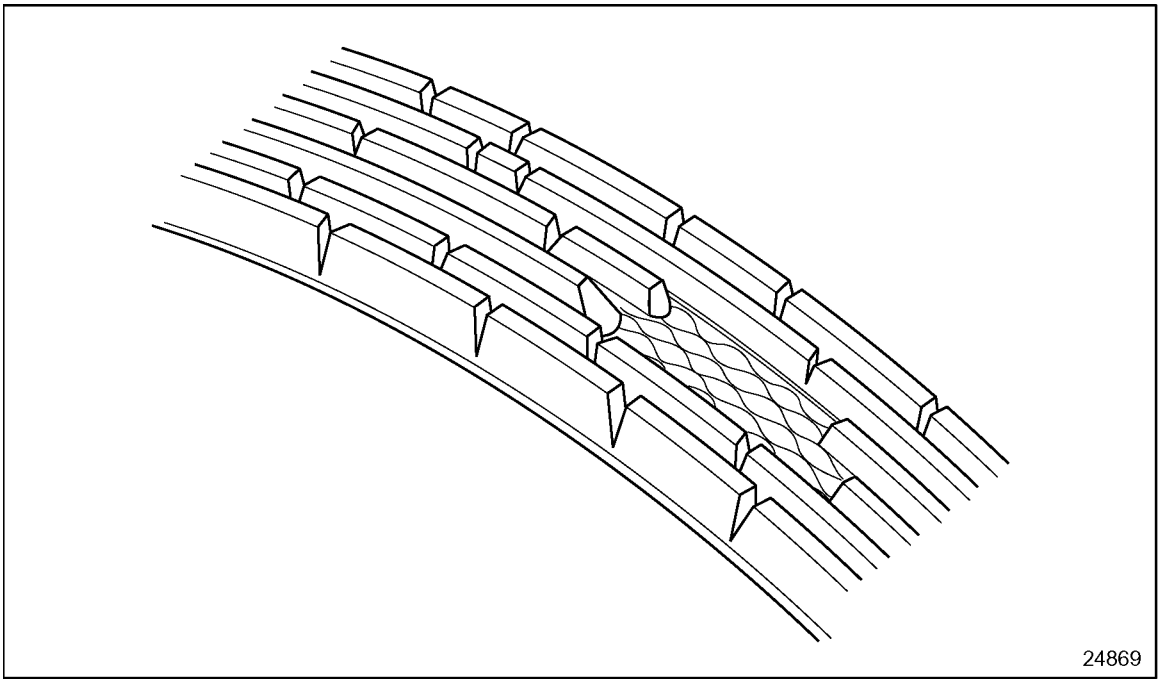


Figure 13-9 Rib Chunking

Inspect for rib sidewall glazing as follows:

2. Inspect for a shiny surface that is hard and brittle.

NOTE:
This is from belt slippage resulting from inadequate tension, extreme temperature, or both.

NOTICE:
Failure to correct the cause of *rib sidewall glazing* will result in severe cracking and failure of the poly-vee accessory drive belts.

3. If this condition occurs, locate the cause and correct it before installing a new belt.

Accelerated wear on any part of the belt fabric backing, tensile cord, or rib rubber should be investigated. Causes for accelerated wear are as follows:

- ☐ Drive misalignment - For efficient belt performance, misalignment must not exceed 1.590 mm (0.0625 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.

Inspect for foreign objects as follows:

NOTE:
If the belt contacts a foreign object, premature failure may occur.

NOTICE:
Any object protruding into the belt drive path that contacts the belt will cause belt damage and failure.

NOTE:
Prior to installing a new belt, verify removal of foreign objects protruding into the belt path.

Much effort has gone into each poly-vee belt drive design to prevent noise vibration. Field problems occasionally occur.

Causes of noise vibration are as follows:

- ☐ Misalignment - This may cause a chirping noise, especially at or near idle speed.
- ☐ Mounting - Accessories must be rigidly bracketed for acceptable free belt span vibration.

NOTE:
Some span vibration is expected during the range of engine speed and accessory loading.

- ☐ Belt tension - Insufficient belt tension may cause a high-pitched squeal or rasping sound during engine acceleration or deceleration

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13.19 BATTERY

A battery is a perishable item requiring periodic servicing. Only when the battery is properly cared can long, trouble-free service be expected.

⚠ CAUTION:

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

⚠ CAUTION:

To avoid injury from battery explosion when jump starting the engine, do not attach the cable end to the negative terminal of the disabled battery.

Inspect the battery as follows:

1. Maintenance-free type batteries.
   - On a battery equipped with a charge alternator "eye", periodically check for adequate charge.

NOTE:
If lead acid or low maintenance batteries are used, check the specific gravity of each cell every 150 hours.

- Although maintenance-free, periodically remove, check, and clean battery posts, terminals, and connections. Check connections for fraying loss of insulation coverings. Repair or replace as necessary.

NOTICE:

Do not overfill the batteries. Overfilling can cause poor performance or early battery failure.

2. On filler cap batteries, check the level of the electrolyte every 100 hours or every 12,000 km (7,500 miles).

NOTE:
In warm weather check more often since water evaporates rapidly from the electrolyte.

NOTE:
Electrolyte should be maintained according to the battery manufacturer's recommendations.

3. Periodically remove, check, and clean the battery post terminals and connections.

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⚠ 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.**

4. Replace corroded or damaged parts. Refer to section 13.19.

NOTICE:

Do not allow baking soda solution to enter the battery. Failure to observe this caution may result in damage to the battery.

- Keep the top of the battery clean. When necessary, wash with a baking soda solution, and rinse with fresh water.
- Inspect the cables, clamps, and hold-down bracket regularly. Clean and apply a coat of grease when needed. Replace corroded or damaged parts.
- Use the standard battery test as the regular service test to check the condition of the battery.

NOTE:
Many electrical problems caused by battery failures can be prevented by systematic battery service. If however, the battery becomes discharged repeatedly, check the electrical system. Refer to section 8.1.

If the engine is to be out of service for more than 30 days, remove the batteries and store in a cool, dry place. Keep batteries fully charged, if possible. Replace any battery that fails to hold a charge.

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⚠ 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.**

Periodically check battery connections for corrosion and tightness. If necessary, remove connections and wire brush any corrosion from terminals and cable ends. Replace damaged wiring.

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13.20 BATTERY CHARGING ALTERNATOR

Inspect the battery charging alternator as follows:

1. Inspect the terminals for corrosion and loose connections.
2. Inspect the wiring for frayed insulation.
3. Refer to OEM maintenance guidelines.

Precautions must be taken when working on or around the alternator. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

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⚠ 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 from accidental engine startup while servicing the engine, disconnect/disable the starting system.

⚠ CAUTION:

To avoid injury from battery explosion when jump starting the engine, do not attach the cable end to the negative terminal of the disabled battery.

NOTICE:

Alternators output wire or terminal is always hot, whether engine is running or not. Avoid grounding the output terminal. Grounding an alternator's output wire or terminal, and accidentally reversing the battery polarity will result in equipment damage.

Never disconnect the battery while the alternator is operating. Disconnecting the battery can result in damage to the alternator diodes. In marine applications which have two sets of batteries, switching from one set to the other while the engine is running will momentarily disconnect the batteries. This can result in equipment damage.

If booster battery is to be used, batteries must be connected correctly (negative to negative, positive to positive) to avoid equipment damage.

To avoid equipment damage never use a fast charger with the batteries connected or as a booster for battery output.

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13.21 ENGINE AND TRANSMISSION MOUNTS

Check the engine and transmission or marine gear mounting bolts and the condition of the mounting pads every 2,000 hours or 96,000 km (60,000 miles), whichever comes first. Tighten and/or repair as necessary.

Refer to OEM maintenance guidelines.

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13.22 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. Check the intake and exhaust valve clearances every 96,000 km (60,000 miles) for vehicle engines. Refer to section 12.2. Minor adjustments in the valve and injector operating mechanisms, governor, etc. are required periodically to compensate for normal part wear.

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13.23 BLOWER BYPASS VALVE

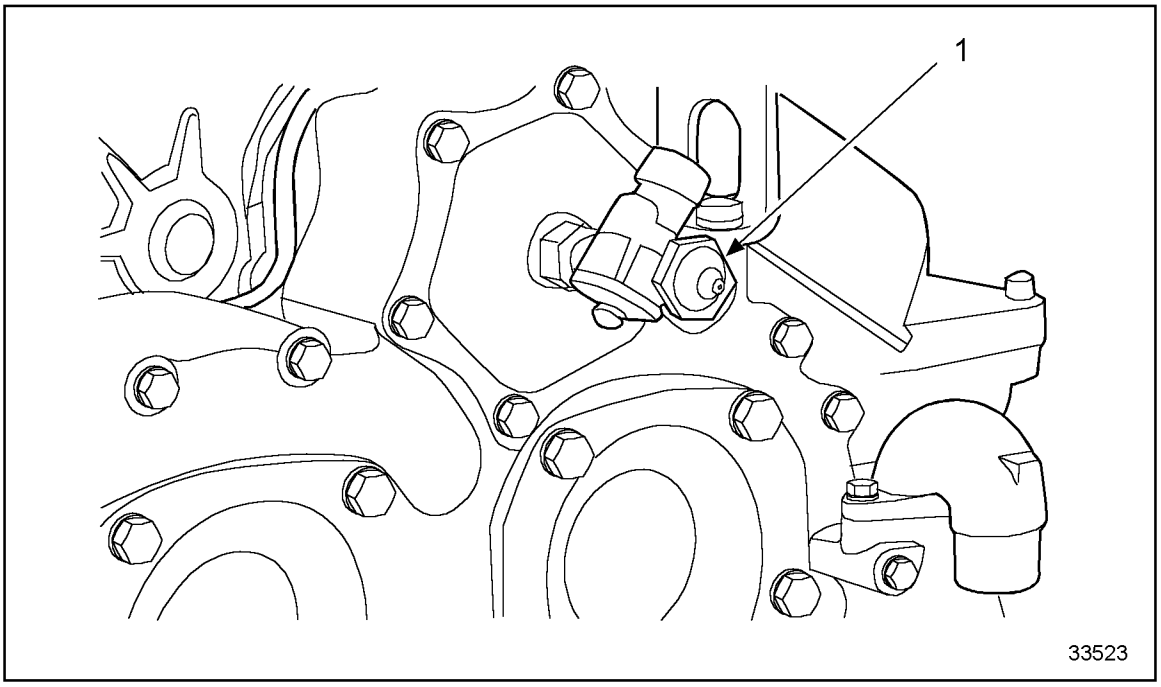
Every 160,000 km (100,000 miles) or approximately 60 months, perform the following:

1. Remove the bypass blower valve.
2. Clean it in solvent, if necessary.
3. Inspect it for free valve operation and piston, piston guide, or sleeve assembly scoring.
4. Repair or replace, as required.

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13.24 TACHOMETER DRIVE

Lubricate the tachometer drive at the grease fitting every 100 hours or 4,800 km (3,000 miles) for industrial engines and every 300 hours on marine engines with an all purpose grease. See Figure 13-10. At temperatures above -1°C (30°F), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.



1. Tachometer Drive

Figure 13-10 Tachometer Drive

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13.25 AIR COMPRESSOR

Maintain the air compressor as follows:

1. Inspect the air compressor daily for loose or damaged fittings, and coolant leaks.
2. Remove and clean all air compressor air intake parts every 150 hours for stationary and industrial, or 9,600 km (6,000 miles) for vehicle engines. Refer to section 13.25.
3. Remove and wash all polyurethane sponge strainer parts every 150 operating hours or 8,000 km (5,000 miles).
4. Clean or replace the strainer element.

NOTE:
If cleaning the strainer element, wash in a commercial solvent or a detergent and water solution.

5. Dip the element in lubricating oil, and squeeze it dry before replacing it in the strainer.

NOTE:
Ensure the air strainer gasket is replaced if the entire air strainer is removed from the compressor intake.

6. Contact the nearest servicing dealer for air strainer element replacement. Replace with the polyurethane element, if available.
7. Every 12 months or 32,000 km (20,000 miles), tighten the air compressor mounting bolts.
8. If the air compressor is belt driven, check the belts for proper tension.

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13.26 THROTTLE AND CLUTCH CONTROLS

Perform the following procedures for maintenance of throttle and clutch controls:

1. Inspect daily for loose linkage and tighten as required.
2. Every 200 hours or 9,600 km (6,000 miles) lubricate the throttle control mechanism with a No. 2 grade all purpose grease at temperatures -1°C (30°F) or above.

NOTE:
At temperatures below -1°C (30°F), use a No. 1 grade grease.

⚠ CAUTION:

To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

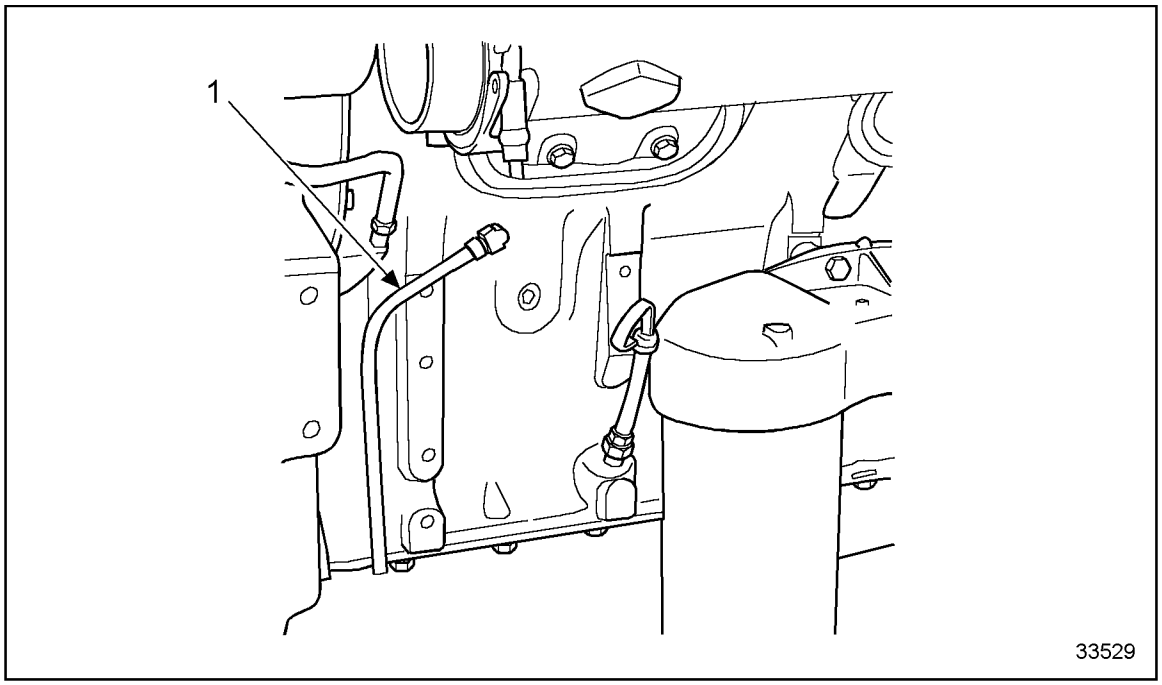
3. Lubricate all other control mechanisms, as required, with engine oil.

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13.27 AIR BOX DRAIN TUBE

Maintain the air box drain tube as follows:

1. With the engine running at idle, check for flow of air from the air box drain tube every 1,000 hours or 48,000 km (30,000 miles). See Figure 13-11.



1. Air Box Drain Tube

Figure 13-11 Air Box Drain Tube

2. If the tube is clogged, remove tube.
3. Clean the tube, and install.

NOTE:
The air box drain tube should be cleaned periodically, even if tube is not clogged.

NOTE:
If the engine is equipped with an air box drain tank, drain the sediment periodically.

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13.28 AIR BOX CHECK VALVES

Every 160,000 km (100,000 miles) or approximately 3,000 hours maintain the air box check valves as follows:

1. Remove the air box check valves.
2. Clean with solvent.

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 the lines with compressed air.
4. Inspect for air flow after servicing.

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13.29 SHUTTER OPERATION

Check the shutter operation, and clean the linkage and controls every 32.000 km (20,000 miles).

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13.30 GOVERNOR, OVERSPEED GOVERNOR

Perform the following maintenance procedures for the governor:

1. Check and record the engine idle speed and no-load speed. Adjust as necessary.

NOTE:
An idle speed lower than recommended will accelerate the engine from a speed lower than the engine certified speed.

NOTE:
A no-load speed higher than recommended will result in a full-load speed higher than rated and higher than the engine certified speed.

2. Lubricate the overspeed governor, if equipped with a hinge-type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours or 24,000 km (15,000 miles).

NOTE:
Avoid excessive lubrication and do not lubricate the governor while the engine is running.

All Synchro-Start top switch electric overspeed governors contain sealed ball bearings which have sufficient grease for their useful life, except Model GT governors. For GT units only, add Aeroshell® 7A grease (or equivalent) to the open upper shaft bearing every 2,500 operating hours. Apply grease sparingly with a hand operated low pressure gun. Grease the upper governor shaft bearing as follows:

1. Remove the governor cap.
2. Apply grease sparingly to the bearing.

NOTICE:
Do not over-grease or use a power gun. Forcing grease onto the weights and springs will damage bearing seals.

3. Replace the cap.

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13.31 THROTTLE DELAY FUEL MODULATOR

Inspect and adjust, if necessary, every 30 months or 80,000 km (50,000 miles).

The throttle delay system limits the amount of fuel injected during acceleration. It limits the injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay. Refer to section 12.15.

13.31.1 Inspection of Check Valve

Inspect the check valve as follows:

1. Fill the throttle delay cylinder with diesel fuel.
2. Watch for valve leakage while moving the throttle from idle to the full-fuel position.

13.31.2 Inspection of Modulator

Inspect the fuel modulator as follows:

1. Inspect the roller and piston outer diameter and the cylinder bore inner diameter for wear and free operation.
2. Inspect the lower roller operating surface, the roller pins at the cam pivot, and the cam attachment to the piston.
3. Replace parts, as required.

NOTE:
The fuel modulator must be set with the proper gage to achieve the correct fuel-to-air ratio. Refer to section 12.15.

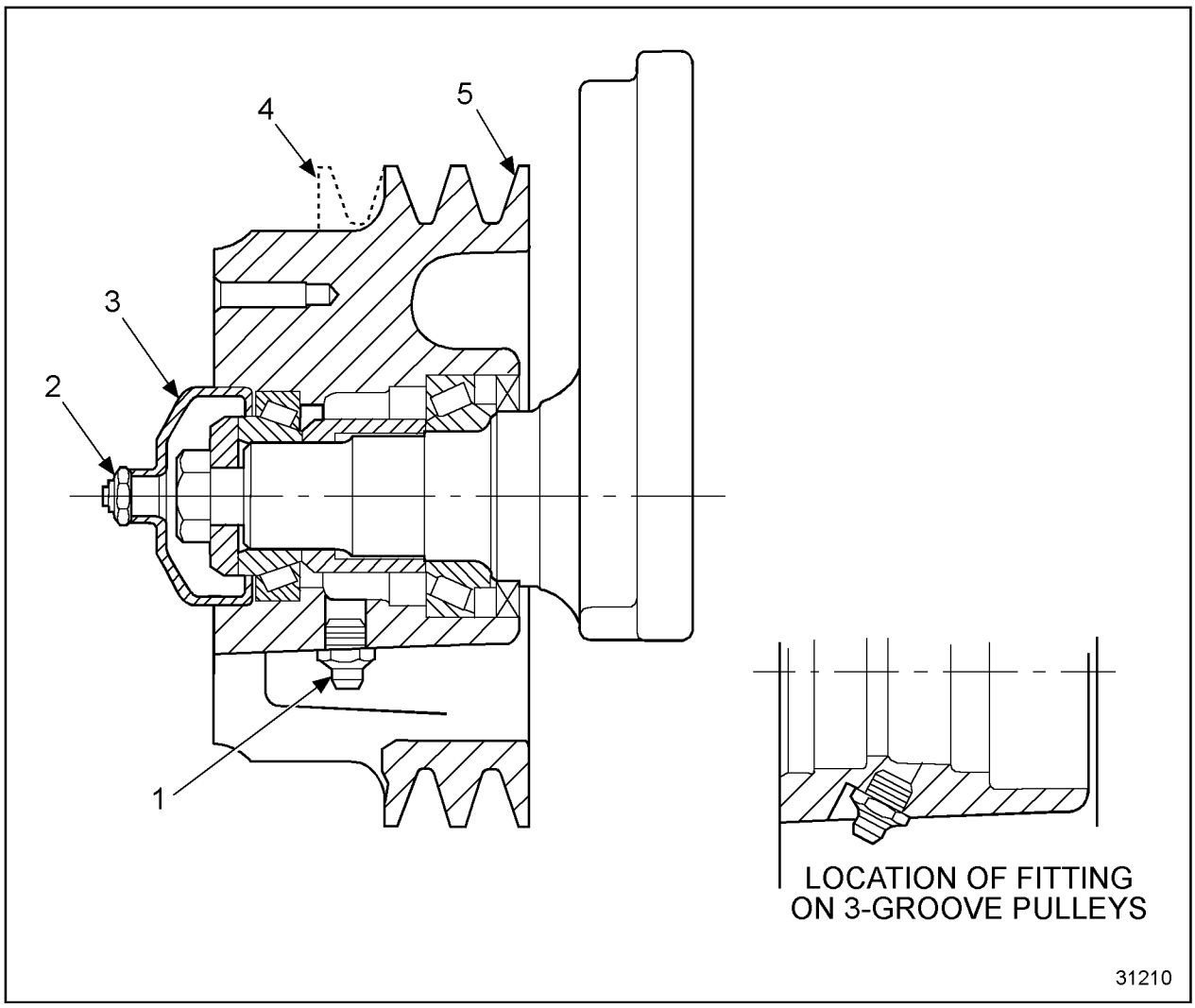
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13.32 FAN HUB

If the fan bearing hub assembly has a grease fitting, use a hand grease gun to lubricate the bearings with one shot of Texaco® Premium RB grease, or an equivalent lithium-based multipurpose grease every 32,000 km (20,000 miles) for vehicle engines. Care should be taken not to overfill the housing.

Every 2,500 hours or 120,000 km (75,000 miles) on vehicle engines or 4,000 hours in non-vehicle engines, the fan bearing hub assembly should be cleaned, inspected and repacked with Texaco Premium RB grease or equivalent lithium-base multipurpose grease.

The bearings in the fan hub assembly should be replaced with new bearings at major engine overhaul. The hub assembly should be packed with Texaco Premium RB grease or equivalent lithium-base multipurpose grease before installing. See Figure 13-12. Refer to OEM maintenance guidelines.



1. Grease Fitting
2. Relief Valve
3. Fan Hub Cap
4. Pulley (3 Groove)
5. Pulley (2 Groove)

Figure 13-12 Location of Fan Hub Grease Fitting and Relief Valve

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13.33 FAN (THERMO-MOUNTED)

Inspect the fan drive fluid level as follows:

NOTE:
Current modulated fan drive housings have an inspection plug for checking the fluid level. Formerly, partial drive disassembly was necessary to check the fluid level. Install a current drive housing, which includes the fluid inspection plug and a grease fitting for lubricating the bearings, to update the former units.

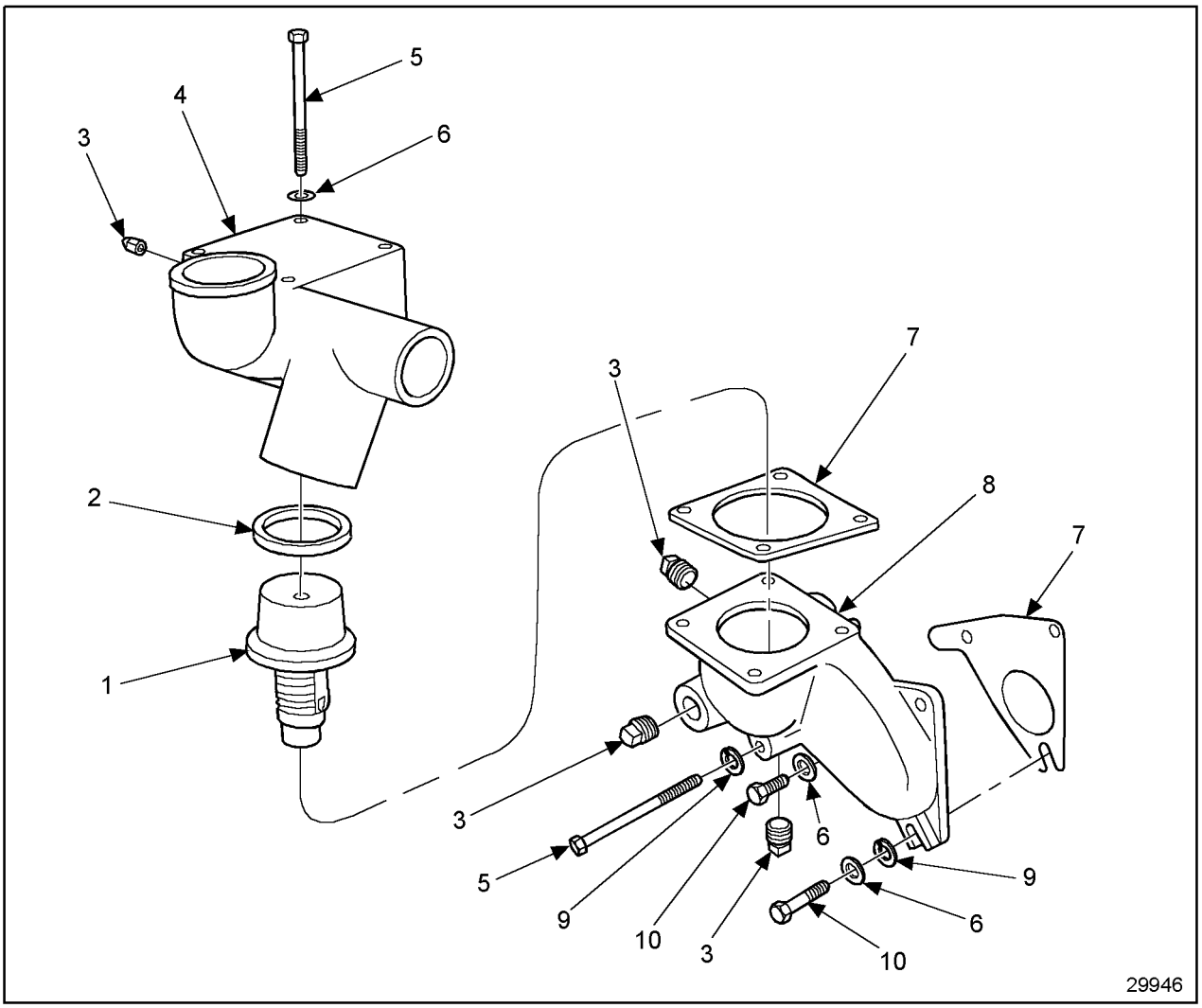
1. Check the fan drive fluid level after the unit has been idle for at least a 1/2 hour.
2. Turn the fan drive so that the inspection plug is 19.1 mm (0.75 in.) below the horizontal center line. Allow the silicone fluid to drain an additional five minutes.
3. Remove the inspection plug.

NOTE:
If fluid flows from the inspection hole, the drive has sufficient fluid.

4. Replace the inspection plug.
5. If the fluid does not flow from the hole, proceed as follows:
   [a] Rotate the fan drive downward, and observe when the fluid begins to flow from the hole.
   [b] If the drain hole is more than 50.8 mm (2 in.) below the horizontal center line for the fluid to flow from the hole, the fan drive should be removed from the engine, disassembled, and inspected for possible component damage.
   [c] Turn the fan drive back so the inspection hole is 19.1 mm (0.75 in.) below the horizontal center line. Add fluid until reaching the overflow point.
6. Replace the inspection plug. Lubricate the drive bearing as follows:
7. Lubricate the fan drive bearing with a medium consistency silicone grease, such as Dow Corning® No. 44, or equivalent.The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Former bearing assembly lubrication requires fan assembly, removal and partial disassembly. Install the current housing to update the former assemblies.

13.34 THERMOSTATS AND SEALS

The thermostats and seals should be replaced every 384,000 km (240,000 miles) for vehicle engines. See Figure 13-13. On non-vehicle engines replace every 4,000 engine hours or two years, whichever comes first and at time of overhaul. Refer to section 4.5.2.2 for thermostat inspection procedures.



1. Thermostat
2. Seal
3. Pipe Plug
4. Cover
5. Bolt
6. Washer
7. Gasket
8. Housing
9. Lock Washer
10. Short Bolt

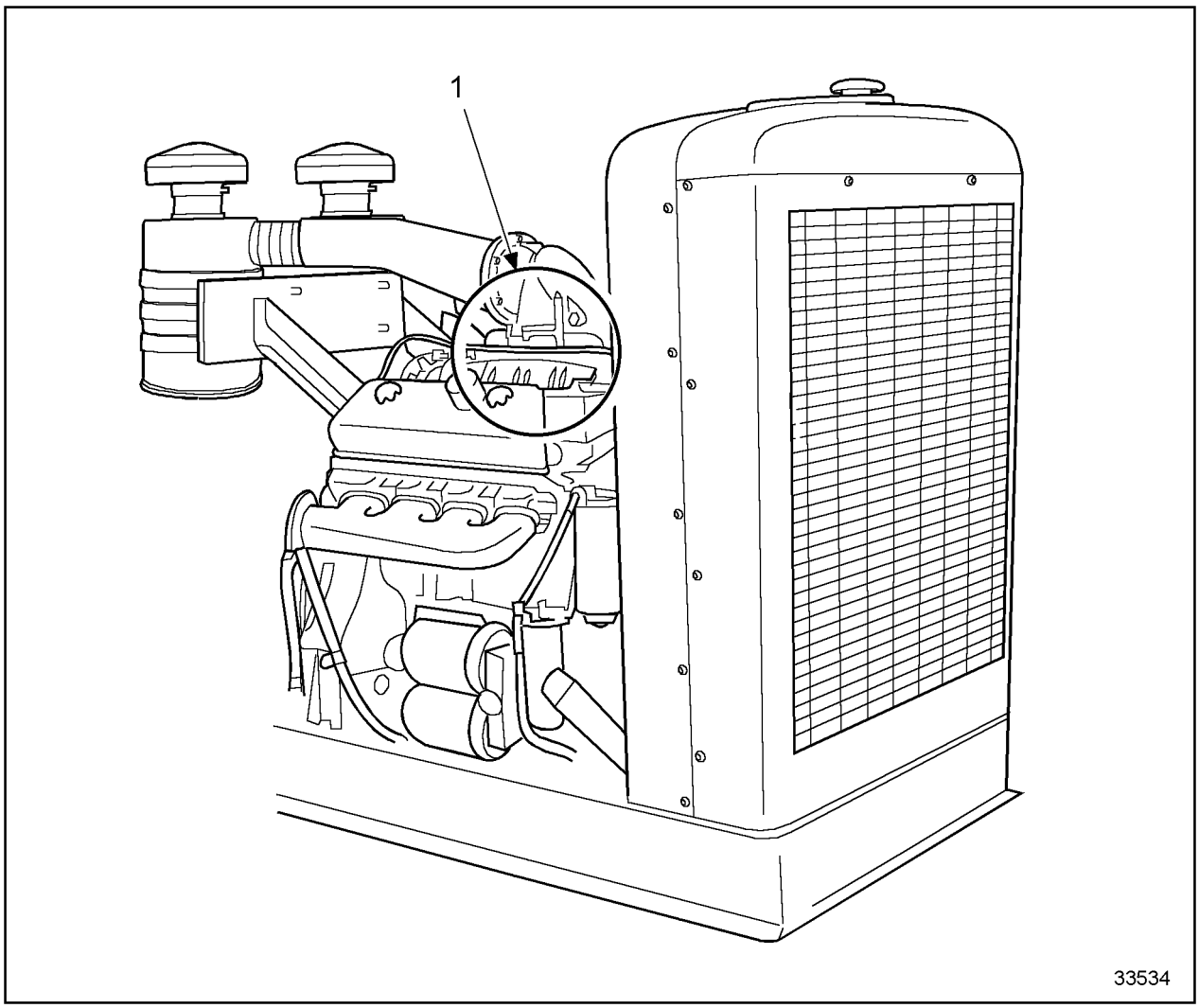
Figure 13-13 Typical Thermostat Housing

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13.35 BLOWER SCREEN

Maintain the blower screen as follows:

1. Inspect the blower screen and gasket assembly annually on vehicle engines or every 1,000 hours or 48,000 km (30,000 miles) on non-vehicle engines. See Figure 13-14.



1. Blower Screen (Mounted Under Air Intake Manifold)

Figure 13-14 Blower Screen

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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. Clean the screen in fuel oil, and dry with compressed air.
3. Install the screen and gasket assembly with the screen side of the assembly toward the blower.
4. Inspect for blower seal leakage.

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13.36 FUEL INJECTORS AND VALVE CLEARANCE

Check the injector timing and exhaust valve clearance every 80,000 km (50,000 miles). Refer to section 12.2 and refer to section 12.3. Emission control relies primarily on the proper height adjustment between the injector follower and the injector body.

Replace fuel injectors on pleasure craft marine engines every 1,000 hours of operation. Replace injectors on commercial marine engines every 5,000 hours of operation.

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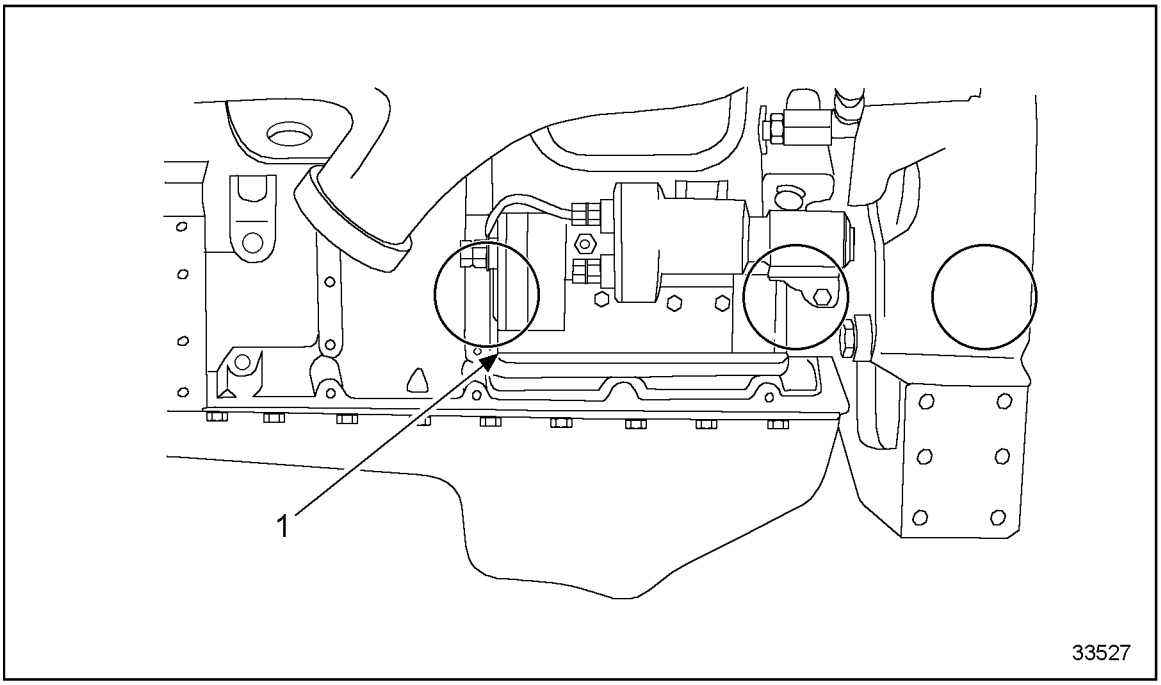
13.37 VIBRATION DAMPER

The viscous damper should be inspected periodically and replaced if dented or leaking. Heat from normal engine operation over a period of time may cause the fluid within the viscous vibration damper to break down and loose its dampening properties. For this reason, the viscous vibration damper must be replaced at time of normal major engine overhaul, regardless of apparent condition.

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13.38 STARTING MOTOR

Starting motors which are provided with lubrication fittings should be lubricated every 6 months or 16,000 km (10,000 miles). See Figure 13-15.



1. Lubrication Fittings

Figure 13-15 Starting Motor Lubrication Fittings

13.38.1 Maintenance of Starter Motor

Maintain a starting motor on vehicle engines as follows:

1. Add 8 to 10 drops of oil (same grade as used in the engine) to hinge cap oilers.
2. If sealed tubes are provided, remove the pipe plugs and add oil.
3. Reseal the tubes.
4. Turn down grease cups one turn.
5. Refill the grease cups, if necessary.

NOTE:
Some starting motors do not require lubrication except during overhaul.

13.38.2 Maintenance of Starter Motor (Non-Vehicle Engine)

Maintain a starting motor on non-vehicle engines as follows:

NOTE:
The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, that extend through each bushing and contact the armature shaft.

1. Remove the pipe plugs on the outside of the motor.
2. Lubricate the wicks.
3. Replace the pipe plugs.

NOTE:
The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The sprag overrunning clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

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13.39 EXHAUST SYSTEM

Inspect the exhaust system as follows:

1. Ensure exhaust manifold retaining nuts and other connections are tight.
2. If equipped, check that the exhaust pipe rain cap is operating properly.

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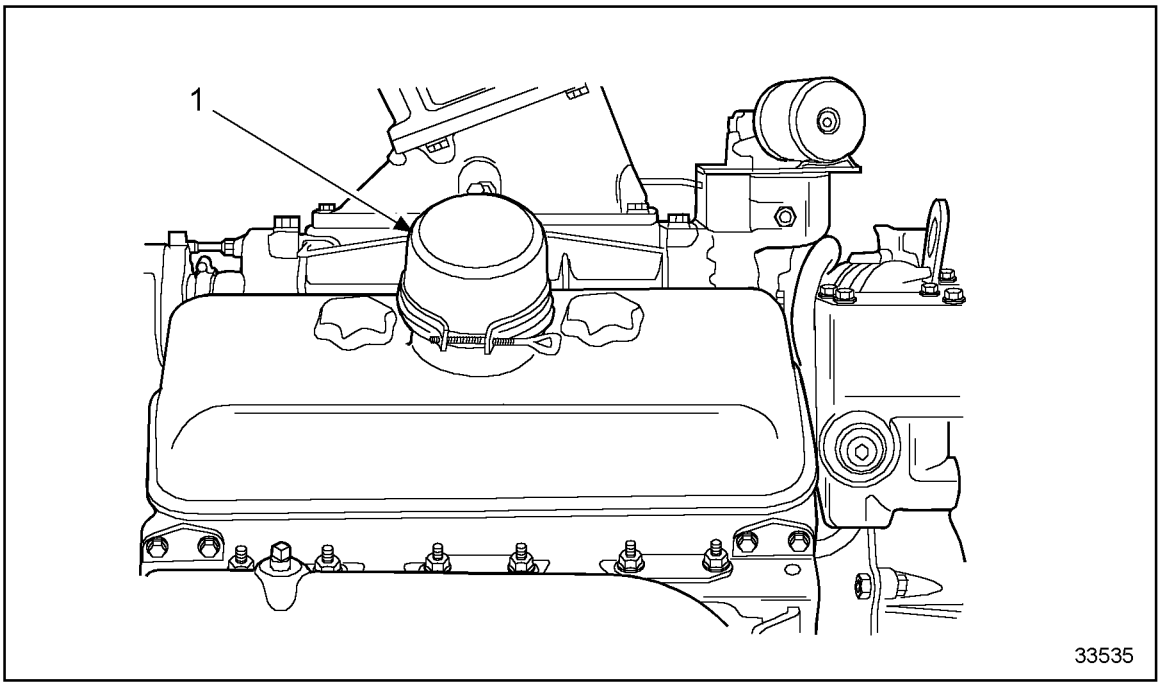
13.40 CRANKCASE BREATHER (EXTERNALLY MOUNTED)

The externally mounted crankcase breather assembly should be removed and the steel mesh pad cleaned in fuel oil annually on vehicle engines or every 1,000 hours, whichever comes first. For marine engines every 5,000 hours. The cleaning period may be reduced or lengthened depending on severity of service.

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13.41 CRANKCASE BREATHER (INTERNALLY MOUNTED)

In vehicle engines, remove and clean the internally mounted crankcase breather assembly annually. See Figure 13-16. Wash the steal mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to the severity of service. On non-vehicle engines, remove and clean the internally mounted crankcase breather assembly every 1,000 hours.



1. Crankcase Breather

Figure 13-16 Crankcase Breather

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13.42 ENGINE (STEAM CLEAN)

Refer to OEM equipment 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. This could damage the electrical equipment.

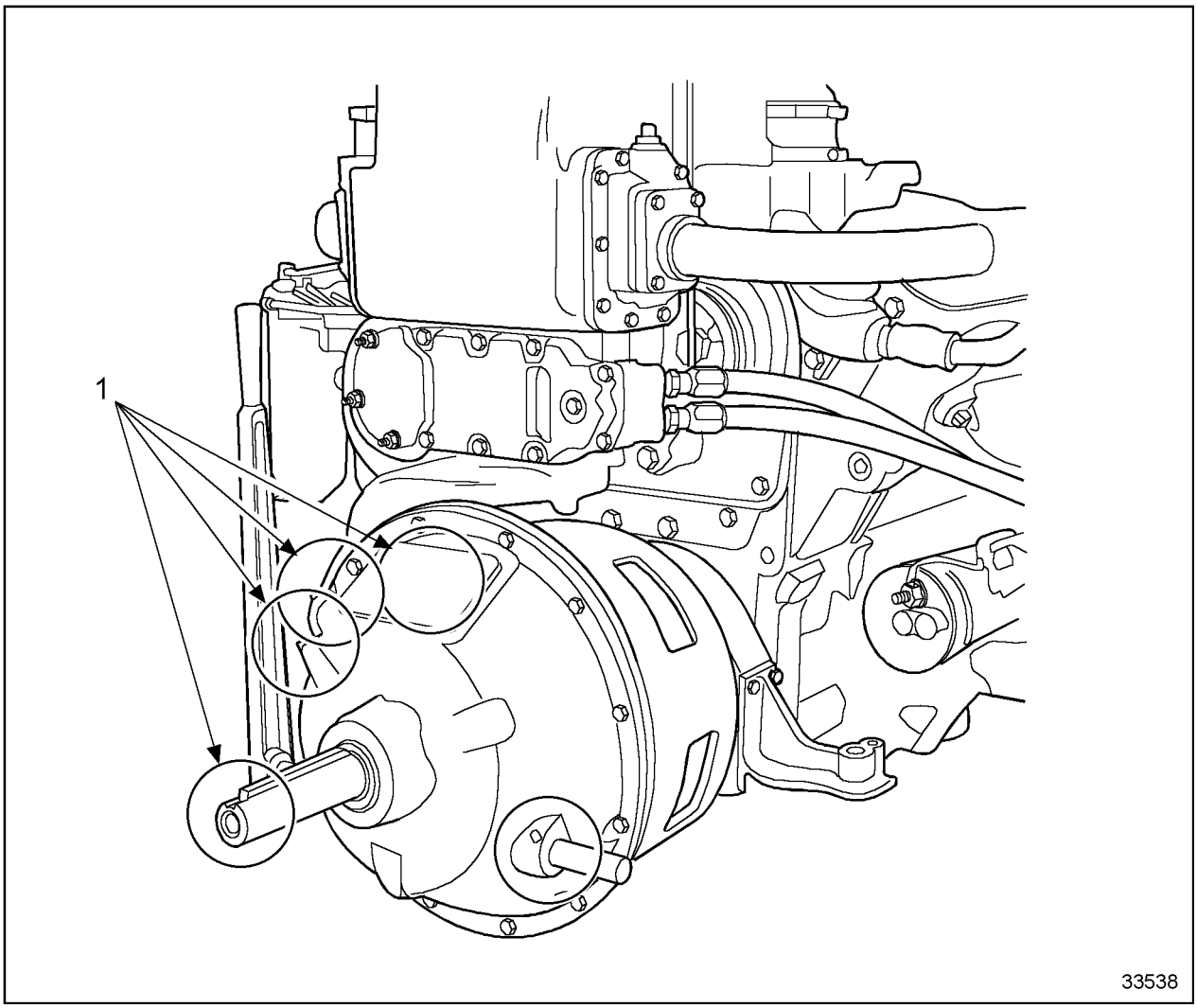
Steam clean the engine and engine compartment only.

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13.43 POWER TAKE-OFF

Maintain the power take-off as follows:

1. Lubricate all power take-off bearings with an all purpose grease, such as Shell Alvania No. 2, or equivalent. Avoid getting grease on the clutch facing. See Figure 13-17.



1. Areas to be Lubricated

Figure 13-17 Power Take-Off Lubrication

2. Lubricate the clutch release bearing, and the disconnect mechanical rear drive shaft shielded bearing every 8 hours or 400 km (240 miles).

NOTE:
The clutch release bearing in the 457.2 mm (18 in.) diameter clutch is prelubricated and is not provided with a grease fitting, since no further lubrication is required.

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3. Lubricate the power take-off main bearing and outboard bearing, if equipped, every 50 hours or 2400 km (1,500 miles).
4. Lubricate the front power take-off clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours or 2,400 km (1,500 miles).

NOTE:
One or two strokes with a grease gun should be sufficient.

5. Every 500 hours or 24,000 km (15,000 miles), remove the inspection hole cover, and lubricate the clutch release levers and link pins sparingly.
6. Lubricate the clutch release shaft through the grease fittings on the front of the housing.
7. Check the clutch facing for wear.
8. Adjust the clutch, if necessary.

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13.44 TORQMATIC CONVERTER

Maintain the Torqmatic converter as follows:

Check the oil level in the Torqmatic converter and supply tank daily. See Figure 13-18. Check the oil level while the converter is operating, the engine is idling, and the oil is up to operating temperature (approximately 93°C or 200°F). If equipped with an input disconnect clutch, the clutch must be engaged.

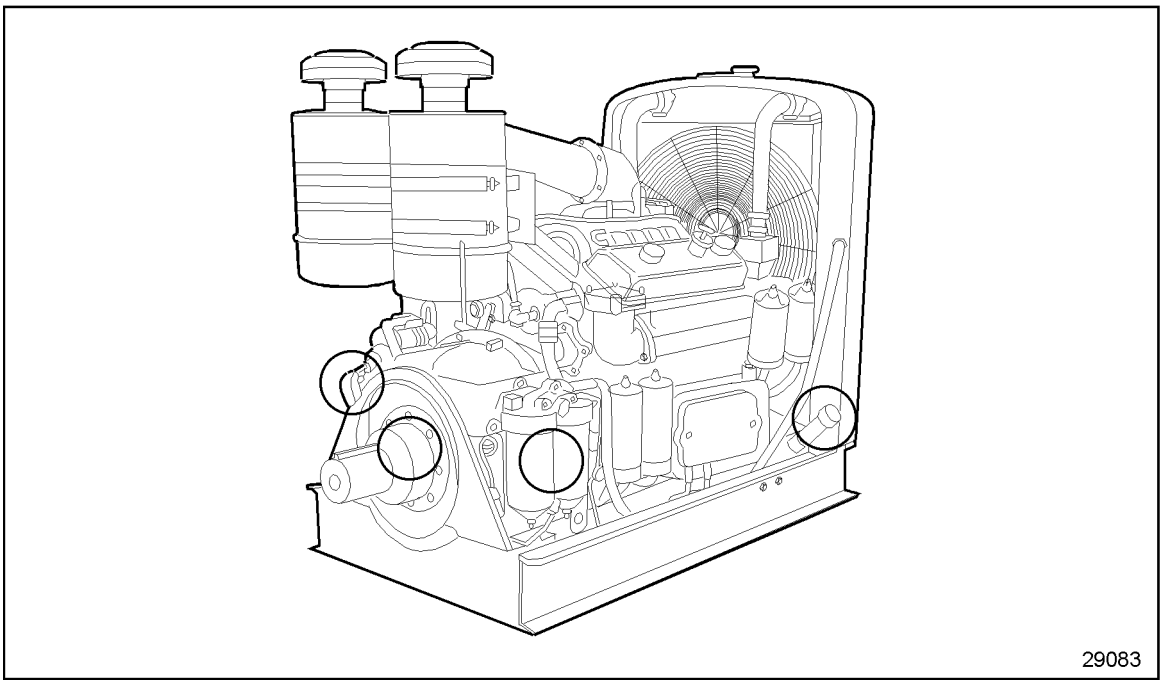


Figure 13-18 Torqmatic Converter Lubrication and Oil Level Check

1. Check the oil level after running the unit a few minutes.

NOTICE:
Do not overfill the converter. Too much oil will foam and create high oil temperatures, leading to potential engine damage.

2. If required, add hydraulic transmission fluid type "C-2" listed in Table 13-7.

Prevailing Ambient Temperature	Recommended Oil Specification
Above -23°C (-10°F)	Hydraulic Transmission Fluid, Type C-2
Below -23°C (-10°F)	Hydraulic Transmission Fluid Type C-2. Auxiliary preheating required to raise temperature in the sump to a temperature above -23°C (-10°F).

Table 13-7 Oil Recommendations

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The oil should be changed every 1,000 hours or 48,000 km (30,000 miles) for Series 400 through 900 converters. Change the oil if it is dirty, discolored, or contains a strong odor. If the oil is contaminated with metal, contact an authorized Detroit Diesel Service Outlet. Change the oil more often under severe operating conditions.

⚠ 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 the converter oil breather on the dipstick each time the converter oil is changed. Soak the breather in solvent, and dry with compressed air.
4. Every time the converter oil is changed, remove the full-flow oil filter element.
5. Clean the shell.
6. Install a new element and gasket.
7. Lubricate the input clutch release bearing, ball bearing, and the front disconnect clutch drive shaft bearing with an all purpose grease every 50 hours or 2,400 km (1,500 miles).

NOTE:
Grease fittings are provided on the clutch housing. Intervals may vary depending on the operating conditions. Over lubrication will cause grease to be thrown on the clutch facing, causing the clutch to slip.

8. Replace or clean the strainer in the Torqmatic transmission and the hydraulic system with each oil change.

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13.45 REDUCTION GEAR

Maintain the Rockford® reduction gear as follows:

1. Check the oil level in the reduction gear every 8 hours. Add oil as needed to bring the oil to the proper level on the dipstick. See Figure 13-19.

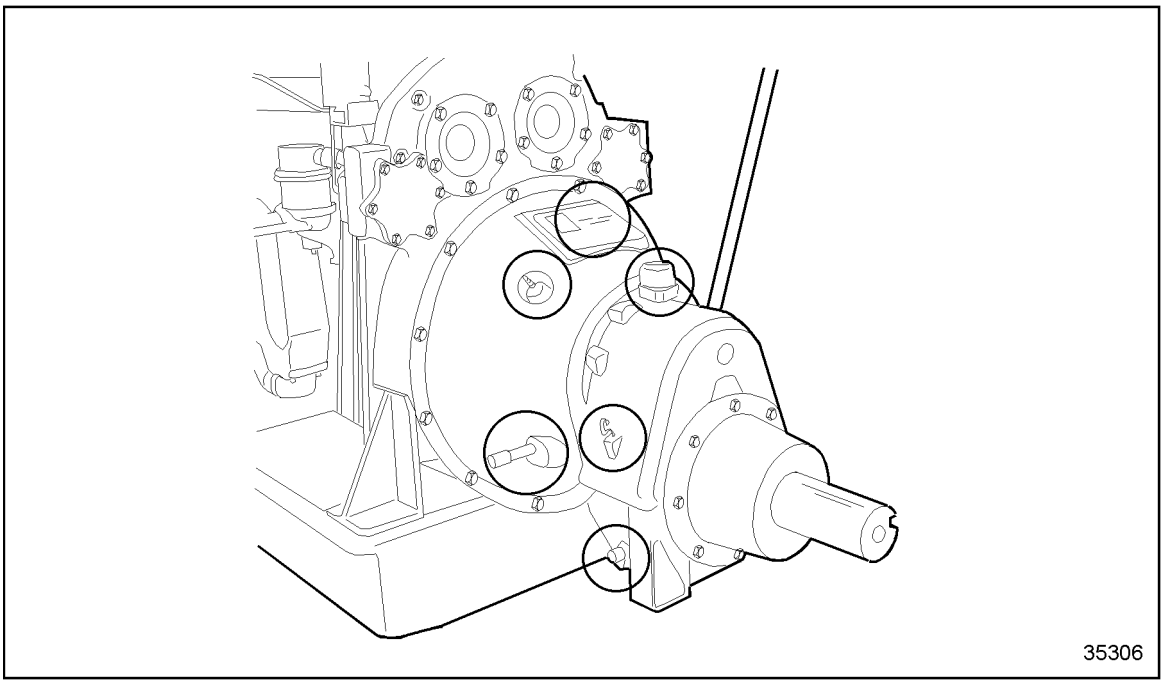


Figure 13-19 Reduction Gear Lubrication Fittings and Oil Level Check

2. Drain the oil every 1,000 hours or 48,000 km (30,000 miles).
3. Flush the housing with engine oil.
4. Refill to the proper level with the same grade and viscosity heavy-duty oil as used in the engine.

NOTE:
Under severe operating conditions, reduce the oil change period.

5. Lubricate the clutch release bearing through the grease fitting on the side of the housing every 8 hours or 384 km (240 miles).

NOTE:
The clutch release bearing in the 457.2 mm (18 in.) diameter clutch is prelubricated and is not provided with a grease fitting. No further lubrication is required.

6. Lubricate the front reduction clutch pilot ball bearing through the fitting in the outer end of the drive shaft every 50 hours or 2,400 km (1,500 miles). One or two strokes with a grease gun should be sufficient.

7. Remove the inspection hole cover.
8. Oil the clutch release levers and link pins sparingly every 500 hours or 24,000 km (15,000 miles).
9. Lubricate the clutch release shaft through the grease fittings on the front of the housing every 500 hours or 24,000 km (15,000 miles).

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13.46 TRANSIT COACH CONVERTER MUFFLER

Donaldson® catalytic converter mufflers are used on many transit busses equipped with Detroit Diesel Series 92 engines. To ensure efficient functioning of these converter systems, the Donaldson Company and Detroit Diesel Corporation have developed new preventive maintenance and servicing procedures.

13.46.1 Preventive Maintenance Procedure Details

During normally scheduled vehicle maintenance, inspect the converter muffler, exhaust piping, and mounting brackets. Look for leaks, structural failures (cracks), or loose or missing fasteners. Repair or replace defective parts, as required.

Catalytic converter mufflers are subject to plugging under the following conditions:

- Engine operation at low load for extended periods of time.
- Improper engine maintenance.
- Improper engine calibration for the specific fuel type.Use the following procedures to check and clean catalytic converter mufflers:

NOTE:
To prevent the reoccurrence of plugging, engine performance concerns must be resolved before operating again with a cleaned converter muffler.

13.46.2 Check Back Pressure

Check back pressure as follows:

1. Remove the plug from the 1/4 in.-18 NPT back pressure tap half coupling located on the side of the converter muffler, and install a manometer or back pressure gage.
2. Start and run the engine. After thoroughly warm, run at high idle, no load for 2-3 minutes.
3. Record back pressure while the engine is still at no load.
   [a] If back pressure is less than 41 in. H_2O or 3 in. Hg (10.2 kPa), continue to operate the converter muffler without further maintenance.
   [b] If back pressure is greater than 41 in. H_2O or 3 in. Hg (10.2 kPa), use one of the following procedures to clean out the muffler.

13.46.3 Clean Out Converter (Muffler On Vehicle)

Clean converter on vehicle as follows:

1. Operate the vehicle with a high engine load (maximum highway speed, uphill, on a chassis dynamometer, for example) for 10-15 minutes, and recheck the high idle, no load back pressure by repeating step 1 and step 2 of *"Check Back Pressure"* procedure.
2. If back pressure is less than 41 in. H_2O or 3 in. Hg (10.2 kPa), continue to operate the converter muffler without further maintenance.

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3. If back pressure is greater 41 in. H_2O or 3 in. Hg (10.2 kPa), use the procedure under *"Clean Out Converter Muffler Off Vehicle"*.

13.46.4 Clean Out Converter (Muffler Off Vehicle)

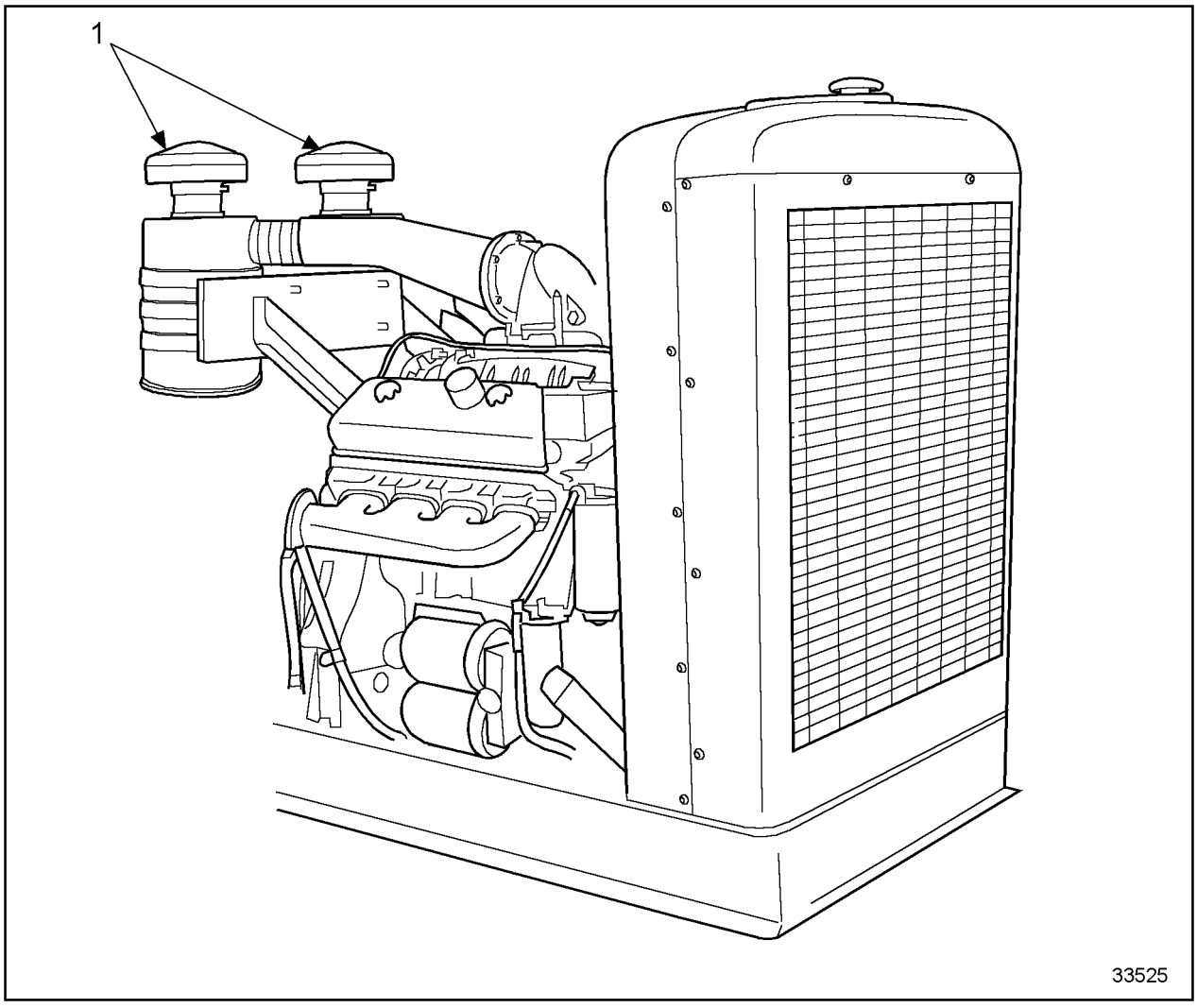
Clean converter off vehicle as follows:

1. Identify and mark the exhaust flow direction on the body of the converter muffler's middle (core) section between the V-band clamps. This section of the converter muffler contains the catalyzed ceramic core assembly.
2. Remove the middle (core) section of the converter assembly by removing the V-band clamps around the body of the converter muffler.
3. Thoroughly vacuum clean both faces of the ceramic core using a non-metallic brush attachment.
4. Install the middle (core) section into the converter muffler in the opposite direction from which it was removed so that exhaust gas flow through the core assembly is reversed. Apply anti-seize lubricant to the inside T-bolts of the V-band, then install the V-band. Tap the outside of the V-band clamps with a hammer as clamp bolts are tightened. Torque bolts to a maximum torque of 200 lb·in. (23 N·m).
5. Repeat step 1 and step 2 of *"Check Back Pressure"* procedure, and check high idle, no load back pressure.
   [a] If back pressure is less than 41 in. H_2O or 3 in. Hg (10.2 kPa), continue to operate the converter muffler without further maintenance.
   [b] If back pressure is greater than 41 in. H_2O or 3 in. Hg (10.2 kPa), use the procedure under *"Clean Out Converter Muffler On Vehicle"*.

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13.47 AIR CLEANER

See Figure 13-20 for illustration of the dry type air cleaner.



1. Dry Type Air Cleaners

Figure 13-20 Dry Type Air Cleaners

NOTICE:
Reusing a damaged air cleaner element or gasket may result in inadequate air filtration and severe engine damage.

A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine. This, in turn, can result in increased fuel consumption, inefficient engine operation and reduced engine life.

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13.47.1 Maintenance of the Dry-Type Air Cleaner

Maintain the dry-type air cleaner as follows:

1. The dry-type air cleaner element should be inspected every 24,000 km (15,000 miles) for vehicle engines, or more often if the engine is operated under severe dust conditions.
2. Discard and replace elements used in on-highway applications after one year of service or 160,000 km (100,000 miles) or when the maximum allowable air intake restriction has been reached, whichever comes first. Refer to section 11.5.

NOTE:
Do not attempt to clean or reuse on-highway elements after these intervals.

NOTICE:
Under no engine operating conditions should the air inlet restriction exceed 6.2 kPa (0.25 in. of water) for non-turbocharged engines, or 5.0 kPa (0.20 in. of water) for turbocharged engines. Failure to follow these guidelines will result in increased fuel consumption, inefficient engine operation and reduced engine life.

3. Discard and replace elements used in off-highway applications after one year of service or when the maximum allowable air intake restriction has been reached, whichever comes first.
4. Check gaskets for deterioration.
   [a] If severely deteriorated, replace the gaskets. Refer to section 6.2.3.
   [b] If no deterioration is found, continue maintenance check.

NOTE:
Keep air cleaner tight on air intake-to-engine.

5. Ensure air cleaner is properly assembled so joints are oil and air tight.
6. Inspect air cleaner, intake, or connections for damage.
   [a] If damage is found, repair at once.
   [b] If no damage is found, continue maintenance check.
7. Cleaning and inspection of the air cleaner must be performed per the manufacturer's recommendations.
8. Cover gasket inspection and replacement of the air cleaner must be performed per manufacturer's recommendations.

NOTE:
In cases where the air cleaner manufacturer recommends cleaning or washing elements, the maximum service life is still one year or maximum restriction.

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9. If the dry type air cleaner is equipped with an aspirator, check for aspirator damage or clogging.
10. Clean and repair, if necessary.

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13.48 AIR SYSTEM

Inspect the air system daily for leaks. Look for torn air inlet piping or boots and loose or damaged clamps. Have worn or damaged parts repaired or replaced, as required. Tighten any loose connections.

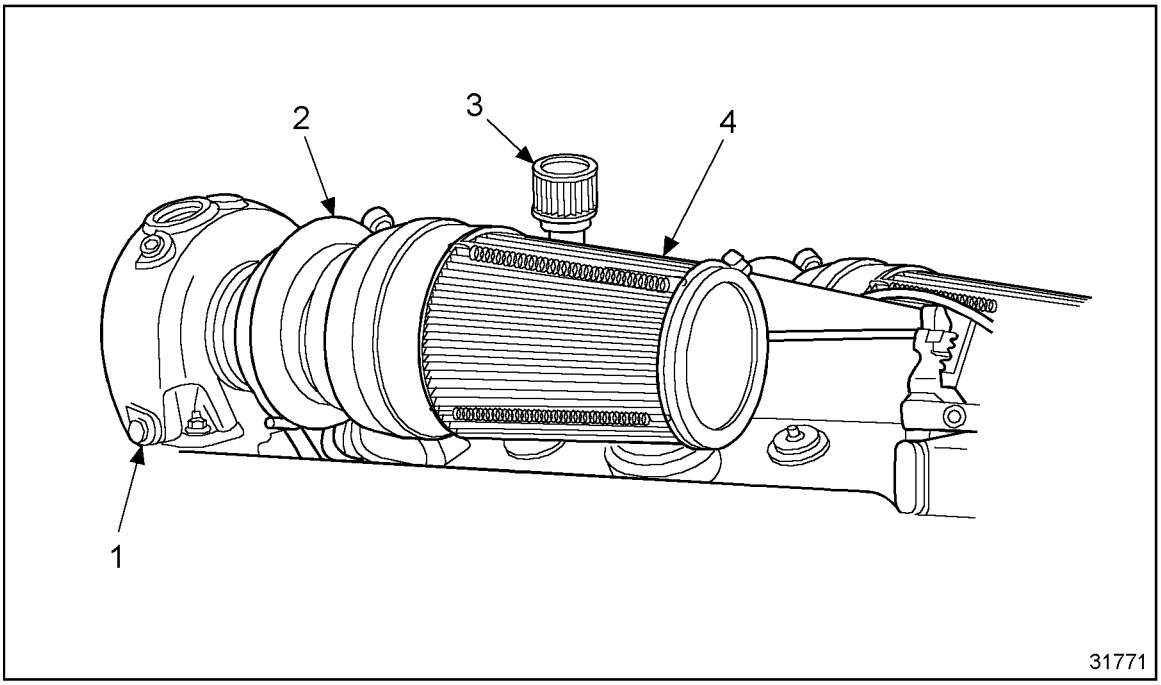
1. Where rubber hose from air cleaner to blower is employed, remove hose connections and cement them in place. Use new hose and clamps, if necessary, to obtain an air-tight connection.
2. After servicing the air cleaner, remove the air inlet housing, and clean accumulated dirt deposits from the blower screen and air inlet housing. Ensure all air intake passages and the air box are kept clean.
3. Make a careful, periodic inspection of the entire air system. Enough dust-laden air will pass through an almost invisible crack to eventually cause serious damage to an engine.

NOTICE:
Paper element overloading will not cause dirt particles to bypass the filter and enter the engine, but will result in engine air starvation.

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13.49 AIR SEPARATOR FILTER ELEMENT

The closed breather system consists of an air separator assembly mounted to the inlet side of each turbocharger. See Figure 13-21.



1. Turbine Housing
2. Compressor Housing
3. Vacuum Limiter
4. Air Separator Assembly

Figure 13-21 Typical Air Separator System

To operate efficiently, air separator filters and vacuum limiters must be properly maintained.

- ☐ Clean and oil the vacuum limiter and filter element every 250 hours of engine operation or once a year, whichever comes first. Refer to section 13.49.1, refer to section 13.49.2, and refer to section 13.49.4.

NOTE:
Filter elements and vacuum limiters must also be cleaned and oiled any time the restriction gage shows red.

- ☐ Filter elements must be replaced after three cleanings.
- ☐ Replace vacuum regulator/limiters every 1000 hours of engine operation or every two years, whichever comes first.

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NOTICE:
Failure to properly clean the engine room may allow loose debris to plug air separator elements. Plugging can lead to high air inlet restriction, causing reduced engine performance and/or engine damage caused by engine overheating.

NOTE:
For best cleaning results, and to avoid damaging filter elements, Walker Cleaning and Re-oiling Kit must be used. Available from Walker Engineering supply distributors or directly from manufacturer: Walker Engineering Enterprises, 7406 Havenhurst Place Van Nuys, CA 91406

13.49.1 Pre-Clean Air Separator Filter Element

Perform the following procedures to clean and oil the air separator filter element:

NOTICE:
Failure to clean the air separator filter and the vacuum regulator/limiter will affect the operation of the air separator and may cause reduced engine performance and/or engine damage caused by engine overheating.

NOTE:
A filter that is damaged or clogged with soot due to an exhaust leak may not be able to be cleaned to maximum air flow condition. Replacement of element may be necessary.

1. Remove filter element from air separator.

NOTE:
Filter elements and vacuum limiters must also be cleaned and oiled when the air inlet restriction turns *red*. This indicates the maximum allowable system restriction has been reached.

2. Tap element to dislodge any large, imbedded particles of dirt.
3. Gently brush outside of element with soft bristle brush, such as a paint brush.
   [a] If complete cleaning is impractical at this time, oil and install element. Refer to section 13.49.2 for oiling procedure.
   [b] If complete cleaning is practical at this time, refer to section 13.49.2 and follow cleaning and oiling procedure.

13.49.2 Cleaning of Air Separator Filter Element

Perform the following procedures to clean air separator:

1. Spray Walker cleaning solution onto element and let soak 10 minutes.

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NOTICE:
To avoid filter damage, do not clean with gasoline, steam, high pressure water or air, caustic solutions, strong detergents, or parts cleaning solvents.

2. Rinse element with clean, low pressure, fresh (not salt) water. Rinse from clean side (inside) to dirty side.

NOTICE:
To avoid filter damage, do not use compressed air, open flame, ovens, or heat dryers. Excess heat will shrink the cotton filter element, and compressed air will blow holes through it.

3. Shake off excess water and allow element of air dry naturally.

NOTICE:
To avoid filter damage, do not use transmission fluid, motor oil, diesel fuel, WD-40® or other lightweight oil.

⚠ CAUTION:
To avoid injury from contact with the contaminants in used engine oil, wear protective gloves and apron.

4. Squeeze Walker air filter oil out of the bottle and into the valley of each pleat. Make one pass per pleat.

NOTE:
Filter effectiveness is reduced if the element is used without being oiled.

5. Allow oil to work into element for 20 minutes.
6. Oil any white spots on the element.
7. Install air separator filter element.

13.49.3 Clean Vacuum Regulator Filter Element

The vacuum regulator filter can be cleaned without removing the regulator from the system.

1. Detach filter using a standard blade screwdriver.
2. Refer to section 13.49.1, and follow same preclean procedure.
3. Refer to section 13.49.2, and follow same cleaning procedure.

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13.49.4 Clean Vacuum Limiter Filter Element

Clean vacuum limiter filter element as follows:

1. Remove entire vacuum limiter assembly. Do not detach filter element.
2. Refer to section 13.49.1, and follow same preclean procedure.
3. Refer to section 13.49.2, and follow same cleaning procedure.

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13.50 AIR SHUTDOWN VALVE

With the engine running at idle speed, check the emergency shutdown operation every 700 hours or 32,000 km (20,000 miles), or 500 hours on marine, whichever comes first. Reset the air shutdown valve in the open position after the check has been completed.

⚠ CAUTION:

To avoid injury from engine run-on when an emergency shutdown is required, do not use damaged shutdown devices.

NOTICE:

To avoid engine damage, ensure shutdown valve is properly adjusted. Failure to do so will prevent valve from closing completely when activated, thus defeating its intended purpose to cut off air flow to the engine and shut it down during abnormal operating conditions.

NOTICE:

Do not use the air shutdown for normal or routine engine stopping. Failure to observe this precaution can result in serious engine damage.

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13.51 COOLING SYSTEM (MARINE)

When a Detroit Diesel marine engine is put into service at the beginning of boating season, the following preventive maintenance checks should be made to ensure optimum cooling system performance:

1. If the raw water pump cover was previously removed or loosened to drain the system for winter lay-up, remove the cover, and replace the gasket with a new one before operating the engine.

NOTE:
Failure to use a new gasket when replacing the raw water pump cover may result in pump leakage at engine start-up. This is a change from the previous recommendation, which allowed reuse of an undamaged gasket.

2. While the cover is off, check the condition of the raw water pump impeller. Replace if brittle, damaged, or excessively worn.

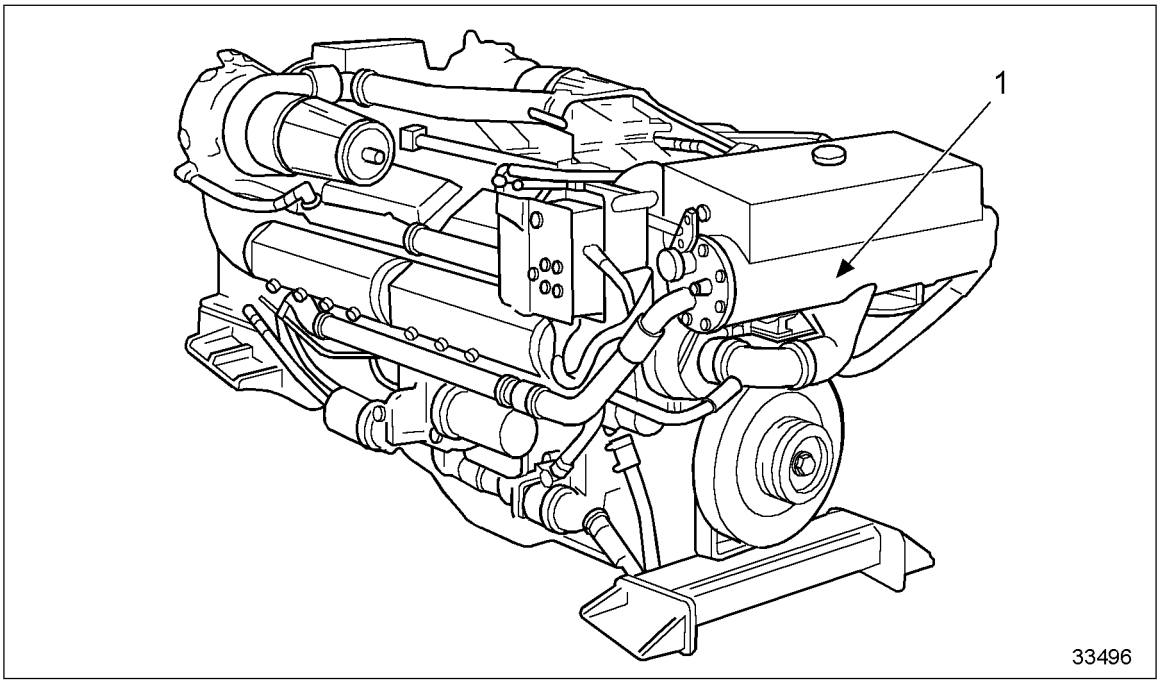
NOTICE:
Do not over tighten standard hose clamps or attempt to retorque constant-torque hose clamps. Hose clamps will break if over tightened.

3. Check the heat exchanger/raw water pump piping and hose connections for tightness and serviceability. Replace hoses that show signs of mechanical damage (cuts, crushing) or deterioration (cracks, bulged areas) or hoses that feel unusually soft or hard when squeezed. Replace all damaged clamps.
4. If resilient isolators are used to mount the heat exchanger, replace if cracked or brittle.
5. Ensure the inhibited coolant level in the heat exchanger tank is at or near the bottom of the filler neck and the fill/pressure cap is secure before starting. For coolant recommendations, refer to section 5.3.1.
6. To avoid impeller damage and ensure a full flow of raw water through the heat exchanger at engine start-up, remove the pipe plug or "zinc" from the raw water pump inlet, and prime the pump before starting.
7. Check the condition of the fresh water pump drive belt (if used) and any other drive belts on the engine. Replace the belt if it is cracked, cut, glazed, or has missing cogs. Tighten reusable or replacement belt to specifications.

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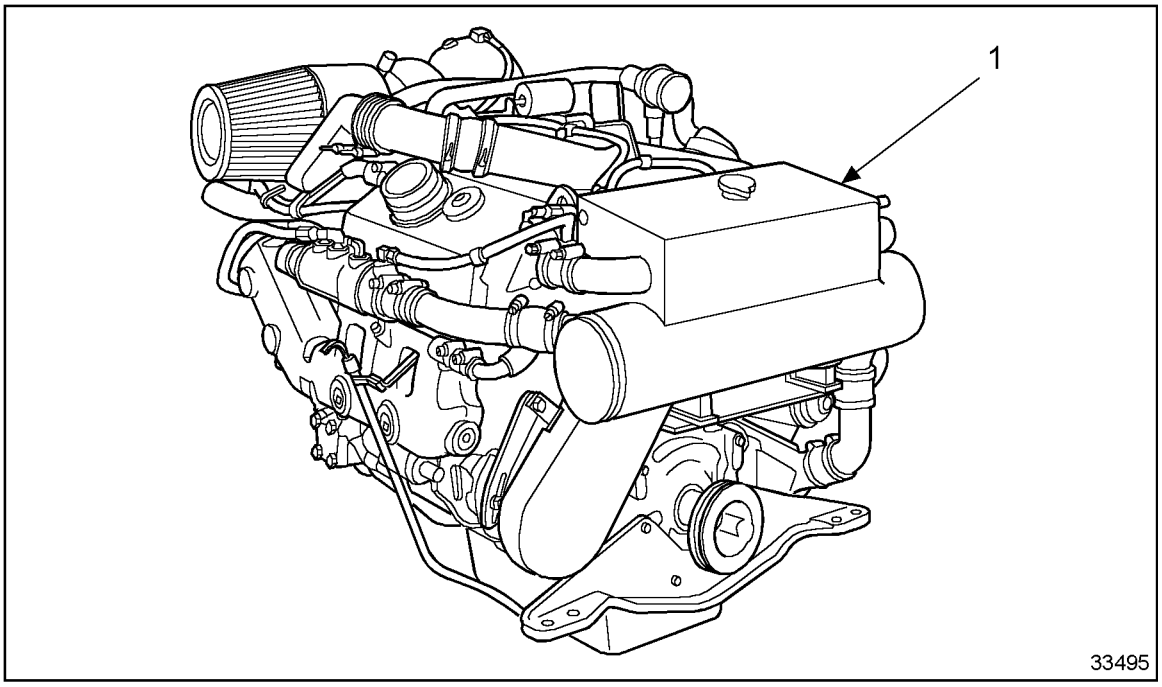
13.52 HEAT EXCHANGER CHANGEOUT INTERVAL

Tube and shell heat exchangers are unitized assemblies with no replaceable components. They can be identified by the barrel-shaped housing at the bottom of the tank which contains the tube bundle core. In some installations, the core may be enclosed in a separate barrel-shaped tank attached to the side of the engine. See Figure 13-22, see Figure 13-23, and see Figure 13-24.



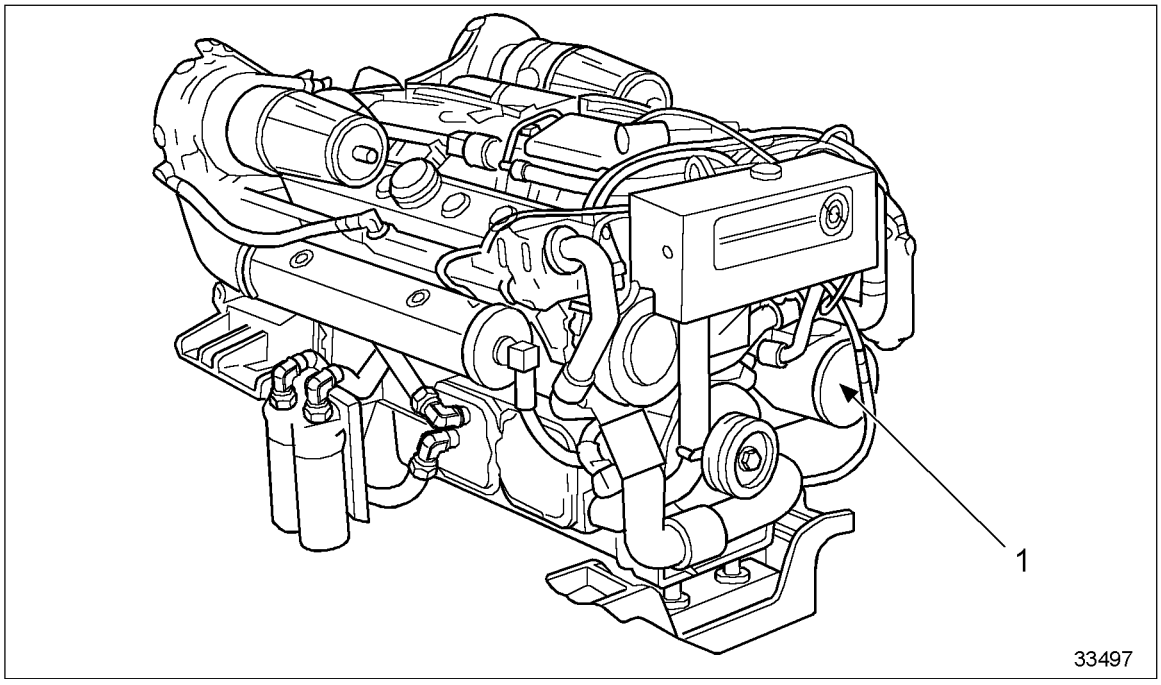
1. Heat Exchanger

Figure 13-22 Heat Exchanger (Tube Bundle Core)



1. Heat Exchanger

Figure 13-23 Typical Heat Exchanger



1. Heat Exchanger

Figure 13-24 Heat Exchanger (Mounted)

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NOTICE:
Failure to replace tube and shell heat exchangers on marine engines at required intervals may permit tube blockage, which can result in engine overheating and serious engine damage.

Tube and shell heat exchangers used in marine engine installations have a service life of 4,000 hours or four years, whichever comes first. At this interval, they must be replaced.

When heat exchangers are replaced, the antifreeze should also be drained and disposed of in an environmentally responsible manner, according to state and/or federal (EPA) recommendations. The cooling system should then be cleaned thoroughly and replenished with ethylene glycol-base antifreeze solution and Detroit Diesel Selected Product supplemental inhibitors in the required concentrations.

NOTICE:
Failure to maintain inhibitors at required levels can result in damage to the cooling system and related components. Conversely, over-inhibiting antifreeze solutions can cause "silicate dropout", which can plug oil cooler and aftercooler cores and/or cause hot spots in the engine. Always follow Selected Product inhibitor recommendations on usage and handling.

In extremely hot environments, clean, soft, properly inhibited water may be used if Detroit Diesel Selected Product supplemental corrosion inhibitors are also added in the right concentration. If water is used, supplemental coolant additive levels should be increased from 3% to 6% by volume.

For detailed coolant and Selected Product additive information, refer to section 5.3.

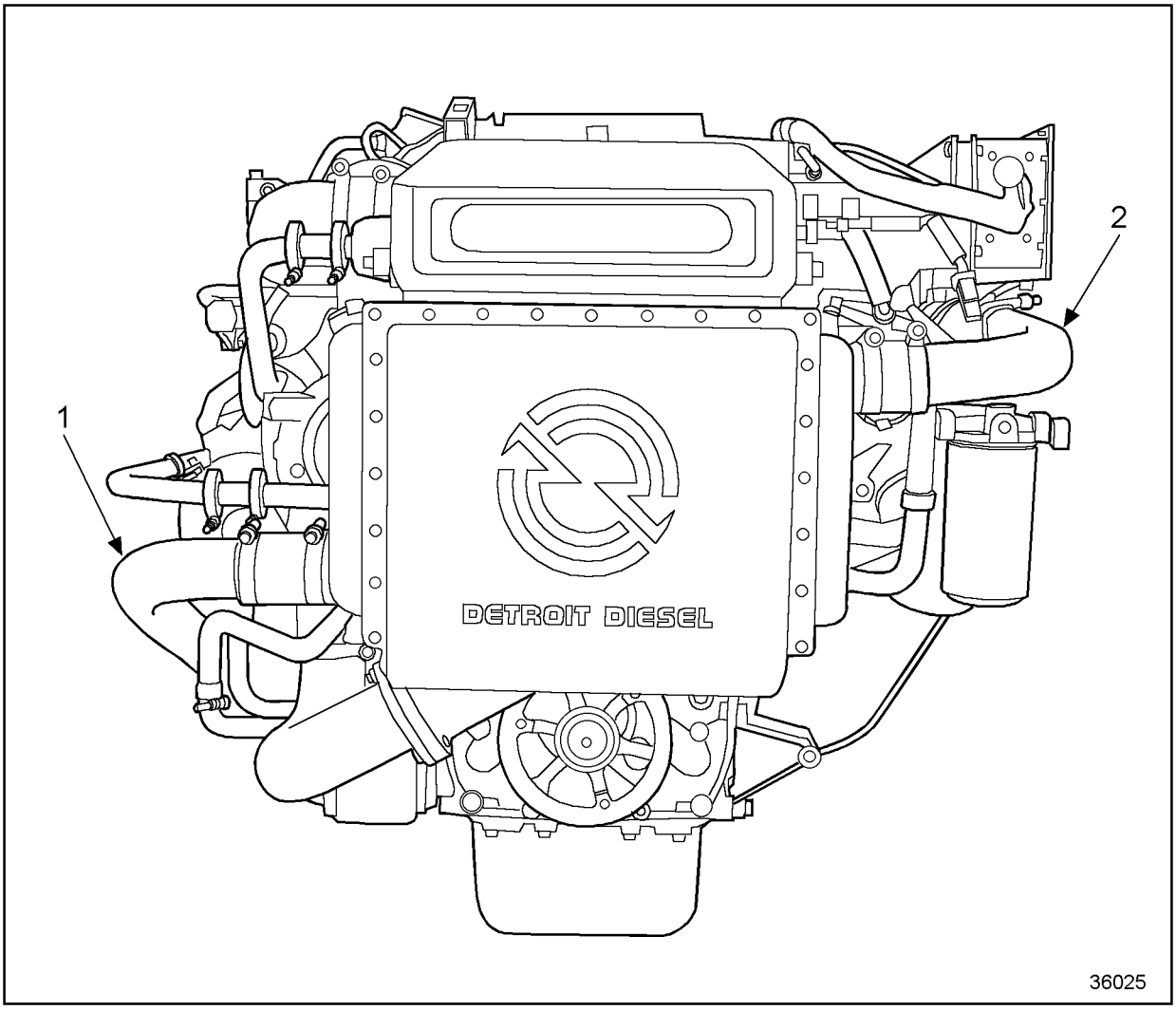
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13.53 HEAT EXCHANGER ELECTRODES AND CORE (RAW WATER SYSTEM ZINCS)

Heat exchanger "zincs" should be checked initially every 60 hours, then as required or annually. Clean with a wire brush if serviceable. Replace if badly deteriorated. Electrodes are generally found in the heat exchanger assembly, raw water pump elbows, fuel and/or boost cooler, and the engine/marine gear auxiliary coolers.

Maintain the heat exchanger electrodes as follows:

1. Every 500 hours or annually, drain the water from the heat exchanger raw water inlet and outlet tubes. See Figure 13-25.



1. Raw Water Outlet Tube
2. Raw Water Inlet Tube

Figure 13-25 Heat Exchanger (6V and 8V Marine Pleasurecraft)

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2. Remove the zinc electrodes form the inlet side of the raw water pump and the heat exchanger.
3. Clean the electrodes with a wire brush, or if excessively worn, replace with new electrodes.

NOTE:
To determine the used electrode condition, strike it against a hard surface. A weakened electrode will break.

Maintain the core as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Disconnect the raw water pipes at the outlet side of the heat exchanger.
3. Remove the retaining cover every 1,000 hours or 48,000 km (30,000 miles).
4. Inspect the heat exchanger core.
5. If a considerable amount of scale or deposits are present, contact a Detroit Diesel Service Outlet.

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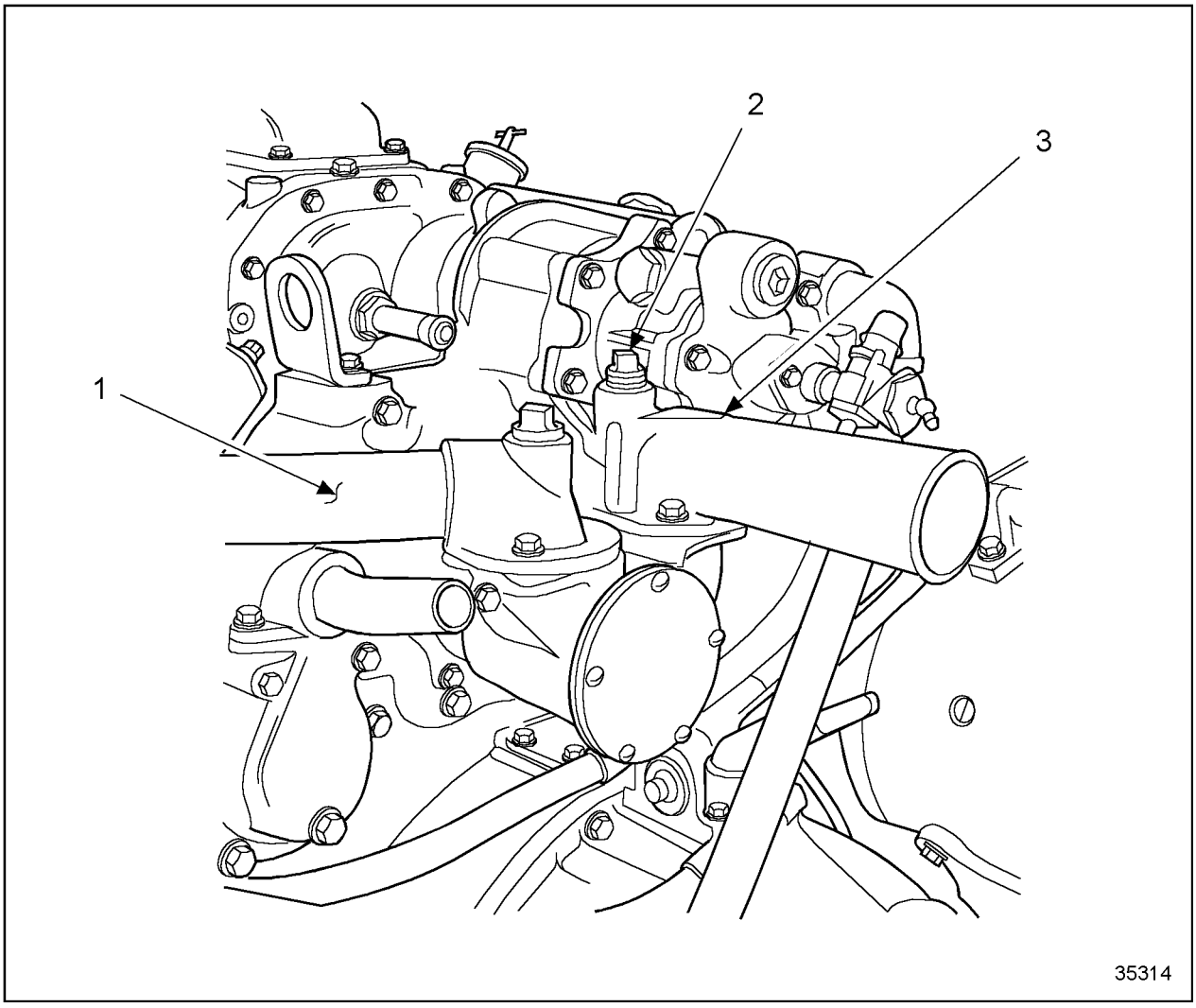
13.54 RAW WATER PUMP

Water leaking from the pump housing openings indicates a raw water pump seal malfunction. The pump housing openings, located between the pump mounting flange and the inlet and outlet ports, must remain open at all times. Leaking seals require replacement. The raw water pump body or liner should be checked for cracks or wear, and replaced if necessary.

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NOTICE:
Always prime the raw water pump before starting the engine. Since water acts as a lubricant for the impeller, failure to prime the pump (or at least wet the impeller vanes to induce a self-priming suction) can result in severe impeller damage when the engine is started. Insufficient raw water flow into the heat exchanger caused by a damaged impeller can lead to overheating and subsequent engine damage.

1. Check the prime on the raw water pump daily. See Figure 13-26. The engine should not be operated with a dry pump.



1. Outlet Tube
2. Pipe Plug
3. Inlet Tube

Figure 13-26 Raw Water Pump

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2. If necessary, prime the water pump as follows:
   [a] Remove the pipe plug in the pump inlet elbow.
   [b] Add water.
   [c] Install the plug.

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13.55 FUEL AND BOOST COOLERS

Replace fuel and boost coolers on marine engines every 4 years or 4,000 hours, whichever comes first. In some applications these are unitized into a single assembly.

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13.56 TORQMATIC MARINE GEAR (6V AND 8V)

Maintain the Torqmatic marine (6V and 8V) gear as follows:

1. With the controls in neutral and the engine running at idle speed, check the oil level daily in the marine gear. See Figure 13-27.

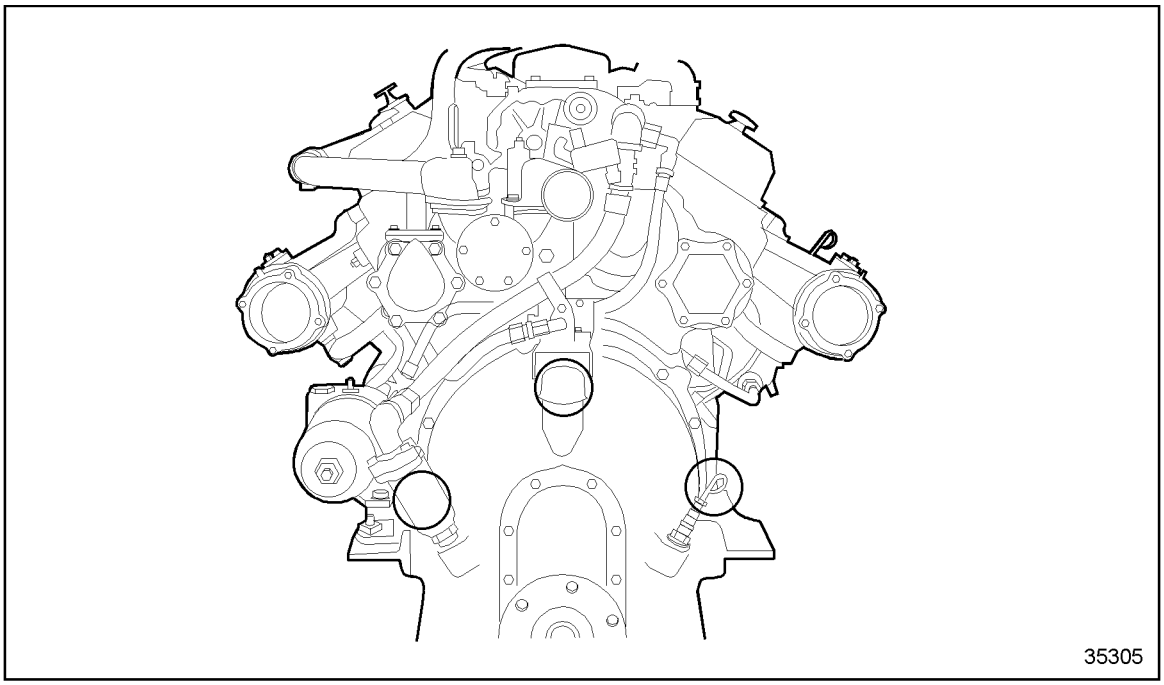


Figure 13-27 Marine Gear Oil Level Check

2. Add oil as required to bring it to the proper level on the dipstick, approximately 5.7 liters (6 quarts) in the M-type and 7.6 liters (8 quarts) in the MH-type gear.

NOTE:
Use the same grade and viscosity heavy-duty oil as used in the engine. Series 3 oil should not be used in the marine gear.

3. Drain the oil every 200 hours or 9,6000 km (6,000 miles), and flush the gear with light engine oil.
4. Start and run the engine at light load for three to five minutes.
5. Place the controls in neutral, and run the engine at idle speed.
6. Check the oil level. Bring the oil level to the proper level on the dipstick.
7. Every time the oil is changed, remove the oil strainer element.
8. Rinse it thoroughly in fuel oil.

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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.

9. Dry with compressed air.
10. Install the oil strainer element.
11. Replace the full-flow oil filter element every time the marine gear oil is changed.

13.57 MARINE GEAR (TWIN DISC 16V)

The requirements for Detroit Diesel (Twin Disc) marine gear lube oil and filter change are listed in Table 13-8.

Sump Temperature, also Oil Temperature into Heat Exchanger (During Start-up)	Sump Temperature, also Oil Temperature into Heat Exchanger (Steady Operating Conditions)	Recommended Oil Viscosity
-	Below 66°C (150°F)	This operating condition *is not* approved.
0°C (32°F) Min.	66-85°C (150-185°F)	SAE viscosity number 40 engine oil 1.12:1-2.54:1
0°C (32°F) Min.	66-85°C (150-185°F)	SAE viscosity number 40 engine oil 3.10:1-4.95:1
0°C (32°F) Min.	80-99°C (175-210°F)	SAE viscosity number 40 engine oil 3.10:1-4.95:1
-	Above 99°C (210°F)	This operating condition *is not* approved.

Oil Service Class: Use API service classification CD, CD-II, CF-2, CE, or CF-4 engine oil which is certified to pass TO2 or TO4 and C-4 specifications or meet the requirements of MIL-L-2104E. Engine oil may be used, provided it meets these requirements.

Oil and Filter Change Interval: First oil and filter change should take place after 10 hours and thereafter every 1000 hours of operation for both filter element and oil, or 6 months, whichever comes first.

Filter Screen: Remove and clean after first 10 hours and thereafter every 1000 hours of operation, or 6 months, whichever comes first.

Table 13-8 Detroit Diesel (Twin Disc) Marine Gear Lube Oil and Filter Change Requirements

Maintain the twin disc marine gear (16V) as follows:

1. Check the oil level daily.

NOTE:
The oil should be at operating temperature when checked.

2. With the engine running at low idle speed and the gear in neutral, check the oil level.

NOTE:
Keep oil up to the proper level on the dipstick. Use oil of the same heavy-duty grade and viscosity that is used in the engine.

3. Change the oil and the oil filter element every 1,000 hours or 48,000 km (30,000 miles).
4. After draining the oil, thoroughly clean the removable oil screen and breather.
5. Install the breather, and refill the marine gear with oil up to the full mark on the dipstick.
6. Start the engine. With the gear in neutral, run the engine at idle speed for three to five minutes.
7. Stop the engine, and check the oil level.

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8. If necessary, add oil to bring it up to the full mark on the dipstick.

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13.58 CLUTCH ACTUATOR (DDEC MARINE)

If the engine is equipped with DDEC marine clutch actuator, perform the following instructions:

Daily:

1. Inspect Morse push/pull cable connecting clutch actuator to marine gear selector lever.
2. If cracked, binding, worn, or loose fittings are found, replace the cable.
3. Check plastic cable end connectors daily for cracks or excessive wear.
4. If worn or damaged, replace the connectors.
5. Inspect cable mountings at servo and transmission mount to ensure they are secure.
6. Check servo operation in dry run mode (ignition on, engine not running) for smooth shifting of selector valve lever.
7. Hit station active button, and observe operating of selector valve when clutches are shifted ahead, neutral, and astern.
8. Inspect servo mechanical backup solenoid clutch assembly for correct cycle actuation.
9. Release and engage the backup system.

If the engine is equipped with DDEC marine clutch actuator, perform the following instructions:

Every Month or 50 Hours or 15,000 hours:

1. Inspect electrical connections for looseness or corrosion.
2. If loose or corroded, replace.
3. Inspect electrical wires for fraying or deterioration.
4. Replace if frayed or deteriorated.
5. Ensure servo base plate fasteners are tight.

NOTE:
The clutch must be mounted securely.

6. Measure actuator servo lever for any change to original setup length.
7. Verify the servo is not over or under stroking the selector valve lever.
8. Adjust as required.

If the engine is equipped with DDEC marine clutch actuator, perform the following instructions:

Every 6 Months or 250 Hours:

1. Inspect servo base plate for stress fractures or stress induced deformation.
2. Replace the entire assembly if damaged.
3. Inspect and lubricate cable connector pins with a high quality marine grade grease.
4. Replace pins and connectors if worn.
5. Measure servo valve for any change to the original set up length.

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6. Verify that the servo is not over or under stroking the selector valve.
7. Adjust as required.

If the engine is equipped with DDEC marine clutch actuator, perform the following instructions:

Every Year or 500 Hours:

1. Replace 33C Red-Jaket® push/pull cables between servo and selector valve.
2. With transmission at operating temperature, verify that the transmission selector valve shift force does not exceed 67 N (15 lbs.) with cable disconnected and 111 N (25 lbs.) with the cable connected at the transmission, but disconnected at the clutch actuator.
3. Repair transmission or replace cable if these values are exceeded.

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14 STORAGE

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14.1 PREPARING ENGINE FOR STORAGE

When an engine will 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 and corrosion.

Remove all rust or corrosion completely from any exposed part before applying a rust preventive compound. DDC recommends processing the engine for storage as soon as possible after removal from operation.

Store the engine in a building which is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

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 can result.

Detroit Diesel Corporation does not recommend storing an engine (or transmission) outdoors. DDC recognizes that in some cases outdoor storage may be unavoidable. If units must be kept outdoors, follow the preparation and storage instructions. Protect units with quality, weather-resistant tarpaulins (or other suitable covers) arranged to provide air circulation.

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14.2 TEMPORARY ENGINE STORAGE (30 DAYS OR LESS)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.
3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 RPM. and no load.

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 section 6.2.
5. If freezing weather is expected during the storage period, add an ethylene glycol base antifreeze solution in accordance with the manufacturer recommendations.
6. Drain the raw water system and leave the drain cocks open.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

7. Clean the entire exterior of the engine, except the electrical system, 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.

8. Dry it with compressed air.
9. Seal all engine openings, use a vapor and water proof material that is resistant to damage by puncture or expansion.An engine prepared in this manner can be returned to service in

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a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission and priming the water pump, if used.

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14.3 RESTORING A TEMPORARILY STORED ENGINE (30 DAYS OR LESS)

Return a temporarily stored engine to service as follows:

1. Remove the seals at the engine openings.
2. Check the engine coolant, fuel oil, lubricating oil, and transmission.
3. Prime the raw water pump, if used.

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14.4 EXTENDED ENGINE STORAGE (MORE THAN 30 DAYS)

Prepare an engine for extended storage as follows:

1. Drain the cooling system. Refer to section 13.12.3.
2. Flush with clean, soft water.
3. Fill with clean, soft water, and add a rust inhibitor to the cooling system. Refer to section 5.3.
4. Remove, check, and recondition the injectors, if necessary, to make sure they will operate when the engine is restored to service.
5. Install the injectors, time them, and adjust the exhaust valve clearance.
6. Operate the engine until normal operating temperature is reached to circulate the coolant. Refer to section 11.5.
7. Stop the engine.
8. Drain the engine crankcase. Refer to section 13.5.2.
9. Install and tighten the drain plug.
10. Install new lubricating oil filter elements and gaskets.
11. 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.
12. Drain the fuel tank.

NOTICE:
If engines in vehicles or marine units are stored where water condensation in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of 0.5 liter (one pint) to 473 liters (125 gallons) of fuel, or 0.010% by volume. Where biological fuel contamination may be a problem, add a biocide such as Biobor JF, or equivalent, to the fuel. When using a biocide, follow the manufacturer's concentration recommendations, and observe all cautions and notices.

13. Fill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes.

NOTE:
If draining the fuel tank is not convenient, i.e., marine, use a separate portable supply of the recommended fuel.

14. Drain and disassemble the fuel filter and strainer.
15. Discard the used elements and gaskets.
16. Wash the fuel filter shells in clean No. 1 diesel fuel or pure kerosene.

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17. Insert new elements.
18. Fill the cavity between the element and shell with No. 1 diesel fuel or pure kerosene, and install on the engine.
19. If spin-on fuel filters and strainers are used, discard the used cartridges, fill the new ones with No. 1 diesel fuel or pure kerosene, and install on the engine.
20. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine.
21. Service the air cleaner. Refer to section 6.2.1.

14.4.1 Marine Gear (More than 30 Days)

Prepare marine gear for extended storage as follows:

1. Drain the oil completely, and refill with clean oil of the recommended grade and viscosity. Refer to section 13.5.2 and refer to section 13.5.1.
2. Remove and clean or replace the strainer and filter elements.
3. Start and run the engine at 600 RPM. for 10 minutes to coat all internal parts of the marine gear with clean oil.
4. Engage the clutches alternately to circulate clean oil through all moving parts.

NOTE:
Torqmatic converter preparation is not necessary on torque converter units.

14.4.2 Torqmatic Converter (More than 30 Days)

Prepare the Torqmatic converter for extended storage as follows:

1. Start and operate the engine until the converter oil temperature reaches 66°C (150°F).
2. Stop the engine, remove the converter drain plug and drain the converter.
3. Remove the filter element.
4. Start the engine and stall the converter for twenty seconds at 1000 RPM. to scavenge the oil from the converter.

NOTE:
Due to lack of lubrication, do not exceed the 20 second limit.

5. Install the drain plug and a new filter element.
6. Fill the converter to the proper operating level with a commercial preservative oil which meets specification MIL-L-21260C.

NOTE:
Grade 2 oil is available from the major oil companies.

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7. Start the engine and operate the converter for at least 10 minutes at a minimum of 1000 RPM.

NOTE:
Do not allow the oil temperature to exceed 107°C (225°F). If the unit does not have a temperature gage, do not stall the converter for more than thirty seconds.

8. Engage the clutch, and stall the converter to raise the oil temperature to 107°C (225°F).
9. Stop the engine, and allow the converter to cool to a touchable temperature.
10. Seal the breather and all exposed openings with moisture proof tape.
11. Coat all exposed, unpainted surfaces with preservative grease.
12. Position all controls for minimum exposure, and coat them with grease. Coat the external shafts, flanges, and seals with grease.

14.4.3 Power Take-Off (More than 30 Days)

Prepare the power take-off for extended storage as follows:

1. Use an all purpose grease, such as Shell Alvania No. 2 or equivalent, and lubricate the clutch throughout bearing, clutch pilot bearing, drive shaft main bearing, clutch release shaft, and the outboard bearings, if so equipped.
2. Remove the inspection hole cover on the clutch housing, and lubricate the clutch release lever and link pins with a hand oiler.

NOTE:
Avoid getting oil on the clutch facing.

3. If the unit is equipped with a reduction gear, drain the gear box and flush with light engine oil.
4. If the unit is equipped with a filter, clean the shell and replace the filter element.
5. Refill the gear box to the proper level with the grade of oil indicated on the name plate.

14.4.4 Turbocharger (More than 30 Days)

Prepare the turbocharger for extended storage as follows:

Since turbocharger bearings are pressure lubricated through the external oil line leading from the engine cylinder block while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

14.4.5 Hydrostarter System (More than 30 Days)

Prepare the hydrostarter system for extended storage as follows:

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Refer to section 11.2.3 and refer to section 13.38 for the lubrication and preventive maintenance procedure.

14.4.6 Extended Engine Storage (More Than 30 Days) Continued

Continue preparing the engine for extended storage as follows:

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.

1. Apply a non-friction rust preventive compound to all exposed parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.
2. Drain the engine cooling system.

NOTICE:
To ensure that all coolant is drained completely from a unit, all cooling system drains should be opened. Should any entrapped water in the cylinder block or radiator freeze, it will expand and may cause damage.

3. When freezing weather is expected, leave all drain cocks open until refilling the cooling system.
4. Open the drain cocks and remove the cooling system filler cap to drain the engine coolant.

NOTE:
Filler cap removal permits air to enter the cooling passages and the coolant to drain completely from the system.

NOTE:
On 6V and 8V engines, cylinder block drain cocks are located on each side of the cylinder block at the rear, below the exhaust manifolds, and at the front of the engine.

NOTE:
On 12V and 16V engines, a drain cock is located on each side of the cylinder block, below the exhaust manifold, at both the front and the rear of the engine.

In addition to the cylinder block drains, the oil cooler housing has a drain cock at the bottom. Open a drain cock in the bottom tank to drain the radiator.

5. Drain the preservative oil from the engine crankcase.
6. Install and tighten the drain plug.

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⚠ 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.**

7. Remove and clean the battery and battery cables with a baking soda solution.
8. Rinse them with fresh water.
9. Add distilled water to the electrolyte, if necessary, and fully charge the battery.

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⚠ 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 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.**

10. Store the battery in a cool (never below 32°F or 0°C) dry place. Keep the battery fully charged, and check the level and the specific gravity of the electrolyte regularly.
11. Insert heavy paper strips between the pulleys and belts to prevent sticking.
12. Seal all engine openings, including the exhaust outlet, with moisture resistant tape.

NOTE:
Use cardboard, plywood, or metal covers where practical.

13. 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.
14. 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.

The stored engine should be inspected periodically. If there is any 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.

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14.5 RESTORING AN EXTENDED STORAGE ENGINE (MORE THAN 30 DAYS)

Restore an extended storage engine as follows:

1. Remove the covers and tape from all openings of the engine, fuel tank, and electrical equipment.

NOTE:
Do not overlook the exhaust outlet.

⚠ CAUTION:

To avoid injury from fire caused by heated diesel-fuel vapors:
- ☐ **Keep those people who are not directly involved in servicing away from the engine.**
- ☐ **Stop the engine immediately if a fuel leak is detected.**
- ☐ **Do not allow open flames or smoke when working on an operating engine.**
- ☐ **Wear adequate protective clothing (face shield, insulated gloves and apron, etc.).**
- ☐ **To prevent a buildup of potentially volatile vapors, keep the engine area well ventilated during operation.**

Diesel fuel is relatively harmless at ambient temperatures.

2. Wash the engine exterior with fuel oil to remove the rust preventive.
3. Remove the rust preventive from the flywheel.
4. Remove the paper strips from between the pulleys and the belts.
5. Remove the drain plug, and drain the preservative oil from the crankcase.
6. Install the drain plug.
7. Fill the crankcase to the proper level with the recommended grade of lubricating oil, using a pressure prelubricator. Refer to section 13.5.1 and refer to section 5.2.
8. Fill the fuel tank with the fuel specified under *Fuel Specifications*. Refer to section 5.1.1.5.
9. Close all drain cocks, and fill the engine cooling system with clean soft water and a rust inhibitor.

NOTE:
If the engine is to be exposed to freezing temperatures, fill the cooling system with a solution of water and an ethylene glycol base antifreeze. Refer to section 5.3 and refer to section 13.12.

10. Install and connect the battery.

11. Service the air cleaner. Refer to section 6.2.1.

14.5.1 Restore Power Generator (More than 30 Days)

Restore power generator from extended storage as follows:

Refer to section 11.1.9 *Operating Instructions*.

14.5.2 Restore Marine Gear (More than 30 Days)

Restore marine gear from extended storage as follows:

1. Inspect the marine gear.
2. Refill it to the proper level, as necessary, with the correct grade of lubricating oil.

14.5.3 Restore Torqmatic Converter (More than 30 Days)

Restore Torqmatic converter from extended storage as follows:

1. Remove the tape from the breather and all openings.
2. Remove all preservative grease with a suitable solvent.
3. Start the engine, and operate the unit until the temperature reaches 66°C (150°F).
4. Drain the preservative oil, and remove the filter.

NOTE:
A Torqmatic converter containing preservative oil should only be operated enough to bring the oil temperature up to 66°C (150°F).

5. Start the engine, and stall the converter for twenty seconds at 1000 RPM. to scavenge the oil from the converter.
6. Install the drain plug and a new filter element.
7. Refill the converter with the recommended oil. Refer to section 13.56.

14.5.4 Restore Power Take-Off (More than 30 Days)

Restore power take-off from extended storage as follows:

1. Remove the inspection hole cover, and inspect the clutch release lever and link pins and the bearing ends of the clutch release shaft.
2. Apply engine oil sparingly, if necessary, to these areas.

14.5.5 Restore Hydrostarter (More than 30 Days)

Restore hydrostarter from extended storage as follows:

1. Open the relief valve on the side of the hand pump, and release the pressure in the system.

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2. Drain, fill, and purge the hydrostarter system. Refer to section 11.2.3 and refer to section 13.38.

14.5.6 Restore Turbocharger (More than 30 Days)

Restore turbocharger from extended storage as follows:

1. Remove the covers from the turbocharger air inlet and turbine outlet connections.
2. Lubricate the turbocharger. Refer to section 6.6.4.

NOTICE:
Before subjecting the engine to a load or high speed, check the engine tune-up.

After all of the preparations have been completed, start the engine.

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14.6 STORAGE OF BATTERY

The lead-acid storage battery is an electro-chemical device for converting chemical energy into electrical energy.

The battery has three major functions:

1. Provides a source of current for starting the engine.
2. Acts as a stabilizer to the voltage in the electrical system.
3. Can, for a limited time, furnish current when the electrical demands exceed the output of the alternator.

When selecting a replacement battery, always select one of an "electrical size" at least equal to the originally engineered battery for the particular equipment. The specifications are listed in Table 14-1.

Engine Model	System Voltage	Minimum Battery Rating SAE Cold Cranking AMPS @ -17.8°C (0°F) Above 0°C (32°F)	Minimum Battery Rating SAE Cold Cranking AMPS @ -17.8°C (0°F) Below 0°C (32°F)
6V, 8V*, 12V*	24V, 32V	950	1250
16V	†24V, 32V	950	1250

* Must use Delco-Remy 50MT cranking motor or equivalent.

†Two cranking motors. Battery recommendation is for each motor.

Table 14-1 Battery Recommendations

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.**

When batteries are being charged, an explosive gas mixture forms beneath the cover of each cell. Part of this gas escapes through the holes in the vent plugs. If ventilation is poor, these gases may form an explosive atmosphere around the battery.

14.6.1 Repair or Replacement of Storage Battery

To determine if repair is possible or replacement is necessary, perform the following procedure.

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14.6.2 Removal of Storage Battery

Remove the storage battery as follows:

1. Disconnect and ground the battery terminal.
2. Detach the cable clamps.
3. Loosen the hold-down clamps evenly.
4. Remove the battery.

14.6.2.1 Cleaning of Storage Battery

Prior to inspection, clean the battery as follows:

1. Clean the battery posts, terminals, and connections.

⚠ 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.**

2. Wash the top of the battery with baking soda solution.
3. Rinse with fresh water.
4. Apply a coat of grease to the connections and exposed metal parts.

14.6.2.2 Inspection of Storage Battery

Inspect the battery as follows:

1. Inspect the charge indicator "eyes" periodically for adequate charge.
   [a] If there is no charge or weak charge, replace the battery. 14.6.3.

NOTE:
If the battery becomes discharged regularly, inspect the electrical system.

   [b] If the battery is sufficiently charged, continue inspection.

2. Inspect the battery posts, terminals, and connections for fraying, loss of insulation covers, wear, or damage.
   [a] If slightly frayed, worn, or damaged, repair the connections, posts, and terminals. Refer to OEM.
   [b] If excessively frayed, worn, or damaged, replace the connections, posts, and terminals. Refer to OEM.
   [c] If not frayed, worn, or damaged, continue inspection.
3. Inspect the electrolyte level frequently if the battery is not the maintenance-free type.

NOTICE:
Do not overfill the battery. Overfilling can cause poor battery performance or premature battery failure.

   [a] If low, add water.
   [b] If no water is needed, continue inspection.
4. Inspect the cables, clamps, and hold-down brackets for corrosion or damage.
   [a] If corroded or damaged, replace the cables, clamps, or hold-down brackets. Refer to section 14.6.3.
   [b] If not corroded or damaged, reuse the parts.

14.6.3 Installation of Storage Battery

Install the battery as follows:

1. Ensure the battery carrier is clean and the battery rests level when installed.

NOTICE:
Do not over tighten the battery hold-down clamps. The battery case will distort or crack.

2. Tighten the hold-down clamps evenly until snug.
3. Attach the cable clamps.
4. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal beneath the cable clamps.
5. Coat the entire connection with a heavy general-purpose grease.

NOTE:
Ensure the ground cable is clean and tight at the engine block or frame.

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⚠ 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.**

6. Check the polarity to ensure the battery is not reversed with respect to the generating system.

NOTICE:

Connect the grounded battery cable last. This will help prevent short circuits that may damage the battery.

7. Connect the grounded battery terminal.

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